PREHEATER BLOCKAGES

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2 types of cause:

1- mechanical
   - design of ducts/cyclones
   - equipment damage

2- chemical
   - chlorine
   - sulphur
Care taken at the inlet to lower cyclones

Preferably the cyclone cone has $20^\circ$ to vertical

Dip tubes or refractory pieces can block cyclone cones. Standard test is to throw a light bottle down. No steel balls!

The inlet from Combustion Chamber to kiln riser is a known issue
Chemical Causes
A) Chemistry of buildups
DEFINITION OF BUILDUPS

Buildups are caused by melt formation followed by solidification that acts as binder for dust particles to agglomerate.

- Agglomeration due to the presence of molten alkali chlorides

- Consequence: preheater blockages
Formation is dependent on the presence of molten salts, especially alkali sulfates and chlorides.

Samples show that the alkali, S and Cl concentration in the build-up material is significantly higher than in the kiln feed.
### Deposits and link to operation

<table>
<thead>
<tr>
<th>Mineral deposited</th>
<th>Chemical Formula</th>
<th>Possible link to kiln operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ternesite</td>
<td>(C_5(SiO_4)_2SO_4)</td>
<td>High sulphur recirculation in flue gas, high sulphur fuel utilization</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>(CaSO_4)</td>
<td></td>
</tr>
<tr>
<td>Langbeinite</td>
<td>(K_2Ca_2(SO_4)_3)</td>
<td></td>
</tr>
<tr>
<td>Sylvite</td>
<td>(KCl)</td>
<td>High chlorine concentration in the fuel or raw materials /high accumulation-recirculation rate</td>
</tr>
<tr>
<td>Halite</td>
<td>(NaCl)</td>
<td></td>
</tr>
<tr>
<td>Arcanite</td>
<td>(K_2SO_4)</td>
<td>Low or no alkali bypass flow rate, high alkali concentration in raw materials</td>
</tr>
<tr>
<td>Aphthitalite</td>
<td>(K_3Na(SO_4)_2)</td>
<td></td>
</tr>
<tr>
<td>thernadite</td>
<td>(Na_2SO_4)</td>
<td></td>
</tr>
</tbody>
</table>
1: Alkalis Combine with Chlorine

Chlorine Cl

Alkali Chlorides
NaCl, KCl

2: Remaining alkalis will combine with sulphur

Alkalis Na, K

Alkali Carbonates, Oxides...KOH, Na₂CO₃

3: Remaining sulphur will combine with calcium

Sulphur S

Alkali Sulphates
Na₂SO₄, K₂SO₄

4: Alkalis in Excess of S, combination with CO₃, OH

Calcium Sulphates
CaSO₄
Alkalis will preferentially combine with any chloride present. Best A/S ratio is when there is just enough sulfur present to combine stochiometrically with the remaining alkalis.

excess of sulfur, $\rightarrow$ CaSO$_4$ formation $\rightarrow$ sulphur in CaSO$_4$ will volatilize completely.

excess of alkalis $\rightarrow$ alkali aluminate can form $\rightarrow$ stiffening problems in concrete and mortar.

Bypass $\rightarrow$ alkali in excess possible $\rightarrow$ low alkali cement + no stiffening problems $\rightarrow$ no sulphur excess problems.
Chemical Causes

B) Volatility
## Melting and Boiling points

<table>
<thead>
<tr>
<th>Component</th>
<th>Melting point °C</th>
<th>Boiling point °C</th>
<th>Volatility %</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>776</td>
<td>1400</td>
<td>60 - 80</td>
</tr>
<tr>
<td>NaCl</td>
<td>801</td>
<td>1413</td>
<td>40 - 60</td>
</tr>
<tr>
<td>K2SO4</td>
<td>1069</td>
<td>1669</td>
<td>50 - 60</td>
</tr>
<tr>
<td>CaCl2</td>
<td>772</td>
<td>1935</td>
<td>35 - 50</td>
</tr>
</tbody>
</table>

Trapped in kiln system due to physical properties
Recirculation of volatiles

Input

800 °C: Condensation Cl

Recirculation

Output

1200 °C: Evaporation Cl
Effects: Transfer of Thermal profile of kiln

Condensation Exothermic
- T rises
- More gas volume,
- gas velocity, dp,
- Energy Fan

Evaporation Endothermic
- T sinks
- Flame shape
- Fuel Consumption
Kiln Conditions: Factors that affect volatility

- **Gas velocity**: A higher gas velocity reduces the vapor pressure of volatiles in the atmosphere, increasing their volatility.

- **A higher sinter zone temperature** as required for harder burning mix will increase volatility. Easier burning material → less burning zone temperature → less volatility.

  **Residence time** at high temperature: longer time at high temp. increases volatilities and the amount of volatiles → main burner flame shape

- **A higher CO₂ concentration** in the kiln will increase volatility of sodium and potassium.

- **Reducing conditions** will increase the volatility of sulfur, while higher oxygen levels will decrease it (up till ~2%)
Sulphate – $SO_2$ equilibrium reaction

Temperature

$CaSO_4 \Leftrightarrow CaO + SO_2 + \frac{1}{2} O_2$

Almost no reaction

SO$_2$ absorption

Volatization
**Sulphate – SO$_2$ equilibrium reaction**

**Oxygen**

\[ \text{CaSO}_4 \rightarrow \text{CaO} + \text{SO}_2 + \frac{1}{2} \text{O}_2 \]

Too little excess air and reducing conditions → Increase of volatility

\[ \text{CaSO}_4 \leftarrow \text{CaO} + \text{SO}_2 + \frac{1}{2} \text{O}_2 \]

O$_2$ % in kiln inlet 1-2%

**Influence of O$_2$ on Sulphur volatility**

only in range: \( 0 – 2\% \)
Typical CI - Mass Balance

Input: 269 kg/h  Raw Meal  
  +8 kg/h  Fuel CC  
  +5 kg/h  Fuel MB  
= 283 kg/h

Output: 130 kg/h  Clinker  
Diff:  153 kg/h

Raw Meal  
Clorine In: 269 kg/h

Cyclone preheaters

Fuels Calciner In: 8 kg/h

Fuels MB In: 5 kg/h

Chlorine Out: 130 kg/h

Rotary kiln

Clinker cooler
Operational issues
Build-ups
- increasing build-ups cause reduced gas flows at the same ID fan pressure

Fluctuating gas flows
- due to fluctuating O2 and heat levels, CO-increases and excess O2 requires ID fan increase
  - Fluctuating fuel
    - fluctuating temps cause fuel increase, thereby increasing S or Cl inputs
  - Cold Air Ingress
    - Increasing the ID fan to keep up, kiln inlet under-pressure increase draws in more false air
  - Circulating Phenomena
    - Destablized operation, CO increase and false air cause volatization to spiral out of control
  - Blockages
    - increasing volatization causes more build-ups. Return to the start...
INVESTIGATION STEPS

1. General description of situation (position of build-ups, reproducible conditions that seem to lead to the situation)
2. Ongoing analysis of hot meal (LOI, SO3, Cl, Na2O, K2O, CaO)
3. Pyro-section mass and heat balance
4. Plot ongoing points on Cl-SO3 graph
5. Sample the build-up material (XRF)
6. Analyse Inputs-Outputs for responsible circulating element
RESULTS OF BUILD-UPS SEVERE!

1. Blockages cause unplanned shut-downs and loss of earnings
2. Constant start-up and stop decreases refractory life
3. Build-up and dropping off causes mechanical wear of refractory
4. Severe safety issues involved with cleaning big build-ups
5. Clinker quality fluctuations + restarts = lots of rejected clinker
6. Increased heat energy use due to:
   a) dusty clinker reduces radiation inside kiln
   b) more false air and operation at more excess air
7. Increase shifts to cope with cleaning and higher maintenance
8. Lower possibility to use alternative fuels because heat levels lower
9. Clinker cooler instability means increased cement setting times
10. Lower production level if preheater, kiln inlet, burner, or cooler is the bottleneck
11. Lower production because away from optimum performance
12. Increase wear on burner and refractories due to dust and velocities increase

and…and…and…and…!
Pendulum flaps
- Reliable operation.
- Low maintenance.
- Increased thermal efficiency.

Expansion joints
- Improper joints split and let in false air

Splash boxes
- Optimized homogenous meal distribution.
- Improved heat exchange.

Dip tubes
- Easy to install, long lifetime
FLEXIFLAME™ burners are the most advanced technology developed by Greco for rotary kilns firing pulverized fuel. Using three shaping airflows and a unique design – two of the airflows rotate to enfold the solid fuel injection flow – it allows, through simple procedures, to optimize complex fuel firing and great control over NOx emissions.
Chlorine Bypass
CL-SO3 balance on fuel change

Coating condition to be expected in relation to Cl and SO₃ in hot meal

- Operation without bypass
- Original operation
- Heavy coating
- Acceptable coating
- No coating
- Operation with bypass

Graph showing the content of Cl and SO₃ in hot meal against SO₃ content in hot meal.
Main Advantages:

- Big take off area
- Low take off velocity
- Particles < 10 µm

• No cyclones needed
• Gas can be used for raw meal drying to reduce thermal losses
QUENCH CHAMBER

- Made completely of metal (no lining required)
- Cooling in one step to 200 °C
- Minimum space requirement
- Simple functionality
10 % bypass rate is sufficient for chloride bypass systems
- Kiln gas take off quantity 6’000 Nm³/h
- First stage cooling from 1100 °C to 450 °C
- 50% coarse dust removed in cyclone, returned to kiln inlet or circulated in cyclone riser
- Second stage cooling from 450 °C to approx 220 °C
- Gas filtration system with max. dust quantity of 10 mg/Nm³ is positioned on top of bypass dust silo
- Cleaned bypass gas 59’000 Nm³/h design is ducted to main stack
- 100% of dust is transported to special storage area; silo discharge capacity 30 t/h
EXAMPLE INSTALLATION

Advantages:

- Reliable operation.
- Low maintenance
- No big civil engineering
- No refractory after takeoff
- Cheap and simple to install

bypass cyclone
2nd stage quench
mixed gas duct to filter
coarse dust return
1st stage quench
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