Energy Efficient Technologies and Operating Practices in Alumina Refinery

by

M.J.Chaddha, and A. Agnihotri

JNARDDC, NAGPUR
Energy Consumption in Alumina Refining

• Today, the average specific energy consumption is around 14.5 GJ per tonne of alumina, including electrical energy of around 150 kWh/t Al₂O₃. The energy value varies from 10.9 – 18.4 GJ/t Al₂O₃.

• The energy required by the Bayer Process is very much dependent on the quality of the raw material, with böhemitic or diasporic bauxites requiring higher temperature digestion, often associated with a higher fuel input.
Energy Consumption in Bayer Process

Energy consumption in Bayer Process is in the following areas:-

- Mining of the Bauxite mainly diesel required for dumpers for transportation of bauxite
- Conveyors requiring electrical energy
- Crushing & Grinding requiring electrical energy
- Desilication area requiring steam & electrical energy
- Digestion area requiring steam & electrical energy
- Evaporation requiring steam & electrical energy
- Hydrate washing/filtration requiring steam & electrical energy
- Red mud washing/disposal requiring steam & electrical energy
- Calcination area requiring fuel oil & electrical energy
Crushing and Grinding of Bauxite

Bauxite

Primary & Secondary Crushers

BALL MILL

Spent Liquor/Digestion Liquor

Ground Slurry
Ball Mills
Energy Saving Opportunities in Crushing/grinding

• Regular checking of input and output size of primary, secondary and ball mill discharge granulometry

• Replace the existing worn out internal lining of the ball mill by high chromium steel lining

• Optimizing grinding media specifically sizing of the balls to obtain better performance which will reduce specific energy consumption
**PRE-DESILICATION**

- \( \text{Na}_2\text{O} + \text{SiO}_2 = \text{Na}_2\text{SiO}_3 \quad \text{------- (1)} \)
- \( \text{Na}_2\text{O} + \text{Al}_2\text{O}_3 = 2\text{NaAlO}_2 \quad \text{------- (2)} \)
- \( \text{Na}_2\text{SiO}_3 + \text{NaAlO}_2 = x \text{Na}_2\text{O} \cdot y \text{Al}_2\text{O}_3 \cdot z \text{SiO}_2 \cdot n \text{H}_2\text{O} \quad \text{-- (3)} \)
- \( A \ (k_1) \rightarrow B \ (k_2) \rightarrow C \quad \text{Where } k_1 >> k_2 \)

---

**Diagram:**

- **Ground Slurry**
  - Flashed Steam/ Low Pressure Steam
  - Indirect Heating

- **Flash Steam/ Low Pressure Steam**
  - Direct Injection

- **Ground Slurry**
Post-Desilication

1. First Washer Overflow
2. Dilution Tank
3. Post Desilication
4. Low Pressure Steam
5. Digested Slurry
ENERGY REDUCTION OPPORTUNITIES IN PRE-DESILICATION

• Study Kinetics of Pre-desilication

Variation of Silica Concentration with Temperature at 800 gpl bauxite
Energy Saving Potential in Pre/Post Desilication

- Optimise residence time based on silica in liquor by increasing solids concentration and raising temperature.
- Go for indirect steam heating instead of direct steam injection.
- Post Desilication will always cause larger steam consumption as well as auto precipitation of alumina.
Digestion

- Digestion energy requirement varies from plant to plant on the basis of mineralogy of bauxite and temperature of digestion
- NALCO processes gibbsitic Bauxite at 106-107°C
- Hindalco (Belgaum) unit and Vedanta (Lanjigarh) unit processes bauxite at 142-145°C
- Hindalco (Renukoot and Muri) unit adopts double digestion technology
Energy Scenario in Atmospheric Pressure Digestion

- Bauxite Slurry
- Low Pressure Steam
- Digestion
- Evaporation
- Water Evaporated
- Low Pressure Steam
Energy Scenario in Medium Pressure Digestion

- Bauxite Slurry
- Low Pressure Steam
- Flashed Steam
- Blow-off Slurry
Energy Saving Potential in Low Pressure Digestion – Flashing system

- Proper descaling of flash tanks
- Maintaining level controllers and last flash temperature close to 116-118°C for efficient heat recovery from flashing
- Proper condensate recovery
Double – Digestion Flow sheet

1st Pressure Decanter

Low Temp Digester

Desilicated Bauxite feed

Digestion liquor

Precipitation

High Temp digester

2nd pressure decanter

Mud circuit
Energy Saving Opportunities in Double Digestion Technology

• Higher the boehmite-content better will be the economics of the process
• Optimise Temperature and residence time of second stage digestion
Condensate

Heating stage assembly

200 mm DIA SHELL

3x76mm DIA TUBES

13000

Tube reactor element

TUBE DIGESTOR FOR DIGESTION OF DIASPORIC BAUXITE
## Comparison of the energy consumption of tube digester with Autoclaves in series

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Tube Digester</th>
<th>Autoclave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency of Heat Recovery, %</strong></td>
<td>74.00</td>
<td>60.40</td>
</tr>
<tr>
<td><strong>Average Heat Transfer Coefficient, W/m$^2\text{oC}$</strong></td>
<td>1795.0</td>
<td>437.5</td>
</tr>
<tr>
<td><strong>Specific Electric Energy Consumption, kWh/m$^3$</strong></td>
<td>3.03</td>
<td>4.14</td>
</tr>
<tr>
<td><strong>Specific Energy Consumption, MJ/m$^3$</strong></td>
<td>295</td>
<td>390</td>
</tr>
</tbody>
</table>
Energy Scenario in Digestion

• Atmospheric pressure digestion requires less steam energy and electrical energy than medium pressure or high pressure digestion, but the energy in evaporation is high due to more evaporation required to remove water.

• Medium Pressure digestion requires slightly higher energy in digestion but due to flashing of digested slurry low steam requirement is in evaporation.

• High Pressure digestion requires higher energy in digestion but due to flashing of digested slurry energy requirement in evaporation is low.
Red Mud Washing

Steam
Hydrate Filtration
Energy requirement in Hydrate and Red Mud Washing

Hydrate washing and red mud washing section requires:

- Electrical energy for running the disc and drum filters, vacuum pumps etc.
- Steam energy for washing / drying
- Energy for pumping red mud to ponds
6 Effect Falling film evaporator for Alumina Refinery
Evaporation

Falling Film Evaporator

In falling film evaporators the liquid feed usually enters the evaporator at the head of the evaporator.

In the head, the feed is evenly distributed into the heating tubes.

A thin film enters the heating tube and it flows downwards at boiling temperature and is partially evaporated.
Backward feeding multiple effect evaporators (5 effects to 7 effects) are always the preferred choice aiming to achieve the steam economy between 3.5 to 4.5 tonnes evaporation on continuous basis per tonne of steam in Alumina refinery.
Energy saving Potential in Evaporation

• Reducing unauthorised dilution in hydrate filtration area.
• Proper maintenance schedule for cleaning of calendria/evaporator tubes
Calcination
## Energy requirement in Calcination

<table>
<thead>
<tr>
<th>Main items of heat balance, MJ/ton</th>
<th>Fluid flash</th>
<th>Rotary kiln</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Evaporation</td>
<td>560</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Reaction Heat</td>
<td>2025</td>
<td>2025</td>
<td>2025</td>
</tr>
<tr>
<td>Stack Loss</td>
<td>270</td>
<td>500</td>
<td>290</td>
</tr>
<tr>
<td>Water Cooling</td>
<td>250</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td>Radiation loss</td>
<td>100</td>
<td>1075</td>
<td>635</td>
</tr>
<tr>
<td>Heat Consumption</td>
<td>3205</td>
<td>4500</td>
<td>3800</td>
</tr>
</tbody>
</table>
Energy Scenario in Calcination

• A large amount of energy is utilized in calcination of alumina hydrate.

• The energy required can be reduced by reducing free moisture content of product hydrate

• The best energy figures are 2,910 MJ/tons for gas suspension calciner
PLATE HEAT EXCHANGERS

Hot and Cold Flows inside Heat Exchanger
Cooling of Aluminate Liquor

Hot Aluminate Liquor

Cold Spent Liquor
Plate Heat Exchangers

- As compared to shell and tube heat exchangers, the temperature approach in a plate heat exchangers may be as low as 1 °C whereas shell and tube heat exchangers require an approach of 5 °C or more.

- For the same amount of heat exchanged, the size of the plate heat exchanger is smaller, because of the large heat transfer area afforded by the plates (the large area through which heat can travel).

- Increase and reduction of the heat transfer area is simple in a plate heat-exchanger, through the addition or removal of plates from the stack.
Plate Heat Exchangers
Plate Heat Exchangers
Plate Heat Exchangers

Figure 1. The plate heat exchanger
Advantages of PHE

- Compared to shell-and-tube units, plate heat exchangers offer overall heat transfer coefficients 3 to 4 times higher.

- **Thermally Controlled Designs:**
  - If the design exceeds the allowable pressure drop for a given thermal duty.
  - More plates be added and pressure drop is reduced by lowering the velocity.
  - Such a design is termed thermally controlled.

- **Hydraulically Controlled Designs:**
  - If the design pressure drop is less than the allowable pressure drop.
  - This results in a greater temperature change across the plate than required, or over-dimensioning.
  - Few plates be removed and pressure drop is increased by increasing the velocity.
  - Such a design is termed pressure drop controlled.
Interstage coolers for precipitators

Counterflow

Cooling Water

Precipitator Slurry

Parallel Flow

Cooling Water

Precipitator Slurry
Cooling Requirements in Precipitation

• Precipitation is an exothermic process requiring large amount of heat to be removed continuously.
• Double pipe concentric coolers are equipments of choice.
• Large scale fouling of inside tubes by precipitated hydrate reduces heat transfer
Conclusion

• There is a considerable scope in reducing energy consumption in alumina manufacture to reach goal of 10.5 GJ/ton and further down.
• The BAT (Best available Technology) for alumina manufacture should be used to bring down the energy consumption in a phased manner.
• Energy in digestion can be targeted by all alumina refineries by increasing alumina extraction and by increasing supersaturation.
• In-house plant measures such as maximizing hot condensate recovery from digester-flashing system and reducing unauthorised water into the system will help in reducing evaporation load thus reducing energy consumption.