Salt slags – the challenges of reprocessing aluminium recycling wastes, and an introduction to ALUSALT™

Alan M Peel C.Eng
Managing Director - ALTEK Group
1. What role does salt play in the recycling furnace? Is its use on the increase or wane

2. The regulatory aspects: is landfill or disposal no longer an option?

3. Process solutions for salt slag treatment: third party or in-house?

4. ALUSALT as a new technology for in-house recycling of salt slags

5. Economic drivers allowing cost-effective in-house recycling

6. Markets for the products of salt slag treatment – optimising revenue streams
Aluminium Dross and Salt Slag

• Both waste (??) streams from aluminium/dross recycling
• ~ 1 mtpy of aluminium drosses generated in Europe p.a
• ~ 2 mtpy of salt slags generated in Europe p.a

• Both of these by product streams can be totally circular as they contain a lot of Al and also the residual oxides can be re-used as material substitution.
Types of salt processing in Rotary Furnace

- **The Salt Process.** Most stable process, Maximizes the Al recovery, generates more salt slag waste.

- **The Low Salt process.** Stable process, does not contribute as much salt slag but still requires down stream recycling of salt slag due to re-active compounds

- **The No Salt process.** Unstable process, and requires less work down stream to recycle “salt free” but still reactive waste. Lower Al % recovery (~10%)
Importance of Salt

- SALT has 3 purposes in aluminium refining:
  - To prevent oxidation and metal loss of Aluminium
  - To break down/remove the oxide layer on Al particles
  - To absorb all impurities /products of combustion – facilitate removal of slag from melting furnace

The use of salt in melting is on the increase NOT decrease because of these factors and will continue to..
Importance of Salt

- The correct salt mix provides an excellent eutectic and minimises Al oxidation
- This can be further reduced with a little cryrolite

<table>
<thead>
<tr>
<th>Ratio KCl / NaCl</th>
<th>Melt Temp °F</th>
<th>Aluminum °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 / 0</td>
<td>1430</td>
<td>777</td>
</tr>
<tr>
<td>30 / 70</td>
<td>1287</td>
<td>697</td>
</tr>
<tr>
<td>50 / 50</td>
<td>1220</td>
<td>660</td>
</tr>
<tr>
<td>60 / 40</td>
<td>1229</td>
<td>665</td>
</tr>
<tr>
<td>0 / 100</td>
<td>1480</td>
<td>804</td>
</tr>
</tbody>
</table>
## Importance of Salt in Dross Recycling

<table>
<thead>
<tr>
<th>% Salt Addition</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dross 40% Metallic</td>
<td>20</td>
</tr>
<tr>
<td>Dross 50% Metallic</td>
<td>18</td>
</tr>
<tr>
<td>Dross 60% Metallic</td>
<td>15</td>
</tr>
<tr>
<td>Dross 70% Metallic</td>
<td>12</td>
</tr>
<tr>
<td>Dross 80% Metallic</td>
<td>10</td>
</tr>
</tbody>
</table>

Salt type, size, quality and ratio are key to maximised Al recovery.
Importance of Salt

Without Salt Flux

With Salt Flux

No salt flux can lose you 10% of available Al
Issues with salt slag

- Typical cooling times are 24 to 36 hours before shipping
- Requires large area for cooling
  - special heat resistant concrete floors,
  - or racking systems
  - Many dross/slag bins
- Aluminium in the slag can burn off/develop AlN’s
- Dealing with the environmental issues for transportation
- Temperature for shipping < 80°C
- Logistics, distances and costs for transportation to recycling centres
- Cost of recycling
Salt Slag Cooling – Typical
Rapid Salt Slag Cooling

Increases Al recovery and reduces AlN generation, fumes etc. and easier for transport.
Regulations

• Directive – 2008/98/EC on waste

• Landfill
  – Europe (limited) special conditions
  – US – Can still do to captive landfills ($15-$25/tonne)
  – Middle East – Zero landfill
  – Japan – Zero landfill
  – Asia – varied but very restricted

• Transport – REACH May 2015 - EWC 10 03 08
  – issues and strict control (lined, sealed containers etc.)

……..and many others……..
Typical solid components in dross

- Aluminium
- Alumina Oxide ($\text{Al}_2\text{O}_3$)
- Spinels ($\text{MgO}.\text{Al}_2\text{O}_3$)
- Aluminium Nitride (2AlN)
- Aluminium Carbides
- Aluminium Sulphites (trace)
- Aluminium Phosphates (trace)

Coming from many sources, fluxes, burners, primary metal etc. etc.
Possible Gaseous Components of Dross

- NH$_3$  (Ammonia)
- H$_2$S  (Hydrogen Sulphide)
- H$_2$  (Hydrogen)
- SO$_2$  (Sulphur Dioxide)
- CO$_2$  (Carbon Dioxide)
- CH$_4$  (Methane)
- NH$_4$OH  (Ammonium) Hydroxide)
- Phosphine
- Phosgene (possibly)

So its not just the salt slag you have to consider!
Compound reactions with water

- $2\text{AlN} + 3\text{ H}_2\text{O} \rightarrow 2\text{NH}_3 + \text{Al}_2\text{O}_3$ (Ammonia)
- $2\text{Al} + 3\text{H}_2\text{O} \rightarrow 3\text{H}_2 + \text{Al}_2\text{O}_3$ (Hydrogen)
- $\text{Al}_4\text{C}_3 + 6\text{H}_2\text{O} \rightarrow 3\text{CH}_4 + 2\text{Al}_2\text{O}_3$ (Methane)
- $\text{Al}_2\text{S}_3 + 3\text{H}_2\text{O} \rightarrow 3\text{H}_2\text{S} + \text{Al}_2\text{O}_3$ (Hydrogen Sulphide)
So....Why Salt...?

• Because it’s the only effective way to maximise metal recovery from Al drosses and many other types of contaminated scrap....

AND

• Many of the ‘issue’ compounds that are reactive are in the dross already
How to Treat Salt Slag?

- Central Processor units
- In house (currently not viable) unless large capacity unit
Central Processor

- Mixed slag – more difficult to segregate
- Large volumes (>80,000tpy)
  - bigger gaseous reactions
  - Less flexibility
  - Everything mixed up
- High CAPEX
- High OPEX
- Big o/head need infeed to be sustainable
In house

- Easy to segregate slag
- Smaller volumes,
- More flexible/adaptable
- Lower CAPEX
- Lower OPEX
- Manage own waste (by-product streams) = SECURITY
Project – ALUSALT

- New ALTEK/EU development project initiated in 2011
- Objective ‘small and medium scale’ local salt recycling of salt slag
- Small capacity pilot plant was tested in late 2014 at ALTEK – 200kg/day
- Funding for full scale demonstration unit secured in Q3 2015
- Installation started end Q1 2017
- Commissioning – in progress
- Commercialisation – end Q1 2018
ALUSALT - Key Principles

- To provide a cost effective solution for recycling salt slag at source of generation
  - From 3000tpy to 30,000tpy
- Benefits:
  - Massive reduction in transportation of salt slag around Europe
    - Fuel cost savings
    - Environmental issues reduced
    - CO₂ footprint reduction
  - Re-use of own salt (avoids ‘other things’ being in it)
  - Re-use of own aluminium
  - By product oxides suitable for re-use
  - Provide security and viability of recycling operation
Plant Design
Plant Construction
So where is it?
So where is it?
Plant Construction (March-May)
ALUSALT – Model 3
ALUSALT

• Takes crushed salt slag and produces:-
  – Recycled Salt
  – Aluminium
  – Oxides suitable for end uses

• On a local scale...
ALUSALT – Leaching and filtration

• Objectives
  – Efficient mixing
  – To remove salt from salt slag
  – Manage gaseous reaction of the reactive compounds
  – Slurry control

• ALTEK have worked on following areas:-
  – Optimum particle size distribution
  – Water control
  – Efficient filtration
Salt slag <2mm infeed
Mixing to remove salts

Transfer to filtration stage
Leaching - Other considerations

\[ \text{AlN(s) + 2 H}_2\text{O(l)} \rightarrow \text{AlOOH (amorph)} + \text{NH}_3(g) \]

...pH starts to increase due to (OH-) ions..and temp

> pH of 9 increases surface oxide breakdown....

\[ 2 \text{Al} + 3 \text{H}_2\text{O} \rightarrow \text{Al(OH)_3} + 3 \text{H}_2 \]
ALUSALT - Filtering
ALUSALT – Salt Recovery

- Moisture < 0.3%
- Yield >98%
- Same consistency as input salt ratio
Economics

• ROI model
• Base on a 15,000tpy facility
• Key drivers/savings
  – Transport costs – *issues CO2 footprint*
  – Tolling fees (or landfill fees)
  – Salt purchase costs
  – Al recovery from salt slag
  – NMP (oxide) – cost or value?
• SECURITY of your operation
### Transport and CO$_2$

<table>
<thead>
<tr>
<th>Distance from salt slag processing</th>
<th>Salt slag generated per site</th>
<th>CO$_2$ generated per tonne, per average trip$^vii$</th>
<th>CO$_2$ generated per recycling site, per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>~719.6 Km</td>
<td>~14,774 tonne</td>
<td>~2.806 tonne of CO$_2$</td>
<td>~41,462 tonne of CO$_2$</td>
</tr>
</tbody>
</table>

Transportation generating > 250,000 tpy of CO$_2$

55,000km of salt slag transport per year @ a cost > Euro 50m
ALUSALT - Commercialisation

- EU Supported project

PESTLE Analysis (in relation to the commercialisation of the R&D project results)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political</td>
<td>Positive – Governments should encourage the benefits that this process brings</td>
</tr>
<tr>
<td>Economic</td>
<td>Positive operational cost drivers for implementation Cost saving process</td>
</tr>
<tr>
<td></td>
<td>Counteracts current monopoly in the market Climate for cutting cost</td>
</tr>
<tr>
<td>Social</td>
<td>Increased employment at each point that introduces the technology</td>
</tr>
<tr>
<td></td>
<td>European-wide impact on employment and sustainability of operation and thereby employment in the Alu recycling process plants</td>
</tr>
<tr>
<td>Technical</td>
<td>Radical shift – opportunities to recycle more Aluminium will be enabled through introduction of this process</td>
</tr>
<tr>
<td></td>
<td>Innovative design to economically “miniaturise” this process for local use</td>
</tr>
<tr>
<td>Legal</td>
<td>Legal compliance for local plants will be enabled at a low cost</td>
</tr>
<tr>
<td></td>
<td>The climate of more legislation to address environmental issues and carbon reducing processes will have a positive impact on this technology</td>
</tr>
<tr>
<td>Environmental</td>
<td>Addresses – land fill, transportation costs, hazardous waste movement, cooling emissions problems with current process</td>
</tr>
</tbody>
</table>
Typical ROI – 15,000tpy
Target end use of NMP

- Steel Industry as a Synthetic Slag ($\text{Al}_2\text{O}_3$)
- Rock Wool
- Cement Industry
- Bricks/Tiles (additive)
- Sandblasting
- Refractory
- Ceramics
- Flux
- Miscellaneous
NMP – Oxides and uses

• Cement
  – Conditions – how much? Ratios – things to consider

• Steel
  – Conditions – how much? Ratios – things to consider

• Rockwool
  – Conditions – how much? Ratios – things to consider

NOTE: Being able to control i/p slag locally allows control of o/p oxides
Dried NMP
ALUSALT Oxide analysis

Image 1 – NMP particle

Image 2 – smooth surface
ALUSALT Oxide analysis

Split NMP Particle to analyse external/internal structures
ALUSALT Oxide analysis
TOTAL DROSS MANAGEMENT

STEP 1: Minimise Dross in Furnace (Stirring - Effective heat transfer)
- 50-70% Al in resulting dross*

STEP 2: Recover 10-20% of this Al and capture remaining Al in skull
- 40-50% Al in resulting dross skull*

STEP 3: Recover 40-60% of this Al in rotary salt furnace
- 5-10% Al in resulting slag*

STEP 4: Recover 5-10% Al, and also salts and NMP (oxides) for re-use

* By weight
Summary

1. With over 500 customers using our Dross Presses, Rotary Furnaces and Slag Presses/Castings...unique insight into issue

2. The use of salt is still the most efficient way to recover Al from drosses and dirty scraps AND WILL CONTINUE TO BE SO!

3. Growth in recycling of aluminium will accelerate this

4. Environmental legislation and changes will drive necessity to manage salt slag locally

5. “Mini Salt Slag” solution allowing localized recycling now possible.

6. Dealing with drosses and salt slags will be seen more and more as a value opportunity

Will now allow maximized Al recovery from waste by-product streams at place of generation.
THANK YOU