Concentrate Treatment Process
SACOME Innovation Summit
23 SEPTEMBER 2016
Worldwide
/ Copper concentrate market is 60Mtpa
/ An average concentrate contains only 25-28% copper prior to smelting
/ Concentrates increasingly contain impurities such as arsenic, lead, zinc, bismuth, mercury, uranium and fluorine
/ Regulators are responding to community concerns about their environment
  – Chinese import limit of 5,000ppm Arsenic
  – Japanese and Korean restrictions on uranium
/ There is greater focus on product stewardship by producers and smelters

Here in South Australia
/ We host 14% of the world’s known copper resource
/ We have very unique geology
/ Total concentrate production of around 800,000tpa
/ 300,000tpa transported out of SA for smelting
/ Freight to market is a significant realisation cost
Innovation
Building a team who think and act differently

Orway Mineral Consultants
/ Specialist hydrometallurgical consultants
/ Background IP in copper and impurity hydrometallurgy
/ Designed and managed testwork programs
/ Engineering studies

IMER at The University of Adelaide
/ Hosting the ARC Australian Copper Uranium Research Hub
/ Fundamental research into the occurrence of impurities in South Australian copper deposits
/ Industrial process sensor development

South Australian Government
/ Joint sponsors of IMER through the Department of State Development
/ $10 million funding towards demonstration scale testing

OZ Minerals
/ Dedicated project team building internal hydrometallurgical expertise
What's in a concentrate?

- Copper minerals (Chalcopyrite and Bornite)
- Iron and silica minerals (Iron oxide, Iron sulphide, silica sand)
- Trace quantities of other minerals that contain impurities

<table>
<thead>
<tr>
<th>Element</th>
<th>Bornite %</th>
<th>Chalcopyrite %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>62.3</td>
<td>33.5</td>
</tr>
<tr>
<td>Iron</td>
<td>11.2</td>
<td>30.6</td>
</tr>
<tr>
<td>Sulphur</td>
<td>26.5</td>
<td>35.9</td>
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</tbody>
</table>

Copper Minerals 70%
Iron and Silica Minerals 29.98%
Minerals containing impurities 0.02%
Innovation
Chemistry. Replace Iron with Copper

Copper minerals Chalcopryite and Bornite react with Copper Sulphate in solution to form a new Copper mineral Covellite and finally Chalcocite with Iron Sulphate released into solution.

No copper is dissolved, which minimises the potential for losses

\[ \text{CuFeS}_2(\text{solid}) + \text{CuSO}_4(\text{solution}) \rightarrow \text{CuS}(\text{solid}) + \text{FeSO}_4(\text{solution}) \]

\[ 3.\text{CuFeS}_2(\text{solid}) + 6.\text{CuSO}_4(\text{solution}) + \text{H}_2\text{O} \rightarrow 5.\text{Cu}_{1.8}\text{S}(\text{solid}) + 3.\text{FeSO}_4(\text{solution}) + \text{H}_2\text{SO}_4 \]

\[ 6.\text{CuS}(\text{solid}) + 3.\text{CuSO}_4(\text{solution}) + 4.\text{H}_2\text{O} \rightarrow 5.\text{Cu}_{1.8}\text{S}(\text{solid}) + 4.\text{H}_2\text{SO}_4 \]
Innovation
Start small, optimise and scale up

2013
/ Benchtop batch testing of individual process steps
/ Each concentrate batch 1.5kg

2014
/ Continuous pilot testing of all unit processes linked together in a circuit
/ 30 days at 1kg/hr
/ Eight process steps

2015
/ Continuous demonstration scale testing of all unit processes linked together
/ Five months at 50-55kg/hr
/ Five process steps

2016
/ Batch and pilot testing of different concentrates
/ Engineering of a plant to treat 25t/hr
/ Four process steps
Innovation
Bring it all together

FOUR UNIT PROCESSES
1. NONOX Autoclave: Dissolves iron and impurities from the copper minerals and replaces iron with copper.
2. FILTER: Separates solution from upgraded Super Concentrate. Solution contains dissolved iron and impurities.
3. CPL (POX) Autoclave: Dissolves copper from a small recycle. Dissolved copper is needed for NONOX.
4. SOLUTION TREATMENT: Ground limestone removes the iron and impurities from the leach solution. Clean solution can then be recycled.
Chalcopyrite and Bornite are converted into a new copper mineral called Chalcocite.

Carrapateena concentrate is upgraded from 37% copper to 55-60% copper.

Removing iron significantly decreases the weight of the concentrate.

Impurities reduced to very low levels.

Successful demonstration. Five months continuous operation at 91% runtime.

Very stable autoclave operation with a homogenous concentrate feed.
Innovation

A product with superior smelting qualities

- Treated concentrate has a low ignition temperature, making it easier to smelt
- No change in particle size distribution means dust is controlled
- No change in filtration characteristics, moisture content or TML
Innovation
Differentiating ourselves from the pack

Grade (% Cu)

Comparison mines: Almalyk, Andina, Antamina, Antapaccay, Batu Hijau, Bingham Canyon, Buenavista (Cananea), Candelaria, Centinela, Cerro Verde Mill, Chuquicamata, Collahuasi, Constancia, Cuajone, Dexing, El Teniente, Erdenet, Escondida, Gay, Highland Valley Copper, Kansanshi, Koktaus, La Caridad, Los Bronges, Los Pelambres, Lubin, Luita, Mina Ministro Hales, Morenci, Mount Isa Cu, Oyu Tolgoi, Polkowice, PT Freeport Indonesia, Rudna, Salobo, Sarcheshmeh, Sossego, Toquepala, Toromocho Project, Zhezkazgan

Source: Woods Mackenzie
Innovation

Leading to a new vision for the Gawler Craton

Several options identified for treatment and distribution hub in South Australia

Studies currently considering the benefits of treatment and distribution hub in Whyalla

Integration of Prominent Hill, Carrapateena and potential third party concentrates

Benefits

Significant freight savings

Increased grade and marketability

Long term protection from penalties

Long term protection from regulatory changes for both operations

Simplified logistics with reduction in carbon emissions

- Total Whyalla CAPEX: c. A$180M to A$200M
- CTP capacity of 200ktpa
- Flexibility to increase capacity to 250ktpa with no additional capital
THANK YOU

2016 SA Resources Industry Awards - Innovation in Resources Award – JOINT WINNER