SME Annual Meeting

Critical Issues With Water & Iron Ore Beneficiation Plants
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> ACKNOWLEDGEMENTS
This document is a dynamic record of the knowledge and experience of personnel at Mineral Engineering Technical Services. As such it has been built upon over the years and is a collaborative effort by all those involved. We are thankful for the material supplied by and referenced from various equipment manufacturers, vendors, industry research and project partners.
Key Attributes

Pragmatic, efficient, complete engineering through quality, personalised & exceptional service delivery

- Working globally since 1988
- Dynamic and innovative niche consultancy
- Dedicated team providing customised service
- Specialist in Mineral Processing & Engineering Projects
- Unique solution finder
Introduction

> Water is critical for ore processing and in short supply
> Three magnetite projects - 3 different solutions
> Balmoral Magnetite Project
> Karara Magnetite Project
> Southdown Magnetite Project
> Common themes and differences with each project
> Specific issues to magnetite processing - new industry for WA
> Summary & findings
Water Scarcity in Australia

Location of main mineral processing centres

Trend in Annual Total Rainfall
1970-2006 (mm/10yrs)

© Commonwealth of Australia 2007, Australian Bureau of Meteorology

new magnetite projects
Total Water Use In WA 1999-2000

- Total: 1790 GL/yr
- Mining: 430 GL/yr

Mining % is growing - 2007 it was 72% of all water used in Pilbara
GOLD, IRON, MANGANESE and NICKEL account for 86% of total water allocation.

Competing uses for water
Important Aspects Water

- Australia is one of the driest continents
- No large rivers
- Murray-Darling is in trouble
- Significant rainfall in the tropical north - short duration, rapid run off, no storage
- Many competing uses for water - mining has no special privilege
- Attitudes to water use are changing
- Roxby- Great Artesian Basin - mound springs
- Millstream - water millions of years old - drawdown
- National policies are being formulated- COAG Water Reforms
  - Water trading
  - Ground water management plans
  - Equitable allocations
  - Charging for extraction
  - Economically sustainable
  - Environmental acceptance
> Transport of ores and waste

> Grinding and separation-critical-must have

> Mineral separation

> Cooling

> Dust suppression

> Washing equipment

> Human consumption

> Manage mine dewatering
Magnetite Advantages

- Previously based on DSO hematite ores
- New projects for Western Australia
- Exothermic in processing
- Easily upgraded to high grade concentrates (68-71% Fe)
- Low in deleterious elements (silica only issue)
- Suitable for high quality pellets
Balmoral South Project

- Large open cut 80 Mtpa magnetite ore - massive projects
- 24 Mtpa magnetite concentrate
- 40 GLpa desalination plant
- 600 MW combined cycle power station
- Filtration of tailings and dry stacking

80 km South West of Karratha
## Water Loss For Balmoral Project

<table>
<thead>
<tr>
<th>Area of Use</th>
<th>Annual Activity</th>
<th>Water Usage Rate</th>
<th>Water Consumption (GLpa)</th>
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<tr>
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<td>160Mtpa total movement in the mine</td>
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<td>Water in concentrate exiting the filter plant</td>
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<td>Water in screened and filtered coarse tailings leaving the plant</td>
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<td>Port Stockyard</td>
<td>24Mtpa</td>
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<td>Power Station</td>
<td>450MW for 7800 hrs</td>
<td>1.28m³/MWh, mostly evaporated in cooling tower</td>
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<td>Camp</td>
<td>4000 people</td>
<td>0.4m³/day</td>
<td><strong>0.6</strong></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td><strong>40.0</strong></td>
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Reverse Osmosis Supply & Water Balance

> Sea water feed—little choice

> Energy recovery by recuperators

> Producing 40 GLpa

> (GL=1X10⁹ and ML=1X10⁶)

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Reverse Osmosis (RO)

- Separates dissolved solids

- Membrane technology getting better - cost/life

- Yield of product depends on feed quality

- Energy biggest cost $$$- recuperators

- Scaling, fouling, chemical cleaning

- Some opposition from Green groups re brine outfall
Reverse Osmosis – 1
(Including Ultrafiltration & Nanofiltration)

- Reverse Osmosis (RO)
  - Non-selective soluble salts removal
- Ultrafiltration (UF) / Nanofiltration (NF)
  - Selective soluble salts removal
- Desalination / Demineralisation
  - multi-stage / two pass
- Water Recovery
  - 50 to 95% vol., limited by SiO₂ and gypsum, etc.
- Salt Rejection
  - generally 95-99.8%
- 50% waste stream from seawater
## Chemicals Used in Water Treatment

<table>
<thead>
<tr>
<th>Dosing chemical</th>
<th>Purpose</th>
<th>Dosing concentration ppm</th>
<th>Discharge concentration ppm</th>
<th>Modelled Mixing-zone boundary concentration ppm (refer Appendix F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Hypochlorite NaOCl</td>
<td>Intake. Intermittent oxidiser</td>
<td>5</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Sulphuric Acid H₂SO₄</td>
<td>Pre-treatment. Continuous</td>
<td>29</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Ferric Sulphate Fe₂(SO₄)₃</td>
<td>Pre-treatment. Continuous</td>
<td>12</td>
<td>8.0 – discharged as Ferrous Hydroxide</td>
<td>0.3 0.2</td>
</tr>
<tr>
<td>Polymer (anionic polyacrilic such as NaIco 8103 Plus or equivalent)</td>
<td>Flocculant. Continuous</td>
<td>0.3</td>
<td>0.5</td>
<td>Nil</td>
</tr>
<tr>
<td>SBS (Sodium Bisulphite)</td>
<td>Pre-treat intermittent oxidiser</td>
<td>10</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Anti-scalant (Permatreat PC 191 or equivalent)</td>
<td>RO. Continuous</td>
<td>1.5</td>
<td>2.2</td>
<td>0.05</td>
</tr>
<tr>
<td>Lime</td>
<td>Pre-treatment. Continuous</td>
<td>46</td>
<td>2 – discharged as silicate impurities</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Selective Separation
- based on ionic radius and molecular charge
  - eg. sulphate (multivalent) / chloride (monovalent)

Capital Cost (1-5 ML/day plant size): (reducing yr on yr)
- Brackish: $600/ML/day product water
- Seawater: $1,200/ML/day product water

Operating cost:
(reducing yr on yr)
- Brackish: $0.40/kL produced
- Seawater: $0.70 to 1.40/kL produced
- HPGR to 3mm
- Coarse cobbing
- Primary grind P80 55 µm
- Intermediate magnetic separation
- Final magnetic separation
- Reverse flotation reduce silica<5%
- Filtration concentrate to 9% moisture
- Dry stacked tailings
Karara Magnetite Project

- 225 km east of Geraldton
- JV Gindalbie Metals Ltd & Anshan Iron & Steel Group
- 20 Mtpa raw feed to produce 8 Mtpa concentrate 68% Fe
- Water supply from bore-field
- Dry stacked tailings
- Slurry pipeline concentrates to Geraldton
# Ground Water Analysis

<table>
<thead>
<tr>
<th>Groundwater Sub Area and Aquifer</th>
<th>Twin Hills GWSA (Yarragadee aquifer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available for allocation (GL/a)</td>
<td>48</td>
</tr>
<tr>
<td>Allocation being sought (GL/a)</td>
<td>6.6</td>
</tr>
<tr>
<td>pH</td>
<td>6.6</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>780 (grav)</td>
</tr>
<tr>
<td>Silica (mg/l)</td>
<td>23</td>
</tr>
<tr>
<td>Sulphate (mg/l)</td>
<td>110</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>0.58</td>
</tr>
<tr>
<td>Manganese (mg/l)</td>
<td>0.08</td>
</tr>
<tr>
<td>Nitrate (mg/l)</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>
Karara Process Flowsheet
Southdown Magnetite Project

- 90 km northeast of Albany
- 6.6 Mtpa concentrate - 120 km concentrate pipeline
- Water supply from pit dewatering and precipitation run off
- Conventional tailings dam and tailings return water
- Low evaporation rates
Thickener Components - Water Recovery

- **Feed Well**
- **Overflow**
- **Underflow**
- **Sludge Rake**
- **Feed Well**
- **Overflow Launder**
Filter Presses - Final Water Recovery

> Set of vertical, recessed plates

> Plates
  - Covered with filter medium
  - Central feed port
  - Ports at corners to collect filtrate

> Plates are pressed together to form series of chambers

Typical Filter Press
Filter Press Operation Cycle

- Chamber filling
- Slurry pumped into feed port
- Chambers fill with slurry
- Pressing
- Uses hydraulic or mechanical system
- Applies pressure to plates ~6 bar
- Liquor squeezed into filter media
- Wash water may be added and sequence repeats
- Cake collection
- Plates separate and cake falls free
- Plates return to original position
Filter Press Sequence

CHAMBER FILLING

Filter Cloth

PRESSING

Slurry in

CAKE COLLECTION

Filtrate

Filter Cake
Southdown Magnetite Process Flowsheet
Availability of water, water conservation and high cost of water are common themes.

Water is scarce and the cost of acquiring process water is increasing.

Water quality is important with chloride limits in the product & processing issues.

Balmoral use sea water, Karara use bore water and Southdown use pit dewatering and run off water.

Water is a sensitive environmental issue.
Water Quality For Processing

> Salinity
- Fresh water - Less than 1,000 ppm
- Slightly saline water - From 1,000 ppm to 3,000 ppm
- Moderately saline water - From 3,000 ppm to 10,000 ppm
- Highly saline water - From 10,000 ppm to 35,000 ppm
- Ocean water contains about 35,000 ppm of salt
- Hypersaline - >35,000 ppm TDS

> Acidity alkalinity

> Chemical analysis

> Pollutants

> Hardness
> Water quality is an important issue in mineral processing operations such as flotation, flocculation, gravity & magnetic separation, grinding, thickening and filtration

> Approximately 80% of water utilised by the mineral industry is sourced from underground- bore fields- desalination is a relatively new source

> Water strategy in terms of quality: “fit for purpose”

> Examples:
   - Mt Keith Nickel Project: uses 15,000 – 20,000 mg/L TDS
   - Some gold projects in WA: use 300,000 mg/L TDS with pH 3-3.5 for CIP/CIL
   - Plutonic good quality water- SRB’s (sulphate reducing bacteria)
   - Paddington- HCN gas levels
Water Quality Issues

- Accumulation of chemical species in recycled water
- Climate impacts on recycled water - build up of salts
- Use of ground water impacts on quality
- Increased cost of water
- Increased maintenance - corrosion issues
Conduct A Water Audit & Analysis

> The water quality circuit constitutes a complex system

> System analysis - absolutely necessary

> Three main levels at which a system can be identified

  Level 1 – Unit Operations

  Level 2 – Processing Plant

  Level 3 – Site Water Tasks
Possible Outcomes from Circuit Analysis

- Model water circuit - scenarios
- Classify water qualities
- Highlight areas of water loss
- Possibilities for re-use
- Economics of water sourcing & re-use
- Conclusions & recommendations from above
Licences & Regulations

- Water licence quota – Department of Water (DoW-Western Australia)
- Bore-field Monitoring and reporting of draw down, volume and analysis of water quality
- Seepage monitoring bores adjacent to tailings dams and heavy metal maximum levels in the groundwater allowable
- Annual reporting requirement
- Draft Pilbara Water In Mining Guideline, DoW, Feb 2009
Methodology for Appraising a Waste Water Re-use Project

> Internal recycling
  - Low tech, low risk
  - Fast track, greatest impact
  - Lowest capital and operating cost

> Holistic Approach – Consider
  - Total capital and operating cost (life cost)
  - Mineral processing plus waste management
  - Various waste treatment options
  - Various water quality requirements
  - Minimise processing of water
Classify Water Types & Quality

- Start paying attention to types, use and quality
- Raw water (bore water, sea water, stream)
- Tailings return water
- Process water (worked water)
- Potable water (drinking)
Water Balance

> Water In = Water out but can you account for it?

> Seasonal changes upset the balance - tropical vs. dry climate

> Ore type can change the balance - clays

> Can't manage what you don't measure

> High evaporation rates
Specific Magnetite Issues

- Water quality important for reverse flotation (no slimes)
- Product has limits with respect to salt content
- Balmoral/Karara/Southdown different approaches - location
- Filtration of large volumes of tailings is mandatory and has not been done before
- Desalination has environmental issues with respect to reject stream dispersion
- Bores can only be used on a sustainable basis - reporting, license, no drawdown, black art
Specific Magnetite Issues

> Mineral processing can improve its management of water quality

> Mineral processing plants can improve recycling

> Auditing and system analysis will assist and is the most appropriate

> Water circuits are complex

> Industry will face a number of challenges with water

> Desalination is only a part of the solution
Summary

> Water has to be managed as a precious resource
> Quantity & quality
> Cost likely to increase - fees for extraction?
> Recycling should be a high priority
> Carry out a risk assessment
> Assess effect of water on process
> Management based on measurement - Risk Analysis
> Water Issues are complex and cannot be considered in isolation - many impacting factors
> Mining companies must win the environmental hearts and minds of people in the cities
What did you get out of this presentation?
Please share your thoughts in an informal discussion

Questions?
Acknowledgement

> Thanks to SME for the opportunity to present
> Thanks to various companies, colleagues, engineers
> METS staff and consultants
> Thanks to laboratory staff
THANK YOU

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