INSIGHTS SESSION

Flotation
Who We Are

Mineral Engineering Technical Services

- 21 years in Mineral Processing
- Global & Local Experience
- Consulting
- Studies
- Detailed Design
- Due Diligence, Ni, U, Pb-Zn, Au, Cu, Fe, Al
- Laboratory Testwork
Objectives

- Introduction to flotation
- Metallurgical Testwork in Flotation Studies
Flotation Basics

- Flotation uses the manipulation of surface chemistry to preferentially upgrade valuable minerals into a concentrate.

- Flotation can be used to concentrate the values into either the floats (direct flotation) or into the tails (reverse flotation – Phosphates, silica from magnetite, Lithium).

- The type of flotation process will be dependant on the valuable and gangue minerals present.

- Most typically flotation is used to concentrate sulphide based minerals or associated values (e.g. gold, copper, nickel).

- Various reagents are used in order to drive the flotation process through the change of surface chemistry.
Flotation Basics

- Air bubbles are introduced into slurry
- Some minerals attach to the air bubbles
- Minerals carried to surface of slurry due to buoyancy
- Stable froth holds the minerals
- Froth collected at overflow launder
- Surface of mineral must be hydrophobic to attach to air bubbles
History of Flotation Technology

- **Zinc and Lead at Broken Hill, 1901-1915**
  - Several processes and machines were developed
    - Froth flotation (1902-present)
    - A film flotation process (1905-1917)
    - Vacuum flotation (1904-1910)
    - Flotation cells such as Potter-Delprat, Elmore Vacuum, Lyster and Owen cells

**Midas**

Potter - Delprat Cell (1916)
treated gravity tails to recover zinc sulfides 1902-1923
Minerals Separation Cells - 1916
History of Differential Flotation

- **Harwood** (BHP - 1910) roasted a float concentrate to oxidise galena allowing flotation of sphalerite (*blende*).

- **Lyster** (Zinc Corp – 1912) recognised the different flotation rates of galena and blende – devised a gentle flotation process to recover galena then floated the blende (eucalyptus oil used as frother).

- **Bradford** (BHP – 1913) patented the use of copper sulphate to activate sulfide minerals.

- **Myers** (US – 1913) independently discovered activation by copper sulphate.
History of Flotation Technology

• **Copper in USA, 1911-1920**
  - Froth flotation process was first used in US to produce copper
  - Compressed air flotation cell
  - Flotation reagents were developed from 1916
  - Xanthates were first introduced in 1923
History of Flotation Technology

• **Flotation in Canada, 1917-1922**
  - First flotation plant was used for copper slimes and copper sands

• **Coal in Europe**
  - The first forth flotation plants for coal cleaning in 1920 in Spain and France

• **Years of consolidation, 1925-1960**
  - Efficient sub aeration cells were available
  - Reagents (activator and depressant) were used
  - Technical progress was slow in this period due to economic depression and war
Flotation Principles
3 Phase Contact

- Contact angle: angle between solid surface and the bubble
- Contact angle measures how well the liquid wets the solid surface.
- Small contact angle: surface hydrophilic
- Large contact angle: surface hydrophobic
- Surface properties altered by adsorption of substances
Collectors

- Principal reagent in the flotation process
- Organic heteropolar compounds
- Charged end of the molecule adsorbs onto desired mineral surface
- Non-polar end extends out of mineral surface
- Mineral surface made hydrophobic
• Surfactants, organic heteropolar compounds
• Frother adsorbs at the air/water interface
• Act to lower the waters surface tension
• Frother provides a stable froth above the slurry
• Should not adsorb onto mineral particles

Source: Your Dictionary website (2012)
Effects of Frothers

- Reduced surface tension
  - Stabilises froth
  - Reduces bubble size

- Entrainment
  - Gangue becomes trapped in the interstitial water between bubbles
  - Sufficient space between bubbles for drainage of gangue

- Can hinder adhesion of mineral to bubble

N.W. Johnsen: Entrainment Mechanism
Main Types

1. **Depressants**
   - Chemical which inhibits or prevents the adsorption of a collector
   - Prevents flotation of specific minerals

2. **Activators**
   - Alters surface of mineral to encourage collector adsorption
   - Prepares the mineral surface for adsorption

3. **pH regulators**
   - Adjust pH of slurry
   - Alters performance of reagents/minerals
   - Common pH regulators
     - lime
     - soda ash
     - sulphuric acid
## Examples of Flotation Sulphide & Non Sulphides

### Sulfide ores

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<table>
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<tr>
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<tr>
<td>Copper</td>
<td>Copper-Molybdenum</td>
<td>Lead-Zinc</td>
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<td>Lead-Zinc-Iron</td>
<td>Copper-Lead-Zinc-Iron</td>
<td>Gold-Silver</td>
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<td>Copper and Lead</td>
<td>Nickel</td>
<td>Nickel-Copper</td>
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### Nonsulfide ores

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<td>Lithium</td>
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<td>Tantalum</td>
<td>Tin</td>
<td>Coal</td>
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<tr>
<td>Silica from Magnetite</td>
<td></td>
<td>Phosphates</td>
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</tbody>
</table>
Flotation Equipment
Bougainville Flotation Floor
Flotation Process

- Rotating Shaft
- Air
- Frothing Tank
- Froth Layer
- Froth Effluent
- Hydrophobic Particle
- Hydrophilic Particle
- Air Bubble

Midas METS
Categorised by means of supply of air to cell

Types of flotation devices:
- Mechanical (sub aeration)
- Pneumatic
- Vacuum
- Dissolved air flotation

Mechanical and pneumatic used industrially

Source: Canadian Institute of Mining Metallurgy and Petroleum Website (2012)
Mechanical Flotation Cells

- Agitation produced by impeller
- Air introduced near impeller
- Provides dispersion of the air bubbles and particle-bubble contact
- Self aerating
  - air drawn in by action of impeller
- Supercharged
  - air supplied from blower
Cell Requirements

- Maintain all particles in suspension
- No short circuiting of the cell
- Disperse fine air bubbles through the slurry
- Promote collision between particles and air bubbles
- Provide stable region below the froth
- Provide sufficient depth of froth for drainage
• Finely dispersed bubbles
  — Increases chance of particle contact

• Air flow rate
  — Sufficient bubbles for particle contact
  — Reasonable depth of froth

• Bubbles – Too small
  — Not enough buoyancy to lift particles

• Bubbles – Too large
  — Less bubbles and less particle contact
Agitation

- Maintains particles in suspension
- Prevents settling on the bottom of the tank

- Too little agitation
  - Particles not maintained in suspension

- Too much agitation
  - Can rupture the bond between mineral and bubble
  - Disrupts the froth layer
Mechanical Cell Arrangement

- Froth removal types
  - Unassisted flow over weir
  - Mechanically scrapping froth with paddles

- Cell connection in series
  - Overflow weir between cells
  - Partial baffle
  - No baffle/hog through

Mechanically Scraped Flotation Cell
Outokumpu: TankCell®

- Supercharged mechanical flotation cell
- Controllable air flow
- Tank Cell® -300 largest flotation cell
- Large size range 5-300 m

TankCell - 200

TankCell Impeller

Model of a TankCell
Column Flotation

- Pneumatic flotation type cell
- Uses a column of pulp
- Air is injected at the bottom
- Feed added counter currently near the top
- Residence times are usually short

Source: Metso Website (2012)
Flotation Column

Schematic diagram of flotation column
Flotation Circuits
Flotation Circuits

Feed from grinding → Rougher cells → Scavenger cells

Rougher concentrate → Cleaner tails → Cleaner cells

Cleaner concentrate → Recleaner tails → Recleaner cells

Recleaner tails → Final Concentrate

Scavenger concentrate → Final Tails
Nickel Flotation Circuit
Metallurgical Testwork

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Development of Flowsheets

- Batch testing
- Locked cycle testing
- Impact of site water
- Pilot Plant Work
- Mini Plant
- Simulation
Samples & Sample Selection

METALLURGY SAMPLES
DDH CROSS SECTION

Variability Samples
1 metre sections
v1, v2, v3

Oxide Ore Zone
Transition Ore Zone
Primary Ore Zone
Testwork plans and studies

- Why do test plans and carry out testwork?
  - Unique properties and mineral contents for each ore deposit
  - To characterise the ore
  - Basis of studies
  - To develop process flow sheet
  - To develop process design criteria
  - To estimate capital and operating cost
  - To minimise process risk
    > Care of sample
• Geometallurgy
• Drill core not RC chips
• Sample all ore >10%
• Include mine waste 10%?

• Geology - recognise ore domains
• Mineralogy
• Processing
• Economics
• Risk management
• Metallurgical mapping
## Testwork Required For Studies

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Scoping</th>
<th>Pre-feasibility</th>
<th>Feasibility</th>
<th>Basic Engineering</th>
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Overall Copper Testplan

Example of Copper ore testwork program

- Comminution Testwork
  - Head Assay: Cu, Pb, Zn, Ag, Au, As, Fe, S + ICP Scan
  - Mineralogy
  - True SG
  - Grind Establishment: P80 - 75μm, P80 - 250μm

- Extraction Testwork
  - Flotation Test: P80 = 75μm
  - Collector Dosage test
  - Flotation test: Rergrid concentrate
  - Collector Test: Collector for Cu, not FeS2 (depress FeS2)

- Reserve
- Crush < 19mm
- Crush < 2mm
- Apparent Relative Density
- Comminution tests
- Bond Work index determination
- Rougher/cleaner Flotation
- Coarser Flotation
Metallurgical Summary Testwork Report

- Introduction
- Interpretation of test work results
  - Development of flowsheets and design criteria
- Recommendations
- Scope of Work
- Samples- domains
- Head assays
- Mineralogy
- Comminution
- Flotation
- Process Design Criteria
- Flowsheet Development
- Etc. etc.
THANK YOU

www.metsengineering.com