PROCESS PLANT TECHNICAL RISK MITIGATION & CAPEX/OPEX COST OPTIMISATION

CENTENARY CONFERENCE
CORNISH INSTITUTE OF ENGINEERS
FRIDAY OCTOBER 11TH

Nigel MacDonald B.Sc.(HONS), ENG. TECH
Operations Manager
October 13
Worlds leading independent testing, verification and certification company

- Ranging from Agricultural -> Customer Goods and Retail - > Life Sciences - > Mining

Minerals Services

- Non-ferrous metals and precious minerals
- Energy minerals
- Fertilisers and dry chemicals
- Industrial minerals
SGS MINERALS SERVICES UK LTD

- HISTORY
- GROWTH
- PEOPLE
DELIVERING TRUST
Services

- **Exploration Projects**
  - Greenfield/Brownfield Exploration Projects
  - Metallurgical studies required as part of resource codes (NI 43-101/JORC)
  - Mineralogical studies
  - Comprehensive metallurgical testing programmes to generate engineering data for process plant design
  - Variability study to test how ore will respond through time periods

- **Operational Mines**
  - Process optimisation
  - Mineralogy on process streams
  - Plant audits
  - Testwork for future ore zones (geometallurgy)
Traditional Approach, Isolated Disciplines
INTEGRATED METHODOLOGY

(After Turner, 2005)
SAMPLE SELECTION CRITERIA
– NOT JUST A GEOLOGICAL TASK

Need to consider:
• Geology
• Geochemistry
• Mineralogy
• Texture
• Mining Technique
• Processing technique
• Environmental Constraints
• Marketing

Design core usage carefully to minimise repeat drilling
METALLURGICAL RISKS

- Increased complexity in mineralogy and liberation
- Increased need to maximise and optimise recovery and concentrate grades
- Concentrate grade specifications and recovery must also be understood as a function of the mining sequence before starting production
- Ultimately, a robust DFS* is crucial to finance

*Definitive Feasibility Study
PROCESS PLANT DESIGN RISKS

- Throughput TPH & Recovery
- Product Quality
- Infrastructural Cost i.e. Capex
- Operating Cost
  - Against a background of lower grade ores and
  - More complex mineralogy
  - Increase in Variability programmes required
PLANT THROUGHPUT RISKS
(TONNES PER HOUR(TPH))

- Low grade ore = Higher TPH

- Very important to achieve nameplate tonnage
  - Drives production directly
  - Liberation is less definitive in more complex ores so indirectly drives production through metallurgical response

- Autogenous and semi autogenous milling attractive for higher tonnages

- Relies completely on understanding the physical ore characteristics by mine sequence

- Finer particles = increased focus on rheological properties for materials transfer
High TPH makes autogenous (AG) and semi-autogenous (SAG) milling more applicable

- Must understand ore physical competence
- Grinding studies are relatively low cost and are not a critical-path activity if well planned
- SGS specialises in “proxy” tests using ¼ HQ core for SAG-ball mill circuits (~2kg) and for HPGR circuits (7kg)
- Relatively low cost in conjunction with direct risk mitigation on achieving nameplate TPH, makes this a vital component
### UNDERSTANDING ORE MINERALOGY

**Copper Mineralogy**
- Primary Sulphide: Chalcopyrite (most common economic copper mineral)
- Secondary Sulphides: Bornite, Covellite, Chalcocite, etc.
- Non-Sulphides: Malachite, Azurite, Cuprite, etc
  - Each of the above groups requires different processing
  - Copper sulphides quite often contain gold and silver credits

**Tin Mineralogy**
- Cassiterite, Stannite, Varlamoffite
  - Only Cassiterite economic

**Tungsten Mineralogy**
- Wolframite, Scheelite
  - Both Minerals Economic

---

<table>
<thead>
<tr>
<th>Mass (% Sn)</th>
<th>Elemental Deportment (Mass % Sn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>40.00</td>
<td></td>
</tr>
<tr>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td>60.00</td>
<td></td>
</tr>
<tr>
<td>70.00</td>
<td></td>
</tr>
<tr>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td>90.00</td>
<td></td>
</tr>
<tr>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Primary Ore</th>
<th>Secondary Ore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassiterite</td>
<td>92.6</td>
<td>79.7</td>
</tr>
<tr>
<td>Fe-Sn Oxy-hydroxide</td>
<td>4.66</td>
<td>10.1</td>
</tr>
<tr>
<td>Stannite</td>
<td>2.71</td>
<td>10.2</td>
</tr>
</tbody>
</table>
UNDERSTANDING ORE METALLURGY

- WHAT IS THE TARGET MINERAL
- OPTIMISED FLOWSHEET
- HOW WILL IT CHANGE DURING THE LIFE OF A MINE
- A ROBUST DFS IS CRUCIAL TO ATTRACT FINANCE
Copper Sulphide: Flotation
Copper Oxide: Acid Leaching
Tin Oxides: Gravity (+ Flotation)
COPPER SULPHIDE: FLOTATION

- Can Deliver High Recoveries (>90%)
- Generates Smelter Concentrate Grades greater than 21% Cu
- Copper Sulphide Flotation Technology well established
- Many newly discovered ore bodies are less 0.2% Cu
  - Processing lower grade ores is more difficult
COPPER OXIDE: ACID LEACHING

- Can use heap leach + tank leach
- Heap Leach requires lower CAPEX and OPEX, generally lower recoveries are achieved
- Tank Leach requires grinding increased CAPEX and OPEX but generally higher recoveries
- Recovery of copper from leach solution by solvent extraction / electrowinning (SX/EW)
TIN OXIDES – GRAVITY SEPARATION

- Gravity traditional route for Cassiterite due to its density (~6.8 SG)
- Gravity recovery better at coarser sizes
- Tin Flotation successful on Cassiterite particles < 45um
CORNWALL

- Technology
- Innovation
- Knowledge transfer
SGS DELIVERS COMPETITIVE EDGE

- Thinking globally
- Acting locally
- Using best practices
- Providing the right technologies
- Enhancing quality
- Improving productivity
- Ensuring compliance
- Reducing risk