Pressure Leaching of Copper Concentrates

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Presentation Outline

- Safety share
- Introduction
  - Global copper reserves/resources
  - Phelps Dodge production & reserves profile
- Commercial drivers for copper concentrate leaching
- The copper concentrate market and TC/RCs
- Phelps Dodge copper pressure leaching developments
  - High temperature
  - Medium temperature
- Critical success factors for commercialization
- Conclusions
Safety Share - Bagdad Concentrate Leach Project

- **Construction Safety Record (total project)**
  - Total man hours: 330,000
  - Lost time injuries: 0
  - Recordable injuries: 3
  - First aid treatment: 9
  - Near miss incidents: 7
  - Recordable Injury Frequency Rate = 1.86 (per 200,000 man hours)

- **Operations & Maintenance (project to date)**
  - Lost time injuries: 0
  - Recordable injuries: 0
  - First aid treatment: 2
  - Near miss incidents: 18 (2004 YTD)
  - Recordable Injury Frequency Rate = 0
  - 651 Zero days since project start
Global Copper Industry by Process Type

2003 Production (Est.)
- Mill, Smelt (cpy/cc): 80%
- Leach, SX/EW (cc): 10%
- Leach, SX/EW (ox): 10%

Remaining Reserves (Est.)
- Mill, Smelt or Con Leach (cpy/cc): 80%
- Leach, SX/EW (cc): 9%
- Leach, SX/EW (ox): 11%
Technology Transformation of Copper Production

(PDC share; millions of pounds)

1983 – 100% conventional
2003 – 70% SX/EW

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Conventional SX/EW

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Drivers for Concentrate Leaching

- Cost effective alternative to conventional smelting & refining
- Capital cost versus greenfield smelter/refinery projects
  - $1,000-2,000 versus $3,000-6,000/annual tonne
  - Ability to utilize existing SX capacity ($300-400/annual mt)
  - Ability to utilize spare EW capacity ($500-600/annual mt)
  - Ability to utilize existing infrastructure
- TC/RCs – Commercial third party smelting & refining rates
- Operating cost
  - Oxygen requirements & cost
    - Altitude
  - Acid balance
  - Freight rates, distances, handling
- Copper recovery
- By-products (Au, Ag, other)
- Smelter penalty elements (As, Sb, Bi, other)
Chalcopyrite Concentrate Pressure Leaching Options

- Atmospheric sulfate media
  - Attrition grind & ferric leach
  - Silver-catalyzed ferric leach
  - Biological ferric leach
- Pressure sulfate
  - High temperature (>200°C)
  - Medium temperature (>100°C < 200°C)
  - Chloride-assisted
- Halide system
  - Chloride
  - Chloride-bromide
- Ammonia
Factors Affecting Process Selection

- Deposit characteristics
- Concentrate mineralogy
- Concentrate grade
- Location
  - Stand-alone versus integrated at mine site
- Site acid requirements
- Regional acid market
  - Availability and cost
- Acid neutralizing material
  - Availability and cost
The Copper Processing Technology Today

- Mine
- Primary Crushing
- Secondary/Tertiary Crushing
- Milling (Chalcocite) (Chalcopyrite)
- Flotation
- Heap Leaching (Oxide) (Chalcocite)
- Stockpile Leaching (Oxide) (Chalcocite)
- Solution Extraction
- Electro-Winning
- Electro-Refining
- Customers

Acid

\[ y = 0.1401x + 10.415 \]

\[ R^2 = 0.7257 \]
Near-Term Shortfall in Copper Supply

Shortfall in mine production expected to be filled by concentrate production

Existing concentrate production w/ majority of restarts & all financed projects

Source: Brook Hunt

Scrap/Other
SX/EW Production
Concentrate Production
SX/EW New Production
Copper Consumption
Primary Smelter Capacity vs. Mine Production

(Cu kmt)

18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000


Smelter Capacity  Smelter Production  Mine Production

Source: Brook Hunt

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Primary Capacity Utilization

- 1992: 76%
- 1993: 78%
- 1994: 80%
- 1995: 82%
- 1996: 84%
- 1997: 86%
- 1998: 88%
- 1999: 86%
- 2000: 84%
- 2001: 82%
- 2002: 80%
- 2003: 78%

Combined TC/RCs (¢/lb)

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Phelps Dodge Copper Pressure Leaching Developments

- Phelps Dodge (& Placer Dome) have developed a suite of proprietary processes, including:
  - High temperature process (HT)
    - Converts essentially all sulfide sulfur to acid
    - Maximizes acid production
    - Suitable for locations where dilute acid can be used beneficially
  - Medium temperature process (MT)
    - Converts a significant portion of sulfide sulfur to elemental sulfur
    - Lower oxygen costs
    - Minimizes acid production
    - Suitable for locations where dilute acid cannot be used beneficially
## Phelps Dodge Concentrate Leaching Milestones

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>2Q 1998</td>
<td>Sulfate-based concentrate leaching development started</td>
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<tr>
<td>1999-2000</td>
<td>Batch testwork at Hazen Research, Dawson and Phelps Dodge Process Technology Center</td>
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<tr>
<td>2000-2001</td>
<td>Continuous Pilot Plant Testing</td>
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<tr>
<td>3Q 2001</td>
<td>Technology Development Agreement executed with Placer Dome</td>
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<tr>
<td>Nov 2001</td>
<td>Bagdad HT Project approved</td>
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<tr>
<td>Nov 2001</td>
<td>Engineering awarded to Kvaerner</td>
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<tr>
<td>Mar 25, 02</td>
<td>Construction started by KIC</td>
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<tr>
<td>Mar 6, 03</td>
<td>Wet commissioning begun</td>
</tr>
<tr>
<td>Mar 20, 03</td>
<td>Start-up: First concentrate feed</td>
</tr>
<tr>
<td>July 2003</td>
<td>All design parameters met, steady state operation</td>
</tr>
</tbody>
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Four years from first testing to commercial demonstration
Phelps Dodge Concentrate Leaching Milestones (cont.)

- April 2004  Bagdad MT-DEW Conversion approved
- July 2004   Construction of MT-DEW started
- 1Q05       Commissioning of MT-DEW scheduled
Concentrate Leaching – Alternative to Smelting & Refining

- Mine
- Primary Crushing
- Sec/Tert Crushing
- Milling (Chalcocite) (Chalcopyrite)
- Heap Leaching (Oxide) (Chalcocite)
- Solution Extraction
- Electro-Winning
- Customers
- Concentrate Leaching
- Electro-Refining
- Smelting
- Flotation
- Stockpile Leaching (Oxide) (Chalcocite)

Acid
Concentrate Leach – Performance Summary

- Operated since March 2003
  - 18 months continuous operation
- All key design criteria achieved
  - Above design throughput
  - Above design availability
  - Above design copper extraction
  - Operating costs in line with expectations
- Demonstrated technical and economic viability of high temperature process in the appropriate application, where the dilute acid can be used beneficially
Start-up Data (adapted from McNulty, 1998)

- Bagdad
- BCLP 3 Mo. Avg.
- Category 1
- Category 2
- Category 3
- Category 4
Concentrate Leach - MT-DEW-SX Process

- Concentrate
- Super-fine grind
- Pressure Leach
- Tails
- DEW
- PLS from stockpile leach
- SX
- EW
- Stockpile Leach
- Cathode Cu
Concentrate Leach – The Path Forward

- Conversion of Bagdad to medium-temperature and direct electrowinning mode of operation under consideration
  - Construction started in 3Q04
  - Start up scheduled in 1Q05
  - Commercial demonstration complete by 4Q05
Phelps Dodge Concentrate Leaching Developments

- High temperature (>200°C) and medium temperature (140-180°C) pressure leaching in sulfate media
- Low cash cost alternative to smelting and refining
- Safe, environmentally-sound
- Acid balance is a critical cost driver
- Concentrate, cathode and acid freight considerations
- Ability to utilize existing SX and EW capacity
- Utilize existing infrastructure
Production Decisions Impacted by Concentrate/Acid Balance

North American Concentrate
- Bagdad
- Sierrita
- Chino (partial capacity)
- Cobre
- Morenci (off line)

Chino Smelter
650,000 tpy capacity (off line)

External concentrate source

Candelaria concentrate

External acid source

North American Leach
- Morenci
- Bagdad
- Sierrita
- Chino
- Tyrone (partial capacity)
- Miami (partial capacity)

Miami Smelter
750,000 tpy capacity (operating)

External acid consumer
Concentrate Leach – Potential Applications

- Morenci
  - Preliminary feasibility study in progress
  - Scheduled for completion 4Q04
- Cerro Verde primary sulfides
  - Preliminary feasibility study scheduled for 1Q05
- El Abra primary sulfides
- Other
Copper Pressure Leaching – Critical Success Factors

- TC/RC market conditions
  - Long term view?

- Ability to understand and exploit acid balance at site(s)

- Materials of construction

- Operating control
  - Mineralogy

- Competitive advantage
  - Speed of implementation
  - Scale of implementation
  - Ability to apply to greater proportion of production

- Other technical developments
  - Improve capital and operating costs

- Environmental permitting

- Intellectual property
  - A complex environment