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): 10%
- Leach, SX/EW (cc): 10%
- Leach, SX/EW (ox): 80%

Remaining Reserves (Est.)

- Mill, Smelt or Con Leach (cpy/cc): 11%
- Leach, SX/EW (cc): 9%
- Leach, SX/EW (ox): 80%
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
  - Sec/Tert Crushing
    - Stockpile Leaching
      - Oxide
      - Chalcocite
  - Milling
    - Chalcopyrite
    - Chalcocite
  - Flotation
  - Solution Extraction
  - Electro-Winning
    - Electro-Refining
    - Customers

Acid

\[ y = 0.1401x + 10.415 \]

\[ R^2 = 0.7257 \]
Forecast Real TC/RCs as a Percentage of Copper Price

Source: Brook Hunt
Near-Term Shortfall in Copper Supply

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

Shortfall in mine production expected to be filled by concentrate production

Source: Brook Hunt

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

Source: Brook Hunt

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- Smelter Capacity
- Smelter Production
- Mine Production
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

- **2Q 1998**  
  Sulfate-based concentrate leaching development started

- **1999-2000**  
  Batch testwork at Hazen Research, Dawson and Phelps Dodge Process Technology Center

- **2000-2001**  
  Continuous Pilot Plant Testing

- **3Q 2001**  
  Technology Development Agreement executed with Placer Dome

- **Nov 2001**  
  Bagdad HT Project approved

- **Nov 2001**  
  Engineering awarded to Kvaerner

- **Mar 25, 02**  
  Construction started by KIC

- **Mar 6, 03**  
  Wet commissioning begun

- **Mar 20, 03**  
  Start-up: First concentrate feed

- **July 2003**  
  All design parameters met, steady state operation

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)
- **Stockpile Leaching** (Oxide) (Chalcocite)
- **Solution Extraction**
- **Electro-Winning**
- **Electro-Refining**
- **Smelting**
- **Concentrate Leaching**
- **Flotation**
- **Acid**

Customers
Bagdad Concentrate Leach Plant

August, 2003
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)

% of Design Capacity

- Bagdad
- BCLP 3 Mo. Avg.
- Category 1
- Category 2
- Category 3
- Category 4

Months Since Commissioning

Months Since Commissioning: 0, 5, 10, 15, 20, 25, 30, 35, 40

% of Design Capacity: 0%, 20%, 40%, 60%, 80%, 100%, 120%, 140%, 160%
Concentrate Leaching & Direct Electrowinning

1. **Mine**
2. **Primary Crushing**
3. **Milling** (Chalcocite) (Chalcopyrite)
4. **Sec/Tert Crushing**
5. **Heap Leaching** (Oxide) (Chalcocite)
6. **Solution Extraction**
7. **Electro-Winning**
8. **Concentrate Leaching**
9. **Electro-Winning**
10. **Flotation**
11. **Customers**
Concentrate Leach - MT-DEW-SX Process

Concentrate

- Super-fine grind
  - Pressure Leach
    - Tails
      - S
      - L
      - DEW
      - SX
      - EW
      - Stockpile Leach
      - PLS from 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)

Miami Smelter
750,000 tpy capacity
(operating)

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

External concentrate source

Candelaria concentrate

External acid source

External acid consumer

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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