Technology in the Potash Industry

Presented to:
U of S Mechanical Engineering
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Technology in the Potash Industry

Presentation Outline

- **PotashCorp**
- Mining, Geophysics and Rock Mechanics
- Process
- Products
- Environment
PotashCorp Profile
Technology and Corporate Goals

Customers for PCS Potash

- Technology leader
- Best products
- Low cost producer
- Safe operations
- 2500 m²/person

5.7 billion people
1.42 Gha arable land
PotashCorp

Business Profile

- Produce, market and transport N, P and K products:
  - Plants in USA (N+P), Canada (K), Trinidad (N)
  - PCS operates 5 potash mines in SK and 1 in NB
  - 2001 Sales: 16.6 million tonnes of N, P and K products

- Financial 2001:
  - Assets: $4.6 billion US
  - Net Sales Revenues: $2.07 billion US
  - Employees: 4997
PCS Nitrogen and PCS Phosphate
Ammonia, Urea, Phosphoric acid, Solutions, Feeds

PCS Phosphate at Aurora, North Carolina
PCS Potash
Mines in Saskatchewan and New Brunswick

Rocanville, SK
Sussex, NB
Technology in Business
Impacts on Revenues, Costs and Risks

Profit = Revenue - Cost - Risk

• Revenue:
  – Sales of products: Marketplace
  – Investment income

• Cost:
  – Operations
  – Maintenance
  – Transportation

• Risk:
  – Probability x Consequence
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Potash Deposits in Saskatchewan
Devonian Period, -350 Ma

- Seas covered continent
- Mountain uplift, then cutoff
- Solar evaporation concentrated brine

- Sea water concentrated
- Chloride salts crystallized in sequence
- Now buried by 1000 m of sediments
Mining, Geophysics and Rock Mechanics

Profits = Revenues - Costs - Risks

- Mining at -1000 m
- Multi-pass room and pillar
- Stress relief chevron method
- Continuous, mechanized system
- High Productivity
- Automated, 3-D control of miners
- Safe operations
Continuous Mining Systems
Plan View of Mining Panels

- **Room and Pillar Mining**
  - Needs stable, flat ore body
  - Multi-pass cutting of rooms
  - Can use automated miners
  - Ore extraction in panels: 42%

- **Stress Relief Mining**
  - Used in clay-banded ore
  - Complex cutting pattern
  - Some automation
  - Ore extraction in panel: 65%, (42% overall)
Continuous Mining Systems
Mechanization and Automation

Lanigan Division 4-Pass System
with moveable extensible panel conveyor

14.6 m
4.9 m

Fixed mainline conveyor moves ore to the mine shaft
Continuous Mining Systems
Tri-axial Control of a Mining Machine in the Ore Horizon

X: Laser beam guidance system for 1st pass mining
   Advance rate sensor

Y: Ultrasonic sensors for 2nd and 3rd pass mining

Z: Vertical array of K-40 gamma radiation sensors for optimum ore grade
   Clay seam sensor
Mining Machine Performance
Bit and Pattern Design for Best Cutting Efficiency

Bit Design:
- Reduce bit wear and frequency of replacement
- Increase machine availability
- Reduce fines and dust from primary rock fragmentation

Tooling Pattern:
- Improve energy efficiency
- Increase average particle size of broken ore
Cutting Profile Goals:
- Rectangular opening
- No cusps
- Reduce dust and fines

Principle:
- Cam-following cutting arm extensions

SK Design:
- Prairie Machine

Prototype at IMC Colonsay
Aquifers above and below the highly soluble ore body are potential sources of inflow water, particularly near collapse structures.
Geoscience Helps to Prevent Mine Flooding
3-D Seismic Surveys to Detect and Avoid Major Anomalies

Seismic Data Collection:

1-D geophone string yields information on structures in 2-D plane

2-D Geophone surface array yields 3-D information

Rocanville Division Collapse Structure:

Image shows elevations of the top of the Dawson Bay formation that lies above the evaporite salts

First application of 3-D seismic method by PCS to confirm a collapse anomaly
Managing Potash Mine Floods
Successful Plug Installed at the Rocanville Division

Location of mined rooms in panel

Technology in the Potash Industry
Instrumented Tri-axial Test Cells  

15 cm diameter core of potash ore shows strain after testing
Rock mechanics monitoring station. Deformation of rock is measured. Data logged underground are transmitted to the surface for analysis. 2-D and 3-D numerical modeling of the displacement and stress distribution around mine openings in viscoelastic rock helps to ensure stability and safety.
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Processing Potash Ore
Mineral Separation and Particle Sizing Unit Operations
Profits = Revenues - Costs - Risks

- Crushing and Sizing
- Desliming
- Flotation
- Crystallization
- Drying
- Compaction and Screening
- Product Handling
- Tailings Management

Mill Feed Rates are up to 1400 tonnes/hour
**Composition:**
- NaCl: 55%
- KCl: 35-40%
- KMgCl$_3$.6H$_2$O: 1-5%
- Insolubles: 1-8%

**Size Range of Natural Crystals in Ore:**
- 1-10 mm
Processing Potash Ore
Particle Size Distributions of Potash Products

Particle Size Distributions of Selected Grades of Potash
Examples of Standard, Coarse and Granular Products

- Fine Standard
- Pink Standard
- Red Standard
- White Standard
- Pink Coarse
- Red Coarse
- White Coarse
- Pink Granular
- Red Granular
- White Granular
Processing Potash Ore
Ore Preparation for Flotation by De-sliming

De-sliming cyclones separate -150 micron particles from coarse slurries of potash ore
**Processing Potash Ore**

**Mineral Separation by Flotation**

Parallel Banks of Flotation Cell units operating in series

KCl-rich slurry is removed as Concentrate
**Processing Potash Ore**  
**Principle of Separation by Flotation**

- **Feed slurry:**
  - NaCl + KCl + Insols
  - Co-saturated brine
  - Reagents
    - Depressant
    - Collector

- **Concentrate:**
  - Mainly KCl slurry

- **Tailings:**
  - Mainly NaCl slurry
Processing Potash Ore
Flotation Process Flowsheet

Rougher & Regrind Flotation

PCS Lanigan Flotation Summary
Processing Potash Ore
Mechanical Cell Banks Separate Particles by Size

Rougher Flotation Particle Size Distribution

- KCl Mass Flow, %
- Particle Size (mm)

Graph showing the distribution of particle sizes and KCl mass flow for different categories labeled as T, C1, C2, C3, C4, C5, C6.
Processing Potash Ore
Rate of Flotation Depends on Particle Size

KCl Grade vs Recovery Flotation Data

- **Fines**: high recovery, low grade
- **Coarse**: low recovery, high grade

Mesh Size
- +6
- +8
- +10
- +14
- +20
- +28
- +35
- +48
- +65
- -65

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Processing Potash Ore
Principle of KCl Recovery from Brine by Crystallization

3 Stage Crystallization at the Cory Division

Temperature, °C

NaCl and KCl, Wt %

Supersaturated KCl

NaCl
Processing Potash Ore
Crystallizer Vessel and Components

Hot Brine Feed

KCl Slurry
**Processing Potash Ore**

**Mass Flows of Solids and Brine**

- Water Evaporation, 4.4 kg/s

- Quiet Zone

- 4550 kg/s (10 x Feed)

- Quiet Zone

- Overflow Brine
  - 404 kg/s
  - Density = 1.24 kg/L

- 84 °C

- Feed Brine at 96 °C
  - 455 kg/s
  - Density = 1.24 kg/L

- Product 30% Solids Out
  - 46.9 kg/s
  - Density = 1.47 kg/L

Draft Tube Top and Bottom Views
**Processing Potash Ore**

*Typical Crystal Size Distribution of KCl*

Maximize Growth Rate = $f(S^*)$

Minimize Nucleation Rate = $f(S^*)^3$

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**Processing Potash Ore**

**Crystallizer Product Characteristics**

- **600-1200 micron particles**
  - rounded by abrasion
  - composites

- **300-425 micron particles**
  - complex microstructures
  - agglomerates

- **150-212 micron particles**
  - primary KCl cubes
  - some agglomerates
Processing Potash Ore
Mineral Separation and Particle Sizing Unit Operations
Profits = Revenues - Costs - Risks

- Crushing and Sizing
- Desliming
- Flotation
- Crystallization
- Drying
- Compaction and Screening
- Product Handling
- Tailings Management

Mill Feed Rates are up to 1400 tonnes/hour
Compactors compress fine particles into sheets before crushing and screening into marketable products. Important variables are feeder design, roll dimensions, speed, surface contour and materials of construction.
Processing Potash Ore
Compaction Circuit Flowsheet Simulation

Lanigan Mill - Base Case

Crushers

Screens

Compactor

12a-Compaction 1&2
Processing Potash Ore
Product Storage and Transportation
Processing Potash Ore

Profits = Revenues - Costs - Risks

- Crushing and Sizing
- Desliming
- Flotation
- Crystallization
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Moisture uptake and release from packed beds of stored potash can occur rapidly, depending on RH, temperature, particle size and type.

Brine films on the surface of the potash particles are controlled by minerals deposited from brine during the drying process. KCl, NaCl and MgCl₂ minerals affect moisture dynamics. SEM image shows cluster of Mg-rich solid.
Compacted Granular potash products creep under applied stress at high RH typical of tropical and coastal climates for fertilizer storage.
Potash Product Quality Management
Modeling Moisture Transport in Hygroscopic Fertilizers

U of S-PCS-NSERC Research Program

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Environmental Management

Profits = Revenues - Costs - Risks

Aerial photo of a potash mine site showing tailings pile and brine pond

About 2 tonnes of salt and insolubles waste solids is separated for each tonne of potash produced
Salt piles are expected to grow during the lifetime of potash mines in Saskatchewan. Decommissioning plans assume that slow disappearance of salt will occur by dissolution in precipitation.

Risk of contamination of groundwater in aquifers by brine seepage is low because of low gradients, low permeability tills, and effective containment systems.
Environmental Management
Alternative Technologies for Tailings Disposal

- Stabilize
- Surface
  - Cover/Cap
  - Dissolve Salts
  - Inject Brine
- Underground
  - Backfill Mine
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The Presentation

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