EURARE Kvanefjeld Refinery Demo Plant
Work Package 5
About Outotec Research Laboratories
Highly Skilled and Experienced in Atmospheric Leaching

- Located in Pori, Finland
- Part of Outotec Global Metallurgy
- Highly skilled and experienced in atmospheric leaching
- Developed the HydroCu process
- Hydrometallurgical expertise
- State of the art facilities
Outotec Research Laboratories

Entrance to Outotec Research Laboratories
About the Refinery Pilot Plant

250 kilograms of concentrated treated

• 1st Kvanefjeld Refinery Pilot Plant Performed
  – Previously completed 100 hour continuous leaches

• Concentrate from 26 tonne flotation pilot plant in May 2015

• Fully integrated two stage leach

• Part of the EURARE Program
  – The EURARE program aims to encourage the sustainable supply of EU rare earth raw materials.
Pilot Plant Flowsheet
Process Piloted in Four Phases

Phase 1
Weak Acid Leach
- Leach Solution
- Partially Leached Concentrate

Strong Acid Leach
- Sulphuric Acid

Phase 2
Rare Earth Conversion
- Caustic

Phase 3
Re-Leaching
- Leached Slurry

Phase 4
Rare Earth Carbonate
- Critical Rare Earths

Uranium Recovery
- Uranium Solution

Fully Leached Concentrate Containing REEs
- Conditioned Rare Earth Hydroxides

Rare Earth Precipitation
- Rare Earth Solution
Pilot Plant Flowsheet Phase 1
Counter Current Atmospheric Leach with Two Products

Two Stage Counter Current Leach Circuit

Sample point number

1. Acidic Feed Liquor
2. Damp Concentrate
3. Pyrolusite Repulp Liquor
4. Seed Recycle
5. Tank 1 220L
6. Na₂SO₄
7. Potable Water
8. Filtrate
9. Thickener UF
10. 14.4 kg/hr
11. SAL Feed Slurry Tank
12. Conc H₂SO₄
13. Tank 3 3L
14. Tank 4 3L
15. Filter Feed tank

Thickener UF to SAL (batch)
Thickener UF Seed recycle (batch)
Thickener GF to storage

Damp filter cake to Metathesis 3.85 kg/hr

Flowsheet diagram with sample point numbers and process flow.
Concentrate Storage
Process Piloted in Three Phases
Weak Acid Leach Tank 1
Large Tank Used to assess scale and seeding
Weak Acid Leach Circuit
Continuously Stirred Tank Reactors
Weak Acid Leach Thickener
Clear Overflows Produced suitable for downstream
Strong Acid Leach Circuit
Ensures High Extractions of Rare Earths and Uranium
Strong Acid Leach Filtration

Good Filtration Observed for SAL Leach Discharge
Strong Acid Leach Filter Cake

Rare Earths in Filter Cake Ready for Next Phase ... Metathesis
WAL Thickener Over Flow
Low Grade Uranium Solution Ready for Solvent Extraction
Pilot Plant Facilities
Great Facilities and long 250 hours of operation

• Computer Controlled
• Operated from Monday 31\textsuperscript{st} August till Friday 11\textsuperscript{th} of September
Overall Performance
Kvanefjeld Flotation Now Well Tested

• High availability with only 4 hours of downtime
• Rare earth leach extraction of ~95%
  – Exceeding Feasibility Design of 77%
• Uranium leach extractions of ~85%
• Good circuit operability
• Silica control effective with no gelling
• Filtration and Thickening working well
Pilot Plant Flowsheet Phase 2
Metathesis – Rare Earth Double Sulphate Conversion
Feed Storage

Re-pulped SAL Leach Residue
Metathesis Cascade
Converting REE Double Salt to REE Hydroxide
Product Thickening
Dynamic Settling Tests for Thickener Sizing
Metathesis Residues Filtration
Filtration and Washing Data Generated.
Overall Performance
Metathesis Demonstrated Continuously

- High availability, no downtime
- Extensive double salt conversion achieved
- No requirement to heat circuit confirmed
- Good circuit operability
- Thickening and filtration working well
Pilot Plant Flowsheet

Phase 3

- Rare Earth Concentrate
  - Weak Acid Leach
    - Leach Solution
  - Partially Leached Concentrate
    - Strong Acid Leach
      - Sulphuric Acid
    - Fully Leached Concentrate Containing REEs
      - Rare Earth Conversion
        - Caustic
          - Conditioned Rare Earth Hydroxides
            - Re-Leaching
              - Leached Slurry
                - Impurity Removal
                  - Rare Earth Solution
                    - Rare Earth Precipitation
                      - Critical Rare Earths
                        - Rare Earth Carbonate
Feed Storage
Re-pulped Metathesis Residue
HCl Releach

Rare Earths Dissolved with HCl
Impurity Removal
Fe / Al / Th Precipitated from Solution
Radionuclide Removal
Pb / Po / Ra Precipitated from Solution
Solid/Liquid Separation
Dynamic Thickener Testwork
Final Residues

Barren Residues for Disposal
Overall Performance

Phase 3

• High availability, no downtime
• Rare earth recovery from converted double salt >95%
• Low iron and aluminium dissolution in HCl releach
• High rejection of impurities.
• No requirement to heat circuit confirmed
• Good circuit operability
• Thickening achieved good underflow density and overflow clarity
Pilot Plant Flowsheet

Phase 4

Rare Earth Concentrate

Weak Acid Leach

Leach Solution

Solution Clarification

Uranium Solution

Uranium Recovery

Partially Leached Concentrate

Strong Acid Leach

Sulphuric Acid

Fully Leached Concentrate Containing REEs

Rare Earth Conversion

Caustic

Conditioned Rare Earth Hydroxides

Re-Leaching

Leached Slurry

Impurity Removal

Rare Earth Precipitation

Phase 4

Rare Earth Carbonate

Critical Rare Earths

Rare Earth Precipitation
Pilot Plant Flowsheet Phase 4
Carbonate Precipitation

Tank 1
20 L

Tank 2
5 L

Tank 3
5 L

Tank 4
5 L

REE Chloride Solution

130 g/l Na₂CO₃

Sample point number

17.8 kg/hr

4.0 kg/hr

17.8 kg/hr

8.9 kg/hr

4.0 kg/hr

260 g/hr

Feed Dilution Tank 1 L

Potable Water

Solution (stored/disposed)

Mixed REE Carbonate

Seed recycle

REE Chloride Solution

Chloride Solution

0.1% Flocc
Carbonate Precipitation
REE Precipitated as Carbonates
Filtered Product
REE Carbonate Filter Cake
Washed Final Product
Approximately 50% TREO
Overall Performance

Phase 4

- High availability, no downtime
- High rare earth recovery from solution
- Good selectivity against impurities (Ca)
- No requirement to heat circuit confirmed
- Simple circuit operability based on pH
About the EURARE Program
GMEL is one of the participating Mining Companies
**Introduction: Greenland Minerals and Energy**

**Key Highlights – A unique world class mining project**

1. **World-class, large scale development project**
   - Economically robust, proven technology, large-scale, long life production of rare earths and uranium
   - Large JORC resource base to produce ~8kt CREO, ~15kt LREO & 1Mlbs U₂O₆ per annum over 37 year mine life
   - Ideally located near international airport, existing towns and potential hydro-electric power source

2. **Very attractive commodity portfolio**
   - Heavy rare earths and uranium are both recognised as strategically important commodities for the future
   - Rare earths market characterised by limited capacity and increasing demand (particularly Dy, Nd, Tb, Eu and Pr)

3. **Strong management and technical team**
   - Experienced management team with proven track record
   - Well-respected and knowledgeable technical/project team in place with exceptional local expertise

4. **Highly advantageous ore-type, makes for simple cost-effective processing, highly scalable production**
   - Low mass -high grade mineral concentrate produced through beneficiation
   - Easy atmospheric leaching of the mineral concentrate

5. **Globally significant, long life, low cost, multi-commodity asset**
   - Company to become one of the largest producers of rare earths globally and major U₂O₆
   - Company has low cost of production due to multiple by-product opportunities

6. **Low political risk**
   - Stable, low-risk operating environment with government looking to develop new industries and employment
   - GME fully permitted to evaluate the project, exploration licence now includes radioactive elements
   - Management and board have a solid working relationship with the government and are socially aware