Uranium Extraction from Wet Process Phosphoric Acid, The Third Time Around

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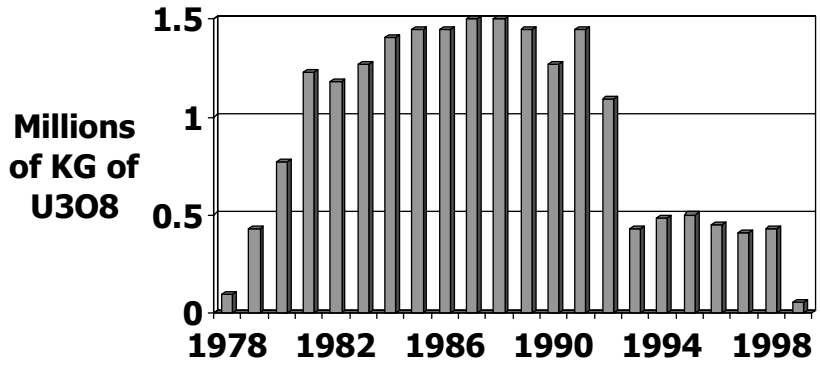
History of Uranium Recovery from Phosphoric Acid First Time

- First Plant was Built in 1952 in Joilet Illinois. It Precipitated the Uranium as a Phosphate
- Two Plants were Built in 1955 & 1957 in Florida. These Used a Solvent Extraction Process (Octyl Pyro Phosphoric Acid)
- All Three Plants Operated until the Early 60's, when the Low Cost Production of Uranium from Western Mines Depressed the Price

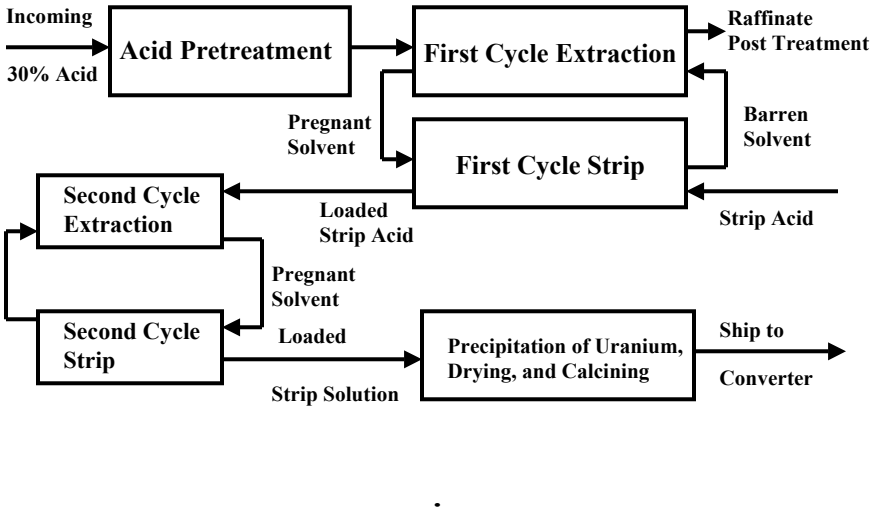
History of Uranium Recovery from Phosphoric Acid Second Time

- The Price of Uranium Increased Dramatically in the 1970's
- Eight new Plants were Built in the United States for the Recovery of Uranium From Phosphoric Acid
- Six were in Florida and Two were in Louisiana
- Plants were also Built in Canada, Spain, Israel, Belgium, Iran, Iraq and Taiwan

Uranium Recovered From Phosphoric Acid in the USA



Flow Sheets of Recent U.S.A. Plants



Flow Sheets of Recent U.S.A. Plants

- All Plants Extracted Uranium from Acid Produced by Dihydrate Processes (27-28% P_2O_5 Plus 1.5-3% Sulfate).
- All Acids were Produced from Central Florida Rock.
- U_3O_8 Content of All Acids was About 1.0 lb/Ton P_2O_5
- All Used a Solvent Extraction Process
- The Processes were Developed by Westinghouse, IMC (3 Plants), Uranium Recovery Corp., Freeport (2 Plants), and Gardinier

Flow Sheets of Recent U.S.A. Plants

- Pretreatment
  - Westinghouse Flash Cooled to 100 ^{o}F, Clarified with Flocculent and Reheated to 104 ^{o}F
  - IMC Used Spiral Coolers to Cool to 120 ^{o}F, Added Clay and Flocculent before Clarification, then Passed Acid Through Carbon Columns (Abandoned after 6 Years)

Flow Sheets of Recent U.S.A. Plants

- Pretreatment (Contd)
  - URC Did Not Cool, and Clarified Only
  - Freeport Did Not Cool, but Added a Flocculent and Clarified
  - Gardinier Cooled the Acid to 90 ^{o}F Using 2 Stage Flash coolers and Clarified the Acid. The Acid was Reduced with Scap Iron and then Filtered Using Pressure Leaf Filters

Flow Sheets of Recent U.S.A. Plants

- Oxidation Change
  - Westinghouse Used Nitric Acid to Oxidize Acid (and Uranium)
  - IMC Used Hydrogen Peroxide (Later Changed to Oxygen) to Oxidize Acid (and Uranium)
  - URC Used Ferro Silicon to Reduce Acid (and Uranium)
  - Freeport Used Oxygen to Oxidize Acid (and Uranium)
  - Gardinier Used Iron to Reduce the Acid

Flow Sheets of Recent U.S.A. Plants

- Uranium Extraction
  - Westinghouse Used DEPA/TOPO as Extractant
  - IMC Used DEPA/TOPO as Extractant
  - URC Used Octyl Pyro Phosphoric Acid as Extractant
  - Freeport Used DEPA/TOPO as Extractant
  - Gardinier Used Octyl Pyro Phosphoric Acid as the Extractant

Flow Sheets of Recent U.S.A. Plants

- Mixer Settler Design
  - Westinghouse Used Holms and Narver Low Profile Pumper/Mixers/Rectangular Settlers
  - IMC Used Circular Mixers and Settlers
  - URC Used Deep Cone Bottom Tank Mixers and Settlers
  - Freeport Used Low Profile Pumper/Mixers & Racked Rectangular Mixer/Settlers
  - Gardinier Used Rectangular Mixer/Settlers

Flow Sheets of Recent U.S.A. Plants

- When Any Organic Solvent is Mixed with Wet Process Phosphoric Acid, a Third Interfacial Phase is Formed that is Termed "Crud" or "Gunk".
- It Must be Removed from the Settlers or it will Interfere with the Performance of the Settler
- "Crud" Contains About 50% Solvent, so the Solvent Must be Recovered

Flow Sheets of Recent U.S.A. Plants

- Crud Removal
  - Westinghouse Continuously Over Flowed Crud from First Settler and Intermittently Pumped from the Rest
  - IMC Pumped Crud From All Circular Settlers
  - URC Batch Overflowed Crud From Settlers
  - Freeport Used Interface Drag Devices to Pull Crud Out of Settlers
  - The Crud Removal System For Gardinier Consisted of Pumping and Pressure Leaf Filtration

Flow Sheets of Recent U.S.A. Plants

- Crud Processing
  - Westinghouse Used Centrifuge (Abandoned) and Pre Coat Vacuum Drum Filter
  - IMC Initially Used Plate and Frame Filters and then Pre Coat Vacuum Drum Filter
  - URC Used Centrifuges and Pre Coat Vacuum Drum Filter
  - Freeport Used Chemical Treatment, a Patented Centrifuge Separation, and a Crud Maker System
  - The Crud Processing System for Gardinier was a Pressure Leaf Filter

Flow Sheets of Recent U.S.A. Plants

- First Cycle Stripping
  - Westinghouse Used 27% P_2O_5 Acid Reduced with Scrap Iron Plus Powdered Iron Within Stages
  - IMC Used 31% P_2O_5 Acid Plus Sulfuric with Iron Ball Towers for Each Stage for Reduction
  - URC Used 40% P_2O_5 Acid Plus Peroxide
  - Freeport Used a Boosted Strength 31% P_2O_5 Acid With Iron Ball Towers for Each Stage for Reduction
  - Gardinier Stripped the Solvent Using 15% HF

Flow Sheets of Recent U.S.A. Plants

- Second Cycle Oxidation
  - Westinghouse Used Nitric Acid to Oxidize Acid (and Uranium)
  - IMC Used Hydrogen Peroxide (Later Changed to Oxygen) to Oxidize Acid (and Uranium)
  - URC First Cycle Acid Was Already Oxidized
  - Freeport Used Oxygen to Oxidize Acid (and Uranium)
  - The Gardinier Process Did not Require Oxidation

Flow Sheets of Recent U.S.A. Plants

- Second Cycles
  - All Plants (Except Gardinier Which Used TBP) Used DEPA/TOPO in Second Cycle with Rectangular Mixer Settlers for Extraction and Strip
  - All Used Ammonium Carbonate for Stripping
  - Each Precipitated the Uranium as an Ammonium Compound
  - All Calcined to a Black Oxide and Shipped in 55 Gallon Drums

Operating Experience with Plants

- Westinghouse Plant Operated With 98+ % On Stream Factor and 92+% U_3O_8 Recovery
  - Turn Around After 2 Years and Down for Mechanical Problems Only
  - Organic Advance was Being Increased to Increase Recovery to 96% when Price of Uranium Dropped and Plant Closed
- IMC Plants Operated at 92% On Stream Factor and 96% U_3O_8 Recovery (Down Weekly for Line Scrubs and Yearly Turn Around)

Operating Experience with Plants

- URC Plant Operated at Less Than 60% On Stream Factor and Less than 80% Recovery (Lots of Mechanical Problems and Problems with Crud Build Up)
- Freeport Plants Operated at 92% On Stream Factor and 95% U_3O_8 Recovery (Down Weekly for Line Scrubs and Yearly Turn Around)
- The Gardinier Plant Obtained About 90% Recovery

Operating Experience with Plants

- Westinghouse Plant Produced Over 300,000 lbs/Yr U_3O_8.
- IMC New Wales Plant Produced as Much as 1,300,000 lbs/Yr U_3O_8. CF Plant City Module Produced as Much as 900,000 lbs/Yr U_3O_8. One CF Plant Closed Down After Less than 3 Years of Operation
- URC Plant Produced About 100,000 lbs/Yr U_3O_8.
- Freeport Plants Produced as Much as 1,060,000 lbs/Yr U_3O_8. (Combined)
- The Gardinier Plant Had a Design Production of 400,000 lbs/Yr U_3O_8.

Economics of Previous Plants

- Westinghouse Total Capital Cost was Less Than $20,000,000.
  (About 20% of the Equipment was Not Used or Eliminated)
- IMC Total Capital Cost was About $200,000,000 (3 Plants)
  (At Least 30% of the Equipment was Eventually Eliminated)
- URC Total Capital Cost was About $30,000,000
- Freeport Total Capital Cost was $40,000,000 for Uncle Sam and $30,000,000 for Faustina
  (About 10% of the Equipment was Eventually Eliminated)
- The Gardinier Capital Cost was About $25,000,000

Economics of Previous Plants

- Westinghouse Total Cash Cost (Including Royalty, Cost of Acid Dilution, Losses and Reheat) was About $17/Lb U_3O_8 ($11/Lb w/o Royalty etc)
- IMC (New Wales) Cash Operating Costs (No Royalty, Dilution, Reheat or Loss Cost) was About $11/Lb U_3O_8
- URC Total Cash Cost (Including Royalty, Cost of Acid Dilution and Acid Losses) was About $45/Lb U_3O_8 (Low Throughput and Operating Factor)
- Freeport Cash Operating Costs (No Royalty, Dilution, Reheat or Loss Cost) was About $12/Lb U_3O_8
- Gardinier Cash Operating Cost was About $18/Lb U_3O_8

Opportunities to Reduce Cost of "Next Generation" Plant

- Each of the Previous Plants had it's Strong Points and Weak Points.
- Combining the Best of Each can Reduce Both Capital and Operating Costs

Opportunities to Reduce Cost of "Next Generation" Plant

- For Example
  - Solvent Losses Varied by over a factor of three
  - Pretreatment Costs Varied by More than a Factor of Three.
  - The Total of Solvent Loss Cost and Pretretment Varied by Over a Factor of Three
  - Freeport and Westinghouse Required 5 First Cycle Stages of Extraction Whereas IMC Only Required 4
  - Freeport Required 5 First Cycle Stages of Strip, Whereas IMC and Westinghouse Only Required 3.
  - Second Cycle Operating Costs Were Similar, but One had a Significantly Lower Capital Cost

Opportunities to Reduce Cost of "Next Generation" Plant

- For Example
  - Average Solvent Concentrations in the Raffinate Ranged From 5 ppm to 100 ppm
  - P_2O_5 Losses Ranged from <0.1% to ~1%
  - Strip Coefficients Ranged from 15 to 150
  - Solvent Loss Due to Settler Cleanings Ranged from <.05 to >.2 lb/ton P_2O_5 Processed
  - Some Equipment Remains From the Original Plants and is Still Operating

Opportunities to Reduce Cost of "Next Generation" Plant

- During the Operation of the Plants, Studies were Conducted to Understand the Reasons for these Differences
- Most are Well Understood
- Taking Advantage of this Understanding can Significantly Reduce Both the Capital and Operating Costs of the "Next Generation" Plants

Estimates of Current Operating Costs Third Time

- Current Operating Costs Will be Higher Due to:
  - Lower Uranium Content of Rock
  (1.0 Lb/Ton Previously to Estimated 0.8-0.9 Lb/Ton for Next 10 Years)
  - Somewhat Higher Solvent Cost
  - Higher Electricity Cost
  - Higher Labor Cost (Can be Offset with Automatic Controls)
  - Total Cash Operating Costs Should be Less than $20/lb
  - + Regulations ??? $

Estimates of Current Capital Costs

- Capital Costs (Adjusted for Inflation) Should Be Lower than Previous Plants, but Highly Dependent on Flow Sheet Adopted

What About North Florida, North Carolina and Western US Operations?

- Uranium Content is about Half
- But Much of the Acid is Produce By Hemi Process (~40% Acid)
- Uranium Content on g/l is Similar to Central Florida
- Octyl Phenol Phosphoric Acid Solvent has Been Demonstrated to Work Effectively in Lab with Phosphoric Acid up to 54%
- Operating and Capital Costs will be about the Same per Pound as Central Florida (But less Pounds Produced)
- Piloting is Probably Required

Other Opportunities

- New Solvents
  - Octyl-Phenol-Phosphoric Acid
    - Lower Cost
    - Higher Extraction Coefficient
- New Contactors
  - Columns
- New Technology
  - Ion Exchange
  - Ultrafiltration
  - Micro-emulsions
  - Chelating Agents
  - Computer Controls

Will the Third Time be the Last!

- It May be the Last Time for the US Plants!
- Let's Get it Right!

US Plants and Trends