


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



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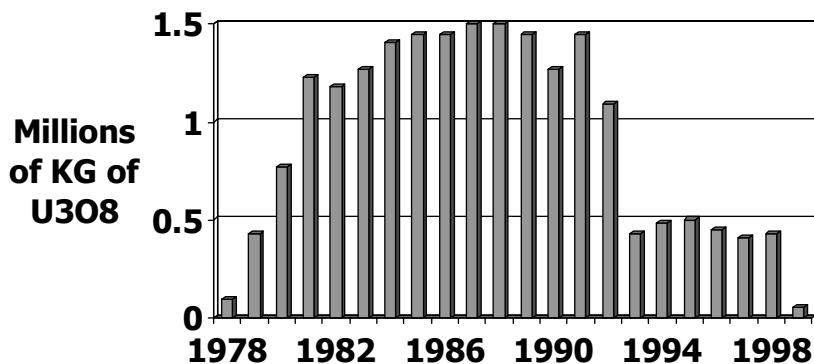
## History of Uranium Recovery from Phosphoric Acid First Time

- 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

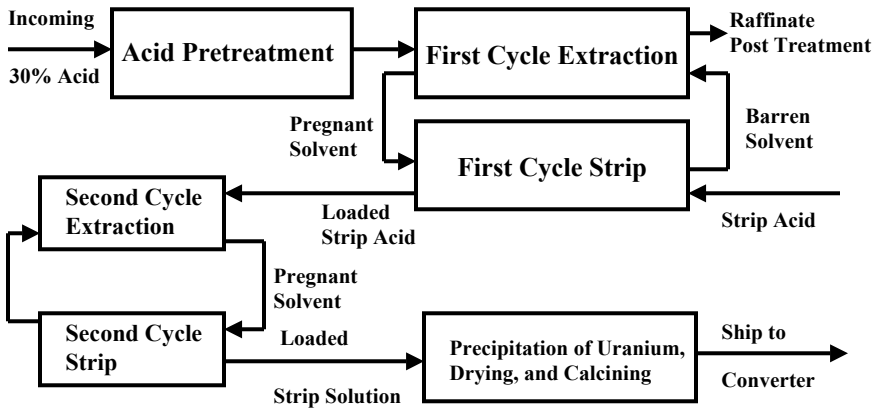
## History of Uranium Recovery from Phosphoric Acid Second Time

- 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 °F, Clarified with Flocculent and Reheated to 104 °F
  - IMC Used Spiral Coolers to Cool to 120 °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 °F Using 2 Stage Flash coolers and Clarified the Acid. The Acid was Reduced with Scrap 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 Pretreatment 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  $\sim 1\%$
  - 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

