An Advanced Recycle Treatment Facility Based on Pyrochemical Separations Techniques

Arthur A. Frigo, Chemical Engineering Division

Introduction

- National Energy Policy recommends development of advanced nuclear fuel cycles.
- Both the Advanced Fuel Cycle Initiative (AFCI) and the Generation IV Program within the DOE-NE support the recycle of spent nuclear fuel.
  - AFCI focuses on recycle for geological repository optimization.
- Pyroprocesses, including their flowsheets, are being developed to meet these goals.
  - These pyroprocesses build on the success of the demonstration of EBR-II metallic fuel treatment.
  - However, each of these processes has been developed on an individual-operation basis, thus far.
  - Therefore, integration of the unit operations into an operational facility is needed to demonstrate an economical recycle process.

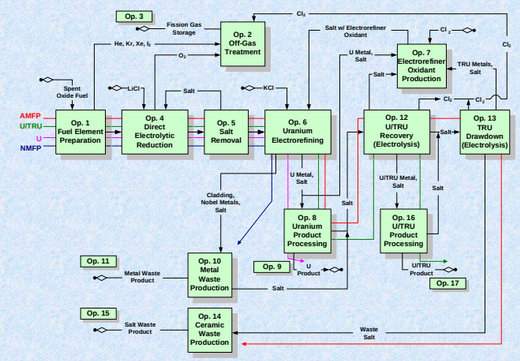
Challenge

To integrate unit operations into an operational facility that can demonstrate an economical recycle process based on pyrochemical separations techniques.

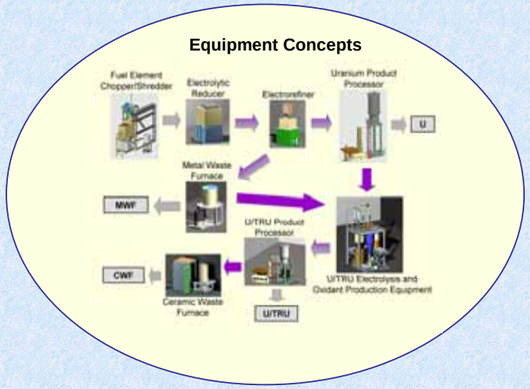
Argonne's Approach

- Identify processing technology, fuel type, and facility throughput by determining the overall requirements to encompass the needs of the process, facility, mechanical and electrical equipment design, operations, maintenance and safeguarding, and to translate these requirements into a conceptual design of an actual treatment facility.
- Select a fuel type and throughput requirement for the facility.
- Develop a process flowsheet and mass balance.
- Determine interrelated facility and equipment requirements.
- Generate concept drawings of the facility and equipment.
- Create an operational model of the facility.
- Optimize the facility.

Process Flowsheet



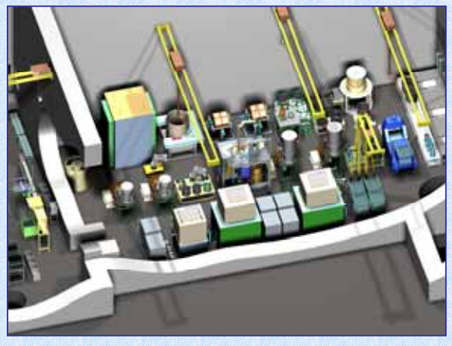
Equipment Concepts



Principal Operations

1. Shred fuel; load into baskets.
2. Off-gas treatment: Sequester fission gases from Operation No. 1; process oxygen from Operation No. 4 and chlorine from Operations12 and 13.
3. Long term storage of fission gases.
4. Direct Electrolytic Reduction: Reduce fuel oxides to metals; oxygen routed to Operation 2.
5. Salt Removal: Recover and recycle adhering electrolyte from Operation 4 to limit carryover to the electrorefiner.
6. Uranium Electrorefining: Recover uranium from the Operation 4 metal product.
7. Electrorefiner Oxidant (UCl3) Production: Electrotransport species required for operation of the electrorefiner (Operation 6).
8. Uranium Product Processing: Separate uranium from adhering salt and consolidate the uranium dendrites into ingots.
9. Uranium Product Handling: Handle and route the uranium product from Operation 8.
10. Metal Waste Production: Stabilize noble metal fission products and cladding from Operation 6; recover residual actinides.
11. Metal Waste Form Handling: Handle and route the product from Operation 10 for ultimate repository disposal.
12. U/TRU Recovery (Electrolysis): Electrolytically recover uranium and transuranic elements from process chloride salts produced during electrorefining (Operation 6); chlorine gas released; will recover about 98% of transuranics and all residual uranium.
13. TRU Drawdown (Electrolysis): Recover of remaining transuranics; chlorine gas released.
14. Ceramic Waste Production: Immobilize any chloride salts that contain fission products and trace actinides.
15. Ceramic Waste Form Handling: Handle and route the product from Operation 14 for ultimate repository disposal.
16. U/TRU Product Processing: Separate the metallic uranium and transuranic cathode product from any adhering electrolyte salt.
17. U/TRU Product Handling: Handle and route the product from Operation 16.

In-Cell Top-Down Conceptual View



In-Cell Operational-Floor-Level Conceptual Views

Results

- A process flowsheet, which includes detailed mass balances, has been developed for treatment of spent pressurized-water-reactor oxide fuel feed. Step-by-step details have been determined for the individual operations.
- A conceptual design of a demonstration advanced recycle treatment facility (ARTF) has been generated. The ARTF can treat 100 tonne of initial heavy metal per year.
- A simulation model of the facility has been created and was utilized to refine the design and operation.

Acknowledgements

1. CMT: J Figueroa, J. Willit, M. Williamson, and D. Graziano
2. NE: J. Krazinski, I. Therios, S. Wiedmeyer, C. Grandy, Y. Park, P. Roach, and J. Herceg
3. ENT: D. Wahlquist, R. Carlson, T. Kraupp, J. Morishita, L. Bumb, C. Knight, T. Pfeiffer, G. Teske, and K. Allen

Research funded by the U.S Department of Energy

Argonne National Laboratory is operated by The University of Chicago for the U.S. Department of Energy Office of Science