Dry (non-aqueous) Processing of Used Nuclear Fuel

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Panel on "Exploring the Options for Used Nuclear Fuel in Light of U. S. and International Decisions"

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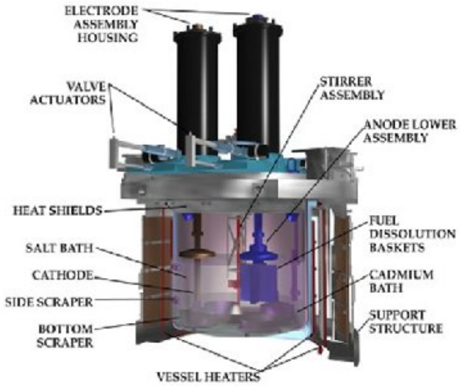
Classes of Dry Processes

- Volatilization (DUPIC, volox, AIROX, DEOX, etc.)
  - Spent fuel is heated to remove volatile or gaseous fission product impurities
  - Chemical form of the spent fuel may be modified to facilitate removal of volatile fission products
  - Recycle of the fuel is severely limited due to remaining impurities in fuel

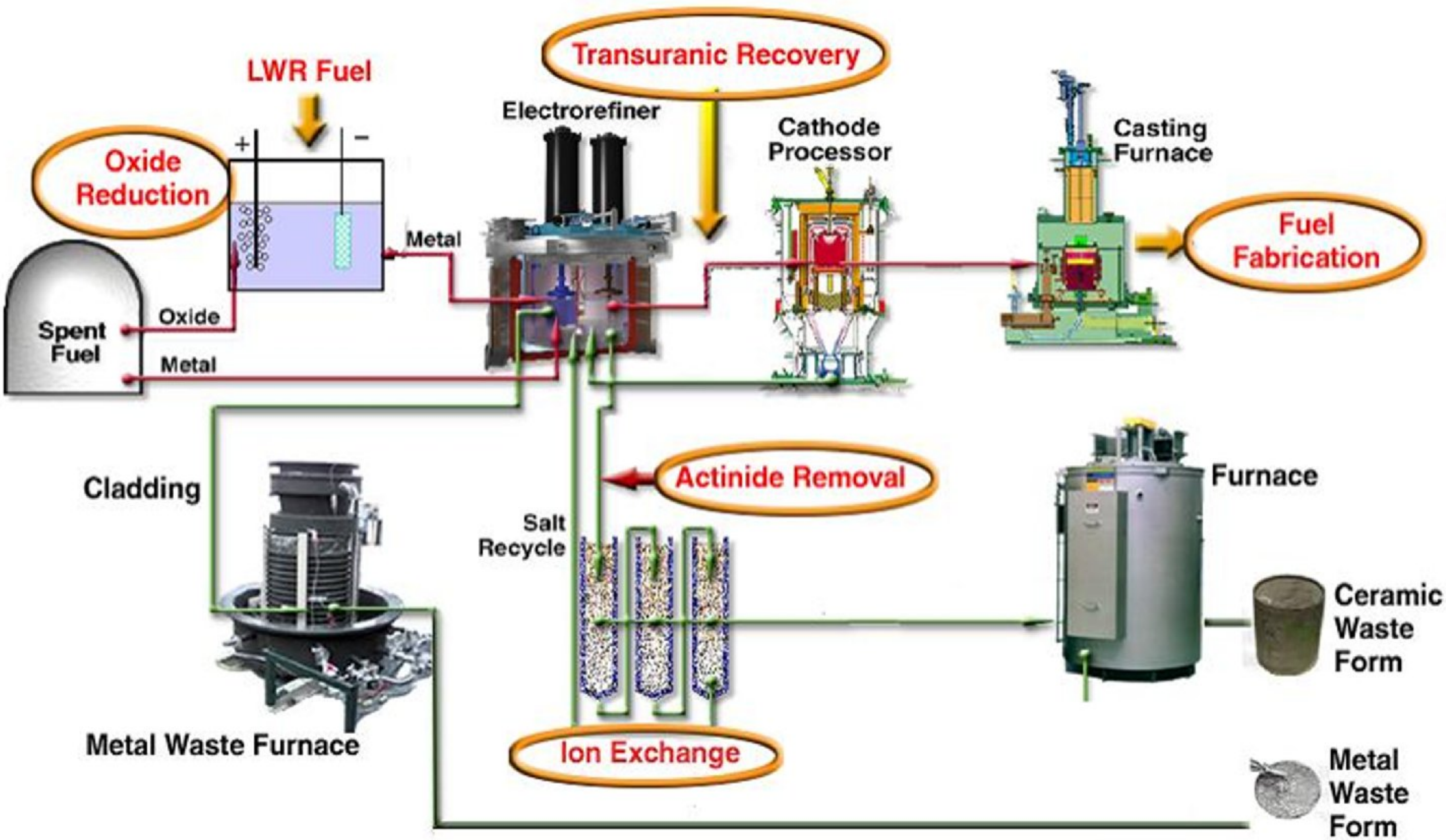
- Halide volatility (e.g. fluoride volatility)
  - Fuel converted from oxide to a halide form (UF_6)
  - UF_6 is gaseous and separated from non-volatile fission products
  - Other actinides can also be converted to gaseous halides to some extent.
- Partial oxidation (melt refining, skull-reclamation, etc.)
- Electrochemical (pyrochemical)
  - Molten salt medium 500 °C
  - Electromotive force to separate U and U/TRU fractions and recover as metals



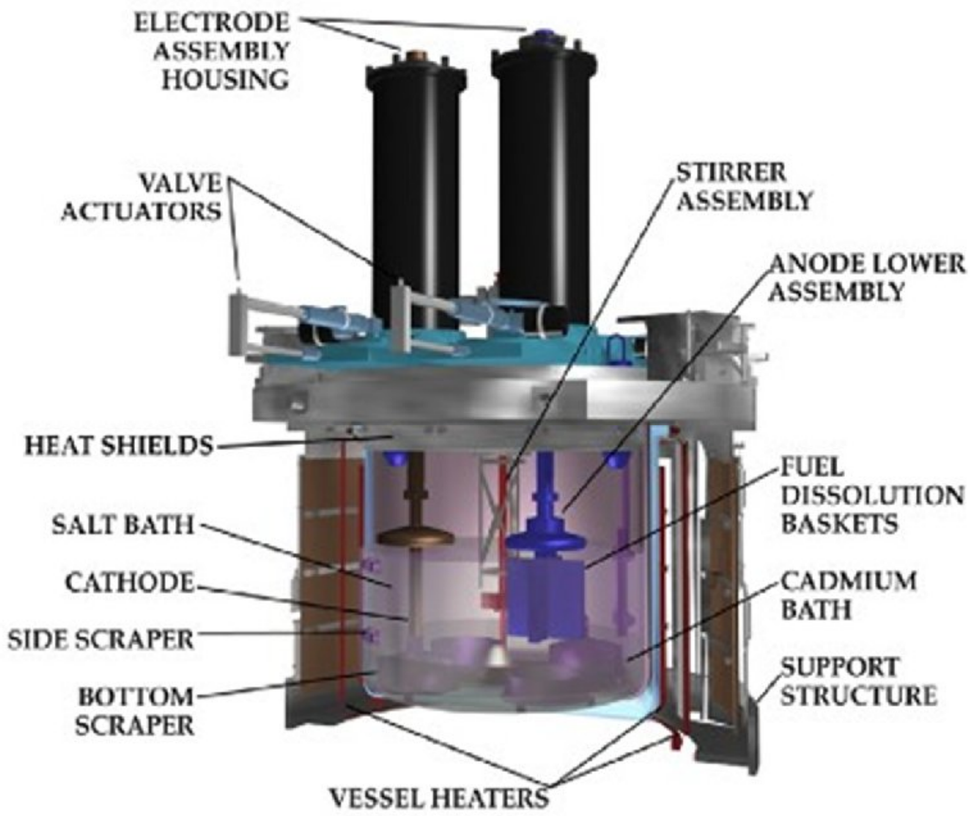
Status of Dry Processing Methods

- Volatilization methods have been demonstrated at small-scale, but due to their limited separation capability, are mostly considered as head-end operations to prepare fuel for further processing (either wet or dry)
- Fluoride volatility is a mature process on the front end of the fuel cycle (conversion), but has not been utilized on the back end
  - Morris Plant incorporated fluoride volatility process for uranium purification cycle after PUREX process
  - Significant research over several decades, with very limited use
- Melt refining was used early on to demonstrate metal fuel recycle for EBR-II
  - Discontinued due to high losses of actinides in slag phase and build-up of impurities over time
- Electrochemical processing was developed to replace melt refining for EBR-II fuel recycle
  - Used to process ~ 4 MT of EBR-II metal fuel from 1996-2012 (recovering uranium only) in a waste stabilization operation mode

Electrochemical Process Flowsheet



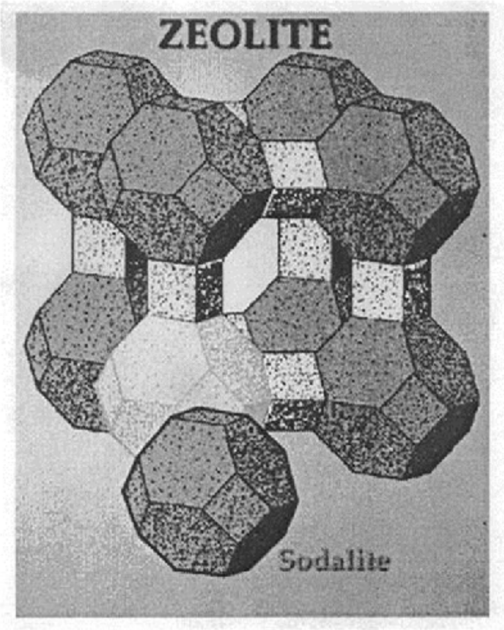
Electrorefining

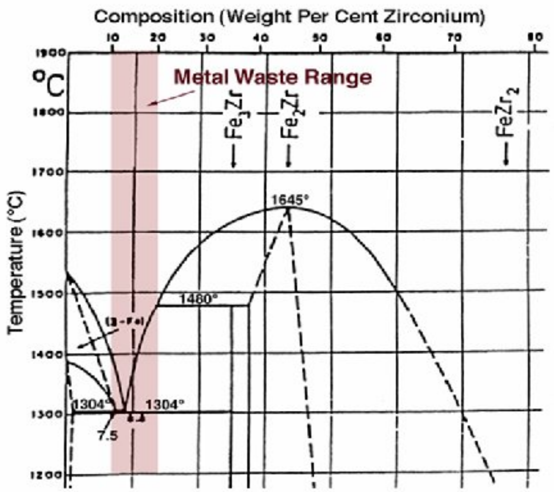


High-Level Wastes from Electrochemical Processing

- Two high-level wastes are produced from electrochemical processing.
- A zeolite-based ceramic waste stabilizes fission products that form chlorides.
- A stainless-steel-15% zirconium metal waste stabilizes the cladding hulls and more noble fission products.

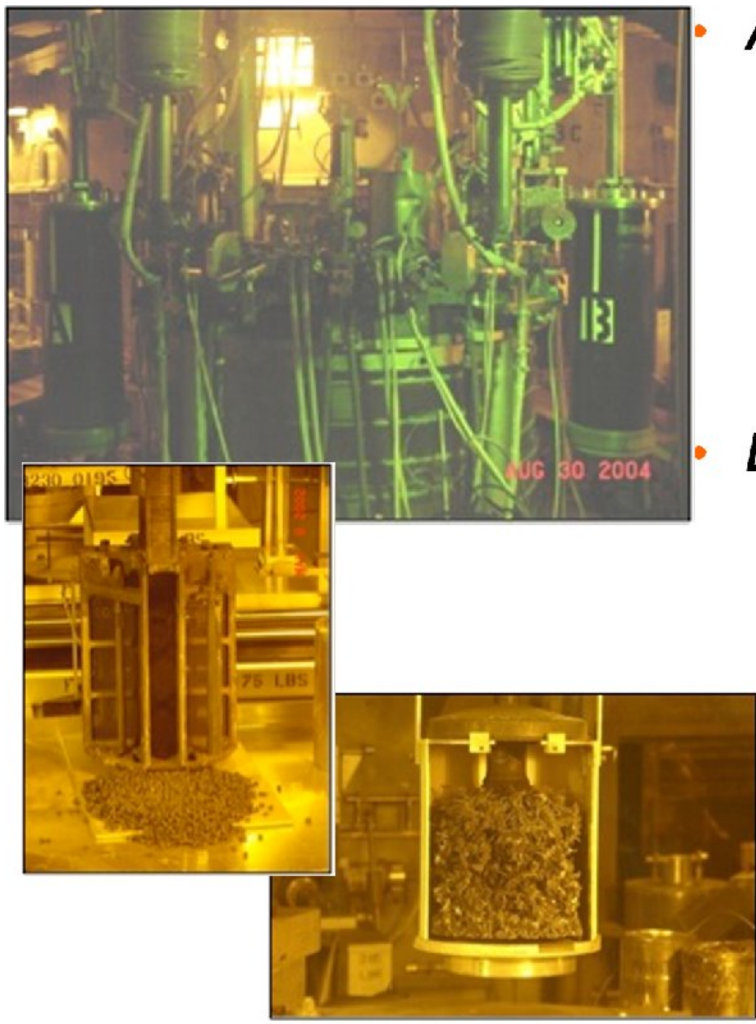
Unit Cell of Zeolite A :
Na_{12} [$(AlO_2)_{12}$ $(SiO_2)_{12}$]





Fe-Zr Phase Diagram for Metal Waste

Electrochemical Processing Advantages/Disadvantages



Electrochemical processes were developed for the fast reactor fuel cycle which does not require a high degree of decontamination

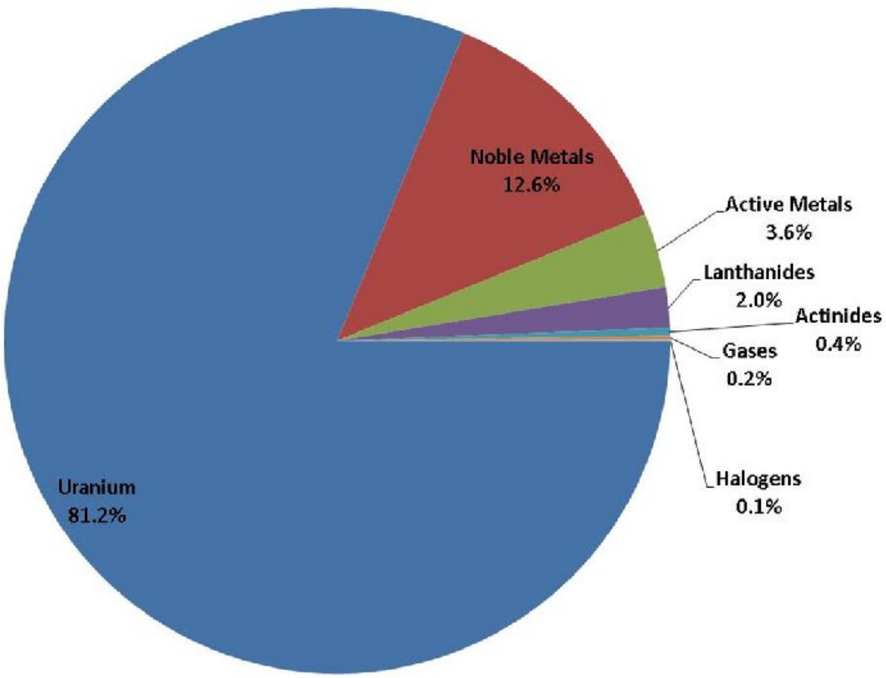
- ***Advantages***
  - Highly resistant to radiation effects (allows processing of short-cooled fuels)
  - Criticality control benefits (no water moderator)
  - Compatible with metal fuels and sodium bond
  - Compact process footprint
  - Produces only small quantities of LLW
- ***Disadvantages***
  - Batch process (limited throughput)
  - Less compatible with oxide fuel (can be processed, but requires additional unit ops)
  - Produces two HLW streams of moderate volume
  - Safeguards methodologies are not fully developed (material control and protection)
  - Cannot recycle product in LWRs without additional processing (requires fast reactors)
  - Much lower technical maturity than aqueous processes

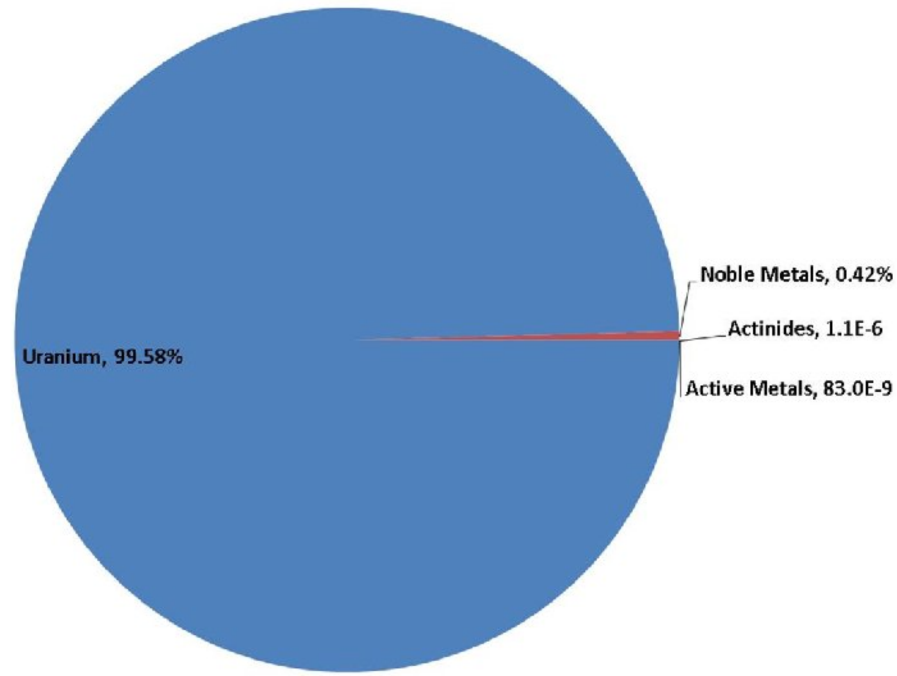
Summary

- "Dry" technologies include volatility, melt refine and pyroprocessing
- Pyroprocessing is particularly suited for processing sodium bonded metal fuels for recycle in fast reactors
- Pyroprocessing throughput is limited by batch processing
  - Reasonable estimates of 50-100 MT/yr throughput
- Pyroprocessing has been demonstrated at engineering-scale for recovery of uranium, but only at gram scale for recovery of TRU
- Technical maturity of pyroprocessing is lower than aqueous processes

Backup slides

Pyroprocessing – EBR II Driver Fuel





Spent Driver **Electrorefined Uranium**

Chemical Bases for Electrochemical Processing