Treatment Options
for
Aluminum SNF Disposition

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Nuclear Waste Technical Review Board
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Metallurgy and Corrosion
Alternate Aluminum SNF Treatment Technology
Outline

• Aluminum Spent Nuclear Fuel
  • Background
  • Corrosion Performance in Wet Storage (Initial As-Received Condition)
  • Corrosion Performance in Dry Storage

• Proposed Path Forward
  • Direct/Co-Disposal
  • Dilution Technology - Melt-Dilute Form
Aluminum MTR Fuel Microstructures

As-Fabricated UAlx MTR Fuel

As-Fabricated U3O8-Al Fuel

As-Fabricaled U3Si2-Al MTR Fuel

Aluminum MTR SNF Microstructures

Irradiated UAlx MTR Fuel

Irradiated U3O8-Al Fuel

Irradiated U3Si2-Al MTR Fuel
Corrosion Performance of As-Received Aluminum SNF

- Key to Corrosion Performance
  - Environmental Condition
  - Integrity of the Oxide Layer

- Reactor Service
- Basins of Origin
- SRS RBOF and L Basins

SNF with Pitting Corrosion
Worst Case SNF Condition - FRR Receipts Program
Total Pitted Area: < 1% SNF Surface

MTR SNF After 25 Years Wet Storage

Alternate Aluminum SNF Treatment Technology

- FY97
  - SRS Initiated Aggressive Implementation of Alternate Aluminum SNF Treatment Program

- Technology Development Program ➔ Dual Track Approach

Direct Disposal

Dilution Option
Alternative Aluminum SNF Treatment Technology
Technology Decision Drivers

Aluminum SNF Form
Development and Qualification
Direct Disposal/Co-Disposal Technology Development

SNF Form Development - Road Ready Package
- Developed Storage Criteria for Al SNF
- Drying Criteria and Specification
  - Field Vacuum Drying Tests
  - Issued Drying Specifications
- Developed Preliminary Functional Requirements for Storage Facility
- Developed Shielded, Instrumented Test Canister
  - Validation of Storage Criteria
  - Lead Surveillance

SNF Form Performance - Criticality Analysis
- Intact SNF Canister
- Degraded SNF in Waste Package
- SNF: HEU and LEU Fuel
- Assumptions
  - Fully Loaded to Physical Limit
  - Fully Flooded WP
  - Boron and Oil Poison
- Preliminary Results

SNF Form Performance - Degradation Models & Materials Reconfiguration
- Developed Corrosion Models for Air Vapor Environments
- Developed Gas Release Rate Models
- Models for Degradation in Waste Package
- Developed Creep Models

SNF Form Performance - Validation of Models
- Road-Ready Storage
  - CFDS-FLOW 3D Code
    - convective heat transport
    - Benchmarked
    - Fuel T <= 200°C
- Repository Storage
  - Codes 2D FIDAP; CFDS-FLOW 3D

Direct Disposal Accomplishments
Melt Dilute Waste Form Accomplishments

Melt Dilute Waste Form Technology Development

AI SNF Form Development - Bench Scale
- Developed Bench Scale Apparatus
- Established Process Feasibility
  - Induction vs. Resistance
  - Induction vs. Mechanical Stirring
  - Evaluated Crucible Materials
  - Evaluated Dilution Levels
  - Evaluated Process Cycles

AI SNF Form Process Requirements
- Analyzed Radium-226 Inventory in FRR/DRR
- Developed Concepts for Treatment Methods
- Analyzed Process and Secondary Waste Stream

AI SNF Form Development - Small Scale
- Developed Resistance Furnace for M-D of Full Scale MTR
- Demonstrated M-D with Full Scale Dummy MTR
- Designed Induction Furnace for Full Scale MTR

AI SNF Form Development Volume Reduction as f (Process Options)

<table>
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<tr>
<th>Additions</th>
<th>Uranium</th>
<th>Uranium and Aluminum</th>
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<tbody>
<tr>
<td>Alloy Wt%</td>
<td>2-20%</td>
<td>15%</td>
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<tr>
<td># of Canisters</td>
<td>253</td>
<td>596</td>
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<tr>
<td>20% Dilution</td>
<td>272</td>
<td>1254</td>
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<tr>
<td>5% Dilution</td>
<td>5%</td>
<td>10%</td>
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FY98
- Ternary Effects
- Intermediate Processing
- Surrogate Development
- Isotopic Studies
- Form DevelopmentAgregar Additions
- AI SNF Form Assessment

FY97
- Off-Gas System Development
- Lab Demonstration (Surrogates)
- Validation Bases

- Facility Development
- MTR Fabrication
- Process Simplification Device

- AI SNF Form Screening
- Passive, Corrosion & Disintegration

Melt-Dilute Waste Form Accomplishments

AI SNF Form Development - Off-Gas System
- Fusion Product Release
- Initial Validation Studies
- Off-Gas System Concept
- Process Waste Stream

AI SNF Form Development - Small Scale Validation and Performance
- Facility Development
- MTR Fabrication
- Process Simplification Device

AI SNF Form Development - Assessment
- AI SNF Form Screening
- Passive, Corrosion & Disintegration
Aluminum SNF Form Testing

**Aluminum SNF Form Testing in Aqueous Environments**

- Glass Waste Form => Release of Radionuclides
  => Tests in Aqueous Environment
- Commercial SNF (UO2) => Release of Radionuclides
  => Dissolution Tests
  "Homogenous Dissolution"
- HEU AI SNF
  - Release of Radionuclides
  - Materials Reconfiguration
  "Heterogeneous Dissolution"

**Test Methods for AI SNF Form**

- Release of Radionuclides:
  - Dissolution Tests => Flow Tests and Drip Tests
  - Corrosion Tests => Anodic Polarization, Cyclic Polarization, Electrochemical Noise
  - Static Dissolution Tests and Vapor Phase Tests

**Dissolution Characteristics - Preliminary Data**

- Microstructure Dependent
- Preferential Dissolution: Al > UA13 > UA14

**Al SNF Form Characteristics**

### SNF Form Stability

- Direct Disposal
- Melt-Dilute

- Irradiated MTR: Al + UA13+UA14
- Al + UA14

- Corrosion Resistance of Al: UA14 > Al+UA13+UA14

- M-D SNF Form: Tailored Microstructure

### AI SNF Form Characteristics - Criticality

- Poisons Necessary for Direct Disposal
- Poisons If Necessary in Melt-Dilute
- Efficacy of Boron (Degradation Rate)

### AI SNF Form Stability - Radionuclide Release

- D-D
  - Fission Gases in Pores
  - Fission & Activation Products Partitioning Between UA13, UA14 and AI

- M-D
  - No Fission Gases
  - Fission & Activation Products Partitioned to UA1s

### AI SNF Form - Proliferation Resistance

- Isotopic Dilution <20%
- Liquid Phase Processing
- No Ready Separation of U235