

Treatment Options for Aluminum SNF Disposition

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Presentation to the Panel on the Repository
Nuclear Waste Technical Review Board
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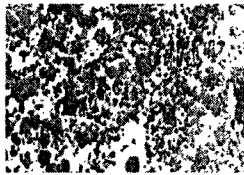
Metallurgy and Corrosion Alternate Aluminum SNF Treatment Technology Outline

- 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

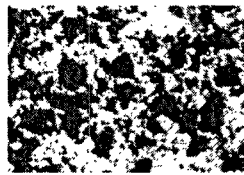
Aluminum MTR Fuel Microstructures



As-Fabricated UAl_x MTR Fuel



As-Fabricated U₃O₈-Al Fuel

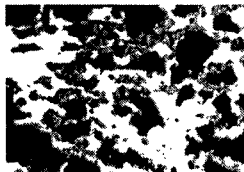


As-Fabricated U₃Si₂-Al MTR Fuel

Aluminum MTR SNF Microstructures



Irradiated UAl_x MTR Fuel



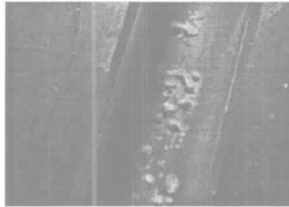
Irradiated U₃O₈-Al Fuel



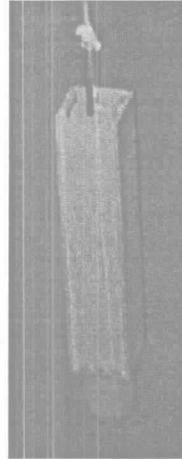
Irradiated U₃Si₂-Al MTR Fuel

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

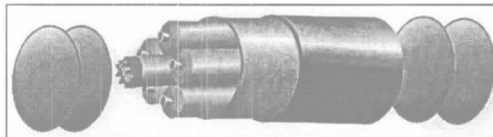


MTR SNF After 25 Years Wet Storage

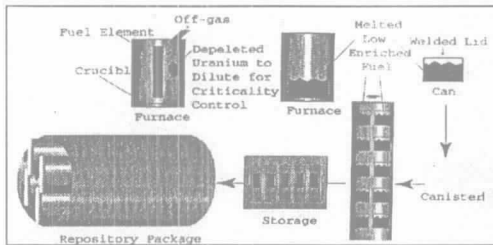
Alternate Aluminum SNF Treatment Technology

- FY97
 - SRS Initiated Aggressive Implementation of Alternate Aluminum SNF Treatment Program
- Technology Development Program → Dual Track Approach

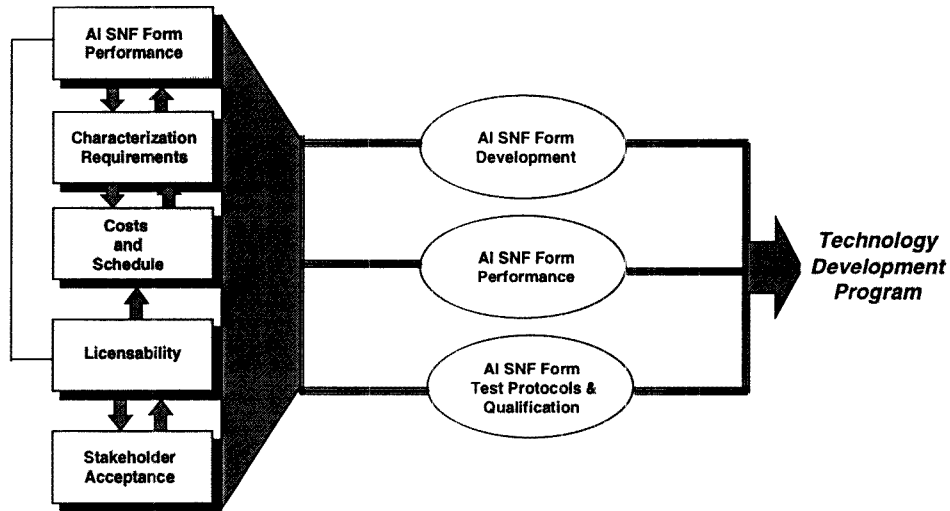
Direct Disposal



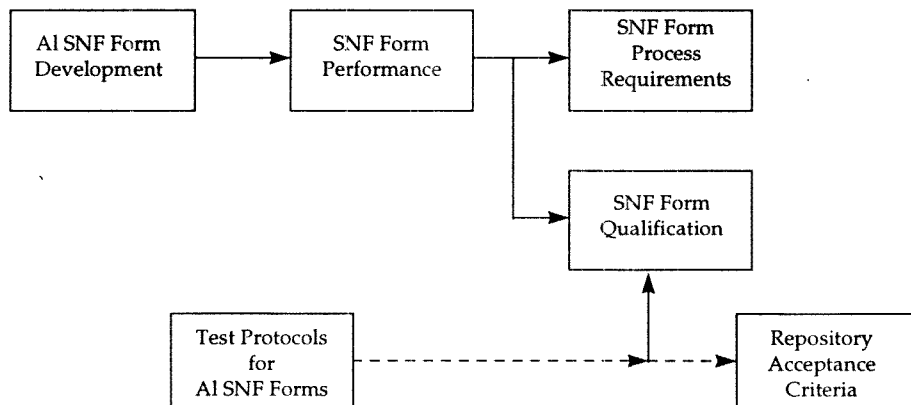
Dilution Option



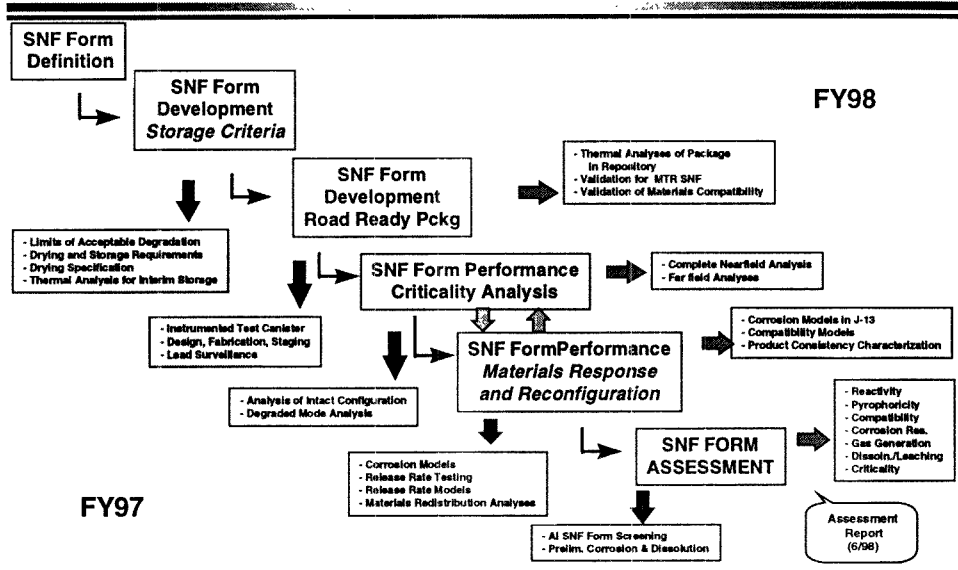
Alternative Aluminum SNF Treatment Technology Technology Decision Drivers



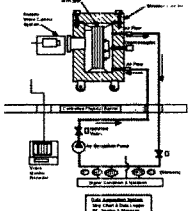
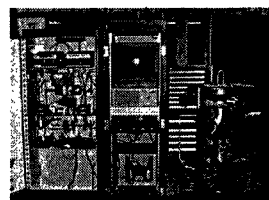
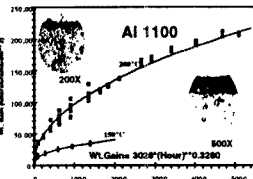
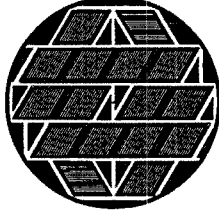
Aluminum SNF Form Development and Qualification



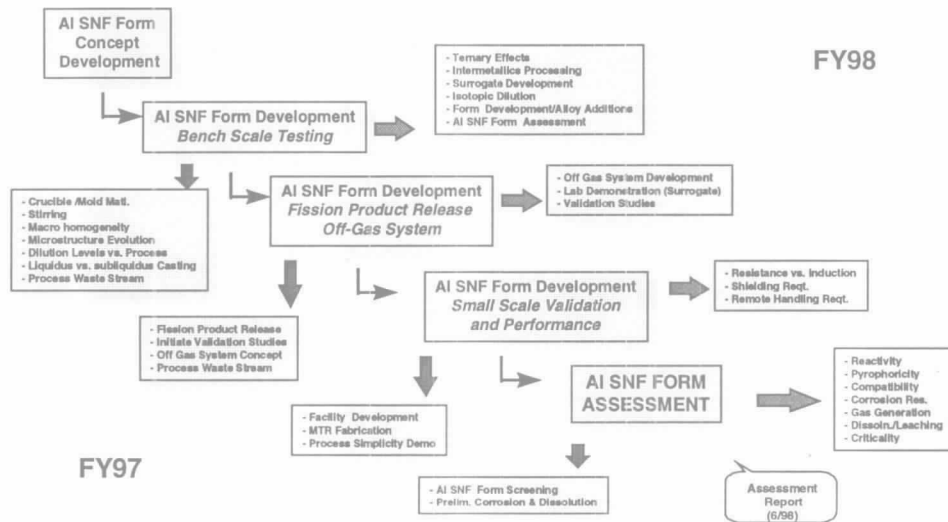
Direct Disposal/Co-Disposal Technology Development



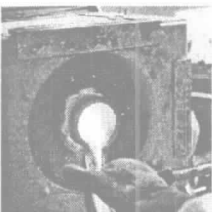
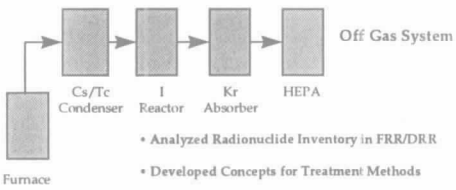
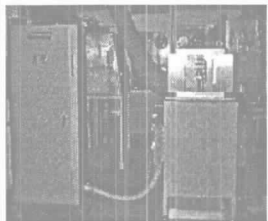
Direct Disposal Accomplishments

<h3>SNF Form Development - Road Ready Package</h3> <ul style="list-style-type: none"> Developed Storage Criteria for AI SNF Drying Criteria and Specification <ul style="list-style-type: none"> Field Vacuum Drying Tests Issued Drying Specifications Developed Preliminary Functional Requirements for Storage Facility Developed Shielded, Instrumented Test Canister <ul style="list-style-type: none"> Validation of Storage Criteria Lead Surveillance 	<h3>SNF Form Performance - Validation of Models</h3> <p>Thermal Models:</p> <ul style="list-style-type: none"> Road-Ready Storage <ul style="list-style-type: none"> CFDS-FLOW 3D Code convective heat transport Benchmarked Fuel T << 200°C Repository Storage <ul style="list-style-type: none"> Codes: 2D FIDAP; CFDS-FLOW 3D;  <p>Shielded, Instrumented Test Canister</p>
<h3>SNF Form Performance Degradation Models & Materials Reconfiguration</h3>  <ul style="list-style-type: none"> Developed Corrosion Models for Air/Vapor Environments Developed Gas Release Rate Models Models for Degradation in Waste Package Developed Creep Models 	<h3>SNF Form Performance - Criticality Analysis</h3>  <ul style="list-style-type: none"> Intact SNF Canister Degraded SNF in Waste Package SNF: HEU and LEU Fuel Assumptions <ul style="list-style-type: none"> Fully Loaded to Physical Limit Fully Flooded WP Boron and Gd Poisons Preliminary Results

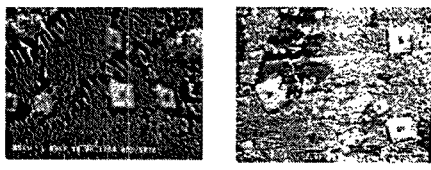
Melt Dilute Technology Development








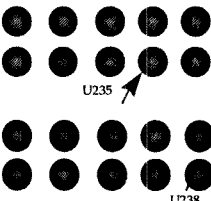
Melt-Dilute Waste Form Accomplishments

<p>AI SNF Form Development - Bench Scale</p>  <ul style="list-style-type: none"> • Developed Bench Scale Apparatus • Established Process Feasibility <ul style="list-style-type: none"> - Induction vs. Resistance - Induction vs. Mechanical Stirring - Evaluated Crucible Materials - Evaluated Dilution Levels - Evaluated Process Cycles 	<p>AI SNF Form Development Volume Reduction as f (Process Options)</p> <table border="1"> <thead> <tr> <th rowspan="2">Additions</th> <th colspan="2">Uranium and Aluminum</th> </tr> <tr> <th>Uranium</th> <th>Uranium and Aluminum</th> </tr> </thead> <tbody> <tr> <td>Alloy Wt%</td> <td>2 - 67%</td> <td>13% 30% 67%</td> </tr> <tr> <td># of Canisters</td> <td></td> <td></td> </tr> <tr> <td>20% Dilution</td> <td>253</td> <td>396 283 320</td> </tr> <tr> <td>5% Dilution</td> <td>272</td> <td>1234 479 326</td> </tr> </tbody> </table>	Additions	Uranium and Aluminum		Uranium	Uranium and Aluminum	Alloy Wt%	2 - 67%	13% 30% 67%	# of Canisters			20% Dilution	253	396 283 320	5% Dilution	272	1234 479 326
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<p>AI SNF Form Process Requirements</p>  <ul style="list-style-type: none"> • Analyzed Radionuclide Inventory in FRR/DRR • Developed Concepts for Treatment Methods • Analyzed Process and Secondary Waste Stream 	<p>AI SNF Form Development - Small Scale</p>  <ul style="list-style-type: none"> • 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 																	

Aluminum SNF Form Testing

<p>Al SNF Form Testing in Aqueous Environments</p> <ul style="list-style-type: none"> • Glass Waste Form => Release of Radionuclides => Tests in Aqueous Environment • Commercial SNF (UO2) => Release of Radionuclide => Dissolution Tests "Homogenous Dissolution" • HEU Al SNF - Release of Radionuclides - Materials Reconfiguration "Heterogeneous Dissolution" 	<p>Test Protocols for Al SNF Form</p> <ul style="list-style-type: none"> • A Test or Series of Test to Characterize Al SNF Form - Model after ASTM Standard for Waste Package - Corrosion by Water Intrusion - Aqueous and Vapor - Release of Radionuclides - Role of Environmental Variables - including co-disposal configuration - Extent of Transport • ASTM Standard Guide or Standard
<p>Test Methods for Al SNF Form</p> <p>Release of Radionuclides:</p> <ul style="list-style-type: none"> - Dissolution Tests => Flow Tests and Drip Tests - Corrosion Tests => Anodic Polarization, Cyclic Polarization, Electrochemical Noise - Static Dissolution Tests and Vapor Phase Tests 	<p>Dissolution Characteristics - Preliminary Data</p>  <ul style="list-style-type: none"> • Microstructure Dependent • Preferential Dissolution: Al > UA13 > UA14

Al SNF Form Characteristics

<p>SNF Form Stability</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Direct Disposal</p>  <p>Irradiated MTR - Al + UA13+UA14</p> </div> <div style="text-align: center;"> <p>Melt-Dilute</p>  <p>Al + UA14</p> </div> </div> <p>Corrosion Resistance of Al+ UA14 > Al+UA13+UA14 M-D SNF Form: Tailored Microstructure</p>	<p>Al SNF Form Characteristics - Criticality</p>  <ul style="list-style-type: none"> • Poisons Necessary for Direct Disposal • Poisons If Necessary in Melt-Dilute Form will be Integral to Structure - Boron Forms Compounds of U or UA1x - Efficacy of Boron f(Degradation Rate)
<p>Al SNF Form Stability - Radionuclide Release</p> <p>Radionuclide Release => f(Inventory, Retention Mechanism)</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>D-D</p>  <ul style="list-style-type: none"> - Fission Gases in Pores - Fission & Activation Products Partitioning Between UA13, UA14 and Al <p>M-D</p>  <ul style="list-style-type: none"> - No Fission Gases - Fission & Activation Products Partitioned to UA1x </div> <div style="width: 45%;"> <p>Al SNF Form - Proliferation Resistance</p>  <ul style="list-style-type: none"> • Isotopic Dilution to <20% • Liquid Phase Processing • No Ready Separation of U235 </div> </div>	