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Technology Base for Direct/Codisposal of DOE Aluminum-Based SNF

RECORDS ADMINISTRATION

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TECHNOLOGY BASE FOR DIRECT/CODISPOSAL OF DOE ALUMINUM-BASED SNF

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I. INTRODUCTION

The DOE Research Reactor Spent Nuclear Fuel Task Team completed a study in May 1996 of alternative technologies and waste forms for the treatment, packaging, and disposal of aluminum-based, aluminum-clad spent nuclear fuel (Al-SNF) from foreign and domestic research and test reactors [1]. Technology programs are in progress at the Savannah River Technology Center (SRTC) to develop the two highest-ranked alternative technologies, namely direct/codisposal and melt-dilute. The goal of the programs is to develop a form acceptable for placement within the waste packages of the Mined Geologic Disposal System and to support the selection of a technology option. This report discusses the technical activities of the direct/codisposal technology development program.

The envisioned path for direct/codisposal of Al-SNF assemblies involves fuel transfer from the L-basin storage into "DOE SNF canisters" and drying the fuel before or after placement within the canisters. The sealed DOE SNF canisters would be-evacuated, back-filled with helium, and stored for up to 40+ years, "road-ready" for shipment to the proposed federal repository at Yucca Mountain. At the repository, the DOE SNF canisters would be loaded, along with the canisters containing the Defense High Level Waste (DHLW) glass, into the engineered barrier waste package (see Figure 1).

The demonstration of acceptability involves developing the technical bases to meet interim dry storage requirements and repository disposal requirements. This includes demonstrating no adverse impact by the DOE SNF on the results of the performance assessment of the repository.

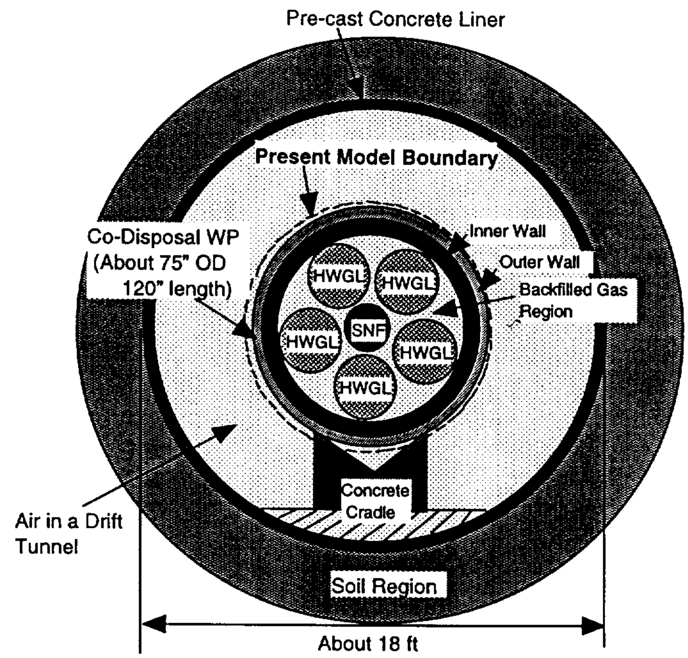

Figure 1—Codisposal Waste Package Conceptual Configuration for Disposal of DOE SNF

II. DISCUSSION

Requirements for Interim Dry Storage and Repository Disposal of Al SNF

Site requirements for interim storage of Al SNF in a road ready package have been developed with the following approach to assure full, safe retrievability through the interim dry storage period:

- limit changes in the Al SNF condition throughout the handling and storage period.
- identify environmental conditions such that SNF changes remain with acceptable
- develop predictive models to demonstrate acceptable conditions are maintained.

The following is a summary of the requirements for interim dry storage:

- consumption of clad or exposed fuel must be below 0.003"
- no gross rupture of cladding
- plastic deformation limited to provide assure clearance of assemblies in canister grid
- release of radionuclides within canister is limited (or provisions made for safe retrieval)
- fuel clad temperature shall be at or below 200 C
- free water is limited to avoid H2 build-up to flammability limits in air (or provisions made for safe retrieval).

Licensing requirements for disposal of waste forms in the federal repository are provided in 10CFR60 [2].

These requirements, along with additional requirements being proposed by DOE-OCRWM [3], would apply to the DOE SNF canister containing the DOE Al SNF. These requirements include limits on chemical reactivity, dissolution, and reactivity of the waste forms in credible reconfigurations. The flowchart in Figure 2 highlights the process steps for placement of DOE Al-SNF into road-ready canisters to meet the interim dry storage and repository disposal requirements. The following discussion summarizes several of the technical activities in progress under the direct/codisposal program from which the bases are developed to demonstrate the requirements are met.

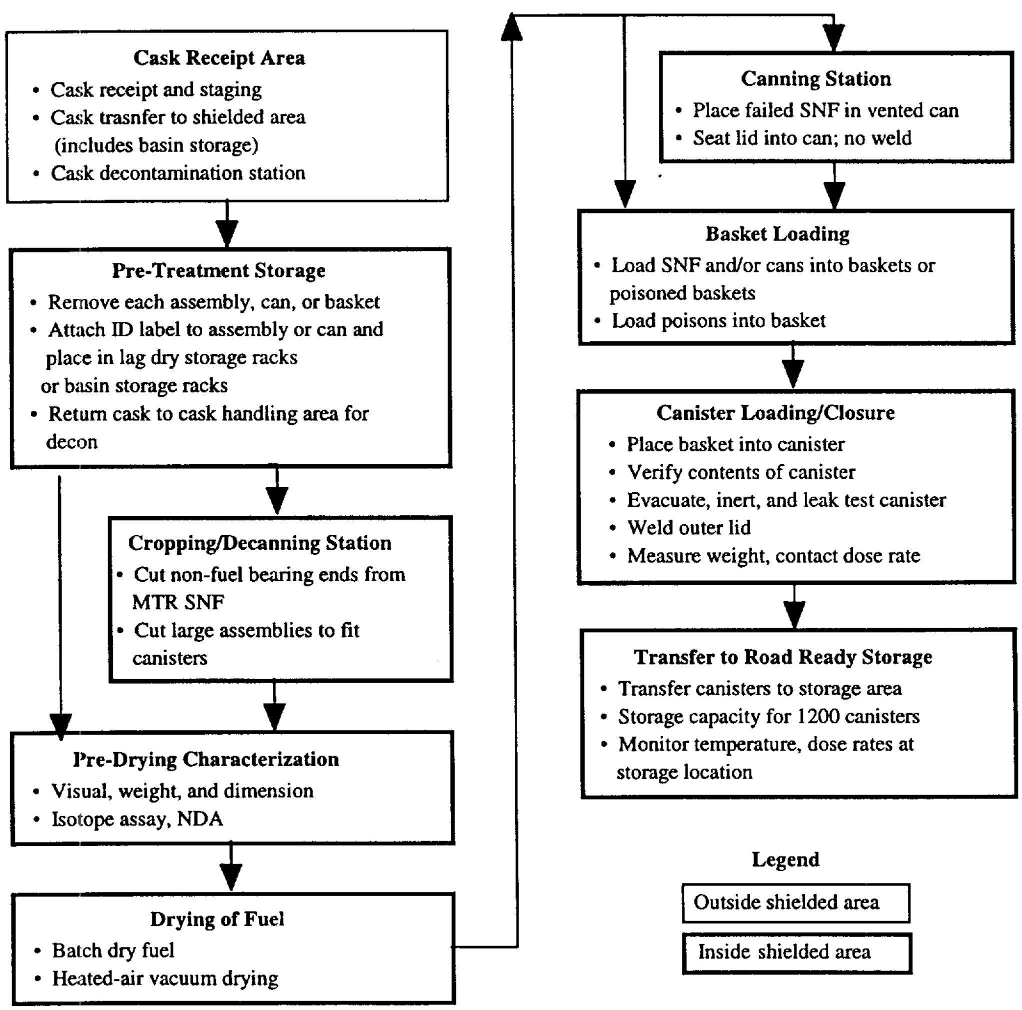

Figure 2—Process Steps for Placement of DOE Al-SNF into Road-Ready Canisters

Validation of Dry Storage Criteria

Characterization of the response of these materials to the interim storage environment had been previously completed, except for validation testing. Two instrumented canisters for single-assemblies were designed and fabricated for tests for validation of the drying and storage criteria for road-ready storage, corrosion and gaseous release models, heat transfer analysis methodology, and to provide lead-assembly-surveillance for a dry storage system. A vacuum drying technique has been developed and MTR assemblies with breached cladding are to be placed in the instrumented canisters. Data to be collected for the environment of storage and fuel condition includes cladding and air temperatures, gas species, pressure, relative humidity, and the video imaging of the fuel assemblies.

Thermal Analysis of Dry Storage and Repository Disposal Configurations

Thermal modeling and analysis methodologies have been established for interim dry storage conditions. A three-dimensional Computational Fluid Dynamics model has been developed using the CFX code to demonstrate that

fuel temperature distributions and buoyancy-induced cooling within an enclosed spent nuclear fuel canister can be predicted and simulated with reasonable accuracy under various expected interim storage configurations and ambient boundary conditions [4]. In addition, the conjugate thermal model has been benchmarked against full-scale experimental test data under various environmental conditions [4].

Degradation Testing and Analysis

Exposure of Al-SNF forms to environments will cause changes in the forms from their initial condition. Al-SNF degradation may result in release of radionuclides from the spent fuel matrix and reconfiguration of fissile species within the engineered barrier system. This may directly effect the performance of the proposed repository. Analytical and experimental activities are being conducted to characterize the response of the Al-SNF materials to anticipated conditions of the repository environment.

Degradation of the Al-SNF and reconfiguration of fissile materials in the repository environment (post-containment) will be controlled by the thermochemical stability and solubility of many possible uranium compounds and rates of the many competing reactions. Based on the natural occurrence of uranium bearing minerals within ore deposits in the western United States, thermochemical data, and the products formed during laboratory corrosion experiments, the hydrated oxides and silicates of uranium and hydrated aluminum oxides or alumino-silicates are the most likely final degradation products. The reconfiguration and redistribution of materials within the waste package are being analyzed to support the criticality analysis.

Criticality Analysis

Initial criticality analyses indicate that, under certain postulated conditions, reactivity would exceed the specified limit, and that neutron absorber materials would be needed in the canister to meet criticality requirements. Neutron poison materials for loading in Al-SNF canisters have been assessed as a method for avoiding criticality with HEU SNF [5]. Candidate materials include borated stainless steel, dispersions of europium oxide, gadolinium oxide, or samarium oxide in stainless steel, and cadmium. Mechanical properties, corrosion resistance, neutron absorption properties, cost and availability are the major factors evaluated for selection of a poison material. Testing and analysis are in progress to demonstrate poison material compatibility with the highly-enriched Al-SNF.

Performance Assessment of DOE Al SNF

The estimated dose to humans from future repository releases over a geologic time frame is performed through a performance assessment (PA). The DOE National Spent Fuel Program has categorized the DOE SNF into 15 categories for performance assessment. The Al SNF comprises two of these categories (Categories 6, & 7). Results of a recent performance assessment prepared by RW for DOE indicate that the Al-SNF forms in Category 6 are one of two categories of DOE SNF that may provide a minor contribution to the dose at the accessible environment [6].

The PA modeling includes quantification of the rate of radionuclide release to the groundwater. The release rate of radionuclides into the groundwater is primarily dependent upon the dissolution rate of the waste form and upon radionuclide solubility. Preliminary experimental investigation indicates that the dissolution rate of the aluminum-base DOE SNF at SRS is about one tenth the dissolution rate of uranium metal. Other important input to the performance assessment of the proposed repository would also include the results of thermal and criticality analyses of the codisposal canister and waste package.

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Acknowledgments

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