REPACKAGING OAK RIDGE SPENT NUCLEAR FUEL*

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ABSTRACT

This paper describes the process and challenges of repackaging Oak Ridge spent nuclear fuel (SNF) for off-site disposition. SNF was retrieved from below-grade storage positions at the Oak Ridge National Laboratory (ORNL) and transferred to a hot cell for repackaging. SNF examination and repackaging activities were performed remotely in hot cells at ORNL's Irradiated Fuels Examination Laboratory (IFEL). Each SNF package was inserted into the hot cell horizontally through a port in the cell wall. After opening the package, the contents were examined, sorted (where obvious non-fuel hardware or material was segregated from the SNF), identified, segmented if needed, and loaded into liners, which were later inserted into the final fabricated canisters. A freeze plug was chilled in liquid nitrogen and placed into the canister's bottom opening, expanding to provide final canister closure. Each repackaged SNF canister was remotely transferred from the hot cell back to dry storage to await shipments off-site.

INTRODUCTION

Research and development programs related to nuclear reactor fuel have historically been a part of ORNL's mission. Many of these programs involved the post-irradiation examination and testing of SNF from various types of reactors. After these programs were completed, the remaining SNF was collected and placed into on-site storage facilities, primarily during the 1960s and 1970s. The Environmental Management Program for the Department of Energy-Oak Ridge Operations Office (DOE-ORO) resolved a major vulnerability, first identified by DOE Headquarters in an assessment performed in 1993. The identified vulnerability was the potential for water intrusion into the outdoor, below-grade storage positions for the Oak Ridge SNF. SNF was stored in below-grade storage positions in facilities 7823A, 7827, and 7829, which are located in Solid Waste Storage Area 5 North (SWSA 5N) at ORNL. In addition, one package of SNF, the Keuring van Electrotechnische Materialen (KEMA) fuel, was stored in SWSA 6 at ORNL.

Video inspection revealed that approximately one-half of the storage positions contained water at depths ranging from trace coverage to 8 ft. The stored SNF packages had known external radiological contamination due to the hot cell conditions when the SNF was originally packaged. As a result, the potential existed for the spread of contamination beyond the boundary of the storage facility. (Note: Subsequent groundwater sampling and analysis demonstrated that there was no migration of contamination from the storage facility.) Deterioration of the SNF packages due to their prolonged contact with water was an additional concern. Many of the contaminated packages of sectioned SNF were stored in these positions for more than 20 years. In response to these conditions, the SNF packages were retrieved and taken to a hot cell on-site at ORNL for repackaging. After retrieval, the storage positions were decontaminated as necessary, and new stainless steel liners were grouted in place to prevent water infiltration.

With the issuance of the Programmatic Environmental Impact Statement Record of Decision (60 FR 28680) for SNF in 1995, smaller sites, like Oak Ridge, were directed to ship aluminum-clad SNF to the Savannah River Site (SRS) and non-aluminum-clad SNF to the Idaho National Engineering and Environmental Laboratory (INEEL). These two sites serve as the regional storage and interim management sites for DOE SNF. Oak Ridge SNF would be repackaged in a hot cell into acceptable canisters to meet the acceptance criteria at those sites.

SNF work in Oak Ridge was divided into phases to accommodate limitations in the hot cells and in funding. It was determined that the initial shipments would be the aluminum-clad SNF to SRS, so the aluminum-clad SNF repackaging was completed first. After repackaging of the aluminum-clad SNF in Oak Ridge was completed, 3 shipments (11 canisters) were made to SRS in October, November, and January of FY 1998. Repackaging of non-aluminum-clad SNF is planned for completion in FY 2002, with 5 eventual shipments (62 canisters and 9 intact Peach Bottom fuel assemblies) planned from Oak Ridge to INEEL.

FABRICATION OF SNF CANISTERS

Canister specifications were based primarily on SRS and INEEL requirements, handling ability in the hot cell and in on-site carriers, storage requirements, and off-site shipping cask limitations. For repackaging aluminum-clad SNF, an aluminum canister (4 ¾ in. in diameter and 38 in. in length) was designed and fabricated. For repackaging non-aluminum-clad SNF, a stainless steel canister (4 ¾ in. in diameter and 34 ¾ in. in length) was designed and fabricated. Figure 1 shows the stainless steel canister with an inner stainless steel liner and the associated data package.

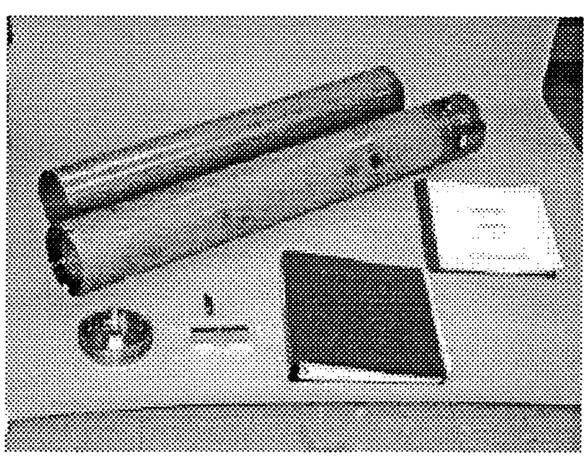

Fig. 1. SNF Stainless Steel Canister with Inner Liner and Data Package.

Both canister designs consisted of two main design components: a canister body with an integral handling head and a closure plug. A fabrication data package was completed to document that canister requirements were met. Fabrication of both types of canisters was performed at ORNL.

For the aluminum canisters, requirements from SRS specified that the canister and plug material be fabricated entirely from aluminum. A design diameter of 4 ¾ in. and an overall length of 38 in. was selected so that the canister could be handled on-site in the HRLEL carrier. This length also allowed four canisters in a single SRS shipment to fit into a single general-purpose bundle in the receiving basin at SRS. Equipment was designed to utilize the ¼-in.-diameter cross bar of the handling head as a grasping feature. SRS handling requirements specified a ¼-in.-diameter lifting bail with a 1 ½-in. clearance. Over-the-road shipping requirements were met using the BMI-1 shipping cask.

For the stainless steel canisters, requirements from INEEL specified that the canister material was to be stainless steel, and no material (or contents) was to be utilized that could cause degradation of the canister. In particular, this meant no presence of organic material or moisture within the canister. The dimensions of the canister were set at 4 ¾ in. in diameter and 34 ¾ in. in overall length so that the canister could be handled on-site in the HRLEL carrier with the new automatic handling tool ("autohandler") installed in the carrier. The canisters were gripped by an integral handling head that features a central pintle, which couples with the autohandler. Over-the-road shipping requirements are to be met using the Transnuclear Fort St. Vrain (TN-FSV) shipping cask.

EXAMINATION OF SNF

The retrieved SNF was examined and repackaged. Repackaging of the KEMA fuel is in process for completion in FY 2002. Examination of SNF was performed remotely in hot cells at the IFEL at ORNL. Prior to retrieving the SNF package from storage, the project team verified that the transfer would not exceed the inventory or fissile limits of the hot cell facility by checking the IFEL fissile material inventory log. One such restriction was a handling limit of 700 g of U-235 fissionable equivalent mass per incoming package or outgoing canister. After the SNF package was transferred to the IFEL, it was inserted into the hot cell horizontally through a port in the cell wall. All surfaces of the SNF package were visually examined for cracks, corrosion, bulging, leakage of liquid, or any other unusual feature. The incoming package number was marked on the outside of the container. The facility and cell inventories were updated following the transfer of the SNF package to the hot cell and before beginning any fissionable material operation. The opening and unloading of packages were videotaped.

To open the incoming package for examination, the lid was loosened from the SNF package in the hot cell, but not removed. The hot cell operators allowed any emerging water to drain into a catch pan before removing the lid. Provisions were made to suppress any chemical reactions arising from exposure of the contents (but no such event ever occurred). The contents were then removed and placed into work pans to be visually examined and documented. Figure 2 shows SNF unloaded from the incoming package into the work pan for examination. Identification of the contents was by comparison with the historical records. The latter varied in the level of detail, but there were no significant discrepancies with the in-cell observations. Non-fuel contents were separated for disposition as waste.

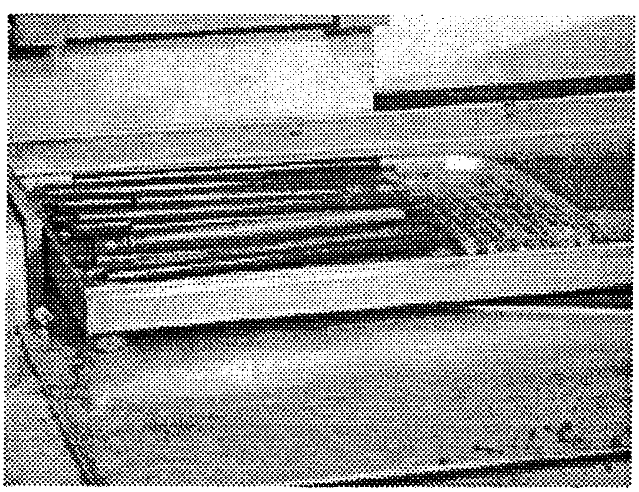

Fig. 2. Examination of SNF in the Hot Cell.

The KEMA fuel was a special case, consisting of a large quantity (5.2 kg) of micro-spheres of uranium-thorium oxide contained in a single, thick-walled (0.4-in.) stainless steel vessel. The KEMA fuel storage vessel had been embedded in concrete at SWSA 6 within an 18-ft-long pipe assembly. This concrete monolith was penetrated to retrieve the KEMA vessel, which then had to be saw-segmented in-cell to recover the fuel.

REPACKAGING OF SNF

After examination of incoming SNF, fuel segments were sorted and grouped for repacking into specific canisters. Typically, fuels of the same general type (commercial fuels, high-temperature gas-cooled reactors, or mixed-oxide fuels) became the contents of a given canister. Any moisture found in the contents was allowed to dry before proceeding to packaging. The contents of some SNF packages required segmentation to allow for the materials to fit into a canister. Often small SNF segments and debris were collected into inner containers: aluminum containers for the aluminum-clad fuel and quart-size steel cans for the SNF to be packaged into the stainless steel canisters.

A thermal treatment (pyrolysis) was applied to epoxy-coated fuel specimens and parts to convert organic material to non-organic carbon residue, which was required to meet the acceptance criteria. The equipment consisted of (1) a small programmable fan-forced air furnace and (2) a benchtop fume collector incorporating a HEPA filter and a flexible stainless steel inlet hose. Typical contents for a pyrolysis run was a total of 24 "metallographic mounts" distributed among four stainless steel beakers—about 1/2--liter volume in all. Other subjects included epoxy-coated items such as small segments of fuel rods or irradiation capsule parts.

Processing conditions were developed to adjust the initial heat-up phase to minimize problems with the fume collector. The standard time/temperature profile was: room temperature to 450°C at 20°C/min, hold 0.4 hr at 450°C, and continued heat-up to 850°C at 10°C/min. After 4.0 hr at 850°C, the materials were allowed to furnace-cool overnight. The remains after pyrolysis consisted of small amounts of black, ash-like residue along with whatever ceramic or metal specimens that had been in the mounts.

All SNF materials were weighed prior to loading into canisters. Aluminum-clad SNF (including any aluminum inner containers) was loaded directly into an aluminum canister, which was then immediately closed as described below. However, for other fuel types, larger pieces of SNF and the quart cans were preloaded into labeled, full-length stainless steel liners designed to fit into the final stainless steel canisters.

CLOSURE OF SNF CANISTERS

To ensure cleanliness, the canisters were loaded while in the cell wall port with only the bottom opening of the canister exposed to the loading cell. Canister closure was performed by placing the outgoing canister into the on-site transfer cask, and the cask was coupled to the load-out port. A liner trough (decontaminated after each use) was installed within the port and a loading chute was placed to span the gap between the work tables and the port, coupling to the liner trough. Using a push rod through the closed end of the cask, the canister was advanced onto the trough until its open end reached the inner wall of the cell. A swivel latch was locked to hold the push rod and canister in place. The pre-loaded canister liner was placed onto the loading chute with the open end facing forward into the canister and moved fully into the canister. Figure 3 shows a loaded liner being inserted into the SNF canister just before closure.

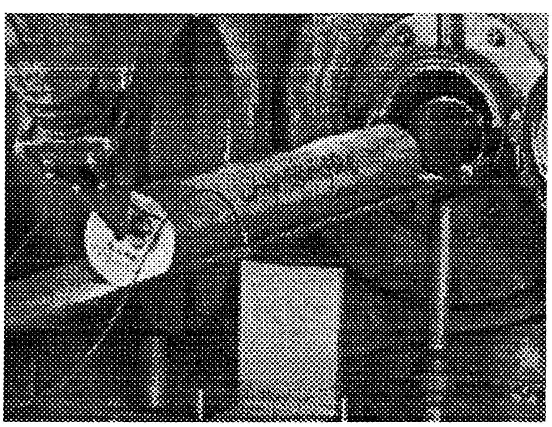

Fig. 3. Insertion of Loaded Liner into SNF Canister.

The jaws of the manipulator were cleaned, and the freeze plug was unwrapped. The freeze plug was submerged and chilled (for about 15 minutes) in a wide-mouth dewar containing liquid nitrogen. In a time-critical operation, the plug was inserted into the mouth of the canister and rotated to engage two pins into bayonet-type slots in the canister wall. About ten seconds were available to complete the plug insertion and twist for full rotation after first making metal-to-metal contact. As the plug returned to room temperature, an interference fit formed between a machined bead on the body of the freeze plug and the inside of the canister wall, which secured the plug in position (see Fig. 4). The pins and slots provided a secondary closure system that formed a positive mechanical load path in accordance with hoisting safety requirements. The push rod was then unlatched and the canister was pulled back fully into the cask.

During repackaging, a data package is prepared for each canister by the hot cell facility personnel and is verified by the SNF Certification Official. Documentation of the contents of a canister includes a list of the items, their fissionable material contents (from the historical records), the measured weights, and digital "group photos" of the items collected in the work pan before loading.

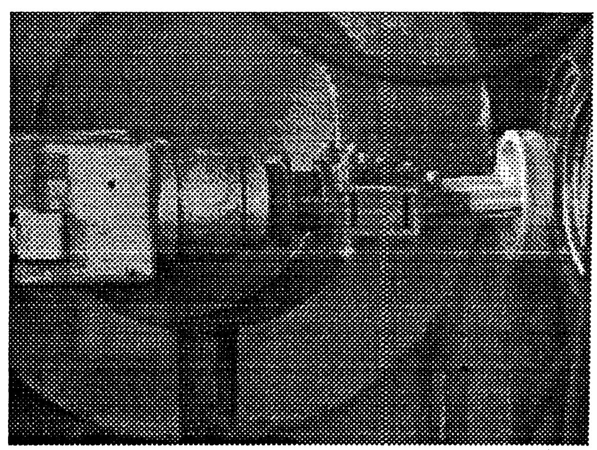

Fig. 4. Insertion of Freeze Plug for SNF Canister Closure.

INNOVATIONS AND EFFICIENCIES

The SNF team developed several processes and designed and fabricated special equipment to ensure that SNF could be repackaged efficiently to meet off-site shipment requirements. To avoid external contamination of the closed canisters, the freeze plug concept was developed to allow the canisters to be loaded and closed without bringing the canisters into the hot cell. Custom equipment also was designed to provide the canister with relock capability in case its freeze plug did not attain full rotation after insertion. This eliminated the need to return the material to the hot cell for a complete repackaging. Fuel items from the incoming SNF packages were segregated from non-fuel items resulting in considerable size reduction. Preloading of SNF into the stainless steel liners made final closure more efficient. The thermal treatment (pyrolysis) of epoxy-coated fuel specimens and parts was developed to convert organic material to non-organic carbon residue. This was required to meet the acceptance criteria, and it also provided the additional benefit of reducing the volume of material to be repackaged.

CONCLUSION

In summary, work to resolve the water intrusion vulnerability and to repackage and ship the aluminum-clad SNF to SRS was successfully completed. Work to complete repackaging and perform off-site shipments of non-aluminum-clad SNF from Oak Ridge to INEEL is proceeding toward a successful completion. The nature and degree of unexpected conditions encountered when operations are performed with SNF packages that have not been handled for an extended period can be diverse and present numerous operational challenges. This project demonstrated that with a cohesive project team, appropriate planning, and attention to safety, the Oak Ridge SNF could be successfully retrieved, repackaged, and shipped off-site.

FOOTNOTE

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