

DISPOSITION OF OAK RIDGE SPENT NUCLEAR FUEL*

D. W. Turner, B. M. Lynn
Bechtel Jacobs Company LLC

ABSTRACT

This paper describes the process and challenges of preparing and shipping Oak Ridge spent nuclear fuel (SNF) off site. The objective of the Oak Ridge SNF Project was to safely, reliably, and efficiently manage SNF that was stored on the Oak Ridge Reservation until it could be shipped off site. The Programmatic Environmental Impact Statement Record of Decision (60 FR 28680) for SNF, issued in 1995, specified that sites with smaller inventories of SNF, like Oak Ridge, were to prepare and 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 would serve as the regional storage and interim management sites for the U.S. Department of Energy (DOE) SNF until final disposition.

Oak Ridge SNF was retrieved and transferred to a hot cell for repackaging. After retrieval of SNF packages, the storage positions were decontaminated, and stainless steel liners were installed to resolve the vulnerability to water infiltration. Each repackaged SNF canister was transferred from the hot cell back to dry storage until off-site shipments were made. Three shipments of aluminum-clad SNF (11 canisters) were sent from Oak Ridge to SRS in FY 1998. Five shipments of non-aluminum-clad SNF [62 canisters and 9 intact Peach Bottom (IPB) fuel assemblies] were sent from Oak Ridge to INEEL in 2003.

This paper will focus on the preparation and shipment of Oak Ridge SNF to INEEL. To prepare for and make off-site shipments of Oak Ridge SNF to INEEL, activities included (1) taking dose measurements of repackaged SNF canisters to ensure compliance with cask shielding constraints; (2) constructing a cask loading facility; (3) upgrading the Transnuclear Fort St. Vrain (TN-FSV) shipping cask to B(U)-85 requirements, fabricating an inner container for the cask, and obtaining a Nuclear Regulatory Commission (NRC) license; (4) performing load planning to ensure the cask contents complied with the cask Certificate of Compliance and completing shipping and INEEL fuel receipt documentation; (5) completing the Oak Ridge SNF shipment readiness and transportation planning efforts; and (6) performing loading and shipment activities. Through the integrated cooperation of several organizations, including DOE, Bechtel Jacobs Company LLC, INEEL, and various subcontractors, SNF shipments from Oak Ridge to INEEL were completed safely and successfully during these times of heightened security.

INTRODUCTION

Research and development programs related to nuclear reactor fuel historically have been a part of the Oak Ridge National Laboratory (ORNL) mission. Many of these programs involved the post-irradiation examination and research 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 DOE–Oak Ridge Operations Office (ORO) resolved a major vulnerability, first identified by DOE Headquarters (HQ) 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.

It was determined that as the packages of SNF were retrieved to resolve the vulnerability, they were to be taken to a hot cell on site at ORNL.

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 SRS and non-aluminum-clad SNF to INEEL. These two sites serve as the regional storage and interim management sites for DOE SNF. An important reason for the consolidation of fuel at these two sites is the enhanced security provided by storing the SNF at two well-protected locations rather than in a variety of facilities scattered around the country. In addition, consolidation of the SNF for interim storage provides for efficiencies in SNF handling, management, and inventory control. Oak Ridge SNF was 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. Three shipments (11 canisters) were made to SRS in the BMI-1 shipping cask in October, November, and January of FY 1998. Five shipments of non-aluminum-clad SNF were made from Oak Ridge to INEEL in 2003. This paper will focus on the preparations and shipments of non-aluminum-clad SNF to INEEL.

Oak Ridge SNF Inventory

The Oak Ridge SNF shipped to INEEL consisted of 62 canisters of stainless steel-, graphite-, and zircalloy-clad SNF and 9 IPB fuel assemblies, a total of approximately 0.22 metric tons of heavy metal (220 kg). Oak Ridge SNF was stored at ORNL in facilities 7823A, 7827, and 7829 in Solid Waste Storage Area 5 North (SWSA 5N), and one package was stored in SWSA 6. All of this material (except for the 9 IPB fuel assemblies) was retrieved from storage, transferred to a hot cell on site at ORNL (Bldg. 3525), removed from its original storage container, examined, and then repackaged into new stainless steel canisters. SNF from containers that may have been exposed to water during previous storage was allowed to dry in the hot cell before repackaging. The examination process ensured the absence of water or organic materials in the contents of the repackaged canisters. The resulting canisters were transferred from the hot cell back to interim storage in facility 7827. Before receiving the repackaged SNF canisters, this facility was upgraded by adding liners and other features to eliminate the vulnerability for water ingress previously identified.

Originating Reactors

The SNF packages originated from various types of reactors, including light-water reactors (LWRs), fast reactors, high-temperature gas-cooled reactors (HTGRs), and the Keuring van Electrotechnische Materialen (KEMA) suspension test reactor in the Netherlands.

The LWR fuel originated from a variety of commercial reactor facilities, including Oconee, Peach Bottom Unit 2, Consolidated Edison, Big Rock Point, Dresden, Point Beach, Quad City, and H. B. Robinson. The LWR fuel was sectioned either during post-irradiation examination or as part of repackaging activities, and consisted of rod segments that were placed directly into the canister or packaged into internal metal containers, which were placed into the canister. The fuel was UO₂ ceramic form with in-bred Pu and stainless steel or zirconium alloy cladding.

The fast reactor fuel originated from several government fast reactor facilities, including the Experimental Breeder Reactor II (EBR-II) and the Fast Flux Test Facility (FFTF). Most of the fast reactor SNF was sectioned either during post-irradiation examination or as part of repackaging activities. The fast reactor SNF consisted of rod segments that were placed directly into the canister or packaged into internal metal containers, which were placed into the canister. The fuel was in the form of (U, Pu)O₂, (U, Pu)C, or (U, Pu)N with stainless steel or zirconium alloy cladding. All of the material associated with each batch of fuel that could contain fissile material was kept together and included in the final package.

The HTGR fuel consisted primarily of SNF from Peach Bottom Unit 1, Core 2 material. However, there were small quantities of SNF from other graphite fuel development programs. The HTGR SNF was sectioned either during post-irradiation examination or as part of repackaging activities and consisted of fuel compacts both with and without the supporting graphite bodies, which were placed loosely in the canister or packaged into internal metal containers. The fuel was primarily a uranium-thorium carbide kernel compact design in a graphite matrix.

The KEMA SNF consisted solely of lightly irradiated UO_2/ThO_2 fuel from the KEMA Suspension Test Reactor in the Netherlands. This prototype nuclear reactor produced approximately 154 MWh of thermal energy from 1975 to 1977. The KEMA SNF had approximately 26 kg of fuel microspheres retrieved from storage.

In addition to the SNF repackaged into the stainless steel canisters, there were nine IPB Unit 1, Core 2 SNF assemblies in dry storage at ORNL. These assemblies were in the same aluminum canisters with steel liners in which they were received in 1976, and they were transported to INEEL in these canisters. They consisted of five fuel test elements, three fuel bed test elements, and one driver fuel element. All of the elements utilized a uranium-thorium carbide kernel compact design in a graphite matrix. These assemblies were retrieved from storage and transferred to lined storage positions until they could be shipped to INEEL.

DOSE MEASUREMENTS FOR REPACKAGED CANISTERS

Dose measurements were performed on the completed SNF canisters to ensure compliance with cask shielding requirements. Measurements were performed with a dose-rate measurement chamber (DMC) to measure near-contact gamma and neutron radiation levels. The DMC is a spool-shaped structure that can support the on-site transfer carrier. It contains a central cavity with 6 in. (0.15 m) of lead shielding and ports for gamma and neutron detectors. Most measurements were performed in Bldg. 3525 at ORNL, but some were performed in the field where completed canisters had already been transferred to lined storage in facility 7827.

The completed SNF canister was retrieved from the storage well in the hot cell charging area or from the 7827 storage position into the on-site transfer carrier using the autohandler, a special device that grips and releases a canister. The carrier door was closed, and the carrier was moved so it could rest upon the DMC. After the carrier door was opened, the canister was lowered into the bottom of the DMC cavity using the autohandler. Dose measurements were taken, and the canister was retrieved back into the cask and returned to the hot cell charging area well or 7827 storage position.

SNF CASK LOADING FACILITY

In 2000, a cask loading facility was constructed in SWSA 5N so that SNF could be loaded for off-site shipment in a safe and efficient manner. The cask loading station (Bldg. 7888) was designed and constructed specifically to transfer SNF from the storage positions in facility 7827 to the TN-FSV shipping cask for shipment to INEEL. Because each shipment could contain up to 20 canisters of SNF and loading could not be accomplished on the back of a trailer, the need for a loading station was established so that the TN-FSV cask could be placed and safely loaded with SNF over several days. Additionally, with the presence of remote-handled low-level waste (RH-LLW) containers in storage in facility 7827, the cask loading station was constructed to allow other shipping casks to be loaded from on-site shielded carriers.

The loading station was constructed by excavating into the hillside south of facility 7827 and positioning the station so that its top was approximately at the level of the existing 7827 pad, about 30 ft (9.1 m) from the

7827 storage wells. The station provides a workspace approximately 12 x 12 x 19 ft (3.7 x 3.7 x 5.8 m) high. The floor and three sidewalls are concrete; the fourth wall has a roll-up door for access. The facility has a cover, which was removed when the cask was being positioned and the SNF was being transferred.

Structural steel is provided to support the cask and to support a work platform near the top of the facility. A crushed rock area, about 30 ft (9.1 m) wide by 75 ft (22.9 m) long, was built south of facility 7827 to provide a level, stable surface for deploying the crane during SNF transfers and to load and unload the cask from its trailer. A mobile crane was positioned so that it did not have to be moved to transfer SNF in existing, on-site shielded SNF carriers directly from facility 7827 to a shipping cask staged in the cask loading facility.

Calculations and inspections were performed to ensure that foundation and concrete walls of the cask loading station were adequate for their intended use. Compaction tests were performed to ensure the parking area could support the simultaneous weight of the crane, loaded cask, and transport trailer and cab.

The structural steel work platform design considered loads expected due to normal nuclear operations (i.e., SNF and cask handling), as well as potential loads from other credible events. The structural steel also was designed with sufficient stiffness to keep deflections of the support structure small and to maintain the top of the 17-ft-long (5.2 m) on-site carrier within 1 in. (2.5 cm) of perpendicular during transfer operations. This requirement kept the on-site and off-site casks properly aligned and ensured the smooth transfer of SNF canisters.

SHIPPING CASK AND CASK BASKET

A Memorandum of Agreement (MOA) was developed in 1996 between DOE–ORO and DOE–Idaho (ID) to ship Oak Ridge SNF to INEEL. The MOA identified the TN-FSV cask (see Fig. 1) as the shipping cask to be used. The TN-FSV is a long, thin cask about 32 in. (0.81 m) in diameter by about 17 ft (5.2 m) in length that has to be loaded in the vertical configuration and shipped in the horizontal mode. The steel and lead shielded cask is a right circular cylinder, with impact limiters at each end.



Fig. 1 TN-FSV cask

Oak Ridge SNF was transported to INEEL in a specially designed inner container to serve as a secondary, leak-tight containment vessel in the TN-FSV shipping cask. This inner container was designated as the Oak Ridge Container (ORC) and met the applicable requirements of 10 CFR 71, “Packaging and

Transportation of Radioactive Material.” As a result, the SNF was contained within two independent containment boundaries (i.e., the primary boundary provided by the TN-FSV cask and the secondary boundary provided by the ORC).

The safety analysis report for the TN-FSV packaging (SARP), along with a SARP Addendum covering the ORC, was prepared and submitted to the NRC to request a license amendment for the TN-FSV cask for shipping Oak Ridge SNF. Based on the SARP submittal, revision 5 to the Certificate of Compliance for the TN-FSV cask was approved by the NRC on October 12, 2001, and this licensed the cask for transport of the Oak Ridge SNF in the ORC. Another license amendment was submitted to incorporate changes encountered during the fabrication of the ORC, and the NRC approved this amendment and issued revision 6 to the Certificate of Compliance on March 29, 2002. Revision 7 was approved in November 2002 to incorporate some dimensional changes to the ORC required during the fabrication process and clarified that the annual leak test did not include the entire cask body, only the seals. Revision 8 was approved in July 2003 to revise the rigging description for the impact limiters. Revision 9 was approved in August 2003 to delay the requirement for repeating the containment system fabrication verification test until after the fifth use of the cask, rather than after the third use.

There were two shipping configurations for the TN-FSV cask. Configuration 1 was for shipping irradiated HTGR fuel elements, and Configuration 2 was for shipping irradiated fuel elements and irradiated IPB Unit 1 fuel elements. The gross package weight of the cask with contents in either Configuration 1 or 2 was 47,000 lb (21,318 kg).

The ORC is a right circular, cylindrical stainless steel enclosure with a five-tube basket to be used in Configuration 2 shipments of Oak Ridge SNF. The ORC was designed to carry up to 20 Oak Ridge SNF canisters (~4.75 in./0.12 m in diameter by 34.75 in./0.88 m in length), or up to 5 IPB fuel assemblies (~5 in./0.13 m in diameter by 153 in./3.9 m in length), or a combination in the following loading arrangements:

- 1 Peach Bottom fuel assembly and 1 canister per fuel compartment, or
- 4 Canisters per fuel compartment with a neutron flux trap spacer between each canister.

The ORC consists of the following components:

- A cylindrical vessel, with a bolted closure lid and seals, which provided radioactive material containment; and
- A basket assembly that (1) located and supported the canisters and the ipb fuel assemblies, (2) transferred heat to the containment vessel (which was dissipated to the tn-fsv packaging), and (3) provided neutron absorption to satisfy nuclear criticality requirements.

The overall length of the ORC is 198 in. (5.0 m). The overall outside diameter is 20.19 in. (0.51 m) at the lid end and 16.85 in. (0.43 m) along the body. The five fuel compartments are 188 in. (4.8 m) long and 5.3 in. (0.13 m) in diameter. The maximum gross weight of the loaded ORC is 4,761 lb (2,160 kg).

LOAD PLANNING AND SHIPMENT DOCUMENTATION

Load Planning

The SARP Addendum outlined the constraints that made up the analyzed safety envelope for making the shipments. The SARP used six categories to group the canisters based on pre-irradiation fissile content. The six groups were:

Category	U-235	Pu-239/241
Category 1	475 g	0 g
Category 2	865 g	191 g
Category 3	200 g	415 g
Category 4	275 g	160 g
Category 5	910 g	0 g
IPB	250 g	0 g

The five shipments were analyzed for four specific loading patterns to ensure that each shipment would remain subcritical under all analyzed operational and accident scenarios.

In addition to the criticality constraints listed, thermal constraints also affected the SNF canister loading. The SNF canisters gave off heat from the decay of radioisotopes. The amount of heat each canister gives off was determined by the quantity and type of radioisotopes in the canister. The thermal constraints were 35 watts (W) per canister, 120 W total per shipment, 55 W total per level, and 35 W total per top level. A level in the cask was considered to be all the canisters on the same horizontal plane. For example, if there was one canister in the bottom of each of the five tubes, those canisters were all on level 1. The second canisters in each of the five tubes were all on level 2, etc.

The canisters in the shipments also were arranged to minimize the dose rate at the top of the cask as much as possible given the above constraints. This was for as low as reasonably achievable (ALARA) reasons, since site personnel had to physically bolt the ORC lid and cask lid in place. If possible, the canisters that emitted the lowest radiation field (primarily the KEMA) were placed in the upper positions near the lid.

Shipment Documentation

A shipper/receiver agreement document was prepared to document the transfer of accountable nuclear material from one facility to another. The actual transfer of accountable special nuclear material (SNM), which included SNF (i.e., SNF contains SNM such as uranium, plutonium, etc.), was documented on the NRC-741 paperwork. The NRC-741 paperwork officially transferred the material from the Oak Ridge inventory to the INEEL inventory.

In addition, data packages were included with shipment documentation. The available records were examined, and additional information was pursued to provide the data requested by INEEL in the data packages. The data packages were reviewed internally for accuracy and completeness before submittal to INEEL. Draft data packages were submitted to INEEL in advance for resolution of any issues prior to actual shipment of SNF. The data packages consisted of the following information:

- Canister Contents Data Package
 - certification sheet
 - canister contents identification sheets
 - canister loading sheet

- SNF fissile material disposition sheets
- photographs
- estimated radionuclide inventory
- INEEL fuel receipt criteria (FRC)

- Canister Fabrication Data
 - canister manufacturing plan
 - certified material test reports
 - weld inspection reports
 - dimensional inspection reports
 - miscellaneous items

TRANSPORTATION PLANNING AND SHIPMENT READINESS

Transportation Planning

The MOA between DOE-ORO and DOE-ID established the responsibilities for planning and performing the transport of the SNF from Oak Ridge to INEEL. A transportation plan, U.S. Department of Energy, Oak Ridge Spent Nuclear Fuel Shipments Transportation Plan for Motor Carrier Transport, Oak Ridge National Laboratory to Idaho National Engineering and Environmental Laboratory (DOE/OR/01-2025), was also prepared to identify responsibilities, requirements, and procedures to ensure the successful, safe, and efficient transportation of SNF. The transportation plan summarized transportation activities, organizational responsibilities, emergency preparedness guidelines, and other methods for achieving safe transport. Responsibilities were described for various organizations including DOE-HQ, DOE-ORO, DOE-ID, the transportation services contractor (TSC), states, tribal authorities, and other federal agencies.

Motor carriage was selected as the mode of transportation, and highway routes were selected in accordance with Department of Transportation (DOT) regulations. DOT and NRC regulations for the routing of Highway Route Controlled Quantities (HRCQ) of radioactive materials (which includes SNF) required the use of the interstate highway system unless a state had legally designated alternative preferred routes (49 CFR 397.101, "Requirements for Motor Carriers and Drivers"). Any reconsideration of routes or modes required DOE to reopen the planning process and include affected states and tribes. The Oak Ridge Transportation Operations Center served as the designated communications center while the shipments were in route from Oak Ridge to INEEL.

A B-12 box was modified to hold up to 20 flux trap spacers and four empty Oak Ridge SNF canisters. This box was used to transport the flux trap spacers and empty Oak Ridge SNF canisters back to Oak Ridge on the unloaded cask trailer.

Shipment Readiness

Shipment readiness activities were performed to prepare for Oak Ridge SNF shipments to INEEL. Fabrication of the ORC was completed, and both the ORC and the TN-FSV cask passed the rigorous leak tests required for B(U)-85 certification. The ORC was installed in the TN-FSV cask, and acceptance testing was successfully completed.

Existing contracts were utilized for performing shipment activities. The subcontractors completed the required procedures, work plans, radiation work permits, and other field documentation (such as a hoisting and rigging plan) for loading operations. A crane was obtained per the lift plan. Safety basis documentation for loading SNF into the TN-FSV cask was prepared.

Both contractor and DOE readiness reviews were conducted to verify that the cask loading facility met all requirements for safe operation. Dry run activities were performed for the retrieval and transfer of canisters from facility 7827 to the cask loading station and for loading operations at the cask loading station. Dry run activities included practicing with the TN-FSV cask, ORC, on-site carriers, and dummy cans, as well as closure, leak testing, and handling operations for the cask. Extensive coordination with INEEL was continued throughout shipment readiness activities.

LOADING OPERATIONS AND SHIPMENT ACTIVITIES

A total of five shipments were made in July, August, September, October, and December of 2003. To make off-site shipments, the designated SNF canisters were retrieved from facility 7827, transferred to the cask loading station, and loaded with any required empty canisters into the cask, inserting the required flux traps between canisters. The cask and ORC were leak tested, and the cask was surveyed before shipment. After a shipment was completed, the empty cask was returned from INEEL to Oak Ridge, and decontamination activities were performed in preparation for the next SNF shipment. Described below are the detailed loading and shipping activities that were performed to make SNF shipments to INEEL.

Loading Operations

The placement and retrieval of an Oak Ridge SNF or IPB canister from a storage position into the High-Radiation-Level Experimental Laboratory (HRLEL) carrier or the IPB shielded carrier, respectively, were part of the normal operations associated with SNF storage in facility 7827. For the TN-FSV cask loading operations, a mobile crane (approximately 90-ton/81.7-mt capacity) was positioned between the storage positions and the cask loading station to make the SNF or IPB canister transfers from the storage positions to the TN-FSV cask in a single lift without trucking (see Fig. 2). The crane was used to remove the concrete plug from the storage position containing the SNF or IPB canister that was to be loaded into the TN-FSV cask. An interface guide was placed into the storage position to assist in the canister transfer into the carrier and to ensure that the carrier was aligned with the storage position insert. For the SNF canisters, a video camera was used to identify the canister to be retrieved prior to positioning its carrier. The crane was then used to place a carrier flush over the storage position opening, and the bottom door of the carrier opened.



Fig. 2 Crane placement between storage and loading facilities

For retrieval of an SNF canister, the HRLEL carrier was used. This carrier had an automated lifting device (referred to as the “autohandler”) that was secured to the top of the carrier and a manual winch that

raised the SNF canister into the carrier from the 5-in. (12.7 cm) schedule 40 stainless steel insert inside the storage position. An insert was present inside each of the storage positions containing SNF canisters and was used to guide a canister and provide stability during storage. For retrieval of an IPB canister, the IPB carrier was used. This carrier used a feed-through for the lanyard attached to each IPB canister that connected to a manual winch assembly. The winch was used to raise an IPB canister into the carrier. Three IPB canisters were stored in each storage position, which were approximately 14.5 in. (0.37 m) inside diameter with a divider that separated the storage position into three compartments.

After an SNF or IPB canister was inside its respective carrier, the bottom door of the carrier was closed. If the number on an SNF canister could not be verified before retrieval, the HRLEL carrier was then placed onto the DMC for verification of the SNF canister number. After the HRLEL carrier door was opened, the canister was lowered into the bottom of the DMC cavity using the autohandler and winch. Once canister identification was verified, the SNF canister was retrieved into the carrier, and the bottom door of the carrier was closed. The HRLEL carrier was then lifted, moved, and placed on the upper shield assembly (USA). Since the identification tag on the handling lanyard was used to identify each IPB canister, the IPB carrier was moved directly from a storage position to the USA.

Prior to initiating the first canister transfer for a shipment, the USA was placed on top of the TN-FSV cask using the mobile crane such that the opening on the USA was properly aligned with an empty fuel compartment in the ORC. A transition guide in the USA, similar to the interface guides for the storage positions, helped keep each canister aligned as it was transferred from a carrier to the ORC in the TN-FSV cask.

As described above, after verifying a canister's identification number and retrieval into the HRLEL or IPB carrier, the loaded carrier was placed on top of the USA using the mobile crane. The canister was then lowered into the ORC and TN-FSV cask using the manual winch attached to the carrier. After disengaging the autohandler from an SNF canister or removing the lanyard from an IPB canister, the carrier was removed from the top of the USA. As required, a flux trap spacer was lowered on top of an SNF canister using a tripod assembly and winch with an autohandler. The spacer was disengaged from the autohandler and left in position for loading of the next SNF canister.

The loading process was repeated for the next canister, and so on, until that fuel compartment of the ORC within the TN-FSV cask was full. The distance from the top of the ORC to the top of the upper canister in each fuel compartment was measured to ensure compliance with the NRC license requirements. The top of the last canister loaded into each fuel compartment was approximately an inch (2.5 cm) below the top of a fuel compartment. Then, the cask was rotated beneath the USA until the next fuel compartment aligned with the hole in the USA. Once all five fuel compartments of the ORC were properly filled, the USA was removed. After it was verified that the canisters were loaded correctly, the ORC lid was installed, after which, the TN-FSV cask lid was bolted on. After each lid was installed, filling each cavity with dry air and performing leak tests were completed as required by the TN-FSV SARP Addendum. The crane then transferred the loaded cask to the trailer parked next to the crane, and the impact limiters were installed in preparation for transport of the TN-FSV cask to INEEL. Loading operations for each shipment were generally completed in one week.

There were five canister groups established for purposes of criticality control during transport. The quantities of U-235, and Pu-239 plus Pu-241, in each canister determined which canister group each canister was placed into. The canister groups were used along with loading patterns for the canisters in the fuel compartments. There were four acceptable loading patterns for the canisters in the fuel compartments in the ORC. In these loading patterns, a fuel compartment had either four SNF canisters with three flux trap spacers, one between each SNF canister, or an IPB canister placed on top of a single SNF canister (no flux trap spacer was used). Two loading patterns had four SNF canisters and three flux

trap spacers in each of the five fuel compartments. One loading pattern had an IPB canister and a single SNF canister in each of the five fuel compartments. The last loading pattern used a combination with one fuel compartment with four SNF canisters and three flux trap spacers, and the other four fuel compartments with an IPB canister and a single SNF canister.

For each loading pattern, there were specific canister groups that had to be in each fuel compartment. Also, there was a specific number of canisters from each canister group that had to be in each fuel compartment. These loading patterns were analyzed in Chapter 6 of the SARP Addendum to ensure that the loaded cask remained safely subcritical for normal and accident conditions of transport. Empty SNF canisters were used in shipments so that the relative positions of the fissile materials remained fixed within all fuel compartments during transport.

A loading checklist was established for each shipment. Each checklist identified the specific SNF and IPB canisters and their sequence for retrieval and loading into the TN-FSV cask for each shipment. The checklists further identified the fuel compartment in the ORC and the level within the fuel compartment for each canister. The loading checklists also specified when an axial flux trap spacer was to be placed in each fuel compartment (i.e., between two SNF canisters). The individual supervising loading operations utilized the checklists to ensure that the specified loading pattern was implemented correctly. Each canister and flux trap spacer was identified and its identification number verified as correct on the checklist as it was loaded into the ORC. In addition, a second individual observed and documented that each canister and spacer was placed in the proper location using the loading sequence established by each checklist.

Normal operations consisted of having only a single SNF or IPB canister outside the storage positions or the TN-FSV cask at any one time. Normal operations also included having two storage positions opened simultaneously if necessary to support the removal of a canister from one storage position and placement into another position in order to retrieve a specific canister needed to continue with the loading sequence established by the checklist. In such an operation, still no more than a single canister was outside a storage position or the TN-FSV cask at one time. Cask loading operations were not performed in rain, high wind, or lightning conditions.

Shipment Activities

The TN-FSV cask was transported on a dedicated trailer designed and constructed specifically for this use. The trailer was built in 1995 to the standards of ANSI N14.30, Semi-Trailers Employed in the Highway Transport of Weight-Concentrated Radioactive Loads – Design, Fabrication, and Maintenance. The trailer was recertified to meet the requirements of this standard in January 2003. At that time, the paint was stripped, and all welds were reinspected; brakes, wheels, suspension, air and electrical systems, etc. were inspected, refurbished, or replaced as necessary; and static and dynamic loads tests required by the ANSI standard were performed. The trailer was inspected, and any required maintenance was performed prior to each SNF shipment.

In parallel with the physical preparations of the cask for shipment, once the departure date was selected, the required 7-day advance notifications and 5-day confirmations of the shipment were made to the states and tribal authorities along the transport corridor. The Oak Ridge Transportation Operations Center was also notified of the planned shipment, as they provided continuous tracking of the shipment via the TRANSCOM system. Proper operation of the TRANSCOM system and communication with the tractor were confirmed immediately prior to departure of the shipment.

Also, as the cask was being prepared for shipment, coordination with INEEL was ongoing to ensure that all required documentation for the shipment had been transmitted to them and had been reviewed and

approved by the appropriate personnel at their site. This documentation included the data package for each canister in the shipment, which documented the integrity of the canister container and provided a detailed description of the canister contents. Nuclear material control and accountability records were also provided to record the transfer of SNM being shipped in each canister from the Oak Ridge inventory to the INEEL inventory. Once all this documentation had been received, reviewed, and accepted, then authorization to make the shipment was sent from INEEL.

After the cask was loaded onto the trailer and its impact limiters were installed, final radiological surveys were conducted to ensure shielding effectiveness and confirm that transportation requirements were satisfied. Following the surveys, qualified personnel installed a tamper indicating device so that the security of the shipment could be verified by receiving personnel at INEEL. The appropriate labeling was applied to the cask, and placarding was placed on the vehicle. At this time, the personnel barrier was installed over the cask and impact limiters, and the trailer was staged to await release for shipment.

Prior to release, radiological health personnel from the Tennessee Emergency Management Agency (TEMA) inspected the shipment. These personnel conducted their own radiological survey and reviewed the results of the survey conducted by project personnel to confirm compliance with requirements for transportation over public roads. In addition, officers of the Commercial Vehicle Enforcement Division of the Tennessee Department of Safety conducted an inspection of the trailer and tractor in accordance with the Enhanced Commercial Vehicle Safety Alliance (CVSA) inspection standards. The inspectors also reviewed the bill of lading, truck driver and vehicle certifications, and other shipping documentation.

Following the successful completion of all inspections, and with concurrence from INEEL that they were ready to receive the shipment, DOE-ORO authorized the release of the shipment (see Fig. 3). The timing and routing of all the Oak Ridge SNF shipments were controlled by the transportation plan (DOE/OR/01-2025) and by the U.S. Department of Energy Security Plan for Oak Ridge Spent Nuclear Fuel Shipments to Idaho National Engineering and Environmental Laboratory (DOE/OR/01-2084). Once the final approval to ship was provided, the bill of lading was signed over from the shipper to the motor carrier, emergency response information and any special instructions were reviewed with the driver, and the cask was ready to depart the site. Armed escorts were continuously provided under the command of U.S. Marshals between Oak Ridge and INEEL. In addition, some states along the route escorted the shipment with state police and/or radiological health personnel. Inspection requirements for the SNF shipments varied from state to state, and the requirements of each state had to be complied with to allow the shipment to proceed. The shipment timing was controlled by the transportation plan, as noted earlier, to avoid traveling during periods established by the states, municipal governments, or tribal authorities along the route to avoid special events, traffic congestion, road construction, or similar events. The SNF shipment normally arrived at INEEL less than 48 hours after its departure from Oak Ridge.



Fig. 3 SNF shipment to INEEL.

CONCLUSION

Three shipments of aluminum-clad SNF to SRS were successfully completed in FY 1998. Five shipments of non-aluminum clad SNF to INEEL were completed in 2003. Preparation for off-site shipments required extensive planning and coordination with many organizations. This project demonstrated that with a cohesive project team, appropriate planning, and attention to safety, the campaign of five Oak Ridge SNF shipments to INEEL could be successfully completed, even in these times of heightened security and increased stakeholder participation.

FOOTNOTE

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