INNOVATIVE TN-FSV CASK DESIGN

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ABSTRACT

This paper describes the innovative TN-FSV Cask design, and explains the simple modifications made to its Configuration 1 in order to accomplish new missions under its Configuration 2. The TN-FSV Package Configuration 1 was approved in May 1999, and was designed to transport the fuel from the Fort St. Vrain (FSV) High Temperature Gas Reactor (HTGR). Configuration 2 refers to a design now developed, which mainly consists of a new container that fits into the TN-FSV Cask. The Configuration 2 packaging is for shipping the spent fuel currently stored at Oak Ridge. This spent fuel has come from various types of reactors, and has been sectioned and stored in stainless steel canisters. The new design provides several configurations for transporting the canisters. License approval for Configuration 2 is expected in September of this year, and the shipment of the SNF from Oak Ridge expected in 2002.

INTRODUCTION

TN-FSV Package is an approved Type B(U) package designed and fabricated by Transnuclear, Inc. for shipments of Fort St. Vrain (FSV) High Temperature Gas Reactor (HTGR) fuel from the Oak Ridge National Laboratory (ORNL) to the Idaho National Engineering and Environmental Laboratory (INEEL). This package, now referred to as Configuration 1, was approved and assigned an identification number [USA/9253/B(U)F] and has a current U.S. NRC Certificate of Compliance [No. 9253[(1)]] granted on May 3, 1999.

A new design, referred to as Configuration 2, for shipping the Spent Nuclear Fuel (SNF) from ORNL to INEEL, has been submitted to the NRC for approval. The ORNL SNF to be shipped consists of approximately 73 Oak Ridge canisters and nine intact Peach Bottom elements. The Oak Ridge canisters are constructed from stainless steel, and contain a variety of SNF types that are well characterized. In compliance with 10CFR71.63, "Special requirements for plutonium shipments," the SNF (in its transport configuration) will be packaged in a separate inner container designated the Oak Ridge Container that meets the applicable requirements of 10CFR71, Subparts E and F. As a result, the SNF will be contained within two independent containment boundaries, i.e., the primary boundary provided by the TN-FSV cask and the secondary boundary provided by the Oak Ridge Container (ORC).

Two TN-FSV packagings, Unit 1 and Unit 2, were fabricated in 1995 and they conform to the approved design. For the Oak Ridge SNF shipments, the TN-FSV Packaging will be modified by replacing the silicone seals with butyl seals and removing the lower axial spacer in the cask cavity. The Oak Ridge Container will be added to the cask cavity as another subassembly of the reusable portion of the packaging, which is the TN-FSV Cask. The Oak Ridge Container performs the containment, shielding, and criticality control functions for a safe transport of the Oak Ridge SNF. The Oak Ridge SNF will be transported in canisters within the Oak Ridge Container. Together, the

two components, the TN-FSV cask with butyl seals, and the Oak Ridge Container with the canister containing the Oak Ridge SNF, are designated as the TN-FSV Package Configuration 2.

TN-FSV PACKAGING DESIGN

The basic structure of the TN-FSV cask is a right circular cylinder, steel-lead-steel type cask with wood-filled impact limiters attached at both ends. The overall dimensions of the packaging are 247.0 inches long and 78.0 inches in diameter with the impact limiters installed. The cask is 207.0 inches long and 30.88 inches in diameter except at the lid end where the diameter is 31.0 inches. The cask cavity has a length of 199 inches. The top 7.12 inches of the cavity has a diameter of 20.83 in. and the remaining, a diameter of 18.0 inches.
The basic components of the TN-FSV packaging are the cask body, closure lid, lid bolts, and impact limiters. The cask body consists of the cylindrical shell assembly and bottom plate. The closure lid is attached to the cask body with twelve 1.0 inch diameter bolts. Two lifting sockets are bolted to the lid end of the cask body, and are a 180^0 apart. Two trunnions welded to the cask body are located near the bottom end with a 180^0 spacing. Two penetrations into the containment, are provided to support cask operations. One is located in the lid and the other is located in the cask bottom. The maximum gross weight of the loaded package is 50,000 pounds, including a maximum payload of 5,000 pounds. The TN-FSV is transported in the horizontal orientation with the lid end facing the direction of travel. During transport, the packaging is supported on the trailer by a front saddle and two rear trunnions.

THE MODIFICATIONS

The principal design modification made to the TN-FSV Packaging, in comparison to TN-FSV Packaging Configuration 1, is the revision of the leakage rate criterion of the containment boundary from 1×10^{-3} ref·cm^3/s to a more stringent requirement of 1×10^{-7} ref·cm^3/s (leak-tight). To meet this more stringent requirement, and to permit helium leakage rate testing of the containment boundary of the package to the revised leakage rate requirement, the material for the elastomer seals is changed from silicone to butyl on the TN-FSV cask. The revised seal material is the same as that used for the Oak Ridge Container seals. The properties of the seal material have been evaluated to demonstrate that the containment function provided by these seals is maintained both during normal conditions as well as during accident conditions of a transport.

The other modification for TN-FSV Packaging Configuration 2, is the removal of the lower spacer used in the cask cavity. The TN-FSV Package Configuration 1 contents consist of a FSV (Fuel Storage) Container and its HTGR spent fuel assemblies. The FSV Container is located axially in the cask cavity, with a spacer above and one below it. For the unit being modified to TN-FSV Packaging Configuration 2, the lower spacer is removed while the upper 0.56 in. thick aluminum spacer that is attached to the lid is retained. The Oak Ridge Container includes a sleeve type radial spacer that locates and supports the Oak Ridge Container in the TN-FSV cask cavity.

THE OAK RIDGE CONTAINER (ORC)

The ORC is a right circular cylindrical stainless steel enclosure with a five-tube basket. The ORC is designed to carry twenty (20) Oak Ridge SNF canisters (approx. 4.75 in. diameter x 34.75 in. long),

or five (5) Peach Bottom fuel assemblies (approx. 5 in. diameter x 153 in. long), or a combination thereof, in the following loading arrangements:

- One (1) Peach Bottom fuel assembly and one (1) Oak Ridge canister per fuel compartment, or
- Four (4) Oak Ridge canisters per fuel compartment with a flux trap spacer between each canister.

These two loading arrangements can be used in four different loading patterns, all of which have been evaluated.

The Oak Ridge Container consists of the following components:

- A cylindrical vessel with a bolted closure lid and seals, which provides containment for the radioactive materials.
- A basket assembly which locates and supports the Oak Ridge canisters and the Peach Bottom fuel assemblies, transfers heat to the containment vessel (which, in turn, is dissipated to the TN-FSV packaging), and provides neutron absorption to satisfy the nuclear criticality requirements.

The general arrangement of the ORC is shown in Figure 1. Figure 2 shows the arrangement of the ORC in the TN-FSV cask. The overall length of the ORC is 198 in, and the overall outside diameter is 20.19 in. at the lid end and 16.85 in. along the body. The five fuel compartments are 188.00 in. long and 5.3 in. in diameter

The maximum gross weight of the loaded ORC is 4761 lbs., consistent with the maximum payload weight evaluated with the TN-FSV Package Configuration 1. The loaded gross weight of the ORC includes a maximum payload of 1800 lbs. for the Oak Ridge canisters with the flux trap spacers, and any Peach Bottom assemblies. The ORC is dry loaded in the vertical configuration in the TN-FSV packaging, and transported in the horizontal orientation, with the lid end facing the direction of travel.

The maximum heat load per Oak Ridge canister is 35 watts, and the total heat load per shipment is 120 watts. However, since the TN-FSV packaging is designed to dissipate a total decay heat of 360 watts uniformly distributed along its cavity wall, administrative controls will be required. These controls will limit the heat load of a cross-section, corresponding to the length of the Oak Ridge canister or to an equal length of a Peach Bottom assembly, to 55 watts so as to remain within the TN-FSV Package Configuration 1 uniform heat flux. In addition, to maintain the seal temperatures reasonably low, administrative controls will be needed to restrict the heat load in the axial cross-section, directly below the ORC lid, to less than 35 watts.

The maximum normal operating pressure of the ORC in the TN-FSV packaging is less than 4 psig. The spent fuel payload within the canisters, in the ORC, is in a dry air atmosphere.

The shielding analysis for the package takes credit for the shielding provided by the ORC and the associated basket. Based on the curie content known for each canister, the expected dose rate for the Package was calculated for a representative loading. Additionally, dose rates for the loaded Oak Ridge canisters have been measured and will be "screened" against the allowable dose rates calculated for the canister, to ensure that applicable regulatory limits are met.

The criticality analysis takes credit for the ORC and the basket materials, as well as the spatial arrangement of the SNF maintained by the basket both during normal and accident conditions. Because of the large variability in the fissile content of the Oak Ridge canisters, some containing only uranium and others containing both uranium and plutonium, five artificial groups were created for the criticality evaluation.
A canister was considered to fall within a given group, if the amount of ^{235}U and ^{239}Pu did not exceed the limits for that group. The criticality safety of the Packaging was evaluated for precisely defined loading patterns, based on the five groups and the Peach Bottom assemblies.

CONTENTS OF THE PACKAGE

As mentioned earlier, there are two general types of SNF to be loaded into the Oak Ridge Container to be transported in the TN-FSV cask. One type consists of a variety of SNF materials in stainless steel Oak Ridge canisters, and the other type is the intact Peach Bottom assemblies (graphite-based HTGR SNF assemblies). The Peach Bottom assemblies are still in the aluminum canisters used to ship the assemblies from the reactor to the ORNL, and will remain in the canisters to be transported to the INEEL.

Although most of the SNF in the Oak Ridge canisters and the Peach Bottom assemblies were placed in dry storage in the 1970's, some underground storage locations were found to be partially flooded when the SNF materials were retrieved for repackaging or for inspection in the 1990's. Since then, all Oak Ridge canisters and Peach Bottom assemblies have been stored in monitored locations expected to remain dry. The reloaded canisters and the Peach Bottom assemblies were placed back, after visual inspections, into storage.

It is anticipated that there are approximately 73 Oak Ridge canisters of SNF and nine intact Peach Bottom assemblies that are to be transported. Each Oak Ridge Canister contains pieces of irradiated nuclear material from various types of reactors, such as light water reactors, fast reactors, high temperature gas cooled reactors, and the Keuring van Electrotechnische Materialen reactor, etc. The maximum fissile material content for each canister is within the five fissile content groups, which are based on the maximum pre-irradiation mass of U-235 and the fissile plutonium (Pu-239 plus Pu-241). The uranium enrichments in the materials vary greatly, depending on the material types. The pre-irradiation uranium enrichment content for any individual fuel component may be a maximum of 98 weight percent U-235. However, only a small amount of material exceeds the 94 weight % enrichment in U-235, and no individual Oak Ridge Canisters are comprised solely of materials with greater than 94 weight % enrichment in U-235. The maximum burn-up for the materials vary greatly, depending on the material types. The highest burn-up materials are from fast reactor facilities that have a maximum burn-up of 15 atom %, and a minimum cool time of 15 years.

Prior to irradiation, each intact Peach Bottom fuel element contained up to 0.25 kg of uranium, enriched to a maximum of 93.15 weight % U-235 and up to approximately 1.5 kg of thorium. The maximum burn-up is approximately 72,700 MWd/MTHM, and the minimum cool time is 27 years. The maximum decay heat for any individual element is < 3 watts.

As described before, multiple Oak Ridge canisters and Peach Bottom assemblies can be loaded into an Oak Ridge Container and transported in the TN-FSV cask. As part of the repackaging activities, the contents of all Oak Ridge canisters are visually examined, inspected, weighed, and photographed in a hot cell facility prior to their closure, in order to verify the contents and also to ensure the absence of water and organic materials. The documented contents of each canister will be provided to INEEL as part of the SNF transfer.

SUMMARY

Packagings for exclusive use are needed to make shipments of Fort St. Vrain (FSV) fuel from the Oak Ridge National Laboratory (ORNL) to the Idaho National Engineering and Environmental Laboratory (INEEL). Two NRC licensed TN-FSV packagings have been fabricated in 1995 as per the approved design, and are currently licensed for transport of the FSV fuel in their special FSV canisters.

The Oak Ridge SNF to be shipped consists of approximately 73 Oak Ridge canisters and nine intact Peach Bottom elements. The Oak Ridge canisters, constructed from stainless steel, contain a variety of well-characterized SNFs. In compliance with 10CFR71.63, "Special requirements for plutonium shipments," the SNF in its transport configuration (Oak Ridge canister) is packaged in a separate newly designed inner container, designated as the Oak Ridge Container (ORC), within the TN-FSV Cask. This TN-FSV packaging with the ORC (Configuration 2) meets the applicable requirements of 10CFR71, Subparts E and F. Thus, the SNF will be contained within two independent containment boundaries, primary boundary provided by the TN-FSV cask and the secondary boundary provided by the Oak Ridge Container.

For the Oak Ridge SNF shipments, the TN-FSV Cask will be modified by replacing the silicone seals with butyl seals and removing the lower axial spacer in the cask cavity. The Oak Ridge Container will be added to the cask cavity as another subassembly of the reusable portion of the packaging. The Oak Ridge Container performs the containment, shielding, and criticality control functions, for safe transport of the SNF. Together, these two components, the TN-FSV Cask with butyl seals, and the Oak Ridge Container, are designated as TN-FSV Packaging Configuration 2.

The ORC is a stainless steel, right circular cylindrical enclosure, with a five-tube basket. It is designed to carry twenty (20) Oak Ridge SNF canisters (approx. 4.75 in. diameter x 34.75 in. long), or five (5) Peach Bottom fuel assemblies (approx. 5 in. diameter x 153 in. long), or a combination thereof.

An Addendum to the TN-FSV Safety Analysis Report has been submitted to the NRC, with License approval expected in September of this year. Shipment of the SNF from Oak Ridge is expected to take place in 2002.

REFERENCES

1. U.S. Nuclear Regulatory Commission Certificate of Compliance for Radioactive Material Packages, No. 9253, Pkg. ID No. USA/9253/B(U)F, Docket No. 71-9253, Rev. 4, May 1999.

2. U.S. Nuclear Regulatory Commission, Regulatory Guide 7.9, Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material, Proposed Rev.2, 1986.

3. ASME Boiler & Pressure Vessel Code, Division 1, Section III, 1998 Edition.

4. U.S. Nuclear Regulatory Commission, Regulatory Guide 7.6, Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, March 1978.

5. U.S. Nuclear Regulatory Commission, Regulatory Guide 7.8, Load Combinations for the Structural Analysis of Shipping Casks, May 1977.

Figure 1 General Arrangement of the Oak Ridge Container

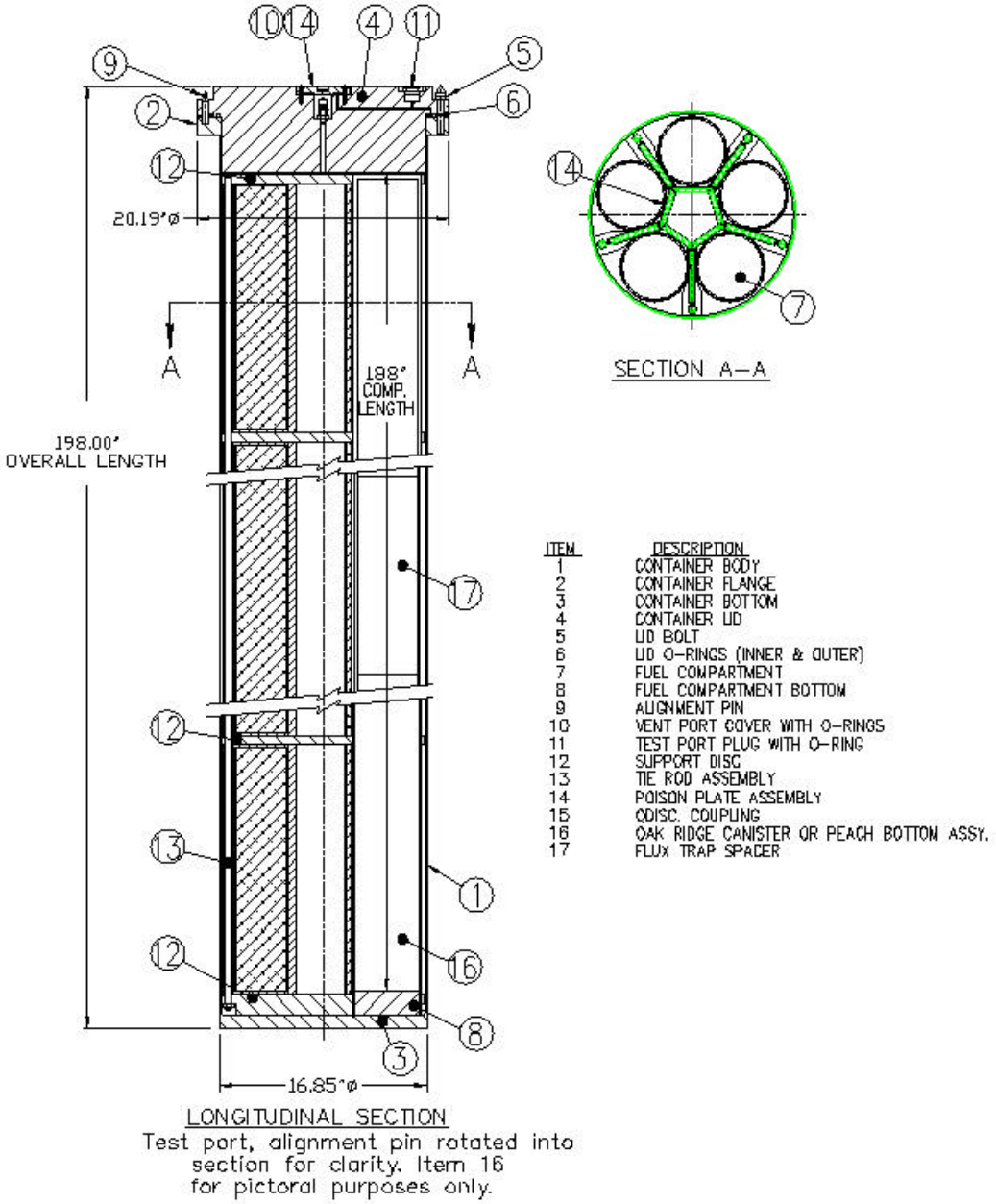

Figure 2 Arrangement of Oak Ridge Container in the TN-FSV Cask