INL/CON-22-69540-Revision-0

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February 2023

Changing the World's Energy Future

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Considerations for Managing DOE Standard Canisters within an Over-canister as Part of an Integrated Waste Management System – 23440

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SUMMARY

To better enable informed decision making regarding the back-end of the nuclear fuel cycle, the Integrated Waste Management Program within the U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) has been sponsoring the research into a comprehensive integrated waste management system (IWMS) that considers all major back-end aspects of the nuclear fuel cycle (i.e., transportation, storage, and disposal). An important aspect of the IWMS is DOE-managed Spent Nuclear Fuel (SNF).[a]

DOE and its predecessor agencies have generated, transported, received, stored, and reprocessed SNF at DOE facilities nationwide, and DOE is responsible for managing the SNF currently in its possession. These fuels come from a wide range of reactor types that employ various cladding materials, fuel materials, and enrichments. To enable interim, road-ready dry storage (RRDS) of the wide variety of SNF types found in the DOE inventory, a standardized canister system (i.e., the DOE Standard Canister) was proposed. This robust, welded canister system is designed to confine radionuclides, prevent criticality by precluding content moderation, and satisfy other requirements as part of a larger storage, transportation, and disposal system. While SNF has yet to be loaded into a DOE Standard Canister, DOE Standard Canister designs were included in past storage facility and disposal facility design licensing endeavors. In a renewed effort to evaluate packaging SNF at Idaho National Laboratory (INL) in a RRDS configuration, researchers are planning the RRDS Packaging Demonstration. This demonstration is supplemented by analytical structural, criticality, and material compatibility evaluations that support management of SNF in DOE Standard Canisters, taking advantage of past analysis work to the extent possible.

One of the largest differences between the current Packaging Demonstration and past analytical evaluations is the inclusion of an over-canister containing multiple DOE Standard Canisters. For the Packaging Demonstration, DOE Standard Canisters loaded with SNF are planned to be placed in a larger diameter over-canister. The sealed over-canister could then be placed in a storage overpack for onsite storage, or in a transportation overpack for shipment to an offsite storage location or disposal site once one becomes available. This paper examines the relevant considerations and provides a preliminary evaluation of integrating the over-canister configuration into the storage, transportation, and disposal processes of the overall waste management system.

For storage and transportation, the over-canister can be considered analogous to a multi-purpose canister (MPC) for commercial SNF. For disposal, the DOE Standard Canisters could be removed from the over-canister and placed in a co-disposal waste package with canisters containing vitrified high-level

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[a] This is a technical paper that does not take into account contractual limitations or obligations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment. To the extent discussions or recommendations in this paper conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this paper in no manner supersedes, overrides, or amends the Standard Contract. This paper reflects technical work which could support future decision making by DOE. No inferences should be drawn from this paper regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

radioactive waste (HLW) similar to configurations examined previously, or the sealed over-canisters might be capable of direct disposal in a waste package.

INTRODUCTION

To better enable informed decision making regarding the back-end of the nuclear fuel cycle, the Integrated Waste Management Program within the U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) has been sponsoring the research into a comprehensive integrated waste management system (IWMS) that considers all major back-end aspects of the nuclear fuel cycle (i.e., transportation, storage, and disposal). An important aspect of the IWMS is U.S. Department of Energy (DOE)-managed spent nuclear fuel (SNF)[b].

DOE and its predecessor agencies have generated, transported, received, stored, and reprocessed SNF at DOE facilities nationwide. DOE is responsible for managing the SNF currently in its possession. These fuels come from a wide range of reactor types featuring various cladding materials and enrichments. Many of these reactors, now decommissioned, had unique design features (e.g., core configurations, fuel element and assembly geometries, moderator and coolant materials, operational characteristics, and neutron spatial and spectral properties), resulting in a large variety of SNF types, now principally stored at DOE-managed sites: Idaho National Laboratory (INL), the Savannah River Site (SRS), Fort St. Vrain (FSV), and the Hanford Site [1].

To enable interim, road-ready dry storage (RRDS) of the wide variety of SNF types found in the DOE inventory, a standardized canister system (i.e., the DOE Standard Canister) was proposed. This robust, welded canister system is designed to confine radionuclides, prevent criticality by precluding content moderation, and satisfy other requirements as part of a larger storage, transportation, and disposal system. The DOE Standard Canister design originated from the Preliminary Design Specification for DOE Standardized Spent Nuclear Fuel Canister [2] and comes in four sizes: lengths of 3.0 m and 4.6 m (10 ft and 15 ft) and diameters of 45.7 cm and 61.0 cm (18 in. and 24in.)[c]. While SNF has yet to be loaded into a DOE Standard Canister, DOE Standard Canister designs were included in the safety analysis report for the Idaho Spent Fuel Facility, which was licensed by the U.S. Nuclear Regulatory Commission and in the Yucca Mountain Repository license application. Figure 1 shows a depiction and some parameters of the DOE Standard Canister. Further details concerning the DOE Standard Canister can be found in History and Status of DOE's Standardized Canister [3].

[b] This report does not necessarily reflect final classifications for the material being discussed; for example, material referred to as "HLW" or "SNF" may be managed as HLW and SNF, respectively, without having been actually classified as such for disposal.

[c] The canisters will be referred to by diameter × length for the remainder of the paper (English units): 18 × 10, 18 × 15, 24 × 10, and 24 × 15. Small diameter represents the 18 in. diameter canister; large diameter represents the 24 in. diameter canister; short represents the 10-ft long canister; and long represents the 15-ft long canister.

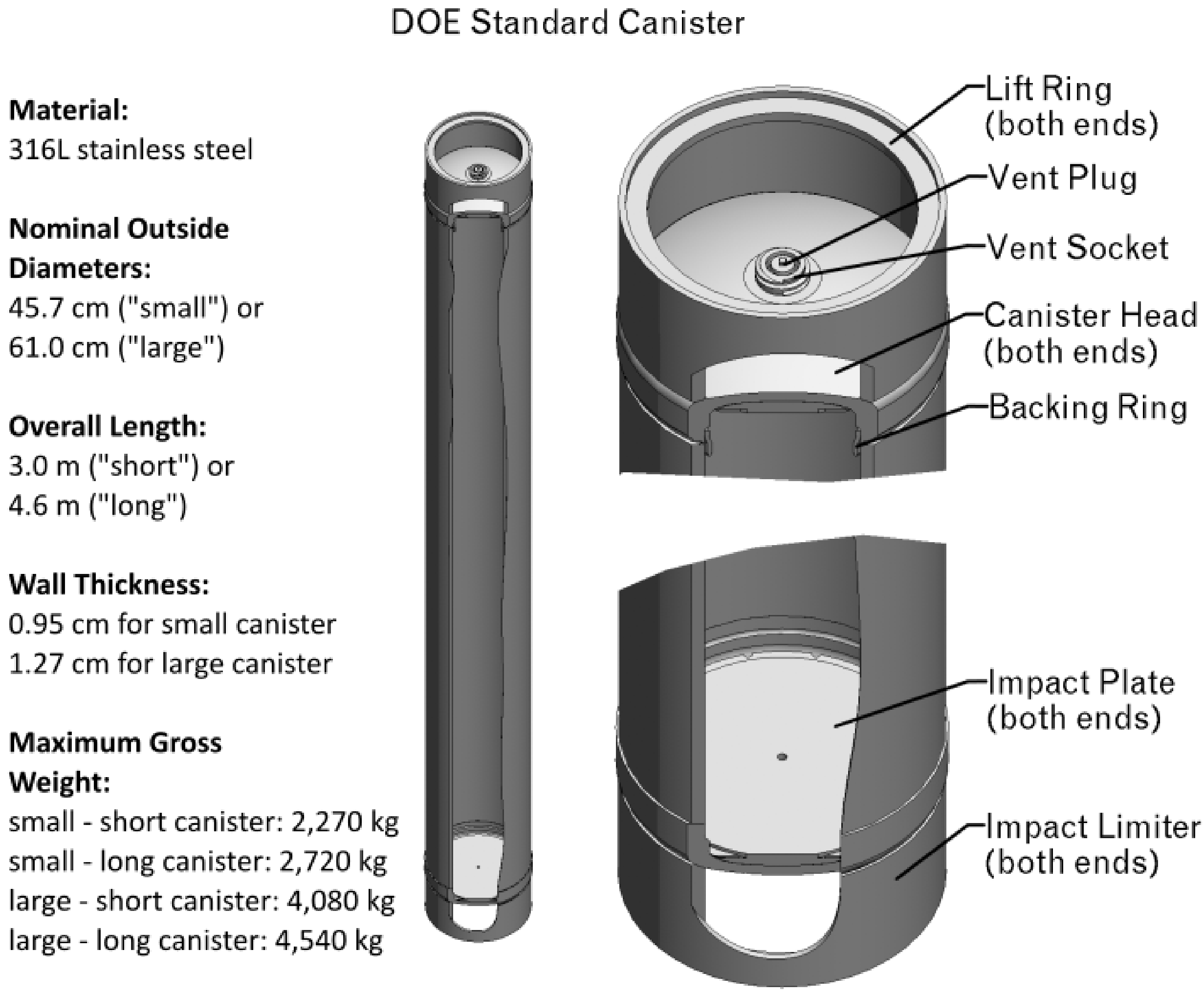

Fig. 1. DOE Standard Canister.

In 2018, efforts to evaluate the DOE Standard Canister were resumed. This included a multi-year plan to prepare the DOE Standard Canister to be loaded with DOE-managed SNF [4]. Additional evaluations were completed to look at the near-term benefits and options for loading DOE Standard Canisters [5, 6]. The DOE SNF Packaging Demonstration (RRDS Packaging Demonstration) was proposed shortly after and is an effort to develop and demonstrate the necessary designs, technologies, processes, and regulatory framework for packaging DOE-managed SNF for RRDS.

This paper supports the integration of the DOE Standard Canister packaged with DOE-managed SNF into the overall waste management system. First, it examines the past acceptance and interfacing concepts for DOE-managed SNF, as well as the developments that have occurred since the Yucca Mountain Repository license application was submitted. This paper then provides a high-level description of potential storage, transportation, and disposal configurations for DOE-managed SNF, and finally assesses any technical interface issues associated with using these configurations in the IWMS.

PAST ACCEPTANCE AND INTERFACING CONCEPTS

In 1995, DOE issued the DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement [7], which identified and analyzed five options for managing DOE SNF:

- No Action: Take the minimum actions required for safe and secure management of SNF at or close to the generation site or current storage location.
- Decentralization: Store most SNF at or close to a generation site or current storage location, with limited shipments to DOE facilities.
- 1992/1993 Planning Basis: Transport and store newly generated SNF at INL or SRS. Consolidate some of the existing fuels at INL and SRS.
- Regionalization: Distribute existing and projected SNF among DOE sites, based primarily on fuel type or geographic location.
- Centralization: Manage all existing and projected SNF inventories at one site, prior to ultimate disposition.

DOE selected the Regionalization option based primarily on fuel type in its Record of Decision [8]. Aluminum-clad fuel would be transported to the SRS, Training, Research, and Isotope Reactors built by General Atomics (TRIGA) and non-aluminum fuel would be transported to INL, and defense production fuel would be retained at the Hanford Site[d]. The Record of Decision also specified that a dry fuel storage facility capable of fuel receipt, canning/characterization, and shipping would be implemented at INL. In preparation for this facility, the National Spent Nuclear Fuel Program (NSNFP) developed the preliminary design of the DOE Standard Canister, which was designed to confine radionuclides, prevent criticality by precluding content moderation, and satisfy other requirements as part of a larger storage, transportation, and disposal system [2].

A contractor, Foster Wheeler Environmental Corporation (FWENC), was selected by DOE to build and operate the packaging facility, named the Idaho Spent Fuel Facility. In 2001 FWENC filed an application with the Nuclear Regulatory Commission (NRC) for a license to receive, package, transfer, and store SNF. The license application included three fuel types: Peach Bottom Unit 1, Shippingport, and TRIGA, along with baskets for each fuel type. DOE Standard Canisters holding the basket and fuel were to be placed in vault storage at the Idaho Spent Fuel Facility until they could be transported offsite. NRC granted FWENC the license in 2004 [9]. While only three types of SNF were listed in the initial design for the Idaho Spent Fuel Facility, researchers envisioned packaging additional fuel types and increasing storage capacity by using the module vault interim storage design. The Idaho Spent Fuel Facility was never built; however, the DOE Standard Canister was included in a license application accepted by the NRC [10].

In the years following the NRC licensing of the packaging facility at INL, the NSNFP shifted to evaluating transportation offsite and eventual disposal in support of the Yucca Mountain Repository license application. The three basic safety objectives of the NRC regulations for transportation of SNF are to prevent criticality, prevent radiological release, and minimize radiological exposure. In the licensing of transportation systems, NRC has traditionally interpreted 10 CFR 71.55(b) to require that the system be designed to withstand the introduction of moderator (e.g., water) and still maintain criticality safety. However, 10 CFR 71.55(c) states:

> "The Commission may approve exceptions to the requirements…if the package incorporates special design features that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to ensure that the containment system does not leak."

The strategy for transporting DOE SNF was to obtain NRC acceptance of moderator exclusion for the DOE Standard Canister under an interpretation of 10 CFR 71.55(b)(2) that credits the additional leak-

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[d] The Record of Decision for the Environmental Impact Statement was amended in 1996 to reflect the 1995 Idaho Settlement Agreement [11], which disallowed additional SNF from FSV from coming into Idaho until a permanent repository or an interim storage facility outside of Idaho was operational and accepting shipments from INL.

tight boundary of the DOE Standard Canister within the leak-tight boundary of the transportation overpack, or under the exception allowed per 10 CFR 71.55(c).

The NSNFP assumed that transportation cask vendors would be able to amend existing transport certificates of compliance to allow transport of the DOE Standard Canister. The DOE Standard Canister would be part of a proposed transportation packaging system consisting of a traditional transport cask containing DOE Standard Canisters. The proposed system would thus have two containment boundaries—the DOE Standard Canister and the cask itself—each fully tested and demonstrated to remain leak-tight under prescribed hypothetical accident conditions. Licensing of the transportation system would thus rely on the engineered features of the DOE Standard Canister rather than on less-certain SNF characterization information. Using this approach, the safety margin formerly provided by an assumption of flooding is replaced by the added protection of an additional engineered barrier. According to the Yucca Mountain Repository license application, once the transportation cask filled with DOE Standard Canisters arrived at the repository, DOE Standard Canisters were to be placed in a co-disposal waste package containing high-level radioactive waste (HLW) canisters[e] (Figure 2) and one DOE Standard Canister. Packaging into the co-disposal waste package required handling of DOE Standard Canister and HLW canisters at the repository.

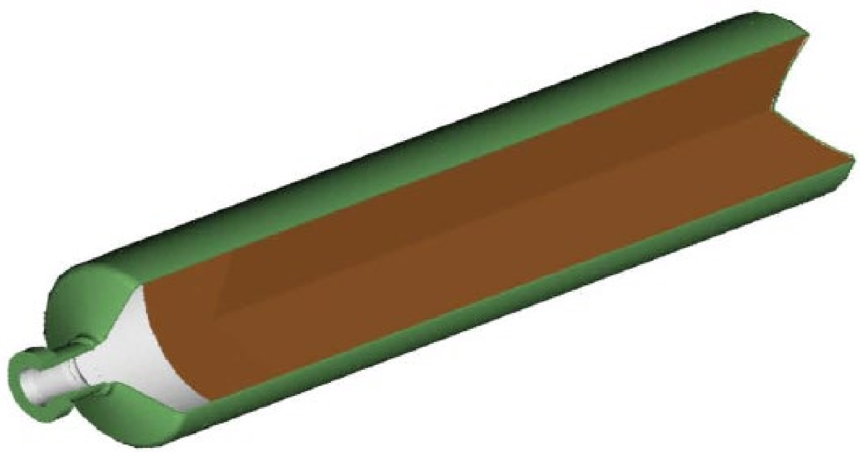

Fig. 2. Cutaway view of a HLW canister.

The co-disposal waste package had two configurations, depending on the diameter of the DOE Standard Canister that was to be packaged within. The small diameter DOE Standard Canister could be placed in the middle of five HLW canisters. The large diameter DOE Standard Canister would take the place of one of the five HLW canisters on the outer ring in the co-disposal waste package. No utilization of the empty space was planned in the Yucca Mountain Repository license application if no small diameter DOE Standard Canisters were available to load in the center of the co-disposal waste package. Figure 3 shows a cross-sectional view of a loaded co-disposal waste package for a small and large diameter DOE Standard Canister.

[e] HLW canisters are 61.0 cm in diameter. The lengths vary between 3 m (short) and 4.6 m (long), although only short HLW canisters currently exist.

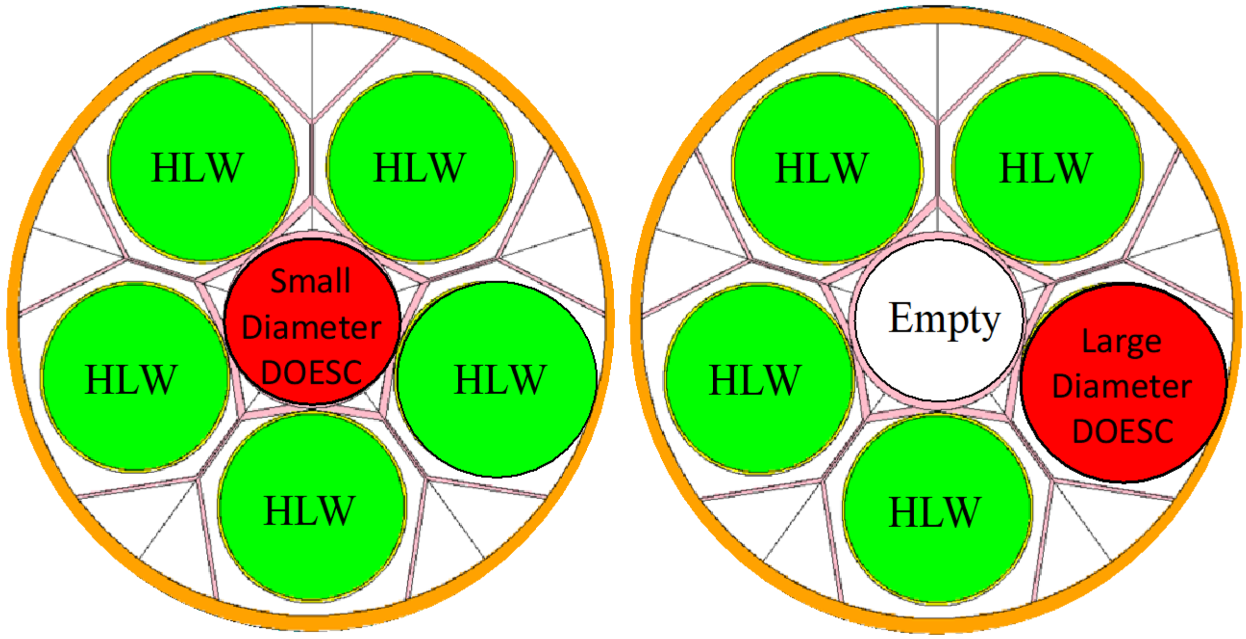

Fig. 3. Cross section of two co-disposal loading configurations for a small and large diameter DOE Standard Canister (DOESC).

RRDS PACKAGING DEMONSTRATION

The RRDS Packaging Demonstration [12] plans to load two types of DOE-managed SNF—Peach Bottom Unit 1 Core 2 (PB2) [13] and FSV [14] SNF into 18 × 15 DOE Standard Canisters. These fuels are both uranium/thorium carbon in a graphite matrix and are materially compatible. Basic depictions of the fuel elements are shown in Figure 4.

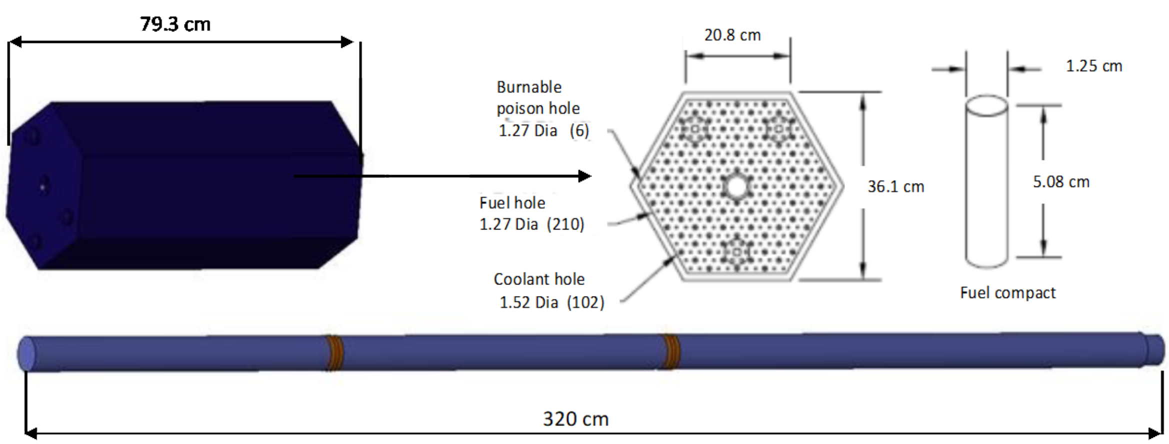

Fig. 4. Peach Bottom Unit 1 Core 2 element (bottom) and Fort St. Vrain element (top).

The 18 × 15 DOE Standard Canisters are to be loaded and sealed into an over-canister. The sealed over-canister is analogous to a multi-purpose canister (MPC) storing commercial SNF. The MPC-like over-canister will then be placed in a storage overpack that will in turn be placed on a concrete cask pad. The DOE Standard Canisters will be designed and developed by INL as a follow-on to earlier work started by the NSNFP. The over-canister and storage overpack are to be supplied by a commercial cask vendor. This process is depicted in Figure 5.

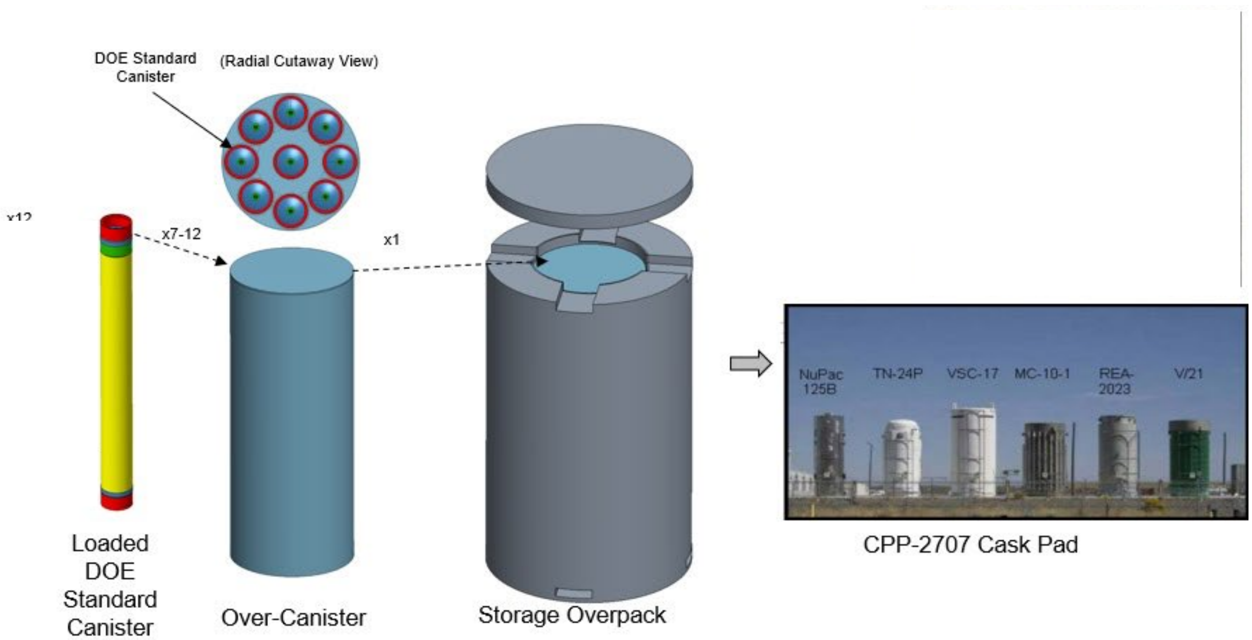

Fig. 5. Processes of the DOE SNF Packaging Demonstration.

One of the largest differences between the current RRDS Packaging Demonstration and past evaluations is the focus on a sealed over-canister containing multiple DOE Standard Canisters in storage, transportation, and possibly disposal.

DOE STANDARD CANISTER CONFIGURATION OPTIONS

This section identifies the storage, transportation, and disposal configuration options for the DOE Standard Canister. It includes configurations that may be used both in the RRDS Packaging Demonstration and beyond; consequently, the over-canister configuration is based off the over-canister expected to be used in the RRDS Packaging Demonstration. This over-canister can hold nine small diameter or five large diameter DOE Standard Canisters.

Storage

The following options in TABLE I are assumed for storage of DOE-managed SNF in DOE Standard Canisters. These configurations could be deployed at an origin site, consolidated interim storage facility (CISF), or a staging facility at a potential repository.

TABLE I. Storage Configurations for DOE Standard Canisters.

	Maximum number of DOE Standard Canisters/HLW canisters that can be packaged in a configuration			
Storage Configuration	**18 × 10/short**	**18 × 15/long**	**24 × 10/short**	**24 × 15/long**
Over-canister in dry storage overpack	9/0	9/0	5/0	5/0
Vault[a]	2/0	2/0	2/0	2/0
Co-loaded with HLW	1/5	1/5	1/4	1/4

[a] The double loading of a vault was used at Hanford for multi-canister overpacks and at SRS for HLW canisters

Transportation

The following options in TABLE II are assumed for transportation of DOE-managed SNF in DOE Standard Canisters. The mode of transportation refers to how DOE Standard Canisters will be transferred.

Rail is the preferred transportation mechanism; however, heavy-haul truck (HHT) and legal-weight truck (LWT) could also be considered. Barging is not considered in this evaluation.

TABLE II. Transportation Configurations for DOE Standard Canisters.

		Maximum number of DOE Standard Canisters/HLW canisters that can be packaged in a configuration			
Transportation Configuration	**Transportation Mode**	**18 × 10/ short**	**18 × 15/ long**	**24 × 10/ short**	**24 × 15/ long**
Over-canister in transportation overpack	Rail/HHT	9/0	9/0	5/0	5/0
Bare DOE Standard Canister in a transportation overpack	Rail/HHT	9/0	9/0	5/0	5/0
Single DOE Standard Canister in transportation overpack	Rail/HHT/LWT	1/0	1/0	1/0	1/0
Co-loaded with HLW	Rail/HHT	1/5	1/5	1/4	1/4

Disposal
The following options in TABLE III are assumed for disposal of DOE-managed SNF. If DOE Standard Canisters are to be packaged in a new over-canister, it is expected this new over-canister will contain fewer DOE Standard Canisters than the original.

TABLE III. Disposal Configurations for DOE Standard Canisters.

	Maximum number of DOE Standard Canisters/HLW canisters that can be packaged in a configuration			
Disposal Configuration	**18 × 10/short**	**18 × 15/long**	**24 × 10/short**	**24 × 15/long**
Existing over-canister in waste package	9/0	9/0	5/0	5/0
New over-canister in waste package	8/0	8/0	4/0	4/0
Single DOE Standard Canister in waste package	1/0	1/0	1/0	1/0
Co-loaded with HLW	1/5	1/5	1/4	1/4

Repackaging
While it is advantageous for the IWMS to avoid repackaging[f], DOE Standard Canisters may need to be repackaged into more suitable transportation or disposal configurations. To repackage DOE Standard Canisters into a different container, the following infrastructure must be provided:

- Crane capable of lifting more than 4,540 kg, the maximum weight of a loaded 24 × 15 DOE Standard Canister

[f] Repackaging meaning changing the container in which DOE Standard Canisters are packaged. It does not mean changing the loading configuration DOE-managed SNF in a DOE Standard Canister.

- Shielding (e.g., mobile) for open-air transfer of DOE Standard Canisters
- DOE Standard Canister lifting fixtures for the small and large diameter DOE Standard Canisters and lifting clearance for the long DOE Standard Canisters.

ANALYSIS

This section provides relevant analysis for the DOE Standard Canister/over-canister, a comparison between the over-canister and a commercial MPC, and comparisons with the Standardized Transportation, Aging, and Disposal (STAD) canister concepts for commercial SNF.

Structural

The DOE Standard Canister was designed to meet the structural conditions specified in 10 CFR 71 and 72. This includes physical drop tests and finite element analysis that met the regulations defined in 10 CFR 71.73 (hypothetical accident conditions). The over-canister containing DOE Standard Canisters will also undergo all the structural evaluations to meet these regulations. It is assumed that an existing MPC could function as the over-canister. Replacing the commercial assemblies with DOE Standard Canisters is not expected to negatively affect the structural performance of existing MPCs.

Thermal

The maximum decay heat from 12 PB2 elements and one FSV element is ~76 W [15]. The maximum decay heat for an over-canister loaded with nine DOE Standard Canisters is 684 W. The commercial MPC-32 containing 32 pressurized-water reactor (PWR) assemblies has a heat load limit of over 1,400 W per assembly for storage [16]. Although storage has a higher heat load limit than transportation or disposal, the graphite-based SNF's thermal conditions are conservatively bounded by commercial SNF.

DOE Standard Canisters loaded with Advanced Test Reactor (ATR) SNF are expected to have one of the highest heat loads of any DOE-managed SNF type. The maximum decay heat from an ATR element is 42 W. A DOE Standard Canister containing 30 ATR elements will have a heat load of 1,260 W [15] [g]. The maximum heat load for nine DOE Standard Canisters loaded with ATR SNF in an over-canister is 11,340 W. The commercial MPC-32 containing 32 PWR assemblies has a heat load limit of over 1,400 W per assembly for storage [16]. Although storage has a higher heat load limit than transportation or disposal, the DOE-managed SNF's thermal conditions are conservatively bounded by commercial SNF.

Shielding

The DOE Standard Canister was not designed to perform any shielding functions. However, due to the limited radiation from DOE-managed SNF, as compared to commercial SNF, any commercial storage/transportation overpack will satisfy shielding requirements for the over-canister loaded with nine DOE Standard Canisters.

Criticality

DOE-managed SNF has unique issues associated with criticality. Some of the SNF contains highly enriched uranium and has self-moderating properties. Preliminary criticality analyses for a single DOE Standard Canister and an over-canister filled with nine DOE Standard Canisters loaded with graphite SNF were conducted. The upper safety limit for these evaluations was defined as 0.93. For all scenarios in which the SNF was intact, the neutron multiplication factor (k_{eff}) never exceeded the upper safety limit for both a single DOE Standard Canister and an over-canister loaded with nine DOE Standard Canisters. However, the upper safety limit was exceeded when the PB2 SNF rubbilizes into a powder and the void fraction is completely saturated with water in a vertical configuration. This degradation mechanism

[g] The Waste Acceptance System Requirements Documents (WASRD) [17] Requirement 4.3.9 puts the thermal limit of a loaded DOE Standard Canister at 1,970 W/Canister.

remains unlikely due to the corrosion properties of the graphite and the orientation of potential waste packages. These scenarios were calculated for a vertically oriented waste package; for the Yucca Mountain Repository license application [18], waste packages were oriented horizontally. Previous preliminary evaluations examining a single DOE Standard Canister packaged with PB2 and FSV SNF in a co-disposal waste package found that rubblilized SNF in a horizontally oriented waste package would not exceed the upper safety limit [19].

Additional evaluations need to be performed to ensure that loading the over-canister with graphite SNF does not exceed the upper safety limit. However, the graphite SNF is likely not a bounding case for criticality evaluations of DOE-managed SNF. Other SNF types could present a problem for direct disposal of the over-canister.

Operational

This section evaluates the operational constraints, such as weight and size, that may impact the DOE Standard Canister or over-canister when incorporated into the waste management system. It also discusses the impact DOE-managed SNF may have on a standardized waste management system.

Weight

Weight limits for MPCs are identified in the NRC Certificate of Compliance. Many of these limits are based on a maximum assembly weight rather than an overall canister weight. Putting limits on the fuel assembly is a typical restriction and is used in other MPC functions as well (e.g., heat load). Limiting the assembly weight effectively limits the internal weight of the canister. Assembly weight limits for a few MPCs are shown in TABLE IV.

TABLE IV. Canister/storage system capacity and assembly weight limits.

Canister/Storage System	PWR Capacity (# of assemblies)	Assembly Weight Limit (kg)	Total Assembly Weight Limit (kg)
MPC-24 HI-STAR [20]	24	762	18,300
Transportable Storage Canister (TSC[a])-37 MAGNASTOR [21]	37	801	29,600
MPC-37 HI-STORM UMAX [22]	37	930	34,400
EOS-37PTH Dry Shielded Canister (DSC[a]) NUHOMS [23]	37	862	31,900

[a] DSC and TSC are vendor-specific names for an MPC

The preliminary design specification of the DOE Standard Canister lists the maximum loaded canister weight for each size. The 18 × 15 DOE Standard Canister's maximum gross weight of 2,720 kg bounds that of the 18 × 10 DOE Standard Canister, just as the 24 × 15 DOE Standard Canister's maximum gross weight of 4,540 kg bounds that of the 24 × 10 DOE Standard Canister [2][h]. The maximum gross weight of the 4.6 m HLW canister is 4,200 kg [24]. Using these weights, the maximum loaded canister weights for the potential DOE Standard Canister configurations are listed in TABLE V.

[h] The current estimated gross canister weight for the RRDS Packaging Demonstration is approximately 1,780 kg. An over-canister filled with nine DOE Standard Canisters from the RRDS Packaging Demonstration would be expected to weigh approximately the same or less as older, smaller canister systems.

TABLE V. Maximum weights of loaded DOE Standard Canister and the over-canister.

Over-canister/waste package configuration	Canister	Maximum loaded canister weight (kg)	Maximum payload of over-canister/waste package (kg)
Over-canister: Nine 18 × 15 DOE Standard Canisters	18 × 15 DOE Standard Canister	2,720	24,500
Over-canister: Five 24 × 15 DOE Standard Canisters	24 × 15 DOE Standard Canister	4,540	22,700
Co-disposal Waste Package: One 18 × 15 DOE Standard Canister and five HLW Canisters	4.6 m HLW Canister	4,200	23,700

For new canister systems capable of loading 37 PWR assemblies, all over-canister/co-disposal configurations fit comfortably within the bounds of the maximum allowable weight of the canister. For older, smaller canister systems, the over-canister/co-disposal configurations may exceed the allowable weight. One primary reason for canister weight limits is the crane capacity at different reactor sites. Many older plants have a crane capacity of 125 tons, while newer plants have a crane capacity of 150 tons. At a CISF or repository, the crane would likely be able to lift the heaviest canisters, and therefore a larger canister containing nine DOE Standard Canisters, or a co-disposal waste package could be handled.

Size

The 18 × 15 DOE Standard is 457 cm long [2] and bounds the length of all other DOE Standard Canisters. This is slightly longer than a traditional commercial assembly; therefore, some MPCs may not have the internal fuel cavity to support the canisters. TABLE VI shows some maximum fuel assembly lengths that can be loaded into corresponding canister systems.

TABLE VI. Maximum fuel assembly length for different commercial canisters.

Canister/Dry Storage System	Maximum Fuel Assembly Length (cm)
MPC-24 HI-STAR [20]	449.1
TSC[a]-37 MAGNASTOR [21]	452.9
MPC-37 HI-STORM UMAX [22]	506.0

[a] TSC is a vendor-specific name for an MPC

Although some MPCs do not support the internal cavity length to package the DOE Standard Canister, at least one MPC already supports the necessary internal cavity length. This is most important when fitting within the scope of handling and transportation within the waste management system. Increasing the length of a canister could impact clearances or lifting procedures at a CISF or repository. For transportation, it is expected that DOE will use rail to transport over-canisters. Two railcar designs are currently being developed by DOE: the 12-axle Atlas railcar, and the 8-axle Fortis railcar. The design basis supporting S-2043 conformance for both railcars includes the analysis of 17 different transportation casks [25]. Some casks are large enough to be capable of containing an MPC-37 and DSC-37.

Standardization

Standardization of the IWMS has been extensively explored for commercial SNF. In fact, preliminary designs for bare fuel casks and STAD canisters were completed as part of Task Orders 17, 18, and 21 [26, 27, 28]. One of the benefits cited for standardization was moving commercial assemblies to smaller canisters that were expected to be disposable in different geologic media. For example, a repository in crystalline rock may require a smaller canister than ones disposed of in salt or volcanic tuft. Decreasing the canister size due to repository constraints significantly impacts integration of the DOE Standard Canister into an overall waste management system.

Three disposal scenarios for DOE Standard Canisters are possible for a repository requiring smaller canisters for commercial SNF disposal. These scenarios assume that DOE Standard Canisters are transported in a sealed over-canister capable of packaging nine DOE Standard Canisters. The implications to the overall waste management system under each of the three scenarios are discussed below.

- The DOE Standard Canisters (i.e., all nine of them) could still be disposed in the existing over-canister used for the RRDS Packaging Demonstration.
    - Requires additional lifting equipment to handle the larger/heavier over-canister.
    - The over-canister has a larger diameter than any standardization scenario that would require repackaging existing loaded commercial canisters for disposal[i].
        - The expected diameter of the over-canister is 185.9 cm with a 1.9 cm thickness[j].
        - The Transportation, Aging and Disposal (TAD) canister used in the Yucca Mountain Repository license application had a diameter of 168.9 cm [18], the largest standard canister that has been evaluated for disposal.
- The DOE Standard Canister(s) could be moved to a smaller waste package for disposal (containing a single or multiple DOE Standard Canisters). This option assumes that the waste package would be of a size similar to that for smaller STAD canisters for commercial SNF.
    - Requires equipment to handle DOE Standard Canisters and cut open the over-canister.
    - The large diameter DOE Standard Canister has a smaller diameter than any standardization scenario that has been evaluated for disposal in the U.S.
        - The large diameter DOE Standard Canister is 61.0 cm.
        - The smallest diameter of the evaluated STADs was 73.7 cm [28].
- The DOE Standard Canister(s) could be placed in a co-disposal waste package. This option assumes one DOE Standard Canister per co-disposal waste package (i.e., nine separate co-disposal waste packages would be needed per over-canister loaded with nine DOE Standard Canisters).
    - Requires additional lifting equipment to handle the larger/heavier over-canister and individual DOE Standard Canisters.
    - Requires intermediate staging locations for DOE Standard Canisters awaiting loading into the co-disposal waste package after removal from the over-canister.
    - Requires equipment to cut open the over-canister.

Standardization has also been examined for transportation by using the same bare SNF transportation cask for all SNF. In 2015, a report was finalized that designed such a cask in response to Task Order 17 [26]. This would effectively standardize the cask handling; however, it would require additional storage systems at a CISF, or repackaging at a repository for DOE Standard Canisters.

All DOE Standard Canisters could fit into a bare SNF transportation cask by changing the basket; however, the long DOE Standard Canisters approaches the 462 cm internal cavity length in the design [26]. Transportation of DOE Standard Canisters in this way, without the use of an over-canister, also would require additional handing equipment at a CISF or repository. However, the equipment and shielding to repackage commercial SNF could satisfy the requirements for repackaging DOE Standard Canisters. Additionally, removing the over-canister from the DOE Standard Canister design could place an additional licensing burden on the DOE Standard Canister.

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[i] The Yucca Mountain Repository license application assumed a waste package nominal diameter of 196 cm. Depending on the internal configuration of the waste package, it is possible that canisters larger than the TAD could be placed inside. However, for the purpose of this evaluation, the TAD canister is determined to be bounding for standardization.

[j] The over-canister is expected to be designed by a commercial vendor; however, this size was used in some preliminary thermal and criticality calculations.

Regulatory

The DOE Standard Canister is anticipated to be licensed for storage and transportation as part of a larger system. The DOE Standard Canister storage system could be licensed under 10 CFR 72 and/or managed under 10 CFR 830. That has not yet been determined. For transportation, the DOE Standard Canister will be licensed as approved contents under a 10 CFR 71 certified transportation overpack. This would be the case with or without the use of an over-canister. When an over-canister is used, the over-canister could act in a similar capacity as a MPC for commercial SNF, and the DOE Standard Canister could be treated as bare SNF for licensing purposes.

DOE Standard Canisters are anticipated to be ready for disposal when loaded. Without a definitive repository, preliminary disposal calculations are performed using the WASRD for the Yucca Mountain Repository license application. Those materials not accepted in the WASRD will not be used. Additionally, each loading configuration will be evaluated for potential pressurization and criticality concerns to ensure long-term storage, transportation, and eventual disposal of DOE-managed SNF in DOE Standard Canisters.

CONCLUSIONS

An important aspect of the IWMS is DOE-managed SNF. DOE and its predecessor agencies have generated, transported, received, stored, and reprocessed SNF at DOE facilities nationwide, and DOE is responsible for managing the SNF currently in its possession. These fuels come from a wide range of reactor types that employ various cladding materials, fuel materials, and enrichments. To enable interim, RRDS of the wide variety of SNF types found in the DOE inventory, the DOE Standard Canister was proposed [2].

In a renewed effort to package SNF at INL in a RRDS configuration, researchers are planning the RRDS Packaging Demonstration. This demonstration is supplemented by structural, criticality, and material compatibility evaluations that supported DOE Standard Canister disposal in the Yucca Mountain Repository license application. Many of these evaluations are expected to remain valid, though new assessments or evaluations must be performed to confirm this when changes occur.

One of the largest differences between the current RRDS Packaging Demonstration and past evaluations is the focus of a sealed over-canister containing multiple DOE Standard Canisters. For the RRDS Packaging Demonstration, DOE Standard Canisters loaded with SNF are planned to be placed in a larger diameter over-canister. The sealed over-canister could then be placed in a storage overpack for onsite storage, or in a transportation overpack for shipment to an offsite CISF or disposal site once one becomes available. The sealed over-canisters might be capable of direct disposal in a waste package, or the DOE Standard Canisters could be removed from the over-canister and placed in a co-disposal waste package with HLW glass canisters.

The DOE Standard Canister fits into the overall IWMS; however, certain planning precautions should be taken to ensure its seamless incorporation. Storage and transportation operations utilizing the DOE Standard Canisters in an over-canister can be executed in a similar manner as commercial SNF. Criticality and disposal evaluations are the most limiting factors for incorporating the DOE Standard Canister in the IWMS. Each DOE Standard Canister and over-canister will be loaded to ensure it remains subcritical for storage and transportation. These loaded configurations should also be analyzed to remain subcritical for generic disposal scenarios. If disposal of the over-canister is not possible due to the selection of geologic media not being conducive to larger packages, the over-canister will need to be unloaded. Then the DOE Standard Canisters will need to be packaged in a way that conforms to the expected disposal criteria.

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