INL/CON-19-56598-Revision-0

Codisposal Waste Package Loading Options for DOE SNF and HLW

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March 2020

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Prepared for the
U.S. Department of Energy

Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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ABSTRACT

The U.S. Department of Energy (DOE) is responsible for managing spent nuclear fuel (SNF) that is currently in, or will in the future come into, its possession. DOE must continue to safely store that SNF, transport it to an interim storage site or a repository, and dispose of it. These fuels come from a wide range of reactor types with various cladding materials and enrichments. Many of these reactors, now decommissioned, had unique design features, such as core configuration, fuel element and assembly geometry, moderator and coolant materials, operational characteristics, and neutron spatial and spectral properties, resulting in a large diversity of reactor and fuel designs.

Because of the wide variety and conditions of SNF, a robust DOE Standard Canister was proposed that would confine radionuclides and preclude moderator. The DOE Standard Canister had four variations: 3.05-meter (10-foot) or 4.57-meter (15-foot) length, and 45.7-cm (18-inch) or 61.0-cm (24-inch) diameter. For ultimate disposal in the Yucca Mountain Repository, these canisters were to be grouped with 61.0-cm (24-inch) diameter high level waste (HLW) canisters in a 2.13-meter (84-inch) diameter co-disposal waste package. The smaller 45.7-cm (18-inch) diameter DOE Standard Canister could be placed in the middle of five HLW canisters. The larger 61.0-cm (24-inch) 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 DOE Standard Canisters have been loaded. A preliminary evaluation has estimated the number of elements of a fuel type that can fit into the different sizes of the DOE Standard Canister, but no definitive loading configuration has been selected. Changing the loading configuration could impact the number of loadable DOE Standard Canisters and the number of co-disposal waste packages needed for eventual disposition. This paper conveys the ranges of DOE Standard Canisters and HLW canisters that may be produced under certain conditions. It also examines the differences in the estimated number of co-disposal waste packages produced for eventual disposal when using different loading strategies in the DOE Standard Canister for Advanced Test Reactor (ATR), Peach Bottom, and High Flux Isotope Reactor (HFIR) SNF.

Changing the loading configurations of ATR, Peach Bottom, and HFIR SNF slightly impacted the number of co-disposal waste packages that may be needed for ultimate disposal. The change in loading configuration was more impactful when a different canister was used, as opposed to varying the number of elements that could fit inside the same size canister. In one case, a reduction of co-disposal waste packages could be achieved by allowing mixing of short HLW canisters with long DOE Standard Canisters.

The main conclusion from this analysis is that the ratio between HLW canisters and DOE Standard Canisters will drive the total number of co-disposal waste packages. If too many HLW canisters (i.e., more than five times the number of 18-inch DOE standard canisters) or DOE Standard Canisters are produced, some co-disposal waste packages may not have all positions filled. A co-disposal waste package may be filled with all HLW with no DOE Standard Canister, or a co-disposal waste package could be filled with a single DOE Standard Canister. A ratio that does not closely align to optimum could allow for the design of waste packages that hold just HLW canisters or just DOE SNF canisters.

INTRODUCTION

The U.S. Department of Energy (DOE) is responsible for managing spent nuclear fuel (SNF) in its possession currently, or in the future. DOE must continue to safely store that SNF, transport it to an interim storage site or a repository, and dispose of it. These fuels come from a wide range of reactor types, such as light- and heavy-water-moderated reactors, graphite-moderated reactors, and breeder reactors, with various cladding materials and enrichments. Many of these reactors, now decommissioned, had unique design features, such as core configuration, fuel element and assembly geometry, moderator and coolant materials, operational characteristics, and neutron spatial and spectral properties, resulting in over 250 unique SNFs encompassing more than 200,000 individual elements [1].

Because of the wide variety and conditions of SNF, a robust canister—termed the DOE Standard Canister—was proposed that would confine radionuclides and preclude moderator. The DOE Standard Canister has four variations: 3.05-meter (10-foot) or 4.57-meter (15-foot) length, and a 45.7-cm (18-inch) or 61.0-cm (24-inch) diameter[a]. Most types of DOE SNF included in the Yucca Mountain License Application were expected to use one of the four variations of the DOE Standard Canister [1]. The DOE Standard Canister could accommodate a number of baskets which fit SNF elements based on either a geometric or a criticality limitation. Figure 1 depicts different fuel types in a 10’ × 18” DOE Standard Canister. These particular fuel types used a Type 1 basket capable of containing 10 elements per layer. In some cases, baskets could be stacked on one another to increase the number of elements which could fit inside a DOE Standard Canister.

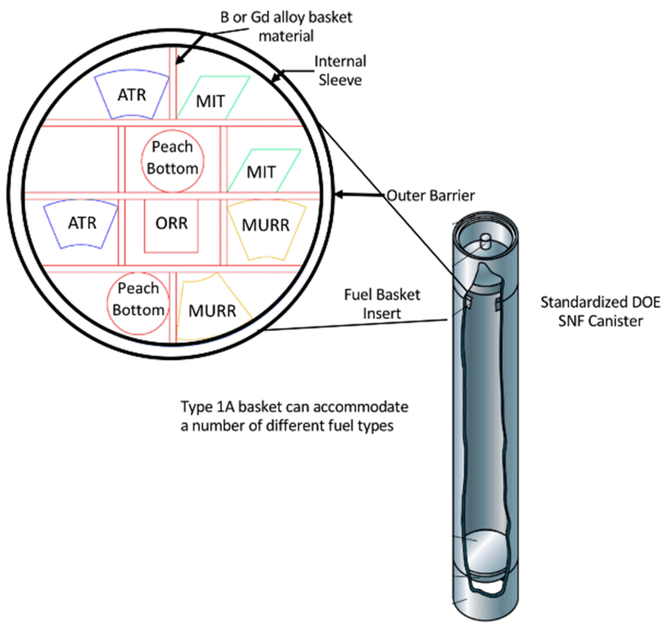

Fig. 1. Type 1 Basket for the DOE Standard Canister

In addition to the proposed DOE Standard Canister, another canister—termed the multi-canister-overpack (MCO)—is currently in use at Hanford. The MCO is designed for storage, transportation, and for eventual disposal for certain types of DOE SNF. It has an approximate diameter of 61.0 cm (24 inches) and a length of 4.27 meters (14 feet). There are currently 412 MCOs or MCO-like canisters loaded at Hanford.

[a] For this paper, the nomenclature for the four DOE Standard Canisters will be 10’ × 18”, 15’ × 18”, 10’ × 24” . and 15’ × 24” for the short small diameter, long small diameter, short large diameter, and long large diameter canisters, respectively.

DOE is also responsible for managing high level waste (HLW). The majority of HLW was originally stored as liquid HLW in tanks located at the Savannah River Site (SRS), Idaho National Laboratory (INL), Hanford, and West Valley. High level liquid waste remains at Hanford and SRS. The liquid waste at INL has been transformed to a dry HLW, and the liquid waste at West Valley has been vitrified into a glass form [2]. The Yucca Mountain Repository License Application [3] planned for HLW to be vitrified and loaded in HLW canisters of two different lengths of 3.05-meter (10-foot) and 4.57-meter (15-foot)[b]. Each HLW canister had a diameter of 61.0 cm (24 inches). SRS and West Valley are the only sites that have vitrified HLW in HLW canisters. West Valley has vitrified all of its HLW, producing 278 short HLW canisters[c]. As of December 31, 2017, SRS has produced 4,162 vitrified HLW canisters. Figure 2 depicts a HLW canister.

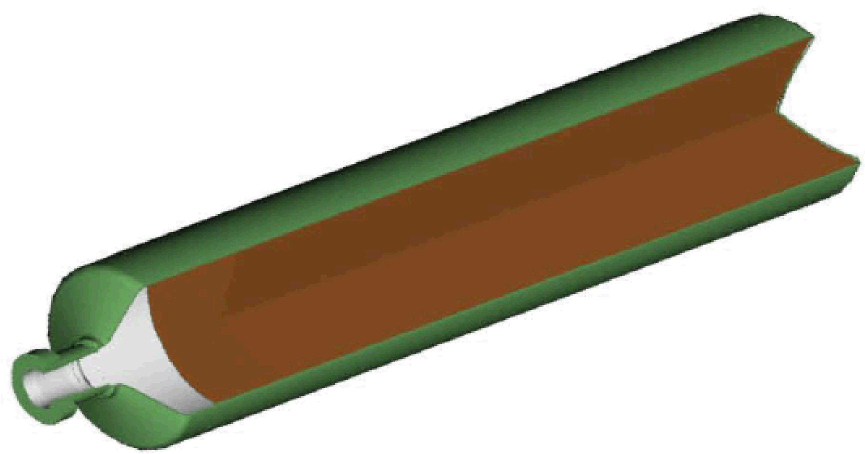

Fig. 2. Cut-away of a HLW Canister.

For ultimate disposal, DOE-managed SNF may be placed in one of three 2.13-meter (84-inch) diameter co-disposal waste packages acknowledged in the Yucca Mountain Repository License Application. The first was the short co-disposal waste package containing short variations of the DOE Standard Canister and HLW canisters. The second was the long co-disposal waste package containing the long variations of the DOE Standard Canister and HLW canisters. The 18” DOE Standard Canister could be placed in the middle of five HLW canisters. The 24” DOE Standard Canister would take the place of one the five HLW canisters on the outer ring in the co-disposal waste package. Figure 3 depicts an 18” DOE Standard Canister loaded in the middle of five HLW canisters. No utilization for the empty space was planned in the Yucca Mountain Repository License Application if no 18” DOE Standard Canisters were available to load in the center of the co-disposal waste package.

[b] For this paper, the 3.05-meter- and 4.57-meter-long HLW canisters will be termed the “short” and “long” canisters, respectively.

[c] 275 canisters held vitrified HLW. Two additional canisters contained material evacuated from the melter prior to decommissioning. One final canister contained non-routine HLW. For the purpose of this analysis, these canisters can all be contained in the co-disposal waste package and will be referred to as HLW canisters.

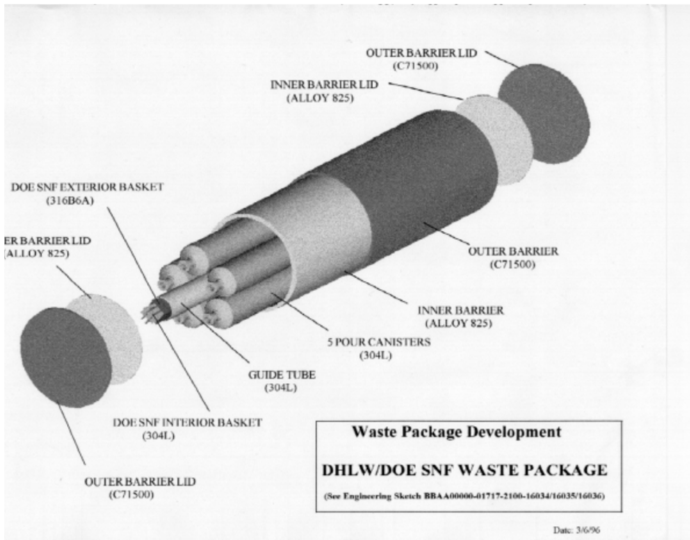

Fig. 3. DOE’s Conceptual Co-disposal Waste Package for SNF.

The third co-disposal waste package had very similar outer dimensions compared to the long co-disposal waste package. While the other co-disposal waste packages only allowed one canister containing DOE SNF to be loaded alongside HLW canisters, this waste package allowed for two MCOs to be loaded alongside two long HLW canisters.

While MCOs have already been loaded, no DOE Standard Canisters have been loaded. A preliminary evaluation has estimated the SNF that can fit into the different sizes of the DOE Standard Canister, but no definitive loading configuration has been selected. Changing the loading configuration could impact the number of DOE Standard Canisters which are loaded and the number of co-disposal packages needed for eventual disposition. In addition, different types of DOE SNF may be able to be combined in a single canister. This could also significantly change the number of DOE SNF canisters that are loaded. This paper examines the results of differing loading strategies for a few DOE SNFs. It also compares the ranges of DOE Standard Canisters that may be produced and the ranges of HLW canisters that may be produced.

METHODS

INL maintains a database of the inventory for all DOE SNF, which is the basis for all DOE SNF used in this report [4]. The database tracks the location and number of elements for each fuel type in addition to a significant amount of information about each SNF. Along with the total number of elements, the database lists the number of SNF elements that can fit inside the DOE Standard Canister that a particular SNF is expected to use. Dividing the number of elements of a particular fuel type by the number of elements that can fit inside the DOE Standard Canister gives the expected number of DOE Standard Canisters required to package all the elements of a particular fuel type.

There are two ways to calculate the total number of DOE Standard Canisters required to package all DOE SNF. The first rounds up the number of calculated DOE Standard Canisters for each fuel type to the nearest whole number before summing. This represents a “Non-Mixing” scenario which only allows SNF from a single fuel type to be packaged together. The second calculates the number of DOE Standard Canisters expected to be required for each fuel type. These values are summed without rounding any numbers up to the nearest whole number. This represents a “Mixing” scenario which combines different SNFs inside the same canister. For example, if 100.5 DOE Standard Canisters were loaded of a certain fuel type, the Non-Mixing scenario would round the total number of DOE Standard Canisters up, making

101 DOE Standard Canisters. In a Mixing scenario for the same example, another fuel type would fill the other half of the last half-full canister. TABLE I lists the expected number of DOE Standard Canisters in the Mixing and Non-Mixing scenario. It is possible that a combination of Mixing and Non-Mixing will be the selected scenario when DOE SNF is packaged into DOE Standard Canisters.

TABLE I. Projected Number of DOE Standard Canisters (DSC) and MCOs at four DOE-Managed Sites

	INL		**SRS**		**Hanford**		**FSVR**		**Total**	
	Mixing	**Non-Mixing**	**Mixing**	**Non-Mixing**	**Mixing**	**Non-Mixing**	**Mixing**	**Non-Mixing**	**Mixing**	**Non-Mixing**
10’ × 18” DSC	416	557	869	994	5	8	0	0	1,290	1,559
15’ × 18” DSC	728	736	247	257	126	139	293	293	1,394	1,425
10’ × 24” DSC	0	0	133	133	0	0	0	0	133	133
15’ × 24” DSC	27	27	0	0	0	0	0	0	27	27
MCO	0	0	0	0	406	406	0	0	406	406
Total	1,171	1,320	1,249	1,384	537	553	293	293	3,250	3,550

The total number of DOE Standard Canisters varies by 300 when comparing the Mixing and Non-Mixing scenarios. This difference could impact the number of co-disposal waste packages needed for final disposition. There was not a plan for disposing of DOE Standard Canisters outside of the co-disposal waste package in the Yucca Mountain Repository License Application. If the ratio for the number of DOE Standard Canisters to HLW canisters is too high, some DOE Standard Canisters may not be able to use a co-disposal waste package surrounded by HLW canisters. For the rest of the analysis, the Non-Mixing scenario will be used.

HLW canister counts, predictions, and best estimates are taken from the *Spent Nuclear Fuel and High-Level Radioactive Waste Inventory Report* [2]. This report provides existing HLW canisters from West Valley and SRS, a range of possible HLW canisters from INL, SRS, and Hanford, and a best estimate from INL, SRS, and Hanford. TABLE II describes the information from the inventory report.

TABLE II. Projected HLW Canisters Created at Four Different DOE-Managed Sites

Site	**Hanford**	**INL**	**SRS**	**West Valley**	**Total**
Existing HLW Canisters[a]	0	0	4,162	278	4,440
Range for Future HLW Canisters[a]	7,200-63,600	1,272-11,335	3,838-4,138	0	12,310-79,073
Best Estimate of Future HLW	7,800	3,802	4,008	0	15,610

Site	Hanford	INL	SRS	West Valley	Total
Canisters[a]					
Best Estimate for Total HLW Canisters[a]	7,800	3,802	8,170	278	20,050
Best Estimate of Short HLW Canisters[a]	0	3,802	8,170	278	12,250
Best Estimate of Long HLW Canisters[a]	7,800	0	0	0	7,800

[a]HLW canisters generated at all sites except for Hanford expect to use short HLW canisters. Hanford expects to use long HLW canisters.

The range of the HLW canister predictions is so large, more than 65,000 HLW canisters, because the processing techniques have not been decided at Hanford or INL. The final products that need to be vitrified depend on the processing technique. For this analysis, the best estimates for the number of HLW canisters will be used. This analysis will focus on aligning short DOE Standard Canisters and HLW canisters within the short co-disposal waste package and the long DOE Standard Canisters and HLW canisters within the long co-disposal waste package. The possibility exists for a short DOE Standard Canister or a short HLW canister to be loaded into a long co-disposal waste package, but that scenario is not addressed in this analysis.

DISCUSSION

The DOE Standard Canister and MCO were designed to satisfy the storage, transportation, and disposal requirements for DOE SNF. For ultimate disposal in the Yucca Mountain Repository License Application, these canisters were to be grouped with HLW canisters of similar length in a co-disposal waste package. The 18” DOE Standard Canister could be placed in the middle of five HLW canisters. The 24” DOE Standard Canister would take the place of one of the five HLW canister on the outer ring in the co-disposal waste package. The third co-disposal waste package consists of two MCOs and two HLW canisters packaged together. Because the sizes of the MCO co-disposal and long co-disposal waste packages are so similar, they are assumed to all use the long co-disposal waste package. TABLE III calculates the expected number of short and long co-disposal waste packages needed for the best estimates provided in the previous section. It also shows the number of co-disposal waste packages containing only HLW canisters. The current best estimates show no co-disposal waste packages that would be loaded with a single DOE Standard Canister. Throughout this section, loading configurations will be changed to alter the number of co-disposal waste packages that may be needed.

TABLE III. Expected Number of Short and Long Co-disposal Waste Packages (CWP) required to put all DOE Standard Canisters (DSC), MCOs, and HLW canisters in a CWP

	CWPs with 18” DSC	CWPs with 24” DSC	CWPs with MCOs	CWPs with only HLW	Total CWPs
Short CWP	1,559	133	0	785	2,477

	CWPs with 18” DSC	CWPs with 24” DSC	CWPs with MCOs	CWPs with only HLW	Total CWPs
Long CWP	1,425	27	203	33	1,688

The number of co-disposal waste packages only containing HLW canisters assumes that when DOE SNF is no longer available to package in conjunction with HLW, five HLW canisters will be packaged into a co-disposal waste package with no DOE SNF.

ATR SNF Loading Configurations

Advanced Test Reactor (ATR) SNF is one of the more extensive fuel types that DOE manages. The SNF Database lists 3,356 SNF ATR assemblies stored at INL. By 2035, the SNF database estimates 4,886 SNF ATR assemblies will be stored at INL. ATR SNF assemblies are just under 1.27 meters in length, which allows for the two layers of assemblies to be stacked in a short DOE Standard Canister. However, geometry is not the only metric for loading. ATR assemblies require special configuration beyond handling, tolerance, and fit-up concerns for packing into canisters because of the criticality challenges associated with highly-enriched uranium SNF. Consequently, multiple loading configurations have been proposed. The original loading configuration used for the Yucca Mountain Repository License Application, and the base case for this scenario, included 20 elements in a 10’ × 18” DOE Standard Canister [5]. Since then, operations at INL have changed the preferred storage configuration for ATR SNF to be packaged into ATR4 Buckets, as shown in Fig. *4*.

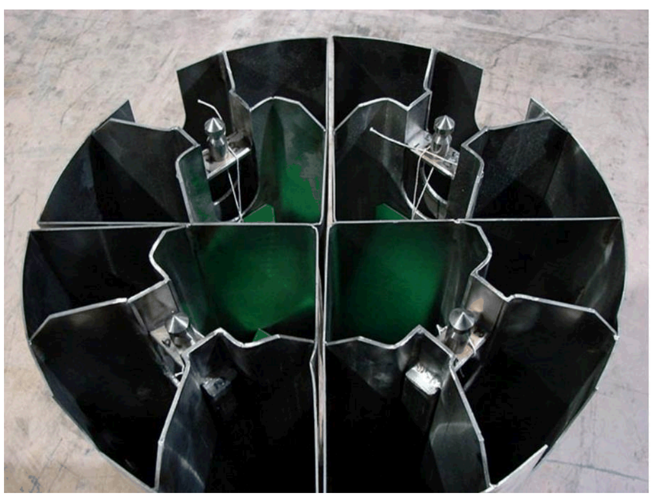

Fig. 4. Four ATR4 Buckets.

Each bucket contains four ATR elements. To accommodate the buckets, two other loading configurations have been explored. The first loads 32 ATR elements in a 10’ × 18” DOE Standard Canister. The second loads 40 ATR elements in a 10’ × 24” DOE Standard Canister [6]. The expected number of DOE Standard Canisters and the number of short co-disposal waste packages for varying the loading configurations of ATR SNF are presented in TABLE IV.

TABLE IV. Estimated Number of Co-disposal Waste Packages (CWP) for Varying the Loading Configuration of ATR Elements in short DOE Standard Canisters (DSC)

	CWPs with 10’ × 18” DSC of ATR	CWPs with 10’ × 18” DSC (Total)	CWPs with 10’ × 24” DSC of ATR	CWPs with 10’ × 24” DSC (Total)	CWPs With Only HLW	Short CWPs
20 ATR Elements in 10’ × 18” DSC (Base Case)	246	1,559	0	133	785	2,477
32 ATR Elements in 10’ × 18” DSC	154	1,467	0	133	877	2,477
40 ATR Elements in 10’ × 24” DSC	0	1,313	124	257	932	2,502

The number of co-disposal waste packages containing five HLW canisters and one 18” DOE Standard Canister decreases by more than 6%—from 1,559 to 1,467—when loading 32 ATR elements compared with the original 20 ATR elements. However, the total number of short co-disposal waste packages will not change, because the number of co-disposal waste packages containing only HLW canisters increases by the same amount. This lack of change is caused by the significant number of short co-disposal waste packages which are expected to contain only HLW canisters with no 18” DOE Standard Canisters. Changing the canister from a 10’ × 18” to a 10’ × 24” DOE Standard Canister increases the total number of short co-disposal waste packages from 2,477 to 2,502. Each additional 10’ × 24” DOE Standard Canister removes one HLW canister from a co-disposal waste package resulting in an additional 124 HLW canisters not included with SNF in a co-disposal waste package. These additional HLW canisters must be loaded into co-disposal waste packages with no DOE Standard Canister ensuing in an increase of 25 short co-disposal waste packages.

Peach Bottom SNF Loading Configurations

Peach Bottom is another fuel where different loading configurations have been explored, including in a thorium-uranium carbide fuel in a graphite matrix. Intact assemblies are 3.66 meters long. A number of fuel assemblies were cropped/shortened to approximately 3.20 meters long. Both configurations require the use of the long DOE Standard Canister. The first loading configuration was proposed for a dry packaging facility in 2001. This facility was never built, but the plan had been to load Peach Bottom SNF in a 15’ × 18” DOE Standard Canister with 10 assemblies per canister [7]. Another loading configuration considered in the Yucca Mountain Repository License Application proposed 13 assemblies loaded into the 15’ × 18” DOE Standard Canister. Currently, a 12-assembly basket is being explored to ease the operational burden of loading Peach Bottom assemblies in the 15’ × 18” DOE Standard Canister. The 13-assembly configuration will act as the base case, because this number is currently in the SNF database. TABLE V shows the expected number of long co-disposal waste packages if the number of Peach Bottom elements in a DOE Standard Canister is varied.

TABLE V. Estimated Number of Long Co-disposal Waste Packages (CWP) for Varying the Loading Configuration of Peach Bottom (PB) SNF in the long DOE Standard Canister (DSC)

	CWPs with 15’ × 18” DSC of PB	CWPs with 15’ × 18” DSC (Total)	CWPs With Only HLW	CWPs With Only SNF	Long CWPs[a]
13 PB Elements in 15’ × 18” DSC (Base Case)	127	1,425	33	0	1,458
12 PB Elements in 15’ × 18” DSC	137	1,435	23	0	1,458
10 PB Elements in 15’ × 18” DSC	160	1,458	0	5	1,463

[a] Excluding CWPs with MCO’s and 24” DOE Standard Canisters

The number of long co-disposal waste packages increases by five when only 10 elements are placed in a long DOE Standard Canister. This occurs because there is a surplus of DOE Standard Canisters. Some of these DOE Standard Canisters are being stored in a co-disposal waste package alone. When loading 12 or 13 elements instead of 10 elements in a basket, the total number of 15’ × 18” DOE Standard Canisters decreases below the threshold required where all DOE Standard Canisters can be stored in a co-disposal waste package surrounded by HLW canisters. For the base case for long co-disposal waste packages, only 34 additional 15’ × 18” DOE Standard Canisters will cause an increase in the number of co-disposal waste packages[d]. Although this analysis does not study the effects of mixing short and long canisters, it is possible that some of the short HLW canisters could be loaded with the additional 15’ × 18” DOE Standard Canisters in a long co-disposal waste package. This would decrease the number of short co-disposal waste packages in direct proportion to the number of long co-disposal waste packages containing only DOE SNF.

HFIR SNF Loading Configurations

The final SNF this analysis examines is the High-Flux Isotope Reactor (HFIR) SNF. HFIR has an inner and outer core expected to be loaded in separate canisters. Currently, 150 total HFIR cores are already produced, but another 235 cores are expected to be produced by 2035 [4]. The inner core is expected to use the 10’ × 18” DOE Standard Canister and the outer core is expected to use the 10’ × 24” DOE Standard Canister. Nominally, the HFIR outer core could fit inside the 10’ × 18” DOE Standard Canister; however, using the smaller diameter canister would require an extremely tight fit. Although the outer core is expected to use the 10’ × 24” DOE Standard Canister, this analysis examines loading the HFIR outer core in the smaller diameter DOE Standard Canister as well. These cores have an approximate length of 61.0 cm (24 inches). They are capable of being stacked three high in the short DOE Standard Canister. The base case packages HFIR outer elements in the 10’ × 24” DOE Standard Canister to match the SNF Database. TABLE VI shows the expected number of short co-disposal waste packages, if the DOE Standard Canister used for HFIR outer cores is varied.

[d] In reality, it is unlikely a co-disposal waste package would store only a single DOE Standard Canister.

TABLE VI. Estimated Number of Short Co-disposal Waste Packages (CWP) for Varying the canister for HFIR SNF into a 10’ × 18” and a 10’ × 24” DOE Standard Canister (DSC)

	CWPs with 10’ × 18” DSC of HFIR	CWPs with 10’ × 18” DSC (Total)	CWPs with 10’ × 24” DSC with HFIR	CWPs with 10’ × 24” DSC (Total)	CWPs With Only HLW	Short CWPs
3 HFIR Outer Elements in 10’ × 24” DSC (Base Case)	0	1,559	133	133	785	2,477
3 HFIR Outer Elements in 10’ × 18” DSC	133	1,692	0	0	758	2,450

Loading HFIR outer cores in a 10’ × 18” DOE Standard Canister decreases the expected total number of short co-disposal waste packages needed by 27. This stems from the 133 fewer 10’ × 24” DOE Standard Canisters produced. Changing to the smaller diameter canister allows more waste packages to contain five HLW and one DOE Standard Canister and reduces the number of waste packages that contain four HLW canister and one DOE Standard Canister. The direct conversion transpires because of the high ratio of HLW canisters to DOE Standard Canisters for the short co-disposal waste package. Every additional 18” DOE Standard Canister has an open slot in a predetermined co-disposal waste package surrounded by five HLW canisters. Changing the canister also has the added benefit of completely eliminating the need for 10’ × 24” DOE Standard Canisters, because HFIR outer cores are the only SNF expected to use that variation of the DOE Standard Canister[e].

CONCLUSIONS

No DOE Standard Canisters have been loaded. A preliminary evaluation has estimated the number of elements of a fuel type that can fit into the different sizes of the DOE Standard Canister, but no definitive loading configuration has been selected. Changing the loading configuration could impact the number of DOE Standard Canisters which could be loaded and the number of co-disposal waste packages needed for eventual disposition. This paper conveys the ranges of DOE Standard Canisters and HLW canisters that may be produced under certain conditions. It also examines the differences in the estimated number of co-disposal waste packages produced for eventual disposal when using different loading strategies in the DOE Standard Canister for ATR, Peach Bottom, and HFIR SNF.

Changing the loading configurations of ATR, Peach Bottom, and HFIR SNF slightly impacted the number of co-disposal waste packages that may be needed for ultimate disposal. The change in loading configuration was more impactful when a different canister was used, as opposed to varying the number of elements that could fit inside the same size canister. In one case, a reduction of co-disposal waste packages could be achieved by allowing mixing of short HLW canisters with long DOE Standard Canisters.

The main conclusion ensuing from this analysis is the ratio between HLW canisters and DOE Standard Canisters will drive the total number of co-disposal waste packages. If too many HLW canisters (i.e., more than five times the number of 18” DOE standard canisters) or DOE Standard Canisters are

[e] This would not be true if ATR was loaded in the 10’ × 24” DOE Standard Canisters as discussed in this paper.

produced, some co-disposal waste packages may not have all positions filled. A co-disposal waste package may be filled with all HLW with no DOE Standard Canister, or a co-disposal waste package could be filled with a single DOE Standard Canister. A ratio that does not closely align to optimum could allow for the design of waste packages that hold just HLW canisters or just DOE SNF canisters.

REFERENCES

1. Petersen G., et. al., “History and Status of DOE’s Standardized Canister, Proc. WM2019, March 2019.
2. Vinson, D., Metzger, K.., “Spent Nuclear Fuel and High-Level Radioactive Waste Inventory Report” FCRD-NFST-2013-000263, Revision 5, August 2018.
3. NRC, DOE's License Application for a High-Level Waste Geologic Repository at Yucca Mountain (updated June 2016), available at http://www.nrc.gov/waste/hlw-disposal/yucca-lic-app.html (noting 2009 updates by DOE).
4. Spent Fuel Database, Version 7.0.5, Idaho Falls, Idaho, BEA, June 2019.
5. OCRWM, “Intact and Degraded Mode Criticality Calculations for the Co-disposal of ATR Spent Nuclear Fuel in a Waste Package,” CAL-DSD-NU-000007 Rev. 00A, DOC.20041018.0001 2004.
6. Orano, “Feasibility Evaluation of ATR4 Buckets in DOE Standardized Canisters Fit and Criticality”, RPT-3022527-000 June 28, 2019.
7. Foster Wheeler Environmental Corporation, “Safety Analysis Report, Idaho Spent Fuel Facility." NRC Docket No. 72-25. ISF-FW-RPT-0033. Rev. 3. Morris Plains, New Jersey: FWENC. 2003.