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Assumptions for Evaluating Feasibility of Direct Geologic Disposal of Existing Dual-Purpose Canisters

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

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ACRONYMS

ADAMS	Agency-wide Documents Access and Management System
ANEP	Advanced Nuclear Energy Program
BRC	Blue Ribbon Commission on America's Nuclear Future
BWR	Boiling Water Reactor
COC	Certificate of Compliance
DOE	U.S. Department of Energy
DPC	Dual-Purpose Canister
DSC	Dry Storage Cask
EBS	Engineered Barrier System
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FEPs	Features, Events, and Processes
FSAR	Final Safety Analysis Report
HLW	High-Level Waste
ISFSI	Independent Spent Fuel Storage Installation
MT	Metric Tons
MTHM	Metric Tons of Heavy Metal
MTU	Metric Tons Uranium
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OFF	Oldest Fuel First
PWR	Pressurized Water Reactor
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RMEI	Reasonably Maximally Exposed Individual
SER	Safety Evaluation Report
SNL	Sandia National Laboratories
TAD	Transportation-Aging-Disposal
TSAR	Topical Safety Analysis Report
TSPA	Total System Performance Assessment
UFD	Used Fuel Disposition
UNF	Used Nuclear Fuel

US	United States
YFF	Youngest Fuel First

ASSUMPTIONS FOR EVALUATING FEASIBILITY OF DIRECT DISPOSAL OF EXISTING DUAL-PURPOSE AND STORAGE-ONLY CANISTERS IN VARIOUS MEDIA

1. INTRODUCTION

In the *Nuclear Waste Policy Act of 1982* (NWPA), Congress required the U.S. Department of Energy (DOE) to cooperate with the private sector to conduct demonstrations of alternatives to storage of used nuclear fuel (UNF) in pools (NWPA 1983). The demonstration was to be licensed by the U.S. Nuclear Regulatory Commission (NRC). The cooperative program, which licensed its first demonstration in Virginia in 1986, and various additional studies, provided a foundation for utilities to build dry cask storage to alleviate the limited wet storage available at reactors. A variety of dry fuel storage systems have been developed and deployed since 1986. The total inventory of UNF consists of more than 65,000 metric tons of heavy metal (MTHM) discharged from reactors as of 2010, and 25% is currently stored in approximately 1,500 dry storage casks (DSCs). The amount of UNF that will be transferred from wet to dry storage is expected to increase at a rate of approximately 100 DSCs/yr. The nuclear power industry is currently using large DSCs, for example containing as many as 32 assemblies from pressurized water reactors (PWRs) or 68 assemblies from boiling water reactors (BWRs). Newer systems may have the capacity for 37 PWR assemblies or 89 BWR assemblies. Most of these systems are dual-purpose (i.e., licensed by the NRC for storage and transportation); however, a few older systems are single purpose (licensed for storage only). None of the systems are currently licensed for disposal.

1.1 Objective of Evaluation

Direct disposal of the large dry storage canisters currently used by the commercial nuclear power industry is beyond current domestic and international capabilities (Hardin et al. 2012). The large capacities of loaded canisters could require significant surface decay storage duration, and still produce relatively high disposal package surface temperatures in the repository. Higher temperatures may limit the choice of geologic disposal media or may require ventilated, open-drift emplacement.

Direct disposal of existing dual-purpose canisters (DPCs) and storage-only canisters without re-packaging could involve significant technical and regulatory challenges.[1] The objectives of this multi-year study by the Used Fuel Disposition (UFD) Campaign of the DOE Fuel Cycle Technology Program are to identify those challenges, and to identify and perform supporting technical work needed to evaluate whether such disposal is feasible. The results will provide input to waste management strategy decisions that include the extent to which direct disposal could be deployed in the U.S. The principal alternative to direct disposal of DPCs is re-packaging of UNF into smaller canisters for disposal.

Re-packaging of UNF from larger DPCs into smaller canisters for disposal would: 1) decrease surface decay storage duration prior to disposal; 2) avoid developing facilities to handle large canisters at a repository; 3) avoid long-distance transport for older UNF and canisters; and 4) avoid the potential need to re-fit DPCs, for example to add additional criticality control

[1] For brevity hereafter, the term dual-purpose canister will include storage-only canisters except where otherwise specified.

measures. Re-packaging would incur significant additional costs. As an example, the Virginia Electric Power Company (Dominion) has estimated that the total cost of re-packaging some of their dry storage canisters would be $1.5 million per storage canister: $150K for unloading, $150K for re-loading, $1M for a new canister, and $200K for disposal of the old canister/cask (Rice 2011). In addition, they estimate that re-packaging would increase personnel radiation exposure by an estimated 250 person-mrem per canister.

1.2 Approach

The general approach for this multi-year feasibility study begins with identifying potentially suitable concepts for direct disposal of DPCs. This report documents the initial Scoping and Assumptions phase, as described in the multi-year plan (Howard et al. 2012, Section 3). The purpose of the report is to: 1) provide background on the current status of DPCs and single-use canisters (Chapter 2); and 2) define the assumptions that will be used throughout the study, describing technical, regulatory, and administrative constraints (Chapter 3). These overarching assumptions were developed from input representing various stakeholders. The next phase conducted in FY13 will identify specific disposal concepts for evaluation, and establish direction for supporting generic research and development (R&D), and disposal concept development activities.

2. CATALOG OF DRY STORAGE SYSTEMS

Chapter 2 documents principal canister characteristics in order to: (1) support future technical analyses related to direct disposal of DPCs; and (2) provide preliminary information for consideration in standardized canister design (Howard et al. 2012, Section 3.1.3). This analysis gathers information on dry storage canisters currently in use at both orphaned and active reactor sites, and is summarized by a spreadsheet (LeDuc 2012) of these characteristics (Appendix A; filename: *DryCask&WetStagedStorage US_20120524.xls*). Values for the characteristics were obtained through license documents available using resources of NRC. Licensed values have been compared to projected values from the UFD logistics simulation code, CALVIN (BSC 2003b), in Section 2.4.

2.1 Methodology and Resources

2.1.1 Information Presented

The starting point for the data collection effort presented here was a spreadsheet developed under the Transportation/Storage Logistics UFD work package, which listed several characteristics of canisters currently in use. These characteristics include: utility company and site, canister vendor, type of reactor (PWR/BWR), total number of canisters by type and location, and other information related to storage and transportation. This analysis extended the information to include characteristics important to direct disposal of DPCs.

The information presented here for DPCs consists of

- External dimensions (length, diameter)
- Assembly capacity (PWR and BWR)
- Maximum loaded mass
- Maximum thermal output vs. time for both storage and transportation.

In addition the following information was sought for the most commonly used systems:

- Design-basis burnup
- Canister shell material composition
- Canister internal materials and structural design
- Basket materials
- Neutron absorber materials
- Spacers and thermal shunts
- Shield plug (if any)
- Other hardware components (e.g., control rods/burnable poison inserts)
- Actual content of loaded DPCs
- Method relied on for criticality control (e.g., burnup credit, flux traps).

The majority of these items were obtained. Items that were not obtained include the time history of the thermal output, and the actual content of loaded DPCs. These two items are not included among the sources used in this study. Although no information was found on DPC thermal output as a function of time, the maximum initial thermal output (before decay) is a well-documented design specification, and time history can be approximated using initial enrichment, burnup, and fuel age. Limits specified by the license are included both for the canister as a whole and on a per assembly basis. Other information that may be important to future analyses was also included. These items include: internal diameter, canister weight without fuel, min/max loaded weights, and min/max initial uranium enrichment. The spreadsheet also lists originating documents for the listed information.

The output from this analysis is both the spreadsheet itself as well as the collected documents. All of this is archived on the Advanced Nuclear Energy Program (ANEP) SharePoint site at Sandia National Laboratories (SNL). The spreadsheet is presented in Appendix A.

2.1.2 Resources Accessed

The majority of the information gathered here originated from the Agency-wide Documents Access and Management System (ADAMS) on the NRC website. The ADAMS website is divided into two main sections: the Public Library and the Public Legacy Library. The Public Library consists of publicly available documents for which electronic, downloadable copies are available. The Public Legacy Library contains documents that are publicly available but which are not currently available electronically. Obtaining these documents requires a fee to transfer the material from microfiche to electronic versions. A final document type, which is not included in ADAMS, is non-publicly available documents. Although these documents cannot be found through a search on ADAMS, their presence can be detected through other generic search engines (e.g., Google) or from other NRC documentation. Obtaining a non-publicly available document requires making a request under the Freedom of Information Act (FOIA). The documents used here all fall into the first category (ADAMS, Public Library) and were downloaded from the ADAMS website. The other two document types were not pursued, mainly because similar information can be found through other avenues. Also, the few documents that fall into the latter two categories are for canister systems making up only a small fraction of the total number of canisters currently in use.

From the ADAMS website, several main document types could be found relating to the performance characteristics of dry storage canisters. These include (1) the Final Safety Analysis Report (FSAR, also referred to as a Topical Safety Analysis Report, TSAR), (2) a certificate of compliance (COC) for licensed canisters, and (3) a safety evaluation report (SER). The FSAR is the most informative of these documents. It is the culmination of thermal, mechanical, criticality, and operational analyses. The vendor must submit the FSAR to the NRC. The NRC response to the FSAR is the SER and eventually a COC in most cases. Common components of the FSAR include: a general canister description, principal design criteria, structural evaluation, thermal evaluation, shielding evaluation, criticality evaluation, confinement evaluation, operating procedures, canister maintenance, radiation protection and accident analyses. Several of the vendors submitted an “umbrella” FSAR with generic analyses for the canister. Specific consideration of a certain packing condition is then given in an appendix. For example, the Transnuclear NUHOMS series of DPCs uses a single external canister for the majority of their designs but uses different internal components to allow for different fuel arrangements and capacities. The umbrella FSAR addresses the external canister, while the separate appendices give specifics on the internal components and associated analyses for the different fuels and configurations.

A few other documents found through internet searching were also used, including documents from DOE and the Electric Power Research Institute (EPRI). These documents describe testing of the canisters by DOE, or general fuel storage documents from EPRI. For a few of the canisters, an FSAR from an Independent Spent Fuel Storage Installation (ISFSI) was used.

2.1.3 Data Limitations

Values tabulated in Appendix A are upper limits, based on license documents. Also, in some cases, optional components or fuel-specific modifications are mentioned with conditions for use. For example, fuel with greater heat output may require thermal shunts. Depending on the geometry of fuel assemblies and the canister, spacers may be required. Licensing documents do not have the as-built information to determine whether such components or modifications are used. A similar limitation is small uncertainties associated with system specifications such as canister length and diameter, system weight, etc., which may vary according to how they are used in supporting analyses. Another limitation is document availability. While the FSARs contain much of the desired information, they are not available for all canister types. As-built information may be protected for security reasons. An ongoing industry survey similar to the RW-859 exercise performed in 2002 by the DOE Energy Information Administration, is expected to round out the available information on existing dry storage, and to improve projections.

2.2 Results

A total of 1,570 loaded canisters in dry storage systems are currently in use at active or decommissioned reactors. Figure 1 shows the proportion of the total made up by each canister type. This same data are re-plotted in Figure 2 with the individual canister types grouped based on design and vendor. Canister systems from a single vendor often share design features such as physical dimensions and material compositions. The top five canisters in use today are the HI-STORM MPC-68 (Holtec), the NAC-UMS UMS-24 (NAC International), the NUHOMS 24P (Transnuclear), the HI-STORM MPC-32 (Holtec), and the NUHOMS 61BT (Transnuclear). When broken down by vendor/design, just three vendors have provided approximately 75% of the total canisters in use. These are, in descending order: NUHOMS (Transnuclear), HI-STORM (Holtec), and NAC-UMS UMS-24 (NAC International).

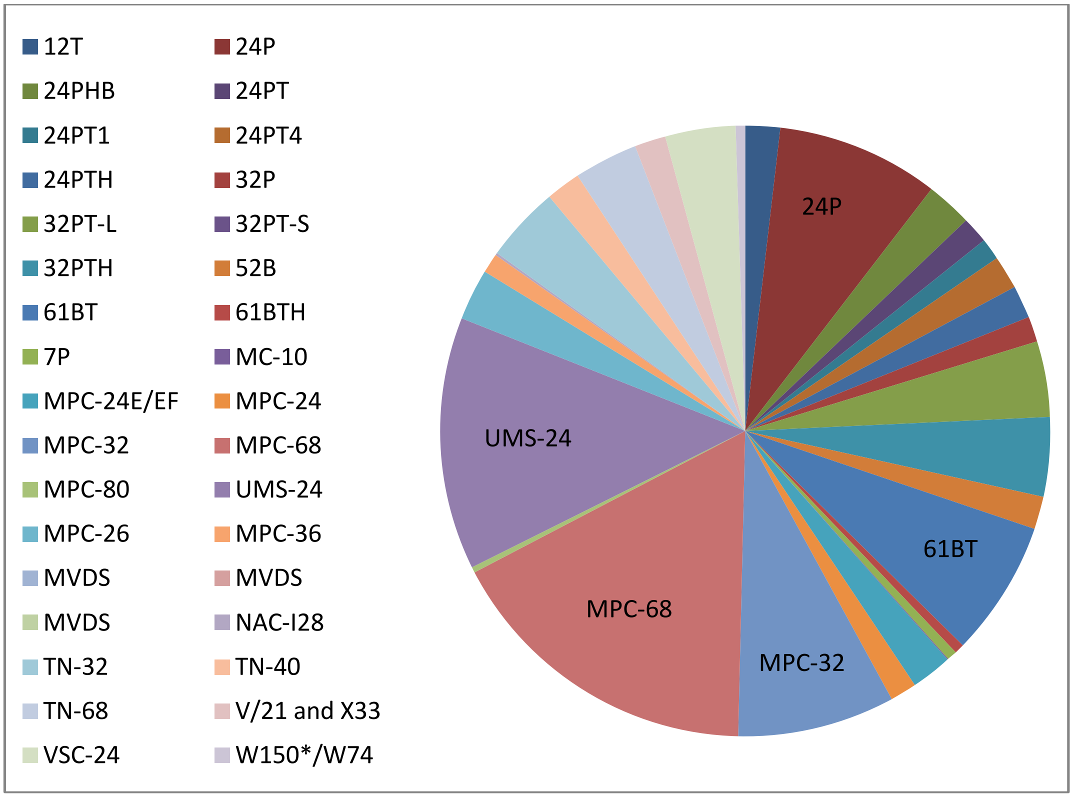


Figure 1. Relative frequency of storage systems in use.

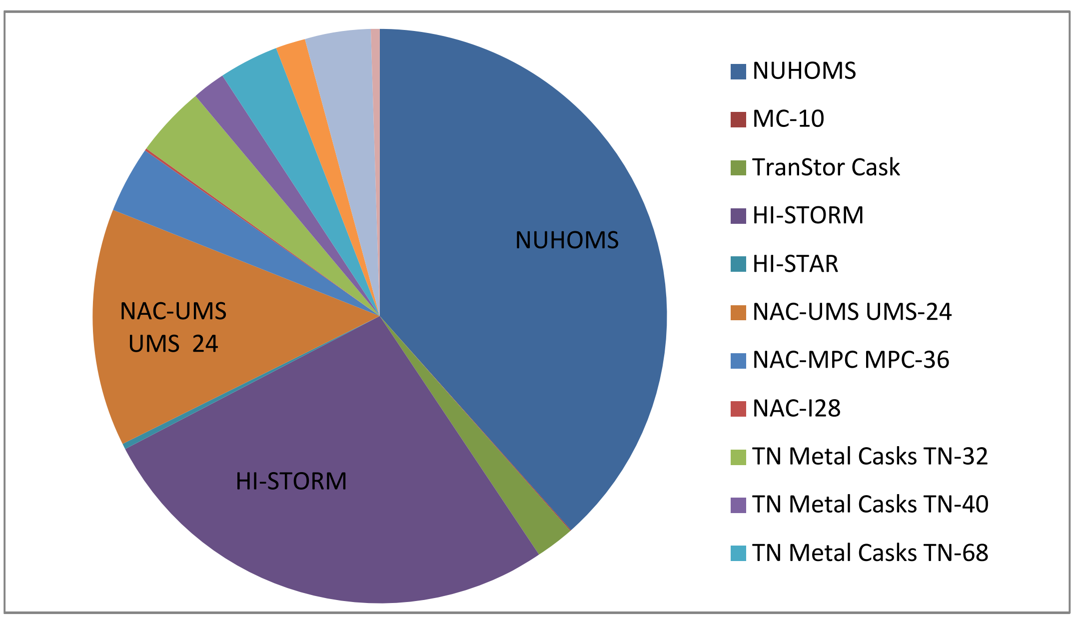


Figure 2. Relative frequency of existing storage systems grouped by design and vendor.

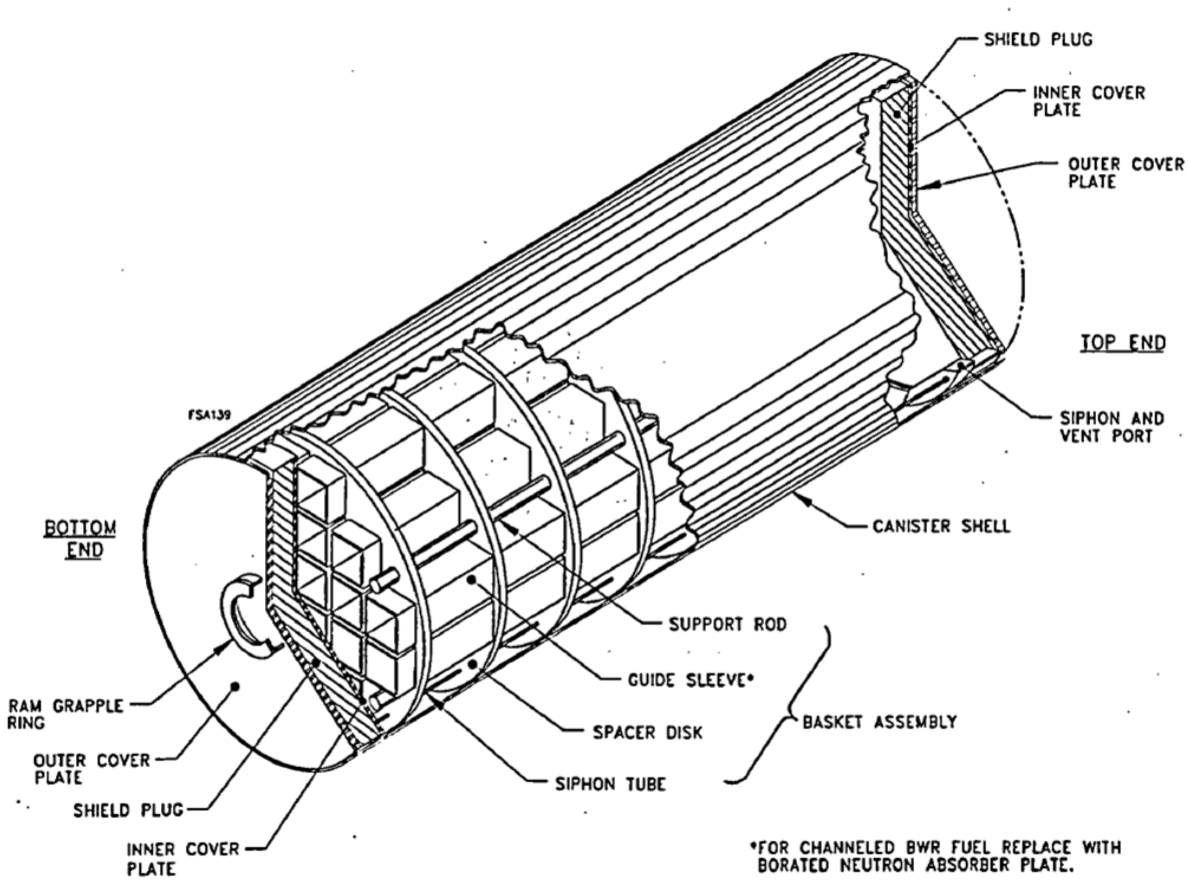
2.3 Comparison of Canister Designs

Designs for the most popular canisters are similar. Popular canister-based storage systems are likely to remain popular for some time, and are therefore likely to be representative. Even among the less popular canister types, the designs are relatively similar. The exceptions are generally canisters designed for a specific type of fuel, or earlier designs that were generated during technology development.

The basic design and components of UNF canisters are shown in Figure 3. Among the commonly used canisters there are few differences in terms of the components present. Nearly all use some form of stainless steel for major components (canister shell, fuel basket, top and bottom containment and structural lids). Overall dimensions are largely determined by the fuel and are therefore similar. The canister wall thickness for the most popular canisters is typically 2.5 to 3.7 cm and overall length is typically 4.85 m. Canister weights are variable, with empty canisters weighing from ~13 to 56 metric tons (MT). Heavier systems are outliers. The most commonly used DPCs weigh from 15 to 25 MT when empty. The maximum loaded weights range from 34 to 46 MT for these commonly used systems. Maximum initial heat ranges from 12.5 to 40.8 kW (including systems for both PWR and BWR fuel). Decay heat for the more commonly used systems ranges from approximately 18 to 37 kW.

Internal component designs are also similar among different storage systems, with the greatest differences in material composition. The major internal components are the shield plug and the basket. The components of the basket, typically made from stainless steel, include the fuel assembly tubes, basket supports (rods and rings), and spacer disks. For criticality control borated aluminum (Boral) is typically used, sandwiched between sheets of stainless steel. Aluminum acts as a thermal shunt, and many of the spacer disks are either replaced or augmented with aluminum alloys to increase heat transfer to the canister wall. Shield plug materials include stainless steel, coated carbon steel, and lead or depleted uranium encased in stainless steel. (Carbon steel is coated to prevent corrosion and particulate shedding in fuel pools.) The major differences in design relate to the numbers of fuel assemblies, and the use of flux traps for criticality control in PWR fuel storage canisters. Figure 3 shows the construction of a typical storage canister of the NUHOMS design, containing 24 PWR assemblies.

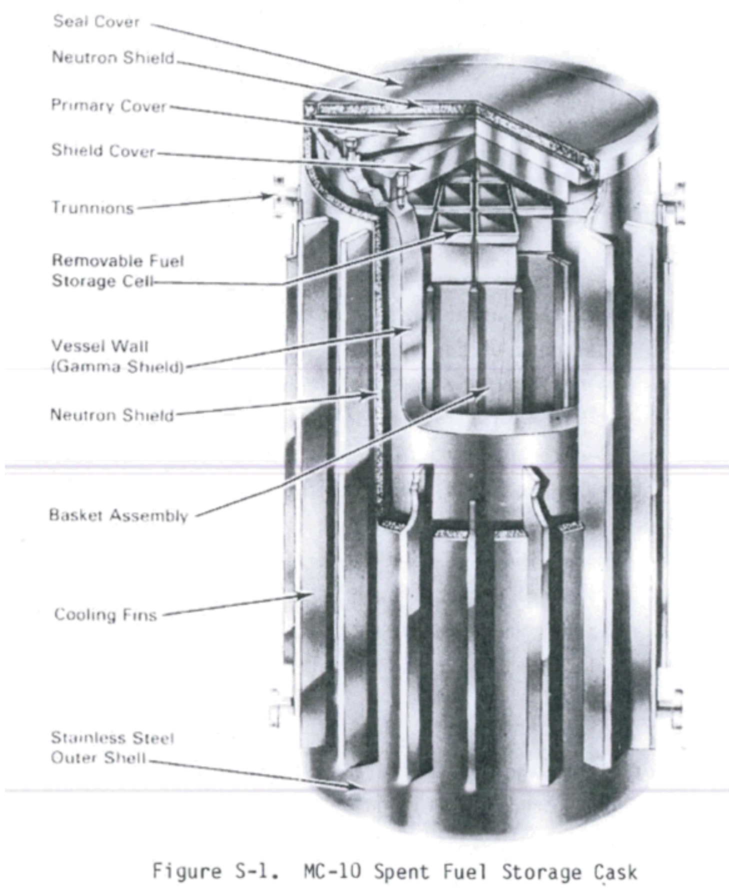
Among less common systems, there is a wider range of canister designs, such as thick-walled canisters with cooling fins. These designs are more difficult to represent with a single selection. For example, the system shown in Figure 4 for the MC-10 design (Efferding 1990) has a wall thickness up to 60 cm for integrated shielding. Hydrogenous moderator rods were used for neutron absorption. The exterior fins dissipate heat and were not analyzed for structural characteristics, so geologic disposal could involve fin damage or removal. In the less common designs there is also wider use of materials other than stainless steel, for example, the CASTOR V/21 system uses a canister shell composed of nodular cast iron with nickel plating (variants of the CASTOR system are common in Europe). Various types of steel are used including: Type 304 and 316 stainless steels in various grades, SA-516 Grade 70, and SA-203 Grade E. Overall, these less common systems comprise a relatively small fraction of the total (<20%) and this fraction is likely to decrease as more recent designs proliferate. There are a small number of old canister-based systems for which little to no information were found in this review.



Source: TransNuclear (2004, Appendix N)

Figure 3. Representative design of DPC canister. NUHOMS 24PHB shown.

A previous study considering the feasibility of direct disposal of DPCs at an unsaturated, open-mode repository (BSC 2003a) found that the major concerns are: 1) postclosure criticality; 2) physical dimensions; and 3) vertical handling modifications for canisters designed for horizontal storage. Neutron absorbing materials used for criticality controls (e.g., Boral) can degrade and mobilize in certain disposal environments, separating from the fuel assemblies. Stainless steel supports can also degrade so that the internal fuel structure collapses. These findings were relevant for a specific disposal concept, in an oxidizing environment with groundwater present in amounts sufficient to flood breached waste packages. Suitability of other disposal concepts for DPC disposal will be addressed in the feasibility study. The previous study identified the importance of principal isotope (or more comprehensive) burnup credit in postclosure criticality analyses for DPCs (BSC 2003a).



Source: Dominion (2004)

Figure 4. Representative uncommon canister design. MC-10 shown.

2.4 Comparison of License Values to Calculated Values

As mentioned previously, the data presented here for burnup and thermal limits on storage systems are defined in licensing documents, and bound the characteristics of UNF actually in storage. For additional perspective, the CALVIN 4.0 (BSC 2003b) database was queried to estimate burnup, enrichment and fuel age for fuel in dry storage. For each of these measures CALVIN reports the average, maximum, and minimum for each site with dry storage. CALVIN 4.0 has limitations, chief among them is that post-2002 data are projections. Also, the data capture most of the sites and most of the systems in use, but are incomplete. Data were tabulated for the more popular canisters located at 53 sites (Table 1), and a few representative values and trends are observed. Figures 5 through 8 show the characteristics for representative storage systems at these sites.

Figures 5 through 8 show the average, minimum, and maximum burnup by site for five commonly used storage systems shown also in Table 1 (HI-STORM MPC-68 and MPC-32, NAC-UMS-24, NUHOMS 24P and 61BT). Of the 37 sites known to be using at least one of these five systems, 27 are represented in the figures. In general, the projected average burnup values are lower than the licensed maximum values. Overall, the average values are distributed through a range of 30 to 90% of the maximum value. The few instances where CALVIN projections are slightly larger than the maximum, can be attributed to limited precision of the estimates.

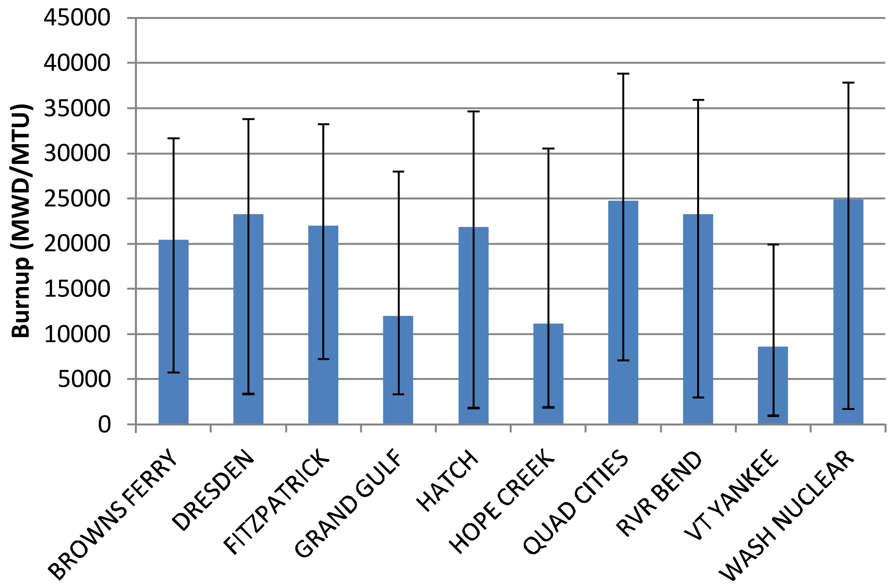
Similarly, the projected enrichment values for UNF in dry storage are mostly lower than the licensed maximum values (Figures 9 and 10). Figure 11 shows that UNF age and burnup have a weak, negative correlation. That trend is expected to continue as facilities continue to increase burnup in reactor operations.

Table 1. Sites and canisters considered at each site (data from CALVIN 4.0, BSC 2003b).

Site	Cask System	Canister Type	Site	Cask System	Canister Type
SURRY	Castor	V/21 and X33	PALO VERDE	NAC-UMS	UMS-24
ARK NUCLEAR	FuelSolutions	VSC-24	HADDAM NECK	Note A	MPC-26
PALISADES	FuelSolutions	VSC-24	BEAVER VALLEY	Note A	Note A
POINT BEACH	FuelSolutions	VSC-24	PERRY	Note A	Note A
BIG ROCK	FuelSolutions	W150	DAVIS-BESSE	NUHOMS	24P
HUMBOLDT BAY	HI-STAR	MPC-80	OCONEE	NUHOMS	24P
BYRON	HI-STORM	MPC-32	RANCHO SECO	NUHOMS	24PT
DIABLO CANYON	HI-STORM	MPC-32	SAN ONOFRE	NUHOMS	24PT1
FARLEY	HI-STORM	MPC-32	CALVERT CLF	NUHOMS	32P
INDIAN PT 1&2	HI-STORM	MPC-32	FORT CALHOUN	NUHOMS	32PT
INDIAN PT 3	HI-STORM	MPC-32	GINNA	NUHOMS	32PT
SALEM	HI-STORM	MPC-32	KEWAUNEE	NUHOMS	32PT
SEQUOYAH	HI-STORM	MPC-32	MILLSTONE	NUHOMS	32PT
BROWNS FERRY	HI-STORM	MPC-68	SEABROOK	NUHOMS	32PTH
DRESDEN	HI-STORM	MPC-68	ST LUCIE	NUHOMS	32PTH
FITZPATRICK	HI-STORM	MPC-68	SUSQUEHANNA	NUHOMS	52B
GRAND GULF	HI-STORM	MPC-68	COOPER STN	NUHOMS	61BT
HATCH	HI-STORM	MPC-68	DUANE ARNOLD	NUHOMS	61BT
HOPE CREEK	HI-STORM	MPC-68	MONTICELLO	NUHOMS	61BT
QUAD CITIES	HI-STORM	MPC-68	OYSTER CRK	NUHOMS	61BT
RVR BEND	HI-STORM	MPC-68	BRUNSWICK	NUHOMS	61BTH
VT YANKEE	HI-STORM	MPC-68	ROBINSON	NUHOMS	7P
WASH NUCLEAR	HI-STORM	MPC-68	TROJAN	Transter Cask	MPC-24E/EF
YANKEE-ROWE	NAC-MPC	MPC-36	NORTH ANNA	TN Metal Casks	TN-32
CATAWBA	NAC-UMS	UMS-24	PRAIRIE ISL	TN Metal Casks	TN-40
MAINE YANKEE	NAC-UMS	UMS-24	PEACHBOTTOM	TN Metal Casks	TN-68
MCGUIRE	NAC-UMS	UMS-24			

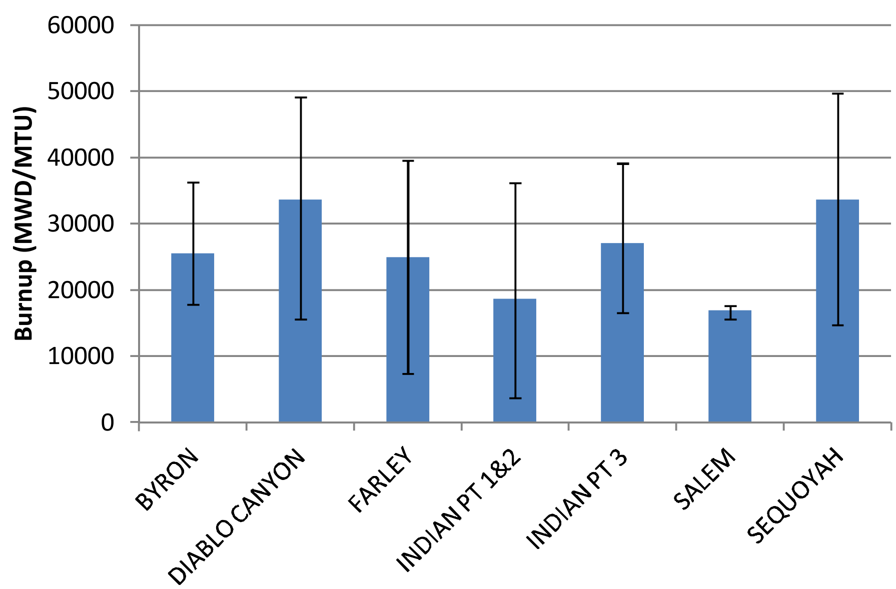
Note A: From CALVIN 4.0 database.

Note: Shaded cells show burnup ranges in Figures 5, 6, 7, and 8.



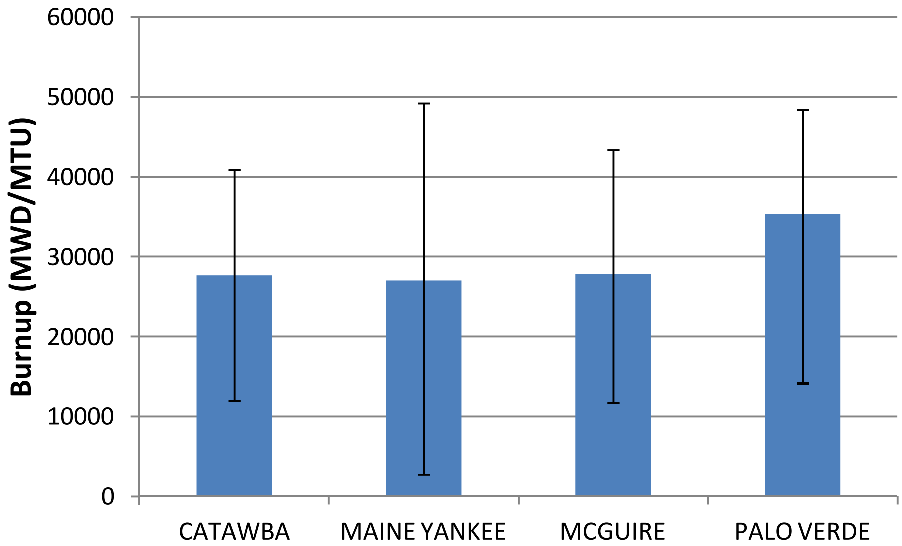
Note: The solid columns represent average burnup, and the bars are maximum and minimum values. The maximum authorized burnup is 68,200 MW-d/MTU.

Figure 5. Burnup for sites using the HI-STORM MPC-68 (BWR) canister.



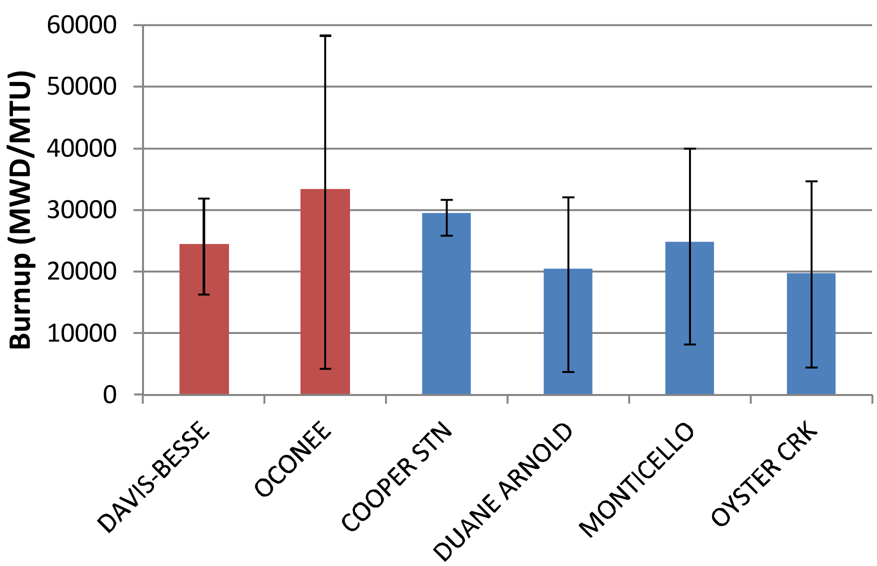
Note: The solid columns represent average burnup, and the bars are maximum and minimum values. The maximum authorized burnup is 68,200 MW-d/MTU.

Figure 6. Burnup for sites using the HI-STORM MPC-32 (PWR) canister.



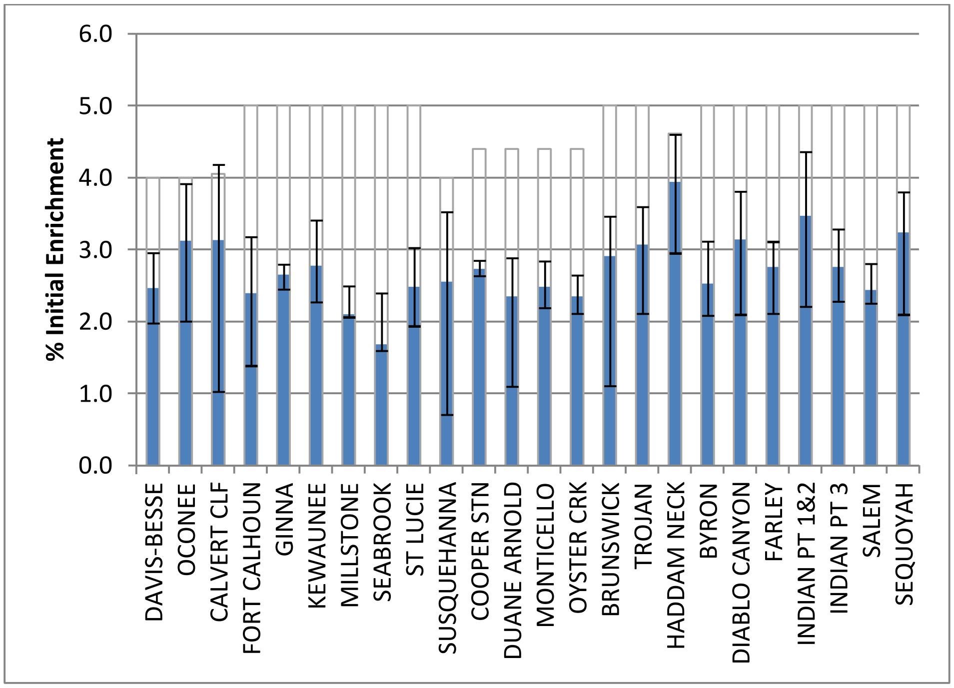
The solid columns represent average burnup, and the bars are maximum and minimum values. The maximum authorized burnup is 45,000 MW-d/MTU.

Figure 7. Burnup for sites using the NAC-UMS 24 (PWR) canister.



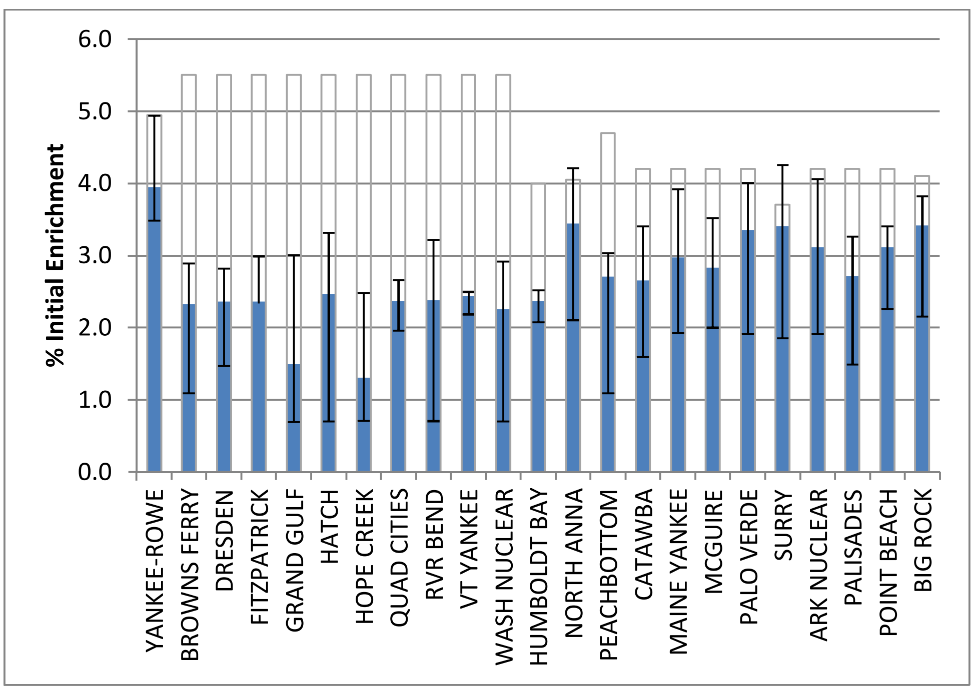
Note: The red columns are type 24P, and the blue columns are 61BT. The columns represent average burnup, and the bars are maximum and minimum values. The maximum authorized burnup is 40,000 MW-d/MTU for both canister types.

Figure 8. Burnup for sites using NUHOMS (PWR and BWR) canisters.



Note: The solid columns are average values, and the bars are maximum and minimum values. The open columns are maximum licensed values.

Figure 9. Percent enrichment by reactor site.



Note: The solid columns are average values, the bars are maximum and minimum values. The open columns are the maximum licensed values.

Figure 10. Percent enrichment by reactor site.

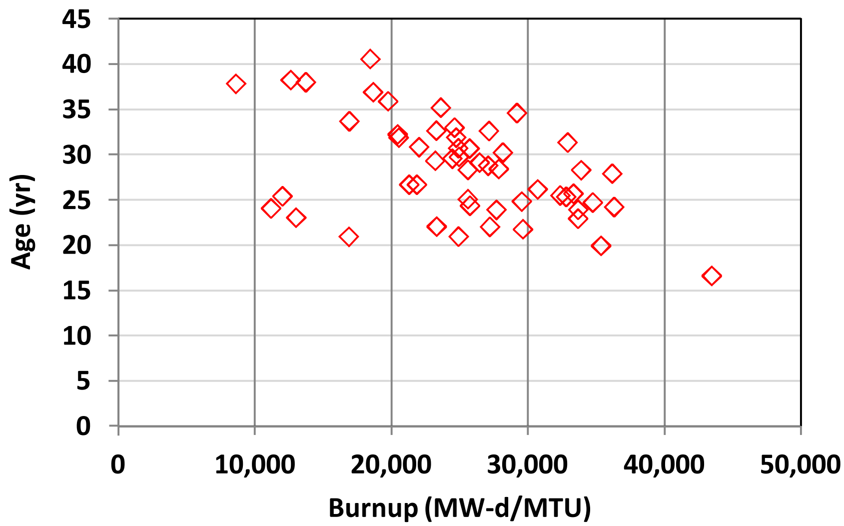


Figure 11. Fuel age as a function of burnup.

It is clear from these figures that using the maximum values from license documents is conservative. A good alternative is to use quantiles of data generated for discrete canisters, to better understand the distributions of important parameters. Generating data for discrete canisters from CALVIN 4.0 is more labor intensive, but for illustrative purposes, projections for individual canisters at the Dresden site were generated. Dresden was chosen as it has a relatively large number of HI-STORM MPC-68 canisters. Dresden has one retired reactor, and the overall fuel age is slightly older than the fleet average. CALVIN estimates the total number of canisters to be 60, while the actual number is 45. Figure 12 shows a cumulative distribution function of burnup for the 60 MPC-68 canisters listed by CALVIN. The distribution (for canister averages reported by CALVIN) is smooth and nearly linear from approximately 7,000 to 32,000 MW-d/MTU.

Further specifics for the Dresden projections are given in Table 2. There are a few small discrepancies between integrating CALVIN data at the site level compared to the canister level. Again, they show that the CALVIN estimates have limited precision, but that using the licensed maximum values for canister characteristics is conservative.

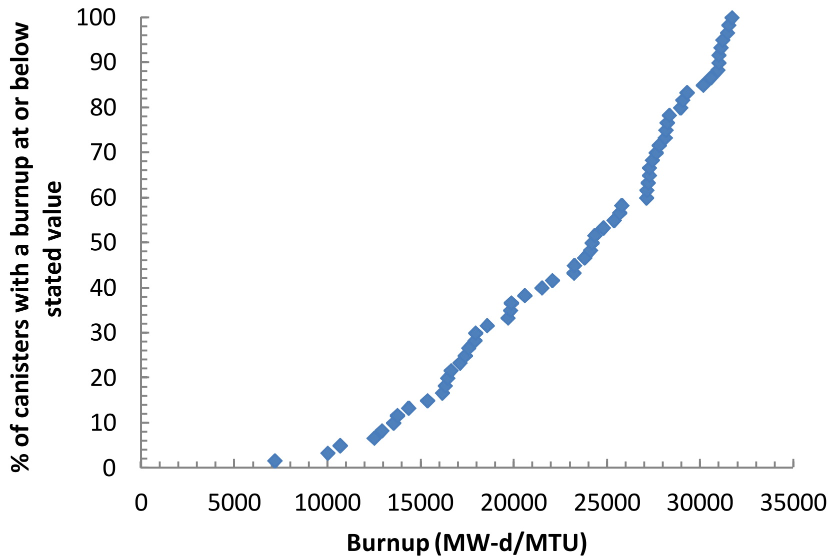


Figure 12. Cumulative distribution of burnup for the 60 total HI-STORM MPC-68 canisters listed in CALVIN for the Dresden site.

Table 1. CALVIN data comparison when integrated by site or by canister.

		CALVIN 4.0 All fuel assemblies at Dresden site	CALVIN 4.0 Averages for loaded canisters
Burnup (MW-d/MTU)	Average	23,271	22,988
	Minimum	3,388	7,161
	Maximum	33,835	31,692
Initial Enrichment (%)	Average	2.37	2.34
	Minimum	1.47	1.99
	Maximum	2.82	2.82
Age (yr)	Average	32.69	32.66
	Minimum	24.17	24.17
	Maximum	43.32	42.37

3. ASSUMPTIONS FOR EVALUATING FEASIBILITY OF DIRECT DISPOSAL OF DUAL-PURPOSE CANISTERS

Feasibility evaluation for direct geologic disposal of dual-purpose and storage-only canisters will be evaluated using targeted technical and regulatory analyses. Assumptions are needed because: (1) the analyses are generic (no site specified); (2) there is a recognized need for statutory and regulatory changes or clarifications (BRC 2012); and (3) the timing of disposal is uncertain so that the future state of the overall fuel management system in the U.S. must be assumed. The goal of these assumptions is to provide a common, underlying basis for targeted analyses, and not to specify how the analyses will be conducted. Assumptions are categorized into three areas:

- Engineering and technology assumptions
- Statutory and regulatory framework for disposal
- Logistical, regulatory, and technological assumptions related to storage and transportation that influence disposal feasibility

3.1 Engineering and Technology Assumptions

3.1.1 DPC Characteristics

1. DPCs contain commercial UNF. Average burnup for existing UNF in dry storage is nominally 40 GWd/MT, with a bounding value of 60 GW-d/MT for future DPCs. These values may be used in generalized analyses to evaluate DPC disposal feasibility (more reactor-site specific or canister-specific bounding values may be available as discussed in Section 2).

   Basis: Analysis and projections in Carter et al. (2012), and an assumption that UNF in DPCs is similar to the overall average of the total inventory. In fact, the enrichment and burnup of UNF in DPCs may be less than the overall averages reported by Carter et al. (2012), as indicated from the data summary (Section 2).

2. The capacity of the DPC is 32 PWR assemblies or 68 BWR assemblies

   Basis: This is a typical value and reasonable bound as discussed in Section 2, although larger systems are becoming available.

3. Storage-only canisters can be included in the evaluations.

   Basis: Plant operators, vendors, or an implementing organization could develop approaches to allow their transport to a centralized storage facility, and then a repository. Storage-only canisters currently exist at the Idaho National Laboratory, and Calvert Cliffs, Surry, Oconee, Arkansas Nuclear One, Palisades, Davis-Besse, Point Beach, Susquehanna, and H.B. Robinson nuclear power plants.

4. DPCs designed for vertical storage can be readily approved, with modifications as appropriate, for horizontal disposal.

   Basis: The NUHOMS canister systems are all designed for horizontal storage and transport, and constitute a large fraction of the existing DPCs. Modifications to canisters designed for vertical storage (and horizontal transport for DPCs) can be readily licensed and implemented to allow horizontal disposal.

5. Existing canisters can be analyzed for uniform average enrichment, average burnup, and average age for the assemblies contained.

   Basis: This simplifying assumption avoids the complication of nonuniform loading within canisters, whereby cooler or less reactive assemblies are intentionally placed in certain positions of a DPC basket. Results obtained with uniform loading can be tested later for specific cases of nonuniform loading.

6. Residual moisture in sealed DPCs can be estimated from the drying procedures required in license documents.

   Basis: Direct measurement of residual water content is not possible for sealed canisters.

3.1.2 Disposal Concepts

1. Surface decay storage of DPCs and storage-only canisters for up to 100 yr (out-of-reactor) can be assumed in disposal feasibility evaluations.

   Basis: This assumption is equivalent to an assumption that storage cask licenses can be extended to 100 yr. Longer durations may pose increasing risk that DPCs cannot be transported from storage and emplaced underground, because of cumulative damage to the fuel or to the canister itself. This assumption is generally consistent with an "No Action Alternative" considered in an Environmental Impact Statement for a geologic repository. The EIS assumed that storage facilities would be completely replaced in 100 years and possibly every 100 years afterword, including the *existing* DPCs (DOE 2002).

2. Open emplacement modes (Hardin et al. 2012) are limited to 50 yr of repository operation after emplacement of the last waste package.

   Basis: The combined durations of surface storage and repository operation will not be evaluated beyond 150 yr, to limit any additional assumptions about long-term stability of institutions responsible for waste management.

3. Thermal constraints will not be assigned to the DPCs, overpacks, engineered materials contacting the overpacks, other engineered barrier system (EBS) features, or the near-field host rock, a priori. Rather, near-field thermal temperatures will be used to evaluate thermal loading of the repository and repository performance.

   Basis: Near- and far-field temperature limits have been imposed previously (DOE 2008), but we wish to evaluate whether previous limits can be relaxed and still show adequate performance, provided sufficient scientific understanding of thermal behavior in various media has increased

4. Underground handling and transport of DPCs will be shielded.

   Basis: Shielded transporters and handling equipment substantially decrease the risk of accidental worker exposure, and are the norm in disposal concepts being investigated world-wide.

5. Disposal mode may be shielded (e.g., by borehole emplacement) or unshielded (e.g., in-drift emplacement).

   Basis: Both shielded and unshielded modes continue to be investigated internationally, and have been investigated by previous studies in the U.S.

3.1.3 Criticality Analysis

1. Low probability arguments for postclosure criticality based on a number of factors may be used to exclude the criticality scenario class, including burnup credit (i.e., consumption of fissile material and presence of actinides and fission products), geologic media specific, assembly specific, and cask specific characteristics.

   Basis: Past studies have identified situations where burnup credit and more detailed modeling (principal isotopes, BSC 2003a; more complete isotopics, EPRI 2008) is needed in DPC disposal analysis.

2. Consequence analysis may also be used to show that criticality after disposal can be excluded.

   Basis: Previous studies (e.g., Rechard et al. 1996) have shown that criticality events may not significantly change postclosure repository performance.

3. Reactor operating records can be used for selecting more realistic modeling parameters to characterize the discharge isotopic composition and residual reactivity levels associated with UNF

   Basis: Numerous studies (e.g., Wagner and Sanders 2003) have examined the impact of depletion and criticality analysis assumptions which suggest that a considerable amount of uncredited margin is incorporated into most cask loadings. Reducing uncertainty associated with parameter selection and calculating more realistic safety margins will enable a higher percentage of UNF to satisfy subcriticality requirements.

3.1.4 Surface Facilities

1. Canisters will be sealed at the reactors or at a centralized storage facility and will not be reopened at the repository as part of the disposal concept.

   Basis: Canister remediation options that involve re-opening the canister (even if fuel is not removed), such as addition of a filler material, may be feasible but are out of scope for this evaluation.

2. Surface facility throughput will be sufficient to dispose of all nominally storage-only canisters and DPCs at minimum age/burnup.

   Basis: Surface facilities can be readily designed, constructed and operated to handle and package DPCs for disposal. Such facilities would be similar in scope, at the same throughput, as previously designed facilities to package transportation-aging-disposal (TAD) canisters (DOE 2008).

3. Any necessary DPC inspection can be done remotely in a hot cell, and detected damage can be corrected or mitigated by re-packaging.

   Basis: Inspections may be required to confirm the condition of canisters prior to packaging and emplacement, to protect workers, and to conform to postclosure waste isolation related requirements as applicable. Canisters may accumulate minor damage from corrosion, especially if stored in marine environments.

3.2 Statutory and Regulatory Framework for Disposal

The generic health standard, 40 CFR 191, for mined geologic disposal first promulgated by the Environmental Protection Agency (EPA) in 1985 is still in force, and could, in concept be applied to future repositories. However, the evolution in the strategy adopted by the EPA and NRC in the site-specific regulations for a repository in tuff, 40 CFR 197 and 10 CFR 63, would likely be adopted for a future repository.

The National Academies/National Research Council (NAS) recommendations for standards specific to a repository in unsaturated tuff developed pursuant to the *Energy Policy Act of 1992* may be judged to be applicable to other repositories for UNF and high-level waste (HLW) even though this Act only requires that the standards for a repository in unsaturated tuff be consistent with those recommendations. The EPA generic geological disposal standard at 40 CFR 191 does not address the peak dose standard for the period of geologic stability (~10^6 yr) as recommended by the NAS and incorporated in 40 CFR 197 (with guidance for addressing uncertainty and projecting performance over such long time periods).

Any changes to EPA's standards for repositories in media other than unsaturated tuff would have to be reflected in changes to the corresponding NRC regulation, 10 CFR 60. The 10 CFR 60 regulations, while still applicable to any repository other than in unsaturated tuff, were not revisited when fundamental changes were made to performance assessment requirements in the promulgation of 10 CFR Part 63. In particular, NRC has evolved from specifying disposal subsystem requirements (e.g., EBS containment) to relying on total system performance assessment (TSPA). Consequently, NRC stated when promulgating 10 CFR 63 that the "generic Part 60 requirements will need updating" (Rubenstone 2012; NRC 2001). Furthermore, NRC has suggested that regulations for future repositories would likely look similar to 10 CFR 63 in presentations to the Blue Ribbon Commission on America's Nuclear Future (BRC) and the Nuclear Waste Technical Review Board (McCartin 2010; 2012).

3.2.1 Statutory Framework

1. Future repositories will be regulated by the NRC, implementing requirements of the National Environmental Policy Act (NEPA), and performance standards promulgated by the EPA.

   Basis: These conditions are required by current legislation in effect.

3.2.2 Regulatory Framework

In general, the regulatory framework controlled and implemented by EPA and NRC will be similar to existing site-specific regulations (§63.113).

1. Expected peak dose to a reasonably maximally exposed individual (RMEI) at the boundary of the accessible environment will be the primary measure of individual dose, for two time periods: a limit of 0.15 mSv/yr before 10^4 yr, and 1 mSv/yr for the mean of simulations beyond 10^4 yr through the period of geologic stability, or approximately 10^6 yr.
2. The accessible environment for performance assessment of DPC disposal will be at least 5 km away from the boundary of the repository (§63.302).
3. The NRC requirement for retrievability will remain similar:

…the geologic repository operations area must be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. (§63.111[e])

4. In general, features, events, and processes (FEPs) and scenario classes formed from these FEPs will be retained or omitted based on their influence on performance in the first 10^4 yr (§63.114). The criterion for screening FEPs and scenario classes based on probability will remain at 10^{-8} in any one year. Seismic and climate change effects will be projected beyond 10^4 years (§63.342).

5. Lead, chromium or other materials used in fabrication of DPCs is part of waste packaging that will not be subject to regulation under the Resource Conservation and Recovery Act (RCRA).

6. NRC requirements for barriers of the disposal system will remain similar: Licensee must identify components of the disposal system that are important for isolation and demonstrate their performance. No subsystem containment requirements will be specified (§63.115).

7. Inadvertent human intrusion will not be included in the probabilistic dose calculations. Individual dose to the RMEI will assessed, conditioned on the intrusion. The dose pathway will be limited to groundwater (or to airborne transport if significant). Dose to the crew responsible for intruding will not be evaluated (§63.321).

8. The circumstances of human intrusion will be similar, in that a stylized calculation will be specified such that a single well bypasses a portion of the natural barrier system vertically above or below the repository, but the remainder of the natural barrier in the horizontal direction to accessible environment is retained (§63.321).

3.3 Assumptions for Storage and Transportation

The condition of DPCs or storage-only canisters during storage and transportation establish initial conditions for disposal. Other limits on storage and transportation such as permitted durations or age of UNF, also interface with disposal.

3.3.1 Storage

1. Parts 71 and 72 will be substantially unchanged, and further licensing activities will proceed to allow transport of commercial UNF in DPCs (or existing storage-only canisters) for up to 100 yr from reactor discharge, in accord with Assumption 3.1.2(1).

   Basis: The influence of shorter and long storage durations can be evaluated in sensitivity studies.

3.3.2 Transportation

1. Transportation casks for all existing and future DPCs, and storage-only canisters, will be developed and licensed for use in transporting UNF to a centralized storage facility, and from there to the repository.

   Basis: The availability of approved infrastructure for transporting DPCs to the repository is beyond the scope of this study.

3.3.3 Movement from Storage

1. Spent fuel will be transported to the repository directly and exclusively from a centralized storage facility operated conjunctively with the repository.

   Basis: This assumption would expeditiously transfer responsibility for UNF to an authority responsible for long-term management and disposal.

2. DPCs or storage-only canisters can be selected for transport to the repository using various strategies, including oldest fuel first (OFF) and youngest-fuel-first (YFF), and variations thereof.

   Basis: Once fuel is stored in a centralized facility, selection can be optimized for disposal and other fuel management priorities without directly involving the electric utilities.

4. NEXT STEPS

Follow-on work will be performed in accordance with the work plan (Howard et al. 2012). The next phase (Section 3.2 of that plan) involves identifying the disposal concepts and contributing technologies that could enable direct DPC disposal. Formulation of those concepts will incorporate information from previous studies (Hardin et al. 2012) and new input. Selected concepts will be analyzed using the assumptions documented in this report.

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Appendix A: Information on Existing DPCs

Appendix A is the full spreadsheet of information for the individual canisters types. The electronic spreadsheet is one file, but because of its size the spreadsheet was broken into two separate tables for the print version. The electronic version has hyperlinks to schematics and drawings for many of the canister types. Also, the 'Critical documents' column has the file name corresponding to the ADAMS based document.

Table A-1. DPC type and physical dimensions.

Cask System	Canister or Cask Type	Type	Vendor	Total # of Canisters of This Type	% of Total Canisters	Summed # of Canisters by Type	Internal Canister Diameter (in.)	Outside Canister Diameter (in.)	Canister Length (in.)	Canister Weight w/o Fuel (lb.)	Gross Weight (lb.)	# Assem-blies	Max Assembly Weight (lb.; PWR)	Max Assembly Weight (lb.; BWR)	Min Assembly Weight (lb.; PWR)	Maximum Decay Heat Load Per Assembly (kW)	Maximum Decay Heat Load (kW; (PWR)	Maximum Decay Heat Load (kW; BWR)	Design-Basis Burnup (MW-d/MTU; PWR)	Design-Basis Burnup (MW-d/ MTU; BWR)
NUHOMS	12T	PWR	TN	29	1.85							12								
NUHOMS	24P	PWR	TN	135	8.60		66.0	67.25	186.0		80,000	24	1,682			1	24		40,000	
NUHOMS	24PHB	PWR	TN	38	2.42		65.9		186.67	37,761 (PHBS)/ 35,426 (PHBL)	78,129 (PHBS)/ 75,794 (PHBL)	24	1,682			1.3	24		55,000	
NUHOMS	24PT	PWR	TN	22	1.40							24								
NUHOMS	24PT1	PWR	TN	18	1.15		65.9	67.19	186.5		82,000	24					14			
NUHOMS	24PT4	PWR	TN	28	1.78		65.9	67.19	196.5			24					24			
NUHOMS	24PTH	PWR	TN	27	1.72		65.9	67.19	186.55 (S), 192.55 (L)	48,600-52,000 (S); 49,700-53,300 (L); 49,100 (S-LC)	89,000 - 92,400 (S); 90,100 - 93,700 (L); 89,500 (S-LC)	24	1682			2.0 (S and L), 1.5 (S-LC)	40.8 (S and L), 24.0 (S-LC)		62,000	
NUHOMS	32P	PWR	TN	21	1.34							32	1533			1.02	32.64		45,000	
NUHOMS	32PT-L	PWR		63	4.01		66.19	67.19	192.2	45,500 (L100)/ 47,600 (L125)	89,200/101,400 (min/max)	32	1365 (L100)/ 1682 (L125)			1.2	24		45,000	
NUHOMS	32PT-S	PWR					66.19	67.19	186.2	44,500 (S100)/ 46,600 (S125)	88,200/100,400 (min/max)	32	1366 (S100)/ 1682 (S125)			1.2	24		45,000	
NUHOMS	32PTH	PWR	TN	66	4,20			69.75	193 (max.)			32	1575		1450	1.5	34.8		60,000	
NUHOMS	52B	BWR	TN	27	1.72		66	67.19	196 (max.)			52		725		0.37		19.24		35,000
NUHOMS	61BT	BWR	TN	113	7.20		66.25	67.25	199.7	45,390	89,390	61		705		0.30	18.3	22.57		40,000
NUHOMS	61BTH	BWR	TN	8	0.51		66.75	67.25	196 (max.)		88,700 Type 1/ 93,120 Type 2	61		705 (w/ channels), 640 (w/o channels)		0.54 (Type 1), 0.70 (Type 2)		22 (Type 1), 31.2 (Type 2)		62,000
NUHOMS	7P	PWR	TN	8	0.51	603						7								
MC-10	MC-10	PWR	W	1	0.06	1	68	88	188			24	1490						35,000	
TranStor Cask	MPC-24E/EF	PWR	Holtec	34	2.17	34	67.375	68.5 (max.)	190.125 (max.)	45,000	90,000	24	1721 (w/o spacers); 1680 (w/ spacers)			1.416 (Zr clad) 0.71 (SS clad)	36.9, 34 (Zr clad)		40,000 (SS clad)	
HI-STORM	MPC-24	PWR	Holtec	22	1.40		67.375	68.5 (max.)	190.125 (max.)	42,000	90,000	24	1720 (w/o spacers) 1680 (w/ spacers)			1.416 (Zr-clad)	36.9, 34 (Zr clad)		68,200	

Cask System	Canister or Cask Type	Type	Vendor	Total # of Canisters of This Type	% of Total Canisters	Summed # of Canisters by Type	Internal Canister Diameter (in.)	Outside Canister Diameter (in.)	Canister Length (in.)	Canister Weight w/o Fuel (lb.)	Gross Weight (lb.)	# Assem-blies	Max Assembly Weight (lb.; PWR)	Max Assembly Weight (lb.; BWR)	Min Assembly Weight (lb.; PWR)	Maximum Decay Heat Load Per Assembly (kW)	Maximum Decay Heat Load (kW; PWR)	Maximum Decay Heat Load (kW; BWR)	Design-Basis Burnup (MW-d/MTU; PWR)	Design-Basis Burnup (MW-d/ MTU; BWR)
HI-STORM	MPC-32	PWR	Holtec	131	8.34		67.375	68.5 (max.)	190.125 (max.)	36,000	90,000	32	1722 (w/o spacers); 1680 (w/ spacers)			1.062 (Zr clad), 0.5 (SS clad)	36.9, 34 (Zr clad)		68,200	
HI-STORM	MPC-68	BWR	Holtec	266	16.94	419	67.375	68.5 (max.)	190.3125 (max.)	39,000	90,000	68		730 (w/ channels)		0.5 (Zr clad), 0.095 (SS clad)		36.9, 34 (Zr clad)		68,200
HI-STAR	MPC-80	BWR	Holtec	5	0.32	5	67.375	68.5 (max.)	114	27,000	59,000	80		400 (w/ channels)		0.05		2	23,000	
NAC-UMS	UMS-24	PWR	NAC	210	13.38	210	65.8	67.06	175.1-190.4 (5 classes of canisters)	33,097-35,263 (PWR); 36,383-36,920 (BWR)	70,705-73,902 (PWR); 75,359-75,896 (BWR)	24 (PWR)/56 (BWR)	1,604	696		0.8 (PWR)/ 0.3 (BWR)	20	16	45000 (up to 50,000 at Maine Yankee)	45,000
NAC-MPC	MPC-26	PWR	NAC	43	2.74		69.39	70.64	151.75			26	1,490			0.67	17.5		43,000 (Zircalloy)/ 38,000 (Stainless)	
NAC-MPC	MPC-36	PWR	NAC	16	1.02	59			122.5		54,730	36	850 (actual weights given range: 351-408)			0.347 (Zircalloy)/ 0.264 (stainless)	12.5		43,000 (Zircalloy)/ 38,000 (Stainless)	
Foster Wheeler	MVDS	HTGR-Peach Bottom	DOE		0.00							10 elements					33		900 EFPD	
Foster Wheeler	MVDS	Shipping-port	DOE		0.00							1 reflector module or 127 loose rods					10		30,000 EFPH	
Foster Wheeler	MVDS	TRIGA	DOE		0.00							108 elements					36			
NAC-I28	NAC-I28	PWR	NAC	2	0.13	2	79.3	94.8	181.2			28	1525						22,000	
TN Metal Casks	TN-32	PWR	TN	63	4.01	63	94.75	97.75	201.6	45,500	57,750	32	1533			1.02	32.7		40,000	
TN Metal Casks	TN-40	PWR	TN	29	1.85	29		99.52	175			40					27		45,000	
TN Metal Casks	TN-68	BWR	TN	53	3.38	53	69.5	72.5	189	124,800	172,700	68		705		0.441 (0.312 for 7x7 fuel)		30		60000 (40,000 for 7x7 fuel)
Castor	V/21 and X33	PWR	GNB	26	1.66	26	60.1	94.5 (with fins)	192.4	50,900	58,450	21	1525						40,000	
Fuel Solutions	VSC-24	PWR	BFS/ES	58	3.69	58	59.8 (w/ tolerances)	62.5	164-192.25	28,428-30,544	56,860-68,685	24	1,585		1,110	1	24		45,000	

Cask System	Canister or Cask Type	Type	Vendor	Total # of Canisters of This Type	% of Total Canisters	Summed # of Canisters by Type	Internal Canister Diameter (in.)	Outside Canister Diameter (in.)	Canister Length (in.)	Canister Weight w/o Fuel (lb.)	Gross Weight (lb.)	# Assem-blies	Max Assembly Weight (lb.; PWR)	Max Assembly Weight (lb.; BWR)	Min Assembly Weight (lb.; PWR)	Maximum Decay Heat Load Per Assembly (kW)	Maximum Decay Heat Load (kW; (PWR)	Maximum Decay Heat Load (kW; BWR)	Design-Basis Burnup (MW-d/MTU; PWR)	Design-Basis Burnup (MW-d/ MTU; BWR)
Fuel Solutions	W150*/W74	BWR	BFS/ES	8	0.51	8	64.8	66	192.3	44,899 (M)/ 42,735 (T)	77,539 (M)/ 75,375 (T)	64 (Big Rock Point Assemblies)		485 (w/o channels)				24.8		40,000
	Little information found				<1% of total															
					1-2% of total															
Legend:	Public/non-electronic SARs available				2-4% of total															
					4-8% of total															
					>8% of total															

Table A-2. DPC Construction and Criticality Control

Cask System	Canister or Cask Type	Canister Shell composition	Canister Internal Materials	Basket Materials	Neutron Absorber Materials	Spacers and Thermal Shunts	Shield Plug (Y/N, material)	Criticality Control	Max U-235 enrichment (wt. %)	Min U-235 enrichment (wt. %)	NOTES	Critical Document
NUHOMS	12T											
NUHOMS	24P	Type 304 Stainless Steel (canister), Type F304 SA182 (top and bottom ends)	4 support rods (Stainless steel type XM-19) welded to guide disks	Carbon and Stainless Steel		24 Stainless steel guide sleeves, 8 carbon steel spacer discs, 4 Type XM-19 Stainless steel	Y, Carbon steel or Steel encased lead	Burnup Credit, BPRA, Soluble boron	4	1.45		Attachment A
NUHOMS	24PHB	Stainless Steel (ASME SA-240 Type 304)	Support rods same as 24P	Carbon and Stainless Steel		Guide sleeves same as 24P	Y, Steel (ASME SA-182 Type 304) encased lead		4.5		Generally identical to the 24P model, additional test port and plug on top cover plate, and integrated cover plate/shield plug	FSAR part 4 of 4 (Appendix N)
NUHOMS	24PT	Stainless Steel		Carbon and Stainless Steel			Y, Carbon steel or Steel encased lead					
NUHOMS	24PT1	Stainless Steel		Carbon and Stainless Steel			Y, Carbon steel or Steel encased lead					
NUHOMS	24PT4	Stainless Steel		Carbon and Stainless Steel			Y, Carbon steel or Steel encased lead					
NUHOMS	24PTH	Type 304 Stainless Steel (canister), Type F304 SA182 (top and bottom ends)	Transition rails (4-aluminum type 6061, 4 steel Type 304)	Type 304 Stainless Steel	Poison plates (borated aluminum, MMC, Boral poison plates)	Aluminum plates (Alloy 1100)	Y, A36 carbon steel or Type 304 stainless encased Lead (ASTM B29) 6.25 inches thick	Poison plates (borated aluminum, boron carbide aluminum MMC, Boral poison plates)	5		Three different configurations: 24PTH-S, 24PTH-L, and 24PTH-S-LC	Appendix P all parts
NUHOMS	32P	Stainless Steel		Carbon and Stainless Steel			Y, Carbon steel or Steel encased lead		4.05			
NUHOMS	32PT-L	Stainless Steel (SA 240 Type 304), Canister outer top and bottom plates	Transition rails (aluminum type 6061)	0.25" thick Stainless Steel (XM-19) welded	Aluminum alloy 1100 plates with basket connected with fasteners	Aluminum alloy 1100 plates with basket connected with fasteners	Y, Carbon steel or Steel encased lead, top plug thickness 6.25-7.5 in., bottom plug thickness 4-5.25 in.	Poison plates (borated aluminum, boron carbide aluminum MMC, Boral poison plates), Geometry, Optional Poison rod assemblies (304 SST shell filled with Boron carbide)	5			FSAR part 2 of 4 (Appendix M)
NUHOMS	32PT-S	Stainless Steel (SA 240 Type 304), Canister outer top and bottom plates	Transition rails (aluminum type 6061)	0.25" thick Stainless Steel (XM-19) welded	Aluminum alloy 1100 plates with basket connected with fasteners	Aluminum alloy 1100 plates with basket connected with fasteners	Y, Carbon steel or Steel encased lead, top plug thickness 6.25-7.5 in., bottom plug thickness 4-5.25 in.	Poison plates (borated aluminum, boron carbide aluminum MMC, Boral poison plates), Geometry, Optional Poison rod assemblies (304 SST shell filled with Boron carbide)	5			FSAR part 2 of 4 (Appendix M)
NUHOMS	32PTH	Stainless Steel	Stainless steel rails for basket support	Stainless Steel	Poison plates (borated aluminum, MMC, Boral poison plates), Borated polyester resin	Aluminum/borated aluminum disks	Y, Steel, 8.75 inches thick (bottom), 12 inches thick (top)	Poison plates (borated aluminum, boron carbide aluminum MMC, Boral poison plates), Geometry, Optional Poison rod assemblies	5			
NUHOMS	52B	Stainless Steel	6 support rods welded to discs	Carbon and Stainless Steel	BPRA, Borated Steel	9 Spacer disks (top-Grade 2 Carbon steel, others-Grade 70 Carbon steel), Spacer sleeves (SA-564 Type 630 steel)	Y, Carbon steel or Steel encased lead, top plug thickness 8.0 in., bottom plug thickness 5.75 in.	Burnup Credit, BPRA, Borated Steel (up to 2%)	4			Attachment A
NUHOMS	61BT	Stainless Steel (SA-240 Type 304); 12 rails same material	6 support rods welded to discs	Stainless Steel SA-240 Type 304 (0.105 in - 0.135 in thick)	Borated Neutron Plates	Poison plates	Y, A-36 steel, top plug thickness 7.0 in., bottom plug thickness 5.0 in.	Burnup credit, Borated aluminum neutron absorber plates for BWR, geometry	3.7, 4.1, 4.4 (Types A,B,C)			FSAR part 3 of 4 (appendix K)
NUHOMS	61BTH	Stainless Steel (SA-240 Type 304)	Type 1- Stainless steel transition rails (SA-240, Type 304), Type 2- Stainless/aluminum	Welded Stainless Steel SA-240 Type 304 (0.105 in -	Borated aluminum, Boron Carbide/Aluminum MMC, or Boral Plates	Poison plates, Type 2- Aluminum in transition rails	Y, Carbon Steel (ASME SA-36) plated with electroless nickel, top 6.25 in. thick	Geometry, Borated aluminum, Boron Carbide/Aluminum MMC, or Boral Plates	5		Type 1 and 2 are two different fuel compartment assemblies	Appendix T

			transition rails (SA-240, Type 304 steel, B209 Type 1100 or 6061 Aluminum, hold down ring	0.135 in thick)	sandwiched between steel rods no welds							
NUHOMS	7P				Borated guide sleeves			Borated guide sleeves				
MC-10	MC-10	Low Alloy Steel		Stainless steel	BISCO NS-3 on outer surface of canister		Y, Low alloy steel, 9 in. thick		3.7		Canister design has cooling fins	Surry ISFSI SAR
TranStor Cask	MPC-24E/EF	Alloy X		Multi flange plate weldment (Alloy X)	Boral/Metamic,	Optional aluminum (Alloy 1100) heat conduction elements, Spacers as necessary (Alloy X)	N, 9.5 in. thick lid and 2.5 in. thick base plate	Geometry, Flux Trap, Boral, METAMIC	5		All MPC components are made of Alloy X (Stainless Steel types 316, 316LN, 304, or 304LN), least favorable thermal and mechanical properties used for modeling	HI-STORM 100 FSAR Rev10
HI-STORM	MPC-24	Alloy X		Multi flange plate weldment (Alloy X)	Boral/Metamic,	Optional aluminum (Alloy 1100) heat conduction elements, Spacers as necessary (Alloy X)	N, 9.5 in. thick lid and 2.5 in. thick base plate	Geometry, Flux Trap, Boral, METAMIC	5		Further schematics in reference; Conflicting guidance on Max heat and Max burnup, absolute maximum given as 36.9kW and 68,200 MWD/MTU, smaller values for specific fuels	HI-STORM 100 FSAR Rev9
HI-STORM	MPC-32	Alloy X		Multi flange plate weldment (Alloy X)	Boral/Metamic,	Optional aluminum (Alloy 1100) heat conduction elements, Spacers as necessary (Alloy X)	N, 9.5 in. thick lid and 2.5 in. thick base plate	Geometry, Boral, METAMIC	5			HI-STORM 100 FSAR Rev11
HI-STORM	MPC-68	Alloy X		Multi flange plate weldment (Alloy X)	Boral/Metamic,	Optional aluminum (Alloy 1100) heat conduction elements, Spacers as necessary (Alloy X)	N, 9.5 in. thick lid and 2.5 in. thick base plate	Geometry, Boral, METAMIC	5.5			HI-STORM 100 FSAR Rev12
HI-STAR	MPC-80	Alloy X		Multi flange plate weldment (Alloy X)	Metamic	Optional aluminum (Alloy 1100) heat conduction elements, Spacers as necessary (Alloy X)	N	Geometry, Boral, METAMIC. Enrichment controls	4	2.09	MPC-80 more commonly referred to as MPC-HB in documentation; Special design for Humboldt Bay; The decay heat listed is that expected from the waste, design parameters are similar to the other HOLTEC MPC systems	HI-STAR 100 951251Rev15 non-proprietary (Supplemental sections)
NAC-UMS	UMS-24	Stainless Steel (Type 304L); 1.75 in. thick bottom plate, 3 in. thick structural lid	Support disks (PWR- 0.5 in. thick, Stainless steel Type 630, 17-4PH {30-34 disks}; BWR- 0.625 in. thick SA533 Carbon steel {40-41 disks});	Type 304 Stainless Steel	Boral Plates	Heat transfer disks (Type 6061-T651 aluminum, 29-31 for PWR, 17 for BWR); Disks separated and supported by Type 304 stainless spacers on 1.63 in. diameter rods of the same material	Y, 7in. thick, Type 304 stainless steel	Boral plates	4,2 (PWR)/ 4.0 (BWR)	1.9 (PWR and BWR)	List of assembly weights and dimensions given in reference, Far more component schematics in reference	NAC UMS Transport SAR - Rev. 2 (1 Volume - 11-05)
NAC-MPC	MPC-26	Type 304 stainless shell, Type 304L stainless 3 in. structural lid, Type 304 L 1.75in. thick base	Reactor control cluster assembly (Type 304 Stainless assembly with Inconel 625 encapsulating boron carbide), Flow Mixer/Thimble plug assembly	Type 304 Stainless Steel	Boral lined basket	28 Type 17-4 PH stainless support disks, 27 Type 6061-T651 aluminum alloy thermal shunts	Y, 5 in. carbon steel encapsulating 1in. of NS-4-FR neutron shielding	Boron carbide	4.61 (Zircalloy)/ 4.03 (Stainless)	2.95 (Zircalloy)/ 3.0 (Stainless)	Specific to Connecticut Yankee, also referred to as CY-MPC. Most reactive fuel used for individual analyses.	NAC-MPC FSAR parts 1 and 2
NAC-MPC	MPC-36	Type 304 stainless shell, Type 304L stainless 3 in. structural lid, Type 304 L 1in. thick base	Reactor control cluster assembly (Type 304 Stainless assembly with Inconel 625 encapsulating boron carbide), Flow Mixer/Thimble plug assembly	Type 304 Stainless Steel	Boral lined basket	22 Type 17-4 PH stainless support disks, 14 Type 6061-T651 aluminum alloy thermal shunts	Y, 5 in. carbon steel encapsulating 1in. of NS-4-FR neutron shielding	Boron carbide	4.94	3.5	Specific to Yankee class fuel also referred to as Yankee-MPC. Type A and Type B baskets, Type A has a protruding corner with fuel rods, Type B omits once corner.	NAC-MPC FSAR parts 1 and 3
Foster Wheeler	MVDS	Stainless Steel		Carbon Steel								
Foster Wheeler	MVDS	Stainless Steel		Carbon Steel								
Foster	MVDS	Stainless Steel		Carbon Steel								

Wheeler												
NAC-I28	NAC-I28	Multi wall structure, outer- 2.63 in. austenitic stainless steel, middle- 3.2 in. lead, inner- 1.5 in. austenitic stainless steel		Aluminum		Aluminum basket			1.9			Surry ISFSI SAR
TN Metal Casks	TN-32	Carbon Steel with sprayed aluminum coating for corrosion resistance				Borated Aluminum plates	N	Geometry, Neutron absorber plates in basket	4.05		Surry fuel also has BPRAa and TPD's	Surry ISFSI SAR
TN Metal Casks	TN-40											
TN Metal Casks	TN-68	SA-203 Grade E (canister and [bottom closure, 9.75 in. thick]), SA-203 Grade E or SA-350 Grade LF3 (confinement lid, 5 in. thick)	Aluminum 6061-T6 support rails	Stainless steel (SA-240, Type 304)/Aluminum Steel; Fusion welds	Borated Aluminum, Boron carbide/Aluminum MMC, Boral	Optional fuel spacers; Neutron shielding as thermal shunt	Y, 4 in. thick, SA-266 Class 2	Geometry, Neutron poisons	3.7-4.7		Safety Analysis Appendix 6a shows measured cask heat loads for Peach Bottom Power Station, measured values 15.7-17.3kW (Table 10.3-3).	Final Safety Analysis Report TN68 part 1
Castor	V/21 and X33	Cast Iron in nodular graphite form, Interior coated with galvanic-applied nickel plating		Borate welded stainless steel	Polyethylene rods within the cask perimeter		N	Borated steel fuel basket, Inter-fuel tube spaces acting as flux traps	3.7			Idaho test report of Castor V21, Surry ISFSI SAR
Fuel Solutions	VSC-24	SA-516 Gr. 70 Steel (1in. Thick wall, 3 in. thick lid, 0.75 in. thick base)		SA-516 Gr. 70 Steel (0.2 in. thick)	RX-877 (lid)	None Specified	Y, Steel and RX-277 neutron shielding (9.5 in thick, sandwiched 2.5 in. steel, 2 in. RX-277, 5 in. steel)	Minimum burnup, Boron Carbide allowed for fuel rod replacement, Steel basket shielding	4.2		Also referred to as an MSB (multi-assembly sealed basket)	Final Safety analysis VSC-24
Fuel Solutions	W150*/W74	Type 316 Stainless steel (M-class), Type 304 (T-class) 0.625 in. thickness, same for top and bottom inner and outer closure plates	Basket support tubes and sleeves M-class Type SA-240, XM-19 Steel, T-class SA240 Type 304 Steel; Guide tubes SA-240, Type 316 Steel	Borated stainless steel (from Bohler, specifics given in reference); Upper and lower basket assemblies	Borated steel A887, Type 304 B5, 0.075 in. thick	M-class: top and bottom spacers 2in. thick SA-240 Type XM-19 Steel, 12 other spacers 0.75 in. thick SA-517 or A514 Grade P or F Carbon steel; T-class: 13 plates, 0.75in. Thick SA-517 or A514 Grade P or F carbon steel	Y, Steel (A36) encased lead (top and bottom)	Borated Steel, geometry	4.1		*W150 is a cask, canisters for that cask are W21 and W74, Heat loads up to 26.4 are also possible, M = multi-purpose canister (storage, transport and disposal), T = transport and storage only	FSAR W74