Reviewing Spent Nuclear Fuel Dry Cask Storage Programs to Identify Challenges for an Integrated Waste Management System
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ABSTRACT

Under the Nuclear Waste Policy Act (NWPA), the U.S. Department of Energy (DOE) has responsibility for removing commercial spent nuclear fuel (SNF) from nuclear power plant sites and disposing of the SNF in a deep geologic repository. However, the methods used by commercial nuclear power plants for onsite storage of their SNF define the starting conditions for DOE efforts to develop a waste management system that includes packaging, transportation, storage, and disposal of commercial SNF. The NWPA (as amended) also charges the U.S. Nuclear Waste Technical Review Board (Board) with evaluating the technical and scientific validity of DOE activities related to the management and disposal of SNF and high-level radioactive wastes (HLW).

DOE's efforts related to developing an integrated program for storing, transporting, and disposing of SNF and HLW were the focus of a public meeting held by the Board on August 24, 2016, in Washington, D.C. To prepare for the public meeting, the Board's staff compiled information on the dry cask storage systems in service at nuclear power plant sites in order to identify issues that would need to be addressed by DOE in planning to transport SNF away from the sites. This paper is based on a briefing presented to the Board members by the Board's staff before the public meeting. Post-meeting findings and recommendations of the Nuclear Waste Technical Review Board are documented in the Board letter to the Department of Energy dated December 8, 2016.

A note about terminology: in this paper, the phrase "dry cask storage system" is generic and applies to a complete system used for dry storage of commercial SNF.

Within these storage systems, commercial SNF is sealed inside a container called either a cask or a canister depending upon the specific type of storage system used. This distinction is discussed in more detail in the body of this paper. When referring to the containers holding SNF in particular systems, this paper uses the terms “casks” or “canisters,” as appropriate. When discussing the collective group of all containers, this paper uses the phrase “casks and canisters.”

Dry cask storage of SNF is a widespread practice throughout the U.S. commercial nuclear industry. As of August 1, 2016, more than 2300 storage casks and canisters were loaded at U.S. commercial nuclear power plant sites. This number is expected to increase by more than 200 casks and canisters annually, reaching a total of approximately 4500 by 2025. Multiple vendors have developed their own unique designs of dry cask storage and transportation systems. The majority of storage system designs (75 percent) feature SNF loaded in welded stainless steel canisters that are stored in ventilated concrete overpacks that allow for convection cooling. Some older dry cask storage system designs do not include a welded stainless steel canister; instead, SNF is loaded directly into a heavily shielded metal cask to minimize radiation exposure to workers and prevent atmospheric release of radionuclides. These types of systems are sealed by O-rings compressed under a bolted lid. After loading, dry cask storage systems are located on concrete pads at Independent Spent Fuel Storage Installations (ISFSI) at nuclear power plant sites and will remain there until the time when they will be transported to a consolidated interim storage facility or a deep geologic repository.

Eventual transportation of canistered SNF will include removing the stainless steel canisters from the concrete overpacks, possibly repackaging the SNF, and loading the canisters into specially designed transportation casks for shipment by truck, rail, or barge. In the case of the non-canistered casks, some are approved for transportation and can be shipped after impact limiters are installed on the casks. SNF will need to be removed from casks not approved for transportation and transferred to transport-approved casks.

This paper highlights five issues and challenges presented by the nuclear industry’s use of dry cask storage systems that will need to be addressed by DOE in developing an integrated waste management system. One example, among the five, is that several dry-storage casks and canisters have received Nuclear Regulatory Commission certificates of compliance for storage only and do not have certificates of compliance for transportation. This will pose a challenge when the SNF must be moved to a consolidated interim storage facility or a deep geologic repository. Another example is that, when loaded with SNF, the total weight of new, larger transportation cask designs will exceed 142 metric tonnes (156 tons) which, when combined with the weight of the railcar, will exceed the gross weight limit for unrestricted operation on some rail lines. This will also affect future transportation planning for shipments of SNF. All five issues and challenges are discussed in detail in the body of the paper.

INTRODUCTION

Dry cask storage of commercial spent nuclear fuel (SNF) is an established and widespread practice throughout the commercial nuclear industry. As the Department of Energy (DOE) continues to develop a program to safely store, transport, and dispose of commercial SNF, DOE will have to address the current state of commercial SNF storage and work to integrate its planning efforts with the storage efforts of the nuclear industry. This paper provides a high-level overview of some of the most important issues and challenges to be addressed as DOE continues to develop plans as part of a program to manage and dispose of SNF.

DOE activities related to developing an integrated program for storing, transporting, and disposing of SNF and HLW were the focus of a public meeting held by the Nuclear Waste Technical Review Board (Board) on August 24, 2016, in Washington, D.C. To prepare for the meeting, the staff collected and analyzed information on commercial nuclear industry dry cask storage systems. That information provides the basis for this paper. Post-meeting findings and recommendations of the Nuclear Waste Technical Review Board are documented in the Board letter to the Department of Energy dated December 8, 2016.

Commercial U.S. Dry Cask Storage Overview

As of August 1, 2016, more than 2300 dry-storage casks and canisters were loaded at U.S. commercial nuclear sites [1]. See Table I for details. This number is expected to increase by more than 200 casks and canisters annually; reaching a total of approximately 4500 by 2025 [2]. Multiple vendors have developed their own unique designs of dry cask storage and transportation systems. The majority of system designs (75 percent of designs [2]) feature SNF loaded in welded

TABLE I: COMPARISON OF CANISTERED AND NON-CANISTERED STORAGE SYSTEMS IN USE

	Canistered	Non-canistered
Number of System Designs Approved for Storage	21	7
Total Number of Casks or Canisters in Use	2160	209

Data as of August 1, 2016 [2]

stainless steel canisters (typically austenitic stainless steels such as SS304 and SS316) that are stored in ventilated concrete overpacks to allow for convection cooling. These canistered systems are used in the United States but not yet used internationally. The overpacks are located on concrete pads at Independent Spent Fuel Storage Installations (ISFSIs) at nuclear power plant sites and will remain there until the canisters can be transported to a consolidated interim storage facility (CISF) or a deep geologic repository. The less common type of storage system design (25 percent of designs) does not include a welded stainless steel canister. Instead, the SNF is loaded directly into a heavily shielded metal cask to minimize radiation exposure to workers and prevent atmospheric release of radionuclides. These types of systems, called non-canistered systems, are sealed by O-rings compressed under a bolted lid.

Eventual transportation of SNF will include removing the stainless steel canisters from the storage overpacks, possibly repackaging the SNF assemblies, and loading the canisters into specially designed transportation casks for movement by truck, rail, or barge. In the case of the non-canistered casks, some are approved for transportation and can be shipped after impact limiters are installed on the casks. SNF will be removed from casks not approved for transportation and transferred to transport-approved casks.

DISCUSSION

The review of dry cask storage systems performed by the Board's staff highlighted five important issues and challenges that need to be addressed by DOE. Addressing these challenges will require communication and coordination between DOE and the commercial nuclear power industry. DOE and its contractors have started a significant effort to analyze the current state of commercial SNF storage and to plan for SNF transportation, possible interim storage, and disposal.

The first issue identified is that several cask and canister designs are not currently approved by the Nuclear Regulatory Commission (NRC) for transportation. This means that these casks and canisters cannot be transported by DOE as is. Table II lists these casks and canisters [2]. The affected casks and canisters will need to receive transportation certificates of compliance (CoCs) from the NRC or the SNF assemblies in those casks and canisters will have to be transferred into transport-approved casks or canisters. It is important to note that all of the casks and canisters at shutdown and decommissioned reactor sites have been approved for transportation by the NRC.

The second issue that will need to be addressed for transportation of SNF is that all transportation cask designs approved to carry commercial SNF exceed the load limit for a legal-weight truck (80,000 lbs). Therefore, the casks will require heavy-haul trucks for transportation away from those sites at which rail or barge transportation is unavailable. This may restrict possible truck routes if weight-limited roads or bridges exist along the transportation route.

TABLE II: SUMMARY OF DRY CASK STORAGE SYSTEMS HOLDING STORAGE-ONLY NRC CERTIFICATES

Vendor	System Designation	Number of Casks or Canisters in Operation
Areva-TN	NUHOMS®*	256
*includes 24P, 24HB, 32P, 52B, and 07P canisters		
Areva-TN	TN-32, TN-40HT	74
EnergySolutions	VSC-24	58
Holtec	HI-STORM UMAX & FW**	34
**includes MPC-37 and MPC-89 canisters		
NAC	MAGNASTOR®	89
NAC	I28	2
GNS	V/21 & X/33	26
Westinghouse	MC-10	1
Total		**540**

Data as of August 1, 2016 [1], [2]

Third, at least one dry cask storage and transportation system, Holtec's planned HI-STAR 190 [3], when loaded with SNF, will exceed 142 metric tonnes (156 tons), which, when combined with the weight of the railcar, will exceed the gross weight limit for unrestricted operation on some commercial rail lines. This may affect future transportation planning for the shipment of SNF to a CISF or deep geologic repository by limiting rail route options and railcar speeds on some rail lines.

DOE currently is developing a dedicated SNF railcar (the Atlas railcar) to eventually transport all commercial SNF to a CISF or to a deep geologic repository for final disposal [4], [5]. The design of Atlas railcar is largely similar to that of the U.S. Navy's M-290 railcar that the Navy has been using successfully on commercial rail lines to transport naval SNF. DOE is taking steps to ensure the Atlas railcar will be capable of carrying the newer, larger commercial SNF transportation casks.

Fourth, there is an industry trend to use larger dry cask storage systems. Many newer system designs can hold as many as 37 pressurized water reactor (PWR) SNF assemblies or 89 boiling water reactor (BWR) SNF assemblies. These larger capacity systems require longer cooling times at the ISFSI before the casks and canisters are sufficiently cool to meet transportation heat load requirements. This may adversely impact transportation and disposal planning [2].

Fifth, and finally, most welded canisters are fabricated of austenitic stainless steel. This material is susceptible to chloride-induced stress corrosion cracking (CISCC). CISCC has the potential to degrade the structural integrity of the canisters and adversely affect their ability to prevent the release of radioactive material. The industry has only recently started taking steps to address this issue. In 2016, the Electric Power Research Institute (EPRI) launched an effort within its Extended Storage Collaboration Program to study possible options for the mitigation and repair of CISCC-susceptible canisters. Such options may include weld-repair of cracks or overpacking a damaged canister, although these options would be faced with significant operational and radiological challenges. Additionally, DOE sponsors ongoing research and development regarding CISCC in welded canisters and much more effort is now being put into collecting data. To date, no CISCC-affected storage canisters have been found, although very few loaded canisters have been inspected.

The potential for CISCC occurring in welded storage canisters has also highlighted the challenge presented in executing in-service canister inspections. The wide variety of canister designs presents a challenge in designing inspection equipment and methodologies. DOE is addressing the need for in-service inspections of storage canisters, in part by funding multiple Nuclear Engineering University Programs and Integrated Research Projects. For example, DOE awarded research grants to Texas A&M University in 2011 and to Pennsylvania State University in 2014 focused on determining the chloride concentration and other environmental factors necessary to initiate CISCC and on developing the robotic delivery systems and instrumentation necessary to perform in-service inspections.

CONCLUSIONS

In the United States, storing commercial SNF in dry cask storage systems has become the industry standard and will continue to be the preferred method of storage. This paper has highlighted five important issues and challenges associated with this storage method, particularly when subsequent SNF transportation is considered. One of the more significant issues is that several dry-storage cask and canister designs have received NRC certificates of compliance for storage only and do not have certificates of compliance for transportation, which will pose a challenge when the SNF must be moved to a CISF or a deep geologic repository. Another important issue is that, when loaded with SNF, the total weight of new, larger transportation casks will exceed 142 metric tonnes (156 tons) which, when combined with the weight of the railcar, will exceed the gross weight limit for unrestricted operation on some commercial rail lines. This will also affect future transportation planning for shipments of SNF. Furthermore, this issue will become more significant over time because the nuclear industry is continuing a trend of loading larger and heavier SNF casks and canisters. DOE recognizes these five issues and challenges and has begun to address some of them as it continues to plan for an integrated program to manage and dispose of SNF.

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