

Evaluating the Potential Impact of Using the Transport, Aging and Disposal (TAD) Canister on Yucca Mountain Pre-Closure Operations – 8037

Authors: Leah Spradley*, Research Assistant, Civil and Environmental Engineering,
Vanderbilt University, VU Station B 351831
2301 Vanderbilt Place
Nashville, TN 37235-1831

Mark Abkowitz, Professor, Civil and Environmental Engineering,
Vanderbilt University, and
James H. Clarke, Professor, Civil and Environmental Engineering,
Vanderbilt University

ABSTRACT

The development and preliminary use of an integrated model to explore the impact of various operational scenarios of the pre-closure waste management system of Yucca Mountain (YM) is described. The capabilities of the model are illustrated by applying it to a simplified operational scenario using Transport, Aging, and Disposal (TAD) Canisters. The application uses existing data on spent nuclear fuel to model the effect on above ground aging at YM by varying four parameters: (1) utility loading behavior, (2) thermal limit for transportation casks, (3) thermal limit for emplacement, and (4) emplacement capacity at YM. Results show that the thermal limit for emplacement is the most important parameter with respect to above ground aging demands at YM. Transportation heat limit is also important, but less so if the capacity of YM is expanded or if older fuel is sent first. Easing the constraint of the emplacement limit, if feasible, would be a preferable method of reducing aging demands, especially under an expanded emplacement capacity. Consequently, there may be incentive for Department of Energy (DOE) to either specify a lower transportation limit or a higher emplacement limit if it wishes to reduce the potential demands on the Aging Facility at YM.

INTRODUCTION

The pre-closure waste management system of Yucca Mountain (YM) is defined as all components, facilities, and activities that collectively manage the spent fuel as it is packaged at the utilities, transported to the repository, processed at the YM surface facilities, and emplaced in the repository. In order to perform smoothly, this system requires long-term planning and cooperation of the spent fuel generators and the Department of Energy (DOE) among other parties (e.g. transportation and storage cask vendors, local and federal regulatory authorities). One must consider the motivations arising from the perspective of waste generators, as well as DOE, to evaluate the potential outcome of various design and operating scenarios.

* Corresponding author

Transport, Aging, and Disposal Canister

DOE has announced a change to the design of the pre-closure system, requiring the operators of facilities in possession of spent nuclear fuel to use a Transport, Aging and Disposal (TAD) Canister to transport shipments of commercial spent nuclear fuel to YM. Prior to this decision, spent fuel assemblies would have arrived either in bare-fuel transportation casks, or in Dual-Purpose Canisters (DPCs), which can be used for transportation and storage, but not disposal [1].

Since the TAD will be used in a variety of applications, it will be governed by several regulations. For example, a TAD loaded and welded at a nuclear power plant will be governed by 10 CFR 50. If the TAD is placed in an Independent Spent Fuel Storage Installation for interim storage, it will be regulated under 10 CFR 72. A TAD placed in an certified over-pack and transported is licensed under 10 CFR 71, while a TAD placed in an over-pack for aging at YM will fall under 10 CFR 63.

To ensure that the TAD is developed according to the requirements of 10 CFR 63, DOE, as opposed to the vendors, specifies the design of the canister. The final design specifications for the TAD were released in 2007. These design specifications will guide vendors as they prepare license applications for the TAD under 10 CFR 71 (transportation) and 10 CFR 72 (storage). It is important to note that the design specifications do not stipulate a specific thermal limit for transportation or storage, but rather provide cladding temperature determination for total thermal outputs of 11.8 kW, 18 kW, or 25 kW. Once the TAD is licensed under Part 71 and 72, utilities can begin using it for storage and transportation. DOE will submit a license application under Part 63, which will describe their use of TADs in the overall design. NRC will determine if the TAD is important to safety in its review of the license application for YM. Specifically, the agency will determine if there are attributes of the TAD that are important to waste isolation, and conversely, if there are attributes of the design that have a detrimental effect on the post-closure performance [2].

The original YM pre-closure design called for *all* the fuel assemblies to be repackaged at YM. DOE changed the design to reduce the number of bare-fuel assembly handlings that would be necessary. While use of the TAD does reduce the number of expected nuclear material handlings, as well as the expected exposure of bare commercial spent nuclear fuel to a potentially oxidizing environment, it creates a potential problem in terms of thermal management. Before any final disposal package, referred to as a Waste Package (WP), can be emplaced in YM, its total thermal heat decay must fall below a specified emplacement limit. The emplacement limit is defined as 11.8 kW in YM design documents, but ongoing studies are exploring the possibility of easing this constraint up to 18 kW or even higher [1,3]. Any packages not meeting the specified limit must be stored above ground until the contents decay to a value below the emplacement limit.

The Nuclear Waste Technical Review Board has expressed concern that the decision to use the TAD canister may impact the thermal management strategy of pre-closure operations, mainly due to the fact that the utilities, as opposed to DOE, will now decide how to blend the fuel assemblies into the *final* disposition canisters. The utilities' discretion to blend fuel to their preferences reduces DOE's control over the thermal decay heats of the packages as they are being prepared for emplacement in the mountain [4].

Spent Fuel Delivery Schedule

Utilities have a fair amount of freedom as to which individual fuel assemblies they load into TADs for transport (so long as they follow the procedures specified in the license documentation for the TAD canister), but they are guided by the Nuclear Waste Policy Act (NWPA) of 1982 when setting delivery schedules for shipments to YM. The NWPA authorizes the Secretary of Energy to develop a general contract with the owners and generators of the spent fuel [5]. The *Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste* (Standard Contract) provides for the acquisition of title to the spent nuclear fuel, its transportation to Federal facilities, and its subsequent disposal [6].

The Standard Contract states that spent fuel must be at least five years old to qualify to be sent to YM. Also, for every year after the repository starts accepting waste there is a specified allocation, measured in metric tons, which each waste generator is expected to send. The term "Purchaser" is used in the contract to refer to a spent fuel generator that has been paying into the Nuclear Waste Fund. A single Purchaser may own anywhere from one to many facilities, depending on the size of the Purchaser's corporation. Allocations given to each Purchaser are detailed in the Acceptance Priority Ranking (APR) and Annual Capacity Report (ACR) developed by DOE. The queuing order (APR) is based on the date the spent nuclear fuel was permanently discharged, giving priority to the oldest spent nuclear fuel, on an industry-wide basis. This order is combined with the annual rate of acceptance for YM to calculate the annual allocations for each Purchaser [7].

Allocations in the APR/ACR Report are not contractually binding on either DOE or the Purchasers. Instead, they are meant to assist Purchasers' planning and submittal of Delivery Commitment Schedules (DCS), which specify what fuel they intend to send and the delivery dates for the shipments. The legal requirements of the DCS allow for back and forth negotiations between DOE as outlined in Article V of the Standard Contract. Purchasers must submit their schedules five years before the shipments are to be made, and DOE has three months to approve of the first submitted schedule. If DOE disapproves of the proposed schedule, the Purchaser has thirty days to revise the schedule. DOE then has sixty days to decide if the revised schedule is acceptable. If the revised DCS is not acceptable, the parties will negotiate a mutually acceptable contract. Specifically, Purchasers have the right to adjust the quantities of spent nuclear fuel by up to twenty percent and the timing of the delivery by up to two months in the negotiations[6].

Purchasers must submit the final negotiated DCS to DOE at least one year before the delivery date. *Still*, DOE may disapprove of the final schedule within forty five days, and a revised schedule may be submitted thirty days after notice of the disapproval. DOE then has another sixty days to approve of the final revised DCS. If the schedule is still not mutually acceptable, the Standard Contract calls for the parties to negotiate again. Six months before the delivery date, purchasers are permitted to *exchange* delivery committed schedules with other Purchasers as long as DOE approves of the exchange [6]. Clearly, the legal opportunity for extended negotiations opens the potential for delays in the system.

Ideally, through careful planning, the parties could create a schedule that facilitates operations of YM and needs of the waste generators. This brings motivation for analyzing the possible reasons for DOE to disapprove of a schedule. One such reason may be that DOE is unable to accept shipments over a certain thermal threshold because it would cause excessive amounts of packages to be stored above ground at YM. Another hypothetical reason DOE might disapprove a schedule is if YM surface facilities do not have adequate processing capacities to handle the ratio of package types (DPCs vs. TADs). The remainder of this paper describes a methodology that can be applied for systematically analyzing possible shipment schedule scenarios and preliminary insights resulting from its application.

DATA, ASSUMPTIONS AND METHODOLOGY

The model provides an opportunity to perform analyses of various delivery schedules, while also exploring the effects of changing the transportation heat limit, the emplacement heat limit, and the planned capacity of YM. This analysis is meant to be a preliminary screening tool to evaluate the relative importance of these parameters with respect to above ground aging requirements at YM, and is not meant to predict a comprehensive set of all realistic performance outcomes. Simplifying assumptions about national fuel inventory characteristics, TAD availability, and repository operations are described below.

Spent Fuel Inventory Characteristics and Projections

Inventory of spent fuel is taken from the Energy Information Administration RW-859 database from 2002 [8]. Projections of spent fuel after 2002 are assumed according to a methodology developed by DOE that assumes an annual fractional burnup increase of 0.01, up to a maximum burnup of 57 GWd/MTU for boiling water reactors (BWRs) and 62 GWd/MTU for pressurized water reactors (PWRs) [9]. Reactor shutdown dates are also assumed. We presume all reactors that are not currently planned for decommissioning are granted extensions to run for a full 60 years. But, we do not analyze scenarios in which new reactors are constructed. To simplify data requirements, the burnup, enrichment, and mass of assemblies are averaged within the same discharge group. Each year, the thermal decay heat of each assembly discharge group is

interpolated using tables for burnup, enrichment and number of years out of the reactor [10].

TAD Availability and Repository Opening

Before the repository opens nuclear power plants are expected to load dry storage when their pools reach full capacity. Assemblies removed from the pool are loaded into DPCs until the TAD is available for use. At the earliest, the TAD will be available in 2012 but to accommodate for possible delays in the licensing process, and because the utilities may lack economic incentive to adopt its use, it is not assumed to be in use by all the facilities until the year 2016.

Yucca Mountain is assumed to open in 2025. DOE plans to submit a License Application (LA) to the U.S. Nuclear Regulatory Commission (NRC) in 2008. The earliest estimate for opening the repository is 2017, but further delays are expected [11]. The assumption regarding the timing of dry storage campaigns, TAD availability, and the construction of the repository are important because the age of the fuel largely determines its heat output, especially for younger fuel. Under these assumptions, approximately 6,400 metric tons, will be loaded into DPCs before the opening of the repository – the equivalent of about 800 TADs.

Allocations for Shipments of Spent Fuel

Each year after the repository starts accepting waste, approximately 3,000 MTU of allocations, dictating the number of TADs each facility loads, are assigned to the Purchasers. Mergers and acquisitions have taken place since the APR/ACR was established in 2004, and it is not clear if Purchasers will adjust their contracts accordingly. In an attempt to account for allocation trading that might be facilitated by owner/operator consolidations since 2004, the Purchasers have been altered to resemble current corporate ownership. Allocations for waste delivery schedules are assigned to Purchasers according to the date of discharge but are measured in units of TADs (300 TADs/year) as opposed to metric tons since it does not make economical sense to send a TAD that is not fully loaded.

Purchasers are assumed to distribute the allocations among their facilities, giving priority to the oldest fuel (OFF), youngest fuel that is at ten years old (YFF10), or the youngest fuel that is at least 5 years old (YFF5). Each facility loads fuel from the spent nuclear fuel pool according to the same algorithm assumed for prioritizing allocations. As many as 10 TADs are permitted to be shipped from a single facility in a given year, since this is considered a reasonable amount for a facility to load during the shipping campaign. Assemblies are packaged into TADs according to a zone loading scheme, meaning that the assemblies in the center are permitted to have twice the thermal output as the assemblies on the perimeter, as long as the total heat limit remains within the thermal criteria for transport.

Surface Facility Operations

Upon arrival at the repository, TADs that meet the emplacement limit are assumed to be emplaced immediately. If all 300 TADs arriving in one year were within the emplacement limit, processing constraints of the surface facilities may realistically prevent emplacement of all 300 in a single year. However, this application attempts to gauge the potential range of demand on the Aging Facility so processing constraints were not enforced. Any packages not meeting the emplacement limit are counted as in the Aging Facility. Sensitivity of the results to varying the transportation heat limit from 18 kW to 25 kW, and the emplacement heat limit from 11.8 kW to 18 kW are explored. The capacity of YM is either assumed to be its current 70,000 metric tons (about 7,500 TADs), or to be extended to the amount required for holding the entire spent fuel inventory projected for all the reactors if they run for a total of 60 years.

RESULTS

Results show that emplacement heat limit is the most important variable with respect to aging above ground at YM in terms of peak aging capacity needed, as well as the length of time fuel remains in the Aging Facility. Transportation heat limit also has a clear influence over above-ground aging at YM. As seen in the Fig. 1, the largest effect is seen when emplacement heat limit is lowered from its central value of 14.9 kW to 11.8 kW, assuming youngest fuel is sent first. Both transportation and emplacement criteria become less important if older fuel is sent in place of younger fuel.

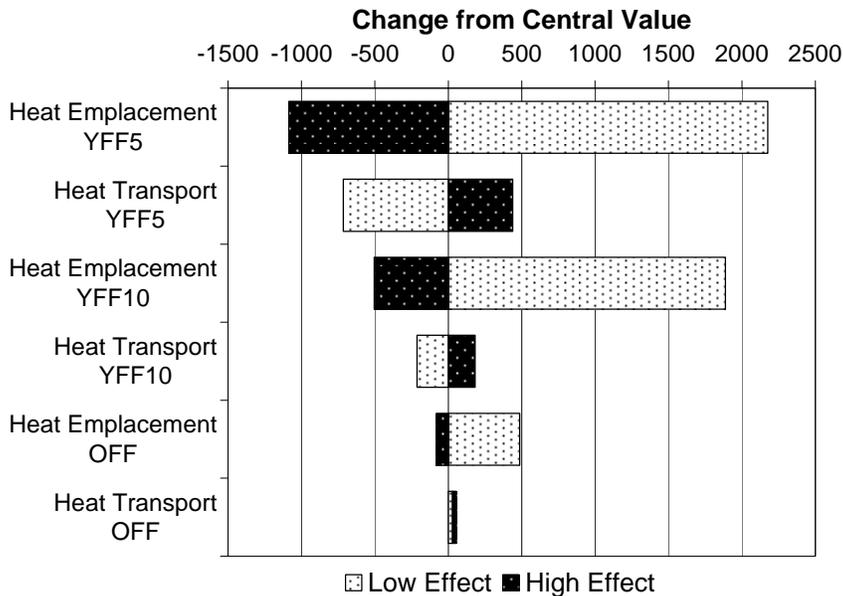


Fig. 1 Importance chart illustrating the relative change in maximum number of TADs aging above ground due to a change in heat limit for emplacement or transportation under various waste acceptance scenarios.

Easing the emplacement heat limit constraint is a way to decrease the above-ground aging that does not impact delivery schedules since emplacement criteria drives the routing of packages *after* it arrives at the surface facilities. Transportation heat limit, on the other hand, governs the characteristics of the fuel *before* it is shipped to YM. Therefore, decreasing the transportation heat limit to a value that is lower than what is common (i.e., 18 kW as opposed to 25 kW) should only be considered a practical way of reducing the aging required at YM if it *does not* prohibit facilities from sending shipments that would have been sent under a traditional transportation heat limit.

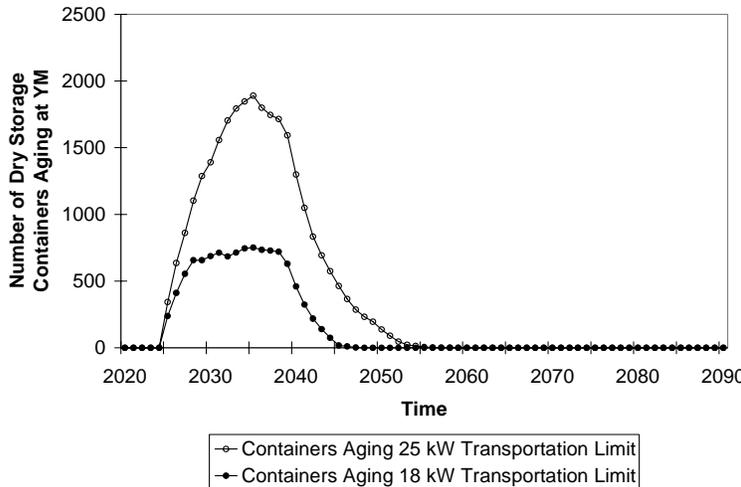


Fig. 2 Impact on decreasing the transportation heat limit from 25 kW to 18 kW on above-ground aging if youngest fuel is sent first, assuming the current YM Capacity.

Fig. 2 shows the amount aging above ground as the transportation limit is varied from 18 kW to 25 kW, while holding the emplacement limit at its central value of 21.5 kW. Note how the peak capacity aging above ground is effectively reduced from about 1,800 TADs to 800 TADs and the longevity of the Aging Facility is shortened by about 10 years. The rate of shipments (not shown in Fig. 2) is not changed by altering the transportation limit. This implies that there are enough cool assemblies in the Purchasers' inventories to fulfill a receipt-rate of 300 TADs per year for the entire shipping campaign under the current capacity of YM, even if the transportation heat limit is set to a lower level than what is common. However, the same is not true if the legal capacity of YM is expanded.

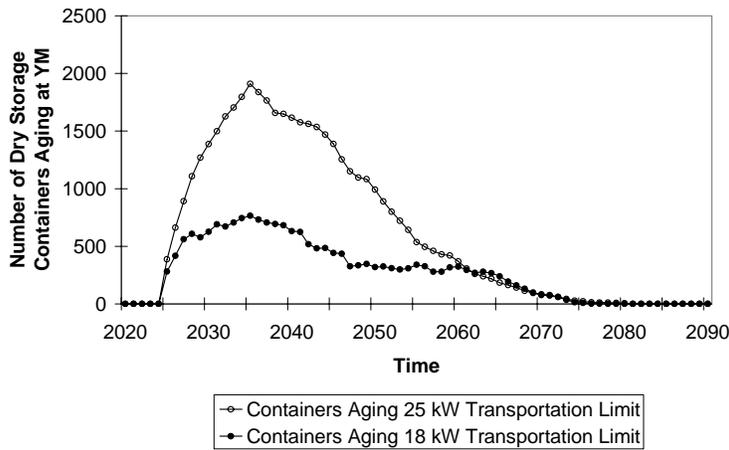


Fig. 3 Impact on decreasing the transportation heat limit from 25 kW to 18 kW on above-ground aging if youngest fuel is sent first assuming an expanded YM Capacity.

Fig. 3 shows the same information as Fig. 2 but assumes an expanded capacity of almost 140,000 metric tons. These scenarios shown assume that youngest fuel (at least 5 years old and meeting the per-assembly heat limit) is sent first. The maximum capacity of the Aging Facility is reduced, but the longevity of the Aging Facility is similar in both scenarios, implying that altering the transportation limit is not as effective at reducing the demands on the Aging Facility under an expanded capacity.

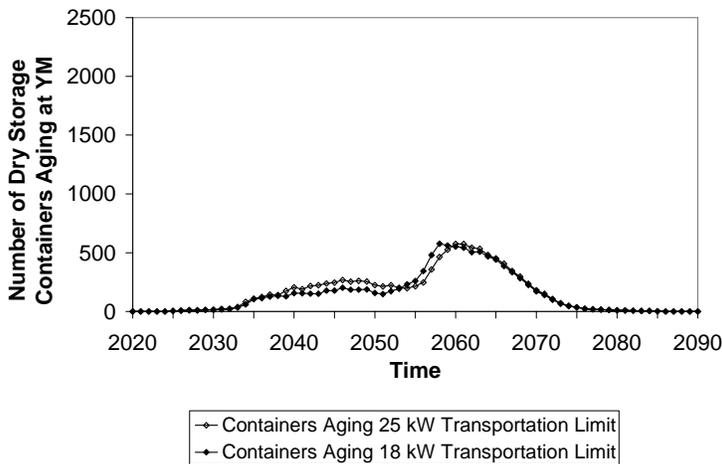


Fig. 4 Impact on decreasing the transportation heat limit from 25 kW to 18 kW on above-ground aging if oldest fuel is sent first and assuming an expanded YM Capacity.

Fig. 4 shows an expanded capacity but assumes that oldest fuel is sent first. During the first 10 years, the demands on the Aging Facility are largely similar under both scenarios. Starting around 2035, the curve for the 25 kW transportation limit scenario begins to exceed that of the 18 kW limit. This is because packages are taken from the dry storage pad at the waste generation sites in the 18 kW scenario, whereas in the 25 kW scenario facilities continue to load hotter fuel from the pool. After the first 30 years, there is a large increase in the number of packages that need to be aged, resulting from the fact that

much of the cooler fuel has been depleted from Purchasers' inventories. Assemblies being loaded are those that are newly meeting thermal criteria, and are therefore much hotter. The peak demand on the Aging Facility occurs around 35 years into the shipping campaign. These results suggest that decreasing the transportation limit is not as effective at reducing demands on the Aging Facility under an expanded capacity, especially if older fuel is sent first.

SUMMARY AND CONCLUSION

The analysis described in this paper highlights inefficiencies of the existing allocation queue stemming from a recent decision to use the TAD canister. The existing method of assigning allocations as stipulated in the Standard Contract was developed prior to the TAD decision, and therefore does not adequately consider the ability of the utilities to optimally blend the waste according to Department of Energy's thermal management strategy. The TAD decision introduces uncertainty concerning the heats of *final* waste packages, causing potential for a highly variable capacity of the Aging Facility at the surface of YM.

The demand on the Aging Facility is minimal if the Purchasers send their oldest fuel first under the current capacity. However, Purchasers are not required to send their oldest fuel first and may prefer to send younger fuel depending on their spent fuel management strategy. If younger fuel is sent first, the aging above ground at YM can be reduced by reducing the thermal decay limit for transporting the TAD. If the legal capacity of YM is lifted to accommodate for substantially more spent fuel, however, reducing the transportation limit is less effective at controlling the demand on the Aging Facility.

In a future application of the model, the indicators of operational performance measured each year should be expanded to include the expected amount of dry storage necessary at each waste generation site as well as above ground storage at YM. In addition, the allocation queue should be dynamically created from feedback signals incorporating real-time inventories of the utilities and YM. Using this more comprehensive approach, future research could explore potential benefits achieved through alternative methods for Purchasers to prioritize allocations besides age of the fuel. The potential for Purchasers to trade allocations should also be analyzed, since the Standard Contract implies this is allowed. This will enable DOE and the Purchasers to explore whether a more efficient waste acceptance plan can be achieved.

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