The Importance and Benefits of Acceptance of Commercial Spent Nuclear Fuel in Canisters at the Repository

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ABSTRACT

This paper describes the results of an evaluation of the logistical and technical issues associated with disposition of commercial spent nuclear fuel (CSNF) that is emplaced within a canister. As of early January 2006, 680 canisters, which contain over 22,000 CSNF assemblies, were in storage at U.S. nuclear power plants [1]. New canisters of CSNF are being loaded at a rate of about 100 per year. At this rate, for a postulated repository opening date of 2015, more than 1,600 canisters containing over 55,000 CSNF assemblies will be in service. Since this constitutes about 25% of the proposed repository capacity of 225,000 CSNF [2], it is of interest to review the options for moving CSNF that is already stored in canisters to final disposal in the repository.

The evaluation examined various options for disposition of CSNF in canisters. The four options evaluated include:

1. Unloading and repackaging the CSNF in transportable casks at the reactor site, then unloading and repackaging the CSNF into the disposal package at the repository site
2. Unloading and repackaging the CSNF in disposable, transportable canisters at the reactor site for direct loading into the waste package at the repository site
3. Shipping intact canisters of CSNF to the repository, then unloading and repackaging the CSNF in the disposal package
4. Shipping intact canisters of CSNF to the repository for direct placement in the disposal package

Based on the outcomes of this study, it is clear that shipping intact canisters of CSNF to the repository, either for repackaging or for direct placement in the disposal package, represents a net benefit to both the Purchasers and to the DOE.

INTRODUCTION

The U.S. Department of Energy’s obligation to accept spent nuclear fuel from commercial power reactors is delineated in Title 10, Code of Federal Regulations, Part 961 (10CFR961) [3], also known as the “standard contract.” Appendix E of the standard contract provides specifications for fuel category identification, including standard, non-standard, and failed. None of the definitions provided address the concept of commercial spent nuclear fuel (CSNF) in a canister.

While the matter of whether or not CSNF in canisters complies with the fuel form in the standard contract may well be settled through legal means, this evaluation addresses the issue from a technical and logistical point of view. Specifically, it is suggested that there may be advantages for the commercial nuclear power industry (i.e. the "Purchaser" under the standard contract) in being able to place a canister of already dried and inerted CSNF into a DOE-supplied transportation cask for shipment to the repository. There may also be advantages to the DOE for CSNF transportation and acceptance operations.

Current CSNF storage data and CSNF canister loading rates will result in over 1,600 canisters containing over 55,000 CSNF assemblies in storage at Purchasers' sites by a postulated repository opening date of 2015, or about 25% of the repository capacity. This evaluation examines the technical and logistical issues associated with choices for dispositioning the large amount of CSNF that will be stored in canisters prior to repository operations. Economic impacts of various approaches to both the Purchasers and the DOE are considered, as are occupational exposure (ALARA) effects. Finally, conclusions are drawn regarding the benefits of the direct shipment of CSNF in canisters to the repository.

EVALUATION CONSIDERATIONS

Generic Considerations

Generic issues considered here are those that are applicable to both the Purchaser and to the DOE. These include fuel handling, disposal of used canisters, and burnup credit for transportation. Each of these is discussed below.

Fuel handling: Generally speaking, the fewer times a CSNF assembly is handled the better. Each handling operation introduces additional occupational exposure, which is contrary to ALARA principles. Each handling of a CSNF assembly also introduces the risk of a mishandling event, which could cause damage to the CSNF assembly, and a fuel handling accident, which could result in increased worker and potential public exposure.

Disposal of used canisters: CSNF canisters currently in use and those that are scheduled or anticipated to be loaded prior to repository operations are not compatible with the repository disposal package. None of the current canister designs include the neutron absorbers of the disposal package, and most current generation canisters are larger than the waste package cavity. Therefore, it appears most likely that the more than 1,600 canisters that will be loaded at the Purchasers' sites with CSNF by 2015 will need to be opened and the fuel repackaged for disposal. This will require that the used canisters be dispositioned. Since these canisters will have contained highly radioactive contents, they will most likely be highly contaminated internally, and there may well be activation of the materials as well. As a result, these canisters will have to be disposed of, presumably as low level waste. The total disposal cost will be driven mostly by the total number of canisters to be disposed. Canister physical size will have a lesser effect, as the volume differences are not significant (around 10%), whereas canister capacities vary by around 40%. Thus, from a system-cost point of view, use of larger capacity canisters for storage of CSNF prior to repository operations will minimize these disposal and disposition costs.

Burnup credit for transportation: In order to transport most of the canister systems to the repository, it will be necessary to license these canisters for transportation. While some designs are currently licensed for transportation, most canister systems , specifically canister systems for PWR CSNF, will require NRC acceptance of either a burnup credit methodology or other means (e.g., moderator exclusion) to provide demonstration of criticality safety under the transportation conditions specified in 10CFR71 [4]. Most high capacity canister systems currently being loaded have not yet received this regulatory approval necessary to allow transport. If 10CFR71 approval is not received, the CSNF in these canisters will require repackaging into a transportable package for transport. While lowering the capacity can provide a design that can meet the 10CFR71 requirements without reliance on burnup credit, current economics of scale for CSNF storage are driving the Purchasers away from such systems.

Considerations for the DOE

The activities considered here relate to those associated with the repository and transporting the CSNF to the repository.

Fuel repackaging for emplacement: From the DOE perspective, if intact CSNF canisters are shipped from the Purchasers' sites to the repository, the fuel will have to be repackaged into the disposal package for emplacement in the repository. However, as compared to repackaging of CSNF in canisters at the purchasers sites into bare fuel casks, acceptance of intact canisters at the repository serves to minimize the number of times the CSNF assembly must be handled. While an even better solution is not to open the canister at all, but rather emplace it directly in the disposal overpack, this is likely not a realistic option because the canisters currently in use are not compatible with the disposal package.

Fuel heat load: An interesting aspect of the current state of CSNF storage is that the burnups of CSNF are increasing significantly, and, as a result, the CSNF heat loads are rising as well. Much of the inventory of CSNF being discharged from reactors today and being placed in canisters for on-site storage is much hotter than the repository design can accommodate. Thus the concept of CSNF aging has emerged as a means for DOE to accept CSNF while it is still too hot for emplacement.

The concept is to accept the CSNF and place it on an aging pad associated with the repository[1] until the CSNF is cooled enough to meet the repository thermal requirements. The CSNF can then be repackaged into the disposal package for emplacement. Use of intact canisters of CSNF directly transported to the repository and placed for thermal aging serves to provide a means for DOE acceptance of the fuel without the need for any significant handling facilities, and permits the aging storage of CSNF without any additional fuel handling operations.

Capability for direct canister disposal: As noted previously, direct disposal avoids an additional fuel handling operation. Further, such an approach would certainly simplify repository operations, improve occupational exposure, and minimize risk introduced by additional CSNF handling. However, other than the use of a licensed disposable canister design, it is unlikely that the repository design basis can be modified at this point to accept current CSNF canister designs for direct disposal. The effect of using a disposable canister design (currently designated as the TAD canister by the DOE) is discussed later.

Number of package shipments: The capacity of the transportation package dictates the number of package shipments required. Higher capacity canisters, which are licensed for transportation, will have a significant effect on the number of shipments required to move CSNF to the repository. While not introducing any significant additional radiological risk (as the transportation of CSNF

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[1] As of the preparation of this paper, Congress was considering another option that would provide for such government sponsored aging storage at sites other than the repository.

in NRC-licensed transportation casks is very low risk), additional shipments do introduce additional costs and an increased risk of accidents
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Considerations for the Purchasers

The activities evaluated in this section are those that the Purchasers perform at the reactor site. Considerations include impact on ongoing plant operations.

Number of cask/canister loadings: Regardless of whether or not canisters are used, the first loading of bare CSNF assemblies occurs in the plant’s spent fuel pool (SFP). The number of loadings in the SFP is a function of the capacity of the cask or canister to be loaded. Higher capacity canisters mean fewer fuel loading campaigns, resulting in lower overall loading costs and occupational exposure. Further, the necessity for fewer CSNF loading campaigns minimizes the impact on other plant operations. Thus, from an operational, ALARA, and direct cost perspective, it is preferable to minimize these loading campaigns provided that doing so does not lead to unloading and repackaging at the Purchasers’ sites.

That being said, should a lower capacity system be directly emplaceable for disposal, the need to unload the canisters is obviated, thus eliminating the cost and dose associated with repackaging CSNF and disposing of the contaminated/activated used canister.

Repackaging of CSNF for DOE transport: Repackaging of CSNF from the current canisters into a DOE package at the Purchasers’ plants requires unloading the CSNF in the SFP and reloading the CSNF in the DOE package. This requires two CSNF handling operations, thus adding significant dose, and introducing risk from the additional handlings. Also, as previously discussed, disposing/dispositioning the contaminated/activated used canisters represents an additional cost.

Repackaging of CSNF at decommissioned plants provides additional challenges. It would be necessary to either transport the CSNF canisters to a facility with a SFP that can accept the CSNF (or relicense their SFP to do so) or utilize other more expensive means, such as hot cells.

EVALUATION OVERVIEW

Based on the evaluation considerations as discussed above, the evaluation rolled up these considerations to determine net impacts for both the DOE and the Purchasers for acceptance of CSNF in canisters at the repository.

DOE Impacts

Acceptance of intact canisters of CSNF at the repository can be of benefit to the DOE by allowing a means to easily accept CSNF that is too hot for disposal. These canisters can be placed directly on an aging pad, thereby avoiding a CSNF handling operation, and can remain on the aging pad until the contained CSNF is adequately cooled to permit placement in the disposal package. The downside is that the used canisters, once unloaded, are a waste stream that must be dispositioned by the DOE. There may be economies of scale for dealing with these used canisters, however, that may reduce overall system costs, as compared to each Purchaser having to separately deal with used canister disposal. However, if the DOE can develop a repository design basis that can permit direct placement of these canisters, the DOE can avoid CSNF handling and used canister disposal altogether.

For transportation cask loadings that utilize CSNF already in canisters at the Purchasers’ sites, the casks need not go into the spent fuel pool, thus eliminating contamination of the cask. Further, spent fuel already emplaced in canisters keeps the interior of the cask from becoming contaminated. Acceptance at the repository of an intact canister of CSNF reduces the amount of time that a cask needs to be at a Purchaser’s plant for loading, and, assuming adequate facilities for canister handling exist at the repository surface receipt and handling facilities, also reduces the amount of time a cask needs to be at the repository for unloading. Keeping the casks clean from contamination means that decontamination is not required, or at least minimized. This results in a significant reduction in dose to DOE workers.

In addition, a clean cask can be put back into service much more quickly than a contaminated one, further reducing turnaround time. If adequate numbers of CSNF assemblies are emplaced in canisters, the size of the DOE cask fleet can be reduced due to the overall improvements in cask utilization resulting from the reduced turnaround times.

Purchaser Impacts

The advantages for the Purchasers of the DOE accepting intact canisters of CSNF at the repository are significant. The direct off-site shipment of intact CSNF canisters eliminates repackaging of CSNF on-site. This avoids two CSNF handling operations at the plant (one for unloading and one for repackaging), which mitigates the risks of CSNF damage or a handling accident.

Further, unloading and repackaging the fuel involves CSNF loading operations at the Purchasers’ sites. These loading operations tend to be relatively personnel intensive, resulting in significant additional occupational exposure. And, unless the repackaging is into a disposable canister, the CSNF will have to be handled yet again at the repository.

If such unloading/repackaging operations are centralized at the repository, the system can be designed for the large quantity of canisters to be unloaded and packaged, and thus designed for ALARA. Also, in this scenario the CSNF need only be handled once, thus minimizing the risks associated with repetitive CSNF handling operations.

Thus, acceptance at the repository of intact canisters of CSNF minimizes the overall system occupational exposures, including those incurred at the Purchasers’ sites, and eliminates the need for the Purchaser to dispose of the used canisters.

Effect of the TAD Canister Concept

As noted in directives issued by DOE on October 25, 2005 [5], the DOE is considering establishing a new baseline for the design of the repository based on the acceptance of a standardized transport, aging, and disposal (TAD) canister. Such an approach is intended to simplify the repository surface receipt facility design, by eliminating or minimizing, at least in the early phases of operation, the need to handle bare CSNF at the repository receipt facilities. Implementation of TAD canisters as soon as practicable would facilitate this goal, in that the number of CSNF assemblies that are emplaced in TAD canisters is maximized, and, correspondingly, the number of CSNF assemblies placed in non-TAD canisters is minimized.

Practically speaking, the use of a TAD canister cannot be implemented with certainty until the NRC has reviewed the TAD canister as part of the 10CFR63 repository license application (LA). As of the writing of this paper, the DOE has no formal plan to include the TAD in the LA, and thus use of a TAD canister may be impracticable until a repository license amendment is filed and reviewed, which is likely to occur at least five years after receipt of the initial license. So at best the use of TAD canisters would be impracticable, given this approach, until 2020. At that time, CSNF in non-TAD canisters will likely exceed 30% of the repository capacity.

For the TAD canister concept to be more effective, it will need to be included in the initial repository LA, in which case the TAD canister may be realistically available in time to reduce, at least slightly, the amount of CSNF in non-TAD canisters. The best-case under this scenario is that TAD canisters will be available by 2010, at which time there are anticipated to be over 1,300 non-TAD canisters loaded with about 44,000 CSNF assemblies, or about 19% of the repository capacity.

Another "soft" consideration is the capacity of current generation canisters vs. the capacity of TAD canisters. The significantly lower capacity of TAD canisters (by about 35%) means 35% more canister loads, and 35% more canister shipments. As such, the use of TAD canisters to transport CSNF from the reactors to the repository is more costly, from both economic and ALARA point of view, than transport of CSNF in non-TAD canisters. Notwithstanding, initial placement of CSNF in a TAD canister is a better option than shipment of bare fuel in that it minimizes the number of fuel handling operations.

TAD canister implementation and the timing thereof, have no real impact on the evaluation of acceptance of CSNF canisters documented herein.

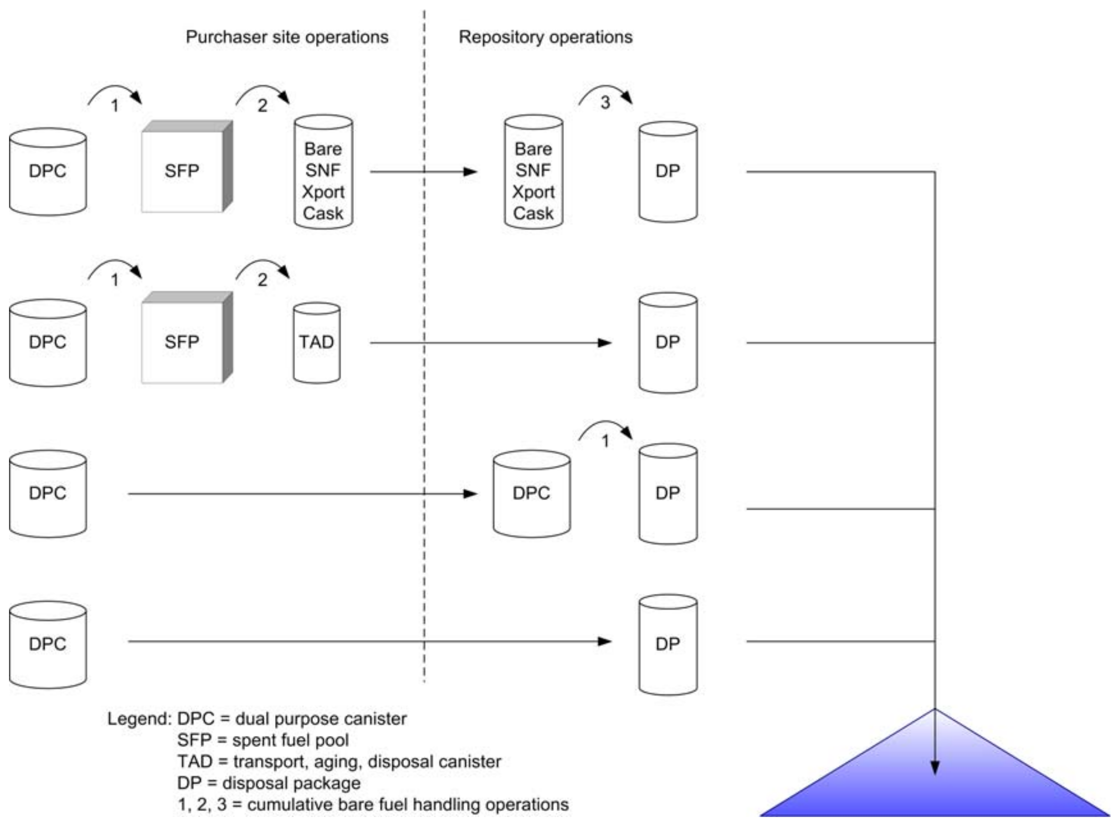

Fig. 1. Options for disposition of CSNF in canisters

CONCLUSION

By 2015, the number of CSNF assemblies placed into canisters will be approximately 25% of repository CSNF capacity. Therefore, disposition of CSNF in canisters is a significant issue for the industry and must be considered and addressed. As discussed herein, the choices for disposition of CSNF canisters have many impacts on the Purchasers and the DOE. The options considered are summarized in Fig. 1.

Based on the evaluation of these options, it is clear that the path that provides the least number of CSNF handling operations is to ship the canisters to the repository intact. There the canisters can be opened for fuel emplacement for disposal upon receipt, or they may be placed directly on an aging pad for cooling and subsequent unloading for emplacement.

There are a number of advantages to this approach. These advantages include significantly lower occupational exposures to the plant workers and a reduced risk of a fuel handling-related accident, both resulting from reduced fuel handling.

The evaluation results show the beneficial consequences to the Purchaser and to the DOE of DOE's acceptance of CSNF in canisters.

REFERENCES

1. Fuel Cycle Week, Vol. 5, No. 164, p. 27, January 10, 2006.
2. Presentation, "Yucca Mountain – Integration in a Forward Moving Industry," Steven P. Kraft, NEI, USTC Transportation Summit III, October 6, 2005.
3. Title 10, U.S. Code of Federal Regulations, Part 961 (10CFR961), *Standard Contract for Disposal of Spent Nuclear Fuel and High Level Radioactive Waste,* 2004
4. Title 10, U.S. Code of Federal Regulations, Part 71 (10CFR71), *Packaging and Transportation of Radioactive Material*, 2005.
5. Letter, U.S. Department of Energy to Bechtel SAIC Company LLC, "Direction to Prepare a Revised Critical Decision-1 (CD-1) for Accepting and Handling Primarily Canisterized Fuel at the Yucca Mountain (YM) Repository, Contract Number DE-AC28-01RW12101," October 25, 2005+