Integrated System for Retrieval, Transportation and Consolidated Storage of Used Nuclear Fuel in the US – 13312

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ABSTRACT

The current inventory of used nuclear fuel assemblies (UNFAs) from commercial reactor operations in the United States totals approximately 65,000 metric tons or approximately 232,000 UNFAs primarily stored at the 104 operational reactors in the US and a small number of decommissioned reactors. This inventory is growing at a rate of roughly 2,000 to 2,400 metric tons each year, (Approx. 7,000 UNFAs) as a result of ongoing commercial reactor operations. Assuming an average of 10 metric tons per storage/transportation casks, this inventory of commercial UNFAs represents about 6,500 casks with an additional of about 220 casks every year. In January 2010, the Blue Ribbon Commission (BRC) [1] was directed to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new plan. The BRC issued their final recommendations in January 2012. One of the main recommendations is for the United States to proceed promptly to develop one or more consolidated storage facilities (CSF) as part of an integrated, comprehensive plan for safely managing the back end of the nuclear fuel cycle. Based on its extensive experience in storage and transportation cask design, analysis, licensing, fabrication, and operations including transportation logistics, Transnuclear, Inc. (TN), an AREVA Subsidiary within the Logistics Business Unit, is engineering an integrated system that will address the complete process of commercial UNFA management. The system will deal with UNFAs in their current storage mode in various configurations, the preparation including handling and additional packaging where required and transportation of UNFAs to a CSF site, and subsequent storage, operation and maintenance at the CSF with eventual transportation to a future repository or recycling site. It is essential to proceed by steps to ensure that the system will be the most efficient and serve at best its purpose by defining: the problem to be resolved, the criteria to evaluate the solutions, and the alternative solutions. The complexity of the project is increasing with time (more fuel assemblies, new storage systems, deteriorating logistics infrastructure at some sites, etc.) but with the uncertainty on the final disposal path, flexibility and simplicity will be critical.

INTRODUCTION

Long-term management of used nuclear fuel assemblies (UNFAs) remains an unresolved topic in the United States. While all would agree that DOE should take action to implement a plan to manage the UNFAs in accordance with its obligation, UNFAs continue to accumulate at utilities. The latest recommendation is that of the Blue Ribbon Commission (BRC) on America’s Nuclear Future, for the creation of one or more consolidated storage facilities (CSF), leaving open the question of whether final disposition would be via recycling or direct geologic disposal.

Transnuclear Inc. (TN), a subsidiary of Areva, is in the unique position of possessing international experience in all of the phases of used fuel management: dry storage, wet storage, transport, recycling, and geologic disposal packaging. TN is taking an overall systems approach to the question of CSF. Thus, rather than starting with some dry storage technology out of its catalog and marketing it as the "the solution," TN started by first defining the problem and its constraints, proposing alternate solutions, and weighing them to select the best path forward . This paper will describe the constraints and criteria for a well-designed integrated consolidated interim storage system, and recommend some options.

Defining the Problem

The simple question "Which is the best system for storage of UNFAs at a CSF?" implies that there is a single best solution, that one size fits all. This may be the case, but standardization is not a goal in and of itself; it is a means to other ends such as safety, dose reduction, schedule or cost efficiency that may or may not be well served under the specific circumstances. In this case, these circumstances may most appropriately be summarized by the status of the UNFAs prior to transport to a CSF:

> UNFAs and greater than class C (GTCC) waste at decommissioned sites, currently 10 sites with 258 canisters, all with transportation packaging either licensed or in licensing [2]. According to the BRC report, these sites are the first priority for transfer to a CSF. At least two more plants will be in decommissioning by the time that a CSF could start to receive fuel: Oyster Creek and Kewanee. These will both have UNFAs in dry storage, which can be transported off-site with a licensed transport cask (MP-197HB), but also in pools. Those UNFAs remaining in pools may also be high in priority for removal.
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> UNFAs inventory in pools at operating reactors is approximately 70% of UNFA inventory or approximately 70,000 MTU at the end of 2012. These UNFAs is being removed to dry storage at a rate about equal to the rate of reactor discharge, about 3000 MTU/year, maintaining space in the pools for full core offload. As burnup of UNFAs increase, and as UNFAs is moved to dry storage, the decay heat of UNFAs in pool storage has increased. If these UNFAs can be taken to a CSF at least at the rate of reactor discharge, about 3000 MTU/year, then on-site dry storage can cease expanding, and be put into a maintenance only mode. At a higher removal rate, pool storage density could be decreased, a goal seen as desirable in the aftermath of Fukushima.
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> Finally, there are those UNFAs that will already be in dry storage at operating reactors at the time that CSF opens; the variety of storage casks here is even greater than that at decommissioned sites, and includes both vertical and horizontal welded canister and bolted metal cask systems, both storage only and dual-purpose systems. At the end of 2012 there are approximately 1450 dry storage systems on operating Independent Spent Fuel Storage Installations (ISFSIs), increasing at a rate of approximately 200 per year. The trend for these systems has been toward larger capacity, higher decay heat systems.

Transportation logistics is another major parameter including limited transportation infrastructures, lack of experience in large scale, long-term UNFA shipping campaigns in the

United States, potential public concerns and need to procure specialized transportation equipment:

> Even at many operating reactor sites, the transportation infrastructure is limited. The preferred mode for transport to a CSF will be rail, but sites which had rail access at the time of construction have removed it or not maintained it. Barge is available a few sites, and heavy-haul road transportation can always be used, but transfer to rail will be necessary at some point, adding cost and complexity for those sites without rail. This emphasizes the need to remove fuel from operating or newly decommissioned sites as early as possible, while the infrastructure is relatively intact.
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> In the United States, while large shipping program such as WIPP (Waste Isolation Pilot Program) have been successfully implemented, there is no UNFA large-scale multimodal rail transportation program in place. However, a proven model such as the one used by TN's parent AREVA in France and other countries can be duplicated in the United States. AREVA has been shipping successfully for the last 40 years to La Hague recycling facility in France using approximately 200 transportation packages. UNFA transportation casks are shipped directly by rail from the utilities or with a preliminary heavy haul truck transport to the nearest rail spur. AREVA owns a fleet of rail cars that are customized to accommodate the casks but locomotives are standard equipment of the French rail transport provider.
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> In comparison, the consolidated storage program in the United States would move between 3000 and 6000 MTU per year. The quantity of casks could depend on their capacity. For bare fuel casks similar to those in France, which might be suitable for transporting relatively hot fuel directly from pools, the capacity is approximately 6 MTU per cask, yielding 500 to 1000 cask transports per year. For the latest generation of high capacity dual purpose canisters, at about 17 MTU per canister, it would be 170 to 340 cask transports per year, but with substantially larger transportation casks and impact limiters limiting the available transport routes. The large size of these systems limits the weight available to dedicate to shielding by the transportation cask, resulting in longer decay times for UNFAs before they can be transported within the regulatory surface dose rate limits.
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> While in France it is not mandatory to use a dedicated train, United States regulations required a dedicated train. In addition, assuming Yucca Mountain transportation program requirements will also be adopted for transportation to a CSF, specialized rail cars in accordance with AAR (Association of American Railroads) Standard S 2043 requirements will have to be built after testing a prototype as such standard does not currently apply for any other dangerous goods.

Public acceptance is one of the most critical elements to be taken into consideration:

> The transportation logistics plan must take into account public acceptance, including communities along the routes. High safety and security standards are the pillars of the radioactive material regulations. Over the years, records limited to minor events confirm the safety and efficiency of these standards. Public education on this record will be

essential; regardless of the technical brilliance of the system design, and the consent of the state and locality of the CSF, the entire plan could fail on the issue of public acceptance of routine transportation of highly radioactive materials.

Criteria for Judging Alternate System Designs

High in the BRC rankings are safety and security and local consent, but these are not likely to play deciding roles for the choice of a CSF system design:

1. Any system to be considered will have to meet the safety and security criteria set, which may be more stringent than those required for ISFSIs today. All the systems proposed for a CSF will have to meet these criteria, and thus the criteria will not be discriminators. The real discriminator may be the cost and/or time to do so.
2. Local consent is likely to be based on local political and economic considerations; the specifics of the storage system are unlikely to be of concern once those hurdles are negotiated, considering that any system will have to meet the safety and security design bases.

A CSF must accommodate either direct geologic disposal or recycling as the eventual outcome. It would not be prudent to store UNFAs in small canisters "suitable for direct disposal," which would incur significant added costs and dose for the large number of canisters this would require, when there is presently no certainty of direct geologic disposal in the U.S., and the record of trying to predict the design of future geologic storage containers has been dismal.

Repackaging of UNFAs already in dry storage casks or canisters should only be considered after all other options for transportation and storage "as is" have been exhausted. It is hard to argue that the cost, dose, and waste generated by repackaging would have any commensurate safety value.

Cost and schedule are naturally important discriminators; enough time and money has already been spent on this subject to tax the patience of both industry and public.

At a CSF, ease of maintenance and provision for aging management will be a concern; experience shows that the duration of "interim" may be longer than we anticipate. Active systems like cathodic protection that have a history of difficult maintenance would be undesirable.

Completing the list for the moment without attempting to be completely comprehensive, the proposed system must be compatible with transportation regulations, and with feasible delivery rates.

Evaluating Design Alternatives

Options for transportation for UNFAs already in dry storage either at decommissioned or at operating plants:

1. Transportation in multiple transportation packages as designed by the welded canister vendors.
2. Transportation in a universal transportation cask suitable for all canisters.
3. Transportation in metal casks with impact limiters added for dual purpose metal cask systems.
4. Transfer UNFAs from existing storage canisters and casks to a new transportation or transport/storage packaging.

Regarding the last option, UNFAs already in dry storage should not be repackaged for transportation or a CSF except as a last resort, as noted above. It is possible to license for transportation canisters and casks originally designed for storage only, as shown by Transnuclear's experience with the TN-40 metal cask.

Option 2 would provide a standardized transportation package rather than the multiplicity of transportation package that would be required by option 1. For the nine currently decommissioned sites alone, there are multiple different packaging licensed to transport the stored canisters. In addition to the cost of procuring the necessary transportation casks, there will be seven sets of transfer and handling equipment, shipping frames, and procedures. Transnuclear has a NUHOMS® MP197HB transportation package currently licensed that can accommodate storage canisters from different vendors at decommissioned reactor sites resulting in saving time and money that would be won by standardization.

<u>Options for transportation of UNFAs already in pools at operating plants</u>:

The trend for UNFAs in storage has been toward higher burnup and decay heat; much of the "old cold" fuel is already in dry storage on site, or will be by the time that a CSF is ready to receive UNFAs. This may make it difficult for transportation of more recently stored fuel to meet the transportation package surface dose rate limits without more on-site decay time. The options then are:

1. Transportation directly from pools in smaller welded canisters, probably at most 24 PWR and 52 BWR UNFAs, designed for storage in concrete overpacks at the CSF.
2. Transportation directly from pools as bare fuel in transportation casks, with transfer to either wet storage or larger dry storage systems at the CSF.
3. Transportation from on-site dry storage, while UNFAs from the pools continues to be placed into on-site dry storage.

The first option would have the disadvantage of increased costs, time, and dose required to process the smaller canister, and the additional space required to store them at a CSF; these are the causes that have driven the dry storage industry relentlessly in the opposite direction, toward higher capacity canisters. Furthermore, this option presumes dry storage will be the preferred mode for UNFAs at the CSF, which may not be the case.

Bare fuel transportation offers simpler operations at the utilities for loading the casks, and the capability to remove higher decay heat fuel using transportation casks like the TN International G3, which has a capacity of 12 PWR or 44 BWR UNFAs with a total 75 kW decay heat.

While it is often assumed that transportation directly from the pools will be the second priority after the decommissioned sites, the fact is that fuel in pools is hotter and will require lower capacity transportation casks and therefore 2-3 times as many transports as fuel in dual-purpose dry storage & transportation systems. Therefore, the pros and cons of option 3 need to be considered in more detail, which is beyond the scope of this paper.

Transport logistics considerations:

The foregoing options include transport of multiple transportation packagings for canisters with both vertical and horizontal handling, metal cask systems with impact limiters as large as 12 feet in diameter, and lower capacity bare fuel transportation casks capable of handling higher decay heat fuels. While it is possible to combine some of these and reduce the variety, it is not likely that this can be completely standardized and reduced to only one or two transportation packagings, even if theoretically possible.

What is practical though is to design rail cars and lifting equipment to accommodate the size and weight of all the anticipated transportation casks, and to design shipping frames that interface with multiple cask designs. Furthermore, the total cost of transportation needs to be considered when evaluating transport directly from pools versus transport from dry storage at active sites. As noted above, the former could require smaller capacity casks and as many as 2-3 times more transportation packages and shipments.

Storage options at the CSF:

For fuel currently in dry storage at the reactor sites, storage at the CSF could be in newly designed overpacks or vaults, but storage in their originally licensed overpacks or metal casks would be the path of least licensing resistance, that is, the least time and expense. This is again a case where standardization seems desirable, but in reality achieves no essential purpose, and a CSF dry storage facility designed for a variety of dry storage overpacks and handling equipment may be the most cost and schedule effective solution.

It is possible that the storage systems used at a CSF in the United States would have to meet more stringent design basis threats than currently considered. Analysis could validate the existing systems for such requirements, or could indicate the need for modification or redesign of the overpacks, but these should be minor. New systems would be designed with these requirements in mind – pools and transfer stations, for example would have to include these new requirements.

As fuel ages, a further concern is that at some point, the surface dose rate will pass below the limit defined as self-protecting, requiring additional protective measures.

We have to acknowledge the possibility that UNFAs could be stored at a CSF for a long time. This means that the facility should have the capability to monitor and inspect the dry storage casks and canisters for the purpose of aging management, along with the capability for repackaging should unexpected deterioration occur. Again, backfits of existing systems to accommodate inspections for aging management should not be difficult, and a small wet pool facility will provide the simplest capability for fuel repackaging should it be necessary.

Finally, while this paper advocates transferring existing dry storage systems "as is" from reactor site to CSF, if fuel is transferred as bare fuel directly from operating or decommissioning reactor pools to the CSF, the method of storage at the CSF is open. As noted above, this 70,000 MTU represents today approximately 70% of the UNFA inventory, and in year 2020 will be approximately 55%. From the perspective of cost, ultimate flexibility for recycling or geologic disposal and capability to handle high decay heat fuels, pool storage seems to be the best option. Interim storage pools are used at La Hague recycling facility while radioactivity of the fuel reduces prior recycling. Security requirements and public sentiment might require enhancements to pool safety and security, particularly hardening against aircraft crash, which could reduce wet storage's cost advantage over dry storage. While wet storage is a preferred option in term of flexibility economics or other considerations drive the design toward dry storage, which would be done most efficiently with large canister systems, loaded at the CSF from bare fuel transportation casks. Here there would be a real opportunity for standardization.

CONCLUSION

The CSF is an interim solution for used fuel management while DOE is defining a final disposal path. Consequently, considering that the CSF is a temporary solution and that there are uncertainties on the final disposition path, flexibility and simplicity are of paramount importance for the CSF design after meeting the criteria for safety and security:

1. As with any integrated approach to design, the entire system must be evaluated to provide a basis for evaluating alternative designs for individual storage and transportation components. The urge to start with the solution rather than the definition of the problem must be resisted.
2. Use proven experience: The experience of Transnuclear and its parent AREVA in transportation of UNFAs and in providing transportation logistics support can be applied to transportation of UNFAs from decommissioned reactors and operating reactors to a CSF.
3. Use of proven regulation: While public acceptance and public education are essential, radioactive materials have proven to be efficient over the years. Tendency to go above the regulatory requirements could surface based more on perception than a probable risk. Any additional requirement should be based on material attractiveness and risk assessments to remain efficient and cost effective.
4. Any unnecessary actions that presume a final destination of UNFAs to either direct geologic repository for storage or recycling is not known with any certainty at this time; the design of the CSF that can accommodate either of these options is the most prudent choice at this time.

5. It is very difficult to justify the dose, expense, and waste that would be incurred by transferring UNFAs from existing dry storage to new canisters. Design and licensing for transportation of the fuel in its existing storage container is feasible.

6. Design and licensing of new storage systems at CSF will probably be not required. To the degree consistent with security and aging management requirements, use the already-licensed storage casks and overpack designs at CSF for UNFAs coming from dry storage at either decommissioned or operating reactors.

7. It is prudent to spend the effort for new design and licensing where it is needed most: to transport and store higher burnup, shorter cooled fuel directly from operating reactor pools. Here again, Areva's logistics business unit has relevant experience designing and operating transportation casks to ship relatively hot fuel to La Hague.

REFERENCES

[1] Blue Ribbon Commission on America's Nuclear Future, Final Report to the Secretary of Energy, January 26, 2012.

[2] Jeffrey Williams, US Department of Energy, Logistical and Operational Issues Associated with the Transport of Stranded Fuel from Shutdown Reactor Sites, presentation to Nuclear Waste Technical Review Board, October 17, 2012.