INL/EXT-12-26218

Dry Transfer Systems for Used Nuclear Fuel

Brett W. Carlsen
Michaele BradyRaap

May 2012

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-12-26218
FCRD-UFD-2012-000115

Dry Transfer Systems for Used Nuclear Fuel

Brett W. Carlsen
Michaele BradyRaap

May 2012

Idaho National Laboratory
Fuel Cycle Research & Development
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

SUMMARY

The potential need for a dry transfer system (DTS) to enable retrieval of used nuclear fuel (UNF) for inspection or repackaging will increase as the duration and quantity of fuel in dry storage increases. This report explores the uses for a DTS, identifies associated general functional requirements, and reviews existing and proposed systems that currently perform dry fuel transfers. The focus of this paper is on the need for a DTS to enable transfer of bare fuel assemblies. Dry transfer systems for UNF canisters are currently available and in use for transferring loaded canisters between the drying station and storage and transportation casks.

Uses for a DTS can be broadly binned into two categories – retrieval of stored fuels for inspection and other research, development, and demonstration (RD&D) applications or for repackaging. Repackaging could be needed for recovery from an unplanned event or discovery of an unforeseen condition; to repair, replace, or overpack a compromised cask or canister; to replace aging canisters; and/or to reconfigure storage or transport packages to meet future storage, transport, or disposal requirements. The basic functions that must be performed by a DTS are similar regardless of why, where, when, and how implemented. However, operational requirements such as the need for transportability, throughput requirements, cask and canister interfaces, and fuel handling needs. will vary considerably based on the specific DTS needs being addressed.

Of the several potential needs and uses for a DTS, only the RD&D application for retrieval and transfer of UNF to an examination facility is anticipated in the near term. The need for a DTS at ISFSI-only sites is not anticipated because all UNF is stored in dual purpose canisters. And the need for a DTS at other ISFSIs is relatively small because pools are maintained. UNF stored at ISFSIs in storage-only packages can be transferred into dual purpose canisters before decommissioning the pools at these sites.

A DTS would, however, provide contingency by enabling repackaging at ISFSI-only sites. And it would provide management flexibility at all dry storage sites by enabling repackaging without the need to return to a pool. Repackaging in a pool could interfere with ongoing pool operations, could risk unacceptably contaminating the pool, or could challenge the fuel due to the additional stresses associated with re-wetting and re-drying operations. A DTS would also be helpful in reducing risks associated with unplanned events or unforeseen conditions and for reconfiguring storage packages to meet future storage, transport, or disposal requirements. A DTS for these purposes could be most effectively implemented at a centralized storage or disposal facility where it could be integrated into the facility design and also provide economies of scale.

Several dry transfer systems are currently in operation for specific applications and others have been proposed and/or designed. A review of these systems indicates that a DTS for limited use to support identified RD&D needs is achievable by modifying existing processes and facilities. This review also confirms that dry transfer systems to meet a number of other needs are achievable with existing technology. However, a generic DTS to accommodate a range of potential needs and canister designs, to be deployable at multiple sites, and/or to provide significant throughput capacity will be costly.

To address the identified RD&D needs, a project should be initiated to evaluate available options, select a path forward, and proceed with conceptual design. To address the potential need for repackaging in the future, the costs and benefits of including a dry and/or wet transfer process should be considered when developing functional and operational requirements and specifying the associated design criteria for future UNF facilities such as a consolidated storage facility (CSF) or disposal site. To fully benefit from the previous recommendation, the UNF management strategy must ensure that packages are transported before repackaging becomes necessary. To this end, an activity should be initiated that identifies the key transport-limiting system parameters and examines alternatives for mitigating these conditions. This is

likely to result in other options for transport of potentially compromised packages from distributed ISFSI sites. This activity will also help identify time constraints and inform schedules for UNF transportation.

Lastly, because both DOE and industry have a shared stake in each of the above recommendations, it is suggested that a dialog be pursued between the two in order to achieve consensus on the needs and recommendations, to identify associated roles and responsibilities, and to coordinate related activities.

CONTENTS

FIGURES

TABLES

ACRONYMS

ALARA	As Low As Reasonably Achievable
BRC	Blue Ribbon Commission
B&W	Babcock & Wilcox
BWR	Boiling Water Reactor
CSF	Consolidated Storage Facility
CPP	Chemical Processing Plant
DCSS	Dry Cask Storage System
DOE	Department of Energy
DPC	Dual Purpose Canister
DTF	Dry Transfer Facility
DTS	Dry Transfer System
EM	Environmental Management
EPRI	Electric Power Research Institute
EST	Extended Storage and Transportation
FHC	Fuel Handling Cave
FCRD	Fuel Cycle Research and Development
HEU	High Enriched Uranium
HFEF	Hot Fuel Examination Facility
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IFSF	Irradiated Fuel Storage Facility
ISFSI	Independent Spent Fuel Storage Installation
LEU	Low Enriched Uranium
LWT	Legal Weight Truck
MPC	Multi-Purpose Canister
MRS	Monitored Retrievable Storage
MTR	Materials Test Reactor
MTU	Metric Tons Uranium
NAC	Nuclear Assurance Corporation
NEI	Nuclear Energy Institute
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission

NWPA	Nuclear Waste Policy Act
NWTRB	Nuclear Waste Technical Review Board
PWR	Pressurized Water Reactor
RD&D	Research, Development, and Demonstration
SER	Safety Evaluation Report
SRS	Savannah River Site
TAN	Test Area North
TN	TransNuclear
TSAR	Technical Safety Analysis Report
UFD	Used Fuel Disposition
UNF	Used Nuclear Fuel
WM	Waste Management
WP	Waste Package
YMP	Yucca Mountain Project
ZWILAG	ZwischenlagerWürenlingen AG (Switzerland)

DRY TRANSFER SYSTEMS FOR USED NUCLEAR FUEL

1. INTRODUCTION

The DOE Used Fuel Disposition (UFD) Program has identified a number of activities to support development and implementation of a national strategy for long-term management of UNF. One of these activities is to evaluate the need for and the feasibility of a dry transfer system (DTS) that enables transfer of bare UNF assemblies to another container without use of a pool.

The purpose of this report is to further define the potential uses and needs for a DTS capability and to review available options and alternatives for addressing these needs. Its objective is to encourage dialog between industry and DOE that will support an informed and mutually beneficial path forward relative to the role of a DTS and development of the associated technologies.

Although the report focuses on dry transfer of commercial fuel assemblies, the discussion can be extended to other UNF types. Similarly, although the final endpoint for the UNF options is assumed to be disposal, many of the same considerations would apply to reprocessing.

1.1 Background

Used nuclear fuel continues to be produced by the nation's 104operating commercial power reactors. As reactor pools reach their capacity, fuel is being moved into dry cask storage systems and stored at the reactor sites. As a result of delays and, most recently, withdrawal of the application for the geologic repository, the duration of the dry storage period and quantity of fuel that must ultimately be accommodated are steadily increasing.

> *In the mid-1980's, spent fuel pool storage was envisioned to continue to be the primary storage method for used fuel until a repository would be available. Dry cask storage was envisioned to be a unique solution that only a few utilities would need to employ with a relatively limited number of casks. Back then, there were only a handful of casks in-service and it was anticipated that only around 10 plants would require dry cask storage prior to the opening of a repository. Today, in contrast, there are over 1,421 casks in-service and it is estimated that nearly 5,000 casks will be in service if a repository opens in 20 years (2031). If it takes several decades before a repository is operational, then there would be significantly more casks in- service*[a].

Figure 1-1 shows, assuming no new nuclear reactors are built, the quantity of UNF that will require storage over the next 50 years. Even under this extreme assumption, the quantity of used fuel in dry storage increases by a factor of nearly seven over the next four decades. Figure 1-2 provides a more realistic picture of the growth of used fuel inventories through 2100 under four different future nuclear growth scenarios, assuming no other means of disposition. The lowest line in Figure 1-2 corresponds to the 'no new nuclear build' scenario. The other three scenarios show the quantity of UNF that must be stored under a 'maintain current nuclear capacity (~100 GWe/yr) and growth scenarios with nuclear capacities of 200 and 400 GWe/yr'. Figure 1-2 illustrates that the quantity of fuel in dry storage is likely to be much higher than even the seven-fold increase shown in Figure 1-1.

---

[a] M. Nichols, NEI, Operational Challenges of Extended Dry Storage of Spent Nuclear Fuel, WM2012 Conference Proceedings, February 26-March 1, 2012, Phoenix, AZ, paper 12550.

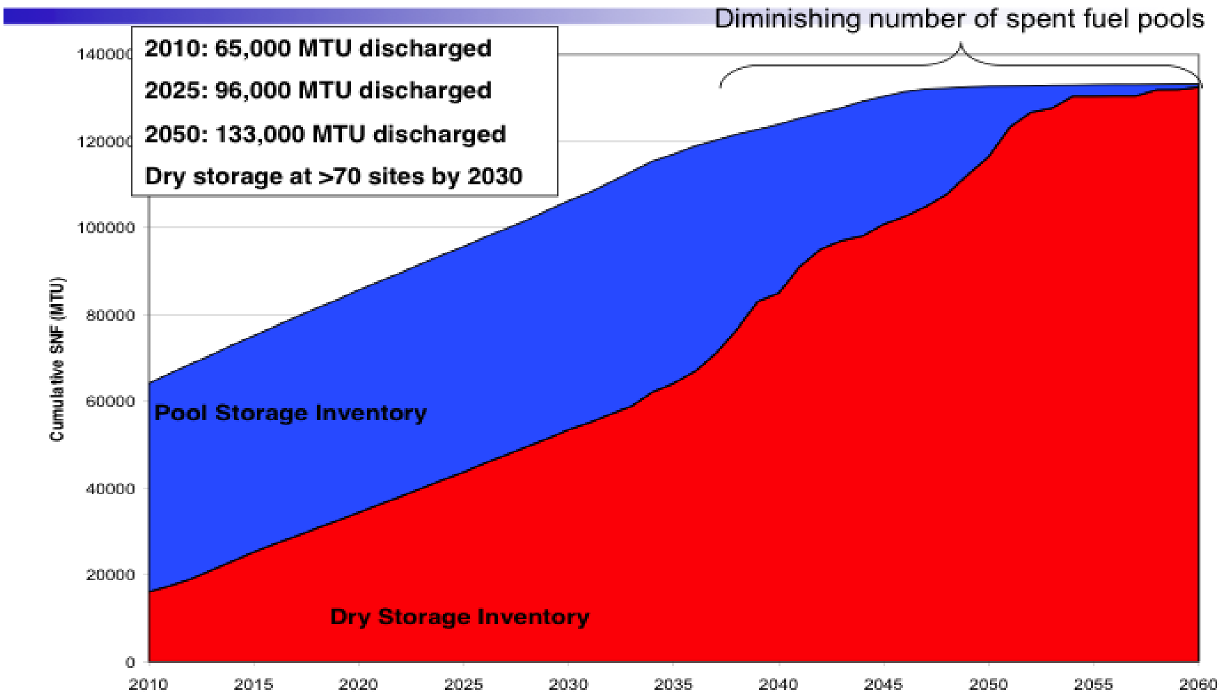

Figure 1-1. Quantity of fuel in dry storage – assuming no new nuclear build[b].

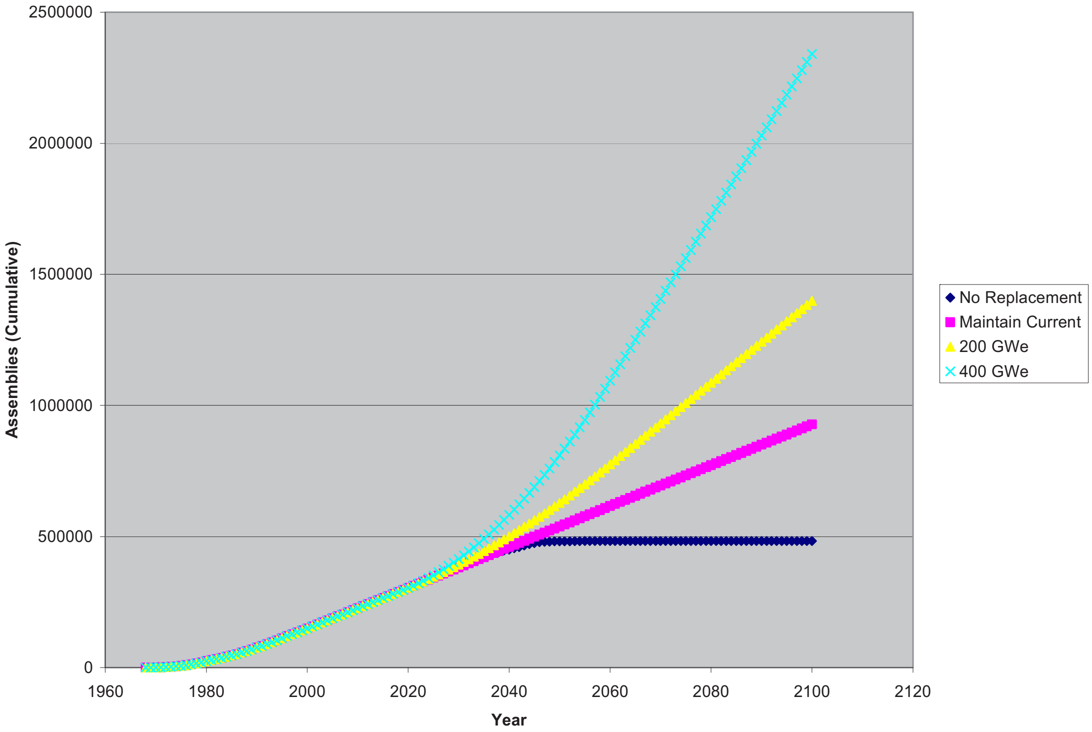

Figure 1-2. Cumulative UNF assembles discharged for no NPP replacement, maintain current capacity, and for 200GWe/year and 400GWe/year growth scenarios[c]

---

[b] *Used Fuel Extended Storage, What the U.S. Industry Wants from DOE*, John Kessler, NEI Used Fuel Management Conference, Baltimore MD, May 4, 2011.

Until a means of final disposition or another alternative to onsite dry storage becomes available, UNF in dry storage will continue to accumulate. As more of the U.S. UNF inventory is placed into onsite dry storage, the locations, types of fuel, types of dry storage systems, and range of UNF conditions will also become more diverse. Hence, the value of systems that assure continued safety and increase management flexibility will become increasingly important.

Industry expects DOE to take the lead in developing extended storage and transportation (EST) technologies and equipment.

> *As DOE is responsible for creating the need for EST, DOE should also be responsible for ensuring the viability of storage and subsequent transportation for as long as necessary and until all used fuel is safely placed in a repository. This includes responsibility for the research and development to produce the technical bases that ensure safe and secure storage and transport beyond 60 years, including those that support development of the regulatory framework and operational capabilities.*
>
> *It is important to note that DOE still has the legal obligation, as stipulated in the NWPA [sic Nuclear Waste Policy Act] and agreed to through Standard Contracts, to accept used fuel from utilities and provide for its ultimate disposal. Although the DOE has already breached the January 31, 1998 requirement to begin accepting used fuel, this does not relieve DOE of either its legal obligation to accept all used fuel or its moral obligation to do so as soon as possible*[d]*.*

John Kessler (EPRI) delivered a similar message in a 2011 presentation entitled '*What the Industry Wants from DOE*'[e]. Kessler noted that fuel canning, repackaging, and/or overpacking will 'eventually' become necessary. The need for a dry transfer capability was identified both to support fuel inspections for evaluating degradation mechanisms and also to enable repackaging fuel when it becomes necessary. The need for a DTS is partially based on the presumption that fuels will continue to be stored at reactor sites after the reactor pools are decommissioned. Other drivers for developing a DTS were also noted. These include having an available contingency plan for addressing emerging needs or unplanned events/conditions and to help ensure continued confidence in long-term management of UNF. Public and political confidence in long-term storage will play a key role in our ability to site new storage facilities.

Brandon Thomas, Energy Solutions, has also noted that a DTS may help DOE meet its obligations to enable fuel retrieval for movement to next phase/facility.

> *The time at which UNF will be moved from onsite dry storage is presently unknown. When the time comes, the UNF will most likely be transported in a combination of large dedicated casks, such as vendor-specific canister-based systems, and smaller special-purposed casks for damaged fuel, sites or routes with weight or size restrictions, or situations requiring bare UNF shipments. Although many UNF storage systems have approved transfer devices for moving canisters from one cask to another, there will be a need for a flexible system capable of transferring a wide range of canisters or bare fuel from storage, transfer, or transportation casks into Department of Energy (DOE) transportation casks.*

---

[c] *Fuel Cycle Potential Waste Inventories for Disposition*, FCRD-USED-2010-000031 Rev. 2, Joe T. Carter and Alan J. Luptak, September 2010.

[d] M. Nichols, NEI, Operational Challenges of Extended Dry Storage of Spent Nuclear Fuel, WM2012 Conference Proceedings, February 26-March 1, 2012, Phoenix, AZ, paper 12550.

[e] *Used Fuel Extended Storage, What the U.S. Industry Wants from DOE*, John Kessler, NEI Used Fuel Management Conference, Baltimore MD, May 4, 2011.

Nonetheless, some have questioned the need for a DTS, particularly in light of safety strategies that do not rely on maintaining fuel integrity for assuring safe storage and transportation. Others have suggested that foreseeable DTS uses could be accommodated by other alternatives such as continued use of pools, specially designed overpacks, or by reconsidering regulatory practices (e.g. limited use of regulatory exceptions and/or new rulemaking).

This task was originally intended to be a review of a DTS design done by TransNuclear[f] in order to determine its applicability and potential uses in view of the present UNF situation. In the early stages of planning for this task, a brief summary of the task, its objectives and plan was sent to several colleagues within DOE and the industry. From the feedback received, it became clear that there are diverse expectations relative to the role a DTS would play in extended storage and subsequent transport as well as to DOE's role in developing a DTS capability for handling bare fuel assemblies. As a result, this activity was re-scoped. Rather than focusing on an evaluation of a specific DTS design, this document focuses on presenting the needs and options to be considered with respect to development of dry fuel transfer capabilities.

1.2 Document Overview

Section 2 summarizes the envisioned uses of a DTS capability, discusses the conditions under which these potential uses would be desirable and/or necessary, and considers the alternatives along with the potential consequences and risks of not having a DTS capability. The identified uses determine when and where DTS capabilities may be needed.

Section 3 discusses how the needs for a DTS capability would be affected by implementation of a centralized UNF storage facility. The *Blue Ribbon Commission on America's Nuclear Future* (BRC) report[g] recommends consolidating UNF from dispersed storage sites into one or more centralized or regionalized facilities. If consolidation of UNF storage sites occurs in the near term, the need for a dry transfer capability at individual reactor sites could be significantly reduced or even eliminated. A dry transfer capability, if needed under a scenario where dry storage is consolidated into a limited number of sites, would likely have very different requirements and constraints than a DTS system intended for implementation at existing ISFSI sites.

Section 4 defines high-level functional requirements based on the envisioned uses for a DTS. Many of these functional requirements cross-cut several identified uses while others are unique to various uses. A review of existing and proposed designs for performing a dry transfer of UNF is given in Section 5 (Appendix A includes a brief discussion of each of the designs considered). Conclusions and recommendations from this evaluation are presented in Section 6.

2. Potential DTS Needs and Considerations

As stated earlier, there is no consensus on the need for a DTS capability and no clear champion for developing the capability. Many in the industry see the use of dual purpose canisters and their supporting

---

[f] The DTS was developed under a cooperative agreement issued by DOE to the Electric Power Research Institute (EPRI) in September 1993. Transnuclear, Inc (TN) subsequently designed the DTS under a contract from EPRI. [*Dry Transfer System for Spent Fuel: Project Report,* EPRI TR-105570, Final Report, December 1995]. On the basis of the TN/EPRI design, DOE initiated a cold demonstration of the DTS prototype in August 1996 at the Idaho National Engineering and Environmental Laboratories (INEEL) [*Spent Nuclear Fuel Dry Transfer System Cold Demonstration Project,* INEEL/EXT-99-01335, February 2000].

[g] Blue Ribbon Commission on America's Nuclear Future Report to the Secretary of Energy, January 2010. brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf

equipment as sufficient to meet identified needs. The situation for DOE is more complicated. Their obligations extend beyond commercial fuel to include research reactor and other diverse fuels with many different material types, geometries, and conditions. Even for commercial UNF, the DOE's responsibility under the NWPA far exceeds the scope and range of fuel and cask types of any individual utility. Additionally, the uncertainties in both the timing and packaging needs for UNF provide additional motivation for development of a DTS capability to provide operational flexibility in the overall management of UNF.

There are several potential needs and uses for a DTS capable of remotely retrieving and transferring bare fuel assemblies. Development and implementation of a DTS capability is not the only solution for many of these needs. The costs and benefits of a DTS as well as the availability of other alternatives are strongly influenced by factors such as the availability of pools, the condition of the canister or cask, the quantity of UNF stored on site.

The following sections identify and discuss the potential needs and uses for a DTS, the available alternatives, and relevant site-related considerations.

2.1 Potential Needs

Identified needs and uses for a DTS can be broadly categorized into those that support RD&D to establish and maintain the technical and regulatory basis for extended storage and transportation and those that enable repackaging to address one or more possible future scenarios. Each of these potential needs for a DTS capability is discussed briefly below.

2.1.1 RD&D-Related Needs

The delay of a final repository has led to a need for the development of technical and regulatory basis for extended storage and subsequent transport. Continued reliance on maintaining the fuel and/or cladding integrity as the safety basis during storage and transport presents the need to perform RD&D to develop a more complete understanding of fuel and cladding behavior. Several recent efforts have identified specific RD&D activities[h]. The need for a DTS to enable retrieval of stored UNF for inspection and examination to support these activities has been acknowledged by DOE, EPRI, NWTRB and others.

The immediate RD&D need for a DTS is to enable transfer of existing commercial fuels at the INL and current generation high burnup fuels from industry into an examination facility to support research on relevant degradation mechanisms and to demonstrate fuel and cladding behavior following extended storage periods. Fuels to support this RD&D would be retrieved from reactor sites, either reactor pools or existing dry cask storage systems. For this RD&D application, the fuel to be examined must be prototypical of fuels that remain in storage. Hence, care must be taken during retrieval, transport, and transfer to avoid rewetting or otherwise exposing the fuel to conditions that could change the fuel or cladding properties to be evaluated. Development of a DTS capability to meet this limited-scope and

---

[h] *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel,* United States Nuclear Waste Technical Review Board, December 2010.

Gap Analysis to Support Extended Storage of Used Nuclear Fuel, Brady Hanson et al, FCRD-USEDD-2011-000136, Rev 0, PNNL-20509, January 31, 2012

Identification and Prioritization of the Technical Information Needs Affecting Potential Regulation of Extended Storage and Transportation of Spent Nuclear Fuel, Draft Report for Comment, U.S. Nuclear Regulatory Commission, May 2012

Key Issues Associated with Interim Storage of Used Nuclear Fuel, Andrew C. Kadak and Keith Yost, MIT-NFC-TR-123, Massachusetts Institute of Technology, Cambridge Massachusetts, December 2010.

well-defined DTS need could also serve as pilot project for demonstration of transportation of high burnup fuel and for development and testing of DTS equipment and technologies that may be adapted to address many of the needs identified in section 2.1.2.

Other RD&D uses for a DTS include enabling periodic retrieval and inspection of fuels in extended storage. This capability would also provide access to dry storage casks for supporting internal cask monitoring equipment and support for development and maintenance of aging management plans required as part of the license extension process.

2.1.2 Repackaging-Related Needs

The NWTRB specifically included design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage as one of its nine specific R&D recommendations. Because extended storage will exceed operating reactor lifetimes, fuel pools and infrastructure needed to support repackaging may not be available for the entire storage period. Extended storage may eventually result in degradation of fuel and cask/canister system internals that could impact safety functions needed for storage and transportation. Consequently, a process for opening casks and performing dry fuel transfers may be necessary to support any repackaging, recovery, inspection, or other fuel retrieval needs.

There are many envisioned uses for a DTS related to a variety of possible scenarios in which repackaging of fuel may be beneficial or perhaps necessary. Because repackaging, whether wet or dry, would result in increased radioactive waste and personnel exposure, routine repackaging of UNF is not likely in the absence of an economic benefit or a safety concern that would outweigh the costs/risks of repackaging. The need for any large-scale repackaging at multiple sites could be avoided if transportation to a CSF occurs before age-related degradation or other circumstances raise questions relative to the transportability of the existing packages.

2.1.2.1 Standardization of Packaging

Beneficial DTS uses that have been postulated include repackaging UNF to standardize packaging. The benefits of standardization are in minimizing the equipment, analyses, procedures, training, and other operational infrastructure needed to service the fleet of storage and transportation casks. The costs of standardization include the necessary resources, personnel exposure, and wastes generated from the repackaging process. A cost-benefit analysis should be performed before undertaking any large-scale repackaging effort for the purpose of standardization.

2.1.2.2 Planned Periodic Repackaging

The duration of the storage period is not presently known. Based on the withdrawal of the YMP license application and the recent recommendations from the Blue Ribbon Commission on America's Nuclear Future[i], it is reasonable to presume that UNF will be stored for at least several more decades. The US NRC has recently initiated an environmental impact statement to evaluate the impacts of storing UNF for up to 300 years[j]. Given that UNF may be stored for several decades and perhaps even centuries, it is

---

[i] Blue Ribbon Commission on America's Nuclear Future Report to the Secretary of Energy, January 2010. brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf

[j] SECY11-0029, Subject: Plan for the Long-Term Update to the Waste Confidence Rule and Integration with the Extended Storage and Transportation Initiative, Catherine Haney to Commissioners, February 28, 2011. pbadupws.nrc.gov/docs/ML1102/ML110260244.pdf

plausible that the UNF management strategy could include planned periodic repackaging campaigns to renew storage canisters and/or other packaging components as they reach the end of their operational life.

2.1.2.3 Mitigation and Recovery

Unplanned events, resulting from either natural phenomena or human activity, must be considered. And the likelihood of occurrence of such an event increases with the storage duration. A DTS would provide a means for mitigation and recovery from an unplanned event or the discovery of an unforeseen condition. Provision of this capability may be required as part of the safety basis for extended storage. In addition to providing a means for recovery from an incident involving a potentially compromised canister, a DTS could facilitate recovery from circumstances where criticality safety is in question (e.g. a potential loss of fuel geometry or degradation of neutron poisons) by allowing fuels to be recovered and evaluated without the re-introduction of moderator or the need for unloading in a borated pool. A suitable DTS capability would also support post-accident recovery from off-normal or accident conditions that do not result in cask or canister breach but may have nonetheless caused fuel or structural damage to the contents. If the condition of the fuel is unknowable, opening the container for inspection and repackaging of the fuel may be necessary. Availability of a DTS capability to address the above-noted risks may also facilitate addressing public concerns and other siting considerations associated with licensing new facilities as well as for extending licenses for existing facilities.

2.1.2.4 Potential Incompatibilities with Future Requirements

UNF management strategies and applicable regulations will continue to evolve over an extended storage period of decades of perhaps even centuries. This could result in legacy packages that may not meet future storage and/or transportation requirements. Hence repackaging could be required in order to achieve compatibility with applicable regulations at the time of transport or disposal. An example of a repackaging need associated with evolving management strategies is the current situation with some UNF presently stored in packages that are not licensed for transportation.

Other envisioned uses of a DTS for repackaging could be to address potential incompatibilities with acceptance requirements at future facilities (e.g. disposal). The motive for repackaging based on this need is a subject of much debate. Some argue that design criteria can be imposed on the disposal system to ensure compatibility with existing UNF packages. Others argue that selection of a final disposal process should be unconstrained. This is a policy issue currently being explored by DOE and industry. Any repackaging for the purposes of achieving compliance with disposal criteria should not be undertaken until clearly defined and stable acceptance criteria are available.

2.1.2.5 Flexibility in the Long-Term Management of UNF

In addition to the above uses, a DTS that enables repackaging would provide additional flexibility in the long-term management of UNF. By providing a means to change the configuration of UNF packages, loading and storage or transport packages that may not be compatible with equipment or facility limitations at reactor sites becomes possible. This could be the case if a cask must be loaded that is not within the size or weight limitations of a facility or existing pool. Similarly, if needed, fuel within storage packages can be repackaged into a different cask for transportation. This could be needed if the desired transportation mode requires a smaller or larger cask or if the existing cask is not compatible with available transportation options.

UNF management strategies and technologies will continue to evolve over an extended storage period of decades of perhaps even centuries. This could result in management strategies and/or new storage systems that provide improved economic and/or safety advantages. Hence repackaging could be performed to take advantage such innovations.

The availability of a DTS increases UNF management flexibility by providing an option for repackaging when a pool is not available, as is the case for the present ISFSI-only sites. And, although wet transfers are an option for many repackaging needs, use of a pool for repackaging may overburden the demand on the spent fuel pool and the fuel handling equipment and conflict with other operational needs. In cases of repackaging of a compromised canister or cask, an operating utility may be opposed to the risks associated with reintroducing the damaged package to the pool. Concerns related to potential large scale contamination of the pool and associated equipment may provide sufficient justification to seek a DTS or other alternative recovery option.

Use of a DTS rather than a pool for any large-scale repackaging also has advantages of reduced radiological waste and personnel exposure as well as elimination of the temperature-related stresses associated with another submersion and drying cycle. Also, a DTS repackaging campaign would preclude the need to address the issue of drying adequacy with a diminished heat load associated with the additional decay time in storage. Further, after any re-drying there would be a new quantity of residual water: a fresh source to renew corrosion processes. Wet transfer of previously dry-stored fuel may be inadvisable due to the thermal cycling associated with immersion and the subsequent drying-process. This can change the material state of the fuel cladding and potentially bias the results for some RD&D material tests as well as reduce the structural integrity of the fuel cladding[k].

2.2 DTS Alternatives

Although there are many envisioned needs and potential uses for a DTS related to repackaging, development and implementation of a DTS, particularly for use at multiple sites, would be a complex and costly undertaking. Alternatives to dry transfer include use of a wet transfer process, overpacking, and developing other engineered solutions. Each of these is briefly discussed below.

2.2.1 Wet Transfer

RD&D needs related to extended dry storage essentially preclude returning UNF to the pool. Rewetting of the fuel and any subsequent drying will affect the fuel and cladding properties of interest. For repackaging-related needs, there are other options – including returning UNF to a pool, if available, for wet transfers. A wet transfer system for large-scale repackaging remains an option but would require conditioning and maintaining the water in the transfer basin and the installation and maintenance of a drying system.

Key advantages of using a pool are flexibility and adaptability to a range of equipment and conditions and the elimination of safety considerations relative to oxidation of UO_2. A 1988 EPRI report[l] concluded that use an on-site transfer system to go from smaller pool-loaded casks into larger storage or transport casks makes sense only if there is no reasonable possibility of upgrading the facility to allow loading the larger casks directly in the pool. Similarly, comments from industry reviewers indicated a preference for employing existing wet transfer processes where possible.

---

[k] Chu, H.C., S.K. Wu, and R.C. Kuo. 2008. *Hydride reorientation in Zircaloy-4 cladding*, Journal of Nuclear Materials, vol. 373, pp. 319-327.

[l] *Design Considerations for On-Site Transfer Systems*, EPRI-NP-6425, Electric Power Research Institute, Palo Alto, California.

Even for potential repackaging needs where a pool is not available, some have suggested that a 'quick pool' that could be assembled/installed at sites, if and when needed. A quick pool concept could consist of a pool of sufficient depth to accommodate the source cask and provide required shielding for cask lid and shield plug removal. It could be largely pre-fabricated and assembled on-site in a pit excavated for that purpose. Use of a fuel handling machine, shielding bell or a direct cask-to-cask transfer would cut the depth and volume needed for the pool by ~50% and may provide a lower cost and relatively adaptable option for responding to fuel transfer needs at sites without fuel transfer capabilities.

Studies performed for the Yucca Mountain Project (YMP) identified the hazards for both wet and dry transfer systems for the remediation and transfer of UNF[m]. The YMP analyses may be helpful in evaluating UNF transfer systems to support final disposal or any other large-scale repackaging effort.

2.2.2 Overpacking

For recovery or mitigation of events that affect only a small number of packages, the preferred option from a cost perspective may be to provide a means to stabilize the package, provide an overpack suitable for special mode transportation and move the package to a consolidated storage facility (CSF) or other site with appropriate remediation capabilities.

If the need for repackaging is the result of degradation affecting only the cask or canister, installation of an overpack may be an alternative to repackaging the fuel. When considering overpacks as a potential solution, attention should be given to the potential need for and feasibility of retrievability as well as any other limitations on future disposition as a result of the added material, weight, and size.

2.2.3 Other Engineered Solutions

A recent report from an NRC working group[n] included an observation that guidance documents which implement NRC regulations (e.g. NUREGs and Office Instructions) are often narrowly focused on current operational practices and may not be appropriate for future operations or designs. Much can change in terms of both available technologies and the regulatory framework over the time frames being considered for UNF storage.

In a recent address to the Institute for Nuclear Materials Management, Doug Weaver, Acting Director of the NRC Spent Fuel Storage and Transportation Division, pointed out that the uncertainty relative to the duration of UNF storage was beginning to strain the paradigm currently used to license storage and transportation casks. Weaver noted the existing paradigm regarding the role of cladding integrity in the safety basis for licensing current spent fuel and transportation cask designs. He spoke of the need to consider licensing bases that do not rely as heavily on maintenance of cladding integrity due to the uncertainty relative to material properties over extended time periods. He suggested that two basic approaches be considered in developing a new licensing paradigm – the first being a scientific approach that relies on sufficient technical data to eliminate sufficient uncertainty and the second being an engineered approach that addresses uncertainty by engineering around it.

Weaver identified several weaknesses associated with an approach that relies solely upon the ability to demonstrate that neither the canister nor the cladding degrade beyond a specified design limit and suggested consideration of an approach that assumes canister and/or cladding degradation and plans for

---

[m] *Internal Hazards Analysis for License Application*, 000-00C-MGR0-00600-000-00C, August 2005].

[n] NRC Memorandum from Thomas Matula to Jack R. Davis et al., Subject: Final Report – Plan for Integrating Spent Fuel Nuclear Fuel Regulatory Activities Working Group, September 28, 2011.

remediation and/or periodic repackaging if and when needed. He specifically noted that the future need for repackaging could be reduced or eliminated by relying on engineering features rather than on maintaining the integrity of the fuel cladding to ensure criticality safety and that an engineering approach that relies on canisters may also lessen the burden on cask designers and regulators to do extensive research on fuel cladding properties[o].

As an example of a possible engineered solution that may facilitate transportation of potentially compromised packages from distributed sites while simultaneously achieving standardization of transportation packaging, one might consider the following. Present cask cavity dimensions are typically limited by constraints associated with providing necessary structural protection and shielding while maintaining cask outer dimensions within transportation size limitations. Impact limiter dimensions are sized to ensure that structural loads transmitted to the cask and the fuel are within specified limits. Advanced materials and analytical methods as well as new design criteria such as the strain-based acceptance criteria currently under development for Section III, Division 3 of the ASME Boiler and Pressure Vessel Code provide significant opportunity for new transportation packaging designs. The strain-based acceptance criteria are applicable to the evaluation of hypothetical accident (energy-limited) conditions, such as drop events. Compliance with the proposed strain-based acceptance criteria is intended to provide assurance of a leaktight boundary, which can result in reduced impact limiter diameters. Further, the shielding needs will be considerably reduced following decades of storage, also allowing reduced shielding thickness. Reductions in impact limiter diameters and shielding thickness can provide for an increased cask cavity size. A transport cask with an increased cavity dimension could accept a cask insert that could provide several benefits including increased structural support, a reliable and standardized means of handling storage canisters, and, if needed, a complete additional inner containment boundary to enhance radiological and criticality safety by preventing both the release of radiological materials and the intrusion of moderator. Reductions in the impact limiter diameter alone may be sufficient for this added cask insert. This cask insert (inner containment) would also be able to utilize the proposed strain-based acceptance criteria for an efficient and functional design. If regulatory requirements related to fuel retrievability can be applied to retrieval of storage canisters rather than to individual fuel assemblies, this transportation packaging approach would likely be acceptable to the regulatory agency on a general design basis rather than a case-by-case. An added benefit of this approach is that the cask insert could be designed to adapt various storage canister designs to a standardized transportation cask – thus reducing costs associated with transportation and handling operations.

Other alternatives that could limit the need for repackaging include the design of special transport trailers or conveyances, tailored route selections, and/or additional administrative controls to reduce transportation risk. For limited and specific needs, developing justification for a license exception allowing transport to a more appropriate facility for storage and/or remediation may also be an option.

2.3 Site-Related Considerations

Although any of the potential needs discussed in section 2.1 could, in principle, arise at any of the locations where UNF is stored, the relative likelihood of the need, the associated operational requirements, and the available alternatives differ. Key distinctions relative to potential DTS needs at ISFSI sites, ISFSI-only sites, consolidated UNF storage site(s), and a disposal site are discussed below.

There are presently over 1500 loaded dry cask storage systems (DCSS) in the U.S. Of the UNF assemblies currently in dry storage, approximately 75% are in dual-purpose canisters, 13% in storage-

---

[o] Address given by Doug Weaver, Acting Director of Spent Fuel Storage and Transportation Division, U.S. Nuclear Regulatory Commission, 27th Spent Fuel Management Seminar, Institute for Nuclear Materials Management, February 2, 2012.

only canisters, and~12% is stored as bare fuel assemblies in bolted casks. About 2/3 of these bolted casks are currently licensed for transport[p]. This UNF is stored at 63 licensed ISFSIs, including eight stranded fuel sites, meaning that the power plants that have been or are being permanently shut down and the pools have been decommissioned. These are often referred to as ISFSI-only sites. Approximately 10% of the total UNF inventory in dry storage is presently stored at ISFSI-only sites.

Future UNF locations include one or more centralized storage facilities where UNF from existing ISFSI sites could be consolidated. The Blue Ribbon Commission has recommended that prompt efforts be undertaken to develop one or more consolidated storage facilities. And it is expected that UNF will eventually be received and handled at a disposal site or other facility for its final disposition.

Considerations relative to a DTS at the site of a fuel examination facility, to support RD&D needs, are also discussed.

2.3.1 At-Reactor ISFI Sites

A routine need for any of the dual purpose canisters to be opened at ISFSI sites is unlikely. The only foreseeable reason to open these canisters would be if there was an indication that the canister (confinement boundary) might be compromised. Due to the numerous ISFSI sites, UNF management strategies that would require a DTS at these sites should be avoided. The costs of multiple DTS facilities or the complexity and cost of designing a mobile DTS that could be deployed at these sites would be prohibitive. In the event that there is a need for limited repackaging or retrieval of fuel at these sites, it could likely be accommodated by the existing pools. UNF at ISFSI sites that is presently in storage-only packages could, for example, be transferred into dual-purpose canisters or transportable casks prior to decommissioning of the site pools.

2.3.2 ISFSI-only sites

ISFSI-only sites lack a pool and other infrastructure that are maintained at operating reactor sites. All UNF stored at current ISFSI-only sites is in dual-purpose canisters that can be transferred to the intended transportation casks using existing systems. Due to the limited number of these sites and the relatively small fraction of casks they store, an unplanned need for repackaging bare fuel is unlikely to arise at these facilities. However, due to the limited capabilities of these sites, stranded fuel at these sites has been identified to be ‘first in line’ for transfer to a consolidated facility. As long as fuel remains at these ISFSI-only sites, there remains a potential for a compromised package and the associated need for remediation and/or repackaging.

2.3.3 Consolidated Storage Facility

There are approximately 24 canister types and 8 transport cask designs along with 7 bare fuel dry casks in use today. A CSF would be the first common site to receive such a diverse range of packages. A CSF would receive and store UNF from multiple sites and eventually ship it to a facility for final disposition (i.e. disposal or reprocessing). Due to the much larger inventory and the potentially longer storage periods that could occur at a CSF, the likelihood of each of the potential needs identified in section 2.1 will be higher than at individual sites. Hence, the benefit of including a DTS and/or a wet repackaging ability will also be much higher. Repackaging UNF assemblies would likely be a core capability for a CSF site to reduce the diversity of package types and to enable the standardization of UNF handling

---

[p] Values regarding percentage of fuel in US in dry storage relative to various storage configurations are taken from StoreFUEL, Vol 13, No 165, May 1, 2012, page 31.

equipment downstream in the fuel cycle. The presence of both wet- and dry-transfer capabilities at the CSF would provide the greatest operational flexibility.

Prior to shipment from a CSF, inspection of storage casks/canisters is desirable and, depending on the duration of the storage period and future requirements, could be required. Inspection under water could limit the variety of inspection techniques that could be utilized. A DTS could also provide the platform for implementing new techniques such as UT- or eddy current-based examination systems to interrogate the canister and welds to make sure they have not degraded and are capable of meeting transportation and handling performance requirements.

Any repackaging that may be needed to address incompatibilities with future regulations or disposal criteria can be effectively accomplished at a CSF – where the economy of scale will make it much more feasible to implement a DTS with sufficient throughput, flexibility, and contingency to deal with the full range of potential needs. Also, as noted in the BRC recommendations, a CSF would provide an excellent platform for ongoing R&D to better understand how the storage systems currently in use at both commercial and DOE sites perform over time. A DTS would play an essential role in a CSF's ability to perform the necessary R&D functions. Lastly, the opportunity exists to integrate appropriate DTS capabilities directly into its design of a future CSF – thus enabling a much more elegant and efficient solution than what may be possible if the DTS is constrained by interfaces with existing facilities.

2.3.4 Final Disposal Site

UNF dry cask systems will also be consolidated at a final disposal site. The location, design, and schedule of final disposal sites are not presently known. The overall UNF management strategy and the timing and progress of licensing a repository will be a key factor in determining if and how much fuel will be repackaged at a disposal site. Costs and risks associated with transportation as well as construction and operation of the repackaging process will be factors in determining whether any repackaging would be done at the storage site or the disposal site

The primary motive for repackaging at a disposal site would be to transfer UNF into packages in order to meet disposal requirements. For both economic and transportation safety reasons, there has been a trend toward larger capacity storage and transport casks. However, repository heat load restrictions may ultimately lead to a lower capacity for the disposal waste package. The allowable thermal loading will depend on the specific geologic formations of the repository. For instance, a salt formation may have a capacity of only 4 PWR (or 9 BWR) assemblies while volcanic tuff repository may accept packages containing 21 PWR or up to 44 BWR assemblies[q]. It should be noted that, as storage durations are extended, the heat generation rates of the fuel will decrease, potentially increasing the allowable UNF assemblies per disposal package.

Other drivers for repackaging at a disposal facility include standardization of packaging and the potential remediation of any damage that may have occurred during transportation to the site or during handling at the site. Both wet and dry options could be incorporated into the design and be available for any repackaging needs at the disposal site. It is unlikely that other alternatives resulting in a non-standard disposal package (i.e. overpacking or license exception) would be employed.

---

[q] *Generic Repository Design Concepts and Thermal Analysis,* FCRD-USED-2011-000143 Rev 0, August 2011

2.3.5 Fuel Examination Facility

Limited quantities of commercial UNF are also stored at the Idaho National Laboratory (INL). This includes 21 assemblies from the Surry reactor, one of which was used to support RD&D conducted in 1999 and early 2000. It has been proposed that some of this fuel be re-examined in order to assess the effects of another ~15 years of dry storage and also to evaluate the impacts of storage in a package that has lost its inert environment. The original Surry assemblies are at the INL in a CASTOR V/21 cask and rods that were removed for the previous examinations are stored in an REA-2023 cask. Both of these casks are larger than can be accepted at the INL's hot fuel examination facility (HFEF). In the past, fuels were transferred from larger casks into HFEF-compatible casks using the test area north (TAN) hot shop. Because this facility has since been decommissioned and is no longer available, a different dry transfer process must be developed to enable fuels from these casks to be retrieved and transferred to an HFEF-compatible cask. The INL is presently evaluating available options for a dry transfer process to retrieve and transfer fuel from these and other commercial casks into the HFEF for examination.

Development and implementation of a dry transfer process to enable fuels to be retrieved from these casks and transferred into the HFEF will establish a process that may be adapted for use for transferring high burnup and other UNF into the HFEF to support current other identified RD&D needs.

2.4 Summary of Potential DTS Needs and Uses

As noted above, there are several potential DTS needs and uses. Many can be accommodated by wet transfers, overpacks, and other engineered solutions. And the relative importance of each of these needs is a function the available options, and the perceived cost-benefit ratio of developing and implementing the necessary DTS capability. A summary of identified needs and their relative importance is given below in Table 2-1.

Table 2-1. Summary of DTS Needs.

Potential Need for Dry Transfer Capability	Operating Reactor Sites	ISFSI-only Sites	CSF Site(s)	Final Disposal Site	Fuel Examination Facility Site
Research, Development, and Demonstration					
Transfer fuel into examination facility	NA	NA	NA	NA	high
Retrieve and Inspect Fuels from DCSS	low	medium	medium	NA	high
Repackaging					
Standardization of Packaging	NA	NA	medium	NA	NA
Planned Periodic Repackaging	NA	NA	medium	NA	NA
Mitigation and/or Recovery	low	medium	medium	medium	NA
Incompatibilities with Future Requirements	low	NA	medium	medium	NA
Flexibility for long-term UNF Management	low	NA	medium	NA	NA

Legend
Need for a DTS not anticipated
transfer capability is essential and no other practical options
other options available but DTS may be preferable
other equivalent or preferable options available

The summary table suggests that near-term efforts be focused on development of a DTS to support dry transfer of fuels needed for RD&D at the site of the fuel examination facility. Other strategies suggested by the summary table support the conclusions that any necessary transfer capabilities should be identified and integrated into the design of a CSF and for making ISFSI-only sites 'first in line' for transfer to a CSF or disposal facility when available.

3. Distributed ISFSI sites vs. Consolidated UNF Storage

There is currently no defined path forward for present and future UNF stored at ISFSIs located throughout the country. A change in this situation will require considerable and sustained political will to achieve and maintain sufficient cooperation among various political entities. In addition a long-term financial commitment to a national strategy will be required. Therefore, it is prudent to assume that UNF storage will remain distributed for the foreseeable future. Aging UNF stored at several sites across the country and in diverse storage packages and configurations establishes one set of conditions for which a DTS capability may be needed. However, although many of the potential DTS needs and uses would be similar, the conditions under which a DTS may be deployed would be substantially different if implemented at a CSF.

Following DOE's request for withdrawal of the license application for the repository proposed for the Yucca Mountain site, Secretary Chu appointed a Blue Ribbon Commission (BRC) on America's Nuclear

Future to re-evaluate the options and to recommend a path forward. The BRC completed its work and issued eight recommendations in January 2012[r]. Among these recommendations were the following:

- Prompt efforts to develop one or more consolidated storage facilities.
- Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.

The fate of these recommendations will significantly impact the context for development and implementation of a DTS capability. DOE is currently preparing responses and plans to address the BRC recommendations. At present, there is broad support within DOE and industry for implementation of these recommendations. If a CSF is implemented in a timely fashion, the potential need for a DTS at distributed ISFSI sites could be substantially reduced. However, there are considerable legal and financial challenges yet to be overcome, including an inventory of over 1500 DCSSs (and growing) that would need to be transported. Therefore UNF is likely to remain at its present storage locations for many more years.

Although the potential uses and needs for a DTS would be similar if implemented at a CSF, their importance and relative priority may change significantly. For example, any needed DTS capabilities could be incorporated directly into the design of a CSF rather than being constrained by requirements associated with retrofitting an existing facility. A repackaging capability at a CSF would also significantly reduce the perceived need for deployable mobile equipment that could address unplanned events at ISFSI sites. Further, a consolidated facility would open the possibility for pools to support UNF transfers, a large cell that could support direct cask-to-cask transfer, and other strategies that may not be practical or even feasible at multiple ISFSI sites. For example, a UNF consolidated storage facility would enable alternate packaging strategies such as storing the fuel as bare assemblies (shipped directly from reactor sites as bare assemblies) in pools or dry vaults where it could be easily monitored and inspected. The assemblies could then be packaged at a future date when packaging requirements and disposal criteria are clearly defined. This would support the ‘package once’ objective without having to guess at future requirements. It would also ensure that packages are able to take advantage of the latest technology and can be designed to address future policy and stakeholder considerations. The designer can also take credit for any decay to design for actual heat loads at the time of future packaging, and the packaging will be in a fresh condition at the time of transport, handling, and disposal.

However, one or more consolidated storage facilities would not completely eliminate the potential needs for a DTS. Although some of the envisioned DTS needs and uses could be postponed and more effectively addressed at a future consolidated facility, others are related to our present situation with distributed ISFI sites. For example, a DTS may still be needed to enable repackaging of fuels presently stored in casks that may not be suitable for transport if there is no pool available or if the pool or pool equipment is not compatible with the new packaging. Further, the timing of a CSF is a factor as it is expected that fuel retrieval of dry-stored fuels will be needed to support RD&D well in advance of a consolidated storage facility. Lastly, the potential for needing a DTS to support recovery from an unplanned condition or event at existing ISFSI sites cannot be dismissed as long as they continue to store UNF. The Fukushima accident and the recent overhaul of the NRC’s emergency planning rules may lead to renewed public interest in severe accidents at these facilities as it has for other nuclear facilities[s].

---

[r] Blue Ribbon Commission on America’s Nuclear Future Report to the Secretary of Energy, January 2010. brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf

[s] Federal Register Volume 77, Number 83 (Monday, April 30, 2012), pages 25375-25378, From the Federal Register Online via the Government Printing Office [www.gpo.gov][FR Doc No: 2012-10314.

Hence, if the BRC recommendations are to be implemented, it is recommended that dry and/or wet transfer capabilities be integrated into the new facility to enable repackaging (if and when needed) and to focus current efforts on development of a limited-scope dry transfer capability to support retrieval of fuels for RD&D.

4. DTS Requirements

High-level general requirements applicable to any system handling UNF can be identified including regulatory, functional and performance requirements. Any DTS must comply with the applicable regulatory requirements as discussed in section 4.1. Section 4.2 presents some generic functional requirements that describe *what* capabilities any DTS must have. However, specific functionality depends upon why, when, where, how, and a number of other questions related to specific DTS objectives and constraints. Some key questions to help define specific functional and operational requirements are discussed in section 4.3. General system performance requirements further define *how* the DTS performs those functions are discussed in section 4.4.

4.1 Regulatory Requirements

Although the regulatory framework is evolving, a DTS at a licensed ISFSI would be required to be licensed by the NRC under 10 CFR Part 72 and should also be readily licensable under 10 CFR Part 50 for deployment at reactor sites. 10 CFR 20 and the ALARA principle are also applicable. Some uses of a DTS could require consideration of 10 CFR Part 71 Certified Transportation Cask System Requirements as well as 10 CFR Part 60 Disposal of High-Level Radioactive Wastes in a Geologic Repository. The specific sections of these regulations that would be applicable may vary according to the specific use of the DTS.

The NRC has issued a number of security orders that contain additional requirements beyond those required by current NRC regulations. Some of these requirements were in response to the September 11 terrorist attacks and others reflect additional security enhancements resulting from the NRC's ongoing comprehensive security review. These orders include: Power Plant Security Orders; Decommissioning Reactor Security Orders; Fuel Cycle Facility Security Orders; Spent Fuel Facility Security Orders; and Possession and Shipment of Spent Nuclear Fuel Security Orders. The potential impact of these orders will have to be reviewed and assessed based on the specific use of the DTS.

NUREG-1567, Standard Review Plan (SRP) for Spent Fuel Dry Storage Facilities, includes guidance specific to dry transfer. The dry transfer system should ensure that fuel cladding (zircalloy) temperature will not exceed 570°C (1058°F)[t]. ISG-11[u] provides further guidance that the temperature should be limited to 400°C for normal conditions and short term operations and that the570°C limit applies to off-normal and accident conditions. ISG-11 also allows for, with justification, exceeding the400°C during normal and short term operations and limits for thermal cycles during loading/drying operations. The NRC also offers guidance on handling bare fuel in ISG-22, recommending precautions such as use of an inert cover gas to avoid gross oxidation of fuel (with breached cladding) in air.

---

[t] NUREG-1567 also notes that the short-term off-normal and accident temperature of 570ºC (1058ºF) for zircalloy-clad fuel assemblies is currently accepted as a suitable criterion for fuel assembly transfer operations but points out that this limit may be lowered for high burnup fuel assembly (e.g., greater than -28,000 MWD/MTU) due to increased internal rod pressure from fission gas buildup.

[u] Spent Fuel Project Office, Interim Staff Guidance-11, Revision 3.

4.2 General Functional Requirements

The primary interface for any DTS is with a transporter which moves the UNF canisters and casks to and from the transfer facility. The two primary DTS functions are to retrieve fuel for inspection and to transfer fuels into another package configuration and prepare it for storage or transportation. These two top level functions, along with an ability to place a cask or canister in an overpack, encompass all of the potential needs described in Section 2. These functions can be further broken down as follows:

1. Interface with on-site transporter to accept source container (canister or bolted cask) and to deliver completed package (i.e. original container, overpacked container, or new canister)
2. Inspect cask/canister
3. Overpack a cask or canister (if inspection determines an overpack is all that is needed)
4. Opening cask/canister (both bolted and welded containers)
5. Verify and retrieve designated UNF[v] from specified location in cask/canister
6. Provide for remote inspection of fuel assembly
7. Place UNF into designated location and verify (i.e. back into same or into new cask/canister)
8. Backfill with inert gas, close and inspect cask/canister (both bolted and welded containers)
9. Disposition excess packaging materials and any wastes generated during the operation

These general DTS functions are illustrated in Figure 4-1 as a block flow diagram. Steps 2 and 3 provide added functionality for recovering from events or conditions that affect only the storage cask and/or canister. All other steps apply to any DTS.

Various implementations of this generic DTS process will differ in operational requirements and other site-specific constraints (e.g. the range of casks/canisters that must be accommodated, the condition of the fuel that must be handled, the required throughput capacity, site infrastructure, mobility requirements, etc.).

---

[v] UNF to be transferredmay include bare assemblies, canned assemblies (i.e. damaged fuel cans). And specimens supporting RD&D activities.

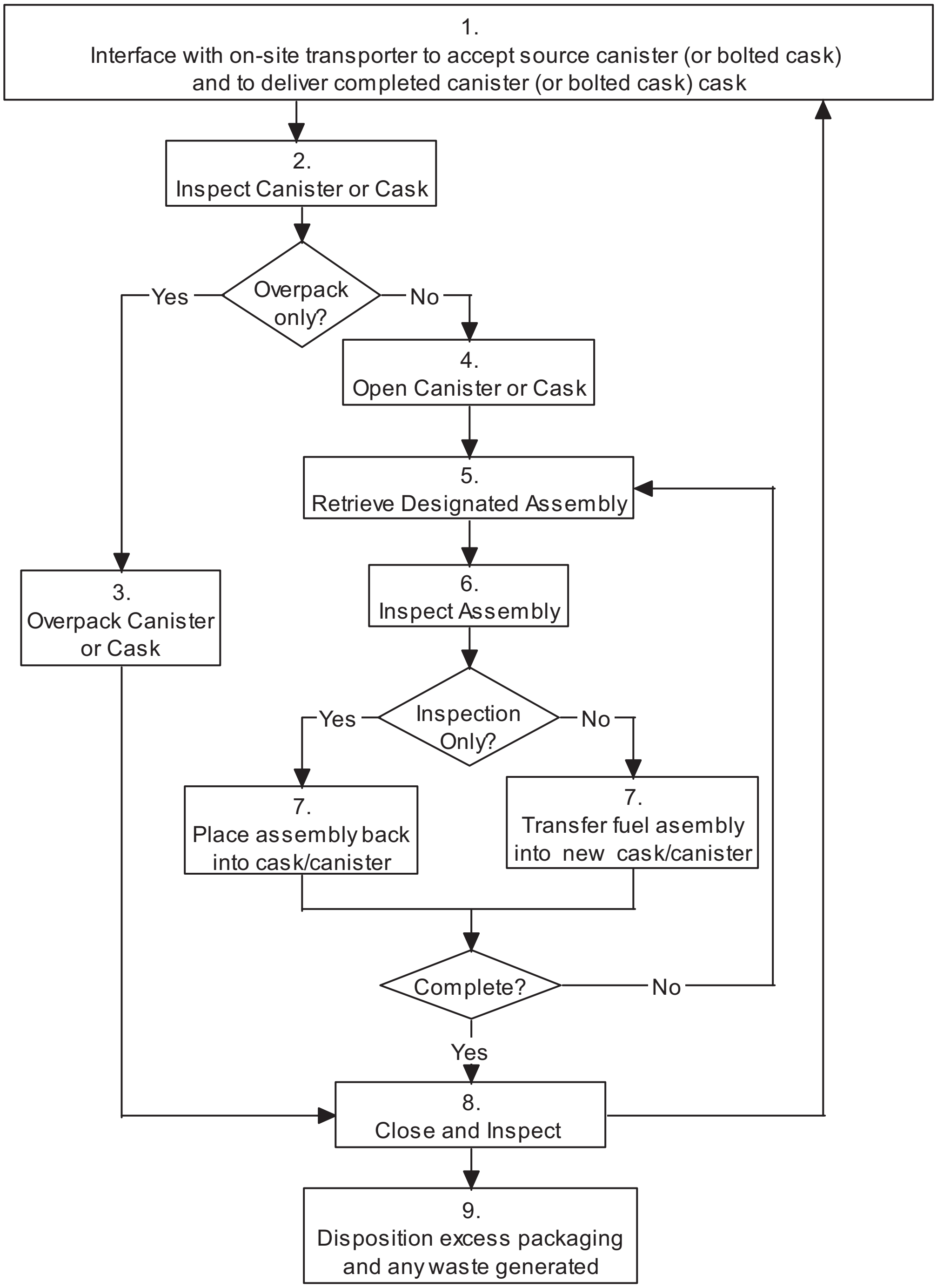

Figure 4-1. Generic DTS Functions

Because the actual condition of the fuel will be unknown prior to exposing the fuel, a DTS must consider the possibility of fuel damage. Of particular concern for any DTS is the need to prevent unacceptable oxidation of UO_2 fuels during the dry transfer process. With sufficient time and temperature, there is a concern that oxidation of UO_2 to U_3O_8 and the attendant swelling of the fuel pellet could cause the cladding to split, further exposing the UO_2 pellet(s) and leading to additional oxidation and eventual unzipping of the clad. This is prevented if the fuel pellet is not exposed. However, because one of the key functions of a DTS is to inspect and evaluate fuel condition following extended storage[w], it is not reasonable to presume no cladding breach. Hence, this hazard must be managed by either eliminating the oxidizing atmosphere, and/or by assuring sufficient heat dissipation to maintain temperatures below thresholds where unacceptable oxidation can occur and by limiting transfer times. At temperatures above ~250°C, fuel exposed to air will begin to oxidize. The rate of oxidation increases with temperature. This oxidation process, its potential consequences during dry fuel handling, and the means for its prevention and/or mitigation were addressed in a *Commercial Spent Nuclear Fuel Handling in Air Study*[x] performed to support YMP design.

Equipment compatibility is a driver for determining the requirements for "interfacing" with the existing storage and/or transport cask systems. Due to the evolution in UNF storage and transport technologies, management strategies, and regulatory framework that could occur over long storage durations, development of a generic interface for all potential on-site transporters may not be practical. However, as DCSSs are designed and licensed, the equipment necessary to handle the various components is also provided. The DTS interface should be designed as a modular system that can be easily adapted to the range of present and future cask and canister designs.

4.3 Specific DTS Uses

Selection of a pathforward for development of an appropriate DTS capability depends on its envisioned uses. Not all of the DTS uses described in section 2 are equal in terms of their likelihood or the relative value of a DTS as the design solution to address the scenario. The scenarios under which a DTS could be utilized can be illustrated using a tree structure with branches for each of the key questions related to the potential need – 'why, when, where, how much, and what?' These decisions are discussed below and shown at the branch points of Figure 4-2.

> Decision 1: Why? A DTS could be needed to address either planned or unplanned needs. Planned needs could include repackaging to assure compatibility with future transport requirements or disposal criteria or to retrieve and inspect fuels to support RD&D or to verify fuel condition to support licensing for continued storage or post-storage transportation of UNF. Unplanned needs would include responding to either an unplanned event that compromises a storage package or the discovery of an unforeseen condition that jeopardized the safety functions of the existing package.
>
> Decision 2: When? A DTS could be needed in the near term (i.e. within ~10 years) or longer-term. A near-term DTS need is to support RD&D by enabling transfer of commercial fuel assemblies into an examination facility without rewetting the fuel. This RD&D work is needed to support relicensing of storage facilities for high burnup fuel and its eventual transportation as well as the successive relicensing of storage facilities for both high and low burnup fuel. There are no other identified near-term planned needs for a DTS. A longer term unplanned need could result if there is a future need to repackage UNF due to unforeseen degradation or changes to storage or transportation requirements.

---

[w] A similar argument applies for use of a DTS for period fuel inspections or for responding to an unplanned condition or unforeseen event.

[x] *Commercial Spent Nuclear Fuel Handling in Air Study*, 000-30R-MGR0-00700-000-000, March 2005.Prepared by Bechtel SAIC Company, LLC for the U.S. Department of Energy Under Contract Number DE-AC28-01RW12101, March 2005

Decision 3: Where? At present, identified RD&D needs cannot be met because existing fuel examination facilities cannot receive and unload existing commercial storage casks. So, unless the appropriate RD&D fuels can be stored and transported in a smaller cask (e.g. NAC LWT or NLI cask), a dry transfer capability will be needed at the site of the fuel examination facility. For other planned or unplanned needs, a DTS could be needed at a single location such as a CSF or disposal site, at multiple known sites, or at one or more unknown sites if and when the need arises (denoted by a '???' in Figure 4-2).

No repackaging, planned or unplanned, is expected to occur at multiple known sites. The only foreseeable needs that could affect multiple sites would be age-related degradation of packaging -- and a CSF or other disposition path is expected to be available before this need occurs. Further, all UNF at ISFSI-only sites is in dual-purpose canisters so repackaging is not expected at existing ISFSI-only sites. UNF in storage-only packages at current ISFSIs would likely be repackaged into transportable casks before decommissioning of the existing pool.

Following extended storage, planned repackaging at a limited number of sites is plausible as is unplanned repackaging at either a consolidated site or at limited sites that may be experiencing problems (e.g. higher corrosion rates or other identified risks). Any planned large-scale repackaging is expected to occur at a CSF or disposal site. The option to opportunistically retrieve fuel for RD&D purposes any time a canister requires repackaging is a desirable function that should be considered when implementing a DTS at a CSF.

Scenarios that would result in unplanned repackaging (e.g. unplanned events or unforeseen conditions) would not be expected to occur at multiple distributed sites. In the event of a recovery from an unplanned event or condition, the site where a DTS could be needed would not be known in advance – resulting in a need for a mobile or deployable DTS.

Decision 4: How Much? A DTS to address a limited and specific type of fuel package is much less complex than a DTS to facilitate large-scale repackaging. A DTS for limited use for a specific package type might be achieved by modifying existing facilities to address prescribed needs or by using direct cask-to-cask transfer methods. The complexity and expense associated with design features for high throughput capacity and for or for minimizing radiological waste and exposure would be less important for a DTS used infrequently.

The identified RD&D need for a DTS to enable transfer of fuel specimens into an examination facility would have clearly defined requirements in terms of the casks, fuels, and facilities that must be accommodated. Its use would be relatively infrequent as its envisioned use is for transfer on only an assembly or two every ~10 years.

A DTS need at a single CSF or disposal site is also plausible to support recovery from an unplanned event or to enable repackaging for standardization, to renew aging packaging, or to change package configuration to achieve compliance with future regulations or acceptance requirements at a future disposal facility.

If UNF is not relocated to a CSF in a timely manner, a DTS need could arise at unforeseen locations.

Decision 5: What? This decision is not included in Figure 4-2 as it multiplies the branches beyond what can be reasonably shown. This decision includes things such as the cask and canister types that must be addressed along with specific fuel types, configurations and conditions. The branches and nodes resulting from these decisions are numerous and not particularly helpful at this stage of the DTS evaluation. It is prudent to presume that the DTS must address all existing fuel and package types that will be in existence at the time of need.

For the immediate RD&D need, these decisions can be made based on identified RD&D needs and currently available fuels, equipment, and facilities.

After constructing the tree shown in Figure 4-2, a qualitative assessment of likelihood was performed for each decision outcome. Three categories were used for the qualitative evaluation – expected, plausible, and not expected. These are color-coded as green, orange, and red, in Figure 4-2. Based on this assessment, only the RD&D DTS need (scenario A) is expected. And, because it is expected in the near term and can be implemented by a limited-use DTS capability with well-defined operational requirements at a single site, the associated design requirements should be identified and a project is recommended to proceed with development and implementation of a DTS capability to meet this need.

Five other scenarios were considered plausible, none of which are expected in the near term. These five scenarios are briefly discussed below.

G: This scenario would utilize a DTS capability that was planned and integrated into the facility design to recover from an unplanned condition or event at a consolidated facility.

H: This scenario would utilize a DTS capability that was planned and integrated into the facility design to enable large-scale repackaging as needed to meet regulatory or disposal requirements or as part of a planned periodic repackaging campaign.

S: Similar to scenario G, but without an integral DTS function designed into the facility, a system to respond to the unplanned event or unforeseen condition would be designed and implemented if and as the needs are identified.

U: This scenario acknowledges that, if UNF remains at distributed sites for extended periods, repackaging will eventually be required.

V: This scenario acknowledges that the previous scenario requiring limited repackaging will eventually affect all packages at all sites.

Scenarios G and H are addressed by including a repackaging and remediation capability into the design of a CSF. Scenario S is precluded by inclusion of these capabilities. Consequently, the capability for dry and/or wet repackaging to support recovery, standardization, or other potential repackaging needs is recommended for inclusion in the design requirements for a CSF and/or the final disposal site.

The specific functional requirements associated with scenarios U and V vary considerably and are large cost drivers (e.g. mobility to address the unknown location of the need, types of casks /canisters to be handled, heat dissipation and other safety considerations, the needs for handling damaged packages and/or fuel, etc.), it is recommended that these scenarios be avoided. Because the likelihood of these scenarios is positively correlated to the duration of storage at distributed sites, the UNF management strategy should seek to relocate UNF to a CSF as quickly as reasonably achievable. However, because there are no postulated mechanisms that would result in this need in the near term, an activity that identifies key transport-limiting system parameters and examines alternatives to repackaging may offer other options for transport of potentially compromised packages from distributed ISFSI sites, if needed. This activity would also help to suggest risk-mitigation strategies, to identify time constraints, and to inform schedules for UNF transportation from distributed storage sites. Section 2.2 provides a brief discussion of some potential alternatives to be considered.

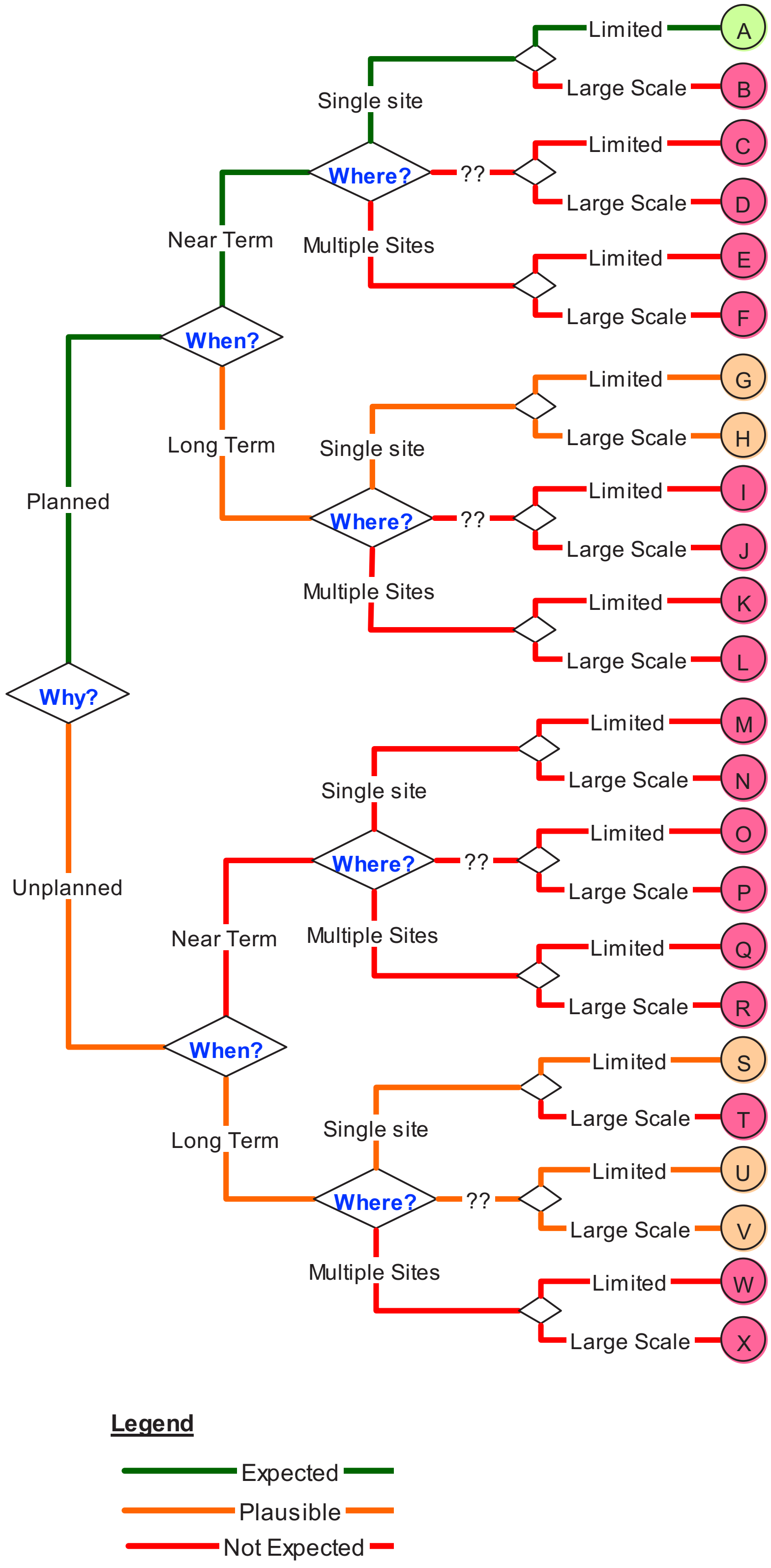

Figure 4-2. Options Tree Identifying Potential DTS Uses

5. Review of Existing DTS Designs

Development of a DTS is not a new idea. Several DTS designs and related concepts have been put forward over the past few decades. Several have been built and are in operation for specific applications. These DTS designs can be binned into three broad categories – direct cask-to-cask transfers using a mating collar or flange between the casks, use of a fuel handling machine or other shielded volume for transferring the fuel between casks, and transfers that take place within a shielded cell.

Direct cask-to-cask transfers rely on the shielding provided by the source cask and the receiving cask rather than a shielded enclosure or cell. This requires that the casks be mated end to end and that a means be available for transferring the fuel while in this configuration (e.g. removable heads on both ends of the receiving cask and a retractable tool to reach through) as well as a means for securing the fuel in the receiving cask during the unmating and cask lid installation process. A direct cask-to-cask transfer process has limited throughput capacity and limited ability for reconfiguring the fuel package during the transfer. As such, this is not expected to be a reasonable approach for any large scale repackaging. It could however, be lower cost and have sufficient capacity to support RD&D needs. These systems are relatively versatile as they impose minimal requirements on the host facility, relying on the cask and other relatively mobile equipment for shielding and operational support. A direct cask-to-cask transfer system may also have value as a contingency for responding to unplanned events or conditions.

Similar to direct cask-to-cask transfers, there are systems that rely on a fuel handling machine or shielding bell. These systems impose minimal requirements on facility infrastructure, may be portable, and would have limited throughput capacity. This type of system however does not require that the receiving cask have removable heads on both ends. And it also may offer more design flexibility for inclusion of an indexing mechanism for aligning to retrieve and emplace a fuel assembly from/to a specific location within the cask.

To achieve throughput rates needed for any large-scale repackaging effort as well as to minimize the associated radiological exposure and waste generation, an in-cell based system should be considered. An in-cell DTS also provides additional opportunities and capabilities for inspection and monitoring of fuels and cask internals. An in-cell DTS is likely to be justifiable only at a consolidated storage location, disposal site, or other facility with the necessary infrastructure and support systems.

Appendix A includes several examples of existing and proposed DTS capabilities, each tailored to specific needs. None of these designs, as presently configured and used, will meet all of the envisioned needs. However, in addition to providing some lessons learned, they illustrate that equipment and processes needed meet a range of envisioned DTS needs are available and/or can be achieved with existing technology.

6. Conclusions and Recommendations

There are several potential applications for a DTS that can be broadly binned into two categories – 1) to retrieve fuel to support RD&D needs and 2) to repackage fuels. Repackaging may become necessary for a variety of reasons including standardization of packaging, recovery from an unplanned event or unforeseen condition, planned periodic repackaging to replace aging canisters or packaging components, and/or repackaging to resolve incompatibilities with future storage, transport, or disposal requirements.

Recommendation 1: For the RD&D needs, a project should be initiated to evaluate available DTS options, select a path forward, and proceed with conceptual design.

With the exception of the RD&D needed to support relicensing of UNF storage facilities for extended periods, all other potential needs are relatively unlikely and/or have other available alternatives. Because UNF can be loaded wet, dried, and stored using standard commercial equipment, RD&D needs can be addressed by a limited-use DTS capability with well defined operational requirements and implemented at the site of the fuel examination facility. Several dry transfer systems are currently in operation to meet specific needs and others have been proposed and/or designed (see Appendix A). A review of these systems indicates that a DTS for limited use to support identified RD&D needs is achievable by modifying existing INL processes and facilities.

Recommendation 2: A repackaging and remediation capability should be integrated into the design of future facilities where UNF will be consolidated.

A key objective is to ensure that UNF is transported to its final destination, or a destination with the necessary repackaging capabilities, before the need for repackaging arises. Although presently small, the likelihood of the need for a DTS to enable retrieval of UNF for inspection or repackaging will increase as the duration and quantity of fuel in dry storage increases. Stored fuel will eventually require remediation and/or repackaging for transport. Any large-scale repackaging operations that may eventually be necessary can be more safely and effectively conducted at a consolidated facility.

A review of available and proposed DTS technologies (see Appendix A) confirms that dry transfer systems to meet a number of needs are achievable with existing technology. However, a generic DTS to accommodate a range of potential needs and canister designs and to be deployable at multiple sites will be costly with only modest prospects for return on investment.

The relative costs and benefits of including a dry and/or wet transfer process should be considered when developing functional and operational requirements and specifying associated design criteria for future UNF facilities such as a CSF or disposal site. Design concepts for these consolidated facilities should address the operational flexibility needed to accommodate scenarios such as beyond design-basis accidents requiring remediation, regulatory changes, and future system compatibility.

Recommendation 3: RD&D activities should initially focus on identifying the key transport-limiting system parameters and developing alternative means for addressing these conditions and/or mitigating their effects.

Fundamentally, the U.S. should assume that UNF will be moved before the ability to transport is lost. Timely UNF transport reduces the risk with storage at dispersed locations without the financial burden associated with repackaging (either wet or dry).

To fully benefit from repackaging and remediation capabilities at a centralized facility, the UNF management strategy must ensure that packages are transported before repackaging becomes necessary. Hence, key needs are to understand the timeframe wherein all UNF can be confidently transported without repackaging and also to identify alternative approaches that may enable transport of potentially compromised packages without the need for repackaging. Alternatives may include remediation techniques such as repairing or overpacking compromised packages, and development of other engineering and/or regulatory approaches (see section 2.2).

> *This activity will help identify time constraints and inform schedules for future UNF facilities and transportation systems.*

Lastly, because both DOE and industry have a shared stake in each of the above recommendations, it is suggested that a dialog be pursued between the two in order to achieve consensus on the identified DTS needs and recommendations, to clarify associated roles and responsibilities, and to coordinate related efforts.

Appendix A

Existing and Proposed Dry Transfer Systems

Commercial Cask-to-Cask Dry Canister Transfer

Commercial storage and transportation vendors such as Nuclear Assurance Corporation (NAC), Transnuclear, Holtec, and Energy Solutions have developed and licensed dry transfer systems to enable canister-based storage systems to transfer fuel-loaded canisters between the pool, drying station, storage cask, and transport cask. These systems rely on a transfer cask that can accept the fuel-loaded canister and then transfer it to the designated storage and/or transportation cask. Although these dry cask-to-cask transfers are not presently capable of handling bare fuel assemblies, the equipment and principles that would be involved are similar.

Conceptual design work has been done by NAC, and potentially others, for integrating an indexed turntable system into the mating collar between the casks in order to allow a designated fuel assembly in the source cask to be retracted into the specified location in the receiving cask. This concept or other appropriate methods could be developed to enable a direct cask-to-cask transfer of bare fuel assemblies.

NAC International[y]

NAC has designed, fabricated, tested and operated a variety of systems for dry transfer of spent nuclear fuel into shipping casks from facilities with limited crane capabilities. The most recent NAC DTS consists of a transfer cask with integrated fuel canister grapple, fuel canisters, facility and cask adapters, and other related tools and equipment. The transfer cask is used to move irradiated HEU and LEU materials test reactor (MTR) fuel where dimensional, weight, or other restrictions prohibit direct loading or unloading of the shipping cask. The transfer cask is used to move canisters of fuel from the fuel storage location to the shipping cask.

When using a DTS loading approach, NAC first prepares the shipping cask for receiving fuel canisters by dry transfer. The fuel canisters are then loaded with fuel and retracted into the transfer cask, which is then moved to the shipping cask. The loaded transfer cask is then used to transfer the fuel canister into the shipping cask. Adapters ensure proper interfacing of the transfer cask with fuel storage locations and NAC shipping casks. Site and equipment-specific adapters can be developed to allow interfacing with virtually any storage facility.

The NAC DTS has been used with research reactor and MTR fuel assemblies in many countries, including direct cask-to-cask outdoor transfers, and have also proven to be effective for transferring fuel to and from spent fuel pools, dry storage and hot cell facilities, and spent fuel transport casks.

Savannah River Site Shielded Transfer System

The L-Basin lacks sufficient water depth to handle the length of typical truck transportable casks requiring the installation of alternate capability. A shielded transfer system is used to facilitate remote and automated unloading of spent fuel transportation casks at the SRS L-Basin. The system provides features for shielding of personnel, remote monitoring, and automated operation.

U.S. Naval Rail Cask Loading and Unloading

The US Navy uses a dry transfer system to support defueling ships and transfer of UNF to rail casks. Nearly 600 shipments have been made with no significant problems. A bottom-loaded fuel-handling machine is used to retrieve the spent fuel, then lifted by overhead crane from the ship and positioned over

---

[y] http://www.nacintl.com/drytransfer

the shipping cask. The UNF is transferred into the rail cask through an adapter collar and an off-center hole in the rail cask lid. This lid is rotated such that the offset hole can be indexed to fill each position in the cask.

After shipment, the cask is unloaded using a similar fuel-handling machine at the storage site[z]. The fuel handling machine includes an indexing mechanism that allows removal of the fuel from the shipping cask one at a time by drawing the fuel from the cask into a shielded volume. The fuel module is then discharged into a receiving receptacle in the water pools.

Idaho National Laboratory CPP-749

The CPP-749 facility is a UNF storage facility containing 218 underground fuel storage vaults. Vaults, constructed of carbon pipe embedded into the ground, include features to test seals, manage moisture, monitor temperature, and sample the atmosphere. Shielding above the vault is provided by a removable concrete shielding plug.

UNF can be transferred to and from CPP-749 vaults and other locations within INTEC using a Peach Bottom cask. The Peach Bottom cask has both a top and bottom lid. It is mated to a CPP-749 vault by use of a mobile crane and a cask centering device. Fuel is lowered into and retracted from the vault by a fuel handling system consisting of a number of lower lift rods fabricated for use with specific fuel packages and two upper lift rods that connect the lower lift rods to a lifting bail. The cask is supported by the cask-centering device which maintains alignment and provides other operational features such as inspection ports for remote cameras or tools to provide assistance to workers during fuel-handling activities. The base is equipped with rails to support a trolley with a hydraulic lift table for support installation and removal of the centering ring and the cask bottom lid.

A schematic of the CPP-749 Dry Transfer System is shown in Figure A-1 below. Design and operational details are further described in CPP-749 design description documents[aa].

It may be possible to adapt CPP-749 equipment and processes to enable a dry transfer from a larger storage/transport cask to a smaller cask capable of mating with the INL's hot fuel examination facility (HFEF). If the larger storage/transport cask has removable lids on both ends, fuel could be transferred from the larger cask into the CPP-749 vault and then from the vault into a smaller cask. As an alternative, if the larger commercial cask were placed into a drywell, it may also be possible to adapt equipment and procedures used for the CPP-749 underground fuel storage vaults to transfer fuel directly from the commercial storage cask into the PeachBottom cask. The fuel in the PeachBottom cask could then be transferred into an HFEF-compatible cask in the IFSF fuel-handling cave without the need for facility modifications.

---

[z] Department of Energy Programmatic Spent Nuclear Fuel Management and INEL Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, Volume 1, Appendix D, DOE/EIS-0203-F, April 1995

[aa] CPP-749 Cask-Centering Device, System Design Description, SDD-71, Rev. 7, December 17, 2009; and
CPP-749 Fuel Handling System, System Design Description, SDD-135, Rev. 3, December 17, 2009.

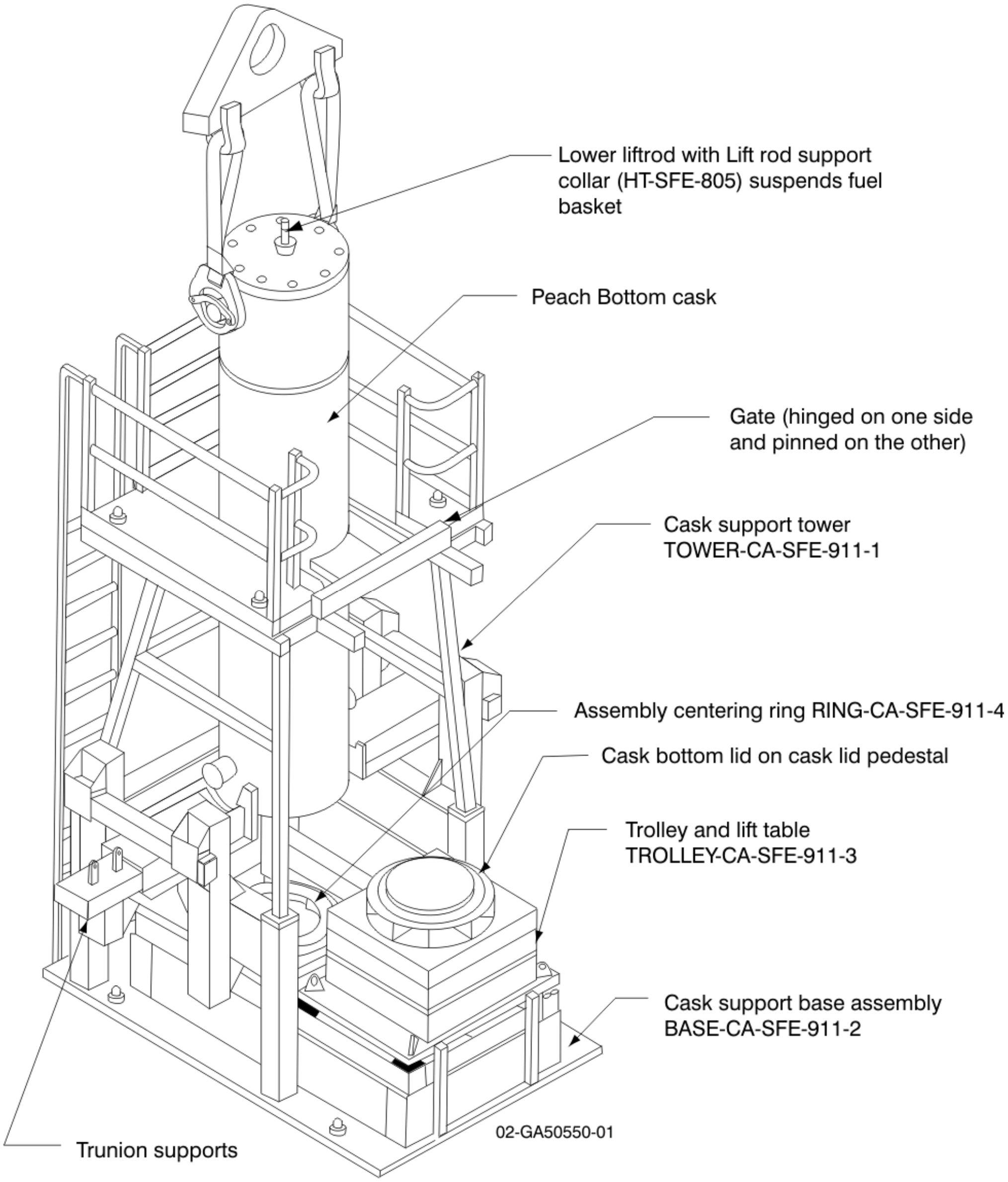

Figure A-1. CPP-749 Cask Centering Device

1983 Study of Dry Transfer Concepts[bb]

Between August 1982 and February 1983, the U.S. Department of Energy (DOE) studied potential concepts for cask-to-cask transfer systems that could be used at a Federal Interim Storage site, assuming the need for a relatively inexpensive but reliable system for transferring spent fuel from transport casks to storage casks.

[bb] K.J. Schneider, Equipment Concepts for Dry Intercask Transfer of Spent Fuel, PNL-4795, Pacific Northwest Laboratory, July 1983; Prepared for U.S. DOE under Contract DE-AC06-76RLO 1830

Based on the intended use, functional requirements and associated design criteria were developed. Of special interest, the criteria included requirements that the system be transportable and also for limiting the fuel temperature to 250°C. The 250°C limit for spent fuel cladding was based on expected limits for dry storage of spent fuel[cc]. The design acknowledged that additional provisions would be needed to add and control the inert gas to the storage cask in the event that an inert gas atmosphere would be required to preclude the possibility of unacceptable UO2 oxidation.

The portability of the cask-to-cask transfer equipment was considered important in providing flexibility for the DOE to disassemble and re-use the equipment at other sites. It was recognized that the value of portability would depend on its total costs and benefits, and that further analysis of these factors would be needed. Due to relative immobility and associated costs of transporting items of great mass and bulk, e.g., the hot cell structures and shielding, the transfer system utilizes expendable shielding such as water or earth. The expendable shielding is then excluded from the transportability requirements.

Based on the functional requirements, four concepts were conceived, all of which include a large crane for lifting the casks, a transfer car for moving the storage casks to their on-site storage positions, and an outer building to help control potential contamination. The four concepts were:

1. **Turntable**. This concept consists of a large lifting crane and a large diameter, shielded cylinder in a prefabricated metal building. The base of the cylinder is a large rotating turntable on which a transport and a storage cask are set. Transfers of spent fuel or canisters between casks are performed by alternately a) rotating the turntable so the transport cask is under the lifting mechanism and a fuel assembly (or canister)is removed, then b) rotating so that the receiving cask is in position to receive the fuel assembly as the lifting mechanism is lowered

2. **Shuttle**. This concept consists of a shielded fuel handling machine mounted on a bridge-1ike structure. The fuel handling and shuttle systems are located in a prefabricated metal building. Shipping and storage casks in a vertical position, each on its individual transfer car, are shuttled into position under the fuel handling machine. Adapters allow mating of the cask openings to the bottom of the fuel handling machine. Spent fuel is lifted from the shipping cask; the shipping cask is then moved back and the storage cask is moved into position to receive the fuel assembly from the fuel handling machine.

3. **Trench**. This concept consists of a small hot cell (called fuel transfer room) that is made of prefabricated stacking concrete sections and that extends from a trench to above grade. Inside the building that houses the fuel transfer system, a large bridge crane places the source and receiving casks vertically onto individual transfer cars located in a short, concrete-lined trench. The transfer cars which are integral with part of the hot cell shielding walls, move the casks into the fuel transfer room where the intercask transfer is accomplished by manipulators and in-cell cranes.

4. **Igloo**. This concept includes a large, rectangular hot cell {called fuel transfer chamber), made of an oval-shaped corrugated steel metal liner shielded by an earthen berm. The two types of casks are placed vertically on a single transfer car by an outside crane. The transfer car moves the two casks into the fuel transfer chamber (through an airlock chamber that is an extension of the fuel transfer chamber). Spent fuel is transferred by alternately moving the transfer car to orient the two

---

[cc] At the time of this study, temperature limits for dry storage had not yet been established. Dry storage of spent fuel was being considered as an option for addressing the fact that pool storage at many reactor sites was nearing capacity. The current temperature limit for zircalloy cladding in dry storage is 400C. See section 4.1 of this document for further discussion.

casks to their position under a fuel transfer tower. The fuel transfer tower, similar to that in the turntable concept, extends to above the earthen berm.

Results of this study included a comparison of these concepts against several criteria including costs, implementation time, transportability, operating capacity, etc. Some of the key conclusions include:

- A variety of concepts may be used as a dry intercask transfer facility for spent fuel or canisters, with a spent fuel transfer capacity of 400 to 500 metric tons of uranium per year (MTU/yr).
- Relocation of a transportable system would take approximately 10 to 14 months and involve, based on 1983 costs, ~$1M in disassembly costs at the former host facility or ~$2M in construction at the new host facility, plus shipping costs.
- More conventional hot-cell transfer systems offer more flexibility for abnormal activities such as repairing or repackaging the spent fuel or canisters than do the more compact and automated systems. The potential advantage of maximum portability must be weighed against its higher cost and lower operational flexibility.

Pre-conceptual Design for an MRS Transfer Facility[dd]

The Nuclear Waste Policy Act contemplated the need for a monitored retrievable storage (MRS) facility to accept UNF and HLW prior to eventual emplacement in a geologic repository. The feasibility of employing a simple transfer facility that could be constructed quickly in order to facilitate earlier acceptance of spent fuel at an MRS was investigated. The Transfer Facility was to serve a twofold purpose: provide a receiving-and-transfer-to storage capability at a relatively low throughout rate [approximately 500 MTU/yr] and provide the recovery capability needed on the site in the event of a transport or storage cask seal failure.

The MRS Transfer Facility in this pre-conceptual design is a hot cell designed specifically for transferring spent fuel assemblies from a mix of truck and rail transport casks from the utility sites into concrete storage casks at the MRS site. Its design basis is for handling and transfer of bare assemblies with a minimum decay time of five years and a maximum burnup of 55,000 GWd/MTU. This design did not include provision for opening and removing assemblies from welded canisters.

Other key criteria for this pre-conceptual design include:

- Receives only intact spent fuel assemblies or canned assemblies that meet the definition of Standard Fuel under 10CFR961.
- Provides a capability for repairs and other necessary actions if there is evidence of a problem with the integrity of the cask seals or contained fuel.
- Provides remote equipment for cask receiving, preparation, and unloading areas
- Provides an in-cell storage capability for the contents of one storage cask.

The base case design provided for no operational functions other than spent fuel assembly transfers and the associated cask handling, opening, and closing. Radioactive wastes collected in the Transfer Facility during operations were to be stored until the treatment facilities in the full-scale MRS Facility became operational. A brief description of the transfer process is provided below.

[dd] Preconceptual Design for an MRS Transfer Facility, Prepared by the Ralph M. Parsons Company for the US DOE under Contract DE-AC06-84RL10436, PNL-7400, September 1990. This document provides additional details of the conceptual design including facility drawings, capital and operational cost estimates, and a health and safety evaluation.

The spent fuel unloading operation begins with the removal of a transfer cell unloading port shield plug, using the remotely operated cell power mast crane, followed by the replacement of the grapple and the removal of the shipping cask lid bolts, lid, and/or shield plug. The bolts and lid removal grapple are replaced with spent fuel assembly grapple and the intact fuel assemblies are removed from the shipping cask, identified, and placed into a concrete storage cask. The transfer cell is equipped with two unloading ports, one dedicated for truck casks and one dedicated for rail casks. However, the port plugs, contamination barriers, and cask carts are designed with adaptors or inserts so that each port will accommodate either cask.

Simultaneous with the initial shipping cask cell port mating operation, a storage cask is mated to the transfer cell loadout port. Then the loadout port plug and the storage cask shield plug removed. After completion of the fuel transfer, the storage cask shield plug and loadout port plug are replaced and the storage cask is moved from the loadout/decontamination room into the transfer/discharge area where the cask lid is seal welded and the cask is removed from the cart by the straddle carrier and moved to the storage field.

After unloading, the shipping cask inner lid or shielding plug and the unloading port shield plug are replaced by the power mast crane. The cask is moved to the cask preparation and decontamination room for final cask closure. After closure, the cask exterior is surveyed and decontaminated if required. These operations are accomplished prior to the cask removal from the room.

A key finding from this study was that there is a minimum size of facility that would be necessary to reliably provide the required functions, and that this facility would have throughput capabilities greatly in excess of the 500 MTU/yr needed to avoid deployment of additional dry storage capacity at the reactors sites. Thus, the study concluded the Transfer Facility, if built as a stand-alone facility rather than as an appendage to the larger MRS spent fuel handling building, could receive and store spent fuel at annual rates of 3,000 MTU/yr or more, making the larger building unnecessary. Estimated that, in 1990 dollars, this facility could be constructed for $48M and would require17 months from the beginning of design until commencement of licensing activities.

Because the stand-alone Transfer Facility could be constructed more quickly, at lower cost, and with a receiving and storage capability equivalent to the spent fuel handling building, the stand-alone Transfer Facility was recommended as the preferred concept for providing the spent fuel receiving and transfer functions of the MRS facility.

TN-EPRI DTS Design[ee]

In the early 1990s, the U.S. Department of Energy established a cooperative agreement with the Electric Power Research Institute (EPRI) to design a spent nuclear fuel (SNF) dry transfer system suitable for licensing by the NRC. The design for this system was developed by Transnuclear, Inc. under a subcontract with EPRI. As designed, the system enables the transfer of individual spent fuel assemblies between a conventional top loading bare fuel cask (e.g. a legal weight truck transportation cask or an on-site transfer cask) and a large multi-purpose canister (e.g. the MPC) in a shielded overpack. The overpack may be a storage cask or a transportation cask.

[ee] Dry Transfer System for Spent Fuel: Project Report, A System Designed to Achieve the Dry Transfer of Bare Spent Fuel Between Two Casks, EPRI TR-105570, Prepared by TransNuclear, Inc., December 1995

The DTS consists of a facility to prepare casks for spent fuel transfer activities and to provide shielding and confinement during the transfer operations. Cask and spent fuel handling equipment and the operations support systems are included in the facility. The key operating systems use proven and demonstrated technology from domestic and foreign sources. For example, the spent fuel transfer and the cask mating subsystems are based on SGN-COGEMA experience with spent fuel operations in France.

The DTS envisioned as a means to facilitate loading of MPCs at facilities without the infrastructure or equipment to handle an MPC in their pools by shuttling the fuel from the pool to the MPC using a smaller cask. Hence, the DTS is designed for an on-site transfer of fuel from a 30-ton 4-assembly source cask to a 125 ton receiving cask. The receiving cask selected for the base design is a multipurpose canister, with two welded lids placed inside of a transport cask. The two casks were selected to determine the feasibility of the DTS design. However, the DTS can be adapted to be suitable for any two casks.

The DTS design is based on transferring B&W 15x15 PWR assemblies, with an initial enrichment of 3.75 weight percent U-235 and 40,000 MWd/MTU burnup. The shielding analysis is based on 5 year cooled fuel. However, the maximum design heat load of the fuel in the receiving cask is 15.5 kW (21 assemblies).

The DTS is housed in a two level concrete and steel structure with an attached single level weather resistant pre-engineered steel building. The concrete and steel structure provides both confinement and shielding during fuel transfer operations. With the exception of the concrete shell, all major components are designed to be transportable. This feature enables the same DTS equipment to be used at different locations. Security, utilities, and other operational infrastructure are to be provided by the host site. The facility consists of three basic areas; the preparation area, the lower access area, and the transfer confinement area as illustrated below in Figure A-2.

The DTS design was completed in sufficient detail to support submittal of a Technical Safety Analysis Report (TSAR) to the Nuclear Regulatory Commission (NRC) in September 1996, requesting that the NRC staff evaluate the TSAR and issue a Safety Evaluation Report (SER) that could be used and referenced by an applicant seeking a site-specific license for the construction and operation of a DTS.[ff]

Concurrently, a project was initiated to demonstrate the DTS design at the Idaho National Laboratory (INL). The demonstration test deliberately challenged the system to determine whether any activities could jeopardize the activities of another function or the safety of the system. All known interlocks were challenged. Following system modifications, additional testing was performed to validate the modifications. In general, all the equipment worked exceptionally well; the system ran smoothly and functioned as designed. The demonstration tests, results, and several recommendations to enhance safety and operations are provided in *Spent Nuclear Fuel Dry Transfer System Cold Demonstration Project*[gg].

In November 2000, the NRC issued an assessment report rather than an SER[hh]. The NRC staff agreed that the DTS concept had merit; however, because the TSAR was not site-specific and was lacking certain specific detailed information, a complete review addressing all the requirements of 10 CFR Parts 20 and 72 was not possible. Because the TSAR had inherent limitations such as no site-specific parameters, limited to one B&W fuel assembly design, no damaged fuel handling capabilities, and limitations on the

---

[ff] *Dry Transfer System Topical Safety Analysis Report*, Volumes 1,2, and 3, Docket No. 72-1024, Revision 0. Washington, DC: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, 1996.

[gg] *Spent Nuclear Fuel Dry Transfer System Cold Demonstration Project,* INEEL/EXT-99-01335, February 2000

[hh] Bill Brach to Leroy Stewart, Subject: Issuance of Assessment Report for the Dry Transfer System, Assessment Report (Docket 72-1024) Enclosed, November 13, 2000.

types of transfer casks and receiver casks that can be used, the NRC staff decided there was not enough information provided to allow a user to implement the DTS without a significant supplemental application.

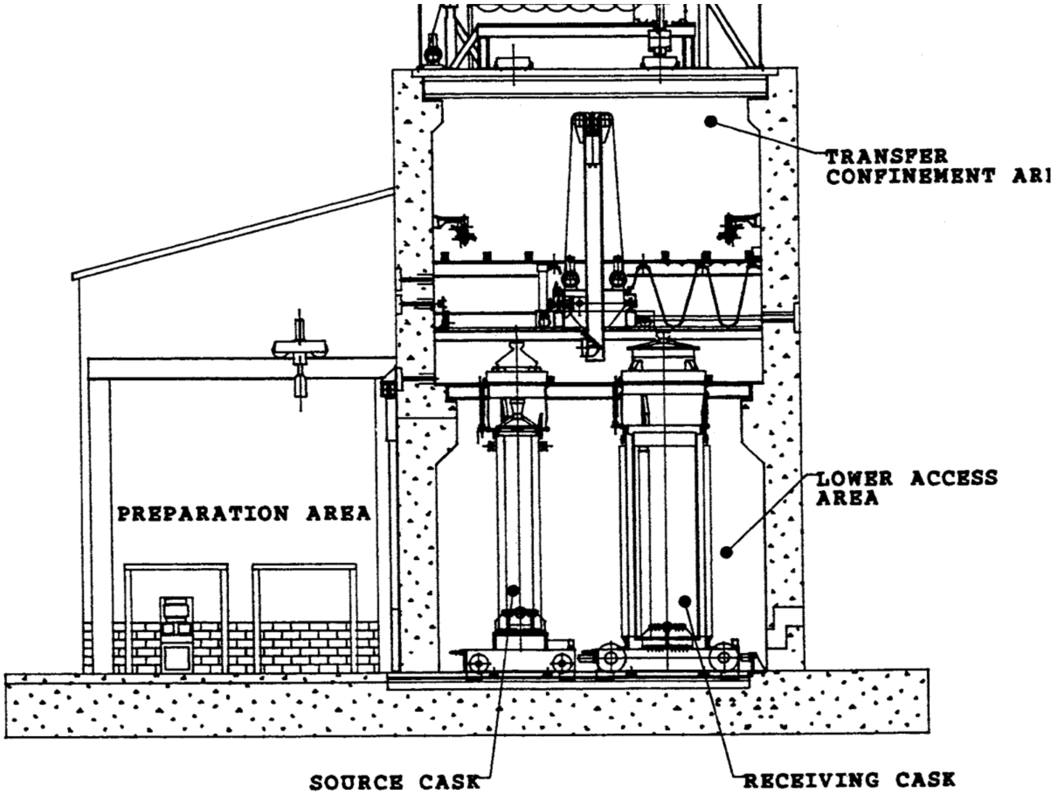

Figure A-2. TN-EPRI Dry Transfer System

The assessment report documented the NRC staff review of those generic design, testing, operations, and maintenance activities described in the TSAR for the proposed DTS. The NRC staff assessment is based on the DTS meeting the applicable requirements of 10 CFR Part 72 for spent fuel storage and handling and 10 CFR Part 20 for radiation protection. It is formatted in accordance with the Standard Review Plan for Spent Fuel Dry Storage Facilities (NUREG-1567) and also includes a 20-page appendix specifying the minimum additional information site-specific information that would be required to satisfy the regulations.

DOE later revised and submitted Revision 1 of the DTS TSAR to the NRC in January 2003[ii]. No further NRC or DOE action appears to have been taken with respect to this submittal.

[ii] Transmittal of Revision 1 of the Dry Tranfer System Topical Safety Analysis Report – Docket: 72-1024, Jeffrey R. Williams to William Brach, January 22, 2003.

Yucca Mountain Project Dry Transfer Facility (DTF)

The mission of the DTF was to receive and package commercial SNF, DOE SNF, naval SNF, and DOE HLW for emplacement into the repository. Two identical dry transfer facilities were originally planned. The first was to be constructed and operated to support initial receipt schedules. The timing and construction of the second was to be determined by throughput requirements.

The YMP DTF design includes systems that …

- Open dual purpose canisters (DPCs) containing commercial SNF
- Load site-specific casks onto surface transporters for transportation to an aging area
- Close loaded site-specific casks for SNF aging
- Prepare loaded casks, empty waste packagers, and empty or loaded site-specific casks for waste transfer
- Stage bare fuel assemblies, DOE SNF canisters, and DOE HLW canisters prior to transfer to WPs
- Transfer canistered SNF, canistered HLW, and bare fuel assemblies to waste packages or site-specific casks
- Close loaded waste packages (WPs) for emplacement
- Stage loaded waste packages prior to emplacement
- Load closed waste packages onto transporter for emplacement
- Remediate damaged waste packages, waste forms, and casks

The YMP DTF design represents a fully functional DTS capable of handling a variety of packages, opening and closing canisters, staging fuels and containers during transfer, and for remediating any damaged packages or fuels. The remediation system also included a pool for remediation of damaged fuel or casks with needs beyond what could be accommodated in the dry remediation system. The *Internal Hazards Analysis for License Application*[jj] provides a description of DTF operations along with drawings of facility layout and a systematic hazards analysis of each DTF operational activity.

It should be noted that, in part, due to the scale, complexity, and safety considerations associated with the DTF, the YMP abandoned the idea of relying on a dry fuel transfer process for loading waste packages in favor of using transport, aging, and disposal canisters which could be loaded and sealed at the reactor sites and then placed directly into a waste package for disposal without re-opening and handling the fuel. The DTF facility design was replaced by the Canister Receipt and Closure Facility where TAD canisters were sealed in a waste package and sent to the Wet Handling Facility where pools were used for bare fuel handling needs.[kk]

ZWILAG – Loading Storage Casks in a Hot Cell

ZWILAG, the Swiss consolidated storage facility, stores spent fuel in dry metallic dual-purpose casks capable of storing up to 37 PWR or 97 BWR assemblies. Casks are normally loaded in the cooling pools at the nuclear power plant (NPP). When the pools are not able to handle the large dual purpose casks, smaller transport casks may be loaded and the hot cell of ZWILAG is used for dry transfer of the spent fuel assemblies from the smaller transport cask to the larger cask for storage.

Spent fuel from the Muhlberg BWR is transported to ZWILAG by road using smaller shuttle casks from the TN9/4 family. The TN9/4 cask is loaded under water with 7 spent fuel assemblies at the Muhlberg

---

[jj] Internal Hazards Analysis for License Application, 000-00C-MGR0-00600-000-00C,

[kk] Packaging, Transport, Storage and Security of Radioactive Material, Volume 17, Number 2, 2006 , pp. 117-121(5)

nuclear power plant (NPP). It is then transported by road approximately 150 miles to ZWILAG where the assemblies are transferred under dry conditions using a hot cell into a TN-24BH cask for storage.

The hot cell has two bays (shown in Figure 5.3) where cask types of different sizes can be docked using appropriate sized docking rings to provide a seal between the hot cell environment and the space below. The casks, with only the primary lid installed, are connected to the hot cell before opening. The respective primary lids are then stored within the hot cell. The fuel assemblies are transferred from the smaller to the larger cask using normal spent fuel assembly handling tools. After the transfer is completed, the primary lid of each cask is re-installed and the casks are discharged from the hot cell. All operations related to installing the secondary lid, bolting, and leak-tightness testing are performed in dedicated work places outside the hot cell. The hot cell also provides capability for inspecting and repairing (e.g. gasket change) for storage casks.

Loading a TN-24 cask from ten TN-4/9 cask loads takes approximately 10 weeks, including transport time from the Muhlberg NPP and two weeks for closing of the TN-24. The first use of this system was in 2003 followed by another successful campaign in 2004. An additional two campaigns occur approximately every three years. The ZWILAG dry transfer system has proven to be an effective system for allowing high capacity casks to be loaded at locations other than the NPP [ll].

Figure A-3. ZWILAG Hot Cell

[ll] BWR Spent Fuel Transport and Storage with the TN9/4 and TN24BH Cask; , L Wattez (Areva Group), Dr Y. Marguerat (BKW FMB Energy Ltd), and C. Hosl (Zwilag); WM ’06 Conference, Tucson AZ.

La Hague[mm]

The reprocessing facility at La Hague France employs both a wet and a dry process for receiving spent fuel. The wet process at the NPH cask unloading facility has been operational since 1980 with a capacity of ~800 MTU/year. In 1986, the T0 receiving/handling facility was brought online using a dry transfer process. The objectives of the T0 facility were to reliably and cost effectively provide an additional 800MTU/year (~200 shipping casks) of fuel unloading capacity while reducing exposure and generation of radioactive waste. Although not a full dry transfer process (fuels are not transferred into another dry cask), the T0 facility is a production scale dry unloading process that shares many of the same operations and features that would be present in a dry transfer facility.

The T0 dry unloading facility consists of a spent fuel cask preparation building and a cask unloading cell, It is connected at the front end to a spent fuel cask receiving and shipping building, and at the back end to a storage pool. Casks received are the TN12, TN13, TN17, Mark II and LK 100 casks with a maximum heat load of 85kW. Upon receipt, casks are placed on a cart and transferred to the cask preparation building where there are four workstations located around a rotating platform. The workstations are 1) cask reception/shipping, 2) loaded cask preparations, 3) cask unloading, and 4) unloaded cask preparations (e.g. rinsing, seal replacement, closure, and radiological survey).

The unloading cell is located above the cask unloading station. The cell floor has a hatch with a connection system that enables an airtight seal to be formed between the top of the cask and the bottom of the cell hatch, thus preventing contamination of the cask exterior, including the upper face of the shield plug, and the cask receiving cell. After fuels are removed from the cask using an automated fuel removal crane and grapple, they are immersed in a cooling pit inside the cell, which also serves as a sipping test for fuel cladding integrity.

Above the unloading cell is a maintenance area with a floor that slides open to provide total access to the unloading cell during maintenance operations. Equipment in the unloading cell is designed in a modular fashion such that it can be easily removed and replaced with minimum downtime, usually within a matter of hours.

Because the La Hague facility operates both a wet receiving and a dry receiving process side by side, direct comparisons of the advantages and disadvantages of each are possible. A paper presented at WM1993 provided a direct comparison of La Hagues wet (NPH) and dry (T0) receiving operations. Key distinctions include:[nn]

- **Process Flexibility** – the dry unloading facility handles only uniform standardized casks while the wet facility can unload all types of shipping casks.
- **Radiological Wastes** –By eliminating the need for cooling/rinsing of casks before unloading and decontamination of cask following unloading, the dry unloading process significantly limits the production of effluents by a factor of ~3. Solid wastes are also reduced by a factor of ~2 due to the reduced decontamination activities.
- **Failed fuel detection**–Capabilities to detect an individual failed fuel assemblies are integral to the design of the dry unloading facility. However, the detection process immerses (rewets) the assembly and uses sipping in an individual pit before sending it on to pool storage.

[mm] Large-Scale Spent Fuel Cask Reception and Dry Unloading at La Hague, C.A. Hutchinson and P. Lemaistre, http://www.wmsym.org/archives/1987/V1/97.pdf

[nn] From Shipping Cask to Interim Storage: Spent Fuel Transfer Technologies at La Hague, Pierre M. Saverot et al, http://www.wmsym.org/archives/1993/V1/166.pdf

- **Cask Processing Time** – The dry process is quicker during cask preparations before and after unloading, but the unloading process itself is slower. Hence, the overall cask receiving/turnaround time is comparable between the wet and dry processes when receiving BWR fuels and ~11 hours (~15%) quicker in the dry process for PWR fuels (i.e. fewer assemblies per cask).
- **Safety** – The dry unloading facility has significantly fewer cask lifts (just to and from the self-propelled lorry), which proportionally lowers the risk of cask drops. The dry unloading process prevents contamination of the cask exterior while this cannot be prevented during wet unloading. The dry facility also eliminates criticality risks. However, the dry facility has some other additional risks not present in the wet facility. There is a risk of contaminating the fuel handling cell in the event of fuel rod failure, and the dry process requires controls to limit the temperature of the fuel assemblies throughout the dry process.
- **Radiation Exposure** – The dry process results in about 1/3 the personnel exposure, compared to the wet process

INL Former Test Area North Hot Shop

The Idaho National Laboratory formerly had a large hot cell at its test area north (TAN) complex. The TAN complex was constructed in the late 1950s. The TAN-607 Hot Shop was a two-story, reinforced concrete building designed and constructed as a nuclear workshop, nuclear fuel storage pool, and manufacturing facility. The Hot Shop was a large, shielded high bay with overhead cranes, a large overhead manipulator, auxiliary wall-mounted manipulators, and other equipment for remote handling of radioactive material.

In 1999 and early 2000, the TAN Hot Shop was used to support a dry fuel transfer. A CASTOR V21 cask containing commercial fuel from the Surry reactor was opened and its contents were inspected. Twelve rods from one of the Surry assemblies were removed and placed in a smaller Fort Saint Vrain cask for transfer to the INL's Hot Fuel Examination Facility for further examination.

As part of an initiative to reduce the footprint of DOE-EM-owned facilities, the TAN complex was decommissioned. Decontamination and demolition of the facility began in 2005 and was completed in early 2009. With loss of the TAN hot shop, the nation lost its only facility capable of housing two spent fuel casks and supporting a cask-to-cask transfer. Restoration of this national capability by creation of a sufficiently large and capable cell at a national laboratory, or as an appendage to an existing or planned UNF or HLW facility such as a consolidated UNF storage facility would provide the capability needed to perform dry fuel transfers in support of research, demonstration, and development and other special needs.

INL IFSF Fuel Handling Cave

Similar to a large transfer cell but with less capability and flexibility, a smaller cell could be used to support dry transfers. It would need to be capable of receiving and loading/unloading fuel from one cask at a time and storing fuel in the cell while the source cask is changed out for the receiving cask. One such facility exists at the Idaho National Laboratory.

The INL's Irradiated Fuel Storage Facility (IFSF) includes a fuel handling cave (FHC) which is essentially an in-cell vestibule to support cask preparation and unloading for fuels to be transferred to/from the IFSF dry storage vault. The FHC, with a footprint of 24' x 23', is equipped with cranes, manipulators, shielding windows, and cameras along with floor wells for temporary storage of fuel. It also contains a fuel conditioning station to support canning and drying fuels.

In 2011, an evaluation was performed to determine the feasibility for using the IFSF FHC to open, inspect, and retrieve fuels from an REA-2023 cask[oo]. The evaluation concluded that the FHC could support the fuel transfer. However, it was limited by the capacities of the cask handling crane and the transfer car that shuttles the cask into the FHC, both presently rated at 60 tons. It is believed that, by performing a suitable analysis, the transfer car could be uprated to a capacity of over 200 tons. If an upgrade the cask handling crane to sufficient capacity is not practical, a portable gantry could be used. The transfer car can accommodate a cask diameter up to 8 feet 7 inches.

[oo] Steven Wahnschaffe, Feasibility Study for using the Irradiated Fuel Storage Facility to Remove Commercial Used Fuel from the REA-2023 Cask, TEV-1187, March 15, 2011.