Applicability of Commercial Nuclear Power Used Fuel Handling and Dry Storage Solutions to DOE Non-Fuel Waste Forms – 14461

David Bland *, Jennifer Gamble **
* TriVis Inc
** OnPoint Power: TriVis Inc.

ABSTRACT

A quarter of a century old technology is gaining a new use in the DOE complex at West Valley (WV) and potentially at Hanford and Savannah River. Designed to store used fuel, dry cask storage is set to be deployed to store vitrified high level waste (HLW) at West Valley as early as 2014. Meanwhile, Hanford is considering the feasibility of storing cesium and strontium capsules in dry cask storage and Savannah River is considering a dry cask storage demonstration project. Commercial nuclear power used fuel handling and dry cask storage solutions have been deployed in both the nuclear power industry and the DOE complex to safely store used fuel since the 1980s. Figure 1 shows dry cask storage in use at the Idaho National Engineering Laboratory (INEL). Dry cask storage technologies and systems were originally developed to address the commercial nuclear power industry's used fuel backlog to free up valuable space in wet storage pools to support reactor refueling. The first dry storage installation in the US was licensed by the Nuclear Regulatory Commission (NRC) in 1986 at the Surry Nuclear Power Plant in Virginia.

TriVis Inc., a woman-owned small business, is supporting the transfer of the West Valley high level waste to canisters and ultimately to the dry cask storage system as part of a team under contract to CH2M HILL B&W West Valley, LLC. In addition, TriVis has completed a survey of the Waste Encapsulation and Storage Facility (WESF) at the Hanford site to assist in determining dry storage utilization options there. TriVis is capable of using its procedures, trained personnel and American Society of Mechanical Engineers (ASME) certified welding program to support the DOE operations. This represents a transfer of experience and capabilities from the commercial nuclear power supply chain to the DOE.

In particular for the cesium and strontium capsules at Hanford, there is significant potential for application of lessons learned and experience from the commercial nuclear power industry. The dry cask storage system creates a safe, long-term, interim and retrievable storage solution that is passive. It allows more than 30 years of research and development and ongoing life extension studies to be put to bear on DOE challenging waste forms.

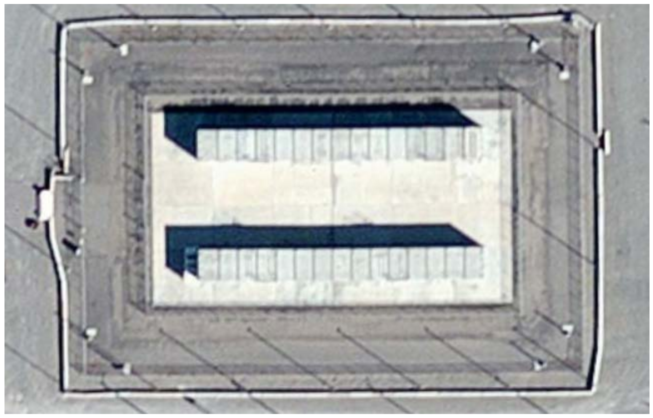

Fig. 1 Three Mile Island Fuel in Dry Cask Storage at INEL

INTRODUCTION

Dry cask storage systems typically consist of an inner steel canister and an outer concrete overpack or vault. The inner steel canister is filled with an inert gas, welded shut and leak tested before being placed inside the concrete cask structure. In the case of spent fuel or other materials that are transferred from wet storage such as a pool, the materials must be mechanically dried prior to placement in the canister. The concrete dry cask systems are assembled (or fabricated) on a specially constructed storage pad which in the commercial nuclear power industry is called an Independent Spent Fuel Storage Installation (ISFSI). Presently there are 54 ISFSI licensed at nuclear power plants and 15 additional site specific licenses away from nuclear power plants at locations throughout the United States; 11 additional licenses are in the works. In all, 34 states are home to a licensed ISFSI utilizing industry standard dry storage systems. In the commercial nuclear power industry, dry cask systems are typically used for the interim storage of spent fuel, however they have also been used (in the case of decommissioned nuclear power plants) to store highly irradiated greater than Class C and Class C decommissioning wastes.

Currently in the United States, the dry cask system vendor technology market is comprised of three major vendors: AREVA Transnuclear, Holtec International, and NAC International. Holtec and NAC systems are vertical systems meaning the system is placed on end with the spent fuel vertically inside of it, while the AREVA Transnuclear System is a horizontal system with the system placed long-ways with the spent fuel horizontally inside of it. Figure 2 illustrates typical dry cask system technologies.

The original cask systems were designed for storage only, but the systems deployed by all three vendors today are designed to support both interim storage and future shipment of the spent fuel.

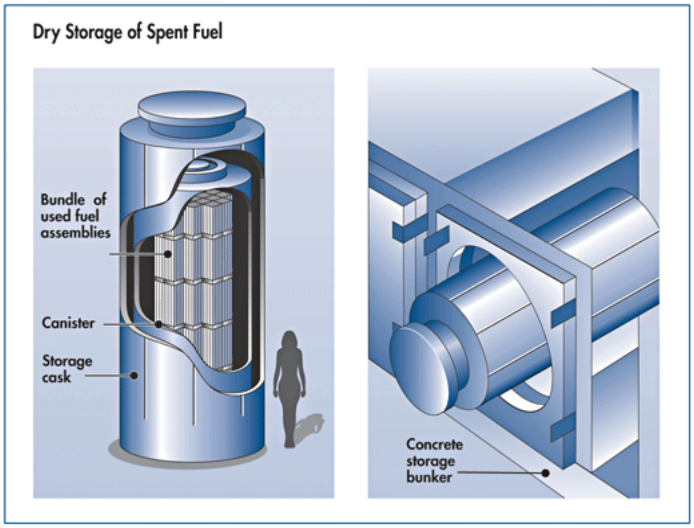

Fig. 2 Typical Dry Cask System Technologies

DESCRIPTION

The following section describes the application of design aspects to a DOE challenge – the cesium and strontium capsules at WESF. The application of dry storage systems at WV is the topic of separate Waste Management 2014 Symposium paper being presented by others and as such is not discussed here to avoid duplication.

Currently, there are 1,936 cesium and strontium capsules in wet storage at the WESF facility [1]. The WESF facility was built in 1971 to 1974 and has challenges associated with the ventilation system and high levels of contamination in multiple hot cell areas. The DOE and the contractor, CH2M HILL Plateau Remediation Company, as well as regulators and the public desire to place the cesium and strontium capsules in a safe longer-term dry storage solution in order to reduce risk. Figure 3 shows the capsules in storage at WESF.

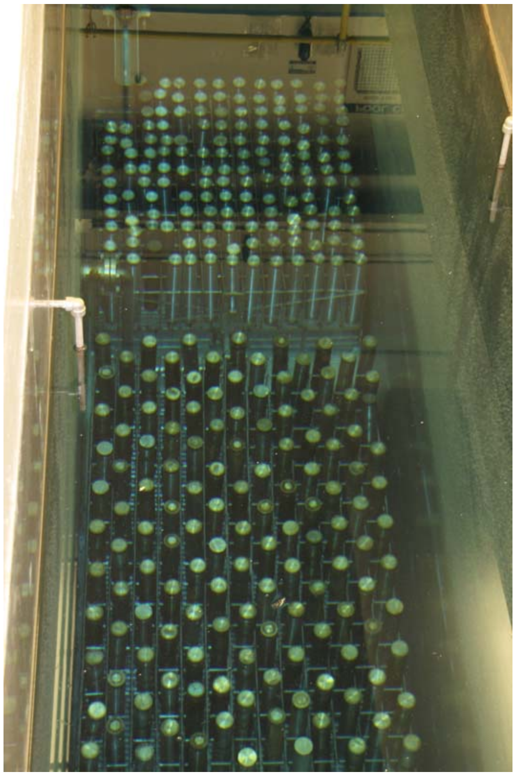

Fig. 3 Cesium and Strontium Capsules

Storage System Design Capabilities Technology Transfer

Long-term storage of highly radioactive material licensed for storage and transport operations in dry storage systems must technically address four fundamental design challenges; Criticality Risk, Thermal Cooling, Structural Integrity, and Radiation Shielding (to include confinement). The following material will summarize the general assessment of application of commercial spent fuel storage devices for the cesium and strontium capsules currently in wet storage at WESF on the Hanford Site for each.

1. Criticality. Regulations require the maintenance of ≤0.95 K-effective (Effective Multiplication Factor) with a 95% confidence level for materials stored in dry storage. As the capsule material anticipated for storage at the Hanford facilities does not contain transuranics, criticality issues are not an area of concern.

2. Thermal. Current generation commercial dry storage systems are designed to the requirements detailed in NUREG-1536 (storage)[2] and NUREG-1617 (transportation)[3] as issued by the Nuclear Regulatory Commission (NRC). Thermal requirements for storage configurations tend to be the more limiting of the four engineering design parameters that control design and analysis for dry storage system considerations. Storage temperature limits associated with commercial spent fuel contained within these systems require the following conditions to be met:

- Contents cladding temperatures for long term and short term operations must be limited to 400°C
- Contents cladding temperatures must be limited to 570°C for accident and off-normal

events.

- Cask and content materials must be maintained within their minimum and maximum temperature limits for all conditions.

Existing dry storage system designs are analyzed for over 40 kW of total heat load. In addition, individual fuel assembly heat loads to meet the above limits are analyzed with decay heat levels in excess of 1 kW. In each case, the above limits are met for designs available in the marketplace today.

The WESF facility capsule material considering dry storage options has limits that for the most part are less restrictive than those associated with commercial spent fuel; typical heat load of 150 watts, accident temperature limits of 600°C or greater, and processing/storage configuration limits of 450°C or greater. The only exception that represents a more limiting value is the storage configuration temperature of 317°C for a population of the capsules. While this would require detailed analysis during the final design configuration analysis, based upon engineering judgment with a reduced allowable total heat load (of say approximately 30 kW) these types of outcomes should represent no problem.

3. Structural. Each domestic cask vendor uses allowable modeling codes and techniques to evaluate their specific design. This includes off-normal and accident events for both storage and transportation circumstances. Included are various drop scenarios for storage and transportation accidents in the transport mode. While significant in storage configuration, the transportation accidents for dry storage systems place an even greater strain on dry storage system design in the area of structural integrity.

The capsules at WESF are designed to survive end drop and side drop forces of 105 g and 97 g respectively. The cask vendor's canister is designed to meet the ASME Code stress allowable limits on all material/seam welds. While the impacts for transportation and storage are different, as are the impact forces for the different designs, the fleet of available dry storage systems in the United States has impact loads of between 45 g and 90 g. Therefore, it is not anticipated that design limitations associated with the DOE campaigns would preclude the use of currently available dry storage systems.

4. Shielding. For on-site storage, 10 CFR 72.104[4] and 10 CFR 72.106[5] provide dose boundary limits for storage sites. This limit is for all sources of radiation from the storage facility to include direct and indirect radiation as well as any effluent leakage contributions for the entire year (normal limit) or for the duration of an event (accident.) These limits are set at 25 mrem whole body for normal and 5 rem whole body for accident situations. Overpack dose rates at 1 meter for the typical dry storage system vary due to the variation in the design. However, design basis calculations for the systems with design basis content (~10 million Curies), while having areas of streaming radiation, will normally be in the general range of a few tens of mrem. Current versions of dry storage systems in use commercially for storage are, for the most part, also eligible for transportation with the same content as that associated with storage (meaning ~ 10 million curies within the shipment container.) As such, they also meet the dose restrictions associated with transport. These restrictions include:

- Less than 200 mrem/hr or less external surface dose, or
- Less than 200 mrem/hr or less at outer surface of vehicle, and

- Less than 10 mrem/hr at 2 meters from edge of transport vehicle, and
- Less than 2 mrem/hr in occupied portions of vehicle.

Current generation dry storage systems (meaning canister based systems) are designed and assembled in a manner that meets the definition of leak tight. Therefore, both confinement (which is assured by redundant barriers) as well as effluent release concerns are not relevant to any consideration of radiation exposure or release risk.

As another design consideration, DOE desires that a storage solution for the material should allow for safe storage for up to 300 years without removal of the items from their primary storage canister and without the need for a repackaging facility. Currently, the commercial industry has numerous studies underway to determine a regulatory answer to this question. This issue is directly tied to any future commercial nuclear power life extension or like regulatory determination so significant resources are being brought to bear to address a definitive and timely final answer. At this time, those studies are not yet complete so no answer with certainty is yet available. However, dry cask storage vendors are uniformly convinced that their respective systems are adequate for extended life-times. They are included in the work ongoing regarding this topic as is the NRC through independent work. On May 17, 2011, the NRC modified the regulations associated with 10 CFR 72.42(a)[5] to allow current commercial facilities to be licensed for up to 80 years from the previous 60; demonstrating a level of regulatory confidence even prior to completion of the research moving to 300 years. This will be necessary to support the environmental impact statement associated with the waste confidence rule which is necessary by court order to further future nuclear plant licensing activities.

At issue for the extended life are basically two broad items; criticality control and material corrosion. For the WESF, critically issues relevant to dry storage systems (slump or degradation of the neutron adsorption material) is not of real concern with regard to extended life. The second item, material corrosion, is relevant and involves a slow buildup of corrosive elements such as chlorine that over years might impact system integrity. At this point, until the research is complete, and the regulatory body concurs, there is little finality on this issue. The issue of material corrosion regarding the WESF capsules is an area where further research may be required if storage is required to meet a 300-year timeframe.

As can be seen, direct transfer of commercial dry storage system technologies to DOE facility packaging problems can be readily accomplished based upon dry storage system technical capabilities. Moreover, reasonable assurance is present that from a technical standpoint, these technology products offer a safe and long term storage option for the DOE.

DOE Facility Design Capabilities Technology Transfer

Existing space capabilities at WV and WESF preclude the use of existing full size commercial nuclear power plant dry storage systems without significant modification. Existing systems are in the range of 100 tons and are roughly 9 feet in diameter and 20 feet tall. Even the canisters themselves (which cannot be used or handled without supplemental shielding) are 20 tons empty and roughly 5 feet in diameter and 18 feet tall. This size alone precludes their access to the majority of the two facilities for loading purposes. Fortunately, at least two of the vendors have previously reduced the size of the systems for application in limiting environments and also have reduced size transfer systems so reduction to support operations seems to be easily accomplished.

Each facility could utilize reduced size systems through easily accomplished system size reductions by the respective cask vendor. In this manner, the building lift and dimensional limitations can be overcome through a sizing reduction process. While each facility will address material transfer in different manners, loading of the systems in either wet, dry, or multi-step processes can be accommodated as necessary to allow system applications. Loading area floors may require some modification to provide a level surface and likely to strengthen the floor due to existing limitations. These changes would be determined during a more detailed review of the facility based upon the proposed dry storage system and its respective size and weight. From here, a sealed storage system can be transferred to the final selected storage facility on site.

The planned location(s) for the on-site storage installation are fairly easy to accommodate. First, the overall environmental conditions of the area must be shown to be adequate for available storage systems. These conditions, while slightly varied from storage technology to technology, are those utilized for the "generic site" and thus used to analyze system safety for placement without NRC approval throughout the United States. They include things such as average temperature, temperature extremes, earthquake considerations, and other environmental threats to system safety.

The second consideration is that transportation route should be included in siting criteria and location consideration for the DOE dry storage facility (pad) to minimize potential interferences from low hanging power / telecommunication lines and minimize any potential upgrades to travel path conditions for ease in transport from the buildings to the selected site. This would include an evaluation of small enclosures and buildings. These items will need to be reviewed for function, content, or hazard and as such may require relocation or evaluation. The storage systems are limited in a number of fire, drop, and environmental hazards that they can accommodate due to the passive nature of their protection. These items will require consideration and potentially modification prior to implementation of any technology for dry storage whether within the vicinity of the dry storage systems.

Implementation Capabilities Technology Transfer

Field implementation of dry storage technology within the commercial sector involve four basic segments of work; ISFSI design, facility evaluations and modifications, ISFSI construction, and operational startup and loading. Each will be covered below. Figure 4 describes a typical ISFSI development process.

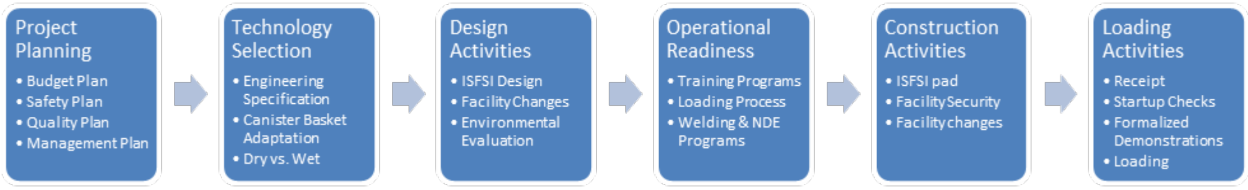

Fig. 4 ISFSI Process

1. ISFSI Design. In the simplest forms, the ISFSI consists of a series of concrete aprons on which the systems will rest, approach capabilities and facilities for movement to this storage location, monitoring systems to determine ongoing status (typically temperature) of the systems, backup power systems for security features, facility lighting, and security features necessary for material protection. The largest variation of the design is related to soil conditions at the implementing site and the design is typically modified to allow for this issue. In addition, dry storage systems have different requirements associated with the design of the facilities. This change is associated with the difference between horizontal or vertical storage configurations. This drives a difference in basic design parameters for the concrete storage pads. While these changes can cause a significant difference in construction costs, the basic design effort involved remains mostly unchanged. Currently, multiple design firms have experience in this work and there are a full range of commercial facility designs to serve as starting points of a successful design. This experience and knowledge is directly transferable to the DOE facilities.

2. **Facility Evaluation.** The facilities must be able to accommodate the activities necessary to complete a successful packaging campaign. This includes items such as floor loadings, lifting capabilities, services availability (such as power, water, air, gases, etc.), and adequate shielding for both the worker and the environment. Moreover, consideration must include whether loading will be done underwater or within hot cell environments as well as whether the loading will be directly within the dry storage canister or involve a transfer activity intermediate step. Depending upon the limitations of the facility, the dry storage system can be modified to accommodate limitations (such as size and weight of the system.) In the case of WV, the material will be loaded directly into a reduced size canister but will be performed within a hot cell as opposed to the commercial plant underwater approach. In the case of WESF, an interim shipping cask system may be utilized due to limited space and HVAC equipment within the facility. In any case, modifications necessary to implement the dry storage technologies at each of the two DOE facilities appear to be minor in nature – allowing a direct transfer of commercial technology with limited additional costs.

3. **ISFSI Construction.** As previously outlined, the construction tasks associated with the building of an ISFSI are fairly simple and straight forward. The facility is limited to adequate concrete storage pads surrounded by adequate security features. This simple construction activity is only complicated by overly “soft” or “hard” soil makeup. Applications in this situation (neither of which appear present for the WV and WESF locations) only require adequate remediation of soils to accommodate the necessary structural strength for all situations.

4. **Operation.** The startup and operational loading phase for dry storage use at DOE sites is almost entirely transferable from commercial experience. The basic tooling, processes, training, and personnel are all directly applicable for use in the DOE environment. Material is readily available for technology transfer for all the current commercial dry storage technologies with minimum changes. This also includes ASME welding programs, ASME Code required Non-Destructive Evaluation (NDE) programs, and designed ancillary equipment. Due to the large number of completed dry storage systems loaded for commercial clients, a reasonably large population of skilled labor is also available for use in loading these systems.

Another operational advantage (and commercial plant requirement that has been proven) is the DOE desire that the material is stored in a configuration that will easily accommodate future disposal decisions. The current generation dry storage systems require the ability to remove any stored material at a future date due to any number of unknown reasons. This is not only a design feature of the system, but is demonstrated prior to use at every site for every type of system utilized. TriVis have in fact opened a significant number of systems during these demonstrations for every dry storage technology currently sold. The ability to retrieve the material from the canister, coupled with reversal of the process outlined elsewhere provide assurance of the ability to accommodate any future decisions regarding the material that might be made. Should future decisions necessitate the return of the material for alternate disposition, the canisters currently marketed can be reopened and the capsules or HLW returned for alternate disposition. Otherwise, the canisters can be directly transferred to a shipping overpack at a future time and shipped to any location desired.

On an occupational exposure level, workers can load these systems well within the commercial limits established within Title 10 regulations. This includes analysis of the selected design basis commercial fuel and all its conservatism. On a real basis, a typical dry storage system involves roughly 300 mrem of cumulative exposure to the entire loading crew per can for spent fuel (an average of 10 mrem per individual crew member). Typical loading crews involve roughly 30 people over the course of a week working in an operating nuclear power plant. Largest doses are received by either the fuel handlers operating over the spent fuel pools or by individuals involved in the welding and/or NDE processes. Significant supplemental shielding as well as remote welding is used to manage As Low As Reasonably Achievable (ALARA) principles. All these techniques are or can be directly transferred to users of this technology at WV and WESF.

CONCLUSIONS

Based on a preliminary review of the two DOE facilities, and knowledge of available dry storage technologies, design basis, and current research in the commercial nuclear power industry on life extension for dry cask storage of spent fuel, we conclude that dry storage is a viable option for a range of DOE high level waste storage and transport needs. Our preliminary assessment is that a dry storage solution could be accomplished using available smaller scale dry cask storage technology without significant modification to both the WV and WESF facilities. With respect to 300-year storage, dry cask storage systems currently in use in the commercial nuclear power industry with limited uses as DOE sites present the most viable potential to achieving safe 300-year storage. Ongoing research into life extension for these systems is not yet completed, but the major cask vendors have assurances that their technologies are suitable for such extended storage. With respect to worker and public dose during a HLW transfer, loading and long-term storage, experience from the nuclear power industry suggests that all of these activities have been conducted on higher activity level spent fuel with minimal worker exposure and extremely low potential dose to the public.

ACRONYMS

ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
C	Celsius
CFR	Code of Federal Regulations
DOE	Department of Energy
g	force of gravity
HVAC	Heating, Ventilation and Air Conditioning
HLW	High Level Waste
ISFSI	Independent Spent Fuel Storage Installation
kW	kilowatt
mrem	millirem
mrem/hr	millirem per hour
NDE	Non-Destructive Evaluation
NRC	Nuclear Regulatory Commission

NUREG Nuclear Regulation
rem Roentgen Equivalent Man
WESF Waste Encapsulation and Storage Facility
WV West Valley

REFERENCES

1. W.G. PLYS and W.C. MILLER, Summary Report for Capsule Dry Storage Project, WMP-17265 (2003).
2. NUREG 1536, Rev. 1, Standard Review Plan for Spend Fuel Dry Storage Systems at a General License Facility, Final Report, U.S. Nuclear Regulatory Commission (July 2010).
3. NUREG-1617, Standard Review Plan for Transportation Packages for Spent Nuclear Fuel, Final Report, U.S. Nuclear Regulatory Commission (March 2000).
4. Title 10 CFR 72.104, Criteria for radioactive materials in effluents and direct radiation from an ISFSI or MRS [53 FR 31658, Aug. 19, 1988, as amended at 63 FR 54562, Oct. 13, 1998].
5. Title 10 CFR 72.106, Controlled area of an ISFSI or MRS [53 FR 31658, Aug. 19, 1988, as amended at 63 FR 54562, Oct. 13, 1998; 66 FR 51842, Oct. 11, 2001].
6. Title 10 CFR 72.42(a), Duration of license; renewal [76 FR 8890, Feb. 16, 2011].