Compact System for Operating and Decommissioned Reactor Used Fuel Management-17243

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ABSTRACT

Most nuclear power plants in operation today were designed with limited wet storage for their discharged used nuclear fuel (UNF), predicated on the assumption that either recycling or geologic storage would be available within the reactor's lifetime. While that has proven to be the case in some countries such as France with its recycling, it has not for most. In the USA, dry storage of UNF at the plant site at an Independent Spent Fuel Storage Installation (ISFSI) has since the mid-1980s been the primary mode of interim storage so that the plant can offload its UNF from the pools at the power plants.

Initially the space reserved for the ISFSI at a reactor site was based on the assumption that the Department of Energy (DOE) would be transporting that UNF to a geological repository site, such as Yucca Mountain [1], by 1998. However, due to the delay in the opening of any geological repository the utilities are running out of space on their existing ISFSIs for additional UNF dry storage systems. Since plants prefer to keep their ISFSIs inside the protected area of the plant, options for expanding the ISFSI are becoming limited. At the same time, increasing the capacity of the dry storage systems is also not an option in most cases as the dry storage systems have almost reached their capacity limits with the 37 PWR or 89 BWR fuel assembly canister designs.

For plants that have announced plans to shut down, their main priority is to offload the UNF from the pool to dry storage at an ISFSI so that they can proceed to "Safe store" or other storage options, and start their decommissioning process as soon as possible. Thus, keeping the size of the ISFSI compact is very important for safety, security and economics.

This paper will describe the details of a reduced footprint version of AREVA TN's NUHOMS® System that addresses the need for maximizing ISFSI capacity. This system not only offers a compact design that stores nearly double the number of UNF assemblies in the same space, it also offers superior radiation protection to the workers and public. In addition, it offers unmatched protection against beyond design basis (BDB) events like the tsunami at Fukushima in Japan [2], the earthquake at North Anna site [3], tornadoes and manmade attacks such as the 9/11 attack on the World Trade Center in New York [4]. It also includes significant enhancement for a robust Canister Evolved Safety Program for Aging Management. The utilities in the USA are currently using dry storage systems with canisters of different diameter, different length, and different weights. The fuel assemblies that are stored in these canisters are also different in their fuel types (PWR or BWR),

different fuel parameters like burnups, enrichments, and cooling times and different storage orientations in the storage overpacks like horizontal or vertical. The compact version of AREVA TN's NUHOMS® System offers a "Universal" Storage Overpack which is designed to accept all these different design dry storage canister available in the industry.

As UNF storage continues to drives the industry towards innovations that address the need for consolidated storage, compact ISFSIs and aging management, this new evolution of the AREVA TN NUHOMS® system [5] offers a significant leap forward in addressing all of these challenges.

INTRODUCTION

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NEEDS OF SHUTDOWN OR SOON TO BE SHUTDOWN PLANTS

OFFLOAD FUEL FROM POOL TO ISFSI

For plants that have announced plans to shut down, their main priority is to offload the UNF from the pool to dry storage at an ISFSI so that they can proceed to "Safe store" or other storage options, and start their decommissioning process as soon as possible. One of the major expenses for a decommissioned plant is the cost of maintenance of the spent fuel pool. Estimates vary from plants to plants depending on the presence of other operating units on the same site among other factors. It is not uncommon for plants to spend between one to three million dollars/month to maintain the fuel safely in the spent fuel pool. Therefore, the ability of the dry storage system to store short cooled fuel is important so that the utility won't have to maintain the pool.

COST OF ISFSI PAD

When a shutdown plant evaluates the dry storage options, total cost of the transferring the fuel from the pool to ISFSI site needs to be evaluated. One of the major costs to the utility for dry storage is the cost of ISFSI pad (basemat) along with the cost of dry storage system hardware. Smaller ISFSI footprint saves utility for the cost of ISFSI site excavation, cost of engineered backfill and cost of ISFSI pad. Fig. 1 shows a typical existing NUHOMS ISFSI layout including ISFSI Basemat/Pad (Item 11) and Approach slab (Item 12).

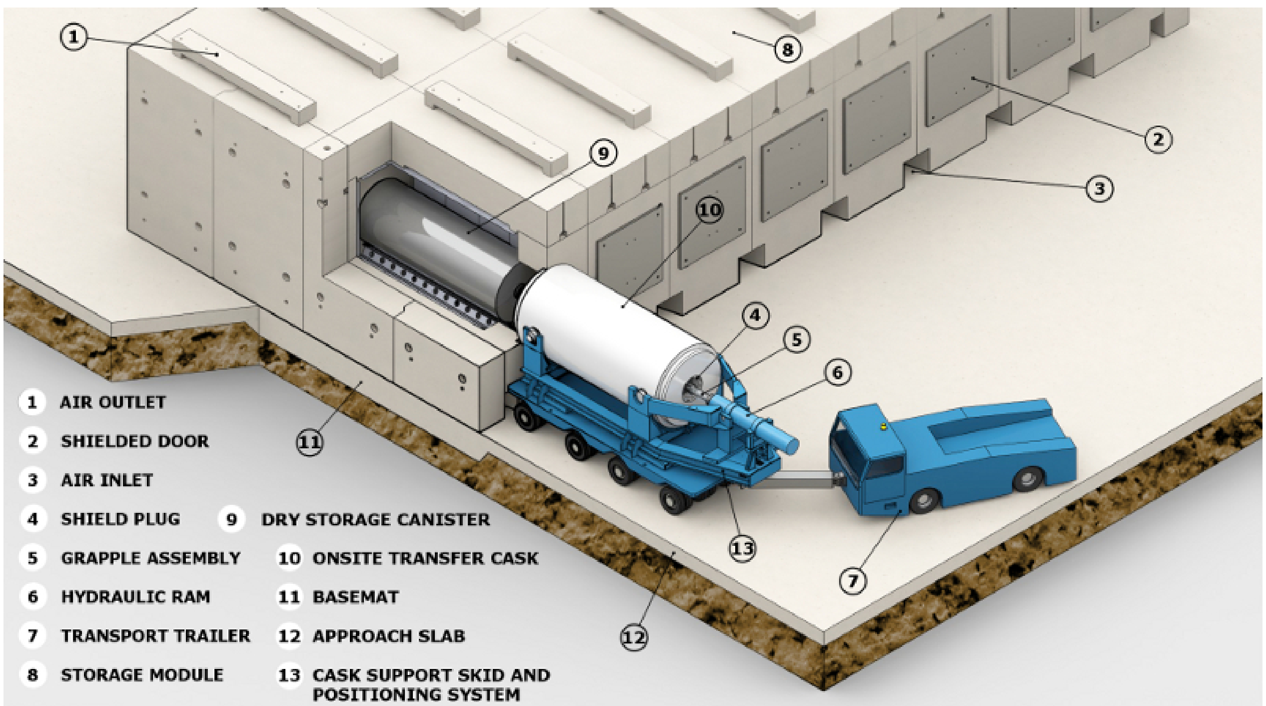

Fig. 1: Typical ISFSI Components

DRY STORAGE SYSTEM CAPACITY

In order to minimize the cost of dry storage systems, besides the size of the ISFSI pad as described above, other important considerations is to use high capacity systems. The highest capacity systems available in the dry storage market today are dry storage canisters with 37 PWR or 89 BWR used fuel assemblies per canister. It is not practical to design and license even higher capacity dry storage systems than these. Main reasons are the existing crane capacities, room in the spent fuel pools for fuel loading, floor load capacities in the spent fuel pool or fuel loading and handling areas of the plants, occupational exposures, and limitations on the size of Transport Packages when these higher capacities canisters will be eventually transported off-site to either an Interim Storage facility or Recycling Facility or Final repository. Therefore, use of canisters higher than 37 PWR or 89 BWR Fuel assemblies is not a practical option.

Fig. 2 and 3 show NUHOMS 37PTH Canister for PWR and 89BTH canister for BWR fuel assemblies.

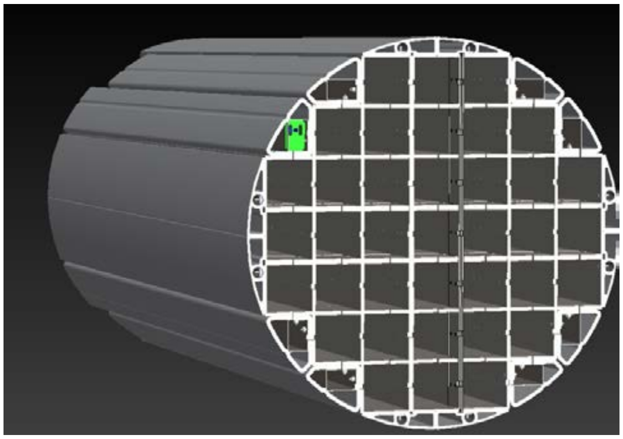

Fig. 2: NUHOMS® EOS 37PTH DSC Basket

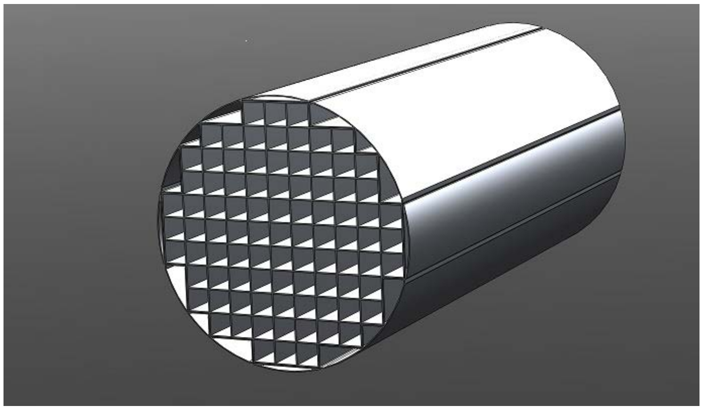

Fig. 3: NUHOMS® EOS 89BTH Basket

SECURITY CONSIDERATIONS

For security reasons, a smaller ISFSI footprint is a preferred option. There is also a preference to keep the ISFSI within the protected area and there is not much space available within the protected area for a large ISFSI. Therefore, size of the ISFSI is an important consideration for safety and security considerations.

Fig. 4: ISFSI with Security Fence

DOSE RATES FROM DRY STORAGE SYSTEM

At the shutdown plant, when decommissioning and dismantling operations start, there are many workers present at the site during these operations. It is imperative to protect those workers from radiation exposure from the dry storage system at the ISFSI site. Utility very strongly prefers dry storage system with very high radiation shielding capability to keep the does rates ALARA to the workers and general public.   Fig. 5 shows the location of NUHOMS® ISFSI in close proximity of the workers (Less than 60 meters).

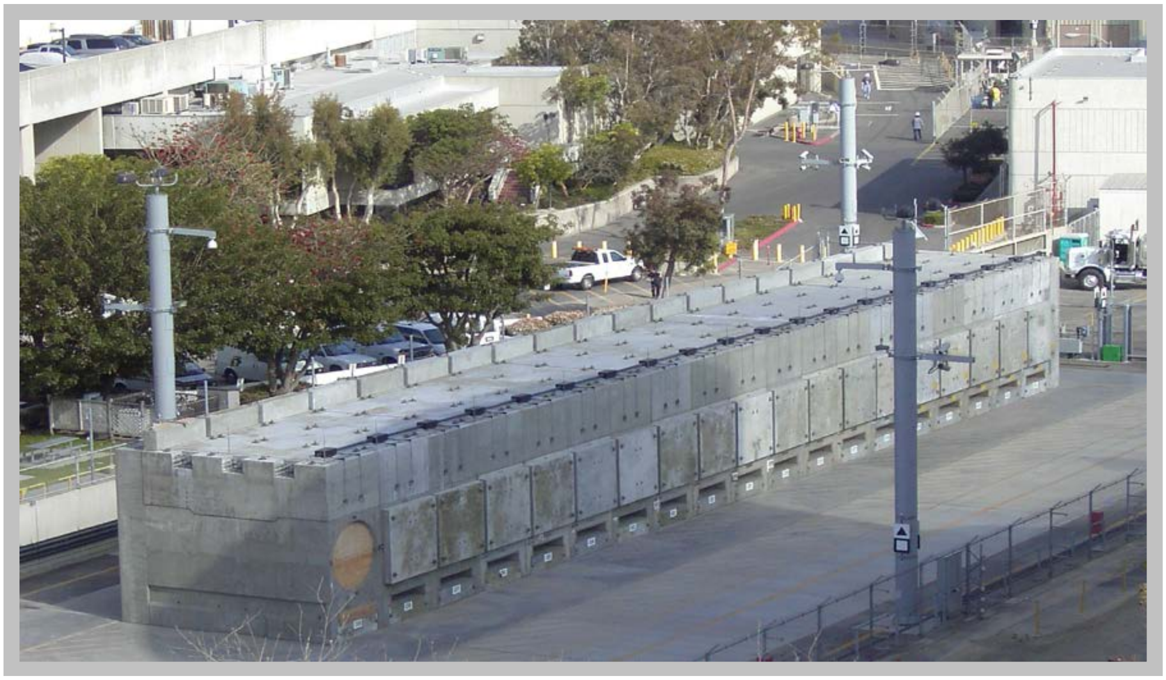

Fig. 5: NUHOMS ISFSI Location in close proximity of workers

BEYOND DESIGN BASIS EVENTS

Beyond design basis (BDB) events are those that were not applicable in the original design basis at the time of the design/analysis/licensing/deployment of a dry spent fuel storage system. Utilities preference is for a dry storage system that offers unmatched protection against BDB events like the tsunami at Fukushima in Japan, the earthquake at North Anna site, tornadoes and manmade attacks such as the 9/11 attack on the World Trade Center in New York. BDB events do happen and the dry storage system needs to be operated safely through these events even though some of these may not be a licensed requirement of the system.

Some of the examples of the BDB Events are:

- Air Craft crash and subsequent fuel fire
- Earthquakes greater than the original design basis
- Floods/Tsunami generated by BDB earthquakes
- Storage at the reactor sites greater than the initial license period due to delay in final disposal solution
- Storage first at ISFSI and then Transportation and then storage again before final disposal

NUHOMS SYSTEM with Matrix HSM

TN's latest NUHOMS® System with Matrix HSM overpack shown in Fig. 6 is specifically designed to address all the priorities listed above for shutdown plants. Note that even though the priorities are listed for shutdown plants, most if not all of they are also applicable to the operating plants with existing ISFSIs or plants to be soon shutdown.

FIG. 6: NUHOMS® Matrix HSM Overpack During Canister Insertion Process

The NUHOMS® System with Matrix HSM Overpack and NUHOMS EOS 37PTH and 89 BTH Canisters use the same transfer cask and transfer trailer as the NUHOMS® EOS System [6]. The Matrix HSM overpack allows for storage of approximately 45% or more fuel in the same ISFSI pad space due to its staggered HSM design. This cuts down the ISFSI pad size by 45 or more for the same number of fuel assemblies which is a significant improvement over the existing dry storage systems available in the marketplace today.

DESIGN FEATURES OF NUHOMS® Matrix HSM:

- The total height of the Matrix HSM is only increased by 20" to 40" compared to the existing NUHOMS® HSM overpack but it doubles the number of DSC

Storage capacity.

- Increased height increases stack height for heat transfer from the top row HSMs that compensates for reduced heat removal from the surfaces of bottom HSM row
- Design allows for storage of canisters with different diameters and lengths making this a truly “UNIVERSAL OVERPACK”.
- The elimination of Canister support rails from a typical HSM design results in improved air flow in the HSM cavity and also simplifies aging management inspections in the future.
- Optimum use of reinforced concrete to maximize shielding capability without compromising heat transfer capability and structural capability
- Superior Shielding capability:
  - Monolith structure: no gaps and offers additional significant self-shielding
  - “Sky shine” and direct dose from HSM array roof is cut in half—No roof and hence no Sky shine and direct dose contribution from the HSM bottom row
  - Significant reduction in dose from the bottom HSM roof vents due to long air outlet vent
  - Dose reduction hardware at the HSM bottom and top arrays reduce inlet and outlet vent dose rates
- The design can also be deployed indoors if required reducing the cost of building due to reduced footprint
- Monolithic construction has superior stability and structural performance during any seismic event
- Canister is resting on the bearing blocks and there are no support rails that keep the aging management inspections in the future very simple. The canister is delivered in place inside the Ultra cavity by the transfer hardware and rests on the bearing blocks during storage period.
- Increased Resistance for Missile and Aircraft Crash:
  - Hexagonal Shape has many advantages
    - Most efficient/effective use of space and material
    - Most efficient shape for compressive strength and tensile strength
    - Increased concrete area for heat transfer
    - Adjacent modules self-shield each other similar to rectangular array
  - Aircraft crash/missile protection built in to roof and shield walls makes this a fortress type structure
- Resistance to Seismic Events:
  - Monolith array: Very high seismic resistance
  - Still free to slide: Not anchored to pad: No need for complex anchors and high seismic pad design
  - Option for even stronger performance by simply choosing a back-to-back HSM array increasing the size of the monolith to offer superior seismic performance
- Tsunami/Flood resistance:

  - The NUHOMS® Matrix HSM horizontal above ground system is even more resistant to flooding than the other NUHOMS Systems due to even larger distance between inlet and outlet vents.
  - Since the HSMs are easy to visually inspect and access, flood debris can easily be seen and removed. Canister cooling is uncompromised, due to the fact that the heat conduction capability is engineered into the Canister basket and not reliant upon internal closed cavity convection. This remains true even in the event of a “smart” flood that blocks the lower inlet air vents, but is not high enough to submerge and cool the Canister
  - Floods are not merely water. The flood water can be contaminated with runoff, include road salts, oils, fertilizers, and other waste, which can cause corrosion. Since the NUHOMS® Matrix HSM stores Canisters about 4 feet off the ground at its lowest point, most floods would not affect its shell. This limits the degradation potential of the DSC shell. Floods which block vents can also be remediated quickly. All vents and airflow paths are accessible without removing the HSM door or lifting and/or removing the Canister.
- Security:
  - Safety and security is enhanced at the ISFSI site due to smaller footprint
  - NUHOMS® Matrix HSM is easier to recover from any Beyond Design Basis (BDB) Events as described below:
  - Seismic: HSM cavity and vent flow paths are visible and easy to inspect
  - Flood: No blockage of both inlets and outlets at the same time
  - Tsunami: Fukushima Type Event: Monolith, still free to slide: Not anchored to pad:
  - 9-11 Type Events: Impact Attenuators, stronger HSM roof, side wall and end walls: steel fibers
- Extended Storage:
  - Inspection ports built in very simple Canister/HSM Cavity inspection
  - The inspection roller rails can simply raise the canister at any time or at inspection time, rotate the canister to a different storage position i.e. 180° and lower the canister back on the storage block resulting in simpler and safer AMP
  - Capacity to rotate the Canister using the loading/unloading hardware if needed for basket creep control.
  - Future UNF unloading in preparation to ship off- site will not require a return to the fuel building, the use of the building or single failure crane or the creation and use of an outdoor cask transfer facility. The NUHOMS® Matrix HSM process will continue to be elegant, streamlined and low risk.
  - The eventual retrieval of the Canister is a simple reverse of the loading operation; the same hydraulic ram that pushes the Canister from the Transfer Cask into the Matrix HSM has a grapple mechanism at its tip that is used to pull the Canister from the Matrix HSM back into the

Transfer Cask or transport cask for transporting them off-site as shown in Fig. 8.

- For a decommissioned reactor site, where a minimum of equipment is required for the eventual Canister retrieval from the NUHOMS® Matrix HSM system for shipment to ISF, geologic disposal, or recycling. There is no need to keep a single failure proof crane at the site for handling the UNF on the ISFSI pad.

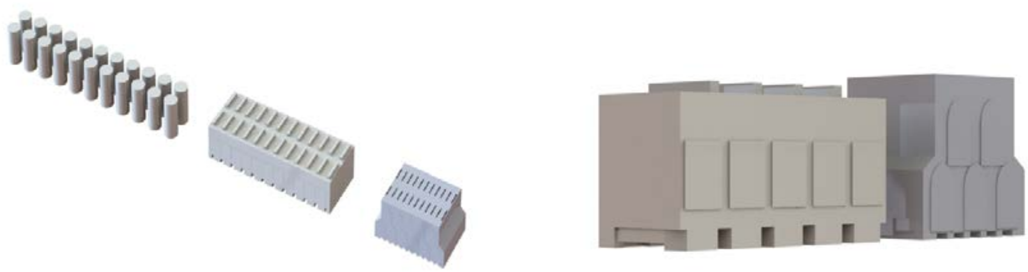

Fig. 7: Illustration of the ISFSI Pad Space for the Standard NUHOMS®, NUHOMS® Matrix HSM and Vertical Storage Systems

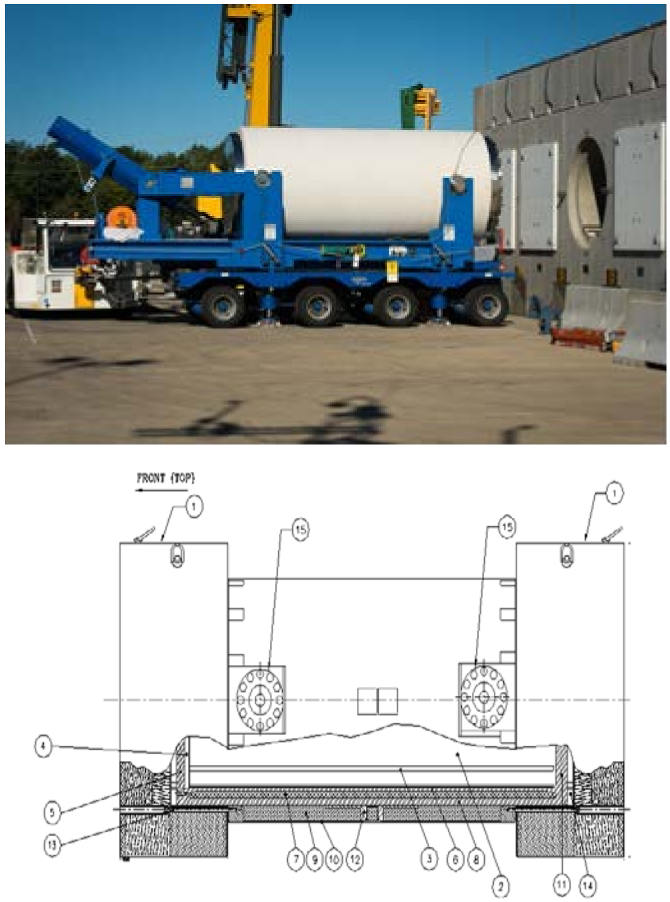

Fig. 8: UNF Unloading Operation with NUHOMS® Matrix HSM System

CONCLUSION

NUHOMS® has been operating safely across the United States for more than two decades and will continue to do so as AREVA TN develops advancements like NUHOMS® Matrix HSM to meet each plant's including shutdown plants critical needs. Not a one-size-fits-all system, the NUHOMS® system offers enhancements such as the ability to withstand and safely operate under BDB events like 9/11 and Fukushima events. If offers special materials for marine environments, advanced capabilities to meet seismic requirements for specific sites, and long-term availability of licensed and highly-engineered transport systems to be ready to move fuel to interim or final storage in the future.

As the industry evolves, the NUHOMS® System with Matrix HSM offer significant safety advantages that are proven to offer highest performance and the most certain path to safe long-term interim storage.

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