NUHOMS® EOS (Extended Optimized Storage): Robust, Advanced, and Dual Purpose Dry Storage System- 16472

Jayant Bondre
AREVA TN jayant.bondre@areva.com

ABSTRACT

AREVA TN has completed the design, analysis, and US NRC license submittal for the NUHOMS®[a] Extended Optimized Storage (EOS) system. NUHOMS® EOS offers a large capacity and high heat load dry storage and transportation solution for UNF. EOS is not a new system, but an evolution of the already-proven safe and low-risk horizontal NUHOMS® storage system, which is one of the most widely used UNF dry storage systems in the United States. The EOS system features a 37PTH dry shielded canister (DSC) for 37 PWR UNF assemblies and an 89BTH DSC for the 89 BWR UNF assemblies. The EOS DSCs will be stored inside a horizontal storage module (HSM) that is a robust, fortress-like concrete storage overpack. Designed with the lessons learned from the Fukushima event in Japan in mind, EOS has robust margins for beyond design basis (BDB) events and offers the lowest risk and highest safety margin of any dry storage system design for recovery from BDB events. EOS also offers innovative aging management features with an aging management program (AMP) to assure safe and low dose long-term storage at the utility sites. EOS incorporates ports for AMP inspections and offers the option of using duplex stainless steel (DSS) for the DSC shell in order to negate corrosion issues. EOS is stored horizontally and above ground, making it easy and quick to access for visual inspection, monitoring, and mitigating actions during AMP.

NUHOMS® EOS is optimized for high capacity, high burnup, high enrichments, and very low cooling times for UNF assemblies. It enables the highest heat load per canister (50 kW) and low dose rates. Even with high heat loads, EOS has significant margins to design basis limits. As the future of used fuel disposition will require the need to move fuel off-site to interim or consolidated storage, EOS is the ideal solution as it enables on-site loading and unloading operations that mitigate risk when transferring fuel on-site or transporting fuel off-site. The EOS design can be safely located in a traditional outdoor setting with fortress-like concrete reinforced modules that offer superior resistance to attack or can be safely operated inside of a building enclosure for those utilities desiring a more discreet siting for its used fuel storage systems.

EOS has an innovative basket design that is made of high strength low alloy (HSLA) material and is easy to fabricate due to its non-welded design. Its innovative inlet and outlet air vent design, which incorporates dose reduction hardware, allows for optimal ambient airflow for highly efficient heat transfer with minimal radiation

[a] NUHOMS® is a registered trademark of AREVA in the United States and/or other countries.

dose. The NUHOMS® EOS storage modules are interlocked in a side-by-side configuration offering superior and robust seismic performance.

The license application for NUHOMS® EOS is currently under US NRC review and this system will be available for deployment in 2017.

INTRODUCTION

When civilian nuclear power plants in the United States were initially constructed, the assumption was that the Federal Government would ultimately take title to the UNF relieving nuclear power plant operators of the burden of managing UNF at their sites. However, this has not been the case and the nuclear industry in the United States is challenged with finding a solution for storing UNF on nuclear plant sites for long periods.

Currently, the only option for United States utilities for UNF management is wet storage in the fuel pools and/or dry storage of UNF on site. The use of on-site dry storage systems on an independent spent fuel storage installation (ISFSI) has become the preferred alternative for many utilities, especially in the United States.

AREVA TN has completed design, analysis, and US NRC license submittal for a NUHOMS® Extended Optimized Storage system that offers a proven-safe large capacity and high heat load dry storage and transportation solution for UNF.

NUHOMS® DRY STORAGE SYSTEM

The design philosophy of the NUHOMS® system was predicated on a system that could be deployed at most nuclear plants with no impact to the existing power plant design. The conservative design basis of the NUHOMS® system gives the user large margins to postulated and BDB natural or man-made events. The other design basis consideration was to design a DSC that would never be lifted, since the lift process, according to the US NRC, is the most risky aspect of the dry fuel storage operation. With the NUHOMS® system, the loaded DSC is only lifted once it is inside the robust onsite transfer cask (TC) which is designed for any drop events.

The NUHOMS® system design consists of the DSC, the TC, and the HSM as shown in Figures 1, 2, and 3 respectively.

The DSC is a stainless steel shell with redundant closure lids at the top and bottom. Steel or lead shielding is provided at each end to keep radiation exposure to workers during loading ALARA as shown in Figure 1. The DSC provides criticality control (prevention of chain reactions), rejection of the heat from the radioactive decay in the UNF, and confinement of the radioactive materials.

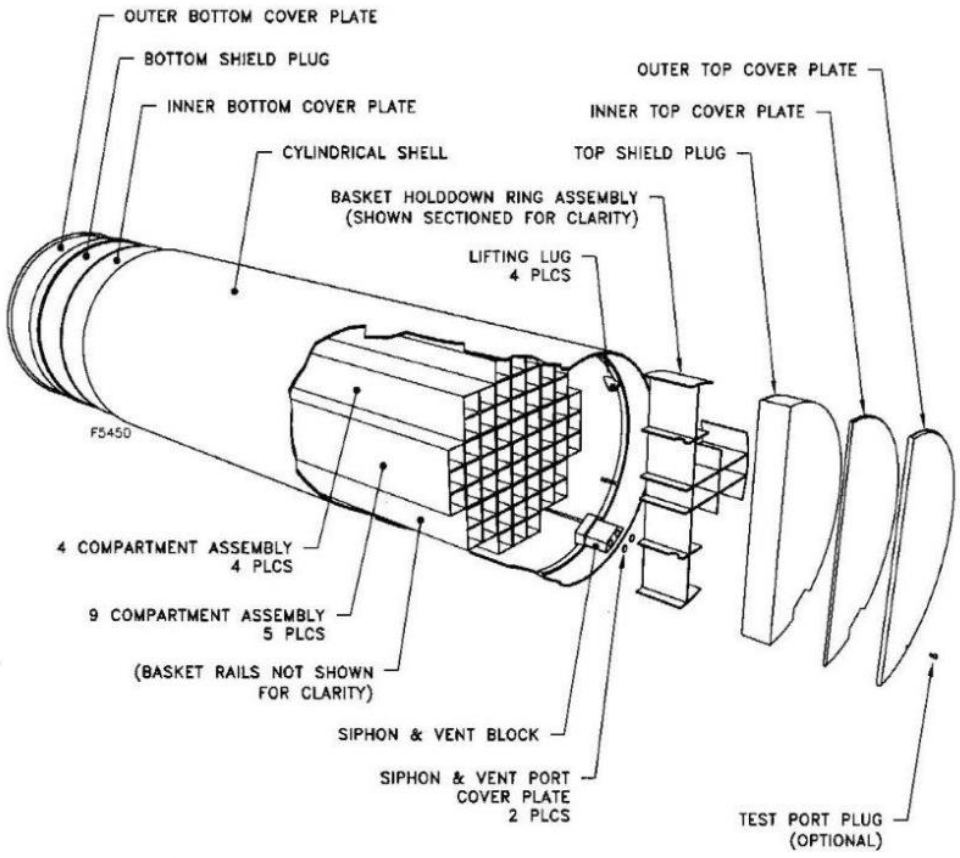

Fig. 1. Typical DSC construction with fuel compartments and basket rails.

The TC includes steel-lead-steel radial gamma shielding and structural support with an outer liquid water jacket for neutron shielding. A bolted lid secures the main opening at the top. There is a penetration at the bottom of the TC for a hydraulic ram that pushes the DSC into the HSM as shown in Figure 2.

During loading operations, the TC with empty DSC is lowered into the spent fuel pool, fuel is loaded, and the TC/DSC is removed from the pool for closure and decontamination. The DSC is sealed and vacuum dried to ensure all water is removed. It is then backfilled with an inert gas (helium) and transferred to the storage pad at an ISFSI.

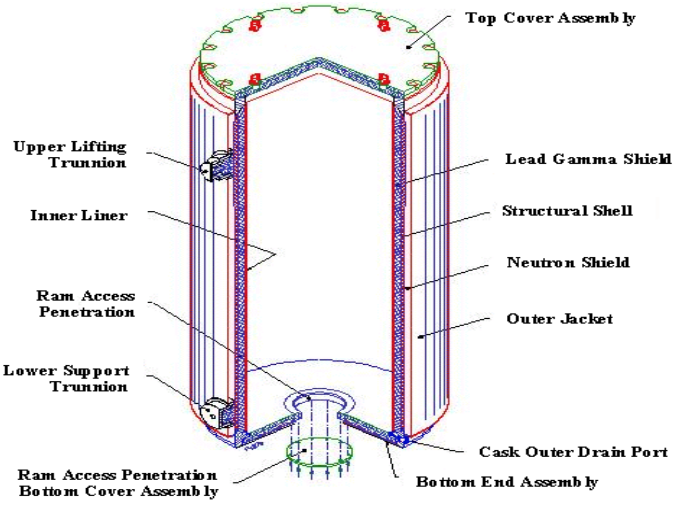

Fig 2. NUHOMS® transfer cask.

The NUHOMS® HSM is a reinforced concrete, fortress-like structure. Multiple HSMs may be placed side-by-side and back-to-back in an array (Figure 3). Additional concrete walls are used at the end of the array for radiation shielding and physical protection. The HSM has vents at the top and bottom for natural convection. Air enters from the bottom and exits at the top. Coated hardened steel rails in the HSM support the DSC. The HSM provides for long-term physical and radiological protection of the DSC containing the UNF during the storage period. The HSM provides protection for the DSC from tornadoes, penetrating objects thrown by tornados (tornado missiles), earthquakes, and floods.

Fig.3. NUHOMS® HSM in an array at ISFSI.

ROBUST, HIGH CAPACITY, AND HIGH HEAT LOAD NUHOMS® EOS SYSTEM

NUHOMS® EOS builds on a state-of-the-art and proven horizontal design that offers features that prepare the industry for the future. It offers unparalleled safety and low dose performance with lowest risk and dose during DSC loading and transfer operations. The NUHOMS® EOS is designed for optimum capacity, capabilities, and economy for customers to deploy at their ISFSI.

The EOS 37PTH (Figure 4) and EOS 89BTH (Figure 5) DSCs can store or transport 37 PWR or 89 BWR assemblies, respectively, with decay heat capacity up to 50 kW, the highest available for any dry storage system. Table I shows a comparison of system capabilities.

TABLE I. EOS 37 PWR and 89 BWR system capabilities.

Parameter	EOS 37PTH System	EOS 89BTH System
Max. initial enrichment (weight% U-235)	5	5
Min. cooling time (years)	3	3
Max. burnup (gigawatt day/MTU)	62	62
Max. decay heat (kilowatt/assembly)	2.0	1.0
Max. heat load (kilowatt/DSC)	50.0	44.0

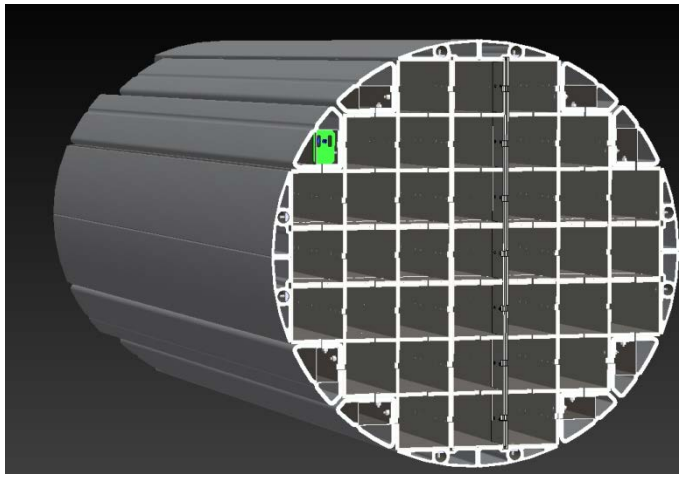

Fig.4. NUHOMS® EOS 37PTH DSC basket.

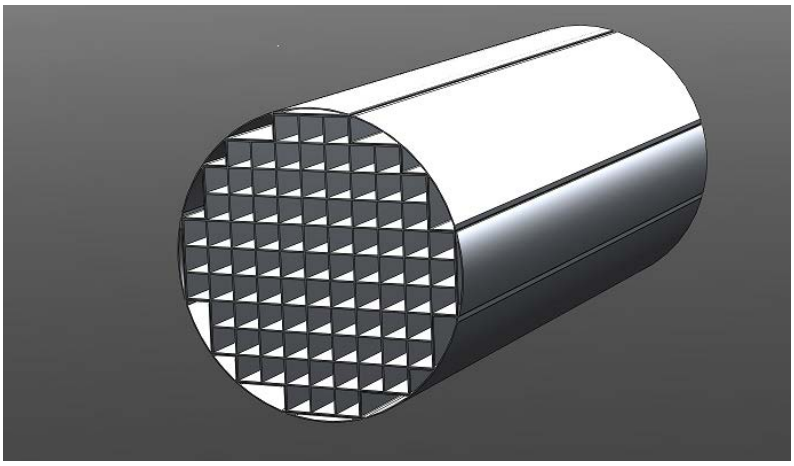

Fig. 5. NUHOMS® EOS 89BTH basket.

EOS is an evolution of the proven safe and low-risk horizontal aboveground NUHOMS® storage system, one of the most widely used UNF dry storage system in the United States. NUHOMS® has a proven track record, with loading of more than 800 DSCs at various sites, which translates to more than 3,000 “canister years” of experience without any issues or challenges to the health and safety of the public. As of January 5, 2016 there are 2,277 casks loaded in dry fuel storage in the United States. AREVA TN is the market leader, with 979 casks loaded at 32 locations in the United States.

EOS has an innovative basket design that is easy to fabricate. It is made of HSLA steel, sandwiched with aluminum and metal matrix composite neutron absorbers, which AREVA TN was first to introduce to the dry storage industry. The innovative inlet and outlet air vent design of the EOS HSM allows for optimal ambient airflow for highly efficient heat transfer with minimal radiation dose through the openings. The license application for the NUHOMS® EOS is currently under US NRC review. The system will be available for deployment in 2017.

The EOS system design also addresses the requirements of AMPs to assure safe and low dose long-term storage at the utility sites. EOS HSMs offer built-in ports for insertion of inspection tools. EOS being above ground allows easy and quick access for any visual inspection, monitoring, and mitigating actions during AMP. The HSM cavity accommodates sensors for continuous data collection, monitoring, and analysis of important parameters of the DSC, HSM, and the environment inside the HSM cavity.

DSCs can have a lifetime of more than 300 years when using 304 stainless steel material for the DSC shell. This is based on pitting rates, although through-pitting of a 1.27 cm to 1.59 cm (1/2 inch to 5/8 inch) steel shell is not the primary failure mechanism that will govern lifetime of the DSC. The greatest concern seen today is due to chloride-induced stress corrosion cracking (CISCC) in coastal atmospheres. For dry storage systems in a coastal or other corrosive environment, the EOS system offers the option of DSS for the most reliable long-term resistance to all

corrosion mechanisms including CISCC. The DSC shell operates in a temperature range where embrittlement of DSS is not a concern.

The DSS materials are suitable for lifetimes in excess of 120 years in a coastal environment with proper aging management. DSS is a proven material that has been used in the offshore oil and gas and desalinization industries as well as in other AREVA nuclear waste applications such as the TRUPACT-III transportation package containment boundary and high integrity radioactive waste containers. It has been successfully used for over 80 years in aggressive corrosive environments. With a proper aging management program, the actual lifetime is longer.

DESIGNED FOR SAFETY DURING BEYOND DESIGN BASIS EVENTS

Long-term interim dry storage is the most likely path forward given the current political and legislative environment in the United States. The safety, security, and BDB events after the 9/11 events in the United States and the Fukushima earthquake and subsequent tsunami in Japan changed the landscape of UNF management in the world. After evaluating the NUHOMS® system for BDB accident conditions more severe than those in the original design basis, we have concluded that NUHOMS® system will perform at a high safety level and withstand such events, both natural and man-made.

The HSM has been proven safe during tornadoes and has been analyzed for tornado-generated missiles. NUHOMS® systems in use at the Davis Bessie Nuclear Power Station have twice experienced a tornado crossing the ISFSI pad. The HSMs performed safely, as designed, and were free from any damage.

The NUHOMS® system has been evaluated for aircraft impact, which is not a required accident condition under 10 CFR Part 72 storage regulations. The time-load curve for the impact of an F-16 fighter plane bounds most aircraft impacts, including the heavier, but slower, commercial aircraft impacts. Analysis of end, front, and top impacts shows concrete deformation and sliding of the module but no damage to the DSC, and thus no release of its radioactive contents. Due to its aboveground design, any likely fuel spill from a crashed aircraft cannot pool inside the HSM. Even in the unlikely scenario where pooling near the base of the HSM may occur, a conservative calculation showed that any resulting fire would burn out long before the DSC materials or the fuel cladding reach their temperature limits.

As discussed earlier, horizontal storage is especially effective for stability in earthquakes. NUHOMS® modules were installed at the North Anna Nuclear Generating Station when an earthquake struck it in August 2011. Minor cosmetic damage and movement was discovered with no impact on the safe operation of the system as shown in Figure 6.

Fig. 6. Cosmetic damage to HSM after North Anna earthquake.

NUHOMS® SYSTEM IS SAFE AGAINST FLOODS

The NUHOMS® horizontal aboveground system is not vulnerable to flooding. Since the HSMs are easy to visually inspect and access, flood debris can easily be seen and removed. DSC cooling is uncompromised because the heat conduction capability is engineered into the DSC 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 DSC.

Floods are not merely water. The floodwater can be contaminated with runoff including road salts, oils, fertilizers, and other waste, which can cause corrosion. Since the NUHOMS® DSC is stored about four 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 that block vents can also be remediated quickly as the system is above ground and easy to inspect and clear. All vents and airflow paths are accessible without removing the HSM door or lifting and/or removing the DSC.

HORIZONTALLY STORED CASKS WERE SAFE DURING FUKUSHIMA EVENT

AREVA TN-designed metal casks were used for dry storage of UNF at the Fukushima site in Japan. They were stored horizontally above ground. The massive earthquake and subsequent tsunami devastated most of the plants but the horizontally-stored AREVA TN dry storage casks performed safely, as designed, and there was no damage to the stored fuel (Figure 7).

Fig. 7. TN-24 Storage casks stored at Fukushima in Japan.

NUHOMS® SYSTEMS CAN BE STORED ON-SITE FOR EXTENDED PERIODS

NUHOMS® DSCs are engineered to ensure continued safe thermal performance in the unlikely event of a crack after extended period of storage. Our DSC design is conservative; it does not credit convective heat transfer in the closed DSC cavity. The helium backfill pressurization is only about 1.14 to 1.20 atmosphere (2 to 3 psig), so any compromise to the DSC containment where the helium fill gas could leak would not risk the ability of the used fuel to continue to cool. The low DSC cavity internal pressure provides a very long period for the discovery, analysis, and repair of a DSC so that preventive and corrective measures can be completed to minimize risk of UNF damage.

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 to meet each plant's 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® systems offer significant safety advantages that are proven to offer highest performance and the most certain path to safe long-term interim storage.

Relying on its long history of safe storage worldwide, NUHOMS® is the practical solution for peace of mind and a system that can be trusted for the generations ahead. Tried and true, NUHOMS® delivers proven dry fuel storage performance

characteristics that meet global needs today and prepares for the future needs of global used fuel storage in all environments and scenarios.

Based on all these considerations, our advanced NUHOMS® EOS system design retains the significant advantages of the proven horizontal and aboveground system and uses the same safe and superior conservative design philosophy that performs in all natural and man-made events. Thus, this evolution of a superior design is the ideal system for long-term and safe storage of used fuel around the world.