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Adaptation of an MPC Dry Cask Technology for Safe Packaging of Vitrified High Level Waste (HLW)

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Abstract

Commercially available multi-purpose concrete based systems can be efficiently adapted for storing vitrified high level waste (HLW) canisters. Such an approach would guarantee that the HLW canisters are not only stored safely, but also packaged in a configuration that would minimize costs while leveraging opportunities to improve waste management system integration. In particular, this HLW storage approach reduces future repackaging and transportation risks by relying on existing transportation casks and packaging infrastructure. Consistent with these performance objectives, the NAC-MPC Multipurpose Canister System has recently been deployed to store HLW canisters on an onsite dry storage pad at a U.S. decommissioning site. Furthermore, these NAC-MPC canisters are being licensed for transport in the NAC-STC casks, offering a transportable solution for the HLW canisters that relies on proven, licensed transport cask technology. This paper provides an overview of the design, licensing and project implementation to adapt a commercially-available spent fuel multi-purpose canister (MPC) system and its applicable transport overpack to efficiently package vitrified HLW for storage and transport. The recent deployments of these packages in the U.S already provide valuable experience and lessons learned, offering significant benefits for similar future projects.

Introduction

The NAC-MPC system is a concrete-based, transportable storage canister system, currently licensed for storage under U.S. NRC Certificate of Compliance (CoC) No. 72-1025. The canister is also approved for transport in the NAC-STC cask licensed under U.S. NRC CoC 71-9235. The system contents include a myriad of spent fuel designs and greater than Class C (GTCC) waste and most recently, this technology has been adapted to accommodate vitrified HLW into dry storage to support decommissioning activities at the U.S. Department of Energy (DOE) West Valley Demonstration Project (WVDP) currently undergoing remediation. The certification and licensing plan for this high level waste storage system, now officially named the MPC-WVDP, required the submittal and approval by the DOE of a design and documented safety analysis (DSA) application in accordance with the requirements of 10 CFR 830, Subpart B. In addition, NAC submitted to the U.S. NRC for review and certification an amendment to the current NAC-STC transportation safety analysis report (SAR) to incorporate the MPC-WVDP metal overpack and the HLW as approved contents, in accordance with 10 CFR 71. This paper provides an overview of the modified system which is now being used for HLW storage and West Valley.

System Description

The principal components of the MPC-WVDP system are the HLW Overpack and Vertical Storage Cask (VSC).

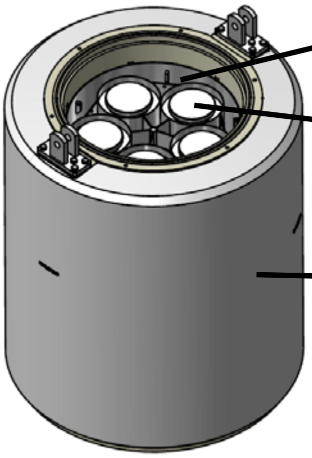

Figure 1 MPC-WVDP System with Loaded HLW Overpack

The MPC-WVDP incorporates a five-cell basket for the HLW canisters, providing the structural support and primary heat transfer paths for the HLW canisters and contents. The basket is placed inside a transportable storage canister (TSC), also referred to as the metal overpack canister.

<u>HLW Contents</u>

A total of 275 canisters:

- Dimensions: 10 feet (3.01m) in length, 25 inches (64 cm) in diameter
- 2,670 R/hr average
- 1,100-7,500 R/hr range
- Canister weight: <5,500 lbs (2500 Kg)

<u>Metal Overpack Design</u>

The basic parameters of the MPC WVDP Metal Overpack are:

- Capacity of five HLW canisters
- 304/304L stainless steel fabrication
- 3/8-inch (9.5 mm) shell, 4-inch (102 mm) closure lid and 2-inch (51 mm) bottom plate
- 71 inches (180 cm) in diameter
- 14,500 lbs (6,600 Kg) unloaded weight

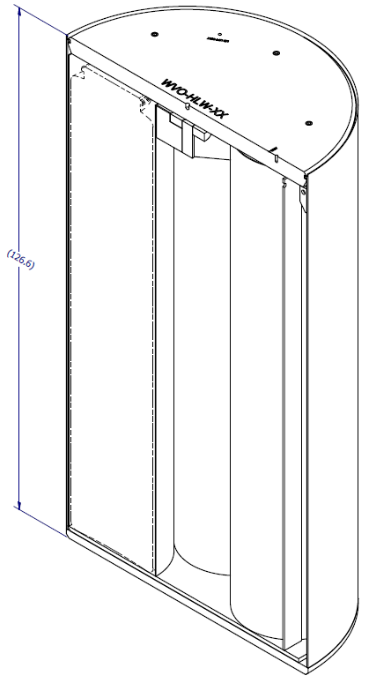

Figure 2 MPC WVDP Metal Overpack

Vertical Storage Cask (VSC)

A cutaway of the steel lined reinforced concrete cask with dimensions is shown in Figure 3.

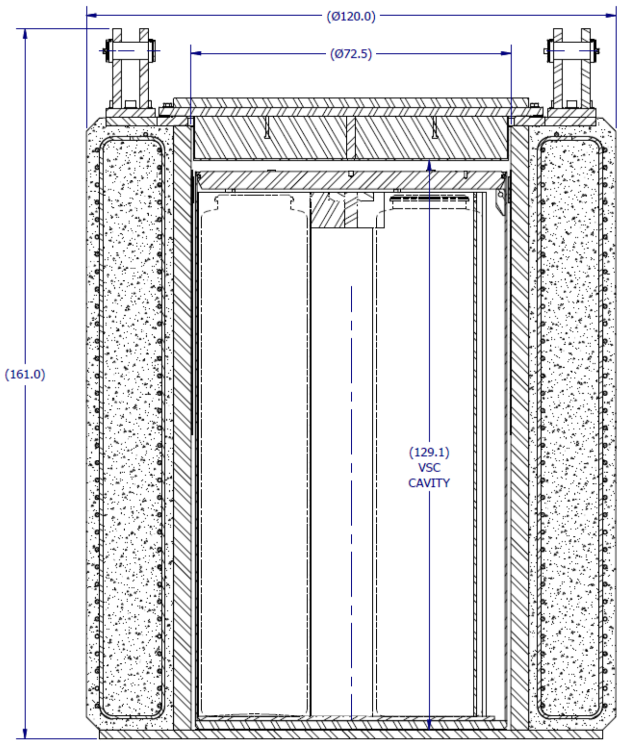

Figure 3 Vertical Storage Cask Dimensions

Key attributes of the design are:

- Reinforced concrete construction, steel-lined with 4-inch (102 mm) low alloy steel
- 120 inches (3 meters) in diameter
- Weight unloaded/loaded 54/80 metric tons.

Overall Functional Requirements

- Minimum Design Life of 50 years
- VSC designed to meet requirements of 10 CFR 72 incorporating HLW content into Safety Documentation for the site safety case per 10 CFR 830B.
- <1 mrem/hr at one meter
- Dry loading operations and transfer to the interim storage pad
- Normal, off-normal, accident conditions for storage and transport

Safety Evaluations

The MPC-WVDP system design, evaluations, and analyses were based on the requirements of the NAC-MPC Final Safety Evaluation Report (FSAR), as applicable, and were incorporated into the West Valley site DSA obtaining DOE interim storage approval in accordance with 10 CFR 830B.

All cask and canister hoisting and rigging were engineered and supplied complying with DOE standard, Hoisting and Rigging (DOE-STD-1090-2011) and in accordance with site-specific Administration of Hoisting and Rigging Activities. In addition, the closure lid and its weld to the overpack shell, and the associated loaded overpack rigging and hardware, were designed to meet the requirements of ANSI N14.6/NUREG 0612 for critical lift through high design safety factors and redundancy. The loaded overpack handling evaluations considered both static and dynamic loads by utilizing a 10% dynamic load factor as used in the current NAC-MPC FSAR.

Analysis of Storage Conditions

The main storage components, primarily the overpack and the VSC, were evaluated for ambient conditions and accident conditions applicable to the WVDP site and facility. The following conditions were considered:

a.) Environmental Temperature Conditions:

- Extreme Minimum Temp.: -40 oC
- Average Ambient Temp.: 24oC
- Extreme Maximum Temp.: 43 oC

Extreme temperatures were expected to be of short duration in accordance with system design criteria and therefore, were evaluated for duration of ≤ twelve hours.

b.) Seismic Accelerations – The MPC-WVDP loaded VSC and overpack confinement boundary was designed and analyzed to withstand horizontal peak ground acceleration (PGA) of 0.1 g and a vertical PGA of 0.067 g. These accelerations bound the WVDP design basis earthquake, quantified in engineering terms using U.S. NRC Regulatory Guide 1.60.

c.) Design Wind Loadings – The MPC-WVDP system is designed for a wind speed of 40.3 m/s (90 mph), and 51.5 m/s (115 mph) with gust factor included. These are considered to be bounding of the site wind loading requirements.

d.) Tornado and Tornado Induced Projectiles – The design and construction of the system is robust and capable of withstanding any credible tornado or tornado driven projectile without any release of the system's radioactive contents. The systems robustness has been evaluated and confirmed in the U.S. NRC certification for the basic NAC-MPC system, which has been specifically improved to meet the specific requirements for the Interim HLW Storage Facility (e.g., four-inch thick liner versus standard NAC-MPC liners of 2.5 to 3.5 inch provided for other decommissioned nuclear facility storage facilities). The design basis tornado characteristics previously evaluated for the NAC-MPC system were consistent with Regulatory Guide 1.76, and severe tornado missiles per NUREG-0800, Spectrum I, were also evaluated for the design basis.

e.) Postulated MPC-WVDP System Drop Conditions – The loaded VSC is transported to the Interim HLW Storage Facility utilizing a non-single-failure-proof towed Vertical Cask Transporter (VCT). The VCT was designed and operationally constrained to limit the loaded VSC lift height of ≤ 6 inches off the transport and storage facility pad surfaces. Accordingly the loaded VSC is evaluated for a maximum six-inch drop onto the Interim HLW Storage Facility pad based on the pad and soil properties established in the facility design. A nine-inch drop is also being evaluated to provide greater operational margins and handling flexibility. The acceptance criteria for the maximum drop condition is no release of radioactive material from the MPC-WVDP system (e.g., no breach in the overpack) and the ability to retrieve the overpack from the VSC and to recover from a drop incident.

f.) Lightning Protection Design – Lightning protection for the VSC complies with NFPA 780. Lightning protection was provided for all features that are part of the Interim HLW Storage Installation in accordance with the requirements of DOE G 420.1-1.

g.) Snow and Ice Loading – Western New York typically receives extensive amounts of snow and ice each year. In particular, the WVDP site area experiences an average of 42 inches of precipitation per year plus 100 to 150 inches of snow. Accordingly, the MPC-WVDP VSC was evaluated for effects of a snow load of 58 lb/ft^2. Snow, rain, and ice design loads were evaluated as given in ASCE 7-10. Intense rainfall was not considered to be a hazard to the Interim HLW Storage Facility and will not result in releases of radioactive materials. The facility and MPC-WVDP systems shall incorporate industrial means and methods for waterproofing and sealing to prevent the intrusion of intense rain.

h.) Handling Loads – The VSC was designed and evaluated for the maximum normal handling loads postulated to occur during vertical transport to/from the Interim HLW Storage Facility storage pad. The design also considered the maximum normal handling loads postulated to occur during transfer operations from the VSC to the NAC-STC transport cask even though offsite transport is not planned at this time.

i.) Internal Pressure – The MPC-WVDP HLW overpack also meet the requirements designed for load combinations, stress limits and other structural requirements contained in Regulatory Guides 7.6 and

7.8. Accordingly, the internal overpack pressure was evaluated based on the initial cavity gas pressure, the optimum gas type and initial backfill pressure. These load combinations are bounded by the MPC system design basis conditions postulated in the original MPC FSAR.

Structural Considerations

Structural analysis of the transport cask containment components are based on the Maximum Normal Operating Pressure (MNOP). The MPC-WVDP overpack is seal welded, thereby limiting the overpack's internal pressure to those caused by variations based on temperature for the normal, off-normal and hypothetical accident conditions. The current limiting MNOP was evaluated to confirm that cask cavity pressure of a breached MPC-WVDP overpack is bounded by the current NAC-STC SAR analyses and its containment boundary, which was designed to the ASME B&PV Code, Section III, Division 1, Subsection NB for Class 1 Components. Therefore, the existing NAC-STC transport cask body analyses was verified as bounding for the MPC-WVDP HLW overpack content conditions. Because the loaded weight of the loaded HLW overpack is less than the standard MPC canister weights, and no credit was taken for the overpack boundary, the NAC-STC drop analysis was valid, which demonstrated bounding conditions for the HLW content. This include considerations and mode predictions for impact limiter responses in the drop scenarios.

Operational handling of the NAC-STC transport cask loaded with the MPC-WVDP overpack and appropriate axial spacer(s) was also verified as bounded by the existing STC handling and lifting analyses. Based on these evaluations, it was confirmed that the loaded NAC-STC transport cask can be shipped on a railcar and can be lifted by the existing transport skid/tie down structure during intermodal transfers.

Thermal Evaluation

The VSC was demonstrated to maintain concrete and HLW canister contents below 400°C in accordance with WVDP design criteria. Each HLW generates less than 200W of heat, resulting in a low average heat load (<1kW) per system. This afforded the opportunity to evaluate, and eventually eliminate, the system inlets and outlet vents to improve system dose performance and seal the system. Analysis of the system to meet allowable concrete temperatures was carried out for the heat loads corresponding to a full system loading of five maximum heat load HLW canisters (i.e., 1.5kW). This demonstrated that for any HLW heat load combination, the concrete did not exceed the temperature limits specified per Section E 4.2 of ACI-349, Appendix E and NUREG-1567.

With respect to thermal evaluation of the content for transport, it is important to consider the HLW heat load content is much less than the design basis heat loads analyzed for the NAC-STC Transport Cask, which is an exclusive use package designed for transport in a 100^{o}F environment such that personnel barrier temperatures do not exceed 185^{o}F, thus, meeting the requirements of 10 CFR 71.43(g). In summary, the HLW contents maximum temperature during normal and accident conditions of transport was shown to be ≤ 400^{o}C.

Shielding Evaluation

The dose rate of the loaded MPC-WVDP system was required to be less than one mRem/hr (for average canister content conditions) and less than five mRem/hr (for maximum Curie canister content conditions) at one foot from any surface of the system.

The dose rate at the perimeter fence (which is the existing WVDP controlled area), the closest point of which is expected to be 250 feet away from the closest MPC-WVDP system, and any continuously occupied facility was required to be less than 50μRem/hr above natural background. To meet these requirements, the MPC concrete cask steel liner was increased to four inches, which provides an up to 1.5 inch of additional metal for gamma attenuation when compared to the standard MPC system.

For transport, the analysis demonstrated that the dose rate requirements of 10 CFR 71.47 are easily met. The dose rate at any point on the external surface of the package will be much less than 1000 millirem per hour and at any point on the external surface of the railcar, including the top and underside, which is ≤ 200 millirem per hour. The dose rate at any point two meters from the outer lateral surfaces of the railcar is evaluated to be ≤ 10 millirem per hour.

Criticality Evaluation

The MPC-WVDP overpack high level waste contents do not contain significant quantities of fissile material and therefore, specific criticality analysis of the new MPC-WVDP overpack content conditions was not required.

System Operations and Transfer

Key challenges to implementing dry storage at the West Valley facility were linked to requirements to perform cask operations in a highly contaminated environment and limitations such as floor loading in existing facilities. For this reason, the MPC-WVDP was designed to be compatible with various methods of conveyance to load a VSC inside the existing HLW storage facility under high dose / high contamination conditions. The approach required some remote handling operations and vertical system loading capabilities, including design features for backup recovery in the event of equipment malfunction. The specially designed TL-220 (Figure 4) is used to move casks in and out of the facility.

Figure 4 TL220 Cask Transporter

Once inside the facility, the cask is transferred onto a second cart, which transfers the VSC into the

HLW storage area. In this mode, one method of conveyance is used for transferring the VSC from the clean cask preparation areas, while the second cart is used for conveyance of the VSC inside the highly contaminated areas within the facility.

After the HLW canisters are loaded in the highly contaminated HLW storage area, a temporary lid is placed to transfer the VSC to a designated decontamination area, the temporary lid is then removed and the overpack lid is installed using the remote handling equipment. With the lid in place, the VSC is then transferred to the welding station and canister preparation area where lid welding operations and processing is performed. For this, project NAC supplied a Liburdi Automatic Welding Machine, utilizing the Gas Tungsten Arc Welding (GTAW) process, similar to welding systems used for canister closure at other commercial plants. The system ensures a predictable, high-quality weld is performed with each canister closure.

After welding, required inspections and processing, the VSC lid is installed and surveys are taken. At this point, the system is ready to be moved to the HLW storage pad. Using air pallets, the VSC is moved outside the building to a rendezvous location with the vertical transport equipment consisting of an A-frame transporter with tugger as shown in Figure 5.

Figure 5 Transfer of VSC to Storage Facility

Outside the building, the A-frame equipment engages the VSC lift lugs at the top to lift the cask off the air pallet and to carry it to the HLW storage pad. At the HLW storage pad, the VSC is then transferred to its specific storage location. These steps will be repeated until all systems are loaded on the pad. A total of 56 systems will be accommodated in the storage pad in a predetermined 7X9 array, leaving six locations open for cask handling and added operational flexibility. The first cask loading was completed in November 2015 (Figure 6). The site operator is now routinely loading systems and expect to complete the HLW relocation by the end of 2016.

Figure 6 First VSC Placement On Storage Pad

Conclusions

The MPC-WVDP system demonstrated the feasibility to adapt and license a commercially available spent fuel multi-purpose canister system and its applicable transport overpack to efficiently package vitrified HLW for storage and transport. The recent deployment of this system in the U.S already provides valuable experience and lessons learned, offering significant benefits for similar future projects. The West Valley project will deploy a total of 56 systems to accommodate the total of 275 HLW containers. Significant lessons learned were gained in the first loading campaign, resulting in process efficiencies that now allow system loading operations within 2.5 days. In fact, recent loadings at West Valley has fully demonstrated that it is possible to load three systems per week.

Licensing of the MPC-WVDP also provided valuable lessons learned. As described in previous sections, the process to license the system leverage the existing design and analysis from an existing 10 CFR 72 and 10 CFR 71 licensed systems. It was demonstrated for the majority of the analyzed conditions, that the bounding scenarios for design basis contents of commercially available spent fuel systems easily envelop many of the conditions and assumption for vitrified HLW contents for both for storage and transport conditions.