SAFETY EVALUATION

FACILITY OPERATING LICENSE NO. DPR-43

DOMINION ENERGY KEWAUNEE, INC.

KEWAUNEE POWER STATION

DOCKET NOS. 50-305 AND 72-64

1.0 INTRODUCTION

By letter dated July 28, 2016, (Agencywide Documents and Access Management System (ADAMS) Accession No. ML16216A187), as supplemented by letter dated September 27, 2016 (ADAMS Accession No. ML16279A069), Dominion Energy Kewaunee, Inc., (DEK or the licensee) requested an amendment permitting modification of the Updated Safety Analysis Report (USAR) for the Kewaunee Power Station (KPS). The supplement dated September 27, 2016, provided additional information that clarified the application, did not expand the scope of the application as originally noticed, and did not change the staff's original proposed no significant hazards consideration determination as published in the *Federal Register* on October 25, 2016 (81 FR 73431).

The amendment would enable the licensee to make changes to the USAR to reflect the use of a non-single-failure-proof intermediate lifting device as part of the cask handling equipment associated with the NAC International, Inc., (NAC) MAGNASTOR System and incorporate a new load drop analysis applicable to the use of this intermediate lifting device. Specifically, the licensee determined that the most appropriate method for transferring a loaded transportable storage canister (TSC) into or out of its vertical concrete cask (VCC) would be through use of a conservatively designed, but non-single failure proof, chain hoist assembly as an intermediate lifting device. Cask handling operations within the KPS auxiliary building have been licensed using the guidelines of NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants,” which specifies use of a single-failure-proof handling system or completion of load drop consequence analyses to verify the heavy load handling activities can be completed in a safe manner with appropriate defense-in-depth. The licensee has provided revised USAR information to summarize changes to the handling activities associated with dry spent fuel storage that take place in the KPS auxiliary building and the new drop analysis of the TSC into the VCC.

2.0 REGULATORY EVALUATION

2.1 Regulatory Requirements and Guidance

Title 10 of the Code of Federal Regulations (10 CFR), Section 50.34, “Contents of Applications; Technical Information,” required that each application for an operating license issued by the Commission include a safety analysis report containing analysis and evaluation of the design and performance of structures, systems, and components of the facility with the objective of assessing the risk to public health and safety resulting from operation of the facility. By letter dated December 22, 1980, the U.S. Nuclear Regulatory Commission (NRC) requested licensees to review controls for the handling of heavy loads. Pursuant to 10 CFR 50.71(e), operating license holders must periodically update the safety analysis report to include the effect of analyses of new safety issues performed at the request of the NRC, such as this review of the handling of heavy loads.

The NRC staff provided regulatory guidelines to support this review in NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants,” July 1980 (ADAMS Accession No. ML070250180). Implementation of these guidelines was intended to assure safe handling of heavy loads in areas where a load drop could impact stored spent fuel, fuel in the reactor core, or equipment that may be required to achieve safe shutdown or permit continued decay heat removal. Section 5.1 of NUREG-0612 explains that the objective of the guidelines is to ensure that either the potential of a load drop is extremely small, or the following criteria for consequences of an accidental load drop are satisfied:

- Any release of radioactive materials resulting from damage to fuel is small;
- Subcriticality of fuel is maintained following damage to or reconfiguration of fuel;
- Water level is maintained over fuel following damage to spent fuel pool or reactor vessel;
- Required safe shutdown functions are maintained following damage to safe shutdown equipment.

Since DEK has certified that KPS has been permanently shut down and defueled pursuant to 10 CFR 50.82(a), there are no required safe shutdown functions at KPS. Therefore, the final criterion is no longer applicable to KPS, and the third criterion is only applicable to the KPS spent fuel pool.

Section 5.1.1 of NUREG-0612 provides guidelines for reducing the likelihood of dropping heavy loads and a measure to reduce the potential consequences of an accidental load drop. These guidelines include the following: criteria for establishing safe load paths; procedures for load handling operations; training of crane operators; design, testing, inspection, and maintenance of cranes and lifting devices; and analyses of the impact of heavy load drops.

The general guideline for design of cranes references the following design standards: American Society of Mechanical Engineers (ASME) B30.2-1976, “Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist);” and Crane Manufacturers Association of America (CMAA) Standard 70 (CMMA-70), "Overhead and Gantry Cranes,” (1967). Comparable standards for underhung hoists are ASME B30.16, “Overhead Hoists (Underhung);” and CMAA-74, “Specifications for Top Running and Under Running Single Girder Electric Overhead Cranes Utilizing Under Running Trolley Hoist.” The ASME Cranes for Nuclear Facilities Committee has issued the following standard to address use of overhead hoists in nuclear facilities: ASME NUM-1, “Rules for Construction of Cranes, Monorails, and Hoists (With Bridge or Trolley or Hoist of Underhung Type).” An overhead hoist designed to the Type III criteria of ASME NUM-1 is comparable in quality and design margins to cranes designed to ASME B30.16 or CMMA-74. The ASME NUM-1 standard defines a Type 1B hoist as a ”hoist with enhanced safety features, including increased design factors and redundant components that minimize the potential for failure that would result in the loss of capability to stop and hold the critical load.”

The guidelines in Sections 5.1.2 through 5.1.5 of NUREG-0612 provide additional measures applicable to certain areas of a nuclear power plant that either further reduce the probability of a load-handling accident or ensure the consequences of heavy load drops in specific areas of the facility would be small. These measures include elements such as: using a highly reliable handling system, employing electrical interlocks and mechanical stops to restrict crane travel to safe areas, or performing load drop consequence analyses to assess the effect of dropped loads on safety and plant operations. Section 5.1.6 of NUREG-0612 specifically addresses design features necessary for a highly reliable load handling system. These design features are intended to reduce the probability of a load handling accident occurring to such a degree that a load drop event would not be postulated as part of the design basis of the facility. These features include use of a single failure-proof crane to improve reliability through increased factors of safety and through redundancy or duality in certain active components. For operations where a highly reliable handling system is not used, Appendix A to NUREG-0612 provides for the performance of load drop consequence analyses to show the load handling system is consistent with the criteria in Section 5.1 of NUREG-0612.

As approved in Amendment 200 to the KPS operating license, issued by letter dated November 20, 2008 (ADAMS Accession No. ML082971079), DEK upgraded the auxiliary building crane and associated equipment to handle a previous dry spent fuel storage system with a single failure proof handling system. These changes are consistent with the guidelines of Section 5.1.6 of NUREG-0612.

The cask loading operation of lowering the TSC onto the VCC pedestal in a stack-up configuration is governed by Certificate of Compliance, No. 1031, Condition 4, “HEAVY LOADS REQUIREMENTS,” for the NAC MAGNASTOR System. Condition 4 requires that each lift of a MAGNASTOR TSC, transfer cask, or concrete cask be made in accordance with the heavy load requirements and procedures described the current SAR of the licensed facility at which the lift is made. Condition 4 further directs that a plant-specific safety review be performed under 10 CFR 50.59 or 10 CFR 72.48, as applicable, to show operational compliance with existing plant-specific heavy loads requirements. The regulations at 10 CFR 72.212(b)(8) require that a general licensee determine whether the cask loading operation involves a change in the facility Technical Specifications or requires a license amendment in accordance with 10 CFR 50.59(c). The applicant performed a safety review pursuant 10 CFR 50.59 and determined the proposed NAC MAGNASTOR dry spent fuel storage system at KPS required changes to the USAR through a license amendment. The staff’s technical evaluation of these changes is presented in the remaining sections of this chapter and in Chapter 3.

The applicant’s transfer operations in the spent fuel building are regulated under Part 50. However, because the suspended load contains a canister holding spent fuel, the NRC’s regulations for a dry spent fuel storage system at Part 72 are also applicable. Specifically, the requirements of 10 CFR 72.122, "Overall Requirements", apply to general license holders of independent spent fuel storage installations. Paragraph 72.122(b)(2)(i)(B), requires that structures, systems, and components important to safety are designed to accommodate the effects of normal and accident conditions and the effects of natural phenomena. General licensees must verify that structures, systems, and components important to safety are capable of performing their intended design functions, including maintaining subcriticality, cooling, and confinement under postulated design basis accidents.

The NRC staff presented revised guidelines for review of cask system performance in NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," Revision 1, July 2010 (ADAMS Accession No. ML101040620). Section 3 of NUREG-1536 provides guidelines for the review of structural performance of the cask systems for withstanding cask drop accidents considered in the design basis. The guidelines include acceptance criteria to ensure that the cask system is capable of maintaining its cooling, confinement, and criticality safety functions after the postulated cask drop events.

2.2 Design and Operation of Cask Handling System

The KPS cask handling system is described in Section 9.5, "Fuel Handling System," of the KPS USAR. The auxiliary building (AB) crane performs the heavy lifts associated with cask loading and handling operations. The licensee upgraded the AB crane from its original design by replacing the trolley with a single failure proof design and modifying the existing crane bridge. By letter dated November 20, 2008, the NRC staff issued Amendment 200 to the KPS operating license (ADAMS Accession No. ML082971079), which determined that the KPS cask handling system met the intent of Section 5.1.6 of NUREG-0612. The licensee intends to use the crane with a new dry fuel storage system. With the original system, the licensee completed all lifts with a single-failure-proof handling system consistent with approval granted in Amendment 200.

The new dry fuel storage system, the NAC International, Inc., MAGNASTOR System, is a vertical storage system. The licensee provided the following description of the storage system loading process:

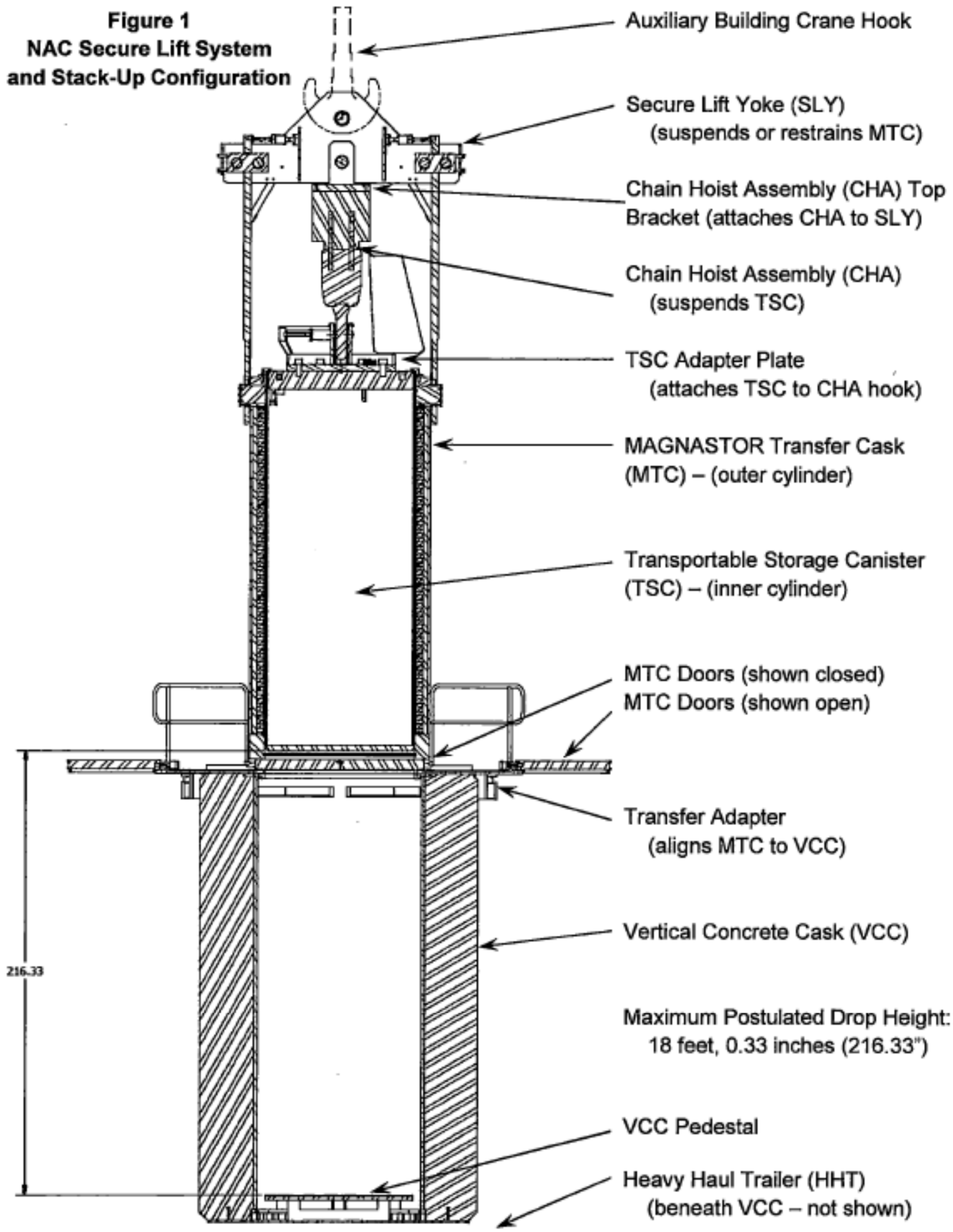
> In preparation for loading spent fuel into a NAC MAGNASTOR transportable storage canister (TSC), an empty TSC and MAGNASTOR transfer cask (MTC) are initially staged in the auxiliary building truck bay area. The empty MTC is first transferred to the cask decontamination area using the KPS auxiliary building (AB) crane (part of the KPS fuel handling system) and NAC in-pool lift yoke. The empty TSC is then placed into the MTC using the AB crane and slings. Both the truck bay and cask decontamination areas are away from the spent fuel pool and designated as safe load path areas. These areas, as well as the auxiliary building areas directly below, do not include any important to safety equipment or equipment needed for maintaining spent fuel pool cooling or water inventory.
>
> The MTC containing the empty TSC is transferred into the spent fuel pool (SFP) cask loading area using the AB crane and NAC in-pool lift yoke. Spent fuel is loaded into the TSC using the KPS fuel handling bridge crane. Once loading of spent fuel into the TSC is complete, the TSC lid is positioned onto the TSC using the AB crane, the NAC in-pool lift yoke, and a sling set. Transfer of the MTC containing a loaded and unsealed TSC from the SFP to the cask decontamination area is performed using the KPS AB crane and the NAC in-pool lift yoke.

Canister processing operations in the cask decontamination area involve the placement of shielding and welding equipment onto the MTC and TSC using the AB crane and slings. After the TSC is processed, sealed (welded), and tested for confinement integrity, the chain hoist assembly is used to lift the TSC adapter plate to place it onto the TSC (the TSC adapter plate is used to attach the TSC to the chain hoist assembly hook for subsequent use). Transfer of the loaded and sealed TSC from the cask decontamination area into the stack-up configuration above its vertical concrete cask (VCC) is performed away from the spent fuel pool using the auxiliary building crane, MTC, and NAC secure lift yoke.

After the entire system is in the stack-up configuration (supported by the auxiliary building crane), the chain hoist assembly is used to lift the TSC off of the MTC doors approximately one-half inch. Following a five minute hold, the MTC doors are opened and the chain hoist assembly is used to lower the TSC into the VCC located on a heavy haul trailer in the truck bay. Once the TSC is in position on the VCC pedestal, the TSC adapter plate is unbolted from the TSC lid and the chain hoist assembly is used to lift the TSC adapter plate into the MTC to permit closure of the MTC shield doors. Throughout this entire operation, the TSC is confined inside the MTC or VCC. Furthermore, the MTC remains connected to the secure lift yoke, which is pinned to the hook of the auxiliary building crane. The chain hoist assembly is used for lowering the TSC from the MTC into the VCC (loading) or raising the TSC into the MTC from the VCC (unloading).

The components described above are shown in the stack-up configuration in Figure 1 provided by DEK below.

Figure 1
NAC Secure Lift System
and Stack-Up Configuration



2.3 Requested Changes

The cask loading operations use the NAC secure lift system for certain load movements within the auxiliary building. The secure lift system consists of two parts, the secure lift yoke and the air-driven chain hoist assembly. The secure lift yoke connects the AB crane hook to the MAGNASTOR transfer cask (MTC) and is used to move the MTC from the cask decontamination area to position the MTC in the stack-up configuration above the VCC in the truck bay. The chain hoist assembly is connected to the center of the secure lift yoke immediately below its connection to the AB crane hook. The chain hoist assembly is connected to the TSC by the TSC adapter plate. The chain hoist assembly is used to lift the TSC off the MTC doors so they can be opened and to lower the TSC from the MTC onto the VCC pedestal.

The secure lift yoke is designed to be consistent with the guidance of Section 5.1.6 of NUREG-0612. The secure lift yoke connects to the licensed MTC, and the MTC supports the sealed TSC with its load of spent fuel during the movement from the cask decontamination area to the stack-up configuration above the VCC.

Once in the stack up configuration, the chain hoist assembly is connected to the TSC and the chain hoist assembly is used to lift the TSC off the MTC doors. The chain hoist assembly is not consistent with guidelines of Section 5.1.6 of NUREG-0612 as a single-failure-proof hoisting device. Consequently, a failure of the hoist is considered a credible accident condition. To ensure an acceptable level of defense-in-depth consistent with NUREG-0612 guidelines, the licensee chose to evaluate the consequences of a postulated drop of the loaded TSC from the highest lift height while attached to the chain hoist assembly to the VCC pedestal.

The proposed amendment would revise KPS USAR Section 9.5.2.2.4, “Auxiliary Building Crane,” to add a description of the chain hoist assembly DEK intends to use to transfer the loaded TSC from the MTC to the VCC and incorporate a new load drop analysis evaluation the consequences of a drop of the TSC onto the VCC pedestal. The proposed revision to the USAR read as follows:

> Certain cask handling activities performed away from the spent fuel pool involving the NAC MAGNASTOR secure lift system rely on an intermediate lift device (chain hoist assembly) between the AB crane hook and the transportable storage canister (TSC). This lift device is used to lift and lower a TSC (loaded or unloaded) when transferring it into or out of its vertical concrete cask (VCC) while the MAGNASTOR transfer cask (MTC) is in a stack-up configuration atop the VCC. The intermediate lift device is used for the purpose of transferring the TSC between the MTC and VCC while the MTC is attached to the AB crane (via the secure lift yoke). Maintaining attachment between the MTC and the AB crane by the secure lift yoke during transfer restrains the MTC and thereby avoids a free standing "stack-up" configuration.
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> To minimize the potential for a drop of a loaded TSC, the intermediate lift device is designed with enhanced safety features to ASME NUM-1-2007, Type 1B standards for handling critical loads. The maximum critical load rating for the lift

> device is 50% of its ASME B30.16 design rating, providing an overall factor of safety of 10 to 1 for the maximum critical load. The design of the lifting device also includes redundant braking and two-blocking protection. Proof load testing of the device is performed at a minimum of 300% of the maximum critical load rating. Pre-use and annual inspections of the lifting device are performed in accordance with manufacturer's recommendations.
>
> Although designed with enhanced safety features, the lift device does not fully comport to the guidance for a single failure proof handling system described in NUREG-0612. Therefore, a load drop analysis was performed, which concluded that the consequences of a potential drop of a loaded TSC into the concrete cask would be within acceptable limits for maintaining physical canister integrity, cooling, and subcriticality. The load drop analysis was approved in License Amendment [217].

The licensee also proposed to add a new Section 8.9.5, “MAGNASTOR Fuel Cask Handling Away from Spent Fuel Pool,” to the KPS Technical Requirements Manual (TRM). This new TRM section would provide administrative limits on the use of the non-single failure proof chain hoist assembly to ensure operations remain consistent with the load drop analysis parameters.

3.0 TECHNICAL EVALUATION

3.1 Chain Hoist Assembly Conformance to NUREG-0612

In Attachment 1 to the letter dated July 28, 2016, DEK provided the following information related to the design standard used for construction of the chain hoist assembly and additional safety features incorporated in the design of the chain hoist assembly:

- The chain hoist assembly has a design rated load of 110 tons, which is more than two times larger than the estimated MAGNASTOR system component load of 49 tons and two times the rated maximum critical load (MCL) of 55 tons. Since the system is designed for a safety factor of 5 times the design rated load, the overall factor of safety to the MCL is 10 to 1.
- The chain hoist assembly meets the requirements of ASME NUM-1, Type 1B, critical load handling hoist standards.
- The chain hoist assembly has redundant braking comprised of an air actuated disc type brake (primary) and drive train braking (redundant).
- The chain hoist assembly has a controlled lowering speed of no greater than 9 inches per minute (field test results confirm 6 inches per minute lowering speed).
- The chain hoist assembly has redundancy on two-blocking protection via an upper limit switch (primary) and an air stall feature (redundant).
- The chain hoist assembly has been load tested to a minimum of 300% of the 55 ton MCL rating, which exceeds the requirements of ASME NUM-1.

The licensee acknowledges that the chain hoist assembly is not consistent with the single-failure-proof criteria of NUREG-0612, but specified that the chain hoist assembly is conservatively designed with enhanced safety features that reduce the likelihood of a load drop. Furthermore, the proposed addition to the KPS USAR identifies that the intermediate lifting device (chain hoist assembly) will be subject to proof load testing at a minimum of 300% of the maximum critical load rating [55 tons] and pre-use and annual inspections of the lifting device in accordance with manufacturer's recommendations.

The staff reviewed the design, testing, and inspection information provided by DEK and compared that information with the general guidelines provided in Section 5.1.1 of NUREG-0612. The staff concluded that the proposed design is consistent with the intent of the general guidelines for the design of hoisting equipment, and the proposed testing and inspection are also consistent with the intent of the relevant guidelines. Therefore, the proposed use of the chain hoist assembly for transfer of the loaded TSC between the MTC and VCC is adequate to maintain a low probability of an accidental drop of a loaded TSC and is consistent with the general guidelines of Section 5.1.1 of NUREG-0612.

3.2 Load Drop Analysis Guidelines

Appendix A, "Analysis of Postulated Load Drops," to NUREG-0612 provides lists of general considerations and considerations specific to spent fuel cask drop analyses. The configuration of the drop is established by the constraints associated with the stack-up configuration, which is the only instance where the chain hoist assembly supports a loaded TSC. The licensee's description of the spent fuel canister handling process notes that the stack-up configuration is established in the auxiliary building truck bay, which is 28 feet away from the spent fuel pool. Therefore, the review against the criteria of Section 5.1 of NUREG-0612 is limited to the effects on the structural performance of the loaded TSC and the indirect effects on the spent fuel pool structure that may result from impacts in the truck bay. As discussed further in Section 3.3 of this safety evaluation, DEK evaluated the TSC primarily through verification that the TSC structure and pressure boundary would remain intact, thereby assuring no release of radioactive materials; the TSC would be cooled by continuous airflow through the VCC air inlet vents; and the subcriticality of the fuel would be maintained by moderator exclusion. Also, in Section 3.3 of this safety evaluation, the staff evaluates the impact of the postulated cask drop on the truck bay floor and the indirect effects on the spent fuel pool structure.

The staff determined that the key considerations from Appendix A to NUREG-0612 for evaluation of the postulated drop of a loaded TSC are that the analysis be based on a true stress-strain relationship and that the analysis consider the maximum potential damage. The analytical methods discussed in Section 3.3 of this safety evaluation provide for a true stress-strain relationship. In Section 4.1 of Attachment 1 to the license amendment request, DEK identified an assumption that maximizes the potential damage from the postulated load drop. Specifically, the analysis used an analyzed drop height of 220 inches that exceeds the maximum potential drop height for the stack-up configuration. Other input parameters were based on the design features of the equipment. Therefore, the staff found that the licensee has met applicable load drop analysis guidelines in Appendix A to NUREG-0612.

3.3 Load Drop Considerations

In Attachment 1 to the LAR (the request), DEK documented the load drop analysis in two enclosures: NAC Calculation No. 30026-2025, "Evaluation of TSC Drop into VCC on the Heavy Haul Trailer" and Dominion Calculation C12036, "Structural Consequences for NAC Cask Drop in the Auxiliary Building Truck Bay." As noted in Section 3.3 of Attachment 1 to the request, DEK evaluated the MAGNASTOR TSC structural performance in accordance with the guidelines in Section 5.1.2, "Spent Fuel Pool Area – PWR," of NUREG-0612. For TSC lifting in the Auxiliary Building Truck Bay, which is 28 feet away from the edge of the spent fuel pool (SFP) floor slab, the applicable guideline comports to addressing the structural integrity of the TSC and the SFP with respect to: (1) preventing the release of radioactive materials from the TSC, (2) the maintenance of subcriticality within the TSC, and (3) the maintenance of spent fuel pool water level. The staff evaluated items 1 and 2 against the guidelines in Section 3 of NUREG-1536, and item 3 against the criteria of Section 5.1 of NUREG-0612.

In the following sections, the staff summarizes its evaluation of DEK's TSC load drop analysis in two parts to demonstrate that (1) the consequences of a drop of the loaded TSC into the VCC would be within acceptable limits for maintaining physical TSC integrity, cooling, and subcriticality and (2) the SFP structure is capable of withstanding the effects of the postulated load drop (i.e., the concrete floor structure would remain stable with adequate ductility).

3.3.1 Load Drop Analysis for Spent Fuel Cask Handling Operations

DEK addresses NUREG-0612, Section 5.1, criteria on the "release of radioactive materials from damage to spent fuel" by analyzing the structural performance of the TSC for a postulated vertical drop into the VCC positioned on the heavy haul trailer (HHT).

The analysis is intended to demonstrate that the TSC can successfully preclude the negative consequences of: (1) unacceptable risk of criticality, (2) unacceptable release of radioactive materials, and (3) unacceptable radiation levels. These TSC performance criteria evaluated in the sections that follow are acceptable because they are in accordance with Section 3.4, NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," Revision 1, dated July 2010, which provides guidance for the review of structural performance of the cask systems for withstanding the cask drop accidents to ensure that the cask system is capable of maintaining its shielding, confinement and criticality safety functions after the postulated cask drop events.

Stack-up Load Drop Scenario

Section 4.1 of the LAR describes a stack-up configuration, used for lowering the TSC through the Magnastor transfer cask (MTC) doors into the VCC pedestal. The VCC seated on top of the heavy haul trailer (HHT) is supported underneath at mid-span of the Truck Bay rail beam. The TSC lowering operation involves using a non-single failure proof chain hoist assembly (CHA) to first lift the TSC slightly off of the MTC door to allow the doors to open. While holding the TSC and proceeding to lower it in order for it to reach the VCC pedestal, the CHA stays engaged to the TSC through an adapter plate assembly installed at the TSC top. For the load drop analysis DEK postulated a CHA failure when the TSC is at its highest held position. This precipitates a TSC load drop to undergo a free fall of 216.33 inches onto the VCC pedestal.

A TSC load drop initiates when the CHA fails and the suspended TSC falls onto the pedestal of the VCC seated on the HHT. The HHT, equipped with a series of assemblies of solid polyurethane wheels, sits on the 3 feet thick by 9 feet wide rail beam, which is integral to the 2 feet thick floor slab supported by the reinforced concrete piers of the Auxiliary Building. Since the VCC pedestal of a weldment of steel grillage of plates and beams rests directly on top of the HHT, the falling TSC is expected to strike and crush the pedestal and the HHT before landing on the rail beam beneath.

Finite Element Analysis Modeling

NAC used the LS-DYNA finite element analysis (FEA) software to model the TSC load drop of the structural performance of the stack-up components. The model includes a finite element representation of the VCC, pedestal, TSC, and rail beam. For simplicity, however, only the central, 18 foot 4 inch long weldment portion of the HHT without the wheels is conservatively considered in the modeling. To add to the modeling conservatism, the wheel assemblies are not considered. Physical gaps of both 3 and 4 inches, each corresponding to the distance between the HHT weldment bottom and top of the rail beam have been assumed. These gaps are retained to maximize the secondary, delayed impact effect on the TSC and rail beam.

The LS-DYNA model uses solid, beam, rigid node, and shell elements. The TSC shells, VCC pedestal and HHT weldment are modeled using shell Element 16, a fully integrated element with 5-point integration, for computational efficiency and solution accuracy. The concrete floor and VCC make use of solid elements. Rebar for concrete is modeled with beam elements. The welds in the HHT are idealized as nodal rigid bodies. Also, a ring of shell elements are used to simulate the mass of the closure lid to facilitate evaluation of shear capability of the TSC lid-to-shell weld subject to the load drop inertia force.

To define the boundary condition precedent to the TSC free fall, NAC used ANSYS software to calculate the gap that would be created between the basket/fuel contents and the top of the TSC bottom plate. The gap is created by the sudden release of the suspended TSC where the individual structural components revert to their un-deformed (pre-fuel load) states by way of a strain energy release. Release of strain energy and permitting free fall of the TSC and its contents through a drop height of 216.33 inches led to a gap of 4.07 inches between them at impact. For conservatism, a slightly larger gap of 4.5 inches was assumed and a drop velocity of 412.3 in/sec, which corresponds to a free fall of 220 inches, was assigned as the initial condition in the LS-DYNA TSC load drop analysis. The staff reviewed the modeling details, including element selection/discretization, and verified the boundary conditions and concluded that the load drop modeling is acceptable because commonly accepted FEA practices (e.g. mesh discretization, material assignment, element selection), were being followed.

Structural Performance of the TSC

In Calculation No. 30026-2025 NAC performed FEAs for two HHT-to-rail beam gap (HHT gap) conditions to evaluate bounding structural performance. The analysis with a HHT gap of 3”, which bounds the TSC performance, is reviewed below. The analysis with a HHT gap of 4”, which bounds the performance of the concrete rail beam and floor, is reviewed in Section 3 of this safety evaluation for the structural consequences associated the TSC load drop in the Auxiliary Building Truck Bay.

NAC used the LS-DYNA stress/strain output to demonstrate the TSC structural performance. For the case of 3” HHT gap, the maximum equivalent plastic strain that the TSC experiences is 5.3% vs 4.6% for the case of 4” HHT gap, which occurred at the center of the bottom plate. The calculated strains assuming a triaxiality factor of 2.0, are much less than the material fracture strain limit of 25% (25% vs. 5.3%) indicating a safety factor greater than 4 (25/5.3 = 4.7) is present in the analysis.

As noted in Appendix E to the calculation, the calculated strain corroborates the resulting TSC diameter reduction at the VCC inlet level by 0.1 inches due to the deformation of the bottom plate and the collapse of the pedestal. Since the VCC inlet height is also demonstrated not to decrease, the analysis confirms that the air flow within the VCC annulus will not be interrupted to compromise the TSC cooling safety function after the stack-up load drop. Further discussion regarding the thermal performance of the TSC is described in the following section.

NAC used the maximum, calculated inertia load of 156 g to evaluate the TSC lid-to-shell weld. Comparing the closure weld stress reduction factor of 0.8 for determining the shear stress allowable of 21.5 kilopounds per square inch (ksi) to the calculated stress of 18.9 ksi results in a factor of safety of 1.14 (21.5/18.9 = 1.14). This indicates that the closure weld will not yield or rupture, ensuring that a breach of the confinement boundary will not result.

NAC performed stress analyses of the most critically stressed sections of the TSC confinement boundary in accordance with the ASME B&PV Code, Section III, Division 1, Appendix F, Paragraph F-1341.2, plastic analysis provisions. The calculated maximum general primary membrane stress intensity of 45.2 ksi occurs at the intersection between the TSC wall and bottom plate. The allowable stress at this location based on material properties at temperature is 49.7 ksi. This corresponds to a factor of safety of 1.10 (49.7/45.2 = 1.10). The maximum primary stress intensity of 55.0 ksi was similarly calculated for a factor of safety of 1.16 (63.9/55.0 = 1.16) where the at-temperature stress allowable of 63.9 ksi is assumed. The greater than unity stress factors of safety demonstrate the TSC confinement boundary will not breach.

The staff reviewed the LS-DYNA analyses discussed above and concludes that they demonstrate, in aggregate, that the TSC confinement function will stay intact to prevent any release of radioactive material after the stack-up load drop. Similarly, because the confinement boundary is expected to remain intact, water ingression into the TSC cavity is not expected to occur, ensuring that the spent fuel, even if damaged, will continue to maintain its subcriticality.

Thermal Performance of the TSC

A steady state thermal analysis using ANSYS Fluent software was conducted by NAC on the post drop configuration of the TSC. NAC assumed a 30 kW heat load and used LS-DYNA drop simulation results which incorporated the crushed VCC pedestal, radial gap between the TSC and VCC, and unchanged inlet height for airflow in the analysis. The analysis showed that peak cladding temperatures of the fuel within the TSC would be lower than the design basis (664 ^{o}F vs 718 ^{o}F). The staff concludes that this ensures that the thermal cooling safety function of the canister is maintained.

3.3.2 Structural Consequences for the NAC Cask Drop in the Auxiliary Building Truck Bay

This section evaluates structural performance of the rail beam and documents a standalone evaluation of the structural consequences of a dropped TSC in the Auxiliary Building Truck Bay. The standalone evaluation supports DEK's analysis of the structural consequences in Dominion Calculation C12036, which focuses on the effects of a drop of the TSC onto the concrete floor of the Truck Bay and its subsequent effect on the SFP slab.

Structural Performance of Rail Beam

To evaluate the structural consequences of the TSC impact onto the Truck Bay slab and rail beam, NAC developed a detailed LS-DYNA finite element model. Since the concrete rail beam is the most important structural component for resisting the TSC impact, Dominion independently benchmarked the NAC LS-DYNA rail beam finite element model. The independent study (model) was based on KPS plant structural drawings. To validate the independent model, the model was loaded with simple static and dynamic test load cases that could be verified by hand calculation solutions. Once the independent model was verified, a common dynamic load test case was run on both it, and the NAC LS-DYNA rail beam models. Reasonably consistent mid-span deflection results in both models demonstrate that NAC's full-scale LS-DYNA model accurately captures the physics of the postulated load drop and produces reasonably accurate results.

NAC's detailed LS-DYNA finite element model of the Truck Bay slabs and rail beam showed that the TSC impact caused a maximum displacement at mid-span of the rail beam of 1.68". The staff performed a standalone evaluation of the Truck Bay rail beam using yield-line theory (R.Szilard, *Theory and Analysis of Plates*, Prentice- Hall, Inc., 1974) to develop a displacement-resistance-ductility relationship for the rail beam (ACI-349 Figure C.3.1). The displacement-resistance-ductility relationship developed by the NRC showed that a mid-span displacement of 1.68" corresponds to a ductility ratio of approximately 7, which is less than the maximum ductility ratio of 10 allowed by the ACI-349 Code.

NAC's LS-DYNA analysis of the Truck Bay floor also determined the shear stress in a rail beam cross-section at a distance d/2 from the supporting pier. The time history plot of the average shear stress acting on the section shows that the average maximum shear stress acting over a duration of 0.04 seconds is approximately 240 psi. The staff compared this demand value to the shear capacity of the section calculated from the ACI-349 equations. The ratio of capacity (approximately 290 psi) to demand (240 psi) results in a safety factor of 1.2. Therefore, the staff concludes that the beam can accommodate 20% more demand than that imposed by the drop scenario indicating adequate structural performance of the beam.

Structural Capability of SFP Slab

As noted in Section 2 above, the MAGNASTOR VCC is positioned at mid-span of the Truck Bay rail beam. On the east side of the Truck Bay rail beam is a 2 foot thick concrete slab, which is attached to a 2 foot 9 inch slab that is supported by two concrete shear walls. The 2 foot 9 inch slab is connected directly to the SFP slab, which is supported from below by concrete walls. Due to the impact of the TSC at mid-span of the Truck Bay rail beam, the rail beam will deflect downward. This downward deflection will very likely induce tensile axial loads in the 2 foot thick slab that will be transmitted to the 2 foot 9 inch thick slab and subsequently some portion of the tensile axial load will be transmitted to the SFP slab. The effect of the axial load on the SFP slab must be evaluated because axial tensile loads will reduce both the moment and shear capacities of the SFP slab.

In lieu of performing a detailed and complex LS-DYNA finite element analysis to derive the axial membrane tension load that would be transmitted to the 2 foot thick slab from the downward deflection of the rail beam, Dominion made a conservative assumption that the axial load was equal to the maximum possible axial load, which is equal to the axial tensile capacity of the slab and that this tensile load was uniformly distributed along the 21 foot 3 inch width of the slab. Assuming a uniform distribution is conservative since the tensile load would be expected to be distributed parabolically along the width of the slab, because the downward deflection of the rail beam will be greatest at mid-span and very small at the piers supporting the rail beam.

The tensile load in the slab is then transmitted from the 2 foot thick slab to the 2 foot 9 inch thick slab. A portion of the tensile load will be resisted by the shear capacity of the two shear walls supporting the 2 foot 9 inch thick slab. The remainder of the load, not transmitted to the ground by the shear walls, is transmitted to a frame structural model composed of the SFP slab and basement supporting walls. The SFP slab is 6 foot 8 inches deep and is separated into two lifts (4 foot 8 inches and 2 feet) by a roughened construction joint. However, in the frame model only the lower 2 foot deep SFP floor slab lift section is utilized for carrying gravity loads from the SFP, above, as well as the tensile load imposed by the adjacent 2 foot 9 inch thick slab. Additionally, the reactions at the base of the SFP frame are treated as pins, which results in more conservative moments calculated in the frame elements than would be achieved using a fixed condition at the foundation slab.

The axial (P) and moment (M) capacity of the 2 foot thick slab are related via a PM interaction diagram. From the PM interaction diagram combinations of axial tensile load and moment were applied uniformly along the west end of the 2 foot thick slab to simulate the loads that may be induced by the downward deflection of the rail beam due to TSC impact. These loads are then applied to the 2 foot 9 inch slab, which are resisted by the capacity of the two shear walls that support the 2 foot 9 inch slab. The remainder of the load that is not resisted by the shear walls is then applied to the frame model.

The results of the frame model static analysis show that the shear and moment capacity of the 2 foot lift and supporting walls exceeds the shear and moment demand caused by the loads applied from the 2 foot 9 inch thick slab. The staff checked the axial tensile load and moment capacities shown on the PM interaction diagrams. The staff concludes that the frame analysis using only the 2 foot lift is conservative because: (1) the 2 foot 9 inch thick slab frames into the 4 foot 8 inch lift, not the 2 foot lift, and (2) the two lifts are tied together at the construction joint by reinforcing steel dowels to enable the two lifts to act together as a single is 6 foot 8 inch deep beam.

4.0 TECHNICAL SUMMARY

The NAC LS-DYNA analysis demonstrates that the TSC confinement function will stay intact to prevent any release of radioactive material after the stack-up load drop. Because the confinement boundary is expected to remain intact, water ingress into the TSC cavity is not expected to occur. This ensures that the spent fuel, even if damaged, would continue to maintain its subcriticality. Additionally, thermal cooling capability of the canister will be maintained. Therefore, the TSC will continue to perform its intended function with respect to confinement, criticality, and cooling as required by 10 CFR 72.122(b)(2)(i)(B).

The results from the NAC LS-DYNA finite element analysis of the TSC drop impact on to the Truck Bay rail beam and slabs, together with the independent benchmarking of the NAC LS-DYNA rail beam model, and the independent evaluations performed by the staff, provide reasonable assurance that the Truck Bay floor can resist the drop impact of the TSC and maintain its structural integrity with adequate ductility. This ensures continuing SFP functionality in that the structural integrity of the SFP slab will not be compromised by the TSC load drop in the Truck Bay, as required under a Part 50 license.

5.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Wisconsin State official was notified of the proposed issuance of the amendment. The State official had no comments.

6.0 ENVIRONMENTAL CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure.

Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

7.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) there is reasonable assurance that such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

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