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PRELIMINARY SAFETY EVALUATION REPORT

DOCKET No. 72-1031
NAC International
MAGNASTOR Cask System
Certificate of Compliance No. 1031
Amendment No. 7

1.0 SUMMARY AND DESCRIPTION

By letter dated August 7, 2015 (Agencywide Document Access and Management System (ADAMS) Accession No. ML15225A468), as supplemented April 15, (ADAMS Accession No. ML16112A029), August 15, (ADAMS Accession No. ML16230A543), September 7, 2016 (ADAMS Accession No. ML16253A001), NAC International (NAC) submitted an application in accordance with Title 10 of the *Code of Federal Regulations* Part 72 (10 CFR Part 72) for an amendment to Certificate of Compliance (CoC) No. 1031 for the MAGNASTOR® Cask System. Amendment No. 7 of MAGNASTOR® Cask System requests to:

a) Provide a new Passive MAGNASTOR® Transfer Cask (PMTC) and associated Technical Specification (TS) changes, and

b) Update TS Appendix A, Section 4.3.1(i) to include revised seismic requirements.

c) Provide clarifying (non-technical) changes to TS.

The PMTC is specifically designed for use in a high ambient temperature environment (<104°F) and to passively cool the loaded TSC during transfer operations by convective air cooling equivalent to that provided by the concrete cask. The PMTC is fabricated from stainless steel. The PMTC is specifically designed to provide for convective air cooling of the TSC by providing an oversized PMTC to TSC annulus, by incorporating a water filled neutron shield tank in place of solid neutron shielding material, and by the provision of large inlets in the PMTC bottom forging specifically designed to provide sufficient air flow to maintain the fuel clad temperature lower than allowable temperature for transfer operations. The PMTC is used to only to transfer Combustion Engineering (CE) 16X16 fuel and is limited to a 30kw heat load.

This safety evaluation report (SER) documents the review and evaluation of the proposed amendment. The staff followed the guidance of NUREG-1536, Rev. 1, “Standard Review Plan for Dry Cask Storage Systems.”

The NRC staff’s (staff’s) assessment is based on a review of NAC’s application and whether it meets the applicable requirements in 10 CFR Part 72. The staff’s assessment focused only on modifications requested in the amendment and did not reassess previously approved portions of the FSAR. The NRC staff also determined that areas that are not affected by this amendment include: general description, principal design criteria, confinement, criticality, materials, operating procedures, acceptance test and maintenance, radiation protection, accident analyses, and quality assurance.

3.0 STRUCTURAL EVALUATION

In this portion of the review, the staff evaluates aspects of the dry storage system design and analysis related to structural performance under normal and off-normal operations, accident conditions, and natural phenomena events. In conducting this evaluation, the NRC staff seeks reasonable assurance that the cask system will maintain confinement, subcriticality, radiation shielding, and retrievability of the fuel under all credible loads for normal and off-normal conditions, accidents, and natural phenomena events.

The applicants following requested changes required staff structural evaluation:

a) Provide a new PMTC and associated Technical Specification (TS) changes, and

b) Update TS Appendix A, Section 4.3.1(i) to include revised seismic requirements.

The staff reviewed the structural design features and design criteria together with an evaluation of the applicant's analysis to demonstrate structural adequacy of the PMTC under normal and off-normal conditions.

3.1 PMTC Evaluation

3.1.1 PMTC Design Description

The applicant described the PMTC as a special lifting device, as defined by ANSI N14.6, that is used to transfer the Transportable Storage Container (TSC) in and out of the concrete storage cask or a transportation cask. According to the applicant, the PMTC is designed for use in high ambient temperatures (< 104 °F), and has a large gap between the loaded TSC and the cask inner shell to allow passive convective air flow to provide cooling equivalent to that provided by the concrete cask. As shown in the applicant supplied drawings 71160-656 and 71160-657, the PMTC is fabricated of stainless steel. Gamma shielding is provided by a lead shield, and neutron shielding is provided by a shield tank filled with demineralized water. The PMTC has two lifting trunnions, two sliding doors supported by rails that are welded to the bottom of the cask to allow TSC transfer and a retaining ring bolted to the top of the cask to prevent an inadvertent lift of the TSC out of the PMTC.

3.1.2 PMTC Design Criteria

The applicant designed the components of the PMTC to satisfy the following design criteria:

- The load bearing members of the PMTC, which include the trunnions, the shell, the doors, the rails and the associated welds as a special lifting device for critical loads to the requirements of American National Standards Institute (ANSI) N14.6 and NUREG-0612 under normal conditions.
- The outer shell to resist hydrostatic forces as part of the shield tank and the upper forging to resist the forces due to thermal expansion to the requirements of American

Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Section III, Division 1, Subsection NB for normal conditions (Service Level A).
- The retaining ring and bolts to the requirements of Code Section III, Division 1, Subsection NF for off-normal conditions (Service Level C).

The applicant used the material properties at 200°F to determine the stress allowables.

The staff reviewed the design criteria and determines that they are consistent with NUREG-1536, Rev. 1, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility", review guidance and are therefore acceptable.

3.1.3 PMTC Loads

Dead load

The applicant used the following dead loads for the associated component analysis in addition to a dynamic load factor of 10% for all lift calculations:

Components	**Dead Loads**
Trunnions, top forging and shell	The weight of a wet, fully loaded PMTC.
Rails and welds	The weight of a fully loaded TSC filled with water, plus the weight of water in the annulus, plus the weight of the doors and the rails themselves.
Doors	The weight of a fully loaded TSC filled with water, plus the weight of the water in the annulus, plus the weight of the doors themselves.

Thermal load

The applicant used temperature curves extracted from the thermal analysis to determine the thermal stresses in the top forging of the PMTC.

Hydrostatic load

The applicant applied a pressure load on the inside of the outer shell that increases linearly from 30 psig at the top to 36.3 psig at the bottom that represents the internal pressure of the demineralized water plus the hydrostatic pressure increase over the 14.5 foot length of the neutron shield tank.

The staff reviewed the applicant's loads and determines that they are consistent with those described in Table 3-2 of NUREG-1536, Rev. 1, and are therefore acceptable.

3.1.4 Analysis Methods

The applicant used a combination of finite element analysis (FEA) using ANSYS computer software and hand calculations to conduct the structural analysis of the PMTC. The applicant developed a three-dimensional finite element model (FEM) of one-quarter of the PMTC which included the trunnions; top and bottom forgings; the inner, intermediate and outer shells; and the lead between the inner and intermediate shells using ANSYS SOLID45 brick elements. The applicant modeled a 1/36th portion of the retaining ring using ANSYS SOILID435 brick elements.

Due to the symmetry of the PMTC, the staff concludes that the ANSYS model of the PMTC is adequate for the analysis of the features considered by the applicant.

Normal Conditions

Lifting Operations

The applicant analyzed the stress in all the components in the load path, to include the trunnions, the cask shell and bottom forging, the shield doors and the rails and associated welds, as well as the bearing stress on the trunnions. Using the FEM, and the dead loads described above, the applicant determined the maximum shear and bending forces in the trunnion, then used hand calculations to determine the maximum combined stress in the trunnion due to shear and bending. From the ANSYS model, the applicant determined the maximum membrane plus bending stress in the top forging. The applicant determined the maximum stress in the inner, outer and intermediate shells as well as the bottom forging using the FEM. The applicant used hand calculations to determine the maximum stress in the doors and the rails, as well as the associated welds that attach the rails to the PMTC. The table below summarizes the maximum calculated stresses in these components as well as the factors of safety (FS) reported by the applicant in the supplied SAR.

Under normal conditions, ANSI N14.6 and NUREG-0612 require a FS of 6.0 with respect to the yield strength and 10.0 with respect to the ultimate strength for the load bearing path of a critical load. Because the reported factors of safety are greater than the required values, the staff finds the PMTC is adequate for lifting.

Component	Stress Type	Max Stress (ksi)	FS (yield)	FS (ultimate)
Trunnion	Shear plus Bending Moment	4.16	6.01	15.9
Top Forging	Membrane plus Bending	2.45	10.2	27.1
Intermediate Shell	Membrane	4.0	6.3	17.8
Doors	Bending	2.93	8.53	22.6
Rails		3.34	7.49	19.9
Rail Welds	Shear	3.07	8.14	21.6
Trunnion Bearing	Bearing	2.98	8.4	

The applicant also determined the maximum bearing stress on the trunnion, based on half of the engagement length of 9.5 inches (the distance the trunnion is inserted into the shell), to be 2.98 ksi and the associated factor of safety with respect to the yield strength of the material to be 8.4. The applicant used the yield strength as the design criteria, but did not state the source of this criteria. The staff notes that ANSI N14.6 and NUREG-0612 do not consider bearing stress, but this design criteria is consistent with the Code Section III, Division 1, Subsection NF-3223.1 and therefore finds the performance of the trunnions for bearing stress for lifting operations is acceptable.

Hydrostatic Pressure

Using the FEM and the hydrostatic pressure load described above, the applicant determined the maximum primary membrane plus primary bending stress to be 9.92 ksi in the outer shell and the associated factor of safety (FS) to be 3.36. Because the FS is greater than one, consistent with the provisions of the Code Section III, Division 1, Subsection NB for normal conditions (Service Level A), the staff finds the performance of the outer shell against the hydrostatic pressure of the shield water is acceptable.

Off-Normal Conditions

Inadvertent Lift of Transfer Cask by TSC

The applicant considered the inadvertent lift of the PMTC by the TSC to be an off-normal event. Using the FEM, the applicant determined the maximum stress in the retaining ring to be 16.53 ksi, the maximum bearing stress on the retaining ring from the bolt head to be 16.3 ksi, and the maximum stress in the bolt due to tension and bending to be 31.7 ksi and the associated factors of safety to be 2.72, 1.53 and 1.24 respectively. Because the FS is greater than 1.0, consistent with the provisions of the Code Section III, Division 1, Subsection NF for off-normal conditions (Service Level C), the staff finds that the PMTC retaining ring will maintain its structural integrity and not allow the loaded TSC to be inadvertently lifted out of the PMTC.

3.1.5 Technical Specification Evaluation

The staff reviewed the changes required to refer to the PMTC in the TS Appendix A and finds they accurately reflect the addition of the PMTC to the MAGNASTOR® Cask System.

3.2 Technical Specification Appendix A, Section 4.3.1(i)

The applicant proposed a change to TS 4.3.1(i) to clarify the acceptable seismic requirements for the MAGNASTOR® Cask System. The applicant declared in TS 4.3.1(i) that “The maximum design basis earthquake acceleration of 0.37g in the horizontal direction (without cask sliding) and 0.25g in the vertical direction at the ISFSI pad top surface do not result in cask tip-over.”

The applicant then provided two alternatives to the above design basis earthquake that allows the user to deploy the MAGNASTOR® Cask System in a seismic environment with higher accelerations that those evaluated by the applicant. For the first option (paragraph two), the user can conduct an analysis that allows cask sliding. In this analysis, the user must show that the cask will not tip over, the casks will remain on the ISFSI pad, and that any g-load resulting from the collision of sliding casks will be bounded by the tip over analysis in Chapter 3 of the FSAR previously evaluated by the staff.

For the second option (paragraph three), the user can install bollards on the ISFSI pad that prevent the cask from overturning. In this analysis, according to the applicant, the user must show that the cask will not overturn, the g-loads resulting from the cask contacting the bollards are bounded by the cask tip-over analysis in Chapter 3 of the FSAR, and the ISFSI pad and bollards are designed, fabricated and installed such that they are capable of handling the combined loading of the design basis earthquake and any contact between the bollard and cask during the design basis event (DBE).

The staff reviewed the revised TS and notes that the allowance of bollards on the ISFSI pad to prevent cask tip-over was established in Amendment No. 5 to CoC No. 1031. The applicant’s revision is not intended to alter the provisions of the technical specification, rather to clarify the options available to the user to deploy the storage system.

The staff concludes that the revised technical specification continues to allow the use of the MAGNASTOR® Cask System at a location where the site earthquake parameters are up to and greater than 0.37g in the horizontal direction and 0.25g in the vertical direction at the ISFSI pad top surface. Furthermore, the technical specification continues to require the user to demonstrate that no tip-over will result from an earthquake. In addition, impacts between casks and casks and casks and bollards, while allowed, are an accident event for which the cask must be shown to be structurally adequate. Therefore, the revised technical specification accounts for the cask earthquake performance criterion consistent with guidance provided in Section 3, "Structural Evaluation," of NUREG-1536, Rev. 1. Additionally, the staff determines that the TS complies with 10 CFR Part 72 paragraph 212.(b)(5)(ii) that requires the cask storage pads and areas be designed to adequately support the static and dynamic loads of the stored casks, consider the potential amplification of earthquakes through soil-structure interactions, and consider the soil liquefaction potential or other soil instability due to vibratory ground motion. The staff therefore concludes that the proposed revision is acceptable and clarifies the provision under which the MAGNASTOR® Cask System may be reasonably implemented by general licensees given the specific earthquake acceleration parameters.

3.3 Technical Specification Appendix B

In Table B2-1, the applicant added a clarifying note c that states that the nominal TSC weight plus maximum contents ≤ 104,500 lbs. This weight is less than the design weight of the TSC, lid, basket and contents, as specified in Table 3.2.1.1 of the FSAR, and the staff finds that no technical evaluation is necessary.

3.4 Evaluation Findings

F3.1 The applicant provided SAR adequately describes all SSCs that are important to safety, providing drawings and text in sufficient detail to allow evaluation of their structural effectiveness.

F3.2 The applicant has met the requirements of 10 CFR 72.236(b). The SSCs important to safety are designed to accommodate the combined loads of normal or off-normal operating conditions with an adequate margin of safety. Stresses at various locations of the cask for various design loads are determined by analysis. Total stresses for the combined loads of normal and off-normal events are acceptable and are found to be within limits of applicable codes, standards, and specifications.

F3.3 The applicant has met the requirements of 10 CFR 72.236(l), "Specific Requirements for Spent Fuel Storage Cask Approval." The design analysis and submitted bases for evaluation acceptably demonstrate that the PMTC will reasonably maintain confinement of radioactive material under normal and off-normal conditions.

F3.4 The applicant has met the requirements of 10 CFR 72.236 with regard to inclusion of the following provisions in the structural design:
- Design, fabrication, erection, and testing to acceptable quality standards.
- Appropriate inspection, maintenance, and testing.
- Structural designs that are compatible with retrievability of SNF.

F3.5 The Applicant has met the specific requirements of 10 CFR 72.236(h) as they apply to the structural design for spent fuel storage transfer cask approval. The PMTC structural design acceptably provides for compatibility with wet or dry loading and unloading facilities.

Based upon its review, the staff has reasonable assurance that the structural design of the PMTC is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the PMTC design provides reasonable assurance that the transfer cask will allow safe storage of spent fuel in accordance with 10 CFR 72.236. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, accepted engineering practices, and the statements and representations in the application.

4.0 Thermal Evaluation

The objective of the thermal review is to ensure that the MAGNASTOR® storage system components and fuel material temperatures will remain within the allowable values for normal conditions and off-normal and accident events. This objective includes confirmation that the temperatures of the fuel cladding will be within acceptable limits throughout the transfer and storage periods to protect the cladding against degradation, which could lead to gross rupture, during normal conditions and off-normal and accident events. The review of this amendment focused on the following:

> a) Thermal analysis of a new transfer cask design for pressurized water reactor fuel designated as PMTC that features a neutron shield containing demineralized water in lieu of solid neutron shielding.

NUREG-1536, Rev. 1, “Standard Review Plan for Dry Cask Storage Systems,” Section 4.0, “Thermal Evaluation,” and Interim Staff Guidance (ISG) - 11, Revision 3, specify the review criteria to be used by NRC staff in performing technical evaluations of applications under 10 CFR Part 72. The purpose of the review is to confirm that the application provides sufficient assurance that the cask system is designed to prevent fuel cladding degradation under normal conditions and off-normal and accident events, including loading and transfer of spent nuclear fuel. This includes confirmation that the thermal design of the cask has been evaluated using acceptable analytical methods.

4.1 Spent Fuel Cladding

To preclude fuel degradation, the maximum cladding temperature under normal conditions of storage and canister transfer operations is limited to 752°F (400°C) per ISG-11 guidance. The maximum cladding temperature for off-normal and accident events is limited to 1058°F (570°C) per ISG-11 guidance.

4.2 Cask System Thermal Design

4.2.1 Design Features

There are no design feature changes in the cask system thermal design.

4.2.2 Design Criteria

The MAGNASTOR® Cask Storage System basis heat load remains unchanged. Given the evaluations presented below for the PMTC, the heat load is limited to 30 kW.

4.3 Thermal Model Specifications

4.3.1 Model Configuration

The model configuration for the MAGNASTOR® Cask Storage System is unchanged. The model configurations for the PMTC are similar to those developed for the MAGNASTOR® Transfer Cask (MTC) that has been previously approved by the NRC (ADAMS Accession No. ML090350589, February 4, 2009). The NRC requested comparison tables with key modeling parameters for both the MTC and PMTC for all transfer operations/phases so that any variations in modeling approach could be evaluated directly. The applicant provided those comparison tables in the first response to a request for additional information (RAI). Inspection of these tables illustrated that the values of some geometric parameters, although different, were not sufficiently different to raise questions about the PMTC. And the PMTC results were produced using the same analytical approach as the previously approved MTC. In one instance, a modeling choice for turbulent fluid flow was used in place of laminar flow, which was previously used for the MTC. The NRC requested that the applicant perform a sensitivity analysis for this revised modeling choice since it can produce less conservative results than the approach used for the MTC. The NRC finds that while the sensitivity study did in fact confirm higher peak cladding temperatures for the fuel using the more conservative approach, the temperature values reported were still below the ISG-11 guidance of 752° F, and therefore are acceptable.

The models used by the applicant for the PMTC are described as follows:

Model 1 – Two dimensional steady state computational fluid dynamics (CFD) model for transfer condition with air in the annulus and helium inside the canister.

Model 2 – Two dimensional steady state CFD model for water phase with water inside the canister and cooling water circulation in operation.

Model 3 – Two dimensional steady state model for vacuum phase with vacuum inside the canister and cooling water circulation in operation. (used to determine temperature boundary condition in Model 5)

Model 4 – Two dimensional transient CFD model for helium cool down condition with helium in canister and cooling water circulation in operation.

Model 5 – Three dimensional finite element steady state and transient model for vacuum drying condition with a vacuum inside the canister and cooling water circulation in operation.

4.3.2 Material Properties

Material properties used in the analytical model models for PMTC are primarily 304 stainless steel, a lead gamma shield, and a demineralized water neutron shield in lieu of solid neutron shielding.

4.3.3 Boundary Conditions and Thermal Loads

The Boundary Conditions for the MAGNASTOR® spent fuel storage system are unchanged.

4.3.4 Normal Storage Conditions

The Normal Storage Conditions are unchanged.

4.3.5 Transfer Conditions

The applicant described the thermal analysis for transfer conditions in Section 4.10 of the Safety Analysis Report. During the transfer condition, the Transportable Storage Canister (TSC) in the transfer cask is subjected to four separate conditions:

(1) water phase when the lid is being welded to the TSC;
(2) drying phase where vacuum drying is used to remove moisture from the TSC;
(3) helium backfill phase when the TSC closure is completed and the transfer cask annulus flow system is operating; and
(4) operation of loading the helium-backfilled TSC into the concrete cask without the transfer cask annulus flow system operating.

4.3.5.1 Operations Involving 24-Hour Cooling

Evaluation of the Water Phase

The applicant's model represents the TSC by a FLUENT 2-D axisymmetric model that includes the TSC shell, lid, and bottom plate, basket fuel and neutron absorber. For the condition of water in the TSC, no contribution due to radiation was considered. The TC and water annulus between the cask and the TSC were also included in the applicant's thermal model. The applicant stated that the TC is represented by effective properties calculated for both the radial and axial directions. In the radial direction, the analysis treats the four different cask wall materials as being in series, and in the axial direction, as being in parallel.

The applicant's CFD analysis for this configuration resulted in a maximum fuel temperature of 143° F.

The NRC staff reviewed the evaluations presented by the applicant and finds the treatment of the geometry, boundary conditions, and overall physics produced results that were acceptable since the reported fuel temperatures were below the ISG-11 guidance.

Evaluation of Vacuum Drying Phase

The applicant developed a 3-D, 1/8th symmetry ANSYS model to perform the vacuum drying analysis for 30 kW, 25 kW, and 20 kW heat loads. The models did not include the canister lid and bottom plate. Adiabatic boundary conditions are assumed on the bottom and top of the TSC. Heat is rejected from the TSC outer shell to the annulus circulating water. Circulating water is not included in the model and a fixed temperature is applied to the TSC outer wall in the analysis.

The applicant's results from the vacuum drying phase analysis are presented in the Table on pp 4.10.2-1 of the supplied SAR. The table illustrates the vacuum duration limit in hours for each of the analyzed heat loads of 30kW, 25 kW, and 20 kW in addition to reporting the maximum temperature of the basket and fuel.

The applicant noted that after the completion of drying and helium backfill, the shield insert will be removed. The applicant performed additional transient evaluation for a period of 4 hours for the 25 kW and 30 kW cases and for 7 hours for the 20 kW case. The applicant reported temperatures of 694° F (30 kW), 697° F (25 kW), and 650° F (20 kW) for the fuel which are below the steady state temperature of 715° F calculated for the transfer condition. Since the transfer condition (moving TSC into concrete cask) fuel temperatures were below their allowable limit, the NRC finds these results acceptable.

The applicant reported that if the dryness verification were not met within the first vacuum cycle time limits, a second cooling phase will be initiated for decay heats that exceed 20 kW. This second phase requires that the TSC be backfilled with helium to a pressure of 84 psig and cooled by recirculating cooling water in the annulus for a minimum of 24 hours. The applicant performed transient analyses to determine the maximum temperatures of the fuel following helium backfill for heat loads less than or equal to 30 kW. The analyses were performed using the same 2-D FLUENT model used for the water phase condition, with the exception of a helium filled TSC at 76 psig. The applicant conducted an analysis of the vacuum drying process to identify the upper bounding limit for the 30 kW heat load. The 3-D ANSYS analysis provides the maximum temperature in the simulated helium backfill condition. The applicant reported maximum temperatures at the end of a 24 hour helium backfill as well as temperatures and durations for a second vacuum operation in the table on pp. 4.10.2-2 of the supplied SAR. The maximum temperature of the fuel under this condition was reported as 663° F (30 kW) and 686° F (25 kW), both of which are below the ISG – 11 guidance of 752° F.

The NRC staff reviewed the evaluations presented by the applicant and finds the treatment of the geometry, boundary conditions, and overall physics produced results that are acceptable because the reported fuel temperatures fall below the allowable limit.

Evaluation of Moving the TSC into the Concrete Cask

The applicant considered the 30 kW heat load as the bounding heat load with an initial ambient conditions temperature of 104°F. The applicant reported a steady state fuel temperature of 715° F for this condition.

The NRC reviewed the evaluations presented by the applicant and finds the treatment of the geometry, boundary conditions, and overall physics produced results that were acceptable because the reported fuel temperatures were below the ISG – 11 guidance of 752° F.

4.3.5.2 Operations Involving Minimum Cooling Time

No evaluations were presented for operations involving minimum cooling time because the applicant's previous evaluations are unchanged

4.3.6 Off-Normal Storage Events

Previous applicant's evaluations for Off-Normal Storage Events are unchanged.

4.3.7 Accident Conditions

Previous applicant's evaluations for Accident Conditions are unchanged.

4.3.8 Temperature Calculations

Component temperature calculations were presented above.

4.3.9 Confirmatory Analyses

The staff reviewed the applicant's models and calculation options to determine the adequacy of the proposed PMTC thermal design. Since the evaluations for this amendment were not significantly different from the methodology and scope of previous amendments reviewed by the NRC, the staff finds that staff confirmatory analyses are not required. Furthermore, the staff performed selected confirmatory analyses for the first submittal of the MAGNASTOR® Cask Storage System and the results were consistent with the applicant's evaluation (ADAMS Accession No. ML090350589).

4.4 Technical Specification Evaluation

Associated TS changes for this amendment include the following:

- Appendix A - Changes to LCO 3.1.1 that include operational time limits for the PMTC during vacuum drying and helium backfill.
- Appendix B - Changes that provide a footnote to loading tables to specify the maximum per assembly heat load for PWR fuel loaded in the PMTC for uniform loading of 811 Watts for CE 16x16 fuel only.

The staff reviewed the changes required to refer to the PMTC in the TS and finds they accurately reflect the addition of the PMTC to the MAGNASTOR® Cask System.

4.5 Evaluation Findings

F4.1 SSCs important to safety are described in sufficient detail provided in SAR Chapters 1, 2 and 4 to enable an evaluation of their thermal effectiveness [10 CFR 72.236(b)].

F4.2 The staff has reasonable assurance that the spent fuel cladding will continue to be protected against degradation that leads to gross ruptures by maintaining the clad temperature below ISG-11 guidance and by providing an inert environment in the cask cavity [10 CFR 72.122(h)(1)].

F4.3 Through the analysis, staff developed reasonable assurance that the MAGNASTOR® Cask System continues to maintain a heat-removal capability having testability and reliability consistent with its importance to safety.

F4.4 The staff concluded that the thermal design of the MAGNASTOR® Cask System, as described in the supplied SAR, is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the MAGNASTOR® Cask System will allow safe storage of spent fuel for a certified life of 20 years. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

5.0 SHIELDING EVALUATION

The objective of this evaluation is to determine that the MAGNASTOR® Cask System design with the requested amendments continues to meet the regulatory requirements of 10 CFR 72.104 and 10 CFR 72.106.

The following requested change required a shielding evaluation:

a) Provide a new PMTC.

The applicant requested to add a PMTC to the MAGNASTOR® Cask System and associated TS changes. The only acceptable payload for the PMTC is TSC containing Combustion Engineering (CE) 16x16 PWR fuel assemblies. Non-fuel hardware, such as a control element assembly (CEA), is also evaluated as an allowable content.

The staff reviewed the application and the supporting technical calculations. The staff's review was performed based on information provided in the MAGNASTOR® SAR Revision 16A, April 2016. The staff followed the guidance and the acceptance criteria specified in Section 6 of NUREG-1536, Rev.1.

The staff's review includes the radiation source term determination and the radiation shielding design for all credible normal conditions and off-normal and accident events encountered during loading, handling, on-site transfer, storage, and retrieval analyses. This review also includes verification of computer code benchmarks and the computer modeling of the cask system for shielding TSC with a shielded closure meets the radiation protection requirements set forth in 10 CFR Part 72 and 10 CFR Part 20, and whether the design and operation continue to follow as low as reasonably achievable (ALARA) guidelines. The following sections summarize the staff's findings and conclusions.

5.1 System Description

The applicant requests to add a new transfer canister design, PMTC, to the MAGNASTOR® Cask System for transporting TSC containing 37 CE 16x16 PWR fuel assemblies. The PMTC is passive cooled TSC system and designed for use in a high ambient temperature environment (≤ 104°F) during transfer operations. The PMTC radial shield is made of stainless steel inner, middle and outer shells with solid steel top and bottom forgings. The middle and outer shells walled the gamma lead shield, and the annulus between middle and outer shells holds demineralized water as neutron shield.

The TSC shell and the basket internal structure provide additional radial shielding. The transfer operation bottom shielding is provided by the TSC bottom plate and solid steel PMTC doors. The TSC closure lid provides radiation shielding at the top of the TSC.

The space between the TSC and PMTC inner shell is wider than previous MTC1 and MTC2 transfer casks. This additional space provides passive additional cooling to the canister and the PMTC during transfer operation. PMTC has vent at the bottom to serve as air inlet and vent has shield and bottom forging provides shielding at the vent positions

The shielding of the streaming through the space between TSC and PMTC is provided by shield and seal assembly and retaining ring during TSC transfer operations.

5.2 Shielding Discussion and Dose Results

The applicant calculated the dose rates for the PMTC transporting TSC that contains 37 CE 16x16 PWR fuel assemblies. The TSC placed inside the PMTC and sealed before it moved to a concrete cask to place on the ISFSI pad. The CE 16x16 fuel is the only authorized fuel to transfer with PMTC.

The applicant performed the dose calculations for bounding heat load of 30 kW. The cooling times presented in Table 5.9.7-1 of the SAR.

The applicant performed dose rates calculations using the MCNP code. The applicant includes statistical uncertainty in the reported dose rates. The statistical uncertainty of the calculated dose rate is part of the computational results of the MCNP code that employs Monte Carlo method for solving neutron and gamma shielding problems.

The applicant performed the dose rate calculations with a focus on the streaming paths above and around the annulus between TSC and PMTC. The applicant performed the dose rate calculations for locations at the vent shields and bottom forging. The applicant considered both the TSC closure operations and transfer operations in evaluations of dose rates.

The three-dimensional MCNP shielding analysis model includes an explicit representation of the PMTC and TSC structure with the following assumptions:

1. Dry canister cavity and TSC to PMTC annulus.
2. Homogenization of the fuel assembly into four source regions.
3. The damaged fuel loaded in the corner basket locations are located between the vent shields.

The NRC staff reviewed the evaluations presented by the applicant and finds the reported dose rates calculations and the MCNP shielding analysis model for undamaged and danged fuel to be acceptable.

5.2.1 PMTC Undamaged Fuel Dose Rates

The applicant used a three-dimensional Monte Carlo analysis using surface detectors and superimposed mesh tally detectors built to assess dose rates. The mesh tally encompasses all streaming paths captured by the defined detectors. The detector geometry is provided in the Section 5.9.5 of the SAR. Table 5.9.1-1 of the SAR shows the maximum dose rate for PMTC. The dose rate at the TSC to PMTC annulus is presented in Table 5.9.1-1 of the SAR. The dose rate for the vent shields is shown in Table 5.9.1-3 of the SAR. Table 5.9.1-4 of the SAR shows the dose rates at the door boundary. Dose rate contributions for reactor control elements (CEAs) are provided in Table 5.9.1-5. The uncertainty in Monte Carlo calculation results is shown in the parenthesis.

The authorized contents for PMTC include intact or damaged CE 16x16 PWR fuel assemblies and burnable poison rods used as replacement rods in the CE core. These rods are constructed with a zirconium alloy and do not contain a significant amount of activated material. Therefore, they are enveloped by the fuel rod which they replace. Only four damaged fuel assemblies are allowed to be loaded into the four corner locations and the damaged fuel assemblies must be placed in damaged fuel cans.

Site specific ALARA determines limited access to area below and around the loaded PMTC

5.2.2 PMTC Damaged Fuel Dose Rates

The TSC authorized for loading damaged fuel cans in the four corner assembly in the damaged fuel basket. The applicant considered two scenarios in modeling the damaged fuel. The first scenario assumed the fuel assembly interstitial volume was filled with uranium oxide resulting in increased fuel neutron, gamma and n-gamma source terms. The second scenario assumed that damaged fuel migrated from active fuel into the lower end-fitting region of the fuel assembly and filling all void space that was modeled.

The maximum dose rates in the PMTC for damaged fuel summarized in Table 5.9.1-6 and Table 5.9.1-7 of the SAR.

5.3 Contents Description

The applicant described in Section 5.2 and 5.8 of the SAR the methodology for defining the fuel assemblies and characteristic of the source term and shielding. The applicant used in three dimensional model. The various source regions, hardware masses, and in core condition are described in Section 5.8.1.1 of the SAR. Only TSC containing fuel type CE 16x16 is authorized to be transferred by PMTC.

5.3.1 Source Specification

To determine the bounding radiation source terms of the CE 16x16 fuel assemblies to be loaded in the MAGNASTOR® system using the PMTR, the applicant grouped the spent fuel assemblies into assembly types, i.e., PWR, and fuel and hardware masses. A bounding fuel assembly is calculated for each assembly type. A bounding assembly is based on the maximum fuel and hardware masses and presents a technically conservative (more restrictive) bounding value of fuel and hardware mass of that group. Table 5.2.3-1 and Table 5.2.3-2 provide the essential characteristics of the fuel assemblies that will be loaded in the MAGNASTOR® system.

The applicant used the SAS2H sequence of the SCALE 4.4 computer code system to evaluate the source terms of each spent fuel assembly group. The 44GROUPNDF5 library is composed primarily of ENDF/B-V cross-sections and limited ENDF/B-VI data for a limited number of isotopes. This use of these data improves the calculation accuracy.

The source terms for the CE 16x16 spent fuel assemblies are evaluated for the following ranges:

- Average assembly burnup from 10 GWd/MTU to 60 GWd/MTU
- Fuel initial enrichment from 1.3 wt% to 4.9 wt%
- Cooling time from 4 years to 90 years (nonfuel hardware is evaluated at cooling times down to 2 years).

The applicant used a response function approach in its shielding evaluation. The applicant calculated the dose rates based on previous calculation for transfer and storage cask using combination of cooling time, initial enrichment and maximum assembly burnup. Table 5.9.3-1 and 5.9.3-2 shows the maximum radial surface PMTC dose rate for gamma and neutron sources, respectively. Table 5.9.3-3 shows the source term for maximum dose rates at the surface and 1 meter from the surface of the PMTC. Table 5.9.3-4 shows the source term for maximum dose rates at the vent shields and around gorging and door. The axial burnup profile described in Section 5.3 is retained. The axial burnup profile is converted to an axial source profile as described in Section 5.4.

5.4 Model Specification

In the MCNP shielding models used by the applicant for the PMTC transfer cask, the fuel and hardware source region are homogenized within fuel basket cells of the TSC canister. The axial volume of the fuel is divided to active fuel, upper and lower plenum, and upper and lower fitting source segments. The three dimensional MCNP model includes shield regions and streaming paths. The MCNP calculations used biasing technique based on window adjustment in mesh cells. This technique used to determine dose rates at the PMTC radial surface and vent shields. The axial biasing used to determine for the cask top and bottom dose rates. The applicant applied DXTRAN sphere as an angular biasing to increase vent shied locations.

5.4.1 TSC, Basket, and Fuel Assembly Model Description

The TSC model includes 37 CE 16x16 assemblies. The applicant calculated the PMTC dose rates for this fuel loading. The TSC model is described in Section 5.5.1.1 of the SAR.

5.4.2 Model Description

The PMTC dose rates evaluated for the TSC closure including welding, draining and drying. As previous transfer cask, all baskets areas with exception of fuel assembly are modeled discreetly with six inches of auxiliary shielding for TSC closure operations. Table 5.9.4- and Figure 5.9.4-1 of the SAR show the key feature of PMTC and model sketch of the PMTC with TSC. The shield and seal assembly for PMTC shows in Figure 5.9.4-2 of the SAR. The radial shielding and inlet structure provided in the Figure 5.9.4-3 and 5.9.4-4 of the SAR.

5.4.3 Shield Regional Densities

Table 5.9.4-2 shows the basket, and cask material densities and compositions used to model the PMTC. The homogenized CE 16x16 fuel assembly material description is provided in Table 5.9.4-3. The maximum initial enrichment 5% used in the modeling. Fuel region densities are calculated quantities dependent on the hardware and fuel masses in the assembly. Material compositions and densities for structural component obtained from Scale 6.1 library except for demineralized water and composition of the neutron absorber sheet in the basket. The density of 0.9116 g/cm^3 for maximum water temperature of 200 °F and areal density of 0.30 g10B/cm2 for neutron absorber based on aluminum boron carbide mixture.

5.5 Detector Definition

The applicant evaluated the dose rates at various distance from the cask top, bottom, and side surface, 1m, 2m, and 4m for PMTC using surface tallies in MCNP code. The applicant used surface tallies using FS tallies card in MCNP. The top surface detectors are at the axial location of the auxiliary for TSC closure operations. The detector is positioned at the axial location of the retaining ring for transfer operations. The applicant subdivided surface into 1 inch segment for surface tally to capture streaming through 2-inch annuals. Table 5.9.5-1 of the SAR shows the detector grids for the PMTC top and bottom. Table 5.9.5-2 of the SAR shows the detector grids for the side detectors are shown in. Side surface detectors surface tally is subdivided into 5 inch axial segments. Shielding over TSC surface away from the annuals is the same as MTC1 and MTC2 transfer casks. Since the vent openings are 6 inches and 6.6 inches the superimposed rectangular mesh tallies less than 1.4 inches are used to calculate dose rates at the vent shields, bottom forging, and doors as shown in Table 5.9.5-3.

The dose maps produced by these methods completely enclose the accessible cask surfaces. The applicant used flux to dose rate conversion factors of the ANSI-ANS 6.1.1 1977 standard to all tallies.

5.6 Response Methodology

The comparison of response function (Section 5.8.2 of the SAR) which is summaries of dose calculation at each energy and MCNP calculation based on the complete gamma, neutron or hardware gamma source spectrum shown in the Figure 5.9.6-1of the SAR for PMTC. The comparison is for 25 GWd/MTU assembly average burnup and 2.1%wt enrichment and 4-year cooling time. The response function for low burnup and low enrichment are in agreement.

5.7 Minimum Cool-Time Tables

The minimum cooling times for cask heat load of 30kW and burnup up to 25 GWd/MTU presented in Table 5.9.7-1 of the SAR. These minimum cooling times for each burnup is bounding for all enrichment above minimum enrichment in the Table.

The minimum cooling time for burnup greater than 45 GWd/MTU should consider uncertainties in source generation using SAS2H. The heat load is reduced by 5% to account for these uncertainties. The cooling time for burn up greater than 45 GWd/MTU generated uses 28.5Kw as heat load limit. Table 5.8.9-2 presents cooling times for heat load of 811 W per assembly for burnup less than 45 GWd/MTU and heat load of 770 W per assembly for higher than 45 GWd/MTU.

The applicant calculated all dose rates with the higher heat load source terms. This adds extra conservatism in the calculated dose rates. The source terms generating maximum dose rates for the PMTC all occur at lower burnups and shorter cool time combinations.

Based on its calculation, the applicant increased the minimum cooling time for fuel assemblies loaded with a reactor CEA by 0.4 years to accommodate for hardware heat load.

5.8 PMTC Dose Rates

The applicant provides in Figures 5.9.8-1 through 5.9.8-4 of the SAR the PMTC dose rates as a function of distance and Figure 5.9.8-5 through 5.9.8-8 of the SAR the dose rates as a function of source type. The peaks dose rates are on the radial cask surface near top and bottom forging locations. The dose rate distribution profile follows the burnup profile over the active fuel region. Due to radiation streaming the dose rates increase in the TSC to PMTC annulus area, During TSC closure operation, the shield and seal provide some shielding at the annulus location. Retaining ring used during the transfer provide shields in streaming paths. The maximum dos rates occur during TSC closure without additional auxiliary shielding. The applicant calculated the dose rates at vent shield and bottom forgings calculated by using superimposed mesh tallies. The maximum dose rate for vent shield is on the top of Vent Bas the result of streaming through the vent. Figure 5.9.8-10 of the SAR provides dose rate contour map for PMTC Vent Shield B. The dose rates at vent shield are higher than bottom forging dose rates. This is because the bottom steel doors is smaller than the full radius of the cask. The dose rate peaks at annulus with combination of the TSC and PMTC. The dose rates calculated using superimposed mesh tally in MCNP code. Figure 5.9.8-11 and Table 5.9.8-11 through Table 5.9.8-11 shown where the maximum dose rates occur on the PMTC.

5.9 Non-fuel Hardware – Reactor Control Elements

The center nine basket allowed for loading non-fuel elements. The applicant evaluated the dose rates for PMTC containing TSC loaded with reactor CEAs using MCNP model. The reactor control elements have additional 0.4 years cooling time. Table 5.8.6-5 provides minimum cooling times for CEAs. The 180 GWd/MTU exposure equivalent and 10 years cooling time is the bounding for dose rates. Table 5.9.1-5 summarized the dose rates for contribution due to CEAs.

5.10 Damaged Fuel

The system is also designed to store up to four damaged fuel (DF) assemblies in cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies including four DFC locations. The applicant considered two scenarios for the damaged fuel evaluation for PMTC. In the first scenario, the applicant assumed the damaged fuel collects over the active fuel length. This scenario modeled with filling fuel assembly volume with UO_2 and increasing the fuel gamma, neutron, and neutron-gamma source consistent with increase in the mass. In this scenario the mass is more than the mass of damaged fuel in four corners of the basket. Due to increase of mass the subcritical neutron multiplication estimated by MCNP code is higher, so neutron dose rates are higher due to increase in mass. In the second scenario, the applicant assumed that damaged fuel migrate into lower end fitting from the active fuel regions, filling all modeled void space. No credit taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel regions to lower fitting. The maximum dose rates from each scenarios added to dose rates from undamaged fuel. In this way contribution from damaged fuel is independent of the location. Therefore estimation of dose rates in these scenarios are conservative. The detectors at vent shields and bottom forging shown in Figure 5.9.8-9 of the SAR are independent and the mesh cells enclosing them are further divided to ensure accurate dose rate calculation. Table 5.9.10-1 provided the CE 16x16 material compositions. Even though the corner plates are thicker, no credit is taken for them in the model. The bounding source for damaged fuel is 2.1wt% U enrichment and 25 GWd/MTU burnup with 4 years cooling time which produced maximum dose rates at 1 meter from the cask.

5.10.1 Active Fuel Scenario

The side dose rates comparison for the damaged and fuel source shown in the Figure 5.9.10.1. Figure 5.9.10-2 shown the dose rates during the TSC closure operation is slightly higher than damaged fuel. The bottom dose rates comparison for damaged fuel shown in Figure 5.9.10-4. The dose rates at the vent shield increased due to the relocation of source in damaged fuel as shown in the Figure 5.9.1-7.

5.10.2 Lower End Fitting Scenario

Figure 5.9.10-5 shown the side surface dose rate from damaged fuel in the lower fitting. The bottom dose rates increase due to assumed source relocation of the damaged fuel as shown in Figure 5.9.10-6. Burnup 40 GWd/MTU is used to observe the contribution of damaged fuel to dose rates at bottom surface, lower end fitting, vents and transfer cask doors. The maximum dose rates is next to transfer cask doors for PMTC. The maximum dose rates for this scenario is higher. Figure 5.9.10-7 shown the maximum dose rates at vent shields and door boundary.

5.10.3 Combined Damaged Fuel Dose Rates

The sum of dose rates contributions from damaged fuel, the active fuel, and lower end fitting are provided in Table 5.9.1-6 and 7 of the SAR for PMTC. The maximum dose rates from undamaged fuel and damaged fuel are simply added together, ignored that fact that the maximum dose rates are at different locations of the PMTC.

5.11 Staff Confirmatory Review and Analysis

The staff reviewed the applicant's shielding analysis and finds it acceptable. The maximum dose rates meet the limits defined by 10 CFR Part 72. The staff reviewed the radiation shielding evaluations, including the calculations of the sources and the dose rates for the transfer cask and the concrete overpack as well as the annual dose at the controlled area boundary. The staff independently calculated source terms for the bounding PWR CE16x16 fuel assemblies using combinations of different enrichments, burnups, and cooling times. The staff also performed confirmatory analyses of the dose rates for the PMTC. Confirmatory analysis were performed by the staff on source term evaluations using the SCALE 6.1 computer code with the ORIGEN/ARP isotopic depletion and decay sequence with the 238-group ENDF/VII cross section library. Using irradiation parameter assumptions similar to the applicant's, the staff obtained bounding source terms that were similar to, or bounded by, those determined by the licensee and therefore finds the applicant's result acceptable. The staff finds the applicant has correctly determined the bounding dose rates for all proposed payloads as defined in Tables 5.9.1.6 and 5.9.1.7 to be acceptable.

5.12 TS Evaluation

Associated TS changes for this amendment include the following:

Appendix B – Addition of Tables B2-42, "Low SNF Assembly Average Burnup Enrichment Limits for CE 16x16 Fuel Loaded via the PMTC," and B-43, "Loading Table for CE 16x16 Fuel Loaded via the PMTC." The staff confirmed that these are identical to SAR tables 5.9.7-1 and 5.9.7-2 used in the staff evaluation above, and are therefore acceptable.

5.13 Staff Evaluation Findings

The staff reviewed the applicant's dose rate calculations and finds that the approaches and methodologies used in these calculations, and the results, are acceptable for the PMTC design. Based on its review of the information and representation provided by the applicant, the staff concludes that the requested change meets the acceptance criteria specified in NUREG-1536, Rev. 1, and meet the regulatory limits and provide reasonable assurance for safe transfer of spent fuel.

F5.1 Chapter 5 of the MAGNASTOR® SAR sufficiently describes the shielding design bases and design criteria for the structures, systems, and components important to safety.

F5.2 The MAGNASTOR® system radiation shielding and PMTC and confinement features are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.11, and 10 CFR 72.236(d).

F5.3 The staff concludes that the shielding and radiation protection design features of the MAGNASTOR® system, including the concrete cask, the PMTC, and the TSC, are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the shielding and radiation protection design features provides reasonable assurance that the PMTC will provide safe transfer of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

13 TECHNICAL SPECIFICATIONS AND OPERATING CONTROLS AND LIMITS EVALUATION

13.1 Objective

The staff reviews the TS and the operating controls and limits of TS to ensure they meet the requirements of 10 CFR Part 72. The applicant requested the following TS changes:

a) Provide a new PMTC and associated TS changes, and

b) Update TS Appendix A, Section 4.3.1(i) to include revised seismic requirements.

c) Provide clarifying (non-technical) changes to TS.

The staff TS evaluations for a) and b) are provided in Sections 3. 4, and 5 above. The staff evaluated the requested clarifying changes and determined that they are non-technical and do not change previous staff approved evaluations and, therefore, do not require a review.

14 CONCLUSION

Based on its review of CoC No. 1031, Amendment No. 7, the staff has determined that there is reasonable assurance that: (i) the activities authorized by the revised certificate will be conducted without endangering the health and safety of the public and (ii) these activities will be conducted in compliance with the applicable regulations of 10 CFR Part 72.

Dated: December 16, 2016