UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT
Docket No. 71-9356
Model No. MAGNATRAN Package
Certificate of Compliance No. 9356
Revision No. 3

SUMMARY

By application dated December 28, 2020 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML21005A014), as supplemented on July 27, 2021 (ADAMS Package Accession No. ML21214A057), and August 23, 2021 (ADAMS Accession No. ML21242A193), NAC International, Inc., (NAC or the applicant) submitted an application requesting revision of Certificate of Compliance (CoC) No. 9356, for the Model No. MAGNATRAN package. In its application, NAC requested moderator exclusion pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 71.55(c); revise the contents for increased enrichment and eliminate the requirement to use burnup credit when the package is transported using moderator exclusion; and to remove the restriction that all high burnup fuel must be loaded as damaged fuel regardless of whether the fuel is damaged (e.g., load high burnup fuel as undamaged fuel when these fuel assemblies meet the definition of undamaged fuel).

The U.S. Nuclear Regulatory Commission (NRC) staff evaluated the application and its supplements against the regulatory standards in 10 CFR Part 71 and the review guidance in NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material—Final Report.” Based on the statements and representations in the application, as supplemented, and the conditions listed in the CoC, the staff concludes that the package meets the requirements of 10 CFR Part 71.

EVALUATION

1.0 General Evaluation

1.1 Package Description

The MAGNATRAN package is canister-based and is part of a dual-purpose system for the storage and transportation of spent nuclear fuel for transporting the MAGNASTOR® transportable storage canister (TSC). The MAGNATRAN packaging includes the overpack, upper and lower impact limiters, and TSC. The overpack consists of the inner and outer shells, lead, upper forging, lid, bottom plate, bottom forging, and solid neutron shield.

The TSC, which contains the basket and is placed into the overpack, is constructed of a stainless steel cylindrical shell, bottom-end plate, closure lid, closure ring, and redundant port covers. The TSC confines the fuel basket structure and the spent fuel or the Greater-Than-Class C (GTCC) waste basket liner and GTCC waste.

The pressurized-water reactor (PWR) fuel basket design is an arrangement of 21 square, stainless steel fuel tubes held in a right-circular cylinder configuration by side and corner

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support weldments that are bolted to the outer fuel tubes. The 21 tubes develop 37 positions within the basket for the PWR spent fuel. The fuel tubes support an enclosed neutron absorber sheet on up to four interior sides of the fuel tube. Each neutron absorber sheet is covered by a thin stainless steel sheet to protect the neutron absorber during fuel loading and to keep it in position. The neutron absorber and stainless steel cover are secured to the fuel tube using weld posts distributed across the width and along the length of the fuel tube.

The PWR damaged fuel basket assembly holds up to 37 PWR fuel assemblies, which may include up to four damaged fuel can locations. A damaged fuel can may be placed in each of the four damaged fuel can basket locations around the corner periphery. The arrangement of tubes and fuel positions is the same as in the standard fuel basket, but the design of each of the four corner support weldments is modified with additional structural support to provide an enlarged position for a damaged fuel can at the outermost corners of the fuel basket. Each damaged fuel can location has a nominal 9.80-inch square opening. A damaged fuel can may contain either a damaged or an undamaged fuel assembly.

The boiling-water reactor (BWR) basket consists of 45 stainless steel fuel tubes that develop 87 basket locations for the BWR spent fuel. The BWR basket fuel tubes are held in a right-circular cylinder configuration by side and corner support weldments that are bolted to the outer fuel tubes. The fuel tubes support an enclosed neutron absorber sheet on up to four interior sides of the fuel tube for criticality control. Each neutron absorber sheet is covered by a sheet of stainless steel to protect the neutron absorber during fuel loading and to keep it in position. The neutron absorber and stainless steel cover are secured to the fuel tube using weld posts distributed across the width and along the length of the fuel tube.

1.2 Contents

The MAGNATRAN package is designed to transport up to 37 undamaged PWR fuel assemblies in a 37 PWR basket assembly, up to 87 undamaged BWR fuel assemblies in an 87 BWR basket assembly, up to 37 undamaged PWR fuel assemblies or a combination of undamaged fuel assemblies and up to four damaged or high burnup fuel assemblies each in a damaged fuel can (or fuel material equivalent to a single fuel assembly) in the 37 PWR damaged fuel basket assembly, or a TSC containing up to 55,000 pounds of GTCC waste in a GTCC waste liner.

NAC revised its contents to increase the upper limit on enrichment to 5 weight percent (wt%) for all fuel assemblies loaded into the package regardless of location when using moderator exclusion. The maximum enrichment is based on moderator exclusion and similarly, the package does not rely on burnup credit or require insertion of reactor control cluster assemblies (RCCAs) for criticality control for packages crediting moderator exclusion.

1.3 Drawings.

NAC did not submit any revised drawings for this certificate revision.

1.4 Summary of Compliance with Tile 10 of the *Code of Federal Regulations* Part 71

In its request, NAC requested submitted two changes: moderator exclusion pursuant to 10 CFR 71.55(c) and associated content changes for packages that use moderator exclusion and remove the restriction that all high burnup fuel assemblies (i.e., burnup greater that 45,000 megawatt-days per metric ton uranium (MWd/MTU)) are loaded in a damaged fuel can.

1.4.1 Moderator Exclusion

The containment boundary for the MAGNATRAN package consists of the bottom inner forging; inner shell; top forging; cask lid and inner O-ring; and lid port cover plate and its inner O-ring. The overpack is designed, fabricated, tested, and inspected in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, Subsection NB, with the exception of code stamping. In addition, the MAGNATRAN entire containment boundary is also leak tested as described in Section 8.1.4, "Leakage Tests," of the safety analysis report (SAR) for fabrication and Section 8.2.2, "Leakage Tests," of the SAR for the pre-shipment leak rate test for the MAGNATRAN containment boundary O-rings prior to each shipment. The MAGNATRAN containment boundary is leak tested to the leaktight criterion (1×10^{-7} reference cubic centimeters per second (ref-cm^3/s) of air) in accordance with American National Standards Institute (ANSI) N14.5-1997, "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment."

In this application NAC stated that it credits the TSC welded boundary as the special design feature that, along with the package containment boundary, prevents a single packing error from permitting leakage into the fissile material, as required by 10 CFR 71.55(c).

The TSC, which is the MAGNASTOR storage system confinement boundary (see storage Certificate of Compliance No. 1031 [Docket No. 72-1031]), is designed, fabricated, examined, tested, and inspected in accordance with the requirements of the ASME B&PV Code, Section III, Subsection NB, with the code alternatives listed in Table 2.1-2[1] of the MAGNASTOR final safety analysis report. The TSC confinement boundary is leak tested, as described in Section 10.1.3 of the MAGNASTOR final safety analysis report, to the leaktight criteria in accordance with ANSI N14.5. The following TSC components are leak tested to the ANSI N14.5 leaktight acceptance criterion:

- the TSC shell weldment after completion of the TSC shell seam and shell to bottom plate weld (performed in the shop),
- the composite carbon steel, stainless steel closure lid assembly (performed in the shop), and
- the vent and drain inner port covers and their welds (performed in the field).

The TSC closure lid weld is not leak tested, consistent with the guidance in NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities," which provides examples of acceptable approaches to demonstrate leak-tightness of welded canister lids. Based on this guidance in which a large, multi-pass weld that is executed and examined consistent with NUREG-2215, the NRC staff has reasonable assurance this weld is free of flaws of significant size that could impair the TSC's confinement capability. The TSC's all-stainless steel closure lid is not required to be leak tested, consistent with the approval in Section 10.1.3, "Leakage Testing," of the initial issuance of the MAGNASTOR safety evaluation report (SER) (ADAMS Accession No. ML090350589) and Section 8.1.4.3, "Leakage Tests for TSCs Shipped Under Moderator Exclusion," of the application, based on the confinement system materials, welding requirements, and testing methods. The TSC closure lid along with the TSC pressure

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[1] Table 2.1-2 spans pages 2.1-3 through 2.1-5. Pages 2.1-3 and 2.1-5 were submitted in Revision 5 (ADAMS Accession No. ML053060314). Page 2.1-4 was submitted in Revision 11 (ADAMS Accession No. ML16341B102).

boundary is hydrostatically pressure tested, consistent with the approval in Section 10.1.2, “Structural and Pressure Testing,” of the initial issuance of the MAGNASTOR SER.

As stated in Section 7.0, “Packages Operations,” of the MAGNATRAN SAR (ADAMS Accession No. ML19186A385), TSCs containing spent nuclear fuel are required to be loaded and prepared for storage in accordance with the applicable procedures for CoC No. 1031, including the technical specifications, for the Model No. MAGNASTOR storage system, whether or not the TSC is placed into storage. Preparing the TSC for storage includes ensuring, via a combination of leak testing and weld inspections, the TSC will be leaktight when it is placed into service for storage or transport. The acceptance tests and operating procedures in the MAGNATRAN SAR ensure that the package containment boundary is leak tested to ensure that, when the MAGNATRAN package is placed into transport, the containment boundary is also leaktight.

NAC requested a condition to the certificate stating that TSCs used for moderator exclusion must be either within the first storage term or new TSCs that were loaded and prepared in accordance with CoC No. 1031, including the technical specifications, for the MAGNASTOR storage system, even if it was not placed into storage.

The MAGNATRAN containment boundary components are designed, fabricated, tested, and inspected to the requirements of ASME B&PV Code, Section III, Subsection NB, with the exception of code stamping. In the side drop evaluation for NRC approval of Certificate of Compliance No. 9356, Revision 0 (see consolidated SAR at ADAMS Accession No. ML19196A079), NAC evaluated the package for the tests for normal conditions of transport (NCT) and hypothetical accident conditions (HAC) in 10 CFR 71.71 and 10 CFR 71.73, respectively. The results of NAC’s evaluations of the tests for NCT and HAC, show that the two package boundaries (TSC and MAGNATRAN containment boundary) remained leaktight.

The staff agrees with the applicant’s assertion that the TSC, as a barrier to intrusion of water into the cavity containing the spent fuel, is a special design feature to ensure that no single packaging error will allow moderation of the spent fuel, as required by 10 CFR 71.55(c). This special design feature (the TSC), together with the entire containment boundary of the MAGNATRAN package that is leak tested as described in Section 8.1.4 of the SAR for fabrication and Section 8.2.2 of the SAR for the pre-shipment leakage rate test preclude water.

1.4.2 High Burnup Fuel

The applicant proposed to revise the MAGNATRAN CoC to no longer classify spent fuel with burnup equal to or greater than 45,000 MWd/MTU as damaged fuel. As a result, this high burnup fuel will no longer be required to be placed in damaged fuel cans. To support this change, the applicant provided structural analyses of high burnup fuel assemblies to demonstrate that the fuel cladding is capable of fulfilling its intended functions under NCT and HAC. The applicant stated that this approach is consistent with the guidance in NUREG-2224.

In its consolidated SAR, Revision No. 0, which formed the basis for issuance of CoC No. 9356, Revision No. 0 (ADAMS Accession No. ML19098A080), NAC provided its evaluation of fuel assemblies for the 30-foot side- and bottom-end drop. NAC stated that, and the NRC agreed that, the fuel assembly did not need to be evaluated for the side drop, since the design basis side drop impact of 60g, which is below the 63g determined in a generic study (Lawrence Livermore National Laboratory report UCID-21246, “Dynamic Impact Effects on Spent Fuel Assemblies,” dated October 20, 1987). The 63g in UCID-21246 is the minimum structural capacity without causing yielding in the PWR and BWR spent fuel rods. However, as discussed in Section 2.11.4 of the SAR, NAC did evaluate the PWR fuel assemblies having cladding oxide layers that are 80 and 120 microns thick for the design-basis 60g side drop evaluation. This evaluation demonstrated that maximum stress in the fuel cladding was below yield (i.e., positive safety factor) for the fuel cladding for three fuel assembly designs [Combustion Engineering (CE) 14×14, Westinghouse (WE) 15×15, and WE 17×17] demonstrating fuel rod elastic performance.

In the end drop analysis the consolidated SAR, NAC demonstrated that the maximum stress for PWR fuel assemblies was below yield and resulted in a factor of safety greater than 2, demonstrating elastic performance of the fuel rod. NAC explained that since the BWR slenderness ratio is smaller than the PWR fuel rods, BWR fuel rods are less vulnerable to buckling due to an end drop didn't perform further evaluations.

In its application for approval of this revision, NAC included both an evaluation of PWR side drop analysis using a dynamic load factor (DLF) and fuel rod fatigue evaluation, as discussed in NUREG-2224, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel." For the side drop evaluation NAC evaluated the fuel assembly response using the maximum acceleration of 45.5g occurs for the cold condition side drop. When adding in the DLF of 1.75 to the fuel rod moment of inertia, NAC demonstrated that the maximum stresses in the fuel rods are all less than the yield strength at 752°F. NRC staff's review of the side drop using a DLF is discussed below in Section 2.1.

In this revision request, NAC also provided an evaluation of fuel rod fatigue due to vibration as an evaluation for NCT in 10 CFR 71.71(c)(5). In this evaluation, NAC determined that the maximum fuel rod strain is less than 0.05% for both PWR and BWR fuel, which are below the 0.06% end point of the Lower-Bound Fatigue Curve as shown in Table 2-5 and Figure 2-12 of NUREG-2224, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel,", indicating that fatigue is not a concern of the high burnup PWR and BWR fuel assemblies for transport conditions. NRC staff's review of fuel rod fatigue is discussed below in Section 2.2.

2.0 Structural Evaluation

The objective of this NRC staff's structural evaluation is to verify that the applicant has adequately evaluated the structural performance of the package to meet the regulations in 10 CFR Part 71 to not require high burnup fuel be loaded as damaged spent fuel regardless of the condition of the spent fuel.

The staff reviewed the applicant's basis for classifying spent fuel with burnup equal to or greater than 45,000 MWd/MTU as undamaged, considering the example certification approaches described in NUREG-2224. The staff notes that NUREG-2224 describes two structural analyses that must be addressed to support such an approach: (1) demonstrate cladding performance in NCT and HAC drop scenarios and (2) evaluate fuel rod performance under fatigue loading. The staff's review of each of these analyses is documented below.

The staff reviewed and evaluated the information provided by the applicant in the SAR, Revision 20C to support treating high burnup fuel as undamaged fuel when it meets the definition of undamaged fuel. Undamaged fuel is spent nuclear fuel that does not have any visible deformation other than uniform bowing that occurs in the reactor, assemblies that do not have missing rods, and assemblies with missing rods that are replaced by solid stainless steel or zirconium filler rods that displace a volume equal to or greater than the original rods and assemblies that do not contain structural defects that adversely affect radiological and/or criticality safety and/or result in unsupported fuel rod lengths in excess of 60 inches and that can be handled by normal means.

The specific proposed changes for evaluations in this section are:

- Addition of an additional structural analysis to the current Section 2.11.4, “Side Drop Evaluation,” in the SAR, Revision 0.

- Addition of a new Section 2.11.6, “Fatigue Evaluation of Fuel Rods,” to the SAR, Revision 0.

This section of the SER documents the staff’s reviews, evaluations, and conclusions with respect to structural safety of the fuel rods.

2.1 Evaluation of Additional Side Drop Evaluation

The applicant evaluated the drop performance of high burnup fuel rods in Section 2.11.4 of the application and proprietary Calculation No. 71160-2139 Rev. 0, “PWR and BWR Fuel Assembly Fatigue Evaluation for MAGNATRAN.” The staff compared the applicant’s analytical approach to evaluate the 30-foot side drop accident to that described in NUREG-2224. The staff notes that Section 2.3 of NUREG-2224 provides a methodology for applying the results of static bending tests on high burnup fuel rods to evaluate the dynamic loading in a drop accident.

The applicant performed an additional structural analysis to calculate stresses of high burnup fuel rods during a side drop under the HAC. The fuel assembly models used for the analysis were identical to the undamaged PWR fuel rod models used in the consolidated SAR, Revision 0, which formed the basis for issuance of Revision No. 0 of Certificate of Compliance No. 9356, were previously reviewed and approved by the NRC staff and are valid for this amendment.

The applicant first calculated stresses of a fuel rod by using the ANSYS finite element (FE) program. A maximum acceleration of 45.5g for a cask side drop was used in the analysis, as discussed in Section 2.6.7.5.1 of the consolidated SAR Revision No. 0. The applicant then used the methodology discussed in Section 2.3 of NUREG-2224 to calculate the cladding stresses of a high burnup fuel rod. Once the cladding stresses were calculated, they were then amplified by a DLF to account for the dynamic effects on the fuel rod as discussed in Section 2.3.5 of NUREG-2224. A DLF of 1.75 was used in the analysis to get a maximum dynamic response, which was based on the information in Reference 2.1.

The results of the analysis are summarized in Table 2.1 below for three PWR fuel rods (CE 14×14, WE 15×15 and WE 17×17) for the undamaged fuel rods and high burnup fuel rods. A factor of safety (FS), a ratio of the maximum calculated stress with respect to the allowable stress of 69.6 thousand pounds per square inch (ksi), which is the yield strength of the fuel rod at 752 °F, was also calculated and provided in Table 2.1. Based on the results of the structural analysis provided in Table 2.1, the applicant concluded that the PWR high burnup fuel rods remain structurally adequate for a side drop accident under the HAC.

The staff reviewed the applicant’s calculations and verified that the applicant’s methodology was consistent with NUREG-2224 and appropriate to assess the drop performance of the fuel rods during hypothetical accident conditions to demonstrate that the stresses in the rods are below the yield strength of the material. The staff reviewed the applicant’s structural analysis and the methodology to calculate the maximum stress of the high burnup fuel rods. The staff confirmed that the applicant considered dynamic effects on the fuel rod during a side drop by applying a DLF of 1.75. The staff found that the results of the analysis showed that the PWR high burnup fuel rods remained structurally adequate for a side drop accident under the HAC.

However, the staff found that NUREG-2224 provides guidance to use a DLF of 2.0 in a stress calculation for a high burnup fuel rod to account for uncertainties involved in natural frequency, load duration, and load time history shape, which depend on the physical characteristics of the fuel assembly, the rod, and the cask. The staff issued a request for additional information (RAI) regarding the use of the DLF of 1.75, instead of using the DLF of 2.0. In its July 27, 2021, response to the RAI, the applicant stated that the dynamic event of the fuel rod during a side drop is a sine wave pulse type event, as evidenced by the acceleration data shown in Figure 2.6.7-13 of Revision No. 0 of the consolidated SAR, where the acceleration increases from 0 to its peak value of 45.5g over a finite amount of time, not instantly. Since the DLF of 2.0 reported in NUREG-2224 corresponds to a suddenly applied load (i.e., impulsive load), it would be more appropriate to use the DLF of 1.75 based on the information in Revision 0 of the consolidated application for a sine wave pulse type dynamic event. The staff agrees with the applicant’s statement that the peak acceleration of 45.5g cannot physically be developed in a suddenly applied manner during a side drop and agrees that the use of a DLF associated with a sine wave pulse is a realistic approach. The staff finds the use of the maximum DLF value of 1.75 acceptable and concludes that the PWR high burnup fuel rods remain structurally adequate for a side drop accident under the HAC.

Table 2.1 – Calculated Maximum Stress and Factor of Safety for Fuel Rods

Fuel Rod (PWR)	**Undamaged Fuel Rod**		**High Burnup Fuel Rod**	
	Maximum Stress (ksi)	Factor of Safety	Maximum Stress (ksi)	Factor of Safety
CE14×14	37.1	1.88	51.1	1.36
WE15×15	48.1	1.45	62.1	1.12
WE17×17	46.3	1.50	60.4	1.15

Regarding side drop evaluations for the BWR fuel rods, the applicant stated that no evaluations for the BWR fuel rods are required because the slenderness ratio (L/r) (L and r are the length and radius of the fuel rod, respectively) for the PWR fuel rods are significantly larger than the L/r for the BWR fuel rods, as discussed in Section 2.11.2 of the SAR (Reference 2.1), and therefore the side drop evaluations for the PWR fuel rods are bounding for the BWR fuel rods.

The staff reviewed the statement and discussions in Section 2.11.2 of the consolidated SAR, Revision No. 0 and confirms the statement that the PWR fuel rod has a larger slenderness ratio (L/r) than the BWR fuel rod. Since a fuel rod having a larger slenderness ratio (L/r) expects to have a larger bending stress, the PWR high burnup fuel rod has a larger maximum bending stress than the maximum bending stress of the high burnup BWR fuel rod. Therefore, the staff finds the statement that the side drop evaluations for the PWR fuel rods are bounding for the BWR fuel rods to be acceptable. The staff reviewed the evaluations and concluded that the BWR high burnup fuel rods remain structurally adequate for the side drop accident under the HAC.

2.2 Fatigue Evaluation of Fuel Rods

The applicant performed a fatigue evaluation for the PWR and BWR high burnup fuel assemblies for the NCT for the MAGNATRAN package. Three PWR fuel rods from CE 14×14, WE 15×15 and WE 17×17 fuel assemblies and four BWR fuel rods from General Electric (GE) 7×7, GE 8×8, GE 9×9 and GE 10×10 fuel assemblies were considered in the evaluation. A FE model representing a single fuel rod for each of the fuel assemblies was used to determine the stress and strain in the fuel cladding under the NCT.

The ANSYS FE program was used for the analysis. The fuel rod was modeled with the ANSYS 3-D BEAM4 element to represent the fuel clad. The density of the clad was adjusted to account for the mass of the fuel pellet. The locations of the grids were modeled as simple supports in the lateral directions. The ANSYS response spectrum analyses were performed for the fuel rods using response spectra of the transport cask platform from seven test cases as documented in the Equipos Nucleares, S.A. (ENSA)/Department of Energy (DOE) rail cask test (Reference 2.2).

The applicant presented the results of the analyses in Tables 2.11.6-1 and 2.11.6-2 of the SAR, Revision 20C with the maximum stress and strain of the PWR fuel and BWR fuel rods, respectively. The maximum strain is 0.046% for the PWR fuel rod and 0.043% for the BWR fuel rod, which are well below the 0.06% end point of the Lower-Bound Fatigue Curve as shown in Table 2-5 and Figure 2-12 of NUREG-2224, indicating that fatigue is not a concern of the high burnup PWR and BWR fuel assemblies for the NCT.

The staff reviewed the evaluations and concluded that high burnup PWR and BWR fuel assemblies will not fail due to fatigue during transport under NCT.

2.3 Evaluation Findings

The staff reviewed the applicant's evaluations for the BWR and PWR high burnup fuel rods during a side drop under the HAC and a transport under the NCT. Based on the applicant's analyses, the staff concluded that the results of the evaluations are acceptable, and that the high burnup fuel rods remain structurally adequate for the side drop accident under the HAC and the fatigue of the high burnup fuel rods is not a concern during a transport under the NCT. The staff finds that the BWR and PWR high burnup fuel rods have adequate structural integrity to meet the structural requirements of 10 CFR Part 71.

2.4 References

2.1 Clough, Ray W. and Joseph Penzien, Dynamics of Structures, 2nd Edition, 1993.

2.2 SAND2018-13258R, Data Analysis of ENSA/DOE Rail Cask Tests, Spent Fuel and Waste Disposition, US Department of Energy, Spent Fuel and Waste Science and Technology, November 2018.

3.0 Thermal Evaluation

In MAGNATRAN Revision 3, the changes proposed in the SAR did not change the thermal evaluation of the package.

4.0 Containment Evaluation

The objective of the NRC staff's containment evaluation is to verify that the applicant has adequately evaluated the performance of the transportation package for radioactive material so that the package meets the regulations in 10 CFR Part 71.

The MAGNATRAN package containment boundary components include: the bottom inner forging, inner shell, top forging, closure lid, lid metal inner O-ring, cover plate, and cover plate metal inner O-ring. The containment boundary is shown in Figure 4.1-1, "Transport Cask Containment Boundary," of the SAR. The containment boundary leak testing acceptance criterion is leaktight which is defined in ANSI N14.5-1997, as 1×10^{-7} ref-cm^3/s of air. The staff provided its containment evaluation for the MAGNATRAN package in the initial issuance of the SER (ADAMS Accession No. ML19105A148).

4.1 Proposed Changes

The TSC, which is credited in the proposed change to serve the 10 CFR 71.55(c) function of being a special design feature that prevents a single packing error from permitting leakage into the fissile material region, is not a component of the containment boundary, but is evaluated in Section 1.4.1 of this SER.

Chapter 4, "Containment," of the application describes that the entire transportation package containment boundary is tested to the ANSI N14.5-1997 leaktight criteria during post-fabrication leak testing as described in Section 8.1.4, "Leakage Tests," of the SAR. Section 4 of the application continues to describe that the periodic, maintenance, and pre-shipment leakage testing is also performed to the ANSI N14.5-1997 leaktight criteria as described in Section 8.2.2, "Leakage Tests," of the consolidated SAR, Revision No. 0. The staff verified that this description to test the entire containment boundary was consistent with the description on page 1.3-8 through page 1.3-9 of the application, the description in Section 6.1.1, "Design Features," of the application, and Section 5(a)(2) of the CoC to provide reasonable assurance that the package containment boundary is leaktight. Section 6.1.1 of the application also describes that, based on a leaktight transport package containment boundary, moderator is not present in the TSC while it is being transported. The containment boundary leakage rate tests are described in Section 8.1.4 of the consolidated SAR, Revision No. 0 for fabrication and Section 8.2.2 of the consolidated SAR, Revision No. 0 for maintenance, periodic, and pre-shipment. The staff provided its evaluation of the leakage rate tests in Section 8.1.4 of the initial issuance of the SER (Revision 0).

The applicant described on page 1.3-11 of the application that the MAGNASTOR damaged fuel can (DFC) is provided to accommodate damaged PWR fuel assemblies and the primary function of the DFC is to confine the fuel material within the can to minimize the potential for dispersal of the fuel material into the TSC cavity. The staff finds the use of a DFC to transport damaged fuel within the MAGNATRAN package to be consistent with the guidance in NUREG-2216, that spent nuclear fuel that has been classified as damaged must be placed in a can designed for damaged fuel.

4.2 Evaluation Findings

F4-1 The staff has reviewed the applicant's description and evaluation of the containment system and concludes that the application identifies established codes and standards for the containment system.

Based on review of the statements and representations in the application, the NRC staff concludes that the package has been adequately described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71.

5.0 Shielding Evaluation

The objective of the review is to verify that, with the proposed changes in Revision 3 to the certificate of compliance, the shielding of the MAGNATRAN package provides adequate protection against direct radiation from its contents and that the package design meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

The staff evaluated the capability of the MAGNATRAN shielding features to provide adequate protection against direct radiation from its contents. This review includes the staff's evaluation of the descriptions of the proposed contents, the package shielding features and the calculation of the dose rates from both gamma and neutron radiation at locations near the package and at distances away from the package during transportation for both NCT and HAC.

The staff reviewed the applicant's safety analyses for the requested changes removing the condition that high burnup fuel must be loaded only in a damaged fuel can.

5.1 Background

The MAGNATRAN transport package packaging consists of five principal structural entities: (1) the cask body, (2) TSC, (3) the fuel basket, (4) the GTCC canister and waste basket liner and (5) the impact limiters. Considering specifically the content configuration, the packaging is designed to transport two categories of PWR fuel assemblies and two categories of BWR fuel assemblies in two lengths of TSCs (long and short). A cavity spacer is used to axially position the short TSC and limit its potential movement under NCT and HAC. The short TSC is also used to transport GTCC wastes in a basket liner.

5.2 Shielding Evaluation

There is no change in contents or fuel configuration in this amendment. The only change on this amendment related to shielding is removing from the CoC the condition for high burnup fuel loaded only in a damaged fuel can.

Staff reviewed the previously submitted Revision 0 of the consolidated SAR, the supplement submitted on July 2019, and the NAC Calculation Package No. 71160-5508, Revision No. 0 , "MAGNATRAN Transport Cask Shielding Analysis with MCNP6" submitted to NRC in 2014 (ADAMS Accession No. ML14356A377) in response to RAIs for a previous revision of the MAGNATRAN package. The applicant, in these documents, demonstrated that the dose rates for up to 60,000 MWd/MTU for the burnup point produced maximum dose rates. The summary of the results is shown in Table 5.1-9 of the SAR. While high burnup fuel was not approved in the undamaged fuel configuration, NAC's dose rate results show that a burnup of 45,000 MWd/MTU produced higher radial dose rates due to a shorter cooling time than that of the high burnup fuel. Thus, the staff concluded that the low burnup fuels are the bounding fuels for the transportation in the MAGNATRAN package and therefore, the high burnup fuel can be transported in any fuel location in the MAGNATRAN package, including a full load of high burnup fuel. The staff documented its shielding evaluation for the MAGNATRAN package in the

SER for issuance of Revision No. 0 of Certificate of Compliance No. 9356 (ADAMS Accession No. ML19105A148).

The dose rates for BWR fuel were also revised to include high burnup fuel dose rates. Revision No. 0 of the consolidated SAR contains dose rates calculation results for high burnup fuel, however the staff only approved burnup up to 45,000 MWd/MTU for BWR fuels. Table 5.1-9 of the consolidated SAR contained dose rates for high burnup fuel for BWR fuel. The pages of the SAR, Revision 0, at that time were rewritten to comply with the NRC approval of up to 45,000 MWd/MTU. The BWR dose rate results for high burnup fuel were provided in this application but were calculated in Calculation Package No. 71160-5508, "MAGNATRAN Transport Cask Shielding Analysis with MCNP6." NAC's dose rate results show that lower burnup produced higher radial dose due to shorter cooling time as in case of PWR system, therefore bounds the higher burnup fuel and, therefore, high burnup fuel can be transport by in any location of the MAGNATRAN System.

5.3 Evaluation Findings

F5-1 The staff has reviewed the application and finds that it demonstrates that under the evaluations specified in 10 CFR 71.71 (NCT), external radiation levels do not exceed the limits in 10 CFR 71.47(a) for nonexclusive-use shipments or 10 CFR 71.47(b) for exclusive-use shipments, as applicable.

F5-2 The staff has reviewed the application and finds that it demonstrates that under the tests specified in 10 CFR 71.73 (hypothetical accident conditions), external radiation levels do not exceed the limits in 10 CFR 71.51(a)(2).

Conclusion

Based on the NRC staff review of the information and representations provided in the application, as supplement, the previous staff approved SAR and calculation package, the staff has reasonable assurance that the proposed package design and contents satisfy the shielding requirements and dose rate limits in 10 CFR Part 71. The staff also finds that the external radiation levels will not significantly increase during NCT and HAC consistent with the conditions specified in the certificate of compliance.

6.0 Criticality Evaluation

As part of the proposed revision, the applicant has requested that the MAGNATRAN transportation package be authorized to ship certain contents under the provisions of moderator exclusion by crediting the TSC sealed boundary as being a special design feature under 10 CFR 71.55(c) that would prevent leakage of water from coming into contact with the fissile material being transported. Staff evaluated the proposed changes to evaluate the ability of the MAGNATRAN transportation package to meet the fissile material requirements of 10 CFR Part 71. Staff reviewed the criticality safety analyses performed by the applicant provided with the SAR revision changed pages. The staff's review considered the criticality safety requirements of 10 CFR Part 71, as well as the review guidance presented in NUREG-2216.

6.1 Background

The MAGNATRAN package is designed to transport up to 87 undamaged BWR fuel assemblies or up to 37 undamaged PWR fuel assemblies in their respective basket assemblies, with the ability to contain a combination of damaged assemblies (up to four) with undamaged fuel assemblies. The design of the MAGNATRAN packaging is unchanged from previous amendments, however, the applicant has revised the allowable contents of fuel assemblies authorize to an upper enrichment limit of 5 wt% for all assemblies loaded into the package provided that the shipment is certified for moderator exclusion. Since moderator exclusion is being used to allow the higher enriched assemblies, the package does not require the use of burnup credit, nor does it require the insertion of RCCAs, for criticality control for those shipments utilizing moderator exclusion.

6.2 Moderator Exclusion

The MAGNATRAN package's containment boundary is unchanged from previous NRC approved package designs. The applicant will also utilize two shipment configurations of the MAGNATRAN package. The first includes moderator intrusion into the TSC containing the fissile assemblies and is unchanged by this amendment. In the second configuration, the applicant proposes to credit the TSC welded boundary as a special design feature for PWR and BWR fuel enrichments up to 5 wt% ^{235}U. This feature, coupled with the package containment boundary, would prevent any single packing error from allowing water in-leakage into the fissile material to be transported, which is required by 10 CFR 71.55(c).

The MAGNATRAN transportation package is designed with two independent boundaries to prevent moderator intrusion into the spent fuel assemblies, the transport cask, and the TSC. The TSC is weld closed and retains its leak-tight integrity for all evaluated transport conditions. The storage configuration has been demonstrated to provide maintain is confinement integrity under both NCT and HAC.

Based on the assessment that the TSC acts as a barrier to intrusion of water into the spent fuel region of the MAGNATRAN package, as detailed in Section 1.4.1 of this SER, the staff agrees that no single packaging error would allow moderation to infiltrate the fissile material region of the package.

6.2.1 Evaluation of Increased Enrichment

Based on the staff assessment that there is no credible way for water to leak through the TSC boundary and given that there is a leak-tight transportation package boundary, there is no credible method for water to be present in the TSC while it is being transported during all NCT and HAC. This allows for the use of moderator exclusion in evaluating the increased enrichment contents of the MAGNATRAN package. Under the conditions of moderator exclusion from the TSC interior, fuel assemblies with a maximum of 5 wt% ^{235}U enrichment are allowed to be loaded into the MAGNATRAN package for all PWR and BWR fuel types, with no burnup credit required.

Since water is precluded within the package during transportation, the MAGNATRAN transportation system is evaluated using a dry TSC and a full payload of 5 wt% ^{235}U fuel assemblies for both the 87 assembly BWR basket (which is modeled with 89 assemblies) and the 37 assembly PWR basket. The basket integral neutron absorber sheets are modeled with a minimum Boron-10 loading of 0.02 g/cm^2 for the BWR basket, and 0.027 g/cm^2 for the PWR basket, with the peripheral absorber sheets for both configurations replaced with aluminum sheets. The applicant evaluated the various fuel assembly types at the increased enrichment to demonstrate the maximum k_{eff} of the dry system, as shown in Tables 6.10.4-1 and 6.10.4-2. As expected, the maximum reactivity of the dry system correlates with the fuel mass, and the maximum mass of Uranium loading yielded the highest k_{eff} of 0.51459, substantially below their maximum upper subcritical limit (0.9376).

The applicant also evaluated the MAGNATRAN transportation package with the fuel baskets removed to account for potential reconfiguration of the fuel during hypothetical accident conditions. The applicant chose to reconfigure the entire fuel mass into a homogeneous UO_2 sphere, with no integral neutron absorbing materials, to demonstrate the subcriticality of the system. This is a very conservative model since the sphere is only constrained by the internal diameter of the TSC, resulting in a much higher ^{235}U mass than either a full PWR or BWR basket loading (i.e., 18.5 MTU for PWR basket and 18.8 MTU for BWR basket vs. 23.8 MTU for the modeled sphere at 5 wt% ^{235}U), as well as minimizing neutron leakage. The applicant calculated a maximum k_{eff} of the dry sphere configuration to be 0.77174, well below the maximum upper subcritical limit.

6.3 Evaluation Findings

Staff evaluated the increased enrichment under moderator exclusion conditions proposed by the applicant and performed a confirmatory calculation for the bounding loaded configuration of the MAGNATRAN package (i.e., BW15H3 fuel for the maximum MTU) using similar assumptions. With moderator excluded from the package, the 5 wt% ^{235}U bounding payload was found to be subcritical with a similar very large margin (i.e., keff ~0.5). Staff also evaluated the reconfiguration assumptions used by the applicant for the spherical model and found them to be adequately conservative and in agreement with NUREG/CR-0095, “Nuclear Safety Guide, TID-7016”, that concluded for enrichments of ≤ 5 wt% ^{235}U that criticality is not possible for unmoderated uranium compounds. The staff concluded that the results of the applicant’s evaluations are acceptable, and that for fuel assemblies enriched up to 5 wt% ^{235}U along with moderator exclusion meets the criticality safety requirements of 10 CFR Part 71.

7.0 Operating Procedures Evaluation

7.1 Package Loading – Physical Condition

The applicant proposed to credit the TSC as a sealed boundary to prevent a single packing error from permitting leakage into the fissile material region. In Section 7.1.2 of the application, the applicant stated that TSCs that are to be retrieved from storage for off-site transport will be evaluated to ensure that they retain their ability to satisfy functional and performance requirements of the MAGNATRAN packaging certified content conditions. This evaluation includes an assessment of aging management program information prior to transport. TSCs will also be evaluated for potential corrosion at the welds and any damage caused by removal of the TSC from the storage overpack. In addition, the applicant proposed a certificate condition (see Condition 6.c) to require that, for TSCs to be shipped under the moderator exclusion option of this certificate, only TSCs that are within their initial term of storage or are new and haven't been loaded and placed into storage are authorized for use under moderator exclusion. The staff notes that this condition provides reasonable assurance that long-term aging effects will not challenge the moderator exclusion assumption.

As a result, based on the limitation of the moderator exclusion option to TSCs that are new or in their initial storage period, the requirements to perform leak testing of the TSC confinement boundary, and the additional TSC corrosion assessments performed prior to transport, the staff finds the applicant’s measures to ensure the adequate physical condition of the TSCs to be acceptable.

7.2 Conclusions

With Condition 6.c in the certificate and the operating procedures stating that placing a package shipped using moderator exclusion into a spent fuel pool is not permitted, the staff has reasonable assurance that the package will be operated in a manner that is consistent with its design evaluation, including moderator exclusion. On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures provide adequate measures and reasonable assurance for safe operation of the proposed package in accordance with 10 CFR Part 71.

CONDITIONS

The following changes were made to the Certificate:

Condition 5.(a)(2) was revised to describe package when using moderator exclusion.

The contents in Condition 5.(b) were revised to increase the enrichment, eliminate the requirement to use burnup credit and reactor control components when the package is transported using moderator exclusion, and include fuel qualification tables for high burnup BWR fuel. Deleted the description of optional spacers to support fuel assemblies from the certificate, since the optional spacers are still listed in the drawings referenced in 5.(a)(3).

Revised Condition No. 6 to state that, for TSCs to be shipped under the moderator exclusion option of this certificate, only TSCs that are within their initial term of storage or are new and haven't been loaded and placed into storage are authorized for use under moderator exclusion.

Corrected Table 16 for boron areal density rather than boron-10 density.

The References was updated to include the supplements dated December 28, 2020, July 27 , 2021, and August 23, 2021.

CONCLUSION

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. MAGNATRAN package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9356, Revision No. 3.