UNITED STATES
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SAFETY EVALUATION REPORT
NAC INTERNATIONAL
MAGNASTOR® STORAGE SYSTEM
DOCKET NO. 72-1031
AMENDMENT NO. 4

Summary

This safety evaluation report (SER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's review and evaluation of an amendment to Certificate of Compliance (CoC) No. 1031 for the Modular Advanced Generation Nuclear All-purpose STORage (MAGNASTOR®) spent fuel dry cask storage system. By application dated June 18, 2013 (Agencywide Documents Access and Management System (ADAMS) accession number ML13171A031), as supplemented September 6, 2013 (ADAMS Accession No. ML13261A278), September 19, 2013 (ADAMS Accession No. ML13268A050), June 13, 2014 (ADAMS Accession No. ML14170A070), June 17, 2014 (ADAMS Accession No. ML14170A022), and July 17, 2014 (ADAMS Accession No. ML14199A501) the cask vendor, NAC International Inc. (hereafter, NAC), submitted a request to the NRC in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 72.244 to amend CoC No. 1031. NAC requested the following changes:

- Revise of time to transfer canister and backfill with helium in Limiting Condition for Operation (LCO) 3.1.1,
- Revise decay times in Technical Specification, Appendix B, Table B2-5 for minimum additional decay time required for the spent fuel when the fuel contains nonfuel hardware, and
- Correct typographical errors in two required minimum actual areal boron densities in Technical Specification 4.1.1(a).

In support of the amendment, NAC submitted Revision 13A, Revision 13C, and 14C of the Final Safety Analysis Report (FSAR) for the MAGNASTOR® system. This amendment request is based on MAGNASTOR® FSAR Revision No. 4 and CoC Amendment No. 3.

The NRC staff reviewed the amendment request and supplements to the amendment request using guidance in NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," Rev. 1, dated July 2010. For the reasons stated below, and based on the statements and representations in the application, as supplemented, and the conditions specified in the CoC and technical specifications (TS), the staff concludes that the requested changes meet the requirements of 10 CFR Part 72.

The NRC staff determined that areas of the previous safety evaluation (ADAMS Accession No. ML120320247) that are not affected by this amendment include: structural, confinement, criticality, materials, operating procedures, acceptance test & maintenance, radiation protection, accident analyses, and quality assurance.

1.0 GENERAL DESCRIPTION

The modifications requested by NAC did not affect the system general description and have not altered the staff's previous system general description evaluation of the MAGNASTOR® cask system. Therefore, the staff did not reevaluate this area for this amendment request.

4.0 THERMAL EVALUATION

The applicant proposed to revise the time limits of helium backfill operation and canister transfer operation specified in LCO 3.1.1 of the Technical Specifications as shown in Table 1:

Table 1 – Pressurized-Water Reactor (PWR) Canister Transfer with Reduced Helium Backfill Time

Heat Load (kW)	Vacuum Time Limit (hours)	Minimum Helium Backfill Time (hours)	Maximum Canister Transfer Time (hours)
≤ 20	No limit	0	600*
≤ 25	50	7*	70.5*
≤ 30	19	7	8
≤ 35.5	15	7	8

* new limits proposed in MAGNASTOR® Amendment 4.

The applicant proposed to revise:
1) the canister transfer time limit from 8 to 600 hours when the heat load is less than or equal to 20 kW, and
2) the helium backfill time limit from 0 to 7 hours and the canister transfer time limit from 8 to 70.5 hours when the heat load is less than or equal to 25 kW.

The annulus cooling water system (ACWS) or the site-approved ACWS equivalent is active and operating during the vacuum drying phase and during the helium backfill phase, as described in the FSAR.

The applicant performed the analyses and documented the model and results in Calculation Package No. 71160-3020, Rev. 14 Appendix AA within the MAGNASTOR® Amendment No. 4 request.

<u>Vacuum Time Limit</u>

There is no change to the time limit for the vacuum drying phase in the amendment request.

<u>Helium Backfill Time Limit</u>

The applicant requested a change in the helium backfill time limit from 0 to 7 hours when the heat load is less than or equal to 25 kW. In analyzing this request for a change in helium backfill time, the applicant performed the transient simulations with a heat load of 25.0 kW and water in the annulus for 7 hours and for 10 hours after a 50-hour vacuum drying process. The applicant then calculated the peak cladding temperatures (PCTs) as shown in supporting Calculation Package No. 71160-3020 (Table 2).

Table 2 – Peak Cladding Temperature after Helium Backfill Operation

Case	Initial PCT (after 50-hour vacuum drying)	Final PCT (after helium backfill)
Helium Backfill (for 7 hours)	665 °F	615 °F
Helium Backfill (for 10 hours)	665 °F	565 °F

The applicant displayed the maximum fuel temperature, the maximum outer canister shell temperature, and the average helium temperature vs. time in Figures AA-3, AA-4, and AA-5 of Calculation Package No. 71160-3020 for the helium backfill operation. The staff reviewed Calculation Package No. 71160-3020 and concludes that the thermal impact is not significant when the helium backfill time is changed from 0 hour to 7 hours (with a PWR heat load ≤ 25.0 kW) because (a) the ACWS or its site-approved ACWS equivalent is operated to reduce the fuel clad temperature during that 7-hour period, and (b) the calculated maximum fuel clad temperatures are below the limit of 752 °F, as specified in the standard review plan NUREG-1536, Rev. 1 and Interim Staff Guidance (ISG) No. 11 (ISG-11).

Canister Transfer Time Limit

The applicant performed a steady state analysis, which had no additional cooling, and calculated a PCT of 653 °F for the ≤20 kW PWR heat load condition. Because the analysis demonstrates that the PCT is below the limit of 752 °F with a significant margin (~100 °F), the staff concludes that the additional cooling is not required for PWR heat loads ≤ 20 kW. Therefore, the staff finds the limit of 600 hours for canister transfer, when the heat load is ≤ 20 kW, acceptable.

For the ≤ 25 kW PWR heat load condition, the applicant simulated the canister transfer operations of 70.5 hours and 73 hours after the helium backfill operation. The applicant identified the time periods for the maximum PWR fuel clad temperature to reach 706 °F with 7 and 10 hour helium backfill as 70.5 and 73.0 hours, respectively (Table 3). The applicant's analysis concluded that the final PCT of 706 °F after helium backfill is below the limit of 752 °F, as specified in NUREG-1536, Rev. 1 and ISG-11. After a review of the applicant's analysis, the staff finds that revising the helium backfill time limit from 0 to 7 hours and the canister transfer time limit from 8 to 70.5 hours are acceptable when the heat load is less than or equal to 25 kW, as it is below the limit specified in NUREG-1536, Rev. 1.

Table 3 – Time Periods for PWR PCT to Reach 706 °F

Case	Initial PCT	Final Time	Final PCT (after helium backfill)
Canister transfer (after 7-hour helium backfill)	615 °F	70.5	706 °F
Canister transfer (after 10-hour helium backfill)	565 °F	73.0	706 °F

The staff reviewed the modeling methods, initial conditions, and boundary conditions described in Calculation Package No. 71160-3020 and determined the calculation to be acceptable. First, the staff determined that the mesh discretization used in the model is acceptable because it does not significantly change the results from the prior model for laminar flows inside the canister and in the annulus between the canister and transfer cask inner shell. Second, the staff determined that the flow resistance factor used by the applicant to model the 14x14 PWR fuel assembly as a porous media is acceptable after comparing to the thermal-hydraulic characterization measurements performed by Sandia National Laboratory (SNL). The applicant's analysis is also acceptable to the staff because the methodology used is the same as the one used in the original CoC No. 1031 that the staff had previously found to be acceptable. Finally, the staff has determined the applicant's analysis is acceptable because the results of the calculation performed in support of this amendment request remain below the limit of 752°F, as specified in NUREG-1536 and ISG-11. For these reasons, the staff concludes that the applicant's thermal analyses provide reasonable assurance the thermal requirements of 10 CFR Part 72 will be satisfied.

4.1 Evaluation Findings

F4.1 The staff concludes that the revised time limits of helium backfill and canister transfer, as shown in TS LCO 3.1.1 and Table 1 of this SER, are in compliance with 10 CFR Part 72. The evaluation of the thermal design provides reasonable assurance that the resulting first table of LCO 3.1.1 (Table 1 above) will allow safe storage of the spent fuel. The finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes, and accepted engineering practices.

5.0 SHIELDING EVALUATION

The objective of this review is to verify that the proposed amendment to the MAGNASTOR® design meets the requirements of 10 CFR 72.104 and 10 CFR 72.106 under normal, off-normal and accident conditions. The proposed change corrects discrepancies in Table B2-5, "Additional SNF Assembly Cool Time Required to Load NONFUEL HARDWARE," which contained non-conservative additional cooling times for fuel assemblies loaded with rod cluster control assemblies (RCCAs, also known as control element assemblies [CEAs]). In addition, the applicant requested Table B2-5 be expanded to cover the use of the three-zone preferential loading pattern with nonfuel hardware similar to the fuel assemblies.

The staff shielding review evaluated the proposed change in conjunction with the findings from previous staff analyses to determine they provide adequate protection from the radioactive contents within. This review looked at the methods and calculations employed by NAC to determine the expected gamma and neutron radiation at locations near the cask surface and at specific distances away from the cask.

5.1 Shielding Design Description

There is no change to the shielding design for the storage system.

5.2 Source Specification

The source term for the bounding Combustion Engineering PWR fuel (CE 16×16) is unchanged.

5.3 Shielding Model

No changes were made to the shielding design of the MAGNASTOR® dry storage system as a result of this amendment.

5.4 Shielding Evaluation

NAC proposed changes to the additional cooling times for RCCAs and some burnable poison absorber assemblies (BPAAs)/hafnium absorber assemblies (HFRAs). NAC utilized previously calculated quantities of activated metal in the control components to re-evaluate the minimum decay time to achieve the maximum decay heat in a fuel assembly containing control components. Results of these calculations are shown in the SAR in Tables 5.8.5-7 for BPAAs and 5.8.6-3 for RCCAs for uniform loading and Table 5.8.7-2 for three-zone preferential loading. According to these results, on the sides of the concrete and transfer casks, the additive dose rate does not affect the maximum dose rates. At the concrete cask inlets and transfer cask bottom, loading of RCCAs increases the maximum dose rates. The maximum decay heat produced by a loading of nine RCCAs is 0.17 kW. According to the applicant, however, an increase in the spent fuel assembly cool time, as shown in Table 5.8.6-3, provides the necessary margin to accommodate the increased dose rates at the concrete cask inlets and transfer cask bottom from loading RCCAs. The applicant stated that the strict application of increased cool time without a recalculation of fuel dose rates is conservative, since an increase in cool time will decrease the fuel source term.

As stated in the June 5, 2014, deficiency letter from NAC (ADAMS Accession No. ML14160A856), Table B2-5, "Additional SNF Assembly Cool Time Required to Load NONFUEL HARDWARE," contained non-conservative additional cooling times for fuel assemblies loaded with RCCAs. This was due to the added heat loads of nine RCCAs being distributed across the entire basket instead of just the nine fuel bundles in which the RCCAs were to be placed. As part of the review for this deficiency, the applicant also requested expansion of Table B2-5 to include additional cooling times for non-fuel hardware in each zone of the three-zone preferential loading pattern. The applicant made adjustments to the heat loads contained in Table B2-5 to correct the deficiency and expand for use in the preferential loading pattern resulting in a new Table B2-5 which is included in the proposed technical specifications. The proposed additional cooling times for fuel assemblies containing non-fuel hardware reduce the fuel assemblies decay heat to account for the decay heat from the non-fuel hardware and still maintain the decay heat in any individual cell below the decay heat limits in the technical specifications, whether for uniform loading or preferential loading.

5.4.1 Confirmatory Review and Analysis

The staff reviewed the applicant's shielding analysis and found it acceptable because the maximum dose rates continue to meet the limits defined by 10 CFR Part 72 and the decay heat from fuel assemblies containing non-fuel hardware will meet the decay heat limits in the technical specifications for each individual basket cell. The staff reviewed the radiation shielding evaluations, including the calculations of the sources, and the dose rates for the transfer cask and the concrete casks. The staff also performed confirmatory analyses of the dose rates for the transfer and storage casks. The applicant has demonstrated and the staff concurs that the MAGNASTOR® dry cask storage system meets the radiation protection requirements of 10 CFR 72.104, 72.126, and 72.128.

5.5 Evaluation Findings

Based on the NRC staff's review of information provided for the MAGNASTOR® application, the staff finds the following:

F5.1 Chapter 5 of the MAGNASTOR® SAR describes shielding structures, systems, and components important to safety in sufficient detail to allow evaluation of their effectiveness.

F5.2 Chapter 5 of the MAGNASTOR® SAR provides reasonable assurance that the radiation shielding features are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F5.3 Operational restrictions to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106 are the responsibility of the general licensee. The MAGNASTOR® shielding features are designed to assist in meeting these requirements.

Based upon its review, the staff has reasonable assurance that the design of the shielding system for the MAGNASTOR® system, including the concrete cask, the transfer cask, and the canister, 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 MAGNASTOR® system will provide safe storage of spent fuel in accordance with 10 CFR 72.236(d). 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.

13.0 TECHNICAL SPECIFICATIONS AND OPERATING CONTROLS AND LIMITS EVALUATION

The applicant requested technical specification changes to:

- the minimum helium backfill time and maximum canister transfer time,
- corrections to discrepancies in Table B2-5, "Additional SNF Assembly Cool Time Required to Load NONFUEL HARDWARE," for non-conservative additional cooling times for fuel assemblies loaded with RCCAs, expansion of Table B2-5 for the three-zone preferential loading pattern with nonfuel hardware similar to the fuel assemblies, and
- an editorial change in Appendix A of the technical specifications to revise the minimum required ^{10}B actual areal density from 0.334 g/cm^2 to 0.0334 g/cm^2 for both borated aluminum alloy and borated metal matrix composite (MMC) for PWR fuel baskets.

13.1 Operating Controls and Limits Evaluation

Changes to Technical Specifications, Appendix A, of MAGNASTOR FSAR, Revision 13A, as supplemented by Revision 13C, are listed below and were evaluated in Chapter 4 of this SER.

Technical Specifications, Appendix A: Proposed Changes:

PWR TSC Transfer with Reduced Helium Backfill Time

Heat Load (kW)	Maximum Vacuum Time Limit (hours)	Minimum Helium Backfill Time (hours)	Maximum TSC Transfer Time (hours)
≤ 20	No limit	0	600
≤ 25	50	7	70.5
≤ 30	19	7	8
≤ 35.5	15	7	8

13.2 Fuel Specification changes

The applicant also requested revision of the values in Technical Specification Appendix B, Table B2-5 in for additional cooling time for fuel assemblies containing non-fuel hardware. The proposed revisions corrected errors in the uniform loading decay heat load for non-and expansion and was expanded to include additional cooling times for non-fuel hardware in the three-zone preferential loading pattern.

Table B2-5 has been revised to include the following table:

Assy		Uniform	Three-Zone A	B	C
CE 14x14	BPRA/HFRA	--	--	--	--
	GTPD/NSA	--	--	--	--
	RCC	0.2	0.2	0.1	0.2
WE 14x14	BPRA/HFRA	0.5	0.5	0.2	0.7
	GTPD/NSA	0.1	0.1	0.1	0.1
	RCC	2.0	2.3	0.7	4.1
WE 15x15	BPRA/HFRA	0.5	0.6	0.2	0.8
	GTPD/NSA	0.1	0.1	0.1	0.1
	RCC	3.1	3.4	1.5	4.5
B&W 15x15	BPRA/HFRA	0.1	0.1	0.1	0.1
	GTPD/NSA	0.1	0.1	0.1	0.1
	RCC	0.2	0.2	0.1	0.2
CE 16x16	BPRA/HFRA	--	--	--	--
	GTPD/NSA	--	--	--	--
	RCC	0.2	0.2	0.1	0.3
WE 17x17	BPRA/HFRA	0.5	0.6	0.2	0.7
	GTPD/NSA	0.1	0.1	0.1	0.1
	RCC	2.9	3.3	1.4	4.3
B&W 17x17	BPRA/HFRA	0.1	0.1	0.1	0.1
	GTPD/NSA	0.1	0.1	0.1	0.1
	RCC	0.2	0.2	0.1	0.2

13.3 Minimum ^{10}B loading in the neutron absorber material

By application dated March 22, 2010 (ADAMS Accession No. ML112630346), as supplemented March 30 (ADAMS Accession No. ML112630345), March 31 (ADAMS Accession No. ML100950172), June 8 (ADAMS Accession No. ML101610085), July 1 (ADAMS Accession No. ML102880325), November 10 (ADAMS Accession No. ML103190427), and November 19, 2010 (ADAMS Accession No. ML103260461), April 22 (ADAMS Accession No. ML11115A146), and May 17, 2011 (ADAMS Accession No. ML11143A101), NAC requested several changes to CoC

No. 1031, one of which is the addition of various ^{10}B areal densities for use with PWR and BWR baskets.

In its application dated March 22, 2010, NAC performed a criticality analysis for PWR baskets and took 90% credit for the ^{10}B in the borated aluminum alloy and borated MMC plates. The effective ^{10}B density (90% of actual ^{10}B density) that was used in the criticality evaluation was 0.036 g/cm^2, 0.030 g/cm^2, and 0.027 g/cm^2 to ensure criticality safety. Table 13-1 (Table 6.1.1-5 in NAC's application) translated the effective areal density of neutron absorber content to actual required areal density using 90% credit.

Table 13-1: Effective Areal Density as a Function of Absorber Credit

	Effective ^{10}B g/cm^2	75% Credit ^{10}B g/cm^2	90% Credit ^{10}B g/cm^2
PWR	0.036	0.048	0.040
	0.030	0.040	0.0334
	0.027	0.036	0.03
BWR	0.027	0.036	0.030
	0.0225	0.030	0.025
	0.020	0.0267	0.0223

Since the NAC criticality evaluation and the NRC staff's safety evaluation report (ADAMS Accession No. ML120320247) both indicate that the effective areal density used was 0.030 ^{10}B g/cm^2, the NRC staff concludes that the value stipulated in LCO 4.1.1(a) of 0.334 ^{10}B g/cm^2 is a typographical error and should be 0.0334 ^{10}B g/cm^2.

13.2 Evaluation Findings

F13.1 The staff concludes that the conditions for use for the MAGNASTOR® storage system identify necessary technical specifications to satisfy 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The proposed technical specifications provide reasonable assurance that the DSS will allow safe storage of SNF. This finding is based on the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

15.0 CONCLUSION

The staff performed a detailed safety evaluation of the application for Amendment No. 4 to CoC No. 1031 for the MAGNASTOR® storage system. The staff performed the review in accordance with the guidance in NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," Rev. 1, dated July 2010. Based on the statements and representations contained in the application, as supplemented, and the conditions established in the CoC and its Appendices (Technical Specifications), the staff concludes that these changes do not affect the ability of the MAGNASTOR® System to meet the requirements of 10 CFR Part 72.

Issued with CoC No. 1031, Amendment No. 4, on April 13, 2015.