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GNRO2024-00033 10 CFR 50.90

November 25, 2024

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: Application to Revise Technical Specifications; Criticality Safety Analysis, Technical Specification 4.3.1, Criticality and Technical Specification 5.5.15, Spent Fuel Storage Rack Neutron Absorber Monitoring Program

Grand Gulf Nuclear Station, Unit 1
Docket No. 50-416
License No. NPF-29

In accordance with the provisions of 10 CFR 50.59 and 10 CFR 50.90, Entergy Operations, Inc. (Entergy) is requesting an amendment to Grand Gulf Nuclear Station, Unit 1 (GGNS) Technical Specifications (TS). The proposed amendment includes, 1) a revision to the criticality safety analysis for the spent fuel storage racks, 2) addition of requirements for the analysis for the fuel pool storage racks as contained in TS 4.3, Fuel Storage; Subpart 4.3.1, Criticality, and 3) the addition of requirements for monitoring of the neutron absorber material in the storage racks in TS 5.5, Programs and Manuals, new Subpart 5.5.15, Spent Fuel Storage Rack Neutron Absorber Monitoring Program.

This amendment is requested to change the neutron absorbing material to be credited for the purpose of criticality control in the spent fuel pool and upper containment pool.

Enclosure 1 includes a description of the change, no significant hazards consideration determination, and evaluation of environmental impact. Attachments to the enclosure include: Attachment 1, a copy of the marked-up TS pages and Attachment 2, a copy of the clean TS pages. Attachment 3 provides the Non-Proprietary version of the Global Nuclear Fuels (GNF) – Americas Report NEDO-34125, Grand Gulf Nuclear Station: Fuel Storage Critically Analysis with Rack Inserts. Attachment 4, provides the NEI 12-16 Criticality Analysis Checklist. Attachment 5 & 6, provides the GNF – Americas and Curtiss-Wright Nuclear Division (CWND) Proprietary Information Affidavits of these companies, respectively. Attachment 7 is Proprietary in its entirety, as it contains information that is proprietary to GNF and CWND.

Accordingly, it is respectfully requested that the information proprietary to GNF and CWND be withheld from public disclosure in accordance with 10 CFR 2.390.

The proposed change has been evaluated in accordance with 10 CFR 50.91(a)(1) using the criteria in 10 CFR 50.92(c) and it has been determined that the proposed change involves no significant hazards consideration.

Entergy requests review and approval of this license amendment request (LAR) to implement the proposed amendment to the TS by May 20, 2026. Once insert installation and LAR review and approval are complete, whichever date is later, the amendment will be implemented within 120 days.

This letter and its enclosure do not contain any new commitments.

Should you have any questions or require additional information, please contact me at (601) 368-5102.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on November 25, 2024.

Respectfully,

Philip Couture

Digitally signed by Philip Couture
DN: cn=Philip Couture, c=US, o=Entergy, ou=Regulatory Assurance, email=pcoutur@entergy.com
Date: 2024.11.25 07:49:07 -06'00'

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Enclosure 1: Evaluation of the Proposed Changes

Attachments to the Enclosure:

1. Technical Specification Pages – Marked-up
2. Technical Specification Pages – Clean
3. Global Nuclear Fuels Report NEDO-34125, Rev. 0, Dated July 2024, Grand Gulf Nuclear Station: Fuel Storage Critically Analysis with Rack Inserts (Non-Proprietary version)
4. NEI 12-16 Appendix C: Criticality Analysis Checklist
5. Global Nuclear Fuels – Americas Proprietary Information Affidavits
6. Curtiss-Wright Nuclear Division Proprietary Information Affidavits
7. Global Nuclear Fuels Report NEDC-34125P, Grand Gulf Nuclear Station: Fuel Storage Critically Analysis with Rack Inserts (Proprietary Version)

cc: NRC Region IV Regional Administrator
NRC Senior Resident Inspector – Grand Gulf Nuclear Station
NRC Project Manager – Grand Gulf Nuclear Station
State Health Officer, Mississippi Department of Health

Enclosure 1
GNRO2024-00033

Evaluation of Proposed Changes
(26 pages below)

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1. SUMMARY DESCRIPTION

In accordance with 10 CFR 50.90, Entergy Operations, Inc, (Entergy) requests an amendment to Facility Operating License No. NPF-29 for Grand Gulf Nuclear Station – Unit 1 (GGNS). The proposed change allows the crediting of NETCO-SNAP-IN® neutron absorbing rack inserts in the criticality safety analysis (CSA) for the storage rack cells in the station's fuel building spent fuel storage facility; i.e., the spent fuel pool (SFP) and upper containment pool (UPC). This change is being requested due to the degradation of the Boraflex neutron absorbing material in the GGNS SFP. The change seeks approval of the aforementioned CSA. The change also seeks approval of changes to Technical Specifications (TS) concerning criticality design features of the spent fuel storage racks (TS 4.3.1.1), to specifically identify the neutron absorbing inserts, remove requirements for Region II storage racks, and to update the value of k-infinity used in the CSA, consistent with Standard Technical Specifications. Finally, the change seeks approval to add a program requirement that implements a monitoring program for the neutron absorbing rack inserts. The addition of this program requirement establishes consistency with Standardized Technical Specification improvement initiatives.

2. DETAILED DESCRIPTION

2.1. System Design and Operation

GGNS Updated Final Safety Analysis Report (UFSAR) Section 9.1.2 documents the GGNS spent fuel storage safety design bases as summarized below.

- Nuclear – The fuel array in the fully loaded spent fuel racks is designed to be subcritical by at least 5 percent Δk. Geometrically safe configurations of fuel stored in the spent fuel array are employed to assure the K_{eff} does not exceed 0.95 under all normal and abnormal storage conditions.
- Structural – The Unit 1 spent fuel storage racks in the auxiliary building and containment are designed to withstand all credible static and dynamic loadings to prevent damage to the structure of the racks, and therefore the contained fuel, and to minimize distortion of the racks arrangement. The spent fuel storage racks are categorized as safety Class 2 and seismic Category I.

The GGNS SFP contains 16 high density fuel rack modules in 5 different module sizes. The module types are labeled A, B, C, D and H on UFSAR Figure 9.1-40a, which also shows their relative placement. The storage rack cells with a center-to-center spacing of 6.26 inches (nominal). There are a total of 4348 fuel storage locations within the spent fuel pool. With current physical, load, and criticality restrictions only 3919 fuel storage locations are available in the spent fuel pool. Currently, in the Spent Fuel Pool, all assemblies are complete with no missing rods, spacers, or other parts. There is a failed fuel basket with 3 rods removed during reconstitution located in the H1 equipment rack. The assemblies which donated these rods had new rods installed.

The upper containment pool contains 7 high density fuel rack modules in 3 different module sizes. The module types are labeled E, F and G on UFSAR Figure 9.1-40a, which also shows their relative placement. There are a total of 710 fuel storage locations in the upper containment pool. With current physical and load restrictions only 584 fuel storage locations are available in the upper containment pool.

The spent fuel storage racks consist of individual cells with a 6-inch-square cross section, each of which accommodates a single BWR fuel assembly. The cell walls consist of a neutron absorber (Boraflex) sandwiched between sheets of stainless steel. Criticality in new and spent fuel storage is prevented by the geometrically safe configuration of the storage rack combined with the use of neutron absorber (Boraflex) material in the high-density storage racks. There is either sufficient spacing or neutron poison material between the assemblies to assure that the array, when fully loaded, is substantially subcritical. Fuel elements are limited by rack design to only being top loaded into a fuel storage rack and typical fuel assembly orientation (oriented vertically).

In order to accommodate known and possible future Boraflex degradation and maintain K_{eff} criterion of less than or equal to 0.95, the GGNS fuel pool racks are allocated into Region I and Region II locations. The Region I rack locations are those locations which are above the Boraflex panel areal density limit and below the dose threshold for accelerated gapping and are bounded by the EPRI model for shrinkage. The Region II rack locations are those locations which are below the Boraflex panel areal density limit or at or above the dose threshold for accelerated gapping and no credit is taken for the Boraflex panels in the criticality analysis in these locations.

Each GGNS storage rack unit employs Boraflex as a fixed neutron absorber for criticality control, to ensure that the effective neutron multiplication factor (K_{eff}) does not exceed the values and assumptions used in the CSA. This analysis is the basis, in part, for demonstrating compliance with plant TS requirements and U.S. Nuclear Regulatory Commission (NRC) regulations. The CSA methodology and inputs reflect the requirements of 10 CFR 50.68, 10 CFR 50 Appendix A General Design Criterion 62, NUREG-0800 Section 9.1.2 Rev. 3 dated July 1981, Generic Letter 78-11, and ANSI N210-1976. Information regarding the Boraflex and the method of its integration into the GGNS storage racks was provided in the station's response to Generic Letter 2016-01 (Reference 1)

2.2. Current Technical Specifications Requirements

The GGNS TS requirements affected by this proposed change are TS Section 4.3.1 "Criticality" and TS Section 5.5, "Programs and Manuals".

- TS 4.3.1.1.a and 4.3.1.1.b identify requirements pertaining to the design of the spent fuel storage racks. Specifically, TS 4.3.1.1.a requires $K_{eff} \leq 0.95$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1.2 of the UFSAR. TS 4.3.1.1.b requires a nominal fuel assembly center to center storage spacing of 6.26 inches in the storage racks.

- TS 4.3.1.1.e requires that Region II racks to be controlled as follows:
  - Storage cells with any Boraflex panel which has received a gamma dose in excess of 2.3E10 rads or which has a Boron-10 areal density less than 0.0165, which are designated within the Spent Fuel Pool Rack Boraflex Monitoring Program, are treated as Region II panels.
  - Storage cells face-adjacent to Region II panels are either restricted from fuel storage by physically blocking the isolated cells or are configured to meet, as a minimum (i.e., additional cells may be blocked), the Region II fuel storage configuration requirements.
  - When a 4x4 array of cell is classified as Region II and face-adjacent to another Region II 4x4 storage array, the new Region II 4x4 array is required to be blocked in the same 8-of-16 pattern and at the same orientation as the adjacent Region II 4x4 storage configuration.
- TS Section 5.5, “Programs and Manuals,” does not contain requirements for a monitoring program for the neutron absorber used in the spent fuel storage racks.

2.3. Reason for the Proposed Change

Entergy plans to install NETCO-SNAP-IN® rack inserts in the GGNS SFP and UCP storage racks in accordance with the provisions of 10 CFR 50.59. This provides an alternative method of neutron absorption to meet the maximum K_{eff} criticality control requirement without reliance on Boraflex, because the Boraflex has experienced degradation of its neutron absorbing capability as discussed in Reference 1. Entergy is requesting this license amendment to obtain approval for a new CSA that credits the use of the NETCO-SNAP-IN® inserts and does not credit Boraflex. The new CSA methodology and inputs reflect the requirements and guidance of 10 CFR 50.68, 10 CFR 50 Appendix A General Design Criterion 62, NUREG-0800, Section 9.1.1 Rev 3 dated March 2007, Nuclear Energy Institute (NEI) 12-16 (Reference 2) and Nuclear Regulatory Commission (NRC) Interim Staff Guidance DSS-ISG-2010-01 (Reference 3).

With the crediting of the neutron absorbing rack inserts for criticality control, it is necessary to change GGNS TS 4.3.1.1 to specifically identify as design features for spent fuel storage the neutron absorbing inserts and fuel-related parameters used in the CSA, as well as remove the need for Region II racks. The proposed change to Section 4.3.1.1 will make the GGNS TS consistent with the “Standard Technical Specifications for General Electric BWR/6 Plants,” NUREG-1434, Rev 5 (Reference 4).

Finally, with the crediting of the neutron absorbing rack inserts for criticality control of the SFP, Entergy plans to implement a monitoring program consistent with NEI 16-03-A, “Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,” Rev 0 (ADAMS ML17263A133) (Reference 5). NEI 16-03-A describes acceptable methods that may be used to monitor fixed neutron absorbers in SFPs to ensure that aging effects, corrosion, and other degradation mechanisms are identified and evaluated prior to loss of the required safety function. Since the GGNS TS do not currently contain any requirements regarding the monitoring of fixed neutron absorbers in its SFP, with the addition of the NETCO-SNAP-IN® rack inserts into the SFP storage racks, Entergy seeks to establish a standardized TS program requirement that implements the aforementioned monitoring program. The proposed change is consistent with Technical Specifications Task Force (TSTF) traveler TSTF-557, "Spent Fuel Storage Rack Neutron Absorber Monitoring Program," Rev 1 (ADAMS Accession ML17353A608) (Reference 6).

In Reference 13, Entergy submitted an application for renewal of the operating license for GGNS for an additional 20 years beyond the current expiration date (NRC Safety Evaluation Report is documented in Reference 14). The license renewal application (LRA) credited the Boraflex Monitoring Program, described in Section B.1.4, for managing aging of Boraflex during the period of extended operation. The Boraflex Monitoring Program will be replaced by a Neutron Absorbing Material Monitoring Program, consistent with the program described in NUREG-1801 (Reference 15), Section XI.M40, "Monitoring of Neutron-Absorbing Materials Other than Boraflex," and will follow the industry guidance in NEI 16-03-A (Reference 5) and the neutron absorbing material will be replaced so that the Boraflex material in the spent fuel pool will not be required to perform a neutron absorption function during the period of extended operation.

The proposed change does not apply to the new fuel storage racks. These storage racks do not contain any neutron absorbing material for criticality control and will not have the new NETCO-SNAP-IN® rack inserts.

2.4. Description of the Proposed Change

The proposed change consists of the following elements:

- A new CSA for the GGNS SFP and UCP storage racks that credits the NETCO-SNAP-IN® rack inserts for criticality control and does not credit Boraflex;
- A revision of TS 4.3.1.1.b to specifically identify the neutron absorber inserts as design features of the spent fuel storage racks;
- A revision of TS 4.3.1.1.c to specifically identify the updated fuel parameter (maximum k-infinity) used in the CSA crediting the NETCO-SNAP-IN® rack inserts as design features of the spent fuel storage racks;
- The deletion of TS 4.3.1.1.e in its entirety to remove Region II as a design feature of the spent fuel storage racks;
- The addition of a new TS 5.5.15 to TS Section 5.5, "Programs and Manuals," to incorporate a program into the TS to monitor the condition of the neutron absorber inserts used in the SFP and UCP storage racks to ensure they will continue to perform their design function.

The addition of TS 5.5.15 is consistent with TSTF-557, Rev. 1 (Reference 6).

A markup of the proposed TS changes is provided in Attachment 1. The clean TS pages, incorporating these changes, are provided in Attachment 2. The UFSAR will also be revised, upon implementation of the approved amendment, as part of Entergy's configuration control process.

3. TECHNICAL EVALUATION

3.1. Overview

The following discussion will show that NETCO-SNAP-IN® rack inserts are a safe and effective replacement for Boraflex to ensure continued compliance with TS requirements. The proposed change will credit NETCO-SNAP-IN® rack inserts for criticality control in individual SFP and UCP storage rack cells to ensure that the requirements of TS 4.3.1, "Criticality," are maintained; specifically, "The spent fuel storage racks are designed and shall be maintained with $K_{eff} \leq 0.95$ if fully flooded with unborated water…" The proposed change also includes changes to TS regarding design features and monitoring program requirements which are related to the analysis which credits these inserts.

The installation of the NETCO-SNAP-IN® rack inserts is being controlled as a design change implemented under the provisions of 10 CFR 50.59 from a structural, seismic, and thermal-hydraulic perspective. As such, Entergy is not seeking NRC review and approval for installation of the inserts, only review and approval of the new CSA for crediting the inserts for criticality control in the GGNS SFP and UCP. Therefore, Sections 3.1.1 through 3.1.3, Sections 3.3 through 3.7, and Section 3.8.2 are provided for information only.

Entergy will not credit the neutron absorbing capability of the inserts for criticality control under the new methodology until and unless this proposed change is approved. The Boraflex material is contained within the GGNS spent fuel storage racks as part of their original fabrication and will remain in place and not be altered by installation of the NETCO-SNAP-IN® rack inserts. The rack inserts installation began in the Fall of 2023 and is projected to be completed during the Summer of 2027.

3.1.1 Boraflex Degradation

Boraflex is used in the GGNS SFP and UCP as a neutron-absorbing material and is credited in the CSA analysis of record (AOR) for the spent fuel storage racks. The condition of the Boraflex and the monitoring program used to measure changes in the material was documented in the station's response to Generic Letter 2016-01 (Reference 1). Consistent with the concern expressed in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks," the GGN monitoring program has identified degradation in the material, with an estimated areal density of 0.0184 g/cm^2 in the peak Region I panel at the time the Generic Letter response was submitted. While this is below the minimum certified Boraflex sheet areal density of 0.0190 g/cm^2

specified by Joseph Oats Corporation, the GGNS storage rack vendor, it remains above the credited areal density of 0.0133 g/cm^2.

The Region II rack locations are those locations which are below the Boraflex panel areal density limit or at or above the dose threshold for accelerated gapping and no credit is taken for the Boraflex panels in the criticality analysis in these locations. Region II storage locations are grouped in a minimum 4x4 arrays which shall have selected storage locations physically and administratively blocked in a “8 of 16 blocked” configuration.

3.1.2 NETCO-SNAP-IN® Rack Inserts Design Description

This proposed change credits NETCO-SNAP-IN® rack inserts for criticality control in SFP and UCP storage rack cells to ensure that the requirements of TS 4.3.1, “Criticality,” are maintained; specifically, “The spent fuel storage racks are designed and shall be maintained with $K_{eff} \leq 0.95$ if fully flooded with unborated water…”

The GGNS NETCO-SNAP-IN® rack inserts will be fabricated from a homogeneous aluminum boron-carbide metal matrix material called BORALCAN® (formerly called ALCAN), supplied by Rio Tinto Alcan. The NRC has approved this material for use in spent fuel racks at LaSalle County Station (LSCS), Peach Bottom Atomic Power Station, Units 2 & 3 (PBAPS), Quad Cities Nuclear Power Stations, Units 1 & 2 (QCNPS), River Bend Station (RBS), and Enrico Fermi Nuclear Power Plant, Unit 2 (References 7-11). The NETCO-SNAP-IN® rack inserts design that will be used at GGNS has been employed in the installation and successful operation of a combined total of over 24,000 NETCO-SNAP-IN® inserts at these stations.

While the basic design of the GGNS inserts, and the material used in them, is the same as that used at LSCS, QCNPS, PBAPS, RBS, and Fermi, the GGNS inserts are fabricated from material with a B_4C neutron absorber content of 23% by volume. The dimensions of the GGNS inserts are also slightly different because they are designed to fit into the GGNS SFP and UCP storage racks, as determined by the performance of confirmatory dimensional sizing measurements in the GGNS racks using non-borated test inserts of different wing widths and bend angles (see Section 3.4.3). A comparison of the insert dimensions and properties is provided in Section 3.3.3.

The NETCO-SNAP-IN® rack insert is designed to become an integral part of the rack upon installation, and does not require any modification to the spent fuel storage rack. The rack inserts slide into the rack and stay in place via friction with enough clearance still available for movement of fuel assemblies into and out of the storage cells. The insert is nominally the same length as a storage rack cell (approximately 169 inches), thereby spanning the full length of the active fuel region of the fuel assembly when installed. Each GGNS insert is formed with a slightly greater than 90-degree bend angle, so that it is L-shaped (chevron shaped). This requires compression of the rack insert to install it into the spent fuel storage rack cell. After installation, the insert will conform to the 90-degree angle between adjacent spent fuel storage rack cell walls. When installed, the insert sides (or “wings”) abut against the two adjacent faces of the spent fuel storage rack cell wall. The force exerted due to this deformation is determined by the material properties of the insert. The force between the wings of the insert and the spent fuel storage rack cell walls in conjunction with the static friction between these surfaces serves to retain the NETCO-SNAP-IN® insert within the cell during normal fuel movement activities and under seismic events.

Entergy plans to install a NETCO-SNAP-IN® insert with the same orientation in every usable (due to travel limitations of the fuel bridge and refueling bridge, certain periphery spent fuel storage rack cells are physically prevented from receiving a fuel bundle) spent fuel storage location within the GGNS SFP and UCP. Also, the H1 rack (SFP) and the J1 rack (UCP) are not receiving inserts. These racks are intended to store control rod blades, control rod guide tube, and/or defective fuel containers, and therefore, are not part of the normal fuel storage cell locations, and are prohibited by station procedure for use as fuel storage locations. Installation of a NETCO-SNAP-IN® insert in every usable storage location and with the same orientation ensures that neutron absorption and criticality control by the rack inserts is uniform across the SFP and UCP. A criticality analysis crediting the NETCO-SNAP-IN® inserts has been performed for the GGNS SFP and UCP to support this design change. This analysis is discussed in Section 3.2.

The NETCO-SNAP-IN® inserts designed for GGNS spent fuel storage racks are fabricated with the top (approximately 4 inches by 1 inch) of the insert bent edges removed or “coped”, to reduce any potential interference between an insert and a fuel channel spacer. The required NETCO-SNAP-IN® insert orientation during installation, insert coping, and the administratively required fuel bundle orientation, reduce the potential for fuel bundle / insert interference.

3.1.3 Demonstration of Proposed Method for Rack Insert Installation

To verify the mechanical compatibility of the NETCO-SNAP-IN® insert with the GGNS SFP and UCP storage racks and compatibility of the fuel stored therein, an insert demonstration program (i.e., the prototype installation and testing program) was performed at GGNS in October 2023. The mechanical feasibility of using NETCO-SNAP-IN® inserts at GGNS was verified by installing fifty-four (54) prototype inserts into randomly selected storage cells within the SFP and by installing two (2) prototype inserts into randomly selected storage cells within the UCP. After installation, retention load testing was performed on all fifty-six (56) of the prototype inserts using the insert removal tool. Additionally, 29 of the SFP storage cells and 2 of the UCP storage cells, containing prototype inserts, were tested using a dummy fuel assembly, which has a cross-sectional dimension of a channeled fuel assembly, to verify adequate dimensional clearances between the insert and a fuel assembly during fuel handling. The NETCO-SNAP-IN® rack inserts used in the GGNS prototype program were designed, fabricated, tested, and inspected under the NETCO quality assurance program to ensure they meet the design requirements for permanent inserts. In summary, the key insert parameters validated during the demonstration program were: 1) insertion installation success; 2) lack of fuel interference; and 3) retention force (i.e. greater than 150 lbf). These parameters are discussed in further detail below in Section 3.4.3, "Insertion / Retention Forces and Fuel Assembly Clearance."

3.2. Criticality

3.2.1 Criticality Evaluation for NETCO-SNAP-IN® Rack Inserts in GGNS SFP

In accordance with the requirements of 10 CFR 50.68, a CSA was performed to support the storage of spent fuel in the GGNS SFP and UCP with credit for the NETCO-SNAP-IN® rack inserts installed. All necessary requirements as outlined in NUREG-0800, Section 9.1.1 Rev 3 March 2007, have been met. Nuclear Energy Institute's (NEI) NEI 12-16, Rev 4 (Reference 2) was used as a guidance document for this analysis. The analysis, described in Attachment 7, demonstrates that the maximum K_{eff} (k_{max}(95/95)) is substantially less than the 10 CFR 50.68 limit of 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account. The analysis assumptions included:

- Uniform pool storage configuration with all usable fuel storage locations loaded with a NETCO-SNAP-IN® insert in the same orientation and a fuel bundle with the highest rack efficiency;
- A NETCO-SNAP-IN® insert Boron-10 (B-10) areal density of 0.0139 g B^{10}/cm^2 (which is less than the minimum certified areal density of 0.0141 g B^{10}/cm^2) to account for potential manufacturing uncertainties;
- No credit for neutron absorption by the Boraflex material installed between the SFP storage rack cells, which has been modeled as water; and,
- The SFP fully flooded with unborated water.

The CSA covers all legacy fuel in storage at GGNS and the current fuel product line in use at GGNS, GNF3. The description of these product lines is provided in Section 4.0 of Attachment 7, while the disposition for all legacy fuel is provided in Appendix B of Attachment 7.

The reactivity of the GGNS SFP storage rack containing NETCO-SNAP-IN® inserts was calculated using the computer codes TGBLA06 and MCNP-05P. In this evaluation, in-core k_∞ and exposure dependent, pin-by-pin isotopic specifications were generated using TGBLA06, the NRC-approved Global Nuclear Fuel (GNF) BWR lattice physics code. The fuel storage criticality calculations were then perform using MCNP-05P, the GNF proprietary version of the Las Alamos National Laboratory Monte Carlo neutron transport code MCNP5. TGBLA06 uses ENDF/B-V cross-section data to perform coarse-mesh, broad-group, diffusion theory calculations. MCNP-05P used ENDF/B-VII.0 point-wise (i.e continuous) cross-section data, and all reactions in the cross-section evaluation are considered. MCNP-05P has been validated and verified for spent fuel pool storage rack evaluations in accordance with the NUREG/CR-6698 guidance (included as part of Attachment 7). The Method of Analysis is discussed in greater detail in Section 3.0 of Attachment 7. Validation of the codes and libraries is described in Section 3.4 and Appendix A of Attachment 7.

The use of TGBLA06 (Reference 16) for BWR core depletion calculations has been reviewed and accepted by the NRC as part of the approval of Reference 17. The NRC has also approved the MCNP/TGBLA06 code package for use in similar fuel pool criticality analyses, as documented in Reference 18. Finally, the NRC has approved use of these codes in the criticality analysis for previous applications of the NETCO-SNAP-IN® inserts in the PBAPS spent fuel pools, as documented in Reference 8. For the analysis of the GGNS SFP, TGBLA06 was used in the manner allowed by the NRC approvals (Reference 16, 17, 18). In addition to the request for approval of Attachment 7, which credits the NETCO-SNAP-IN® inserts for criticality control in the GGNS SFP, there are two other related elements of the proposed change:

- A maximum cold, uncontrolled peak in-core k-infinity of 1.29 was set as the limit for the analysis. In the proposed TS 4.3.1.1.c, this value is incorporated into the GGNS Design Features section on spent fuel storage criticality, consistent with Reference 4.
- In the proposed TS 4.3.1.1.b, the description of the neutron absorber inserts within the spent fuel storage racks is incorporated into the GGNS Design Features section on spent fuel storage criticality, consistent with Reference 4.

3.2.2 NEI 12-16

NEI 12-16 (Reference 2) was used as the guidance documents for this analysis. Guidance pertaining to soluble boron in the SFP is not applicable because GGNS is a BWR plant and has no soluble boron in the SFP. Attachment 4 includes the Criticality Analysis Checklist from NEI 12-16 to identify the areas of the analysis that conform or do not conform to the guidance in NEI 12-16.

3.3. Materials

The NETCO-SNAP-IN® Rio Tinto Alcan composite rack inserts must ensure that the neutron absorber remains in place over the lifetime of the SFP and UCP storage racks during normal operation and abnormal events. Reference 12 provides a detailed evaluation of the Rio Tinto Alcan composite material. This report demonstrates that the material is suitable as a neutron absorber to maintain the SFP and UCP within design and regulatory limits over the life of the SFP and UCP storage racks. Qualification testing has been performed to confirm its acceptability and the monitoring program discussed in Section 3.9 will confirm its continued acceptability to perform its required design function in the GGNS SFP and UCP.

The production process for manufacturing the rack inserts is described in detail in Reference 12. The technique developed by Rio Tinto Alcan to produce the aluminum/boron carbide metal matrix composite results in a homogeneous distribution of the B_4C in a rolled sheet, which is trimmed to produce rack insert blanks. Insert flats are then cut from the blanks and bent on a press brake to an angle somewhat larger than 90° to provide the chevron shaped insert and the long edges of the insert are roll formed to establish the winglets. Additionally, test coupons are cut from each of the blanks and used to confirm acceptable minimum areal density and material properties.

3.3.1 Insert Boron-10 (B-10) Areal Density

The insert manufacturing quality assurance testing lower limit for the areal density of boron in the Rio Tinto Alcan composite is given in terms of B-10, and is 0.0141 g B^{10} /$cm^2$for GGNS. Verification of the minimum certified areal density of B-10 in the rack inserts (i.e., pre-characterization) is performed for 100 percent of the material used for the inserts. Each blank (from which the insert flats are cut) will have a traceable test coupon removed and subjected to neutron attenuation testing.

For each coupon, a specific areal density value is obtained, to which a 3-sigma (99.7%) uncertainty is applied, to confirm that the measured areal density exceeds the minimum certified areal density before the corresponding inserts are accepted. Given 100 percent sampling and the 3-sigma uncertainty applied to the measurement, GGNS is assured that none of the inserts have an areal density below the minimum certified value. The CSA, discussed in Section 3.2.1, assumes an insert B-10 areal density of 0.0139 g B^{10} /cm^2, which is significantly less than the minimum certified areal density of 0.0141 g B^{10} /cm^2.

Reference 12, Section 3.4 (Table 3.1), refers to a B-10 areal density limit of 0.0087 g B^{10} /$cm^2$for the quality assurance test program. This value is for the NETCO-SNAP-IN® rack inserts manufactured for LSCS. All of the NETCO-SNAP-IN® rack inserts manufactured for a particular user have the same minimum certified B-10 areal density, but that value may be different user-to-user. The 0.0087 g B^{10} /cm^2 is an example value used in the NETCO material qualification report and is not the minimum certified B-10 areal density in all NETCO-SNAP-IN® rack inserts for all customers. The B-10 areal density in the inserts for a given plant is customized for each user's needs based on the criticality analysis and rack design. Each user specifies the minimum certified B-10 areal density for their plant's inserts in the procurement specification. For GGNS, the minimum certified manufactured B-10 areal density is 0.0141 g B^{10} /cm^2. Verification of the areal density of B-10 over the lifetime of the racks will be performed through the rack insert monitoring program discussed in Section 3.9.

3.3.2 Corrosion

Resistance to material loss, pitting, cracking, and blistering is important to ensuring that the B-10 will not be lost, and that distortion of the rack insert will not interfere with fuel movement. Therefore, an accelerated corrosion test program was performed to determine the susceptibility of the Rio Tinto Alcan composite to general (i.e. uniform) and localized (i.e. pitting) corrosion in BWR SFPs. This program is described in detail in Section 5.0 of Reference 12. The material qualification program included material at 16 volume percent and 25 volume percent loadings of boron carbide (B_4C). This range of as-tested boron carbide loadings of the test coupons bounds the loading to be used at GGNS (23 volume percent B_4C).

In summary, the material qualification test program concluded that the A1100 aluminum boron carbide composite produced by Rio Tinto Alcan is a highly suitable neutron absorber for use in spent fuel storage racks. The program determined that general corrosion of the material would occur at an extremely low rate (approximately 0.02 mils/year); no local corrosion (pitting) or cracking was detected; and there was no measurable change in the B-10 areal density. The program also determined, through a review of pertinent literature, that the aluminum alloy used to make the inserts is not susceptible to stress corrosion cracking (SCC). Verification that unexpected material degradation is not occurring, over the lifetime of the racks, will be performed through the rack insert monitoring program discussed in Section 3.9.

3.3.3 NETCO-SNAP-IN® Rack Insert Dimensions and Physical Properties

The NETCO-SNAP-IN® rack inserts to be used in the GGNS spent fuel storage pools are dimensionally and physically similar to those already in use at other BWR stations – RBS, LSCS, PBAPS, FERMI, and QCNPS, as shown in Table 3.3-1

Table 1: Insert Dimension/Property Comparison

Property	GGNS	RBS	FERMI	LSCS	PBAPS	QCNPS
Length (in.)	169	169	175	167.75	169	Style 1 – 165.25 Style 2 – 165.00
Thickness (in.)	0.080	0.080	Proprietary	0.065	0.075	0.085
B-10 Min Areal Density (g B^{10}/cm^2)	0.0141	0.0129	0.0157	0.0087	0.0105	0.0116
B_4C Density (vol %)	23	21	23	17	19	17

3.4. Mechanical

3.4.1 Fuel Assembly Clearances

Placement of the rack insert in a SFP or UCP storage rack cell slightly reduces the cell inside dimension available for fuel assembly insertion. The prototype installation and testing program (Sections 3.1.3 and 3.4.3) confirmed adequate clearance between a fuel assembly and rack cells containing prototype inserts by inserting and removing a dummy fuel bundle that is dimensionally the same as a channeled fuel assembly.

The NETCO-SNAP-IN® inserts designed for GGNS spent fuel storage racks are fabricated with the top (approximately 4 inches by 1 inch) of the insert bent edges removed or “coped”, to reduce any potential interference between an insert and a fuel channel spacer. The required NETCO-SNAP-IN® insert orientation during installation, insert coping, and the administratively required fuel bundle orientation, reduce the potential for fuel bundle / insert interference.

If there is unexpected warping or bowing of the rack insert after installation that reduces the fuel assembly-to-spent fuel storage rack insert clearance, then the fuel handler would notice increased force indicated on the hoist load cell when attempting to raise (i.e., remove) an assembly. If the rack insert would inadvertently come out of a spent fuel storage rack cell with an assembly, this condition is bounded by the missing rack insert evaluation in the criticality analysis (see Section 5.5.2 of Attachment 7).

If a channeled spent fuel assembly cannot fit into the spent fuel storage rack cells containing rack inserts due to mechanical clearances, the fuel assembly may be de-channeled and stored. The new criticality analysis demonstrates that this is a conservative configuration compared to storing fuel assemblies with the channel (see Section 5.4.2 of Attachment 7)

3.4.2 Mechanical Wear

Minimal insert material wear is expected within the active fuel region due to adequate clearance between the fuel assembly and rack insert. The clearance between the fuel and insert has been verified using a dummy fuel assembly, as part of the prototype testing (see Sections 3.1.3 and 3.4.3). The combined effects of adequate clearance and infrequent fuel assembly movement will preclude significant wear of the rack insert.

3.4.3 Insertion / Retention Forces and Fuel Assembly Clearance

<u>Dimensional Sizing Testing</u>

Past experience from installing the NETCO-SNAP-IN® inserts in other spent fuel storage racks has shown that the manufactured dimensions for the rack cells do not always match the tolerances shown on design drawings. Because the NETCO-SNAP-IN® insert relies heavily on the spring force of the insert obtained when compressing the insert into the cell, even small deviations of the cell dimensions can have a large impact on how an insert fits into a rack cell. In order to determine the optimal wing width and initial bend angle needed for an insert to successfully fit into the GGNS spent fuel storage racks, test inserts made from non-borated, 3000 series aluminum were installed into and removed from fifty-seven (57) randomly selected storage cells within the GGNS SFP and seven (7) randomly selected storage cells within the GGNS UCP in February 2023. The main purpose of these test installations was to provide a basis for determining the appropriate size of the wing width and initial bend angle needed for the final insert design that will be installed in the GGNS SFP and UCP. Load tests were also performed during the removal of these test inserts to determine the force required to remove the insert. Due to slight differences in mechanical properties of the materials, the load test results for the aluminum test inserts were not expected to be identical to those of the inserts made from BORALCAN®. However, the results were useful as a guide to ensure the final design of the absorber inserts will provide the minimum force required for insert removal.

Prototype Installation and Testing

A demonstration program using prototype NETCO-SNAP-IN® rack insert was completed at GGNS in October 2023, as described in Section 3.1.3 above. The prototype installation and testing provided a confirmation that BORALCAN® inserts, made to the final design, meet the interference and retention load testing requirements. The GGNS specific parameters observed during the demonstration program were: (1) installation force; (2) retention force (greater than 150 lbs.); and (3) fuel assembly clearance. Additional detail is provided below.

Insertion Force – The insertion or installation force is produced by the installation tool, through the use of an impact mechanism at the top of the tool and the weight of the tool itself. The combined weight of the installation tool and insert is less than 1000 pounds to maintain a load under the hoist limit for the refueling bridge auxiliary hoist. It is also less than the heavy load limit of GGNS of 1140 pounds. Some of the installation tool weight is due to the external frame that is part of the tool design that helps to guide the insert into place, and therefore the full weight of the tool is not applied to seat the insert. Most of the time, the weight provided is sufficient. But in some instances, the insert may stop just before it is fully seated into the storage rack cell. In those cases, a separate insert setting tool, which does not have the external frame of the installation tool, is used to provide additional force to fully seat the insert the last few inches. The yield stress of the aluminum-boron carbide composite material is less than the yield stress of the SFP and UCP storage rack material (i.e., stainless steel); therefore, the applied stress on the SFP and UCP storage rack is significantly less than the allowable stress for the stainless steel SFP and UCP storage racks and will not damage the existing racks.

Retention Force – Acceptance testing was performed to measure the force required to remove an insert from a fuel storage rack cell once installed (i.e., the retention force). The minimum acceptable force was 150 lbf, which meets the GGNS specific design criteria for seismic accelerations and stress relaxation (see Section 3.4.4 below). It also provides a significant margin in retention force to reduce the possibility that the insert will move during normal fuel movement operations due to drag force, if the fuel were to contact the insert during removal from a storage cell.

Fuel Assembly Clearance - During the prototype installation and testing program, a dummy fuel assembly was inserted and then removed from 29 SFP test locations in which a prototype insert was installed, with no indication of clearance issues. For the UCP, 2 test locations were tested with no indication of clearance issues. The dummy fuel assembly used has a cross-sectional dimension of a channeled fuel assembly. This testing was performed to confirm that the installed inserts would not interfere with fuel movement.

In summary, the results of the prototype installation and testing program demonstrated the mechanical compatibility with the fuel stored therein. The results provide reasonable assurance that NETCO-SNAP-IN® inserts will perform their intended safety function when installed in the GGNS SFP and UCP.

3.4.4 Stress Relaxation in the Absorber Rack Inserts

During installation, the NETCO-SNAP-IN® rack inserts are compressed from an initial bend angle of greater than 90 degrees to fit in the square dimensions of the spent fuel storage rack cell interior. Once installed, the internal stresses in the rack inserts may be susceptible to relaxation over time. This relaxation would result in less force against the spent fuel storage rack cell wall and lower retention force. An analysis of stress relaxation in aluminum alloys has been performed to establish the expected performance of the rack inserts in this regard (Reference 12).

The GGNS insert design has an assumption of approximately 50% stress relaxation during the course of its service life (Reference 12). This assumption is conservative due to the reinforcing properties of the boron carbide particles. This assumption was used to determine the minimum retention force requirements of the inserts during installation, discussed in Section 3.4.3, that would hold the inserts in place during a seismic event even after relaxation has occurred.

3.5. Seismic

A reconciliation of the seismic AOR for GGNS was performed to demonstrate that the conclusions developed in the original analysis remain valid with the inserts installed in the GGNS fuel storage racks. The reconciliation considered the added mass and the effect on the natural frequency of the fuel storage racks due to the addition of the inserts. The reconciliation evaluation determined the effect of the additional mass of the inserts (17 lbm each) on the maximum displacements and stress factors due to the slightly greater kinetic energy for the same seismic inputs. The assessment determined that the changes to displacement are proportional to the percent increase in kinetic energy as a result of the addition of the inserts and would not produce displacements that exceed the gaps between storage racks or between the racks and walls. It was also shown that a proportional increase in the value of each stress factor equal to the percent increase in kinetic energy does not significantly reduce the available margin reported in the AOR for the calculated stresses based on a time history analysis.

For all conditions, it was concluded that the allowable limits were not exceeded as a result of the addition of the inserts. Finally, the concern that an insert may slide upwards out of the rack cell during a seismic event is precluded by the low seismic g-level in the vertical direction, and the total retention friction force between the insert and the cell wall. The prototype installation and testing program confirmed that sufficient retention force exists to prevent the insert from moving upward during a seismic event (see Section 3.4.3).

3.6. Structural

A reconciliation of the structural AOR for the GGNS spent fuel storage racks was performed to demonstrate that the conclusions developed in the analysis remain valid with the NETCO-SNAP-IN® inserts installed. The margins of safety calculated in the AOR were used as a basis for reconciliation. Each of the components analyzed in the AOR were evaluated for changes in the margin of safety, to determine if the addition of the inserts will significantly change the stresses under normal and seismic conditions. The evaluated components included:

- The fuel storage cell assemblies;
- The fuel storage rack support assemblies;
- The spent fuel pool structure was evaluated for the additional mass added by the installation of the NETCO-SNAP-IN® inserts.
- The upper containment pool structure was evaluated for the additional mass added by the installation of the NETCO-SNAP-IN® inserts.

The evaluation determined that the changes in margins of safety for each component due to the addition of the inserts were not significant. Therefore, it is concluded that the addition of the inserts does not cause an impact that would compromise the structural integrity of the fuel storage racks or the storage pools.

The structural performance of the NETCO-SNAP-IN® inserts under GGNS design conditions were also evaluated. The objective of this evaluation was to confirm that the neutron absorber inserts will continue to perform their safety function under the required loading conditions. It was concluded that in the installed condition at GGNS, stresses on the inserts will be significantly less than the material yield strength and therefore the inserts will not deform plastically. Additionally, it was concluded that no significant stresses will be produced as a result of thermal expansion.

3.7. Thermal-Hydraulic

A reconciliation of the thermal-hydraulic AOR for the GGNS spent fuel storage racks was performed to demonstrate that the conclusions developed in the analysis remain valid with the NETCO-SNAP-IN® inserts installed. Changes in the fuel storage cell geometry due to the addition of the inserts were evaluated. The effects of these changes on the thermal-hydraulic analysis were then determined and it was concluded that the addition of the NETCO-SNAP-IN® inserts will not adversely affect the existing thermal-hydraulic analysis.

3.8. Accident Conditions

3.8.1 Accident Considerations Related to Criticality

As part of the criticality analysis discussed in Section 3.2 and described in Attachment 7, the spent fuel rack configuration was analyzed for credible accident scenarios. The scenarios analyzed are listed below and are discussed in Section 5 of Attachment 7.

- Dropped / damaged fuel
- Abnormal positioning of a fuel assembly outside the fuel storage rack
- Misplacement of fuel bundles in unpoisoned equipment racks next to the fuel racks

In addition, the following scenarios were considered bounded by the analysis, with the justification provided in Section 5.5.3 of Attachment 7.

- Dropped fuel assembly on rack
- Closure of water gap between racks caused by rack sliding due to seismic event
- Loss of spent fuel cooling

The analysis, described in Attachment 7, demonstrates that the maximum k-effective (k_{max}(95/95)) is less than the 10 CFR 50.68 limit of 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account.

3.8.2 Fuel Handling Accident

A reconciliation review of the fuel drop AOR was performed to verify that the spent fuel storage racks with NETCO-SNAP-IN® inserts will continue to accommodate the fuel handling uplift load and impact loadings resulting from the analyzed fuel assembly drop accidents. The evaluation of the Fuel Handling Accident analysis determined that there is no adverse impact on the analysis due to the presence of the inserts.

The evaluation of a fuel handling uplift load with the inserts installed concluded that addition of the inserts does not impact this analysis. Additionally, insert and insert tool drop accidents were evaluated including (a) the straight drop of an insert and insert tool onto the top of a rack; (b) an inclined drop onto the top of a rack; and (c) a straight drop through the cell to the bottom of the rack. For all cases, the review concluded that the accidental drop of the inserts and insert tool would not adversely affect the results of the AOR.

3.9. Rack Insert Monitoring Program

GGNS is committed to the monitoring program for the spent fuel storage racks Boraflex panels described in Section B.1.4 of the UFSAR supplement of the GGNS license renewal application (Reference 13). The current monitoring program is consistent with the NRC-recommended program described in NUREG-1801, Section XI.M22, Boraflex Monitoring (Reference 15).

GGNS will have an updated monitoring program for the spent fuel storage rack neutron absorbing inserts for Section B.1.4 of the UFSAR supplement of the GGNS license renewal application. The program will be consistent with the NRC-recommended program described in NUREG-1801, Revision 2, Section XI.M40, Monitoring of Neutron-Absorbing Materials Other than Boraflex. Upon issuance of the GGNS renewed operating license, the program will become part of the GGNS UFSAR and the licensing basis.

The program will use monitoring coupons and in-situ inspections and will follow the most current industry guidance (Reference 5). Degradation of the neutron absorbing material that could compromise the criticality analysis will be detected to assure that the required 5% sub-criticality margin is maintained during the period of extended operation. The parameters monitored include the physical condition and dimensions (e.g., corrosion, pitting, wear, blisters, and bulges) and areal density (neutron absorber loss). Inspection and test frequencies will be based on plant-specific experience and will be informed by industry operating experience, but will be at least once every 10 years. Test results will be trended and, if necessary, corrective action will be taken to ensure the subcriticality margin is maintained.

Since the GGNS TS do not contain any requirements regarding the monitoring of fixed neutron absorbers in its SFP (and UCP), with the addition of the NETCO-SNAP-IN® rack inserts into the SFP and UCP storage racks, Entergy seeks to establish a standardized TS program requirement that implements the aforementioned monitoring program. The proposed change, the addition of TS 5.5.15, is consistent with Reference 6.

3.10. Summary and Conclusions

The proposed change to credit the NETCO-SNAP-IN® rack inserts in the SFP and UCP storage racks for criticality control has been evaluated and shown to be a safe and effective manner in which to resolve the Boraflex degradation issue for the remaining period of time that spent fuel needs to be stored in the GGNS SFP storage racks, ensuring that the plant's safety design bases for the SFP continue to be maintained. Furthermore, the proposed change establishes consistency with Standardized Technical Specification Improvement initiatives and the updated monitoring program satisfies the commitment Entergy made to implement a Neutron Absorbing Material Monitoring Program for license renewal for GGNS.

4. REGULATORY EVALUATION

4.1. Applicable Regulatory Requirements/Criteria

10 CFR 50.68, "Criticality accident requirements," paragraph (b)(4) states that the k-eff of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity and flooded with unborated water must not exceed 0.95, at a 95 percent probability, 95 percent confidence level. The GGNS SFP CSA crediting the neutron absorbing rack inserts provided as Attachment 7 to this submittal, demonstrates that this requirement is met.

Paragraph (b)(7) of 10 CFR 50.68 states that the maximum nominal U-235 enrichment of the fresh fuel assemblies is limited to 5.0 percent by weight. The aforementioned CSA assumes a maximum of 4.9 percent by weight of U-235 enrichment for current and future fuel used at GGNS and TS 4.3.1.1.d meets this requirement.

General Design Criteria (GDC) 62 "Prevention of criticality in fuel storage and handling" states that criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations. The evaluation of conformance with GDC 62 is discussed in Section 0.1.2, "Spent Fuel Storage," of the GGNS UFSAR. The NETCO-SNAP-IN® rack insert CSA has been performed to demonstrate that K_{eff} will remain less than or equal to 0.95 with no credit taken for the Boraflex neutron poison material in the spent fuel storage racks in the final configuration.

4.2. Precedent

The NRC has approved the use of NETCO-SNAP-IN® rack inserts as an alternative method of criticality control to address the Boraflex degradation for five other plants as documented in References 7-11. If the proposed change is approved, GGNS would become the sixth boiling water reactor (BWR) nuclear station to credit use of NETCO-SNAP-IN® rack inserts for criticality control in the SFP.

Additionally, the NRC has approved NEI 16-03-A (Reference 5) concerning guidance for monitoring of fixed neutron absorbers in spent fuel storage pools. The requested change to add a new program to the GGNS TS for monitoring of the neutron absorbing rack inserts is consistent with Reference 5. It is also consistent with Reference 6.

4.3. No Significant Hazards Considerations

In accordance with 10 CFR 50.90, Entergy Operations, Inc (Entergy) requests an amendment to Facility Operation License (NPF-29) for Grand Gulf Nuclear Power Station (GGNS) – Unit 1. The proposed change requests NRC approval for:

- The crediting of NETCO-SNAP-IN® neutron absorbing rack inserts in the criticality safety analysis (CSA) for the storage rack cells in the station's fuel building spent fuel storage facility; i.e., the spent fuel pool (SFP) and the station's containment building spent fuel storage facility; i.e. the upper containment pool (UCP). This change is being requested due to the degradation of the Boraflex neutron absorbing material currently being used in the GGNS SFP and UCP.
- Changes to the Technical Specifications (TS) concerning criticality design features of the spent fuel storage racks (TS 4.3.1.1), to specifically identify the neutron absorbing inserts and fuel-related parameters used in the CSA, consistent with Standard Technical Specifications (NUREG-1434).
- Changes to the Technical Specifications (TS) to remove Region II requirements of the spent fuel storage racks (TS 4.3.1.1), consistent with Standard Technical Specifications (NUREG-1434).
- The addition of a TS program requirement (TS 5.5.15) that implements a monitoring program for the neutron absorbing rack inserts. The addition of this program requirement establishes consistency with a Standardized Technical Specification Improvement initiative (TSTF-557, Rev 1).

According to 10 CFR 50.92, a proposed amendment to an operating license involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not:

1. Involve a significant increase in the probability or consequences of an accident previously evaluated; or
2. Create the possibility of a new or different kind of accident from any accident previously evaluated; or
3. Involve a significant reduction in a margin of safety

Entergy has evaluated the proposed change for GGNS using the criteria in 10 CFR 50.92, and has determined that the proposed change does not involve a significant hazards consideration. The following information is provided to support a finding of no significant hazards consideration.

Criteria

1. **Will operation of the facility in accordance with this proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?**

   Response: No

   The proposed change involves a new CSA for the GGNS SFP and UCP to credit the neutron absorbing capability of the NETCO-SNAP-IN® rack inserts installed in the SFP and UCP storage rack cells for criticality control. The neutron absorbing capability of the Boraflex material contained in the SFP and UCP storage racks would no longer be credited. The new CSA is not a physical change to the plant and does not affect the ability of any structures, systems or components (SSCs) to perform a design function. The proposed new CSA demonstrates adequate margin to criticality for spent fuel storage rack cells and therefore does not affect the consequences of any accident previously evaluated.

   The proposed change also involves changes to the requirements specified in TS 4.3.1.1 for spent fuel storage racks. These changes are consistent with the new CSA and impose additional requirements in the plant's Technical Specifications. These new requirements for the spent fuel storage racks do not involve a physical change to any plant systems and do not affect the ability of any SSCs to perform a design function. The new requirements support the assumptions of the new CSA and therefore do not affect the consequences of any accident previously evaluated. Finally, the proposed change involves the addition of a new programmatic requirement in TS 5.5 to perform monitoring of the NETCO-SNAP-IN® rack inserts to ensure that they continue to perform their design function, consistent with the assumptions of the new CSA. Monitoring of the SFP Neutron absorber does not affect the ability of any SSCs to perform a design function. A SFP storage rack neutron absorber monitoring program is not an initiator to any accident previously evaluated and does not affect the consequences of any accident previously evaluated.

   Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. **Will operation of the facility in accordance with this proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?**

   Response: No

   Onsite storage of spent fuel assemblies in the GGNS spent fuel pool is a normal activity for which GGNS has been designed and licensed. The new CSA does not involve any physical changes to the plant and does not change the method of spent fuel movement or storage. It only provides an analysis of the existing SFP and UCP storage racks, with credit for the NETCO-SNAP-IN® rack inserts, to demonstrate adequate margin to criticality.

Similarly, the addition of new requirements in TS 4.3.1.1 for the spent fuel storage racks, and the removal of Region I / Region II requirements, and a requirement in TS 5.5 for a new storage rack neutron absorber monitoring program does not involve any physical changes to the plant and does not change the method of spent fuel movement or storage.

Based on the above information, the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. **Will operation of the facility in accordance with this proposed change involve a significant reduction in a margin of safety?**

Response: No

The safety margin which is relevant to the proposed change is the safety margin for criticality in spent fuel storage racks. This margin is 5% (i.e., K_{eff} less than or equal to 0.95 when fully flooded with unborated water), including a conservative margin to account for engineering and manufacturing uncertainties. The new CSA demonstrates that this margin is maintained when the NETCO-SNAP-IN® rack inserts are credited for criticality control in the GGNS SFP and UCP, without credit for Boraflex.

The safety margin is unaffected by the addition of new requirements in TS 4.3.1.1 for the spent fuel storage racks. The new requirements are consistent with the assumptions of the new CSA and therefore support the basis of the safety margin demonstrated in the CSA.

The safety margin is unaffected by the removal of Region I / Region II requirements from TS 4.3.1.1 for the spent fuel storage racks. The new requirements are consistent with the assumptions of the new CSA and therefore support the basis of the safety margin demonstrated in the CSA.

The addition of a new programmatic requirement in TS 5.5 to perform monitoring of the SFP neutron absorber inserts does not affect the margin to safety for criticality. Performance of monitoring in accordance with this new requirement will support the criticality safety margin as it provides assurance that the inserts continue to perform their assumed design function which is credited in the new CSA.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above evaluation, Entergy concludes that the proposed amendment presents no significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and accordingly, a finding of no significant hazards considerations is justified.

4.4. Conclusions

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

5. ENVIRONMENT CONSIDERATION

The proposed change does not change any requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or does not change an inspection or surveillance requirement. The proposed change does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed change meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9).

Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed change.

6. REFERENCES

1. Entergy Letter: Response to Generic Letter 2016-01, “Monitoring of Neutron Absorbing Materials in Spent Fuel Pools.” (GNRI-2016/00059 dated November 1, 2016) (ADAMS Accession No. ML16306A433)
2. NEI 12-16, Revision 4, “Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants,” September 2019. (ADAMS Accession Number ML19269E069)
3. NRC Interim Staff Guidance DSS-ISG-2010-01, “Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools,” Revision 0 (ADAMS Accession Number ML110620086)
4. NUREG-1434, Rev. 5.0, Standard Technical Specifications for General Electric BWR/6 Plants
5. NEI 16-03-A, “Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,” Revision 0, March 2017 (ADAMS Accession No. ML17263A133)
6. TSTF-557, “Spent Fuel Storage Rack Neutron Absorber Monitoring Program,” Rev. 1, dated December 19, 2017 (ADAMS Accession No. ML17353A608)
7. LaSalle County Station, Units 1 and 2 – Issuance of Amendments Concerning Spent Fuel Neutron Absorbers (TAC Nos. ME2376 and ME2377), dated January 28, 2011 (ADAMS Accession No. ML110250051)
8. Peach Bottom Atomic Power Station, Units 2 and 3 – Issuance of Amendments Re: Use of Neutron Absorbing Inserts in Spent Fuel Pool Storage Racks (TAC Nos. ME7537 and ME7539), dated May 21, 2013 (ADAMS Accession No. ML13114A929)
9. Quad Cities Nuclear Power Station, Units 1 and 2 – Issuance of Amendments Regarding NETCO Inserts (TAC Nos. MF2489 and MF2490) (RS-13-148), dated December 31, 2014 (ADAMS Accession No. ML14346A306)
10. River Bend Station, Unit 1 – Issuance of Amendment No. 201 Re: Change to the Neutron Absorbing Material Credited in Spent Fuel Pool for Criticality Control (EPID L-2018-LLA-0298), dated December 31, 2019 (ADAMS Accession No. ML19357A009)
11. FERMI 2 – Issuance of Amendment No. 220 Re: Revision to the Renewed Facility Operating License Including the Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Spent Fuel Pool Storage Racks (EPIC L-2019-LLA-0199), dated May 24, 2021 (ADAMS Accession No. ML21029A254)
12. NETCO Report NET-259-03, Revision 5, “Material Qualification of Alcan Composite for Spent Fuel Storage,” August 2008 (ADAMS Accession Number ML13199A039)
13. Entergy Letter: License Renewal Application Grand Gulf Nuclear Station, Unit 1, Docket No. 50-416, (GNRO-2011/00093 dated October 28, 2011)
14. NRC Letter and Enclosure: Updated Safety Evaluation Report Related to the Grand Gulf Nuclear Station License Renewal Application (TAC No. ME7493), October 18, 2016 (ADAMS Accession Number ML16288A185)

15. NUREG-1801, “Generic Aging Lessons Learned (GALL) Report,” Revision 2, December 2010 (ADAMS Accession Number ML103490041)
16. General Electric Company, “Steady-State Nuclear Methods”, NEDE-30130-P-A, April 1985 (Non-Proprietary Version - ADAMS Accession No. ML14104A064)
17. NRC Letter: Amendment 26 to GE licensing Topical Report NEDE-24011-P-A, “GESTAR II” – Implementing Improved GE Steady-State Methods (TAC No. MA6481), November 1999 (ADAMS Accession Number ML993230387)
18. NRC Letter: Final Safety Evaluation for GE Hitachi Nuclear Energy Licensing Topical Report NEDC-33374P, Revision 3, “Safety Analysis Report for Fuel Storage Racks Criticality Analysis for ESBWR Plants.”, September 2010 (ADAMS Accession Number ML102430582)

Attachment 1
GNRO2024-00033

Technical Specification Pages – Marked-up
(3 pages below)

4.0 DESIGN FEATURES

4.1 Site Location

The site for Grand Gulf Nuclear Station is located in Claiborne County, Mississippi on the east bank of the Mississippi River, approximately 25 miles south of Vicksburg and 37 miles north-northeast of Natchez. The exclusion area boundary shall have a radius of 696 meters from the centerline of the reactor.

4.2 Reactor Core

4.2.1 Fuel Assemblies

The reactor shall contain 800 fuel assemblies. Each assembly shall consist of a matrix of Zircaloy or ZIRLO clad fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material, and water rods. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all safety design bases.A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

4.2.2 Control Rod Assemblies

The reactor core shall contain 193 cruciform shaped control rod assemblies. The control material shall be boron carbide or hafnium metal, or both.

4.3 Fuel Storage

[illegible]

4.3.1 Criticality

4.3.1.1 The spent fuel storage **racks** are designed and shall be maintained with:

a. $k_{eff} \le 0.95$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1.2 of the UFSAR;

b. ~~A nominal fuel assembly center to center storage spacing of 6.26 inches in the storage racks.~~

c. Fuel assemblies having a maximum K-infinity of ~~1.26~~ 1.29 in the normal reactor core configuration at cold conditions;

(continued)

4.0 DESIGN FEATURES

4.3.1.1 (continued)

d. Fuel assemblies having a maximum nominal U-235 enrichment of 4.9 weight percent;

e. ~~Region II racks are controlled as follows:~~

~~1. Storage cells with any Boraflex panel which has received a gamma dose in excess of 2.3E10 rads or which has a Boron-10 areal density less than 0.0165, which are designated within the Spent Fuel Pool Rack Boraflex Monitoring Program, are treated as Region II panels.~~

~~2. Storage cells face-adjacent to Region II panels are either restricted from fuel storage by physically blocking the isolated cells or are configured to meet, as a minimum (i.e., additional cells may be blocked), the Region II fuel storage configuration requirements in Figure 4.3-1.~~

~~3. When a 4x4 array of cells is classified as Region II and face-adjacent to another Region II 4x4 storage array, the new Region II 4x4 array is required to be blocked in the same 8-of-16 pattern and at the same orientation as the adjacent Region II 4x4 storage configuration.~~

~~Figure 4.3.1~~
~~Region II 4x4 Storage Configuration~~

Delete

Fuel Assembly Storage Location

Location Physically Blocked to Prevent Storage

(continued)

5.5 Programs and Manuals

5.5.15 Spent ~~Fuel Storage Rack Neutron Absorber~~ Monitoring Program

This program provides controls for monitoring the condition of the neutron absorber inserts used in the high density spent fuel storage racks to verify the Boron-10 areal density is consistent with the assumptions in the spent fuel pool criticality analysis. The program shall be in accordance with NEI 16-03-A, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," Revision 0, May 2017

Attachment 2
GNRO2024-00033

Technical Specification Pages – Clean
(3 pages below)

4.0 DESIGN FEATURES

4.1 Site Location

The site for Grand Gulf Nuclear Station is located in Claiborne County, Mississippi on the east bank of the Mississippi River, approximately 25 miles south of Vicksburg and 37 miles north-northeast of Natchez. The exclusion area boundary shall have a radius of 696 meters from the centerline of the reactor.

4.2 Reactor Core

4.2.1 Fuel Assemblies

The reactor shall contain 800 fuel assemblies. Each assembly shall consist of a matrix of Zircaloy or ZIRLO clad fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material, and water rods. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

4.2.2 Control Rod Assemblies

The reactor core shall contain 193 cruciform shaped control rod assemblies. The control material shall be boron carbide or hafnium metal, or both.

4.3 Fuel Storage

4.3.1 Criticality

4.3.1.1 The spent fuel storage racks are designed and shall be maintained with:

a. $k_{eff} \leq 0.95$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1.2 of the UFSAR;

b. A nominal fuel assembly center to center storage spacing of 6.26 inches, with a neutron absorber insert within the storage cells, in the spent fuel storage pool and in the upper containment pool.

c. Fuel assemblies having a maximum K-infinity of 1.29 in the normal reactor core configuration at cold conditions;

(continued)

4.0 DESIGN FEATURES (continued)

4.3.1.1 (continued)

d. Fuel assemblies having a maximum nominal U-235 enrichment of 4.9 weight percent;

(continued)

5.5 Programs and Manuals

5.5.14 Risk Informed Completion Time Program (continued)

c. When a RICT is being used, any change to the plant configuration, as defined in NEI 06-09-A, Appendix A, must be considered for the effect on the RICT.

1. For planned changes, the revised RICT must be determined prior to implementation of the change in configuration.

2. For emergent conditions, the revised RICT must be determined within the time limits of the Required Action Completion Time (i.e., not the RICT) or 12 hours after the plant configuration change, whichever is less.

3. Revising the RICT is not required if the plant configuration change would lower plant risk and would result in a longer RICT.

d. For emergent conditions, if the extent of condition evaluation for inoperable structures, systems, or components (SSCs) is not complete prior to exceeding the Completion Time, the RICT shall account for the increased possibility of common cause failure (CCF) by either:

1. Numerically accounting for the increased possibility of CCF in the RICT calculation; or

2. Risk Management Actions (RMAs) not already credited in the RICT calculation shall be implemented that support redundant or diverse SSCs that perform the function(s) of the inoperable SSCs, and, if practicable, reduce the frequency of initiating events that challenge the functions(s) performed by the inoperable SSCs.

e. The risk assessment approaches and methods shall be acceptable to the NRC. The plant PRA shall be based on the as-built, as- operated, and maintained plant; and reflect the operating experience at the plant, as specified in Regulatory Guide 1.200, Revision 2. Methods to assess the risk from extending the Completion Times must be PRA methods approved for use with this program in Amendment No. 234, or other methods approved by the NRC for generic use; and any change in the PRA methods to assess risk that are outside these approval boundaries require prior NRC approval.

5.5.15 Spent Fuel Storage Rack Neutron Absorber Monitoring Program

This program provides controls for monitoring the condition of the neutron absorber inserts used in the high density spent fuel storage racks to verify the Boron-10 areal density is consistent with the assumptions in the spent fuel pool criticality analysis. The program shall be in accordance with NEI 16-03-A, “Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,” Revision 0, May 2017.

Attachment 3
GNRO2024-00033

Global Nuclear Fuels Report NEDO-34125, Rev. 0, Dated July 2024,
Grand Gulf Nuclear Station: Fuel Storage Critically Analysis with Rack Inserts
(Non-Proprietary Version)
(65 pages below)

Global Nuclear Fuel

NEDO-34125
Revision 0
July 2024

Non-Proprietary Information

Grand Gulf Nuclear Station: Fuel Storage Criticality Safety Analysis with Rack Inserts

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-34125P Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of providing the results of the fuel storage rack criticality analysis for Grand Gulf Nuclear Station. The only undertakings of GNF with respect to information in this document are contained in the contracts between Entergy and GNF, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than Entergy, or for any purpose other than that for which it is furnished by GNF is not authorized; and with respect to any unauthorized use, GNF makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

Revision Status

Revision Number	Date	Description of Change
0	July 2024	Initial issue.

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ACRONYMS

Term	Definition
2D	Two-Dimensional
AOA	Area of Applicability
BAF	Bottom of Active Fuel
BASE	Base Lattice
BOL	Beginning-of-Life
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CW	Curtiss-Wright Flow Control Service, LLC
DOM	Dominant Lattice
EALF	Energy of the Average Lethargy Causing Fission
[[	]]
GE	General Electric
GEH	GE-Hitachi Nuclear Energy Americas, LLC
GGNS	Grand Gulf Nuclear Station
GNF	Global Nuclear Fuel - Americas, LLC
H/X	Hydrogen-to-Fissile
HTC	Haut Taux de Combustion
MID	Mid Lattice
MOX	Mixed Uranium-Plutonium Oxide
NCA	Nuclear Critical Assembly
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
SCCG	Standard Cold Core Geometry
TCH	Corner Thickness
TCM	Side Thickness
TCS	Groove Thickness
TCS	Tank Critical Assembly (as used in Table 2)
UO_2	Uranium Dioxide

Term	Definition
US	United States
VAN	Vanished Lattice
WCS	Groove Width
WML	(Major) Side ½-Width
WMS	Minor Side Width
WRL	Corner Ramp Width
WRS	Groove Ramp Width

1.0 INTRODUCTION

This report describes the criticality analysis and results for the Grand Gulf Nuclear Station (GGNS) fuel pool and upper containment pool with credit for Curtiss-Wright Flow Control Service, LLC (CW) NETCO-SNAP-IN® neutron absorbing inserts in each usable rack cell. No credit for the Boraflex neutron absorber is taken in this analysis. This analysis includes sufficient detail on the methodology and analytical models utilized in the criticality analysis to verify that the storage rack systems have been accurately and conservatively represented. This analysis covers the current GNF2, GNF3 and GE14 fuel product lines and all legacy fuel stored in GGNS's fuel pool and upper containment pool.

The racks are analyzed using the MCNP-05P Monte Carlo neutron transport program and ENDF/B-VII.0 cross-section library. The methodology used in this analysis is the peak Standard Cold Core Geometry (SCCG) in-core eigenvalue (k_∞) criterion. A maximum cold, uncontrolled peak in-core k_∞ of 1.29 as defined by the lattice physics code TGBLA06 (Reference 1) is set as the limit for this analysis. As demonstrated in Table 1, the analysis resulted in a storage rack maximum k-effective (k_{max}(95/95)) less than 0.95 for normal and credible abnormal operation with tolerances and uncertainties taken into account.

Table 1 – Summary k_{max}(95/95) Result

Region	k_{max}(95/95)
Fuel Pool and Upper Containment Pool	0.92632

2.0 REQUIREMENTS

Title 10 of the Code of Federal Regulations (CFR) Part 50 defines the requirements for the prevention of criticality in fuel storage and handling at nuclear power plants. 10 CFR 50.68 details specifically that the storage rack k_{max}(95/95) for fuel storage racks must be demonstrated to be ≤ 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account. The Standard Review Plan (Reference 2) outlines the standards that must be met for these analyses. All necessary requirements are met in this analysis. Nuclear Energy Institute (NEI) 12-16 (Reference 3), endorsed by Regulatory Guide 1.240 (Reference 4) is used as the guidance documents for this analysis.

3.0 METHOD OF ANALYSIS

In this evaluation, in-core k_∞ values and exposure dependent, pin-by-pin isotopic specifications are generated using the GE-Hitachi Nuclear Energy Americas, LLC (GEH)/GNF lattice physics production code TGBLA06. TGBLA06 solves Two-Dimensional (2D) diffusion equations with diffusion parameters corrected by transport theory to provide system multiplication factors and perform burnup calculations.

The fuel storage criticality calculations are then performed using MCNP-05P, the GEH/GNF proprietary version of MCNP5 (Reference 5). MCNP-05P is a Monte Carlo program for solving the linear neutron transport equation for a fixed source or an eigenvalue problem. The code implements the Monte Carlo process for neutron, photon, electron, or coupled transport involving all these particles, and computes the eigenvalue for neutron-multiplying systems. For the present application, only neutron transport is considered.

3.1 Cross-Sections

TGBLA06 uses ENDF/B-V cross-section data to perform coarse-mesh, broad-group, diffusion theory calculations. It includes thermal neutron scattering with hydrogen using an S(α,β) light water thermal scattering kernel.

MCNP-05P uses pointwise (i.e., continuous) cross-section data, and all reactions in a given cross-section evaluation (e.g., ENDF/B-VII.0) are considered. For the present work, thermal neutron scattering with hydrogen is described using an S(α,β) light water thermal scattering kernel. The cross-section tables include all details of the ENDF representations for neutron data. The code requires that all the cross-sections be given on a single union energy grid suitable for linear interpolation; however, the cross-section energy grid varies from isotope to isotope. The libraries include very little data thinning and utilize resonance integral reconstruction error tolerances of 0.001%.

3.2 Geometry Treatment

TGBLA06 is a 2D lattice design computer program for Boiling Water Reactor (BWR) fuel bundle analysis. It assumes that a lattice is uniform and infinite along the axial direction and that the lattice geometry and material are reflecting with respect to the lattice boundary along the transverse directions.

MCNP-05P implements a robust geometry representation that can correctly model complex components in three dimensions. An arbitrary three-dimensional configuration is treated as geometric cells bounded by first and second-degree surfaces and some special fourth-degree elliptical tori. The cells are described in a cartesian coordinate system and are defined by the intersections, unions and complements of the regions bounded by the surfaces. Surfaces are defined by supplying coefficients to the analytic surface equations or, for certain types of surfaces, known points on the surfaces. Rather than combining several pre-defined geometrical bodies in a combinatorial geometry scheme, MCNP-05P has the flexibility of defining geometrical shapes from all the first and second-degree surfaces of analytical geometry and elliptical tori and then combining them with Boolean operators. The code performs extensive checking for geometry errors and provides a plotting feature for examining the geometry and material assignments.

3.3 Convergence Checks

The use of TGBLA06 as a depletion code in this criticality analysis is consistent with its use for BWR fuel design and its associated user's manual. Convergence checks are encoded in the standard error routines and the absence of error messages is confirmed in all code output.

In this analysis, the following criticality code parameters are specified. At a minimum, all MCNP-05P cases are run with 20,000 neutrons per generation, 200 cycles skipped, and 500 total cycles run. Some cases are run for more cycles skipped and more total cycles to meet all the convergence checks. For this analysis, the following MCNP-05P convergence checks are reviewed and confirmed passed for each case:

- Sampling of all cells that contain fissionable material
- Matching of first and second half eigenvalue
- Fission source entropy check

3.4 Validation and Computational Basis

MCNP-05P has been compared to [[ ]] critical experiments for validation purposes using ENDF/B-VII.0 nuclear cross-section data. The experiments cover a number of moderator-to-fuel ratios and poison materials that represent material and geometric properties similar to that of BWR fuel lattices both in and out of fuel racks. The critical experiments to which MCNP-05P has been compared are provided in Table 2. All are either low-enriched Uranium Dioxide (UO_2) or Mixed Uranium-Plutonium Oxide (MOX) pin lattice in water experiments. The Area of Applicability (AOA) considered covered by this validation is listed in Table 3, along with the parameters which characterize the fuel rack system for comparison. The critical experiment modeling results, along with the calculation of the associated bias and bias uncertainty terms at the 95/95 confidence level using NUREG/CR-6698 (Reference 6) guidance is provided in Appendix A. The study concluded that the appropriate bias to apply to systems covered by this AOA is [[ ]], and the appropriate uncertainty of that bias is [[ ]].

Table 2 – Summary of the Critical Benchmark Experiments

Experiment		Experiments	Year	Where
[[				
				]]

Table 3 – Area of Applicability Covered by Code Validation

Parameters	Validation Area of Applicability	Fuel Rack Characteristics
Fissionable Material	Uranium, Plutonium	Uranium, Actinides
Chemical Form	UO_2, MOX	UO_2, MOX
Enrichment (wt.% ^{235}U)	wt.% $^{235}U \leq 4.9$	wt.% $^{235}U \leq 4.9$
Enrichment (wt.% ^{239}Pu)	wt.% $^{239}Pu \leq 5.3$	wt.% $^{239}Pu \leq 4.9$
Physical Form	Solid Compound	Solid Compound
Temperature	~20°C up to ~100°C	4-126°C
Moderator (in fuel region)	H_2O	H_2O
Physical Form	Solution	Solution
Temperature	~20°C up to ~100°C	4-126°C
Reflector (in fuel region)	H_2O	H_2O
Physical Form	Solution	Solution
Temperature	20°C	4-126°C
Absorbers	None/Boron/Gadolinium Stainless Steel /Copper	Boron/Gadolinium/ Fission Products
Neutron Energy Spectrum	Thermal	Thermal
Energy of Average Lethargy Causing Fission (MeV)	6.8E-8 – 8.6 E-7	3.53E-7 (Limiting In-rack k_∞ Case)

Table 3 demonstrates that the AOA of this validation encompasses the majority of storage characteristics of new fuel in the fuel storage racks. [[

]]

For the storage of fuel, however, it is appropriate to add additional uncertainty terms to the k_{max}(95/95) result. Specifically, these items are:

a. Uncertainty in fuel depletion calculations

Consistent with NEI 12-16 (Reference 3), a conservative approximation of the fuel depletion uncertainty is quantified by assessing the reactivity difference between a Beginning-of-Life (BOL) system and the exposure dependent, peak reactivity system of interest. Specifically, the cold, in-core, BOL reactivity of the fuel rack design basis lattice with no gadolinium present is compared to the reactivity of the exposed design basis lattice at its cold, in-core, peak reactivity statepoint. Both reactivities are calculated for comparison in the rack system. Five percent of the difference in reactivities between these two cases is included as an uncertainty to the fuel rack studies in Table 21 to cover the depletion isotopic benchmarking gap, including the gap for minor actinides and fission products.

b. TGBLA06 eigenvalue uncertainty

An additional uncertainty is also added to the fuel rack studies related to eigenvalue calculations performed using TGBLA06. A bias of [[ ]] and a 95/95 bias uncertainty of [[

]] This uncertainty is applied to the fuel rack's k_{max}(95/95) value to cover uncertainty in the assignment of in-core k_∞ values to fuel lattices.

3.5 In-Core k_∞ Methodology

The design of the fuel storage racks provides for a subcritical multiplication factor for both normal and credible abnormal storage conditions. In all cases, the storage rack eigenvalue must be ≤ 0.95. To demonstrate compliance with this limit, the peak in-core k_∞ method is utilized.

The peak in-core k_∞ criterion method relies on a well-characterized relationship between infinite lattice k_∞ (in-core) for a given fuel design and a specific fuel storage rack k_∞ (in-rack) containing that fuel. The use of an infinite lattice k_∞ criterion for demonstrating compliance to fuel storage criticality criteria has been used for all General Electric (GE)-supplied storage racks and is currently used for re-rack designs at a number of plants. This report demonstrates that the methodology is also appropriate for use at GGNS by presenting the following:

a. A well-characterized, linear relationship between infinite lattice k_∞ (in-core) and fuel storage rack k_∞ (in-rack)

b. The use of a design basis lattice with a conservative rack efficiency and in-core k_∞ for all criticality analyses

The analysis is performed to calculate the lattice k_∞ to confirm compliance with the above criterion by utilizing the Nuclear Regulatory Commission (NRC)-approved lattice physics methods encoded into the TGBLA06 engineering computer program. One of the outputs of the TGBLA06 solution is the lattice k_∞ of a specific nuclear design for a given set of input state parameters (e.g., void fraction, control state, fuel temperature).

Compliance of fuel with specified k_∞ limits will be confirmed for each new lattice as part of the bundle design process. Documentation that this has been met will be contained in the fuel design information report, which defines the maximum lattice k_∞ for each assembly nuclear design. The process for validating that specific assembly designs are acceptable for storage in the GGNS fuel storage racks is provided below.

1. Identify the unique lattices in each assembly design.
2. Deplete the lattices in TGBLA06 using the following conditions:
    a. Assembly aligned according to GGNS specific lattice spacing and zero leakage
    b. [[

]]

3. Ensure that the k_∞ values obtained from Step 3 for each lattice are less than or equal to the k_∞ limit of 1.29.

Documentation that all legacy fuel types currently in the GGNS fuel storage racks comply with this in-core limit is found in Appendix B.

3.6 Definitions

Fuel Assembly – A complete fuel unit consisting of a basic fuel rod structure that may include large central water rods. Several shorter rods may be included in the assembly. These are called "part-length rods." A fuel assembly includes the fuel channel.

Fuel Storage Rack – An array of usable rack cells, which refers to both the spent fuel pool and the upper containment pool. Both the spent fuel pool and upper containment pool have the same usable rack cell configurations.

Usable Rack Cell – A rack cell containing a neutron absorbing insert that is accessible by fuel handling equipment where a fuel bundle can be physically placed within.

Gadolinia – The compound Gd_2O_3. The gadolinium content in integral burnable absorber fuel rods is usually expressed in weight percentage gadolinia.

Lattice – An axial zone of a fuel assembly within which the nuclear characteristics of the individual rods are unchanged.

Base Lattice (BASE) – An axial zone of a GNF2 or GNF3 fuel assembly located in the bottom half of the bundle within which all possible fuel rod locations for a given fuel design are occupied.

Dominant Lattice (DOM) – An axial zone of a GE14 fuel assembly typically located in the bottom half of the bundle within which all possible fuel rod locations for a given fuel design are occupied.

Mid Lattice (MID) – [[

]]

Vanished Lattice (VAN) – An axial zone of a fuel assembly typically in the upper half of the bundle within which a number of possible fuel rod locations are unoccupied.

Rack Efficiency – The ratio of a particular lattice statepoint in-rack eigenvalue (k_∞) to its associated lattice nominal in-core eigenvalue (k_∞). This value allows for a straightforward comparison of a rack's criticality response to varying lattice designs within a particular fuel product line. A lower rack efficiency implies increased reactivity suppression capability relative to an alternate design with a higher rack efficiency.

Design Basis Lattice – The lattice geometry, exposure history, and corresponding fuel isotopics for a fuel product line that result in the highest rack efficiency in a sensitivity study of reasonable fuel parameters at the desired in-core reactivity. This lattice is used for all normal, abnormal, and tolerance evaluations in the fuel rack analysis.

3.7 Assumptions and Conservatisms

The fuel storage rack criticality calculations are performed with the following assumptions to ensure the true system reactivity is always less than the calculated reactivity:

1. [[

]]

3. Design basis lattices with in-core k_∞ values greater than the proposed 1.29 in-core k_∞ limit is used for all criticality analyses.

4. [[

]] Sensitivity studies of the storage system reactivity to these depletion parameters are presented in Section 5.5. [[

]]

5. For conservatism, only positive reactivity differences from nominal conditions determined from depletion sensitivity and abnormal configuration analyses are added as biases to the final storage rack k_{max}(95/95).
6. Neutron absorption in spacer grids, concrete, activated corrosion and wear products (CRUD) and axial blankets is ignored to limit parasitic losses in non-fuel materials.
7. TGBLA06 defined "lumped fission products" and Xe-135 are both conservatively ignored for MCNP-05P in-rack k_∞ calculations.
8. [[

]]

9. The neutron absorber inserts are modeled with nominal minimum wing width of [[ ]] inches and nominal wing thickness of [[ ]] inches. The wing length does not include the insert material which is bent at a 90-degree angle at the end of each wing. Including this material, the total unbent insert length is greater than [[ ]] inches. Each wing is modeled at a wing length of [[ ]] inches to represent all inserts in the rack which is an equivalent [[ ]] inches total unbent insert length. Because the analysis models less material than is actually present in the insert, this approach is conservative. Modeling the inserts in this way minimizes thermal neutron absorption in the inserts.
10. Only B^{10} is modeled in the rack inserts. The minimum certified areal density is [[ ]] g B^{10}/cm^2. Each insert is assumed to contain an areal density of 0.0139 g B^{10}/cm^2 to account for potential manufacturing uncertainties. All other insert material is ignored. Ignoring the other materials conservatively limits neutron absorption in the inserts.
11. No credit is taken for the Boraflex in the storage racks in the analysis, and all material between the inner cell wall and outer wrapper of the fuel rack is modeled as water. Modeling this material as water is reasonable, as the outer wrapper does not provide a watertight seal between the Boraflex and pool environment, and therefore any significant gap formations within the poison material will be filled with water.

4.0 FUEL DESIGN BASIS

The rack criticality analysis covers the GE14, GNF2, and GNF3 fuel product lines as well as all legacy fuel stored at GGNS. Justification for the storage of all legacy fuel is provided in Appendix B. The description of the fuel product lines, GE14, GNF2 and GNF3, are found in Sections 4.1, 4.2, and 4.3. All of these product lines are investigated to determine the design basis lattice in Section 5.3.

All fuel is UO_2 with some fuel rods containing gadolinia, Gd_2O_3.

This criticality analysis covers reconstituted fuel where a rod containing fuel is replaced with another fueled or non-fueled rod. This analysis does not cover reconstituted fuel where there are missing rod locations that are not part of the normal fuel product line design.

This criticality analysis also bounds the storage of non-fuel items such as channels in fuel rack locations because this analysis utilizes peak reactivity fuel in every rack cell location.

4.1 GE14 Fuel Description

The GE14 fuel lattice configuration is a 10x10 fuel rod array [[ ]], as shown in Figure 1. Figure 1 also demonstrates the part-length rod locations, which cannot be changed for this fuel design. [[ ]] Information regarding the GE14 pellet stack density is provided in Table 4. The corresponding dimensions of Figure 1 are provided in Table 5.

Table 4 – GE14 Fuel Stack Density as a Function of Gadolinia Concentration

Gadolinia Concentration (wt. fraction)	[[							
Pellet Density (g/cc)								]]

[[

]]

Figure 1 – GE14 Fuel Lattice Configuration

Table 5 – Nominal Dimensions for GE14 Fuel Lattice

Features	Reference	(mm)	(inches)
Channel Dimensions:			
[[			
			]]
Fuel Rod Dimensions:			
[[			
			]]
Water Rod Dimensions:			
[[			
			]]
Bundle Lattice Dimensions:			
[[			
			]]

[[ ]] The full lattice, also referred to in this report as the dominant lattice (DOM), [[ ]] The vanishing rod lattice, or vanished lattice (VAN), [[

]] Variation in axial height of these regions is irrelevant to this analysis due to the fact that all criticality calculations are performed with a single lattice design and burnup that corresponds to the highest rack efficiency.

4.2 GNF2 Fuel Description

Criticality safety analyses to determine storage system reactivity are performed using the GNF2 fuel design. The GNF2 fuel lattice configuration is a 10x10 fuel rod array [[ ]] as shown in Figure 2 with corresponding dimensions in Table 6. Figure 2 also demonstrates the part-length rod locations, which cannot be changed for this fuel design. The references in Figure 3 correspond to Table 7. GNF2 pellet stack density is provided in Table 8. [[

]]

Figure 2 – GNF2 Fuel Lattice Configuration

Table 6 – Nominal Dimensions for GNF2 Fuel Lattice

Features	Reference	(mm)	(inches)
Channel Dimensions:			
[[			
			]]
Fuel Rod Dimensions:			
[[			
			]]
Water Rod Dimensions:			
[[			
			]]
Bundle Lattice Dimensions:			
[[			
			]]

[[

]]

Figure 3 – Channel Dimensions

Table 7 – Nominal Channel Dimensions for GNF2 Lattice

Dimension	mm	inches
[[		
		]]

Table 8 – Fuel Stack Density as a Function of Gadolinia Concentration

Gadolinia Concentration (wt. fraction)	[[							
Pellet Density (g/cc)								]]

[[ ]] The full lattice, also referred to in this report as the base lattice (BASE), [[ ]] The first vanishing rod lattice, or vanished one lattice (VAN1), [[ ]] The second vanished rod lattice (VAN2) [[ ]] Variation in axial height of these regions is irrelevant to this analysis because all criticality calculations are performed assuming a single lattice design.

4.3 GNF3 Fuel Description

The GNF3 fuel lattice configuration is a 10x10 fuel rod array [[ ]] as shown in Figure 4 with corresponding dimensions in Table 9 and Table 10. Figure 4 also demonstrates the part-length rod locations. Fuel channel dimensions are provided in Figure 5 and Table 11. The pellet stack density is in Table 8. [[ ]]

[[

]]

Figure 4 – GNF3 Lattice Configuration

Table 9 – Lattice Dimensions

Item			Dimension	
			mm	in
Channel	[[			
Fuel Rod				
Pellet				
[[ ]]				
Bundle Lattice				]]

Table 10 – Cell Dimensions

Lattice Type	Channel Name	½ Wide Gap, Q		½ Narrow Gap, R		Control Blade Pitch, S	
		mm	in	mm	in	mm	in
[[							]]

[[

]]

Figure 5 – Channel ${}^{1}/_{8}$ Cross-Sections

Table 11 – Channel Dimensions

Channel Name		**93AV**			
Channel Section		**Zone 1**		**Zone 2**	
Dimension		**mm**	**in**	**mm**	**in**
[[					
					]]

4.4 Fuel Model Description

The fuel models considered include 2D geometric modeling of all fuel material, cladding, water rods, and channels. In the depletion model, appropriate depletion time steps are used consistent with depletion timesteps used in BWR core design analyses. [[

]] Pin specific isotopic modeling as a function of exposure is performed based on the lattice physics code TGBLA06. To obtain the isotopic composition of the fuel pins, each lattice design considered is "burned" at reactor operating conditions [[
]] and depleted through to a final exposure of [[

]] The isotopics utilized exclude Xe-135 and TGBLA06 defined "lumped fission products" [[
]] An example of a GNF2 VAN1 lattice model in MCNP-05P (Case 12 from Table 13) is depicted in Figure 6. The black pins are the gadolinia rods. [[ ]]

[[

]]

Figure 6 – GNF2 VAN1 Lattice in MCNP-05P

The fuel loadings considered for each lattice span a range of exposures, average enrichments, number of gadolinia rods, gadolinia concentration, and void histories considered to be reasonably representative of any GGNS fuel design. The lattice type and exposure history that result in the worst-case rack efficiency for an in-core k_∞ greater than the proposed limit is then used to define the design basis lattice. This lattice is assumed to be stored in every location in the rack being analyzed. Details on the determination of the design basis lattice using the process outlined above are presented in Section 5.3.

5.0 CRITICALITY ANALYSIS OF FUEL STORAGE RACKS

5.1 Description of Fuel Storage Racks

The GGNS high-density fuel storage rack is a Joseph Oat design and uses Boraflex as a neutron absorber. Racks of this design are present in the fuel pool and upper containment pool. This analysis applies to racks in both locations. The rack design uses "L" and "T" shaped sub-elements to assemble each fuel storage array. Each sub element is composed of stainless-steel sheets, Boraflex inserts, and stainless steel edge strips.

Originally, the storage racks at GGNS employed thermal neutron absorption in the B^{10} of the Boraflex as the primary mechanism of reactivity control; however, the Boraflex has been demonstrated to be degrading over time. Therefore, no credit is taken for the Boraflex in this analysis, and all material between the inner cell wall is modeled as water. Modeling this material as water is reasonable, as the outer wrapper does not provide a watertight seal between the Boraflex and pool environment. Therefore, any significant gap formations within the poison material will be filled with water.

To supplement the reactivity suppression capability of the rack, neutron absorbing inserts are installed in each of the usable storage cells in the storage rack module. In this analysis, a lower B^{10} areal density of 0.0139 g B^{10}/cm^2 is used in the base model instead of the certified minimum B^{10} areal density of [[ ]] g B^{10}/cm^2 to account for potential manufacturing uncertainties. The minimum designed wing length for these inserts is [[ ]] inches. This length does not include the insert material which is bent at a 90-degree angle at the end of each wing. Including this material, the total unbent insert length is greater than [[ ]] inches. For simplicity, each wing is modeled with a [[ ]]-inch wing length to conservatively represent all inserts in the rack. Each insert is installed with the same north-east orientation with respect to the cell. In this way, one leg of an insert exists between each bundle in the storage rack assembly.

Based on the insert configuration, peripheral storage cells on two sides of the storage pools will not be surrounded by four wings of the absorbing insert. The reactivity effect of this storage limitation is assessed in Section 5.5.

5.2 Fuel Storage Rack Models

A 2D infinite 4x4 array was constructed to analyze the fuel storage rack. [[

]] Figure 7 displays a simplified 2D layout of the rack cells. The numbers 1-16 are unit identifiers, and each unit includes a fuel assembly. The i and ii identify the unit type, which is shown in Figure 8. Boraflex is not credited in this analysis, and all Boraflex is modeled as water. Neutron absorbing inserts are positioned in a north-east orientation relative to each rack cell (see Figure 7). The fuel pool and the upper containment pool storage racks are the same dimensions and are denoted as "fuel storage racks" in this analysis.

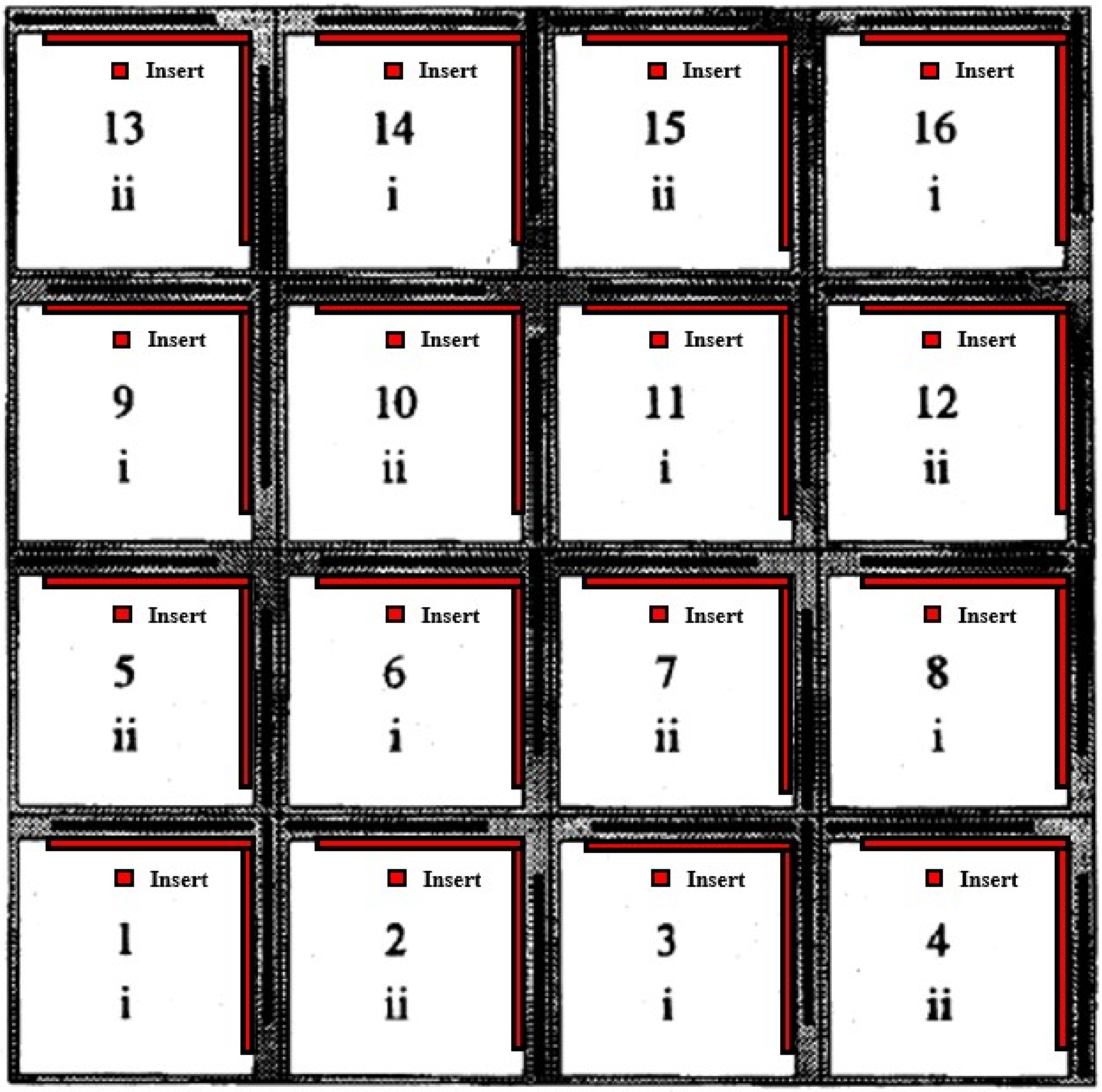

Figure 7 – 4x4 Fuel Storage Rack Model

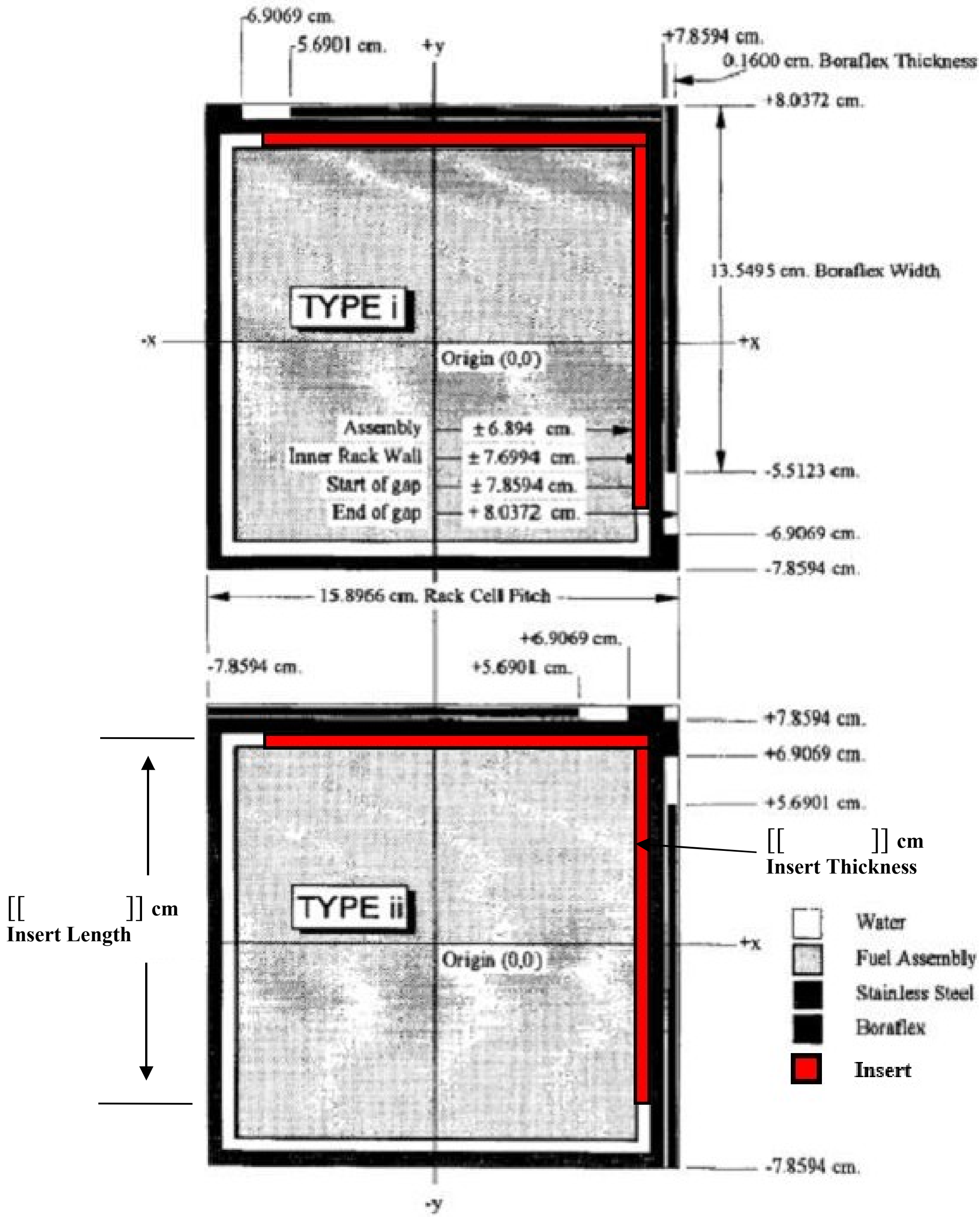

Figure 8 – Cell Identifiers in the 4x4 Fuel Storage Rack Model

To simulate an infinite array, periodic boundary conditions were specified in the X and Y dimensions and reflective boundary conditions were specified in the Z dimension. An image demonstrating the inner four bundles of the 4x4 infinite array model is provided in Figure 9 with a zoomed in view in Figure 10. Storage rack dimensions and tolerances are presented in Table 12.

[[

]]

Figure 9 – Storage Rack Model Schematic

[[

]]

Figure 10 – Zoomed Storage Rack Model Schematic

Table 12 – Storage Rack Model Dimensions

Storage Rack Component	Nominal (inch)	Tolerance (inch)
Rack Pitch	6.259	0.062
Primary Fuel Box Inner Width	6.063	-
Rack Wall Thickness	0.063	0.006
Rack Insert Wing Length	[[	
Rack Insert Thickness		]]

* Modeled wing length of [[ ]] inches. See Section 3.7 for modeling assumptions.

5.3 Design Basis Lattice Selection

Table 13 defines the lattice designs and exposure histories that are explicitly studied in the fuel storage rack to determine the geometric configuration and isotopic composition that results in the worst rack efficiency. Note that void state is not a relevant parameter for zero exposure peak reactivity cases, and, therefore, only a single result is presented for these fuel loadings. The highest rack efficiency with an in-core k_∞ greater than the proposed limit of 1.29 is found to result from the parameters defined in Case 12 from Table 13. The geometry and isotopics defined for this case are used to define all bundles in the remaining fuel rack analyses.

Figure 11 presents a graph that demonstrates the linear nature of the in-core to in-rack results over all rack efficiency cases studied in the rack system. Figure 11 provides infinite in-core and in-rack eigenvalue pairs for GE14, GNF2, and GNF3 lattices at [[ ]] to allow for the linear relationship to be demonstrated over a large range of exposures and fuel lattice designs.

Table 13 – Fuel Parameter Ranges Studied in Fuel Rack

Case	Lattice Type	Void	Average Lattice Enrichment (^{235}U wt.%)	Number of Gadolinia Rods	Gadolinia Concentration (Gd wt. %)	Peak-Reactivity Exposure (GWD/ST)	TGBLA06 Defined In-Core k_∞	MCNP-05P Defined In-Rack k_∞	Rack Efficiency
1	[[							0.8806	[[
2								0.8791	
3								0.8743	
4								0.8913	
5								0.8830	
6								0.8725	
7								0.8500	
8								0.8849	
9								0.8843	
10								0.8818	
11								0.8624	
12								**0.8961**	
13								0.8908	
14								0.8807	
15								0.8589	
16								0.8878	
17								0.8846	
18								0.8792	
19								0.8747	
20								0.8758	
21								0.8720	
22								0.8765	
23								0.8732	
24								0.8521	
25								0.8457	
26								0.8860	
27								0.8780	
28								0.8676	
29								0.8831	
30								0.8812	
31							]]	0.8622	]]

Table 13 – Fuel Parameter Ranges Studied in Fuel Rack

Case	Lattice Type	Void	Average Lattice Enrichment (^{235}U wt.%)	Number of Gadolinia Rods	Gadolinia Concentration (Gd wt. %)	Peak-Reactivity Exposure (GWD/ST)	TGBLA06 Defined In-Core k∞	MCNP-05P Defined In-Rack k∞	Rack Efficiency
32	[[							0.8615	[[
33								0.8949	
34								0.8883	
35								0.8783	
36								0.8755	
37								0.8718	
38								0.8357	
39								0.8443	
40								0.8882	
41								0.8833	
42								0.8766	
43								0.8889	
44								0.8829	
45								0.8759	
46								0.8746	
47								0.8729	
48								0.8677	
49								0.8439	
50								0.8850	
51								0.8845	
52								0.8842	
53								0.8935	
54								0.8915	
55								0.8856	
56								0.8726	
57								0.8742	
58							]]	0.8753	]]

* Six gadolinia rods at 3 wt.% concentration and one gadolinia rod at 4.0 wt.% concentration.

[[

]]

Figure 11 – In-Rack Fuel Eigenvalue as a Function of In-Core Eigenvalue

5.4 Normal Configuration Analysis

5.4.1 Analytical Models

The most reactive normal configuration is determined by studying the reactivity effect of the following credible normal scenarios:

1. Storage of non-channeled assemblies
2. Eccentric loadings
    - When neutron absorber inserts with an areal density above 0.01 g $^{10}B/cm^2$ are present on all four sides of the fuel assembly, a centrally located positioning of the fuel assembly in the storage cell is the most reactive configuration. Therefore, no eccentric loading cases are performed, which is consistent with NEI 12-16 (Reference 3).
3. [[

]]

4. Pool moderator temperature variation

As the non-channeled assembly evaluation demonstrates a decrease in reactivity when compared to nominal, channeled storage conditions, the remaining normal configuration studies are performed with channeled bundles.

5.4.2 Normal Configuration Results

The results of the normal configuration study are provided in Table 14. This information demonstrates that none of the normal configurations analyzed increase the system reactivity by a statistically significant amount over the nominal loading pattern. The in-rack k_∞ associated with this nominal combination of conditions is 0.89613 and is hereafter referred to as k_{Normal}. This configuration will be used for all abnormal and tolerance studies that are performed on an infinite basis. Any positive reactivity differences from this nominal condition are included in the calculation of the system bias in Section 5.5.2.

Table 14 –Fuel Storage Rack In-Rack k_∞ Results – Normal Configurations

Term	Configuration	In-Rack k_∞	MCNP-05P Uncertainty (1σ)
Base	Nominal - Centered, channeled, [[ ]]	0.89613	[[
Δk_{N1}	Non-channeled assemblies	0.89185	
Δk_{N2a}	[[	0.89636*	
Δk_{N2b}	]]	0.89628	
Δk_{N3a}	Moderator Temperature decrease to 4ºC (ρ=1.000 g/cc)	0.89655*	
Δk_{N3b}	Moderator Temperature increase to 126ºC with 20% void (ρ=0.7508 g/cc)	0.86062	]]

* Largest positive reactivity increase from nominal case for each term is included in roll-up of Δk_{Bias}

5.5 Bias Cases

5.5.1 Depletion Bias Cases

The following configurations related to the depletion conditions of the stored bundles are explicitly considered, where each description defines a condition all bundles in storage experience over their entire exposure histories. These bound the conditions the bundles actually experience.

1. [[

]]

The following potential reactivity effect of changes that occur during depletion are considered:

a. Fuel rod changes (clad creep, fuel densification/swelling)

   Clad Creep - [[

   ]]

   Fuel Pellet Densification – [[

   ]]

b. Material dependent grid growth

   [[

   ]]

5.5.2 Normal Bias Cases

The following bias cases are included for normal conditions. As seen in Table 14, [[ ]] and moderator temperature decrease cases resulted in positive reactivity increases from the nominal case. Therefore, these cases are included in the roll-up of Δk_{Bias} in Table 20.

1. No inserts on rack periphery

   There may be assemblies loaded in storage cells on two sides that will not be surrounded by neutron absorbing inserts. [[

   ]] Results are provided in Table 15. The reactivity increase from this study is included in the final Δk_{Bias} term.

Table 15 – Rack Periphery Study Results

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[ ]]	[[		
No Inserts on Rack Periphery			]]

2. Missing rack insert

   A missing insert from the [[ ]] was analyzed to cover the periodic removal of an insert from a cell for inspection purposes or an insert being accidently removed during fuel movements. Thus, [[ ]] The relative reactivity increase from this condition is included in the bias table in Table 20.

3. Fuel out of rack during normal fuel handling/inspections

   Several fuel assembly geometric configurations are possible in the fuel storage racks and fuel transfer area during fuel handling activities such as fuel stored in the fuel prep machines. [[

]]

5.5.3 Abnormal/Accident Bias Cases

Additionally, perturbations of the normal fuel rack configuration were considered for credible accident scenarios. The scenarios considered are presented in the lists that follow, with explanations of the abnormal condition provided below each listing of similar configurations. Results of these abnormal/accident conditions is included in the final Δk_{Bias} term in Table 20.

1. Dropped/damaged fuel
   a. Justification – The dropped/damaged fuel scenario [[

      ]]
      The relative reactivity change from this abnormal condition is included in Table 19 and included in the in the final Δk_{Bias} term in Table 20.
2. Abnormal positioning of a fuel assembly outside the fuel storage rack
   a. Justification – There is not enough space for a bundle to fit between racks in the fuel storage racks; however, there is space for a misplaced bundle outside the fuel racks and between the fuel storage rack walls. [[
      ]] as shown in Figure 12. [[

      ]] in the described directions provided in Table 16). Results from these analyses are presented in Table 16. As seen in Table 16, there is little sensitivity in the placement of the misplaced bundle. Therefore, the cases analyzed here are sufficient.

b. Abnormal positioning of a fuel bundle pushed against corner of fuel rack

Justification – A bundle could be misplaced at the edge of the fuel racks against the corner of the rack as shown in Figure 13. [[

]] Several orientations of the misplaced bundle were performed to assess the most reactive location as shown in Table 17. As seen in Table 17, there is little sensitivity in the placement of the misplaced bundle. Therefore, the cases analyzed here are sufficient.

[[

]]

Figure 12 – Finite Misplaced Assembly Outside of Rack

[[

]]

Figure 13 – Finite Misplaced Assembly Pushed Against Corner of Rack

Table 16 – Results for a Misplaced Assembly Outside of Rack

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[			
			]]

Table 17 – Results for a Misplaced Assembly Against Corner of Rack

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[			
			]]

3. Misplacement of fuel bundles in unpoisoned equipment racks next to the fuel racks

   Justification – It is possible for fuel bundles to be placed in unpoisoned equipment racks next to the fuel racks. The configuration of this study is a [[ ]] This scenario was explicitly considered by studying three possible configurations with two bundles, as depicted in Figure 14. [[ ]] The calculation was reperformed with bundles in the unpoisoned equipment racks to determine the limiting configuration. Results are provided in Table 18. The results of this study are bounded by the results of the misplaced bundle against the corner of rack study.

[[

]]

Figure 14 – Storage of Fuel in Unpoisoned Equipment Racks

Table 18 – Results for Bundles in Unpoisoned Equipment Racks

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[			
			]]

The following abnormal configurations are also considered bounded, with the justification provided:

4. Dropped bundle on rack

   Justification – For a drop on the rack, the fuel assembly may come to rest horizontally on top of the rack with a minimum separation distance from the fuel in the rack of more than 12 inches. At this separation distance, the fissile material will be separated by enough neutron mean free paths to preclude neutron interactions that increase k_{eff}, and the overall effect on reactivity will be insignificant. Therefore, no case was performed for this analysis consistent with NEI 12-16 (Reference 3).

5. Rack sliding due to seismic event which causes water gap between racks to close

   Justification – The racks modeled in this analysis are infinite in extent with no inter-module water gaps. This essentially assumes all racks are close-fitting and bounds possible reactivity effects of rack sliding.

6. Loss of fuel pool cooling

   Justification – Normal sensitivity analysis results demonstrate that system reactivity decreases as moderator density decreases and pool temperature increases; therefore, reactivity effects of loss of fuel pool cooling are bounded by the nominal reactivity results.

Table 19 –Fuel Storage Rack Abnormal Bias Summary

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk	Δk Uncertainty (2σ)
Dropped/Damaged Fuel	0.89665	[[ ]]	0.00052	[[ ]]
[[				
				]]

* Per the double contingency principle (Reference 3), only the most limiting of the misplaced bundle cases is included in the bias roll-up in Table 20.

5.5.4 Results

The results of the bias studies are provided in Table 20. The Δk term in this table represents the difference between the system reactivity with the specified bias case and k_{Normal}. Δk_{B6} is the MCNP-05P bias from Section 3.4. The total contribution from these independent conditions to the k_{max}(95/95) of the fuel rack is calculated using Equation 1. In this equation, a Δk_{Bi} value must be both positive and the largest for its respective term to be considered.

$$\Delta k_{bias} = \sum_{i=1}^{n} \Delta k_{bi} \quad (1)$$

Table 20 –Fuel Storage Rack Bias Summary

Term	Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk	Δk Uncertainty (2σ)
Δk_{B1}	[[	0.88088	[[	-0.01525	[[
Δk_{B2a}		0.89621		0.00008	
Δk_{B2b}		0.89747		0.00134*	
Δk_{B3a}		0.89737		0.00124*	
Δk_{B3b}		0.89572		-0.00041	
Δk_{B4a}		0.89711		0.00098*	
Δk_{B4b}	]]	0.89649		0.00036	
Δk_{B5}	Depleted with clad creep	0.89717		0.00104	
Δk_{B6}	MCNP-05P bias	-		[[ ]]	
Δk_{B7}	Dropped/damaged fuel	0.89665		0.00052	
Δk_{B8}	No inserts on rack periphery	-		[[ ]]	
Δk_{B9}	Missing insert	0.90165		0.00544	
Δk_{B10}	[[	-		[[ ]]	
Δk_{N2a}	]]	0.89636		0.00023	
Δk_{N3a}	Moderator temperature decrease to 4°C (ρ=1 g/cc)	0.89655	]]	0.00042	]]
Δk_{Bias}				[[	]]

* For conservatism, only positive values that are the largest for their respective term are considered.

**[[

]]

5.6 Uncertainties

5.6.1 Tolerance Analytic Models

The following tolerance study configurations were explicitly considered for the fuel rack:

1. Fuel enrichment increases by [[ ]] ^{235}U
2. Fuel pellet density increased by [[ ]] of nominal value
3. Gadolinia concentration decreased by [[ ]]
4. Rod cladding thickness decreased by [[ ]] and rod cladding outer diameter decrease by [[ ]]
5. Rod cladding thickness increased by [[ ]] and rod cladding outer diameter increase by [[ ]]
6. Channel thickness increase by [[ ]]
7. Channel thickness decrease by [[ ]]
8. Fuel pellet outer diameter increase by [[ ]]
9. Fuel pellet outer diameter decrease by [[ ]]
10. Fuel rod pin pitch increase by [[ ]]
11. Fuel rod pin pitch decrease by [[ ]]
12. Rack wall thickness increase by 0.006 inches
13. Rack wall thickness decrease by 0.006 inches
14. Rack pitch decrease by 0.062 inches
15. Rack pitch increase by 0.062 inches
16. Rack insert thickness decrease by [[ ]]
17. Rack insert wing length decrease by [[ ]]

All the tolerances used in these analyses are at least 2σ design limits. The models developed for these studies were all based on the normal configuration presented in Section 5.4.

The inner width tolerance case is covered by the rack pitch tolerance case because the rack pitch tolerance bounds the inner cell width tolerance. Because there is no tolerance on the rack wall thickness, the only way to change the inner box width is by changing the pitch.

Because the Boraflex is modeled as water in this analysis, no tolerance cases are performed on the Boraflex thickness or width.

5.6.2 Results

The results of the tolerance studies and uncertainties are provided in Table 21. The values are summed using Equation 2 which is adopted from NEI 12-16 (Reference 3).

The Δk_{Ti} term in this table represents the difference between the system reactivity with the specified tolerance perturbation and k_{Normal}. In Equation 2, a Δk_{Ti} value must be both positive and the largest for its respective term to be considered.

The Δk_{Ui} terms in the table represent the uncertainty contributions to $k_{max}(95/95)$ of the fuel rack and from the problem and code specific uncertainties which are combined with the tolerance contributions (Δk_{Ti}) using Equation 2.

$$\Delta k_{uncertainty} = \sqrt{\sum_{i=1}^{n} \Delta k_{Ti}^2 + \sum_{i=1}^{n} \Delta k_{Ui}^2} \tag{2}$$

Table 21 –Fuel Storage Rack Tolerance and Uncertainty Δk Results

Term	Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk	Δk Uncertainty (2σ)
Δk_{T1}	Fuel enrichment increase	0.90023	[[	0.00410	[[
Δk_{T2}	Fuel pellet density increase	0.89719		0.00106	
Δk_{T3}	Gadolinia wt.% decrease	0.90244		0.00631	
Δk_{T4}	Rod clad thickness/outer diameter increase	0.89034		-0.00579	
Δk_{T4b}	Rod clad thickness/outer diameter decrease	0.90181		0.00568*	
Δk_{T5a}	Channel thickness increase	0.89619		0.00006	
Δk_{T5b}	Channel thickness decrease	0.89619		0.00006*	
Δk_{T6a}	Pellet outer diameter increase	0.89713		0.00100*	
Δk_{T6b}	Pellet outer diameter decrease	0.89611		-0.00002	
Δk_{T7a}	Fuel rod pin pitch increase	0.89778		0.00165*	
Δk_{T7b}	Fuel rod pin pitch decrease	0.89503		-0.00110	
Δk_{T8a}	Rack wall thickness increase	0.89736		0.00123*	
Δk_{T8b}	Rack wall thickness decrease	0.89557		-0.00056	
Δk_{T9a}	Rack pitch decrease	0.90024		0.00372*	
Δk_{T9b}	Rack pitch increase	0.89246		-0.00406	
Δk_{T11a}	Poison inserts thickness decrease	0.89603		-0.00049	
Δk_{T11b}	Poison inserts thickness increase	0.89654		0.00002*	]]
Δk_{T12}	Poison inserts wing length decrease	0.89636	]]	-0.00016	-
Δk_{U1}	Critical benchmark bias uncertainty (95/95) (MCNP-05P versus critical experiments)	-	-	[[	-
Δk_{U2}	TGBLA06 eigenvalue uncertainty (95/95)	-	-		-
Δk_{U3}	Uncertainty on k_{Normal} (2 x 1σ value for base term in Table 14)	-	-		-
Δk_{U4}	Uncertainty of ⊗k bias contributors (2σ)	-	-		-
Δk_{U5}	Uncertainty of ⊗k tolerance contributors (2σ)	-	-		-
Δk_{U6}	Uncertainty in fuel depletion	-	-		-
$\Delta k_{Uncertainty}$				]]	-

* For conservatism, only positive values that are the largest for their respective term are considered.

5.7 Maximum Reactivity

The maximum reactivity of the fuel storage racks without crediting Boraflex and with rack inserts installed, considering all biases, tolerances, uncertainties, is calculated using Equation 3. The final values are presented in Table 22.

$$k_{max(95/95)}=k_{normal}+\Delta k_{bias}+\Delta k_{uncertainty} \quad (3)$$

Table 22 – Fuel Storage Rack Results Summary

Term	Value
k_{Normal}	0.89613
Δk_{Bias}	[[
$\Delta k_{Uncertainty}$	]]
$k_{max}(95/95)$	0.92632

[[

]]

6.0 INTERFACES BETWEEN AREAS WITH DIFFERENT STORAGE CONDITIONS

The fuel pool and upper containment pool are neutronically decoupled because the pools are not connected. A scenario was investigated in Section 5.5.3 to determine the reactivity effect in the fuel storage racks as a result of placing two bundles in unpoisoned equipment racks next to the fuel racks. This effect was found to be negligible to the final result of the storage rack maximum k-effective ($k_{max}(95/95)$).

7.0 CONCLUSIONS

The GGNS fuel pool and upper containment pool with neutron absorbing inserts have been analyzed for the storage of GE14, GNF2, and GNF3 fuel using the MCNP-05P Monte Carlo neutron transport program and the in-core k_∞ criterion methodology. A maximum SCCG, uncontrolled peak in-core eigenvalue (k_∞) of 1.29 as defined by TGBLA06 is specified as the rack design limit for GE14, GNF2, and GNF3 fuel in the fuel pool and upper containment pool with neutron absorber rack inserts installed. The analyses resulted in a storage rack maximum k-effective ($k_{max}(95/95)$) less than the 10 CFR 50.68 limit of 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account. Justification for the continued storage of all legacy GGNS fuel is found in Appendix B.

8.0 REFERENCES

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APPENDIX A - MCNP-05P CODE VALIDATION

Table 23 presents the results of the benchmark calculations described in Section 3.4. Note that it is necessary to make an adjustment to the calculated k_{eff} value if the critical experiment being modeled was not at a critical state. This adjustment is done by normalizing the k_{calc} values to the experimental values, which is valid for small differences in k_{eff}. This normalization is reported as k_{norm} and is determined using Equation A-1. The combined uncertainty from the measurement and the calculation (σ_t) is also determined using Equation A-2.

$$k_{norm}=k_{calc}/k_{exp} \qquad \text{(A-1)}$$

$$\sigma_t= \sqrt{\sigma^2_{calc}+\sigma^2_{exp}} \qquad \text{(A-2)}$$

Table 23 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								
								]]

Table 23 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								
								]]

Table 23 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								
								]]

Table 23 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								
								]]

Table 23 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								
								]]

A.1 - Trend Analysis

To determine if any trend is evident in this pool of experiments, the parameters listed in Table 24 were considered as independent variables.

Table 24 – Trending Parameters

Energy of the Average Lethargy Causing Fission (EALF)
Uranium Enrichment (wt.% ^{235}U)
Plutonium Content (wt.% ^{239}Pu)
Atom Ratio of Hydrogen to Fissile Material

Each parameter was plotted against the k_{norm} results independently for each case that was analyzed. These plots are provided in Figure 15 through Figure 18. This scatterplot of data was first analyzed by visual inspection to determine if any trends were readily apparent in the data. During this inspection, the axes of the graphs were modified to different scales to allow for a more thorough review. No clear evidence of a trend, linear or otherwise, was observed from this inspection.

[[

]]

Figure 15 – Scatterplot of EALF versus k_{norm}

[[

]]

Figure 16 – Scatterplot of wt.% ^{235}U versus k_{norm}

[[

]]

Figure 17 – Scatterplot of wt.% ^{239}Pu versus k_{norm}

[[

]]

Figure 18 – Scatterplot of H/X versus k_{norm}

To further check for trends in the data, a linear regression was performed. The linear regression fitted equation is in the form y(x)= a +bx, where y is the dependent variable (k_{calc}) and x is any of the predictor variables from Table 24. Unweighted k_{calc} values were used in this evaluation, though it is noted that, due to the very similar σ_{calc} values reported in Table 23, using weighted values would produce very similar results. This regression was performed using the built-in regression analysis tool in Excel. The fitted lines are included in Figure 15 through Figure 18. Again, it is noted through visual inspection that the trends do not appear to exhibit a strong correlation to the data. A useful tool to validate this claim is the linear correlation coefficient. This is a quantitative measure of the degree to which a linear relation exists between two variables. It is often expressed as the square term, r^2, and can be calculated directly using built in functions in Excel. The closer r^2 gets to the value of one, the better the fit of data is expected to be to the linear equation. Results from this linear regression evaluation are summarized in Table 25.

A final method to test for goodness of fit is the chi squared test (χ^2). This method is explained in detail in (Reference 7). In general, it can be stated that χ^2 is an indicator of the agreement between the observed (calculated) and expected (fitted) values for some variable. For linear goodness of fit testing using this method, Equation A-3 is utilized, where the expected value of $f(x_i)$ corresponds to the linear fitted equation for the trending parameter, x_i.

$$\chi = \Sigma_{1}^{(\,)} \frac{\qquad}{(J}) \qquad \text{(A-3)}$$

A more convenient way to report this result is the reduced chi squared value, which is denoted as χ and is defined by Equation A-4, where d is the degrees of freedom for the evaluation.

$$\chi \; = \chi \; /d \qquad \text{(A-4)}$$

If a value of order one or less is obtained for this equation, then there is no reason to doubt the expected (fitted) distribution is reasonable; however, if the value is much larger than one, the expected distribution is unlikely to be a good fit. Results for each trending parameter are summarized in Table 25.

Table 25 – Trending Results Summary

Trend Parameter	Intercept	Slope	r^2	χ^2	Valid Trend
H/X	[[				No
^{235}U wt.%					No
EALF					No
^{239}Pu wt.%				]]	No

The results in Table 25 clearly demonstrate that there are no statistically significant or valid trends of k_{norm} with any of the trending parameters.

A.2 - Bias and Bias Uncertainty Calculation – Single Sided Tolerance Limit

As no trends are apparent in the critical experiment results, a weighted single-sided tolerance limit methodology is utilized to establish the bias and bias uncertainty for this AOA and code package combination. Use of this method requires the critical experiment results to have a normal statistical distribution. This was verified using the Anderson-Darling normality test. A graphical image of the results for this normality test, including the p-value for the distribution, is provided in Figure 19. Because the reported p-value is greater than 0.05, it is confirmed that the data fits a normal distribution, and the single sided tolerance limit methodology is confirmed to be applicable.

[[

]]

Figure 19 – Normality Test of k

When using this method, the weighted bias and bias uncertainty are calculated using the following equations:

$$Bias = k \qquad 1 \tag{A-5}$$

$$Bias\ Uncertainty = U \cdot S \tag{A-6}$$

$$\bar{k}_{norm} = \frac{\sum_{i=1}^{n} \frac{k_{norm_i}}{\sigma_t^2}}{\sum_{i=1}^{n} \frac{1}{\sigma_t^2}} \tag{A-7}$$

$$S_P = \sqrt{s^2 + \sigma^2} \tag{A-8}$$

$$\sigma^2 = \frac{n}{\sum_{i=1}^{n} \frac{1}{\sigma_t^2}} \tag{A-9}$$

$$s^2 = \frac{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n}\frac{1}{\sigma_i^2}\left(k_{norm\,i} - \bar{k}_{norm}\right)^2}{\frac{1}{n}\sum_{i=1}^{n}\frac{1}{\sigma_i^2}} \qquad \text{(A-10)}$$

Where:

$\bar{k}_{norm}$ = Average weighted k_{norm}

S_P = Pooled standard deviation

s^2 = Variance about the mean

σ^2 = Average total variance

U = one-sided tolerance factor for n data points at (95/95 confidence/probability level)

n = number of data points (= [[ ]])

Table 26 summarizes the results of these calculations.

Table 26 – Bias and Bias Uncertainty for MCNP-05P with ENDF/B-VII

Bias (weighted)	[[
Bias Uncertainty (95/95 level)	
Variance About the Mean	
Average Total Variance	
Pooled Standard Deviation (1σ)	
One-Sided Tolerance Factor	]]

Using the average weighted bias and pooled standard deviation; the upper one-sided 95/95-tolerance limit (bias uncertainty) was calculated for use in criticality calculations, in accordance with NUREG/CR-6698 guidance (Reference 6). As seen in Figure 19, [[

]] As shown in Table 26, the MCNP-05P bias uncertainty (95/95) was [[

]] Table 27 summarizes the recommended bias and bias uncertainty to be used in criticality calculations.

Table 27 – Recommended Bias and Bias Uncertainty in Criticality Analyses for MCNP-05P with ENDF/B-VII

Bias	[[
Bias Uncertainty (95/95)	]]

APPENDIX B - LEGACY FUEL STORAGE JUSTIFICATION

Exposure dependent, maximum, uncontrolled in-core k_∞ results have been calculated for each fuel assembly in the GGNS fuel storage racks and are confirmed to be less than 1.29. The limit for the highest in-core k_∞ value for the bundles currently in use at the GGNS is 1.26. The in-core k_∞ values have been calculated using the process for validating that specific assembly designs are acceptable for storage in the GGNS fuel storage racks, as outlined in Section 3.5. The legacy lattice with the highest in-core reactivity value is presented in Table 28. This information demonstrates that all fuel assemblies currently in the GGNS fuel storage racks have considerable margin to the reactivity of the GNF2 design basis lattice used in this analysis.

The GNF2 design basis lattice with an in-core k_∞ value of 1.29 has been shown to be below the 10 CFR 50.68 0.95 in-rack limit when analyzed in the storage racks. Because of this, and the fact that the legacy fuel types are sufficiently less reactive than this design basis lattice (see Table 28), it is confirmed that all legacy fuel bundles are safe for storage in the GGNS fuel storage racks with rack inserts installed.

Table 28 – Limiting SCCG In-Core Eigenvalue of all Legacy GGNS Bundles

Bundle Name	**In-core k_∞**
[[	]]

Attachment 4
GNRO2024-00033

NEI 12-16 Appendix C: Criticality Analysis Checklist
(8 pages below)

APPENDIX C: CRITICALITY ANALYSIS CHECKLIST

The criticality analysis checklist is completed by the applicant prior to submittal to the NRC. It provides a useful guide to the applicant to ensure that all the applicable subject areas are addressed in the application, or to provide justification/identification of alternative approaches.

The checklist also assists the NRC reviewer in identifying areas of the analysis that conform or do not conform to the guidance in NEI 12-16. Subsequently, the NRC review can then be more efficiently focused on those areas that deviate from NEI 12-16 and the justification for those deviations.

Subject	Included	Notes / Explanation
1.0 Introduction and Overview		
Purpose of submittal	YES	
Changes requested	YES	
Summary of physical changes	YES	
Summary of Tech Spec changes	NO	Not included in the criticality analysis. To be included in a separate license amendment.
Summary of analytical scope	YES	
2.0 Acceptance Criteria and Regulatory Guidance		
Summary of requirements and guidance	YES	
Requirements documents referenced	YES	
Guidance documents referenced	YES	
Acceptance criteria described	YES	
3.0 Reactor and Fuel Design Description		
Describe reactor operating parameters	NO	See Section 5.5.1 for discussion.
Describe all fuel in pool	YES	Section 4.0 and Appendix B
Geometric dimensions (Nominal and Tolerances)	NO	Section 4.0 for GE14, GNF2, and GNF3 designs only. Geometric data not provided for legacy fuel.
Schematic of guide tube patterns	YES	Water rod locations described in Section 4.1 for GE14, GNF2, and GNF3 designs only. Water rod locations not provided for legacy fuel. Guide tube patterns not applicable for BWR fuel.
Material compositions	YES	Section 4.0 for GE14, GNF2, and GNF3 designs only. Material compositions not provided for legacy fuel.

Subject	Included	Notes / Explanation
Describe future fuel to be covered	YES	Section 4.0
Geometric dimensions (Nominal and Tolerances)	YES	Section 4.0
Schematic of guide tube patterns	YES	Water rod locations described in Section 4.2. Guide tube patterns not applicable for BWR fuel.
Material compositions	YES	Section 4.0
Describe all fuel inserts	NO	There are no fuel inserts in this analysis.
Geometric Dimensions (Nominal and Tolerances)		
Schematic (axial/cross-section)		
Material compositions		
Describe non-standard fuel	YES	Section 4.0
Geometric dimensions		
Describe non-fuel items in fuel cells	YES	Section 4.0
Nominal and tolerance dimensions	NO	Not applicable
4.0 Spent Fuel Pool/Storage Rack Description		
New fuel vault & Storage rack description	NO	The proposed change does not include the new fuel storage racks.
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
Spent fuel pool, Storage rack description	YES	Sections 5.1-5.2
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
Other Reactivity Control Devices (Inserts)	YES	Sections 5.1-5.2
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
5.0 Overview of the Method of Analysis		
New fuel rack analysis description	NO	The proposed change does not include the new fuel storage racks.
Storage geometries		
Bounding assembly design(s)		
Integral absorber credit		
Accident analysis		
Spent fuel storage rack analysis description	YES	Section 5.0 and Sections 3.5-3.7
Storage geometries	YES	Section 5.2
Bounding assembly design(s)	YES	Section 5.3
Soluble boron credit	NO	Not applicable. No soluble boron is used at GGNS.
Boron dilution analysis		

Subject	Included	Notes / Explanation
Burnup credit	NO	No burnup credit in BWR peak reactivity analysis. Fuel is evaluated at peak reactivity.
Decay/Cooling time credit	NO	No decay/cooling time credit.
Integral absorber credit	YES	Section 5.3
Other credit	NO	No other credit.
Fixed neutron absorbers	YES	Credit for neutron absorbing inserts.
Aging management program	YES	
Accident analysis	YES	Section 5.5.3
Temperature increase	YES	Section 5.5.3 and Section 5.4.1
Assembly drop	YES	Section 5.5.3
Single assembly misload	NO	Uniform pool with peak reactivity fuel, so no opportunity for misload.
Multiple misload	NO	
Boron dilution	NO	Not applicable. No soluble boron is used at GGNS.
Other	YES	Section 5.5.3
Fuel out of rack analysis	YES	Section 5.5.2
Handling		
Movement		
Inspection		
6.0 Computer Codes, Cross Sections and Validation Overview		
Code/Modules Used for Calculation of k_{eff}	YES	Described in Section 3.0.
Cross section library	YES	Section 3.1
Description of nuclides used	YES	Section 4.4
Convergence checks	YES	Section 3.3
Code/Module Used for Depletion Calculation	YES	Described in Section 3.0
Cross section library	YES	Section 3.1
Description of nuclides used	YES	Sections 3.7 and 4.4
Convergence checks	YES	Section 3.3
Validation of Code and Library	YES	Section 3.4 and Appendix A
Major Actinides and Structural Materials	YES	Section 3.4
Minor Actinides and Fission Products	YES	Section 3.4
Absorbers Credited	YES	Section 3.4
7.0 Criticality Safety Analysis of the New Fuel Rack		
Rack model	NO	
Boundary conditions		
Source distribution		
Geometry restrictions		

Subject	Included	Notes / Explanation
Limiting fuel design		
Fuel density		
Burnable Poisons		
Fuel dimensions		
Axial blankets		
Limiting rack model		
Storage vault dimensions and materials		
Temperature		
Multiple regions/configurations		
Flooded		
Low density moderator		
Eccentric fuel placement		
Tolerances		
Fuel geometry		
Fuel pin pitch		
Fuel pellet OD		
Fuel clad OD		
Fuel content		
Enrichment		
Density		
Integral absorber		
Rack geometry		
Rack pitch		
Cell wall thickness		
Storage vault dimensions/materials		
Code uncertainty		
Biases		
Temperature		
Code bias		
Moderator Conditions		
Fully flooded and optimum density moderator		
8.0 Depletion Analysis for Spent Fuel		
Depletion Model Considerations	YES	Described in Section 3.3, Section 3.7, and Section 4.4.
Time step verification		
Convergence verification		
Simplifications		
Non-uniform enrichments		
Post Depletion Nuclide Adjustment		
Cooling Time		
Depletion Parameters		
Burnable Absorbers		
Integral Absorbers		
Soluble Boron		

Subject	Included	Notes / Explanation
Fuel and Moderator Temperature		
Power		
Control rod insertion		
Atypical Cycle Operating History		
9.0 Criticality Safety Analysis of Spent Fuel Pool Storage Racks		
Rack model	YES	Section 5.2
Boundary conditions		
Source distribution		
Geometry restrictions		
Design Basis Fuel Description	YES	Section 5.3
Fuel density	YES	Section 4.0
Burnable Poisons	YES	Section 5.3
Fuel assembly inserts	NO	No fuel assembly inserts in this analysis.
Fuel dimensions	YES	Section 4.1, Section 4.2, and Section 4.3
Axial blankets	NO	Section 3.7
Configurations considered	YES	Single configuration, uniform pool. See Section 6.0.
Borated	NO	Not applicable for this analysis.
Unborated	YES	
Multiple rack designs	NO	Not applicable. One rack design with inserts in every location.
Alternate storage geometry	NO	Not applicable for this analysis.
Reactivity Control Devices	YES	
Fuel Assembly Inserts	NO	No fuel assembly inserts in this analysis.
Storage Cell Inserts	YES	Section 5.1
Storage Cell Blocking Devices	NO	No cells are required to be empty, so no blocking devices are considered in this analysis.
Axial burnup shapes	NO	Section 3.7
Uniform/Distributed	YES	
Nodalization	NO	
Blankets modeled	NO	
Tolerances/Uncertainties	YES	Section 5.6
Fuel geometry		
Fuel rod pin pitch		
Fuel pellet OD		
Cladding OD		

Subject	Included	Notes / Explanation
Axial fuel position	NO	Section 3.7
Fuel content	YES	Section 5.6
Enrichment		
Density		
Assembly insert dimensions and materials	NO	No fuel assembly inserts in this analysis.
Rack geometry	YES	Section 5.6
Flux-trap size (width)	NO	Not applicable
Rack cell pitch	YES	Section 5.6.1
Rack wall thickness	NO	Section 5.6.1
Neutron Absorber Dimensions	NO	Not applicable because Boraflex is modeled as water. See Section 5.6.1
Rack insert dimensions and materials	YES	Section 5.6.1
Code validation uncertainty	YES	Described in Section 3.4 and Section 5.6.2.
Criticality case uncertainty	YES	Section 5.6.2
Depletion Uncertainty	YES	Described in Section 3.4 and Section 5.6.2.
Burnup Uncertainty	NO	Not applicable for BWR peak reactivity analysis.
Biases	YES	Section 5.0
Design Basis Fuel design	YES	Section 5.3
Code bias	YES	Section 3.4 and Section 5.5.4
Temperature	YES	Section 5.4 and Section 5.5.4
Eccentric fuel placement	YES	Not applicable. See Section 5.4.1.
Incore thimble depletion effect	NO	Not applicable for this analysis.
NRC administrative margin	NO	Not applicable for this analysis.
Modeling simplifications	YES	Sections 3.7 and 4.4
Identified and described		
10.0 Interface Analysis		
Interface configurations analyzed	NO	Not applicable because the pool is uniform with rack inserts in every cell. See Section 6.0.
Between dissimilar racks	NO	
Between storage configurations within a rack	NO	
Interface restrictions	NO	None

Subject	Included	Notes / Explanation
11.0 Normal Conditions		
Fuel handling equipment	YES	Section 5.5.2
Administrative controls	YES	Defective fuel storage locations are procedurally not allowed to have fuel stored in the edge tubes. Fuel can only be stored in the interior tubes.
Fuel inspection equipment or processes	YES	Section 5.5.2
Fuel reconstitution	YES	Replaced rods are covered, but storage of assemblies with missing pins is not allowed. See Section 4.0.
12.0 Accident Analysis		
Boron dilution	NO	Not applicable. No soluble boron used at GGNS.
Normal conditions		
Accident conditions		
Single assembly misload	NO	Uniform pool with peak reactivity fuel, so no opportunity for misload.
Fuel assembly misplacement	YES	Section 5.5.3
Neutron Absorber Insert Misload	YES	Section 5.5.2
Multiple fuel misload	NO	Uniform pool with peak reactivity fuel, so no opportunity for misload.
Dropped assembly	YES	Section 5.5.3
Temperature	YES	Section 5.5.3
Seismic event/other natural phenomena	YES	Section 5.5.3
13.0 Analysis Results and Conclusions		
Summary of results	YES	Sections 5.7 and 7.0
Burnup curve(s)	NO	Not applicable for BWR peak reactivity analyses.
Intermediate Decay time treatment	NO	Not applicable for BWR peak reactivity analyses. See Section 4.4.
New administrative controls	YES	Fuel with missing fuel rods shall not be loaded into a spent fuel rack cell. If not already present, this administrative control needs to be added in the site fuel movement procedure(s).
Technical Specification markups	YES	

Subject	Included	Notes / Explanation
14.0 References	YES	**Section 8.0.**
Appendix A: Computer Code Validation:		**Appendix A.**
Code validation methodology and bases	YES	Appendix A
New Fuel		
Depleted Fuel		
MOX		
HTC		
Convergence		
Trends		
Bias and uncertainty		
Range of applicability	YES	Described in Section 3.4.
Analysis of Area of Applicability coverage	YES	Described in Section 3.4.

Attachment 5
GNRO2024-00033

Global Nuclear Fuels – Americas Proprietary Information Affidavits
(4 pages below)

PROPRIETARY INFORMATION NOTICE

This document contains proprietary information of Global Nuclear Fuel – Americas, LLC (GNF). and is furnished in confidence solely for the purpose(s) stated below in the notice regarding the contents of this report. No other use, direct or indirect, of the document or the information it contains is authorized. The recipient shall not publish or otherwise disclose this document or the information therein to others without the prior written consent of GNF and shall return the document at the request of GNF.

The header of each page in this document carries the notation, "GNF Proprietary Information – Non-Public."

GNF proprietary information within the text and tables is identified by a dotted underline inside double square brackets. [[This sentence is an example.{3}]] GNF proprietary information in figures and large objects is identified by double square brackets before and after the object. In all cases, the superscript notation {3} refers to Paragraph (3) of the enclosed affidavit that provides the basis for the proprietary determination.

Curtiss-Wright Flow Control Service, LLC (CW) information is identified by a solid underline inside double square brackets. [[This sentence is an example.{C}]] CW proprietary information in figures and large objects is identified by double square brackets before and after the object. In all cases, the superscript notation {C} refers to the enclosed affidavit that provides the basis for the proprietary determination.

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of providing the results of the fuel storage rack criticality analysis for Grand Gulf Nuclear Station. The only undertakings of GNF with respect to information in this document are contained in the contracts between Entergy and GNF, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than Entergy, or for any purpose other than that for which it is furnished by GNF is not authorized; and with respect to any unauthorized use, GNF makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

Global Nuclear Fuel – Americas, LLC

AFFIDAVIT

I, **Lisa K. Schichlein,** state as follows:

(1) I am a Senior Licensing Engineer, Regulatory Affairs, Global Nuclear Fuel – Americas, LLC ("GNF"), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in GNF proprietary report, NEDC-34125P, "Grand Gulf Nuclear Station: Fuel Storage Criticality Safety Analysis of Spent Fuel Storage Racks with Rack Inserts," Revision 0, July 2024. GNF proprietary information within the text and tables is identified by a dotted underline placed within double square brackets. [[This sentence is an example.{3}]] Figures and large objects containing GNF proprietary information are identified with double square brackets before and after the object. In all cases, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GNF relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GNF's competitors without license from GNF constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GNF customer-funded development plans and programs, resulting in potential products to GNF;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GNF, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GNF, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GNF.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GNF are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains details of GNF's fuel design and licensing methodology. The development of this methodology, along with the testing, development and approval was achieved at a significant cost to GNF or its licensor.

The development of the fuel design and licensing methodology along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GNF asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GNF's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GNF's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical, and NRC review costs comprise a substantial investment of time and money by GNF.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GNF's competitive advantage will be lost if its competitors are able to use the results of the GNF experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GNF would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GNF of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 9th day of July 2024.

Lisa K. Schichlein

Lisa K. Schichlein
Senior Licensing Engineer
Regulatory Affairs
Global Nuclear Fuel – Americas, LLC
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Attachment 6
GNRO2024-00033

Curtiss-Wright Nuclear Division Proprietary Information Affidavits
(2 pages below)

CURTISS-WRIGHT AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Karl Scot Leuenroth, depose and say that I am the Division Manager of Curtiss-Wright's Scientech Division, duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below.

I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding Curtiss-Wright's information for which proprietary treatment is sought as contained in NEDC-34125P, "Grand Gulf Nuclear Station: Fuel Storage Criticality Safety Analysis with Rack Inserts," Revision 0, July 2024.

I have personal knowledge of the criteria and procedures utilized by Curtiss-Wright in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure is a list technical information related to the Snap-In Insert technology, which involve considerable research and development of intellectual property by Curtiss-Wright. Curtiss-Wright Flow Control Service, LLC (CW) information is identified by a solid underline inside double square brackets. [[This sentence is an example.{C}]] CW proprietary information in figures and large objects is identified by double square brackets before and after the object.

2) The information is of a type customarily held in confidence by Curtiss-Wright, and not customarily disclosed to the public. Curtiss-Wright has a rational basis for determining the types of information customarily held in confidence by it.

3) The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.390 with the understanding that it is to be received in confidence by the Commission.

4) The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

5) Public disclosure of the information is likely to cause substantial harm to the competitive position of Curtiss-Wright because:

a) A similar product is manufactured and sold by competitors of Curtiss-Wright.

b) Development of this information by Curtiss-Wright required expenditure of considerable resources. To the best of my knowledge and belief, a competitor would have to undergo similar expense in generating equivalent information.

c) In order to acquire such information, a competitor would also require considerable time and inconvenience related to the development of a design and analysis of a similar neutron attenuation technology for use in a spent fuel pool.

d) The availability of such information to competitors would enable them to modify their product to better compete with Curtiss-Wright, take marketing or other actions to improve their product's position or impair the position of Curtiss-Wright's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

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Karl Scot Leuenroth