ENCLOSURE 2

M190195

GEH Responses to the U.S. NRC RAIs ML19296C273 for the GE Model No. 2000 (GE2000) Transportation Package

Non-Proprietary Information

Shielding Review

NRC RAI 5.1

Revise the safety analysis report (SAR) to clearly identify the source strength shielding model assumptions.

SAR section 5.3.1.1 states, on page 5-7, "For the segmented irradiated fuel content, the NCT source geometry is a single 5.3-inch line source across which the photon and neutron sources are distributed uniformly." Staff inferred that this statement meant the applicant modeled the entire irradiated fuel source strength in a 5.3-inch line segment. The applicant confirmed the veracity of this assumption during a telephone call on September 24, 2019 (ML19269E524). The applicant should revise the SAR to clearly identify the source strength associated with the line segment described in the SAR.

This information is needed to verify compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) 71.47(a).

GEH Response

Additional information was included in Section 5.3.1.1 of NEDE-33866P Revision 5 [1] to clarify that a single 5.3-inch line source was used to represent the entire irradiated fuel content in the Normal Condition of Transport (NCT) model configuration. The updated wording is provided in Section 5.3.1.1 of M190195 Enclosures 4 [2] and 5 [3].

Criticality Review

NRC RAI 6.1

Justify the height chosen for the contents in the criticality model.

The SAR states that fuel rod contents are modeled as the maximum height that would fit within the high performance insert internal cavity height. However, there are no constraints on fuel rod height, and actual rod segments may be much shorter than the heights considered. Using a shorter fuel column height for all the rod segments in the package may result in a higher k_{eff} for the same mass of fuel, even at the same $H/^{235}U$ ratios considered, due to a lower neutron leakage geometry. The applicant should consider shorter height fuel rods, for the ^{235}U mass limit requested, in its criticality model of the package and revise the application if necessary.

This information is needed to ensure that the package meets the criticality safety requirements of 10 CFR 71.55 and §71.59.

GEH Response

Additional criticality sensitivity studies were included in Section 6.9.4 of NEDE-33866P Revision 5 [1] to assess the geometric effects of changing fuel height and diameter while holding the system Hydrogen to Uranium-235 ($H/^{235}U$) ratio constant. An overview of these evaluations is provided below; they are provided in their entirety in Section 6.9.4 of M190195 Enclosures 4 [2] and 5 [3].

1) Starting with the bounding fuel rod configuration from Chapter 6, the fuel rod radius and height were varied to maintain the same system $H/^{235}U$ ratio (i.e. same ^{235}U mass).
2) The new optimal fuel rod-to-rod pitch was determined.

As a result, the ^{235}U enrichment was limited to 5 weight percent (wt.%). The original fuel rod studies using ^{235}U at 6 wt.% in Chapter 6 were kept because they form the initial basis for the starting point for Item 1 above (i.e. initial limiting fuel rod geometry). However, the new criticality evaluations were completed using a ^{235}U enrichment of 5 wt.%. Additional information is provided in Chapter 6.

It should be noted that the new evaluations used MCNP6.2 [4], which provides identical results as MCNP6.1 [5] as documented via a direct code-to-code comparison by Los Alamos National Laboratory ([4] and [6]). Therefore, the bias and bias uncertainty as determined using MCNP6.1 remains applicable to those k-eff values calculated using MCNP6.2. A similar statement was added to Section 6.8 of NEDE-33866P.

While the Chapter 6 analysis covers a wide range of fuel rod radii, the only authorized irradiated fuel content is limited to GE Boiling Water Reactor (BWR) 10x10 designs.

NRC RAI 6.2

Revise the benchmarking evaluations in the application to include an adequate range of experiments to cover the enrichment of the fuel in the Model No. 2000 criticality model. Alternatively, describe the methods used to extrapolate the bias and bias uncertainty of the criticality code beyond the range of applicability of the benchmarking analysis, and include an additional uncertainty to account for this extrapolation.

The application discussed the experiments selected to benchmark the MCNP6 Version 1.0 criticality code and continuous energy ENDF/B-VII.1 cross section library for use in modeling the GE 2000 package with spent iron-chromium-aluminum clad fuel rod segments. Although the amendment is requesting fuel enriched up to 6.0 weight percent ^{235}U, experiments selected by the applicant for benchmarking are from only two series. In addition, the applicant included only two different enrichments: 2.35 and 4.306 weight percent ^{235}U. There are many additional experiments available in the International Criticality Safety Benchmark Evaluation Project Handbook (ICSBEP, OEDC-NEA, 2018) which would be applicable to the GE 2000 system being modeled (i.e., low enriched uranium oxide rods moderated by water). While most of these experiments include uranium enriched to less than 5.0 weight percent, there are a small number above 5.0 weight percent enrichment which would be applicable to the system, and these experiments would extend the range of applicability of the benchmarking analysis to cover the 6.0 weight percent fuel modeled in the application. Specifically, LEU-COMP-THERM (LCT) -070, -075, -078, -080, -085, -094, -096, -097, and -098 from the ICSBEP Handbook all contain uranium oxide enriched to greater than 5.0 weight percent, and these experiments may be applicable to the GE 2000 system. Absent additional experiments to extend the range of applicability, the applicant should include additional margin in the calculated upper subcritical limit to account for uncertainty due to extension beyond the range of applicability of the benchmarking analysis.

This information is needed to ensure that the package meets the criticality safety requirements of 10 CFR 71.55 and §71.59.

GEH Response

GEH is no longer pursuing ^{235}U enrichments up to 6 wt.%. Consistent with the benchmarking provided in Chapter 6, the ^{235}U enrichment is now limited to 5 wt.%. Extrapolation beyond the validation range for average enrichment is not considered significant, as the magnitude of the difference in average enrichments is small. All affected sections within NEDE-33866P Revision 5 [1] have been updated accordingly and are provided in M190195 Enclosures 4 [2] and 5 [3].

NRC RAI 6.3

Revise the application to correct inconsistencies, both in the number of experiments included and the enrichments of experiments, in the benchmarking analysis.

Section 6.8.1 of the SAR states that the benchmarking analysis included 69 critical experiments. However, Table 6.9.2-1 of the SAR only shows results from 36 experiments. Additionally, Section 6.8.1 of the SAR states that the enrichment of the selected critical experiments ranged from 2.35 to 4.92 weight percent ^{235}U. However, the maximum enrichment shown in the results in Table 6.9.2-1 is 4.306 weight percent ^{235}U. The application should be revised to correct these inconsistencies.

This information is needed to ensure that the package meets the criticality safety requirements of 10 CFR 71.55 and §71.59.

GEH Response

GEH made the corrections in NEDE-33866P Revision 5 Section 6.8.1 [1], which are provided in M190195 Enclosures 4 [2] and 5 [3].

NRC RAI 6.4

Revise the application to demonstrate that the k_{eff} results used to determine the code bias and bias uncertainty in the benchmarking analysis are normally distributed.

The applicant used two methods from NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages," to determine the code bias and bias uncertainty. NUREG/CR-6361 assumes normally distributed k_{eff} values for using these two methods. In addition, NUREG/CR-6361 requires that normality be demonstrated by a statistical test. However, the application does not contain a statistical test demonstrating the normality of the k_{eff} values. The application should be revised to include a demonstration of normality for the reported k_{eff} values in the benchmarking analysis.

This information is needed to ensure that the package meets the criticality safety requirements of 10 CFR 71.55 and §71.59.

GEH Response

Both the chi squared test (X^2) [7] and the Shaprio-Wilk method [8] were used to test for normality of the benchmark eigenvalues (k_{eff}) used in Section 6.8 of NEDE-33866P Revision 5 [1] to develop the Upper Sub-critical Limit (USL). Both of these methods confirmed that the data fits a normal distribution. Section 6.8.2.2.1 was added to NEDE-33866P Revision 5 [1] for clarification and is provided in M190195 Enclosures 4 [2] and 5 [3].

NRC RAI 6.5

Justify the exclusion of several critical experiments from the selected experiment series used in the benchmarking analysis of SAR Section 6.8 or revise the application to include these experiments.

Table 6.9.2-1 of the SAR shows that experiments used in the benchmarking analysis were selected from LCT-010 and -017 of the ICSBEP Handbook. However, cases 14-19 and 28-30 of LCT-010 and case 1-14 of LCT-017 were excluded. The application should be revised to include these experiments, or the applicant should justify excluding them from the benchmarking analysis.

This information is needed to ensure that the package meets the criticality safety requirements of 10 CFR 71.55 and §71.59.

GEH Response

The benchmarking analysis in NEDE-33866P Section 6.8 [1] included a subset of the LEU-COMP-THERM-010 and LEU-COMP-THERM-017 critical experiments from the International Criticality Safety Benchmark Experiment Program (ICSBEP) Handbook [9]. These experiments were chosen because they were publicly available in the ICSBEP Handbook and adequately covered the material to be transported within the GE2000. Those additional benchmark cases that were excluded from LEU-COMP-THERM-010 (cases 14-19 and 28-30) and LEU-COM-THERM-017 (cases 1-14) were determined to be similar enough to those used for the benchmarking analysis in NEDE-33866P Section 6.8. Therefore, it was not necessary to continue the process of independently creating new inputs for the LEU-COMP-THERM-017 and modifying the remaining LEU-COMP-THERM-010 input files.

Inclusion of these other benchmark cases would not provide additional benefits to the MCNP6 [5] benchmarking analysis. The benchmarking analysis shows that MCNP6 with the ENDF/B-VII cross-section library does not have a trend, linear or otherwise, for those benchmarks used. Inclusion of other benchmark cases would not change this conclusion.

Due to the limited number of ICSBEP experiments used in the MCNP6 benchmarking analysis, the resulting USL is overly conservative as compared to other USLs derived from benchmarking with more critical experiments.

The MCNP6 benchmarking analysis in NEDE-33866P [1] is acceptable. No changes were made to NEDE-33866P [1] for RAI 6.5.

References:

1. GE Hitachi Nuclear Energy, NEDE-33866P, “Model 2000 Radioactive Material Transport Package Safety Analysis Report,” Revision 5, January 2020.
2. GE Hitachi Nuclear Energy, M190195 Enclosure 4, “Amended Sections and Pages for NEDE-33866P GE2000 SAR Revision 5 – GEH Proprietary Information – Non-Public,” January 2020.
3. GE Hitachi Nuclear Energy, M190195 Enclosure 5, “Amended Sections and Pages for NEDE-33866P GE2000 SAR Revision 5 – Non-Proprietary Information,” January 2020.
4. LA-UR-18-20808, “MCNP Version 6.2 Release Notes,” Los Alamos National Laboratory.
5. T. Goorley et al., "Initial MCNP 6 Release Overview - MCNP6 Version 1.0," Los Alamos National Laboratory, LA-UR-13-22934, April 2013.
6. LA-UR-17-24406, “Verification of MCNP6.2 for Nuclear Criticality Safety Applications,” Los Alamos National Laboratory, June 2017.
7. J.R. Taylor, “An Introduction to Error Analysis,” page 268-271, 2nd Edition, University Science Books, 1997.
8. S.S. Shapiro and M.B. Wilk, “An Analysis of Variance Test for Normality (Complete Samples),” General Electric Co. and Bell Telephone Laboratories, Biometrika, Vol. 52, No. 3/4, 1965.
9. Organization for Economic Cooperation and Development - Nuclear Energy Agency (OECD-NEA), "International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03," 2014.