June 9, 2015

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
GE-Hitachi Nuclear Energy
P.O. Box 780 M/C A-18
Wilmington, NC 28401

SUBJECT: NON-PROPRIETARY VERSION OF REQUEST FOR ADDITIONAL INFORMATION REGARDING REVIEW OF LICENSING TOPICAL REPORTS NEDC-33376P, "LANCR02 LATTICE PHYSICS MODEL DESCRIPTION" AND NEDC-33377P, "LANCR02 LATTICE PHYSICS MODEL QUALIFICATION" (TAC NO. ME1695)

Dear Mr. Head:

By letter dated June 30, 2009, Global Nuclear Fuel – Americas, LLC submitted for U. S. Nuclear Regulatory Commission (NRC) staff review Topical Reports (TRs) NEDC-33376P, Revision 1, "LANCR02 Lattice Physics Model Description" and NEDC-33377P, Revision 1, "LANCR02 Lattice Physics Model Qualification" (Agencywide Documents Access and Management System Accession Nos. ML091820493 and ML091820513). Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. Enclosed with this letter is a non-proprietary version of our Request for Additional Information (RAI). On March 23, 2015, James Harrison, GEH Vice President, Fuels Licensing, Regulatory Affairs, and I agreed that the NRC staff will receive your response to the NRC staff's RAI questions within 60 days of receipt of this letter. If you have any questions regarding the enclosed RAI questions, please contact me at (301) 415-1002.

Sincerely,

/RA/

Joseph A. Golla, Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosure:
RAI Questions (Non-Proprietary)

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REQUESTS FOR ADDITIONAL INFORMATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NEDC-33376P, REVISION 1, "LANCR02 LATTICE PHYSICS MODEL DESCRIPTION" AND

NEDC-33377P, REVISION 1, "LANCR02 LATTICE PHYSICS MODEL QUALIFICATION"

GLOBAL NUCLEAR FUEL – AMERICAS, LLC (TAC NO. ME1695)

MODEL DESCRIPTION NEDC-33376P, REVISION 1 RAIs

RAI 1: Range of Applicability

1-1. Please provide more specific details regarding the range of application of LANCR02. To this end, please specify any limits on the following parameters:

- The range of beginning of life (BOL) uranium enrichment
- The range of BOL plutonium concentration
- The range of BOL gadolinia concentration
- The range of in-channel void fraction
- The range of inactive flow channel void fraction (e.g., bypass)
- The range of channel bow

1-2. Please also specify any inherent limitations of the LANCR02 methodology that would preclude the application of this method to particular analyses. As an example, the code may presume symmetry of the lattice along particular dimensions, and as a consequence may not be applicable to non-symmetric fuel designs.

1-3. Please provide the functions and restrictions for LANCR02 that are specified in the user manual.

1-4. Lattices have been proposed that include control blade spans that exceed one fuel bundle. Is it the intent to seek approval of LANCR02 to analyze such lattices?

RAI 2: Items in the Cross-section Libraries

2-1. Please clarify what is meant by the following identifiers in Table A-2:

- PSD-1
- PSD-2
- Act_resd
- FP_resd
- Energy

2-2. Please specify how the "H2O" and "D2O" cross-sections were generated. Do these cross-sections consider chemical binding effects?

Please incorporate this information in a revision to the LANCR02 model description licensing topical report (LTR).

ENCLOSURE

RAI 3: Gamma Cross Sections

3-1. Please specify the source of the gamma cross sections.

3-2. Please specify the source of the fission and capture gamma spectra. Please incorporate this information in a revision to the model description LTR.

RAI 4: NJOY Broadened Libraries

The staff requires additional details regarding the generation of the temperature dependent 118 group libraries.

4-1. Please specify the standard production temperatures that are used in NJOY to broaden the evaluated nuclear data file (ENDF) cross-sections.

4-2. Describe the process for fitting the f-tables to NJOY output. Please incorporate this information in a revision to the model description LTR.

RAI 5: Energy Boundaries of the Group Structures

5-1. Verify that 1.0E-5 electron-volts (eV) are the lower boundary of the final group structure in Table A-4.

5-2. Please clarify the **[**

] mentioned below Table A-4?

5-3. Verify that 1.1175E+05eV is the lower boundary of the eighth group in Table B-1.

RAI 6: Thermal Microscopic Neutron Cross-section Processing

6-1. Please describe any features of the process for generating fine group cross-sections in the thermal energy range that account for differences in the neutron flux spectrum at low energies.

6-2. Does LANCR02 accept coolant temperature as an input?

6-3. If so, where and how is this information utilized in the cross-section generation process?

Please incorporate this information in a revision to the LANCR02 model description LTR.

RAI 7: Background Cross Section Calculation

7-1. Please provide additional information regarding the determination of an acceptable Bell factor.

7-2. Are the Bell factors determined from Monte Carlo N-Particle (MCNP) calculations?

7-3. If so, how are the Bell factors deemed appropriate for problem-specific application if a set of pre-determined Bell factors are used for standard production purposes?

Please incorporate this information in a revision to the model description LTR.

RAI 8: Isolated Pin Flux Calculation

8-1. When performing the isolated pin flux calculation to determine the Dancoff factor, how is the calculation performed?

8-2. Please describe the problem size and specify the boundary conditions that are applied.

RAI 9: Dancoff Factor Calculation for Non-Fuel Pin Regions

The discussion regarding the calculation of the Dancoff factors for non-fuel pin regions is not sufficiently detailed for the NRC staff to review this method.

9-1. Please provide a more detailed description of the calculation of the Dancoff factors for these other regions.

9-2. Please comment on the validity of **[ ]**.

RAI 10: Ultra-fine Group Calculation

The staff requires additional descriptive details of the ultra-fine group structure.

10-1. How are the ultra-fine group-wise cross sections determined from the continuous cross sections?

10-2. Are there a set number of ultra-fine groups used for this analysis, or is it determined on a case specific basis?

RAI 11: Resonance Interference Effects

The model description LTR describes an ultra-fine group spectrum calculation that is performed to account for resonance interference effects utilizing the narrow resonance (NR) approximation. The LTR states that this approximation is less accurate below 50 eV. The staff would expect that at lower epithermal energies (1-10 eV) strong low-lying resonances may be inaccurately treated in the current method.

11-1. Comment on the accuracy of this method to predict plutonium-240 absorption. Please specifically address the absorption resonance at 1.056 eV.

11-2. The staff anticipates that LANCR02 depletion calculations will be performed at high instantaneous and historical void conditions (such as 100% in-channel void). Please discuss any consequences of high void depletion modeling given potential inaccuracies in the treatment of strong low-lying resonances. Specifically address gadolinium and plutonium.

RAI 12: Sub-Bundle Void Distribution

12-1. Please confirm that the sub-bundle void distribution model is fully consistent with the previously approved void distribution model in TGBLA06. Please provide a direct comparison between pin-wise void fractions generated by TGBLA06 and LANCR02.

12-2. If there are any deviations, please note these deviations and justify them.

RAI 13: Buffer Zone

Please discuss the rationale behind treating the buffer zone based on lattice average quantities as opposed to nearest neighbors.

RAI 14: Gas Gap

14-1. Please describe at what stages in the flux condensation calculations and in the lattice spatial flux distribution calculations that the gas gap is considered.

14-2. Please address equation (7) in terms of the source of the geometric data (cladding inner diameter or fuel pellet outer diameter).

14-3. Please provide clarifying text to accompany Figure 2-1. Specifically, is the gap treated as part of the cladding or fuel region, or neglected?

14-4. Please clarify Figures 7-1, 7-2, and 7-3 in terms of the treatment of the gas gap.

14-5. Please list and justify any assumptions made in the calculation regarding the gas gap.

Please incorporate this information in a revision to the model description LTR.

RAI 15: Pin-Cell Calculations for Non-Fuel Pins

The pin-cell calculations appear to require a cylindrical geometry similar to a fuel pin.

15-1. Please provide a description of how the pin-cell spectra are calculated for non-fuel pins, such as water rods and the water gap.

15-2. Please also provide additional details regarding the pin-cell calculations for plena. These details should include a discussion of any features that address the very low density of the gas.

RAI 16: Control Blade and Channel Box Two-Dimensional Coupling

The NRC staff requires additional details regarding the two-dimensional coupling calculation in terms of the treatment of the control blade and the channel box.

16-1. The channel box is very thin. Is the channel box homogenized with inter- or intra-assembly water?

16-2. If so, does this introduce any appreciable error in the calculation of the spectra at or near the channel?

16-3. The control blade may extend into mesh cells such that only a fraction of a mesh cell is filled with part of a control element. How are these cells homogenized?

16-4. Would such homogenization introduce error in the calculation of the contribution of the tips of the control blade to its worth?

RAI 17: Calculation of the Angular Dependent Neutron Source

In the method of characteristics solution of the detailed two-dimensional flux distribution, the LTR states that the neutron sources may be calculated using either transport corrected cross-sections or explicit anisotropic scattering.

17-1. Which approach is used in LANCR02?

17-2. Are source neutrons other than prompt or delayed fission neutrons considered (e.g., $(n, 2n)$ reactions)?

17-3. Please provide an equation that relates the angular source in any mesh to the local flux and cross-sections consistent with the LANCR02 method. This should consider the differential scattering or double differential scattering cross-section.

17-4. Please provide the source of the scattering matrix (or matrices) used to perform the mesh source calculation.

RAI 18: Volume Preservation

Please provide figures that are substantially similar to the figures provided in slides 11 and 12 of the LANCER pre-submittal meeting held at NRC headquarters in November 2008.

Please incorporate this information in a revision to the LANCR02 model description LTR.

RAI 19: Energy Dependent Azimuthal Angles

19-1. When the azimuthal directions are adjusted for perfect reflection, are the weights associated with the angles updated?

19-2. If not, please describe those aspects of the method that ensure this does not introduce appreciable error.

19-3. Please provide the standard production energy dependent number of azimuthal directions.

19-4. Considering that the staff requested additional information in another RAI regarding the double-differential cross section, when downscattering occurs how are the different azimuthal separations and associated weights partitioned to model anisotropic scattering where the energy loss results in a change in energy group?

19-5. Please provide an assessment of the validity of any assumptions that are made to model the process of anistropic downscatter.

19-6. The LTR appears to indicate that this azimuthal energy dependent quadrature may be **[ ]**. How is the adequacy of the azimuthal quadrature confirmed to be acceptable on **[ ]**?

Please incorporate this information in a revision to the model description LTR.

RAI 20: Polar Quadrature

The LANCR02 model description LTR is not clear regarding the polar quadrature sets. In particular, the NRC staff cannot determine which of the available quadrature sets is the **[ ]** set.

20-1. The LTR states that three optimal quadrature sets are specified in LANCR02 as being available to the user. Are all three of these sets generated using the optimization method of Tabuchi-Yamamoto where they vary in polar order?

20-2. The LTR states that the Legendre quadrature sets come directly from Reference 13 of the LANCR02 model description LTR. Does this refer specifically to the P_N quadrature sets?

20-3. The LTR states that the **[ ]** quadrature. Please specify these angles and weights. Please incorporate this information in a revision to the LANCR02 model description LTR.

20-4. Please describe how these were determined (either Tabuchi-Yamamoto optimization, Nth order Legendre polynomial approximation, or by some other method).

20-5. The LTR states that results using the **[ ]**. Please demonstrate this assertion.

RAI 21: Cold Shutdown Margin Cross-sections

21-1. When using LANCR02-generated data to perform downstream shutdown margin calculations, how are the bladed cross-sections determined? In particular, the fundamental mode calculation adjusts the radial power distribution to deplete the lattice in a “critical” manner.

21-2. Under cold shutdown conditions the reactor should be in subcritical condition, and the fundamental mode adjustment to the power shape for determining the nuclear parameters may introduce a bias because the flux shape is artificially adjusted. Please describe how nuclear data are calculated to perform cold shutdown evaluations.

RAI 22: Cold Calculations

When determining nuclear parameters to perform cold calculations, how are moderator temperature effects taken into account?

RAI 23: Fundamental Mode Adjoint Flux

Equation (47) appears to be in error. The staff would expect (47) to read as:

$$\bar{\Sigma}_r^g \Psi^{+g} = \sum_{g' \neq g} \bar{\Sigma}_s^{g \to g'} \Psi^{+g'} + \nu \bar{\Sigma}_f^g \sum_{g'} \chi^{g'} \Psi^{+g'}$$

Please explain Equation (47)

RAI 24: Prompt and Delayed Spectra

Equations (45) and (46) indicate that an averaged spectrum is used to perform the adjoint weighting. Please provide some clarifying details.

24-1. The prompt and delayed spectra appear isotope independent. If so, please justify this approximation.

24-2. The equations include a bar over a fission spectrum symbol in the equations. The staff takes this to be an average quantity. It appears to be the spectrum for the total fission yield (prompt + delayed). Is this the case?

24-3. When LANCR02 is performing the calculation, does it perform the integration based on the prompt and delayed spectra as shown in the first portion of Equation (45) or (46) or is the calculation based on the second portion of the equations?

24-4. What does the superscript “j” denote?

24-5. The staff assumes that subscript “γ” denotes delayed. Please confirm.

RAI 25: Power Calculation

Please provide clarification regarding the power calculation.

25-1. When calculating the kinetic energy deposited from epithermal neutron capture, the calculation is performed using a multi-group calculation, how is the neutron energy treated?

25-2. What is the source of the beta energy release data? Please incorporate this information in a revision to the model description LTR.

25-3. Please describe how heat deposition factors are determined. For example, neutron slowing down energy deposition in the coolant. The LTR states that this calculation is not part of the gamma transport and gamma heat deposition calculation.

25-4. Does LANCR02 consider/calculate heat deposition in spacers?

RAI 26: Instrumentation Model

26-1. Please provide a comprehensive description of the application of the detailed instrument model in LANCR02.

26-2. Using the detailed approach and simplified J-factor approach, provide a comparison of the models to demonstrate the relative efficacy of these two approaches. Please consider typical and modern instrument designs (i.e., thermal TIP, gamma TIP, and gamma thermometers).

26-3. Is the detailed instrumentation model capable of accounting for spacer effects on gamma instrument signals?

RAI 27: Depletion Chains

The staff requires additional characterization of the depletion chains.

27-1. Are Figures 5-1 through 5-4 comprehensive?

27-2. To assist the staff in its review of these chains, please provide a comparison of the LANCR02 chains to the TGBLA06 chains.

RAI 28: Dual Time Step

28-1. Please specify in greater detail the conditions where the dual time step model is deactivated.

28-2. Please provide specific details as to how LANCR02 will treat lattices with “split” gadolinia loadings, for example, a lattice that includes fuel pins with two different concentrations of gadolinia burnable poison.

RAI 29: Control Blade Depletion

How is the control blade depletion model used?

RAI 30: Gamma Sources

Please clarify that the fission gamma sources include the effect of delayed gamma emission.

RAI 31: Convergence

31-1. Please specify the convergence criteria used in the qualification analyses.

31-2. Please specify whether or not the convergence criteria are internal to the LANCR02 code or specified through user input.

31-3. Does user guidance exist for the selection of appropriate convergence criteria if these values are input on a problem-specific basis?

31-4. Please provide any user guidance to this effect including any available guidance in the LANCR02 user manual.

31-5. If maximal limits are established, either internal to the code or through administrative controls, how do these limits compare to those employed for the qualification analysis.

31-6. If maximal convergence criteria limits have not been established, please establish such limits to be used in standard production cases. If the established limits are greater than those used in the qualification analyses, please demonstrate that the accuracy of the results, throughout the range of the applicability of LANCR02, is not unreasonably affected.

RAI 32: Code Output

Please provide the following clarifying details regarding the LANCR02 code output.

32-1. When determining the flux discontinuity factors, is the lattice flux solution utilized based on the leakage corrected flux?

32-2. The listing of code output includes a term "BDC." These appear to be boundary diffusion coefficients. What is the purpose for generating these parameters?

32-3. The CDFNW calculation refers to the southwest corner. The LTR states that LANCR02 is not limited to diagonally symmetric lattices, but discontinuity factors would be required for the northeast corner. Is this output not listed in the LTR?

32-4. Please provide equations for the FLUX1 and FLUX1C outputs. Please incorporate this information in a revision to the model description LTR.

32-5. Please provide the LANCR02 output descriptions that provide heat deposition factors in fuel bundle structures (spacers, cladding, channels, and water rods) and heat deposition factors for the coolant. Please incorporate this information in a revision to the model description LTR.

RAI 33: Model Updates

33-1. **[**

] however, such capability could be applied to an expanded application scope – which would require NRC review and approval. An example may be **[**

]. In these instances the predictive capabilities of the code are being relied upon for an application purpose that is beyond the scope of the staff's current review. Please update this section of the LTR to state that **[**

].

33-2. In terms of model updates to implement the LANCR02 transport solutions [ ] without NRC review and approval, the staff requires clarification on this proposed model update. The staff cannot presume the [ ] would have to be implemented. This type of change would be considered by the staff a departure from the approved method that would require review and approval. However, the staff has some degree of assurance that [ ] Revise the model description LTR to include a requirement that when LANCR02 is updated to [ ]

RAI 34: Empirical Tuning

34-1. Please provide descriptive details of any "corrective models" in the LANCR02 method. Here "corrective models" refers to adjustment factors or additional terms that are applied within the base methodology to tune calculated results to match more accurate transport calculations. An example may be adjusting water rod cross sections internal to the code to fit the slowing down power in water rods to more accurate predictions of water rod slowing down using higher order transport methods.

34-2. TGBLA06 included several of these types of models, please address how the analogous phenomena are addressed in LANCR02. At a minimum please address the following:

- [
-]

RAI 35: Water Cross Specific Questions

35-1. Relative to the fuel assembly designs with water rods or water boxes, it would appear that significant geometric approximations are made for water crosses. These approximations may introduce errors in the analysis of these geometries that would not be apparent in the analysis of designs with water rods or water boxes. Please provide a complete list of the geometric approximations that are made in order for LANCR02 to model the water wing fuel design geometry. Please justify each of these. Where possible, please provide some quantitative basis to demonstrate the magnitude of the error introduced into the analysis, otherwise provide a qualitative basis. Compare these errors to typical values for biases and uncertainties derived from the comprehensive qualification.

35-2. Please provide details of the two-dimensional coupling calculation as it is applied to water-cross lattices. In particular please address the treatment of the diamond and wings in the homogenization process of the cell results. Section 7.4.2 does not describe the water wings of the water cross design. Please provide a detailed description, including equations, that describes how LANCR02 approximates and analyzes these geometries.

35-3. Please describe how the sub-bundle void distribution model is executed for water cross designs.

35-4. Please describe how the out-of-channel flow area for water cross designs is calculated. Please also provide details of how the UWR parameter is calculated.

MODEL QUAILIFICATION NEDC-33377P, REVISION 1 RAIs

RAI 36: Standard Production and Qualification Analyses

Please clarify what user-selected options in LANCR02 were utilized for the qualification calculations provided in the qualification LTR (NEDC-33377P, Revision 1, "LANCR02 Lattice Physics Model Qualification Report"). Examples may include the number of parallel rays or the power density used for the depletion. If there are differences between the options selected for the qualification analyses and standard production analyses, please provide justification for the differences.

RAI 37: Doppler Coefficient

While "CDOP" is used to calculate the Doppler coefficient, and is representative of the change in lattice reactivity with temperature, it is not technically the Doppler coefficient. Rather, it is a parameter that characterizes the Doppler coefficient (see Equation 10 of NEDO-20964-A). Please reconcile this inconsistency and update the qualification LTR.

RAI 38: "W/F"

The NRC staff assumes that "W/F" refers to the water to fuel ratio. This ratio as provided in Table 4.4-1 does not agree with the moderator to fuel volume ratio provided in the International Handbook, September 2008 edition. Please reconcile this inconsistency and update the qualification LTR to define "W/F."

RAI 39: MCNP Light Water Reactor Critical Benchmarks

Please provide Reference 8: NEDO-32028, "MCNP: Light Water Reactor Critical Benchmarks," dated March 1992.

RAI 40: MCNP Results for LWR Critical Benchmarks

There appear to be minor inconsistencies with the MCNP results reported in the International Handbook and the GNF MCNP results for several cases (LEU-COMP-THERM-001, -002, -006, and -039) when the same cross section libraries are referenced (Evaluated Nuclear Data File B-VII.0 (ENDF/B-VII.0)). Please reconcile.

RAI 41: Test Suite Perturbations

For completeness, please specify the lattice-type analyzed (C-, N-, S-, or D-) and the control blade design in the description of the test suites in the qualification LTR.

RAI 42: Mixed Oxide Test Suite

The mixed oxide (MOX) suite does not consider gadolinia-bearing MOX fuel rods. Is this a limitation for LANCR02?

RAI 43: Reactivity Worth of Depleted Lattice Test Suite

43-1. Please describe the process by which depleted fuel compositions are determined for the MCNP calculations.

43-2. Table 5.5-16 appears to be inconsistent with the LTR text in Section 5.5.7. Please reconcile this inconsistency.

RAI 44: Gadolinia Loading

44-1. To provide the staff with reasonable assurance in the capability of LANCR02 to simulate the depletion of gadolinium using the standard two-step approach, please supplement the Depletion Test Suite (Section 6) with a comparison of gadolinium-155 and gadolinium-157 pin-wise inventory between LANCR02 and MONTEBURNS.

44-2. Please supplement test suite 7 with some cases at alternative temperatures to compare the Doppler reactivity predictions.

44-3. Please supplement test suite 7 with some controlled cases to compare the control rod worth predictions.

RAI 45: Enrichment Test Suite

45-1. It is assumed that for each enrichment the void fraction increases from left to right. Please update Figures 5.9-2 and 5.9-3 to distinguish the cases according to void fraction.

45-2. Please provide a pin peaking factor figure similar to Figure 5.1-3 of this LTR.

45-3. There appears to be a typographical error in Section 5.9.5. The maximum eigenvalue error appears to be **[ ]** according to Table 5.9-4.

RAI 46: Borated Lattices

Please confirm that the units of boron concentration are provided in parts per million natural boron equivalent.

RAI 47: Control Blades

47-1. Please define the following terms in the qualification LTR: “OEM” and “ABB.”

47-2. Please update Figure 5.11-2, 5.11-3, and 5.11-4 to depict the various void fractions. The NRC staff assumes that the void fraction increases from left to right in these figures.

47-3. The alternative control blade design test suite does not consider cold eigenvalue. The NRC staff notes that other test suites address the variation in reactivity with temperature. Please assist the NRC staff in assessing the capability of LANCR02 to provide cross-section data for cold shutdown margin calculations by providing statistical summary results for the 0 percent void fraction cases.

47-4. It appears there is a trend **[ ]**. Please clarify the LTR text regarding observed trends.

RAI 48: Channel Bow

48-1. The channel bow results appear to consider water rod bow within the channel. Has this type of bow been observed?

48-2. The degree of bow considered is 2 millimeters (79 mils). How does this compare with the expected range of bow for current operating plants?

RAI 49: Fuel Rod Variation

49-1. Please clarify in the qualification LTR what is meant by **[ ]**

49-2. Please provide the dimensions of the fuel rods in this test suite in the qualification LTR.

RAI 50: Neutron Balance

Is the production term for the zirconium isotopes listed in Tables 15.6-3 through 15.6-6 from (n, 2n) reactions?

RAI 51: Infinite vs. Critical Flux weighting

A study in NUREG-CR-7164 has shown that appreciable error in the calculation of β_{eff} may be introduced when using the formulation in LANCR02. Specifically, the issue arises when using a critically adjusted (fundamental mode/B1) adjoint flux in the calculation of β_{eff} (the approach LANCR02 will use for production cases) rather than an infinite adjoint flux. See NUREG-CR-7164 Section 5 for detailed information. Please provide a comparison of β_{eff} as calculated using an adjoint critical flux weighting and an adjoint infinite flux weighting for both controlled and uncontrolled lattices. Also, please discuss any other differences in the results of LANCR02 that may be introduced by using a critical spectrum as compared to an infinite spectrum.

RAI 52: Lattice Compositions and Test Suites

Please provide a summary of the lattice compositions (e.g., Gadolinium loading, fuel enrichment, etc.) used in each of the qualification test suites. If any lattice's composition changes for a specific test suite in the qualification LTR, please indicate these changes in the summary and at the beginning of the corresponding test suite section. Please incorporate this information in a revision to the model qualification LTR.