ENCLOSURE 2

MFN 09-647 Supplement 1

Response to NRC RAI 8 - NEDC-33173P, Supplement 3

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 09-647 Supplement 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]]

RAI # 8

NRC Staff Question

Void history exposure reactivity coefficient biases and uncertainties predicted for GE14 may not be applicable to GNF2. The staff notes that the GNF2 heavy metal loading is higher than for GE14 and, as such, at equivalent void conditions the GNF2 spectrum is expected to be harder than the GE14 spectrum on this basis.

Please provide a limited demonstration that is similar to Table 2-11 from the IMLTR for the GNF2 lattices presented in IMLTR Supplement 3. It is not necessary to provide an equally comprehensive table, but please consider the higher exposure range and please focus on lattices expected to experience higher void fractions located near the top of the core (e.g., PLN2, VAN2, etc.).

Alternatively, the staff is aware of a higher order transport based lattice method under development by GNF, LANCER 2. It would be acceptable to address this RAI with a table similar to Table 2-11 that compares the TGBLA06 void reactivity coefficient biases and uncertainties for GNF2 compared to LANCER 2.

Alternatively, the staff is aware that a void history exposure reactivity coefficient biases and uncertainties were incorporated in TRACG04. This model requires a database generated using MCNP and TGBLA06 for GE14 and GNF2 lattices. Please provide a comparison of these void reactivity coefficient data between the two fuel designs. To justify the continued applicability of the bias and uncertainty used in ODYN.

Alternatively, using a GNF2 MELLLA+ core design, provide sensitivity studies using TRACG04 (with and without the void history exposure reactivity coefficient biases and uncertainties model) to generate a table similar to Table 2-10 of the IMLTR to demonstrate that the sensitivities for GNF2 are essentially the same or conservative relative to GE14.

GEH Response

Overview

This response addresses the RAI by means of the approach suggested in paragraph 4 of the RAI. This response is an update to the previous RAI responses related to the void coefficient correction model in TRACG04. The void coefficient corrections have been updated based on extensive TGBLA06/MCNP comparisons for GNF2 lattices. The method to account for the biases and the uncertainties in the void coefficient model had previously been modified to include the effects due to void history (VH). Section *C1AX* in Reference [8-1] describes the TRACG methodology with the void history effects included. Calculations had previously been performed including the void history effects as part of the void coefficient correction model. By comparison to similar calculations performed with the model deactivated, these calculations reveal that correcting for biases in the void coefficient can result in small changes to the key AOO calculated parameter of ΔCPR/ICPR. A similar comparison updated to include the GNF2 lattices is indicated here as Figure 8-1. The figure shows a typical calculated CPR response for the most limiting channel for the usually limiting pressurization event, a turbine trip with no bypass (TTNB). [[

]] These impacts may vary by core and cycle since the model depends on core and cycle-specific elements such as exposure, instantaneous voids and void history. One key point is that the impacts, either positive or negative, are incorporated in the TRACG AOO methodology as amended in Reference [8-1] to incorporate the effects due to void history in determining the biases and uncertainties in the void coefficient on a plant and cycle-specific basis. [[

]] Both key points were previously supported in Reference [8-1] and are by this response also shown to continue to be supported for applications involving GNF2 fuel.

In addition to the ΔCPR/ICPR value tabulated for the limiting channel at the limiting point in time (as plotted in Figure 8-1), Table 8-1 shows how the void coefficient correction model impacts other key transient quantities. [[

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Figure 8-1 Typical CPR Impact of Updated Void Coefficient Correction Model

Table 8-1 Typical Impact on Other Key Transient Outputs
(turbine trip with no bypass)

Description	TRACG04P model on	TRACG04P model off	ODYN
peak total power (%)	392	357	426
peak vessel pressure (MPa)	8.909	8.892	8.842
limiting ΔCPR/ICPR	0.165	0.155	0.200
peak centerline temperature (K) (UO_2 melting occurs at ~3000 K)	1568	1565	not available
max. hoop / yield stress ratio	0.0904	0.0898	not available
water level decrease (inch)	44.7	44.7	45.0

Additional Details

The technical basis for the TRACG04 model was previously provided in Reference [8-1] so it will not be duplicated here. This response will simply compare how the model has been updated to incorporate additional information for GNF2 lattices.

As previously described in Reference [8-1], TRACG04 uses a 3-D neutron kinetics model based on the PANAC11 model[8-2] that uses neutronics parameters provided by TGBLA06. The nodal reactivity is calculated[8-3] [[ ]]. All of these parameters are expressed in terms of the instantaneous moderator density and also include a dependency on moderator density history and nodal exposure. Consequently, the infinite multiplication factor also has these same dependencies.

The biases and uncertainties in void coefficient as determined from the PANAC11 originate in the biases and uncertainties in the infinite lattice eigenvalues (k_∞) calculated by the TGBLA06 lattice physics code [[ ]] Values of k_∞ at a number of points were calculated for a representative set of lattices with 10x10 geometry at [[ ]] different exposures of [[ ]] and at different void histories (VH) of [[ ]] for in-channel instantaneous voids (IV) of [[ ]] using both TGBLA06 and MCNP. The number of lattices of each type and other details related to the previous and current datasets are provided in Table 8-2. The processing of the k_∞ point values to determine the void coefficient values is the same as used previously so the details provided previously in Reference [8-1] will not be repeated here.

In the previous evaluations described in Reference [8-1], a number of 10x10 lattices (set "a") were considered, but none represented the exact GNF2 partially-rodded lattices. However, the previously-considered fully-rodded lattices were representative of those found in the lower part of GNF2 bundles. Many additional lattices (set "b") representative of those used in GNF2 bundles have been evaluated. Table 8-2 provides details about the number of lattices in sets "a" and "b". The additional new lattices in set "b" were used together with the lattices previously evaluated for set "a" in order to extend the validity of the TRACG04 model to GNF2 lattices.

Table 8-2 Details of Previous and Current Databases

Description or Quantity	Set "a"	Set "b"	Combined "a" and "b"
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			]]

As previously observed in Reference [8-1], the implementation of void history effects into the TRACG04 model has allowed us to demonstrate (see Figure 8-1 and Table 8-1) that the CPR response with the complete model produces a ΔCPR/ICPR value that is [[ ]] resulting in a slightly [[ ]] minimum CPR value than when the model is turned off. For comparison purposes, the CPR response calculated by ODYN for the same core and conditions is also shown. [[

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Several statistical tests were performed to see how the new lattices for GNF2 bundles in set "b" were different or similar to those in set "a". By performing two-sample t-tests it was determined that it was appropriate to make the following combinations. [[

]] The resulting composition of the combined dataset is indicated in the rightmost column and bottom four rows of Table 8-2.

Like before, the response surfaces for the biases and uncertainties in the void coefficient that are modeled in TRACG04 are obtained from the derived void coefficient values by characterizing the response surfaces as a function [[

]]. The response surfaces from the previous evaluation were shown in Reference [8-1] so they are not shown here; however, a visual comparison of the figures from Reference [8-1] to the updated ones shown here reveals that they are quite similar [[

]].

The updated response surfaces for the relative biases are shown in Figure 8-2 and the updated response surfaces for the relative standard deviations are shown in Figure 8-3. In both figures there are [[ ]] surfaces corresponding to different void histories. For each surface the vertical axis is the in-channel instantaneous void fraction and the horizontal axis is the nodal exposure. The color scheme shown in the legends at the top of the figures denotes the ranges for the biases in Figure 8-2 and the ranges for the standard deviations in Figure 8-3. A negative bias means that the TGBLA06 void coefficient is smaller in absolute magnitude than the corresponding MCNP value.

The response surfaces for the biases in Figure 8-2 and the uncertainties in Figure 8-3 show that in the exposure range from about 15 to 25 GWd/STU that corresponds to the limiting CPR bundle for AOO analyses that the void coefficient bias [[

]] For exposures less than 15 GWd/STU the PANAC11 standard process as supplied with TGBLA06 nuclear information [[

]] Also for low exposures, the uncertainties tend to be [[

]]. As the poison is *burned* and the bundles approach their peak reactivity and power, the void coefficient biases and uncertainties [[

]]. Void history does not begin to make any discernable differences until the exposure

has exceeded about 25 GWd/STU as previously noted in Reference [8-1]. At exposures above this point the standard process tends to [[

]] A larger void coefficient (in the absolute sense) is conservative because it tends to produce a more dynamic power response and a less favorable CPR response. [[

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The relative biases in Figure 8-2 are higher for exposures less than 15 GWd/STU simply because the absolute void coefficient values to which the relative values are normalized are smaller for these exposures. The same statement applies to the relative uncertainties shown in Figure 8-3. The *standard process* used in PANAC11 to capture these trends is based on void coefficient dependencies with respect to IV that were established at a void history of 40%. As previously noted in Reference [8-1], at exposures above 25 GWd/STU the standard process tends to [[

]] The model used in TRACG04 to correct the standard process remains unchanged from what was described previously in Reference [8-1]; therefore, those details are not repeated here.

As previously explained in Reference [8-1],

]]. The normality of these normalized residual errors for the entire population was analyzed to determine whether it is appropriate to assume that the residual errors are normally distributed. The histogram for the [[ ]] normalized standard residual errors is shown in Figure 8-4 together with the red normal curve and a statistical summary for the residuals.

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Figure 8-2 Void Coefficient Relative Bias Updated for GNF2 Lattices

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Figure 8-3 Void Coefficient Relative Standard Deviation Updated for GNF2 Lattices

Because this population of residuals is in standard form, it should theoretically have a mean of zero and a standard deviation of unity. The actual mean of the residuals is essentially zero but the standard deviation is 0.976 which means that modeling the residuals with an assumed normal

distribution conservatively yields a larger variability. [[

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[[

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Figure 8-4. Histogram and Statistical Summary of the Standard Residual Errors

How TRACG04 applies the uncertainties and biases has not changed from what was reviewed and approved by the NRC staff in connection with Reference [8-4]. [[

]] As stated previously in Reference [8-1], the impact of not modeling the void coefficient biases is on the order of [[ ]] in the TRACG calculated values of transient ΔCPR/ICPR for most fast pressurization events. The current results shown for GNF2 in Table 8-1 are consistent with this generalization. Whether the bias is conservative or not depends on the exposure distribution and the relative water density distribution in the core and that is why it is important for a best-estimate calculation like TRACG

to model the bias as a function of the nodal conditions. On the other hand, the model used in ODYN (where the bias is not considered) is seen from the comparisons presented in Figure 8-1 and Table 8-1 to be adequately conservative even without considering the bias. This is the justification for continuing to use ODYN for transient applications involving GNF2 fuel.

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Figure 8-5. Normality Probability Plot of the Standard Residual Errors

For sensitivity studies, a core-wide bias and uncertainty in void coefficient can be specified through the TRACG04 input in a way that is comparable to how ODYN would apply this uncertainty. As an example of the importance of the void coefficient uncertainty, consider that for a typical BWR/4 plant a variation at the one-sigma level of [[ ]] in the void coefficient when applied to all nodes in the core corresponds to a sensitivity of [[ ]] in the ΔCPR/ICPR for a turbine trip without bypass. Since the turbine trip without bypass tends to be the most limiting AOO transient for purposes of calculating ΔCPR/ICPR, this uncertainty value can be bounded by the conservative ODYN methodology[8-5] at greater than two sigma [[

]].

Because it has not changed, the detailed *Technical Description* of the TRACG void coefficient correction model previously provided in Reference [8-1] in the latter part of the RAI response has not been duplicated here.

Response References

[8-1] Response to Request for Additional Information (RAI) 30, RE: NEDE-32906P, Supplement 3, *Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients,* (TAC No. MD2569), Letter from R. E. Kingston (GEH) to M. C. Honcharik (USNRC) and USNRC Document Control Desk, MFN 08-483, May 30, 2008.

[8-2] *Steady-State Nuclear Methods*, NEDE-30130-P-A and NEDO-30130-A, April 1985, and for TGBLA Version 06 and PANACEA Version 11, Letter from S.A. Richards (NRC) to G.A. Watford (GE) Subject: "Amendment 26 to GE Licensing Topical Report NEDE-24011-P-A, GESTAR II Implementing Improved GE Steady-State Methods," (TAC NO. MA6481), November 10, 1999.

[8-3] J. G. M. Andersen, et al., *TRACG Model Description*, NEDE-32176P, Revision 4, January 2008.

[8-4] Final Safety Evaluation for General Electric Nuclear Energy (GENE) topical Report (TR) NEDE-32906P, Revision 2, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses" (TAC No. MD0249), Letter from Ho K. Nieh (NRC) to Bob E. Brown (GE), August 29, 2006.

[8-5] *Qualification of the One-dimensional Core Transient Model for Boiling Water Reactors*, NEDO-24154-A and NEDE-24154-P-A, Volumes I, II and III, August 1986.