GE-Hitachi Nuclear Energy Americas LLC

James C. Kinsey
Project Manager, ESBWR Licensing

PO Box 780 M/C J-70
Wilmington, NC 28402-0780
USA

T 910 675 5057
F 910 362 5057
jim.kinsey@ge.com

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 66 – Related to ESBWR Design Certification Application – RAI Numbers 21.6-66 through 21.6-68, 21.6-80, 21.6-82, 21.6-84**

Enclosures 1 and 2 contain GHNEA's response to the subject NRC RAIs transmitted via the Reference 1 letter. There is no Proprietary information in the enclosure 2 errata pages.

If you have any questions or require additional information regarding the information provided here, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

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NRO

Reference:

1. MFN 06-377, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 66 Related to the ESBWR Design Certification Application*, October 10, 2006

Enclosures:

1. MFN 07-352– Response to Portion of NRC Request for Additional Information Letter No. 66 – Related to ESBWR Design Certification Application –RAI Numbers 21.6-66 through 21.6-68, 21.6-80, 21.6-82, 21.6-84
2. MFN 07-352– Response to Portion of NRC Request for Additional Information Letter No. 66 – Related to ESBWR Design Certification Application –RAI Numbers 21.6-66 through 21.6-68, 21.6-80, 21.6-82, 21.6-84, NEDE-32176P, Rev. 3 Errata Pages

cc:	AE Cubbage	USNRC (with enclosures)
	DH Hinds	GHNEA (with enclosures)
	RE Brown	GHNEA (w/o enclosures)
	eDRF	0068-7963, 0067-6455, 0068-8381

Enclosure 1

MFN 07-352

Response to Portion of NRC Request for

Additional Information Letter No. 66

Related to ESBWR Design Certification Application

RAI Numbers 21.6-66 through 21.6-68, 21.6-80, 21.6-82, 21.6-84

NRC RAI 21.6-66

NEDE-32176P, Rev. 3, Section 6.3.2 starts a list with item 6. Is this a formatting error or is part of the list missing?

GE Response

There is a formatting error. The list should start with 1 as indicated by errata page 6-44 provided in Enclosure 2.

Affected Documents

No DCD changes will be made in response to this RAI.

LTR NEDE-32176P, Rev. 3 is revised by the errata page 6-44 provided in Enclosure 2 of the transmittal package for this RAI response.

NRC RAI 21.6-67

In NEDE-32176P, Rev. 3, Section 6.5.8, the characteristic length (L) is defined for a plate. (a) Are other geometries considered, for example circular, and if so how is L defined for other geometries? (b) Since L is part of the Gr number, is k2 in Eq. 6.5-21 typically 1/3, such that the value for L is not important in determining the heat transfer coefficient?

GE Response

The characteristic length (L) for the code implementation is calculated for all geometries as $L = \sqrt{\frac{V}{H}}$ where V is the volume of the cell and H is its height. The model applies only for cells where the level-tracking model indicates a free surface corresponding to a level. The level-tracking model applies only for a cell that is oriented vertically such as in a VSSL cell or a vertically-oriented cell in a one-dimensional component. For these applications, the ratio $\frac{V}{H}$ corresponds to the average surface area of the two-phase level when a level is present in the cell. The definition of L used in the code models the surface area of the two-phase level as though it were a square. This approach is consistent with the common practice of using the average of the length and width as the characteristic length when modeling non-cylindrical geometries.

The Grashof number (Gr) is proportional to L^3 so the evaluation of the heat transfer coefficient in Equation (6.5-52) will be independent of L when k_2=1/3 in Equation (6.5-51). The coding of the McAdams correlation allows four different geometries according to Table 21.6-67.1 but only the case where IGEOM=3 is invoked when the module is called. Note that for all geometries k_2=1/4 or k_2=1/3.

Table 21.6-67.1 Values of Coefficients k_1 and k_2 in Equation (6.5-51)

IGEOM index	Geometry Description	$N_{Gr} \cdot N_{Pr}$	k_1	k_2
1	horizontal cylinders	10^3 - 10^9	0.53	1/4
2	vertical plates and cylinders	10^4 - 10^9 $10^9 - 10^{12}$	0.59 0.13	1/4 1/3
3	horizontal plates: heated upper surface or cooled lower surface	$10^5 - 2x10^7$ $2x10^7 - 3x10^{10}$	0.54 0.14	1/4 1/3
4	horizontal plates: heated lower surface or cooled upper surface	$3x10^5 - 3x10^{10}$	0.27	1/4

Affected Documents

No DCD changes will be made in response to this RAI. No changes to the subject LTR will be made in response to this RAI.

NRC RAI 21.6-68

On page 6-135 of NEDE-32176P, Rev. 3, should the reference to Figure 6-34 actually be to Figure 6-37?

GE Response

Yes. The reference to Figure 6-34 has been changed to Figure 6-37 as indicated by errata page 6-135 provided in Enclosure 2.

Affected Documents

No DCD changes will be made in response to this RAI.

LTR NEDE-32176P, Rev. 3 is revised by the errata page 6-135 provided in Enclosure 2 of the transmittal package for this RAI response.

NRC RAI 21.6-80

The variable f in Eq. 9.3-2 in NEDE-32176P, Rev. 3, is described as the sum of the five decay heat group fractions, fk. However, in the preceding paragraph you state that TRACG04 allows for a variable number (Nd) of decay heat groups. Please update your documentation to reflect this change.

GE Response

The word "five" in the line just below Eq. (9.3-2) on page 9-21 should be deleted as indicated by errata page 9-21 provided in Enclosure 2.

Affected Documents

No DCD changes will be made in response to this RAI.

LTR NEDE-32176P, Rev. 3 is revised by the errata page 9-21 provided in Enclosure 2 of the transmittal package for this RAI response.

NRC RAI 21.6-82

Section 9.1.3 in NEDE-32176P, Rev. 3, indicates that at the beginning of the calculation with the PANCEA wrapup, that the TRACG cross sections include the presence of Xenon. However, the transient calculation procedure does not indicate that the Xenon concentration is updated. The staff is aware that TRACG is capable of simulating transients with transient Xenon conditions, but is unable to locate any details about your models and calculation procedures. Please provide these details. Are transient Xenon conditions used in the simulation of any AOO and ATWS events? Include information on how the treatment of Xenon is conservative for these events.

GE Response

In TRACG calculations, the initial Xenon distribution is obtained from a converged PANACEA case. As stated in the last sentence of the first paragraph of Section 9.0 of NEDE-32176P, Rev. 3, the Xenon concentration is assumed to be constant during the transient. This is true for all AOO and ATWS TRACG calculations.

The quantity of Xenon changes on the order of hours with immediate changes in power. The effect of Xenon changes on CPR, containment pressure, and reactor pressure is considered negligible on the order of seconds or even a few minutes after reasonable changes in power. The AOO and ATWS cases result in the MCPR, peak cladding temperature, or maximum pressure on the order of seconds, up to about 6 minutes.

Based on this assessment, it is judged that the actual Xenon concentrations would have an insignificant impact on the AOO and ATWS conclusions.

Affected Documents

No DCD changes will be made in response to this RAI.

No changes to the subject LTR will be made in response to this RAI.

NRC RAI 21.6-84

Question Summary: Comparisons between TGBLA06 and MCNP

Reviewer Summary: In discussing the biases and uncertainties for the void coefficient in NEDE-32906P "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses" in response to Staff RAI 12 (MFN-06-046, dated 2/14/2006, ML0605305750) you state "When the PANAC11 model is implemented in TRACG it will be necessary to make a similar assessment TGBLA06 and MCNP and change the TRACG void coefficient model accordingly." Please state if this has been done and provide the staff with the documentation that includes the details of the new evaluation.

GE Response

Yes, the void coefficient reassessment for TRACG04 has been performed. This assessment was completed in order to apply the void coefficient correction model in TRACG04. TRACG04 can only utilize the 3D kinetics model based on PANAC11, which in turn can only utilize cross section information provided by TGBLA06. For this reason, the void coefficient correction model implemented in TRACG02 that was previously based on PANAC10 and TGBLA04 was updated prior to performing TRACG04 qualification cases that required use of the 3D neutron kinetics model. The updating entailed the evaluation of the TGBLA06 lattice calculations relative to MCNP in order to re-establish the void coefficient correction model as it should be applied for TRACG04.

RAI 13 of Reference 21.6-84-1 originally requested the details for how the evaluations are performed. The requested details were supplied by Reference 21.6-84-2. The evaluation process was subsequently revised to correct the TRACG02 implementation error that was discovered when the re-evaluations for TRACG04 were initiated. (Note that the error in TRACG02 never existed in TRACG04.) The revised process for applying the void coefficient correction model was transmitted to the NRC by Reference 21.6-84-3. Included were modifications to pages 5-2 through 5-5 and an update to the RAI 13 response previously provided in Reference 21.6-84-2. References 21.6-84-1 and 21.6-84-2 pertain specifically to the TRACG02/PANAC10/TGBLA04 implementation. Reference 21.6-84-3 correctly describes the process that applies for both TRACG02 and TRACG04. For the TRACG04/PANAC11/TGBLA06 implementation, the complete re-assessment of the NRC-approved applications for AOO and ATWS overpressure were documented and submitted as NEDE-32906P Supplement 3 via Reference 21.6-84-4. This LTR is currently being reviewed by the NRC staff.

References

21.6-84-1 NRC Letter, R. Pulisfer to J. F. Klapproth (GE), Request for Additional Information on General Electric Nuclear Energy NEDE-32906P, TRACG Application for Anticipated Operation Occurrences Transient Analyses, (TAC NO. MA7779) dated July 26, 2001.

21.6-84-2 GE Transmittal Letter, MFN-01-043, dated August 21, 2001, Subject: Response to July 26, 2001 NRC Staff Request for Additional Information on General Electric Nuclear Energy Licensing Topical Report NEDE-32906P.

21.6-84-3 GE Transmittal Letter, MFN-06-046, dated February 14, 2006, Subject: GE Licensing Topical Report NEDE-32906P, Revision 2, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses".

21.6-84-4 GE Transmittal Letter, MFN-06-155, dated May 25, 2006, Subject: GE Licensing Topical Report NEDE-32906P, Supplement 3, "Migration to TRACG04 / PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients," May 2006.

Affected Documents

No DCD changes will be made in response to this RAI.

No changes to the subject LTR will be made in response to this RAI.

Enclosure 2

MFN 07-352

Response to Portion of NRC Request for

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NEDE-32176P, Rev. 3 Errata Pages

Each of these regimes is simulated in the TRACG. In each case, the method used to calculate the homogeneous sound speed a_{HE} is slightly different. The presence of noncondensable gases introduces an additional degree of complexity in the approximation of a_{HE}. The presence of noncondensable gases is accounted for in all of the break flow regimes with one exception. Noncondensable gases at the break choke plane are ignored for the low void regime (Table 6-4) when the Alamgir-Jones-Lienhard (AJL) correlation is used. In the sub-cooled blow-down regime, the effects of noncondensables on the local sonic speed are assumed to be small and are therefore ignored.

6.3.2 Implementation Details

This section summarizes how the choking model is implemented in TRACG. The choking model is implemented in only one-dimensional components. The critical flow model is called by the subroutine TF1DE, which is the subroutine to solve the governing equations for one-dimensional TRACG components. TF1DE passes donor cell parameters based on new-time velocities to CHOKE. Table 6-5 and Table 6-6 summarize the principal variables passed to CHOKE and the calculated output variables. The alphanumeric identifiers in Table 6-5 and Table 6-6 should not be necessarily interpreted as subroutine call arguments. After CHOKE has been entered, control is passed to a particular model, depending on the void conditions defined in Table 6-4. Each model that is invoked follows the same computational sequence:

1. The throat pressure and temperature conditions are calculated. The subroutine THERMO is called to calculate additional thermodynamic properties at the throat conditions.
2. The throat sonic speed is calculated and the choking criteria evaluated to determine if the flow is choked.
3. If the flow is not choked, control is returned to TF1DE.
4. If choking criteria are met, new-time throat velocities and derivatives are recalculated. To calculate the derivatives, the throat pressure is perturbed by 1% and a second pass is made to calculate the liquid and vapor velocities. The choked derivatives are calculated by dividing the change in the choked velocity calculated between passes by the pressure perturbation.
5. Control is returned to TF1DE with the new calculated junction phasic velocities and derivatives.
6. The following sections detail how CHOKE calculates the throat conditions, the details of particular models that are invoked, and how they are implemented in the code.

and

$$f_{2,He} = \begin{cases} 1.0 - 35.81 x_{He}^{1.074}, x_{He} < 0.010005 \\ 1.0 - 2.09 x_{He}^{0.457}, \ 0.010005 \le x_{He} < 0.099895 \\ 1.0 - x_{He}^{0.137}, \quad 0.099895 \le x_{He} \le 1.0 \end{cases} \tag{6.6-102}$$

Given the appropriate value for f_2 (see Section 6.6.11.2) the Kuhn-Schrock-Petersen correlation is formulated as

$$h = f_1 f_2 h_{Nusselt} = f_{1_{shear}} \cdot f_{1_{other}} \cdot f_2 \cdot h_{Nusselt} \tag{6.6-103}$$

or

$$h = f_2 \left(1 + 1.83 \times 10^{-4} Re_\ell\right) \frac{k_\ell}{\delta_2} \tag{6.6-104}$$

The K-S-P correlation[149] has a database for Re_ℓ extending to 2000. For turbulent films, a turbulent correlation is needed. The Burmeister correlation[148] was used in conjunction with Vierow-Schrock. Further review of correlations in the literature indicated that the correlation of Colburn and models developed by Dukler and Seban were better accepted. These models agree with Burmeister only at high Prandtl number and predict lower heat transfer coefficients for water. TRACG incorporates a correlation, which is proportional to $Re_\ell^{1/3}$ (similar to Burmeister), but with a coefficient of 0.01, which puts it in the same range as the Dukler, Seban, Colburn models (see Figure 6-37). The coefficient was chosen so that the correlation merges smoothly with the K-S-P correlation.

The heat transfer coefficient for turbulent condensate flow ($Re_\ell > 2000$) is calculated as:

$$h = 0.01 f_2 k_\ell \left(\frac{\rho_\ell^2 g Re_\ell}{\mu_\ell^2} \right)^{1/3} \text{ for } Re_\ell > 2000 \tag{6.6-105}$$

A cubic spline interpolation is used for $1000 < Re_\ell < 2000$.

Steam Condensation in Containment

The formulation of the local condensate film thickness in Equation (6.6-73) was derived for flat plates and is therefore suitable for use for steam condensation in the containment. The default application for condensation is to use the K-S-P correlation (Equation (6.6-104)) with the f_{1shear} factor set equal to 1, or $\delta_2 = \delta_1$. This is appropriate, since velocities in the containment will be small compared to the tubes and the f_{1shear} factor was developed specifically for tubes. The f_2 factors will remain the same.

$$\Sigma_3^{Corrected} = \Sigma_3^{Dop} + N_{B10}\sigma_{B10} \tag{9.2-11}$$

Once all the reactivity corrections are incorporated in this fashion, the nodal K_∞ is recalculated using Equation (9.2-3) with the corrected thermal group cross section, $\Sigma_3^{Corrected}$.

9.3 Decay Heat Model

The decay heat model for TRACG02 that is described in NEDE-32176P, Revision 1 and 2 has been enhanced to add the 1979[21] and 1994[22] ANS decay heat models.

9.3.1 Decay Heat Integration

The decay heat model calculates the delayed component of the volumetric heat generation rate in the fuel. A time integral relation links the fission rate to the decay heat. Nodal power history is accounted for in TRACG by using the power calculated from the 3-D neutron kinetics model. TRACG04 allows for a variable number (N_d) of exponential decay heat groups to fit the decay power curve. The decay heat model described in this section is used with the 3-D neutron kinetics model for transient simulation and optionally may be used for other applications where the 3-D neutron kinetics model is not activated. For example, these models can be applied for LOCA applications, or optionally, the power due to decay heat can be input in tabular form as a function of time.

The total volumetric heat generation rate in the fuel at axial location "z" and time "t" can be expressed as:

$$q(z,t) = q_p(z,t) + q_d(z,t) \tag{9.3-1}$$

where q_p is the prompt power

$$q_p(z,t) = (1-f)P(z,t) \tag{9.3-2}$$

and "f" is the sum of the decay heat group fractions, f_k.

The decay power, q_d, consists of several components with different time constants (by dividing the continuous spectrum of fission product decay into N_d groups):

$$q_d\ (z,t) = \sum_{k=1}^{N_d} q_{d,k} \tag{9.3-3}$$

The individual decay power terms can be related to the total fission power by:

$$q_{d,k}\ (z,t) = \int_{-\infty}^{t} f_k\ P\ (z,t')\ K_k\ (t' \rightarrow t)\ dt' \tag{9.3-4}$$

Here, K_k (t' → t) is the fraction of the decay power released at t due to fission occurring at time t'. An exponential form has been chosen in TRACG:

$$K_k(t' \rightarrow t) = \lambda_k e^{-\lambda_k(t-t')} \tag{9.3-5}$$