ENCLOSURE 2

MFN 12-073

Response to NRC RAIs - NEDE-33147P, Revision 3

Non-Proprietary Information – Class I (Public)

INFORMATION NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 12-073, 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. [[ ]]

NRC RAI-1: Approved Code Versions

NEDE-33147P, Revision 3, states that "Best-estimate analyses performed with TRACG have been approved by the NRC to support licensing applications in different areas, including specific T-H [thermal-hydraulic] instability performance and Anticipated Operational Occurrence (AOO) transients." Please provide a reference to the most recent versions of the approved ("–A") TRACG LTRs for those topics, if different from References 4-6 of NEDE-33147P. Which version of the TRACG code is approved?

GEH Response

TRACG has been reviewed and approved for AOO for operational BWRs and ESBWRs; the version of the TRACG code that was used in each of the Licensing Topical Reports (LTRs) is shown below:

Approved LTR	Code	Application Scenario
NEDE-32906P-A, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," Revision 3, September 2006.	TRACG02	BWR/2-6 AOO
NEDE-32906P-A, Supplement 1, "TRACG Application for Anticipated Transient Without Scram Overpressure Transient Analyses," November 2003.	TRACG02	BWR/2-6 ATWS Overpressure
NEDE-32906P-A, Supplement 3, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients," Revision 1, April 2010.	TRACG04	BWR/2-6 AOO and ATWS Overpressure
NEDE-33083P-A Supplement 3, "TRACG Application for ESBWR Transient Analysis," Revision 1, September 2010.	TRACG04	ESBWR AOO

TRACG has been reviewed and approved for stability calculations for operational BWRs and ESBWRs; the version of the TRACG code that was used in each of the LTRs is shown below:

Approved LTR	Code	Application Scenario
NEDE-32906P-A, “TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses,” Revision 3, September 2006.	TRACG02	BWR/2-6 limited to the applications approved in NEDO-32465-A
NEDE-33147P-A, “DSS-CD TRACG Application,” Revision 2, November 2007.	TRACG02	BWR/3-6 DSS-CD
NEDC-33083P-A Supplement 1, “TRACG Application for ESBWR Stability Analysis,” Revision 2, September 2010.	TRACG04	ESBWR Stability

NRC RAI-2: Applicability of DSS-CD TRACG04 Methodologies to Other Designs

NEDE-33147P, Revision 3, Section 1.3, states that "GEH requests approval of the TRACG04 code for the application to the analysis of BWR [boiling water reactor]/3-6 plants employing the DSS-CD stability solution." The Economic Simplified Boiling Water Reactor (ESBWR) is expected to use DSS-CD as a backup solution. Will the TRACG04-based DSS-CD methodology also be applicable to ESBWR?

GEH Response

The TRACG04 based DSS-CD methodology applied to ESBWR has already been approved (Reference 2-1) and includes the following unique characteristics with respect to the TRACG04 based DSS-CD methodology applied to BWR/3-6 (Reference 2-2):

- As specified in Section 4D.3 of Reference 2-3, the TRACG04 based DSS-CD methodology applied to ESBWR is used in the defense-in-depth stability solution with modifications on specified settings for the ESBWR application.
- The ESBWR stability evaluations were done based on the approved TRACG04 application methodology specific for ESBWR stability, which is documented in Reference 2-4. The results show that ESBWR is free of undamped oscillations and other thermal-hydraulic instabilities for all conditions of normal operation and for anticipated operational occurrences (AOOs). This demonstrates conformance to GDC 12 which states that power oscillations that can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

References:

2-1. Final Safety Evaluation for Chapter 4 "Reactor" Regarding ESBWR Design Certification Review, http://pbadupws.nrc.gov/docs/ML1034/ML103470435.pdf

2-2. GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P, Revision 3, January 2011.

2-3. GE Hitachi Nuclear Energy, "ESBWR Design Control Document," Tier 2, 26A6642AP, Revision 9, December 2010.

2-4. GE Hitachi Nuclear Energy, "TRACG Application for ESBWR Stability Analysis," NEDE-33083 Supplement 1P-A, Revision 2, September 2010.

NRC RAI-3: Applicability to the Advanced Boiling Water Reactor (ABWR)

Assuming DSS-CD was approved for use in ABWR, what process would be required to use TRACG04 methodology in that application?

GEH Response

DSS-CD is applicable to ABWR. The process to apply DSS-CD to an ABWR is defined in NEDC-33075P Section 6 (Reference 3-1). As stated in Section 6 of Reference 3-1, design changes beyond the DSS-CD plant-specific applicability checklist envelope that affect stability performance will require a confirmation analysis according to the DSS-CD applicability extension procedures of Tables 6-3 and 6-4 in Reference 3-1. [[

]]

NEDE-33147P (Reference 3-2) does not limit the use of TRACG04 for DSS-CD applications to specific reactor types.

References:

3-1. GE Hitachi Nuclear Energy, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density (DSS-CD)," NEDC-33075P, Revision 7, June 2011.

3-2. GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P, Revision 3, January 2011.

NRC RAI-4: Code Scaling, Applicability and Uncertainty (CSAU) Applicability to non-LOCA Events

NEDE-33147P, Revision 3, Section 2.2, states that "While the CSAU methodology was developed for application to Loss-of-Coolant Accident (LOCA) scenarios, there are no technical reasons that prevent CSAU methodology from being applied to other event scenarios, such as stability." Please provide references of "-A" LTRs in which the CSAU methodology has been used for non-LOCA events.

GEH Response

The CSAU methodology has been reviewed and approved for non-LOCA applications; the Licensing Topical Reports (LTRs) are:

Approved LTR	Code	Application Scenario
NEDE-32906P-A, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," Revision 3, September 2006.	TRACG02	BWR/2-6 AOO
NEDE-32906P-A, Supplement 1, "TRACG Application for Anticipated Transient Without Scram Overpressure Transient Analyses," November 2003.	TRACG02	BWR/2-6 ATWS Overpressure
NEDE-32906P-A, Supplement 3, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients," Revision 1, April 2010.	TRACG04	BWR/2-6 AOO and ATWS Overpressure
NEDE-33083P-A, Supplement 1, "TRACG Application for ESBWR Stability Analysis," Revision 2, September 2010.	TRACG04	ESBWR Stability
NEDE-33083P-A, Supplement 2, "TRACG Application for ESBWR Anticipated Transient Without Scram Analyses," Revision 2, October 2010.	TRACG04	ESBWR ATWS
NEDE-33083P-A, Supplement 3, "TRACG Application for ESBWR Transient Analysis," Revision 1, September 2010.	TRACG04	ESBWR AOO

NRC RAI-5: TRACG04 Version

NEDE-33147P, Revision 3, Section 2.2.1, states that "A frozen code version (TRACG04P) has been used in this evaluation." What quality assurance level is version P? Please provide additional details (e.g., compilation date, etc.) to further define the version of TRACG04 used in this evaluation.

GEH Response

Please see the detailed information regarding the Engineering Computer Program (ECP) TRACG04P ("P" stands for PC platform) applied in the development of Revision 3 of NEDE-33147P.

Executable Name	TRACG04P.exe
Platform	PC
Version Number	04.02.60.03
Executable Built Date	October 30, 2009
ECP Status Level	2, See Note 1
Level 2 Date	December 10, 2009
Quality Program	See Note 2

Notes:

1. Level 2 ECPs are approved production programs that are verified and documented for design applications or for all technical activities used in developing design-related information.
2. TRACG04P has been developed under the NRC-approved GEH/GNF 10 CFR 50 Appendix B quality program (NEDO-11209-A) and can be used for safety-related analysis and evaluations that are within the ECP's application range.

RAI-6: Bypass Boiling

How do TRACG calculations account for bypass boiling? Please provide a very short description of how the bypass is modeled, and how it handles feedback of the cross-sections during the transient calculation. Is the hot-channel bypass modeled in TRACG04, or only an average bypass region? How do bypass region results compare with ISCOR (a BWR steady-state thermal hydraulic methodology) calculations?

GEH Response

A description of the methodology used to account for the thermal-hydraulic conditions for transient and stability calculations in the bypass region was provided in the RAI-3.1a response (Reference 6-1):

> "In the 3D simulator PANACEA, the bypass regions and the water rod regions are combined into a single axial nodalized channel for purposes of modeling moderator density. The in-channel, bypass and water rod regions are then combined to form the nodal average lattice moderator density. In the plant transient simulator TRACG04, the bypass and water rod regions are treated separately and are nodalized in the axial direction as specified by application. The in-channel, bypass and water rod regions are then combined to form the nodal average lattice moderator density. Thus, by the use of the lattice average water density parameter, potential changes in the bypass and water rod voiding (water density) are accurately modeled in the core steady-state and transient simulators."

As described in Section 9.4 (Reference 6-2), the power distribution in the core is calculated in the orthogonal 3-D geometry in the kinetics model, which takes into account feedback due to changes in fuel temperature, coolant density, and control rod movement. In the transient calculation, the change in density and temperature are given by the channel model. The bypass density is obtained from the vessel component and combined by volume weighting with the channel and water rod density to provide the overall relative water density for each channel node. Qualification of the bypass model is provided in Reference 6-3.

Boiling in the bypass region is a result of Direct Moderator Heating (DMH). DMH is the energy released into the moderator as the fast neutrons are slowed down. In the TRACG DMH model, [[

]] The TRACG DMH model has been reviewed and approved in Reference 6-4.

TRACG models an average bypass region. In the TRACG model, the average bypass void fraction is calculated at each axial level across the core. A comparison of the TRACG calculated average bypass voiding at different power / flow conditions with the ISCOR hot channel bypass voiding were provided in RAI 3.2.a.ii response (Reference 6-1). The differences between the values calculated by the different codes are a function of the code assumptions. For example, the difference between the core-average TRACG and ISCOR values are caused by [[

]]. The ISCOR four-channel bypass

edit estimate is a very conservative bounding calculation which [[ ]] The actual value of the hot channel bypass void fraction is somewhere between the estimates for core-average, [[ ]] TRACG calculated bypass region axial void fraction profiles following a 2RPT transient were provided in response to Part 1.1 of RAI 1 (Reference 6-5).

References:

6-1. GE Hitachi Nuclear Energy, "Applicability of GE Methods to Expanded Operating Domains," NEDC-33173P-A, Revision 3, April 2012.

6-2. GE Hitachi Nuclear Energy, "TRACG Model Description," NEDE-32176P, Revision 4, January 2008.

6-3. GE Hitachi Nuclear Energy, "TRACG Qualification," NEDE-32177P, Revision 3, August 2007.

6-4. GE Nuclear Energy, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," NEDE-32906P-A, Revision 3, September 2006.

6-5. GE Hitachi Nuclear Energy, " DSS-CD TRACG Application," NEDE-33147P-A, Revision 2, November 2007.

RAI-7: Control Rod Patterns to Excite Regional Mode

Section 4.2.6 states that [[

]] Please provide some examples of [[
]]

GEH Response

Figure 7-1 provides [[ ]] for a regional case [[

]] and Figure 7-2 provides its [[

]]

Figure 7-3 provides the [[ ]] for a core-wide case [[

]] and Figure 7-4 provides its [[

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[[

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Figure 7-1. [[ ]]

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Figure 7-2. [[ ]]

[[

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Figure 7-3. [[ ]]

[[

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Figure 7-4. [[ ]]

NRC RAI-8: Solution Uniqueness

Section 4.2.7, “Instability Solution Uniqueness,” does not seem to address the issue of uniqueness. Please describe the purpose of this section and/or provide additional uniqueness information.

GEH Response

The purpose of including Section 4.2.7 in NEDE-33147P-A Revision 2 (Reference 8-1) was historical in nature and aimed to describe the differences (characterized as ‘uniqueness’) of the DSS-CD application versus the DIVOM calculation process. In order to accomplish this task a description of the DIVOM process was included in NEDE-33147P-A Revision 2 (Reference 8-1). In NEDE-33147P Revision 3 (Reference 8-2) it was deemed no longer necessary to include a discussion of the DIVOM calculation process for two reasons:

1) [[ ]]
2) [[ ]]

However, by removing the discussion and comparison to the DIVOM calculation process, Section 4.2.7 does not provide any value or additional information to the licensing topical report content.

Therefore, this historical Section 4.2.7 will be entirely removed from NEDE-33147P Revision 3 (Reference 8-2) when the accepted (-A) version is published.

References:

8-1. GE Hitachi Nuclear Energy, “DSS-CD TRACG Application,” NEDE-33147P-A, Revision 2, November 2007.

8-2. GE Hitachi Nuclear Energy, “DSS-CD TRACG Application,” NEDE-33147P, Revision 3, January 2011.

NRC RAI-9: Scram Time for Example in Figure 8-5

Section 8.1, "Best Estimate TRACG Simulation," states [[ ]] Please indicate the time of scram in Figure 8-5 to show graphically the final critical power ratio (CPR).

GEH Response

As shown in Figure 9-1, the scram time has been indicated with a vertical red line and the corresponding Final Minimum CPR (FMCPR) is also labeled with a red dot. [[ ]]

A detailed discussion on the process for determining the FMCPR is given in Section 4.4.1.2 of the DSS-CD LTR (Reference 9-1).

[[ ]]

Figure 9-1. [[ ]]

References:

9-1. GE Hitachi Nuclear Energy, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," NEDC-33075P, Revision 7, June 2011.

NRC RAI-10: Uncertainty Values

Table 8-1 provides the [[

]] Please provide the actual results of the statistical analysis in terms of percent minimum CPR (MCPR) per sigma.

GEH Response

[[

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[[ ]]

[[		
		]]

References:

10-1. GE Nuclear Energy, “TRACG Application for Anticipated Operational Occurrences Transient Analysis,” NEDE-32906P-A, Revision 3, September 2006.
10-2. GE Hitachi Nuclear Energy, “DSS-CD TRACG Application,” NEDE-33147P, Revision 3, January 2011.

NRC RAI-11: Figure 8-23 Labels

The labels in Figure 8-23 are not clear. Please explain the meaning of "Statistical CSAU SLMCPR [safety limit MCPR]" and "Nominal SLMCPR." Please add this explanation to the text of the LTR.

GEH Response

The "Nominal SLMCPR" denoted in Figure 8-23 is the Safety Limit Minimum Critical Power Ratio (SLMCPR) that would be determined for a specific core design or for a cycle-specific fuel reload analysis (i.e., the actual SLMCPR that a plant would report in the cycle-specific Supplemental Reload Licensing Report (SRLR)). For the TRACG cases analyzed in Section 8.0, the reference "Nominal SLMCPR" is [[ ]].

[[ ]] This process is also detailed in Section 7.2 of Reference 11-1.

This explanation will be added at the end of Section 8.3, page 8-3, of Reference 11-1 when the accepted (-A) version is published.

References:

11-1. GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P, Revision 3, January 2011.

NRC RAI-12: Process for Implementing [[ ]]

Please describe the process used to calculate the [[ ]] curve in Figure 8-23. How is the calculation performed?

GEH Response

Figure 8-23 is just an illustration to visually show the comparison between the [[ ]] and the [[ ]] The process used to calculate the numerical value of the [[ ]] is described in Section 4.4.1.2, page 4-15, "MCPR Uncertainty Assessment" in NEDC-33075P Revision 7 (Reference 12-2) and shown in Figure 4-12 of Reference 12-2. This process is exactly the same as the one approved in NEDC-33075P-A Revision 6 (Reference 12-3) and has not been changed in Revision 7 (Reference 12-2).

This process is applied as follows to the case shown in Figure 8-23 in Reference 12-1. The calculated nominal best-estimate CPR trace for the selected limiting channel is shown as the brown curve in Figure 8-23. [[

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References:

12-1. GE Hitachi Nuclear Energy, “DSS-CD TRACG Application,” NEDE-33147P, Revision 3, January 2011.

12-2. GE Hitachi Nuclear Energy, “GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density (DSS-CD),” NEDC-33075P, Revision 7, June 2011.

12-3. GE Nuclear Energy, “General Electric Boiling Water Reactor Detect and Suppress Solution – Confirmation Density (DSS-CD),” NEDC-33075P-A, Revision 6, January 2008.

NRC RAI-13: TRACG04 Configuration Options

Please specify the required TRACG04 configuration options for stability calculations (e.g., full-core channel mapping, axial nodalization, semi-implicit method, etc.).

GEH Response

The TRACG04 configuration requirements for the DSS-CD stability analyses are consistent with References 13-1 and 13-2 as indicated in Item 8 of Table 2-1 in Reference 13-3. The followings items are the key configuration requirements for the DSS-CD stability analyses:

Thermal-Hydraulic Nodalization:

- [[

]]

Neutronics Nodalization:

- [[

]]

Numerics:

- [[

]]

References:

13-1. GE Hitachi Nuclear Energy, "TRACG Qualification," NEDE-32177P, Revision 3, August 2007.

13-2. GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P-A, Revision 2, November 2007.

13-3. GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P, Revision 3, January 2011.

13-4. GE Hitachi Nuclear Energy, “TRACG Model Description,” NEDE-32176P, Revision 4, January 2008.

13-5. GE Nuclear Energy, “TRACG Application for Anticipated Operational Occurrences Transient Analysis,” NEDE-32906P-A, Revision 3, September 2006.

13-6. GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients,” NEDE-32906P, Supplement 3-A, Revision 1, April, 2010.

13-7. GE Nuclear Energy, “Steady State Nuclear Methods,” NEDE-30130P-A, April 1985.

13-8. Letter from S. A. Richards (NRC) to G. A. Watford (GE), “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.

NRC RAI-14: Dryout Correlation Applicability to Oscillatory Conditions

Please provide a reference and/or a short description of the justification of the applicability of GEH CPR correlations under oscillatory flow conditions.

GEH Response

Onset of boiling transition (BT) is predicted using the GEXL correlation, developed for each fuel product type using full scale critical power test data. The GEXL correlation is applied in the approved transient codes (TRACG or TASC) in order to calculate the critical power ratio (CPR). A nominal calculated value of CPR=1.0 corresponds to the minimum value for which the GEXL correlation applies and also corresponds to the point at which BT is expected. Although GEXL is developed from steady-state data, its application for transient conditions has been validated by conducting comparisons to transient tests performed at the same facility with configurations used to develop the GEXL correlation. Examples of these tests are documented in Section 3.6 of the TRACG Qualification Licensing Topical Report (LTR) (Reference 14-1) and also in Section 6 of References 14-3, 14-4, and 14-5.

For licensing calculations with TRACG, such as those used for Anticipated Operational Occurrences (AOOs) and Detect and Suppress Solution – Confirmation Density (DSS-CD) stability evaluations, the bias and uncertainty associated with the TRACG calculations are explicitly considered. It is important to note that, for stability applications, the minimum CPR for all rods in the core remains above the Safety Limit Minimum CPR (SLMCPR). Consequently, BT is not reached. The calculated change in CPR during these events is used to assess the margin to the SLMCPR, so it is important to establish the fidelity of the calculated change in CPR during the evolution of the transient.

It is not possible to directly measure a change in CPR, but it is possible to infer, from the response in measured temperatures, the onset of BT (i.e., CPR=1.0). [[

]] The transient testing is used to assess the GEXL transient performance for a range of conditions corresponding to licensing basis transients. The transient testing performed for relatively modern fuel designs is summarized in Table 14-1.

Each GEXL correlation is implemented as outlined in Section 7.5.5 of Reference 14-2. The transient performance of an implementation is assessed by comparing the calculated transient results to transient test data. Comparisons between the calculated and measured values are shown in the GEXL correlation reports for AOO-like transients. Section 6 in References 14-3, 14-4, and 14-5 are three relatively recent examples of the type of information that has been provided to the NRC. Figure 6-2 in References 14-3, 14-4, and 14-5 provides a summary of the transient CPR tests and the comparison with the code calculations. Note that References 14-4 and 14-5 provide comparisons of ATLAS test data and TASC code calculations, whereas Reference 14-3 provides comparisons of Stern Labs test data and TRACG code calculations. TRACG comparisons to ATLAS transient test data have also been performed. An example is provided in Figure 3.6-10 of Reference 14-1, which shows that, for a variety of GE fuel products, TRACG predicts the transient CPR test data. Note that only the most limiting AOO-like CPR transient test scenarios are represented.

In addition to AOO-like transient CPR tests, flow oscillation tests have also been performed. Measured temperatures for these tests typically indicate that some bundle locations oscillate in and out of BT. An increasing measured surface temperature corresponds to a time interval during which boiling transition is occurring and CPR is less than 1.0. Similarly, a decreasing measured rod surface temperature corresponds to the better heat transfer characteristics of nucleate boiling and a time interval during which CPR is greater than 1.0. TRACG calculates CPR values greater than or equal to 1.0 using the GEXL correlation. In comparing TRACG calculated temperatures with the measurements, the absolute comparison of the temperature values is of less significance than the timing and period of the temperature inflections because there are complications in where and how the measured values are obtained. The ability to predict BT and subsequent return to nucleate boiling is judged based on the inflections in the temperatures as they begin to increase at the onset of BT and then decrease when nucleate boiling is re-established.

The rod surface temperature comparisons provided in Figures 3.6-4, 3.6-5, and 3.6-6 of Reference 14-1 for a simulated GE11 bundle represent a small subset of the historical flow oscillation test data. For these tests, a nominal inlet mass flux of [[ ]] is used (see Figure 14-1, which corresponds to Figure 3.6-3 of Reference 14-1). The iCPR value of Run 209 is [[ ]]. Figure 14-2, which corresponds to Figure 3.6-6 of Reference 14-1, shows similar behavior in the test and the TRACG calculation for Run 209 with a clear indication that both have experienced cyclic BT and rewet, followed by a temperature excursion when rewet no longer occurs. The calculated time for the onset of the temperature excursion [[ ]] These results illustrate that, for this particular example, TRACG conservatively estimates the approach to the onset of BT, and thus conservatively over-estimates the transient dCPR associated with the flow oscillations.

More recent GE14 and GNF2 flow oscillation tests performed at Stern Labs used nominal inlet mass fluxes of [[ ]] Because of the relatively high iCPR, the absolute amplitude of the flow oscillations must be large in order to drive the test assembly to a transient CPR less than 1.0. The data to code comparisons of inlet mass flux and maximum temperature change from the initial value are given for a GE14 test and two GNF2 tests in Figures 14-3 through 14-8. These cases are selected as representative of the available flow oscillation tests indicated in Table 14-1. The data and TRACG inlet mass flow rates are identical (Figures 14-3, 14-5, and 14-7) because the test data was input directly to TRACG. The maximum temperature change from initial was compared (Figures 14-4, 14-6, and 14-8), rather than transient temperatures, in order to distill the important information to a single plot from roughly [[ ]] temperature measurements at varying axial and rod locations.

For the example GE14 comparison (Figures 14-3 and 14-4), the temperature excursions were relatively limited, indicating relatively limited time periods in BT. Despite this, the TRACG predictions of BT had good agreement with the data, [[ ]] This particular test was chosen because it had the largest temperature excursion of any of the GE14 inlet peaked flow oscillation test series.

Two GNF2 flow oscillation test comparisons are provided – an inlet peaked test (Figures 14-5 and 14-6) and an outlet peaked test (Figures 14-7 and 14-8). The TRACG temperature excursions agree extremely well with the data for the inlet peaked test case. The agreement is reasonable, [[ ]]

From these results it is evident that the transient implementation of the GEXL correlation is capable of representing the reduction in CPR required to approach BT for conditions that are similar to those that would be expected should the flow oscillations during an instability event be so large as to drive the mCPR down to 1.0. **Notwithstanding, current detect and suppress strategies and licensing calculations are such that even for the most extreme cases a reactor scram occurs while the calculated mCPR is greater than the SLMCPR so that conditions resulting in boiling transition are not reached.**

References:

14-1. GE Hitachi Nuclear Energy, "TRACG Qualification," NEDE-32177P, Revision 3, August 2007.

14-2. GE Hitachi Nuclear Energy, "TRACG Model Description," NEDE-32176P, Revision 4, January 2008.

14-3. GE Hitachi Nuclear Energy, "GEXL17 Correlation for GNF2 Fuel," NEDC-33292P, Revision 3, April 2009.

14-4. GE Hitachi Nuclear Energy, "GEXL14 Correlation for GE14 Fuel," NEDC-32851P-A, Revision 5, April 2011.

14-5. GE Nuclear Energy, "GEXL10 Correlation for GE12 Fuel," NEDC-32464P, Revision 2, September 2001.

14-6. GE Nuclear Energy, "TASC-03A, A Computer Program for Transient Analysis of a Single Channel," NEDC-32084P-A, Revision 2, July 2002.

Table 14-1. Transient CPR Testing

Fuel Type	Design Features	Test Facility	Test Type	Reference(s)
GE11	9x9 Lattice 2 Large Central Water Rods 8 Part Length Rods	ATLAS	TTNBP with RPT[1] TTNBP without RPT ABWR All RIP Trip[2] Flow Oscillation	1, 6
GE12	10x10 Lattice 2 Large Central Water Rods 14 Part Length Rods	ATLAS	TTNBP with RPT TTNBP without RPT	5, 6
GE13	9x9 Lattice 2 Large Central Water Rods 8 Part Length Rods	ATLAS	TTNBP without RPT	6
GE14	10x10 Lattice 2 Large Central Water Rods 14 Part Length Rods	ATLAS	TTNBP with RPT TTNBP without RPT ABWR All RIP Trip	4, 6
		Stern Labs	Inlet Peaked Axial Power Shape Flow Oscillations	
			Outlet Peaked Axial Power Shape TTNBP with RPT TTNBP without RPT ABWR All RIP Trip Flow Oscillations	

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[1] TTNBP = Turbine Trip with No Turbine Bypass Valve Actuation (pressurization event).
RPT = Recirculation Pump Trip (flow coastdown).

[2] Rapid flow coastdown similar to a postulated ABWR simultaneous trip of all Reactor Internal Pumps.

Table 14-1. Transient CPR Testing

Fuel Type	Design Features	Test Facility	Test Type	Reference(s)
GNF2	10x10 Lattice 2 Large Central Water Rods 6 Short Part Length Rods 8 Long Part Length Rods	Stern Labs	Inlet Peaked Axial Power Shape TTNBP with RPT TTNBP without RPT ABWR All RIP Trip Flow Oscillations[3]	3
			Outlet Peaked Axial Power Shape TTNBP with RPT TTNBP without RPT ABWR All RIP Trip Flow Oscillations[3]	
			Cosine Axial Power Shape TTNBP with RPT TTNBP without RPT ABWR All RIP Trip	

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[3] These tests are not included in Reference 3.

[[

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Figure 14-1. GE11 ATLAS and TRACG Inlet Mass Fluxes for Flow Oscillation Test (Run 209)

[[

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Figure 14-2. GE11 Rod Temperature Comparison for ATLAS Run 209 at 5.2 MW

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Figure 14-3. GE14 Stern Labs Flow Oscillation Test 570 Test Data and TRACG Inlet Mass Flow Rate

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Figure 14-4. GE14 Stern Labs Flow Oscillation Test 570 Test Data and TRACG Maximum Temperature Change from Initial

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Figure 14-5. GNF2 Stern Labs Flow Oscillation Test 952 Test Data and TRACG Inlet Mass Flow Rate

[[

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Figure 14-6. GNF2 Stern Labs Flow Oscillation Test 952 Test Data and TRACG Maximum Temperature Change from Initial

[[

]]

Figure 14-7. GNF2 Stern Labs Flow Oscillation Test 2490 Test Data and TRACG Inlet Mass Flow Rate

[[

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Figure 14-8. GNF2 Stern Labs Flow Oscillation Test 2490 Test Data and TRACG Maximum Temperature Change from Initial

NRC RAI-15: Process to implement Future Dryout Correlations

Please define the process to be used to implement future CPR correlations in the DIVOM or DSS-CD calculation procedure. Specify what criteria will be used to evaluate whether a new CPR correlation needs to be benchmarked against oscillatory dryout rewet data.

GEH Response

To comply with the NRC SER requirements documented in Section 2.8 of Reference 15-1, correlations to predict Critical Power Ratio (CPR) are developed for each fuel bundle product. For each new CPR correlation, a document describing the CPR correlation is provided to the NRC justifying both steady-state and transient application of the specific correlation including application for transients that involve flow reduction that simulate a Recirculation Pump Trip (RPT). Some more recent examples of the GEXL reports include References 15-2, 15-3, and 15-4. These reports include the assessment and justification for transient application of each CPR correlation by using the correlation in either TASC or TRACG to calculate the transient dCPR/iCPR value and comparing to the dCPR/iCPR value determined from the data as explained in the response to RAI-14. In summary, the transient tests measure the change in CPR required to approach boiling transition (BT) as evidenced by an increase in the measured rod temperature response. Additional detail for how this is done is described in the GEXL reports. After a GEXL correlation has been developed and qualified for a particular fuel type, it is used in all steady-state and transient applications for that fuel type which includes the DIVOM and DSS-CD calculations performed with TRACG. Future CPR correlations will follow the same process.

Table 14-1 of the response to RAI-14 shows for what bundle designs flow oscillation tests were performed. These tests have been performed when the lattice array or axial profile in the fuel bundle design could suggest a change in the void profile of the bundle which might affect the response to an imposed flow oscillation. For example, flow oscillation tests were conducted for the 9x9 designs with two large central water rods when part length rods (PLRs) were introduced. Flow oscillation tests were also performed when the lattice array was changed to 10x10. Most recently flow oscillation tests were performed with the introduction of two different PLR lengths in the GNF2 design. It is important to note that comparisons of calculations to dryout and rewet data per se are not relevant for the DIVOM and DSS-CD applications because the minimum CPR is always maintained at or above the Safety Limit Minimum Critical Power Ratio (SLMCPR) so BT (film dryout) does not occur. The salient comparison is for the onset of BT rather than the temperature response after BT. Accurate prediction of the onset of BT corresponds to accurate prediction of the transient dCPR up to the point of dryout. Even without flow oscillation tests, the transient CPR performance associated with flow changes can be confirmed from the transient tests that simulate Anticipated Operational Occurrence (AOO) events, especially those tests that simulate RPT. Some examples comparing TRACG to data for oscillatory flow tests for GE11 are shown in Section 3.6.1 of Reference 15-5 and are replicated for convenience in the response to RAI-14. A selection from more recent comparisons for GE14 and GNF2 flow oscillations tests are provided in the response to RAI-14.

References:

15-1. Letter, A. C. Thadani (NRC) to J. S. Charnley, Acceptance for Referencing of Amendment 22 to General Electric Licensing Topical Report NEDE-24011-P-A "General Electric Standard Application for Reactor Fuel" (TAC NO. 71444), MFN 100-90, July 23, 1990.

15-2. GE Hitachi Nuclear Energy, "GEXL17 Correlation for GNF2 Fuel," NEDC-33292P, Revision 3, April 2009.

15-3. GE Hitachi Nuclear Energy, "GEXL14 Correlation for GE14 Fuel," NEDC-32851P-A, Revision 5, April 2011.

15-4. GE Hitachi Nuclear Energy, "GEXL10 Correlation for GE12 Fuel," NEDC-32464P, Revision 2, September 2001.

15-5. GE Hitachi Nuclear Energy, "TRACG Qualification," NEDE-32177P, Revision 3, August 2007.