FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT NEDE-33147P, REVISION 3

"DSS-CD TRACG APPLICATION"

GE-HITACHI NUCLEAR ENERGY AMERICAS, LLC

PROJECT NO. 710

1.0 INTRODUCTION AND BACKGROUND

By letter dated January 27, 2011, GE-Hitachi Nuclear Energy Americas, LLC (GEH) submitted Topical Report (TR) NEDE-33147P, Revision 3, "DSS-CD [Detect and Suppress Solution – Confirmation Density] TRACG Application" (Reference 1) to the U.S. Nuclear Regulatory Commission (NRC) staff for review. NEDE-33147P, Revision 3, provides the licensing basis and methodology to demonstrate the adequacy of the TRACG04 [a GEH proprietary version of the Transient Reactor Analysis Code (TRAC)] analyses as part of the DSS-CD solution. DSS-CD is a type of long-term stability solution that has been reviewed and approved by the NRC staff in TR NEDC-33075P-A, Revision 6 (Reference 2) for boiling water reactor (BWR) operating conditions including the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain.

The GEH TRACG04 code model description, qualification, and application for anticipated operational occurrences (AOOs) are documented in TRs NEDE-32176P, NEDE-32177P, NEDE-32906P-A, and NEDE-32906P-A, Supplement 3, respectively (References 3-6). References 5 and 6 have been reviewed and approved by the NRC staff (References 3 and 4 were submitted for information or as part of other reviews). Revision 7 of the DSS-CD TR (Reference 7), which is a revision based on the use of TRACG04 in the DSS-CD process, has been submitted and is also under review by the NRC staff. The "Delta CPR [critical power ratio] over Initial MCPR [minimum CPR] Versus Oscillation Magnitude (DIVOM)" methodology using TRACG04 is documented in a separate TR, NEDO-32465 Supplement 1 (Reference 8), which is also under review by the NRC staff. NEDE-33147P, Revision 3 (Reference 1) is the subject of this safety evaluation (SE), and it incorporates the essential information from the above TRs to describe and justify the use of TRACG04 for modeling instabilities in the DSS-CD process.

In NEDE-33147P, Revision 3 (Reference 1), GEH requests approval of the TRACG04/PANAC11 methodology for application to the analysis of BWR/3-6 plants employing the DSS-CD stability solution. GEH requests that the application include all power-to-flow domains up to and including the MELLLA+ domain and all licensed operational enhancements.

In addition, GEH requests that the application not be limited to any type of current or future fuel, including fuel from other vendors, because TRACG04 explicitly models all the characteristics of those fuels. In addition, GEH requests a review of the justification for the use [ ]

The NRC staff was assisted in this review by staff from Oak Ridge National Laboratory (ORNL). The NRC staff's review is based on the subject TR and its previous revisions, requests for additional information (RAIs), and information obtained during meetings with GEH to clarify and supplement the RAIs. The main conclusion from this review is that the proposed code migration from TRACG02/PANAC10 to TRACG04/PANAC11 and the [ ] are acceptable for DSS-CD related calculations.

The NRC staff is currently evaluating the TRACG04 models for post-critical heat flux (CHF) heat transfer, dryout, and rewet, including the correlations for stable film boiling temperature (Tmin) and the quench front model (Reference 9). This SE documents the NRC staff's review regarding the application of TRACG04 for DSS-CD, where calculations are not analyzed past the point of CHF; therefore the approval of TRACG04 application for DSS-CD does not imply the approval of the TRACG04 post-CHF models.

1.1. Long Term Solutions

Following the March 1988 instability event at a LaSalle County Station BWR, the BWR Owners Group (BWROG) initiated a task to investigate actions that industry should take to resolve the stability issue as an operational concern. Through analysis, the BWROG found that the existing plant protection system, which was based on a scram on high average power range monitor (APRM) signal, may not provide enough protection against out-of-phase modes of instability; thus, the BWROG decided that a new automatic instability suppression function was required as a long-term solution and that this function should have a rapid and automatic response which does not rely on operator action.

The BWROG submitted and the NRC staff approved three different long-term stability options (Reference 10). It is up to the individual licensees to choose which solution will be implemented in their reactor. These options can be summarized as follows:

> **I. Exclusion Region**. A region outside which instabilities are very unlikely is calculated for each representative plant type using well-defined procedures. If the reactor is operated inside this exclusion region, an automatic protective action is initiated to exit the region. This action is based exclusively on power and flow measurements, and the presence of oscillations is not required for its initiation. Two concepts of Solution I were submitted by the BWROG and approved by the NRC staff:
>
> **I-A** Immediate protection action (either scram or select rod insert) upon entrance to the exclusion region.
>
> **I-D** Some small-core plants with tight inlet orifices have a reduced likelihood of out-of-phase instabilities. For these plants, the existing flow-biased

high APRM scram provides a detect and suppress function to avoid safety limits violation for the expected instability mode. In addition, administrative controls are proposed to maintain the reactor outside the exclusion region.

II. Quadrant-Based APRM Scram. In a BWR/2, the quadrant-based APRM is capable of detecting both in-phase and out-of-phase oscillations with sufficient sensitivity to initiate automatic protective action to suppress the oscillations before safety margins are compromised.

III. LPRM-Based Detect and Suppress. Local power range monitor (LPRM) signals or combinations of a small number of LPRMs are analyzed on-line by using three diverse algorithms. If any of the algorithms detects an instability, automatic protective action is taken to suppress the oscillations before safety margins are compromised.

All of the above solutions have been implemented in commercial nuclear power plants in the United States (U.S.). Nevertheless there are three significant areas of consideration, which merit a revisit of these long-term solutions. These areas are: (a) deficiencies identified in the CPR versus oscillation amplitude correlation used for detect and suppress solutions (i.e., the DIVOM correlation,) which resulted in a Title 10 of the *Code of Federal Regulations* (10 CFR) Part 21 notification, (b) proposed increases in power density, and (c) lessons learned from instability events that occurred at Nine Mile Point Nuclear Station, Unit 2 (hereafter, Nine Mile Point 2) in July 2003 and Perry Nuclear Power Plant, Unit 1 (hereafter, Perry) in December 2004.

The DIVOM correlation is used to estimate the delta CPR as function of oscillation amplitude, and it is required to select the scram set point for detect and suppress solutions. The DIVOM correlation was approved on the basis that it would be bounding for all reasonable circumstances; however, later analysis demonstrated that some plant-specific calculations result in larger loss of CPR margin than the DIVOM prediction. Therefore, the generic DIVOM curve could be non-conservative for some plant applications. A non-conservative DIVOM curve, would then result in stability-related setpoints that would not guarantee that specified acceptable fuel design limits would be maintained if a limiting instability event were to occur. This potential for a non-conservative DIVOM curve made Solution III invalid as a viable long-term solution, unless cycle-specific DIVOM correlations were used, which is the approach used by most plants today.

In recent years, the industry has been moving to reactor operation at higher and higher power densities and power-to-flow ratios. This operation is, in principle, detrimental to the stability characteristics of the reactor and results in two consequences: (a) it increases the probability of instability events, and (b) it increases the severity of the event should it occur (e.g., larger amplitude oscillations). Indeed, simulations of two recirculation pump trip (RPT) transients initiated at MELLLA+ conditions (80 percent flow and 120 percent original licensed thermal power) indicate that instabilities of sufficiently large amplitude to compromise the Safety Limit MCPR (SLMCPR) in short time are not only possible, but very likely.

Since implementation of the long-term solutions, instability events have occurred at two U.S. plants: Nine Mile Point 2 in July 2003 and Perry in December 2004. Both events occurred in Solution III plants. Some deficiencies were identified in the performance of Solution III for the Nine Mile Point 2 event, resulting in a 10 CFR Part 21 notification. The deficiencies were related to the adjustable parameters for period-based detection, which are now recommended to be placed at their most sensitive settings. Most parameter settings for the long-term solutions are evaluated on a plant-specific basis by collecting noise data over a relatively long period of time. The parameters are adjusted during this trial period until normal plant transients do not trigger the stability detection algorithms. In Nine Mile Point 2, these parameters had been set to be fairly insensitive to avoid spurious actuations; however, this resulted in continuous resetting of the confirmation count because the Nine Mile Point 2 oscillation was very small in magnitude. In spite of the identified deficiencies, Solution III automatically scrammed the reactor and the SLMCPR was never compromised in the Nine Mile Point 2 event. The Perry event resulted from a malfunctioning valve, which triggered scram actuation by Solution III without compromising the SLMCPR.

1.2. <u>DSS-CD Long Term Solution</u>

The DSS-CD methodology is described in detail in NEDC-33075P (References 2 and 7). In summary, DSS-CD is based on the approved Solution III, and it shares most of its features. There are only two major differences between Solution III and DSS-CD:

1. DSS-CD does not require the calculation of an amplitude setpoint to trigger scram actuation if the period-based algorithm (PBA) identifies an instability event. Instead, DSS-CD implements a small-amplitude discriminator that is set just above normal noise level. The efficiency of that discriminator is demonstrated generically. With DSS-CD implemented, the reactor will trip automatically if a coherent oscillation of very small amplitude is identified with amplitude above the noise level. Therefore, DSS-CD does not rely on generic correlations like DIVOM or cycle-specific calculations.

2. To prevent spurious scrams, DSS-CD requires period based algorithm confirmations of a significant number of oscillation power range monitor (OPRM) cells, referred to as "density of confirmations." The confirmation density algorithm (CDA) is relatively complex to cover all possibilities of combinations of failed and unresponsive OPRM cells, but under most conditions, [ ], the reactor will scram.

Other features of the DSS-CD methodology include:

1. DSS-CD maintains the defense in depth algorithms that were approved for Solution III: the PBDA, the amplitude based algorithm (ABA), and the growth rate algorithm (GRA). The ABA and GRA remain unchanged from the approved solution and provide defense in depth in the unlikely event that the CDA algorithm fails to detect the instability due to unforeseen situations.

2. PBDA was the primary algorithm in Solution III, and it is retained in DSS-CD with fixed parameter settings. PBDA will provide a scram if a single OPRM (in each protection system channel) provides at least 15 confirmations with amplitude greater than the setpoint. PBDA thus provides defense in depth in case the CDA fails in an unexpected mode. [ ]

3. DSS-CD can be implemented as a software change using the existing GEH NUMAC hardware used currently for Solution III.

4. In addition to the DSS-CD algorithm, a backup stability protection (BSP) methodology is well defined. The BSP is intended to provide SLMCPR protection if the regular DSS-CD is declared inoperable. With BSP, the DSS-CD methodology attempts to incorporate the lessons learned from recent notifications pursuant to 10 CFR Part 21, "Reporting of Defects and Noncompliance," when the primary stability protection system is declared inoperable.

1.3. <u>DSS-CD Uncertainty Treatment</u>

For DSS-CD applications, [ ], and it was judged acceptable by the NRC staff in earlier reviews of the DSS-CD methodology (Reference 2).

Sections 5 through 8 of NEDE-33147P, Revision 3 (Reference 1) present the full CSAU analysis methodology and an example case [ ]. The analysis is supported by the Phenomena Identification and Ranking Table (PIRT) developed in Section 3 of the subject TR. [ ], depending on the case analyzed. Thus this analysis confirms the conclusion reached by the NRC staff in previous reviews [ ].

1.4. <u>LTR Revision 3 Modifications</u>

NEDE-33147P, Revision 3 (Reference 1) documents 23 modifications to the approved methodology. Most of these modifications are clarifications of the methodology. The most significant modifications are:

1. Use of the TRACG04 version (References 2 and 3), including PRIME (Reference 7) fuel properties and gap conductance fuel input files.

2. Use of PANAC11 as the three-dimensional neutron kinetics model (References 6, 8, and 10).

3. Move the CSAU methodology application from the DSS-CD TR (Reference 2) into this one.

4. Use of realistic CSAU methodology [ ] that was approved for DSS-CD use.

5. Updated the CSAU results.

6. Updated TRACG channel grouping methodology to require one-to-one mapping between thermal-hydraulic and neutron bundles. Channel grouping is no longer necessary.

2.0 REGULATORY EVALUATION

The DSS-CD design provides the capability for automatic detection and suppression of reactor instability events and minimizes reliance on the operator to suppress instability events. The CDA is designed to recognize an instability and initiate control rod insertion before the power oscillations increase much above the noise level. The DSS-CD solution and related licensing basis were developed to comply with the requirements of 10 CFR Part 50, Appendix A, "General Design Criteria [GDC] for Nuclear Power Plants," GDC 10 and 12.

GDC 10, "Reactor design," requires that:

> The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

GDC 12, "Suppression of reactor power oscillations," requires that:

> The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

The purpose of the DSS-CD TRACG analyses is to confirm the inherent MCPR margin afforded by the solution design. To ensure compliance with GDC 10 and 12, the NRC staff confirms that the thermal and hydraulic design of the core and the reactor coolant system RCS has been accomplished using acceptable analytical methods, provides acceptable safety margins from conditions that could lead to fuel damage during normal reactor operation and AOOs, and is not susceptible to thermal-hydraulic instability or can be reliably and readily detected and suppressed. Regulatory guidance for the review of the thermal and hydraulic design and the suppression of reactor power oscillations is provided in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 4.4, "Thermal and Hydraulic Design," and SRP Section 15.9, "BWR Core Stability." As prescribed in NUREG-0800, Chapter 4, the NRC staff will confirm that the licensee performs the plant-specific trip setpoint calculations using NRC-approved methodologies. SRP Section 15.9 describes review procedures to evaluate the possibility of thermal-hydraulic instability in BWRs, analytical methods and codes to predict the stability characteristics of BWRs, and the use of approved long-term stability solutions.

3.0 TECHNICAL EVALUATION

NEDE-33147P, Revision 3 (Reference 1) makes a number of claims, which are evaluated in this SE.

NEDE-33147P, Revision 3, states that the applicability of TRACG04 for DSS-CD calculations is limited to BRW/3-6 plants. The NRC staff issued an RAI inquiring about the applicability for new reactors like the Advanced BWR (ABWR) or the Economic Simplified BWR (ESBWR). In the RAI response (Reference 12), GEH states that TRACG04 is approved for ESBWR stability calculations, including DSS-CD calculations; however, DSS-CD in ESBWR plays a defense in depth role, so the calculations simply confirm that instabilities are highly unlikely in ESBWR (Reference 13). The RAI response also specifies the calculations that would be required to demonstrate DSS-CD compliance for new reactor types like ABWR.

Section 1.3, "Purpose and Scope," of NEDE-33147P, Revision 3, claims that the applicability of TRACG04 for DSS-CD calculations is not limited to current or future fuels, including other vendor fuels. The reason behind this claim is that TRACG04 explicitly models all the characteristics of the fuel and, therefore, any future fuel changes are automatically accounted for by the methodology. In cases of mixed-core design (i.e., fuels from different vendors), an agreement is always in place where the characteristics of the other-vendor fuel are known in detail, including pressure drop and CPR correlations. Those details are modeled in TRACG whether the fuel is a GE product or from another vendor. Therefore, the NRC staff finds this evaluation acceptable for NRC-approved and future NRC-approved fuels.

In Section 2.2, "TRACG Analysis Approach for Licensing Compliance," of NEDE-33147P, Revision 3, [ ]. This is an acceptable approach because for DSS-CD calculations the first step is to trip the recirculation pumps; therefore, [ ]. In addition, SLO operation is subject to more restrictive initial MCPR conditions due to the operating limit MCPR requirements. [ ]

Section 2.2.1, "CSAU Methodology Application," and Table 2-1 of NEDE-33147P, Revision 3, document the CSAU methodology [ ]. It describes the 14 steps used in the uncertainty determination. Step 1 defines the transients analyzed, which are [

] for the TRACG demonstration analyses, and
[ ] are chosen for the demonstration analyses.
[ ]
These steps conform to the established CSAU methodology and are acceptable (Reference 10).

Section 2.4, "NRC Review Requirements for TRACG Code Updates," of NEDE-33147P, Revision 3, specifies the conditions that would require NRC staff review for future TRACG code updates. According to NEDE-33147P some modifications of the code will not require NRC staff review, but rather will only require a simple notification to the NRC staff. Specifically, GEH proposes that:

1. TRACG nuclear methods can be updated in the future without NRC review and approval if the updates are intended to ensure compatibility with steady-state nuclear methods that have been reviewed and approved by the NRC staff. GEH will confirm that the delta CPR/Initial CPR (ICPR) shows less than 1 sigma deviation difference compared to the method presented in this TR. If the difference is greater than 1 sigma, a review will be required. If the difference is less than 1 sigma, GEH will provide to the NRC staff for information a typical 2RPT transient showing compliance.

2. TRACG numerical methods can be updated in the future without NRC review and approval if the updates result in a more conservative (i.e., larger) calculated decay ratio or oscillation amplitude. If the updates result in a non-conservative (i.e., smaller) decay ratio or oscillation amplitude, the numerical methods must be reviewed by the NRC staff.

3. TRACG features that support effective code input/output and do not significantly affect the calculation results may be added without NRC staff review and approval.

The proposed TRACG update methodology described above is acceptable because it allows for the normal lifecycle of the software as minor improvements, compatibility with other systems, and error corrections become necessary. Only when the changes are significant and result in non-conservatisms, is a review necessary. For the purposes of this review, [

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Section 2.4, "NRC Review Requirements for TRACG Code Updates," of NEDE-33147P, Revision 3, also proposes a methodology to be used when new uncertainty data becomes available (e.g., new experimental data). Specifically, GEH proposes:

1. In the case that new data becomes available to reassess the basic uncertainty data of the physical phenomena, nuclear uncertainties, or correlations, the uncertainty analysis can be reanalyzed with the new data without an NRC staff review as long as the

methodology described in the Licensing TR (LTR) remains unchanged. The results will be transmitted to the NRC staff for information.

2. Changes to the uncertainty methodology or statistical treatment are not allowed without review.

The proposed uncertainty updates described above are acceptable because they allow GEH to incorporate better experimental data as it becomes available.

Section 3, "Phenomena Identification and Ranking," of NEDE-33147P, Revision 3, documents a PIRT analysis for the DSS-CD stability calculations. This PIRT analysis is the first step in the uncertainty determination. The PIRT analysis is performed for channel thermal-hydraulic instability, core-wide instabilities, and regional or out-of-phase instabilities. The NRC staff concurs with the PIRT evaluation of these phenomena. The phenomena identified as having high importance are:

[

]

In addition, all of the [

]

Section 4.2.1, “Explicit Integration Scheme for the Channel Component,” of NEDE-33147P, Revision 3, describes the numerical integration schemes of TRACG. Even though the default TRACG time integration scheme is fully implicit, for stability calculations TRACG uses explicit integration for the convective terms in the channel model. This numerical technique is the standard methodology for time-domain stability calculations and it is acceptable because it minimizes numerical diffusion and it is compatible with the TRACG stability qualification bases.

Section 4.2.2, “Detailed Nodalization Scheme for the Channel Component,” of NEDE-33147P, Revision 3, specifies that [

] scheme for stability calculations is acceptable because it is consistent with the TRACG qualification basis.

Section 5.0, “Model Biases and Uncertainties,” of NEDE-33147P, Revision 3, documents the disposition of the items in the PIRT ranked with high impact. The results are summarized in Table 5-1 of the TR. The NRC staff finds this evaluation acceptable.

Section 6.0, “Application Uncertainties and Biases,” of NEDE-33147P, Revision 3, documents in Table 6-1 the key plant initial conditions and parameters that are high and medium ranked for stability applications. Table 6-1 appears to be a complete list of all these boundary conditions and plant parameters, and its use is acceptable.

Section 7.0, “Combination of Uncertainties,” of NEDE-33147P, Revision 3, describes the methodology used to combine the basic uncertainty data. The approach used for TRACG DSS-CD calculations is similar to the approved methodology for [

]

Section 8.0, “Example Demonstration Analyses,” of NEDE-33147P, Revision 3, documents the results of a number of RPT transients for one and two pumps tripped, [ ]. Section 8.1 shows the best-estimate TRACG04 results and Section 8.2 documents the uncertainty analysis following the CSAU procedure. For all cases analyzed, [ ]. The uncertainty margin is summarized in Table 8-1 of NEDE-33147P, Revision 3, and it ranges from [ ]. Thus, the NRC staff concludes that [ ] is acceptable for DSS-CD applications because [ ].

As described in the NRC staff’s SE for NEDE-33075P, Revision 6 (Reference 2), a [ ]. This is illustrated in Figure 1 below (Figure 7-10 of Reference 2). Typically, DSS-CD scrams the reactor with a higher CPR margin that at initial conditions.

Figure 2 below (Figure 8-23 of Reference 1) illustrates the [ ].

[

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Figure 1. [ ]

[

]

Figure 2. [ ]

4.0 RAI RESOLUTION

The staff requested additional information from GEH about a number of topics. Most of these requests were clarifications to the statements in the TR, or requests to define more specifically the methodology for future applications. The detailed reposes are documented in Reference 12. The resolution of these responses is provided in this section. No open issues remain following this evaluation.

4.1. 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?

TRACG02 was approved for AOOs for operating reactors. The upgrade to TRACG04 was approved for both operating reactors and ESBWR applications in 2010.

TRACG02 was approved for stability calculations for operating reactors. In 2010, TRACG04 was approved for stability calculation in ESBWR.

4.2. 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?

Even though NEDE-33147P does not specifically include ESBWR in the applicability list, TRACG04 has been approved for DSS-CD use in ESBWR applications. The methodology is documented in two separate TRs because, for ESBWR, DSS-CD is not a "licensing basis" implementation, but rather a "defense in depth." This is because ESBWR has been demonstrated by analyses to be free of instabilities.

4.3. 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?

Applications of TRACG04 for DSS-CD in the ABWR would require the DSS-CD applicability extension procedure documented in Section 6 of the DSS-CD LTR NEDC-33075P, Revision 7 (Reference 7), to be implemented, which will [
].

4.4. 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.

Even though the CSAU methodology was developed specifically for LOCA transients, it has become the de-facto standard for uncertainty analysis, and it has been approved by the NRC staff for other TRACG04 applications, including AOO, Anticipated Transient Without Scram, and ESBWR Transient Analysis and Stability.

4.5. 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.

The details have been provided in the RAI response (Reference 12). The analyses in the TR were performed with TRACG04P, which is a Level 2 quality controlled code version. The specific version number is 04.02.60.03, compiled October 30, 2009.

4.6. 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?

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. The resulting average coolant density is used to define the effective cross section from the pre-calculated cross section tables, which are also a function of burnup, void history, and fuel temperature. Thus, if any bypass boiling is calculated by TRACG, its effect is fed back to the neutronic calculations.

Thermal-hydraulically, TRACG models [ ]. TRACG uses [ ]. The bypass model in TRACG [ ]; whereas ISCOR uses [ ].

4.7. RAI 7 - Control Rod Patterns to Excite Regional Mode

Section 4.2.6 states that "[ ]." Please provide some examples of [ ].

The RAI response provides a set of [ ].

4.8. 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.

Section 4.2.7 of the TR does not address the mathematical uniqueness of the solutions (i.e., the non-existence of other mathematical solutions). The term "uniqueness" in the TR referred to the solution being "special" or "one of a kind;" thus the confusion. The unique features of DSS-CD addressed in the TR are related to the fact that the DSS-CD [

].

4.9. 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).

The information was provided in the form of Figure 3, where one can see that, at the time of the DSS-CD scram, [

]

[

]

Figure 3. [ ]

(FMCPR is the Final MCPR)

4.10. <u>RAI 10 – Uncertainty Values</u>

Table 8-1 provides the [ ]. *Please provide the actual results of the statistical analysis in terms of percent minimum CPR (MCPR) per sigma.*

The actual uncertainty values were provided in Table 10-1 of the RAI response (Reference 12). [ ]

4.11. <u>RAI 11 – Figure 8-23 Labels</u>

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.

The explanation provided in the RAI response is satisfactory, and will be added to the –A version of the TR.

4.12. <u>RAI 12 – Process for Implementing the [ ]</u>

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

The process illustrated in Figure 8-23 of the TR is not straight forward and could possibly be implemented in several ways, yielding different results. The response to RAI 12 (Reference 12) documents the precise [ ]. This is the methodology that is approved by this SE and should be added to the –A version of the subject TR for clarification.

4.13. <u>RAI 13 – TRACG04 Configuration Options</u>

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

TRACG is a very flexible computer code which can be configured in many ways to perform DSS-CD calculations, which would yield different results. The response to RAI 13 defines the accepted configuration and it is part of the accepted methodology. The RAI response defines minimum thermal-hydraulic nodalization schemes, neutronic nodalization schemes, and numeric solution options. Specifically, the use of [ ] in the channel components, which are modeled one-to-one (i.e., no channel collapsing), is an acceptable process.

4.14. <u>RAI 14 – Dryout Correlation Applicability To Oscillatory Conditions</u>

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

The data was provided. Onset of boiling transition is predicted using the GEXL correlation, developed for each fuel product type using full-scale critical power test data. As part of this full-scale test data, the fuel bundle is subjected to oscillatory flow conditions that result in periodic dryout and rewet. The resulting temperature oscillations on the heated fuel rods were modeled with TRACG04 and the GEXL correlation and compared with the measured temperature transients.

Complete details are provided in the RAI response (Reference 12). Figure 4 -Figure 6 below show some examples for the most recent tests with GE14 and GNF2 type fuels. The [ ], and the CPR margin is calculated using the GEXL correlation. Reasonable agreement is observed, [ ].

Based on this experimental data, the NRC staff concludes that the GEXL correlation implemented in TRACG can predict oscillatory conditions of the kind experienced during DSS-CD calculations. The NRC staff notes that for DSS-CD calculations, [ ]. The experimental data provided in this RAI response confirms that TRACG-GEXL can be used to calculate these oscillatory operating conditions even if dryout does not occur.

[

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Figure 4. [ ]

[

]

Figure 5. [ ]

[

]

Figure 6. [ ]

4.15. 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.

In the response to this RAI, GEH states that, to comply with current regulations, correlations to predict 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 RPT. Oscillatory flow tests are performed [

]

5.0 CONCLUSION

Based on the NRC staff's review of the subject TR, as stated above, NEDE-33147P, Revision 3, is approved with the following conclusions:

1. The use of TRACG04 for DSS-CD stability calculations is acceptable for BWR/3-6 plants employing the DSS-CD stability solution.

2. The TRACG04 DSS-CD application may include all power-to-flow domains up to and including the MELLLA+ domain and all licensed operational enhancements.

3. Key fuel parameters are explicitly input to the TRACG04 model. Therefore the applicability of TRACG04 for DSS-CD applications is not limited to the fuels demonstrated in NEDE-33147P, Revision 3 (Reference 1), and the methodology may be applied to future NRC-approved fuel types, including fuel designs from other vendors.

4. The full statistical application of the CSAU methodology in NEDE-33147P, Revision 3 (Reference 1) [ ] and is, thus, acceptable.

6.0 REFERENCES

1. TR NEDE-33147P, Revision 3, "DSS-CD TRACG Application," dated January 2011. (ADAMS Package Accession No. ML110270071)

2. TR NEDC-33075P-A, Revision 6, "General Electric Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," dated January 2008. (ADAMS Package Accession No. ML080310384)

3. TR NEDE-32176P, Revision 4, "TRACG Model Description," dated January 2008. (ADAMS Package Accession No. ML080370259)

4. TR NEDE-32177P, Revision 3, "TRACG Qualification," dated August 2007. (ADAMS Package Accession No. ML072480007)

5. TR NEDE-32906P-A, Revision 3, "TRACG Application for Anticipated Operational Occurrences Transient Analysis," dated September 2006. (ADAMS Package Accession No. ML062720163)

6. TR NEDE-32906P-A, Supplement 3-A, Revision1, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients," dated April 2010. (ADAMS Package Accession No. ML110970401)

7. TR NEDC-33075P, Revision 7, "General Electric Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," dated June 2011. (ADAMS Package Accession No. ML111610593)

8. TR NEDO-32465 Supplement 1, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing

Basis Methodology for Reload Applications," dated September 2011. (ADAMS Package Accession No. ML112550358)

9. Letter from Monticello Nuclear Generating Plant to NRC, L-MT-12-108, "Maximum Extended Load Line Limit Analysis Plus License Amendment Request – Request for Additional Information Responses for TRACE/TRACG Differences (TAC ME3145)," dated December 21, 2012. (ADAMS Accession No. ML13002A261)

10. TR NEDO-31960-A, "BWR Owners' Group Long-Term Stability Solutions Licensing Methodology," dated November 1995. (ADAMS Legacy Accession No. 9603130105)

11. NUREG/CR-5249, "Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large-Break, Loss-of-Coolant Accident," NRC, dated December 1989. (ADAMS Package Accession No. ML030380503).

12. Letter from GEH to NRC, MFN 12-073, "Response to Request for Additional Information Re: GE-Hitachi Nuclear Energy Americas Topical Report (TR) NEDE-33147P, Revision 3, "DSS-CD TRACG Application" (TAC No. ME5406)," dated June 19, 2012. (ADAMS Package Accession No. ML121790572)

13. TR NEDE-33083P-A, Supplement 1, Revision 1, "TRACG Application for ESBWR Stability Analysis," dated January 2008. (ADAMS Package Accession No. ML080310454)

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