ENCLOSURE 2

MFN 14-070

NEDO-32465 Supplement 1-A, Revision 1

Non-Proprietary Information– Class I (Public)

**IMPORTANT NOTICE**

This is a non-proprietary version of NEDE-32465 Supplement 1P-A, Revision 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 [[ ]].

Note the NRC's Final Safety Evaluation is enclosed in NEDO-32465 Supplement 1-A, Revision 1. Portions of the Safety Evaluation that have been removed are indicated with a single square bracket as shown here. [ ].

GE Hitachi Nuclear Energy

NEDO-32465
Supplement 1-A
Revision 1
October 2014

*Non-Proprietary Information - Class I (Public)*

**LICENSING TOPICAL REPORT**
**SUPPLEMENT**

# Migration to TRACG04/PANAC11 from TRACG02/PANAC10

# for

# Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications

**Juswald Vedovi**
**David G. Vreeland**

## INFORMATION NOTICE

This is a non-proprietary version of the document NEDE-32465, Supplement 1P-A, Revision 1, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

Within the US NRC Safety Evaluation, the proprietary portions of the document that have been removed are indicated by an open and closed bracket as shown here [ ].

## IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

## PLEASE READ CAREFULLY

The information contained in this document is furnished for the purpose of obtaining NRC approval of the licensing requirements for implementation of the use of TRACG04 for reactor stability detect and suppress solutions licensing basis methodology. The only undertakings of GEH with respect to information in this document are contained in contracts between GEH and participating utilities, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone other than those participating entities and for any purposes other than those for which it is intended is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

October 24, 2014

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
General Electric-Hitachi
Nuclear Energy Americas, LLC
P.O. Box 780, M/C A-18
Wilmington, NC 28401-0780

SUBJECT: FINAL SAFETY EVALUATION FOR GENERAL ELECTRIC HITACHI NUCLEAR ENERGY AMERICAS, LLC TOPICAL REPORT NEDO-32465, SUPPLEMENT 1, "MIGRATION TO TRACG04/PANAC11 FROM TRACG02/PANAC10 FOR REACTOR STABILITY DETECT AND SUPPRESS SOLUTIONS LICENSING BASIS METHODOLOGY FOR RELOAD APPLICATIONS" (TAC NO. ME7104)

Dear Mr. Head:

By letter dated September 9, 2011 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML112550358), GE Hitachi Nuclear Energy Americas, LLC (GEH) submitted Topical Report (TR) Supplement 1, NEDO-32465, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications" to the U.S. Nuclear Regulatory Commission (NRC) staff for review.

By letter dated June 2, 2014, an NRC draft safety evaluation (SE) regarding our approval of TR Supplement 1, NEDO-32465 was provided for your review and comment (ADAMS Accession No. ML14086A456). The NRC staff's disposition of the GEH comments on the draft SE are presented in the attachment to the final SE enclosed with this letter.

The NRC staff has found that TR Supplement 1, NEDO-32465 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR Supplement and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR Supplement.

Our acceptance applies only to material provided in the subject TR Supplement. We do not intend to repeat our review of the acceptable material described in the TR Supplement. When the TR Supplement appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR Supplement will be subject to a plant-specific review in accordance with applicable review standards.

NOTICE: Enclosure 2 transmitted herewith contains Proprietary Information. When separated from Enclosure 2, this transmittal document is decontrolled.

In accordance with the guidance provided on the NRC website, we request that GEH publish approved proprietary and non-proprietary versions of TR Supplement NEDO-32465, within three months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE Supplement after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The approved versions shall include an "-A" (designating approved) following the TR Supplement identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR Supplement, GEH and/or licensees referencing it will be expected to revise the TR Supplement appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

***/RA/***

Aby S. Mohseni, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosures:
1. Final Safety Evaluation (Non-Proprietary)
2. Final Safety Evaluation (Proprietary)

cc: See next page

In accordance with the guidance provided on the NRC website, we request that GEH publish approved proprietary and non-proprietary versions of TR Supplement NEDO-32465, within three months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE Supplement after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The approved versions shall include an "-A" (designating approved) following the TR Supplement identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR Supplement, GEH and/or licensees referencing it will be expected to revise the TR Supplement appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

***/RA/***

Aby S. Mohseni, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosures:
1. Final Safety Evaluation (Non-Proprietary)
2. Final Safety Evaluation (Proprietary)

cc: See next page

<u>DISTRIBUTION</u>:
PUBLIC (Cover Letter, Encl. 1, and Attachment)

| | |
|---|---|
| NON-PUBLIC (Encl. 2) | RidsNrrDpr |
| RidsNrrDprPlpb | RidsNrrPMJGolla |
| RidsNrrLADBaxley | RidsOgcMailCenter |
| RidsAcrsAcnwMailCenter | RidsNrrDss |
| RidsNrrDssSrxb | UShoop |
| JGolla | RidsResOd |
| RidsNroOd | AMendiola |

**ML14251A036 (Pkg.); ML14247A209 (Cover letter); ML14247A244 (Encl. 1/Non-Prop SE); ML14247A255 (Encl. 2/Prop SE); ML14247A258 (Non-Prop Attachment) NRR-106**

| **OFFICE** | PLPB/PM | PLPB/LA | SRXB/BC | PLPB/BC | DPR/DD |
|---|---|---|---|---|---|
| **NAME** | JGolla | DHarrison | UShoop | AMendiola | SMohseni |
| **DATE** | 9/29/2014 | 9/25/2014 | 10/4/2014 | 10/23/2014 | 10/24/2014 |

**OFFICIAL RECORD COPY**

~~OFFICIAL USE ONLY-PROPRIETARY INFORMATION~~

GE-Hitachi Nuclear Energy Americas Project No. 710

cc:

Mr. James F. Harrison
GE-Hitachi Nuclear Energy Americas LLC
Vice President - Fuel Licensing
P.O. Box 780, M/C A-55
Wilmington, NC 28401-0780
james.harrison@ge.com

Ms. Patricia L. Campbell
Vice President, Washington Regulatory Affairs
GE-Hitachi Nuclear Energy Americas LLC
1299 Pennsylvania Avenue, NW
9th Floor
Washington, DC 20004
patriciaL.campbell@ge.com

~~OFFICIAL USE ONLY-PROPRIETARY INFORMATION~~

# SAFETY EVALUATION BY THE OFFICE NUCLEAR REACTOR REGULATION

# TOPICAL REPORT NEDO-32465, SUPPLEMENT 1

# "MIGRATION TO TRACG04/PANAC11 FROM TRACG02/PANAC10 FOR REACTOR STABILITY DETECT AND SUPPRESS SOLUTIONS LICENSING BASIS METHODOLOGY FOR RELOAD APPLICATIONS"

# GE-HITACHI NUCLEAR ENERGY AMERICAS, LLC

# PROJECT NO. 710

## 1.0 INTRODUCTION

By letter dated September 9, 2011 (Agencywide Documents Access and Management System Accession No. ML112550358), GE Hitachi Nuclear Energy Americas, LLC (GEH) submitted Topical Report (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," to the U.S. Nuclear Regulatory Commission (NRC) staff for review (Reference 1). NEDO-32465, Supplement 1, provides the licensing basis and methodology for Delta Critical Power Ratio (CPR) over Initial Minimum CPR (MCPR) Versus Oscillation Magnitude (DIVOM) calculations using the TRACG04 code [TRACG is the designation for the GEH proprietary version of the Transient Reactor Analysis Code (TRAC)]. The DIVOM methodology was reviewed and approved by the NRC staff as documented in TR NEDO-32465-A (Reference 2). Supplement 1 to NEDO-32465 addresses a code migration from TRACG02/PANAC10 to TRACG04/PANAC11, which had previously been implemented following a GEH evaluation in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.59 (Reference 3).

Two related submittals have been recently approved by the NRC staff: Revision 8 of the DSS-CD Methodology TR, NEDC-33075P-A (Reference 4), and Revision 4 of TR NEDE-33147P-A (Reference 5). These TR revisions are based on the use of TRACG04 in the DSS-CD process and document the applicability of TRACG04/PANAC11 for DSS-CD calculations.

The GEH TRACG04 code model description, qualification, and application for anticipated operational occurrences are documented in TRs NEDE-32176P, NEDE-32177P, NEDE-32906P-A, and NEDE-32906P-A, Supplement 3, respectively (References 6 thru 9). References 8 and 9 have been reviewed and approved by the NRC staff (References 6 and 7 are included for information).

In NEDO-32465, Supplement 1 (Reference 1), GEH requests NRC staff review and approval of this supplement to the licensing basis for the Detect and Suppress Solutions Licensing Basis Methodology (Reference 2) to use TRACG04/PANAC11 for applications to the Option 1-D, Option II, and Option III Stability Long Term Stability Solutions (LTS).

The NRC staff was assisted in this review by staff from Oak Ridge National Laboratory. The NRC staff's review is based on the submitted TR supplement, requests for additional information (RAI) questions, and information obtained during meetings with GEH to clarify and supplement the RAI questions. The main conclusion from this review is that the proposed code migration from TRACG02/PANAC10 to TRACG04/PANAC11 is acceptable for DIVOM 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 10). This safety evaluation covers the application of TRACG04/PANAC11 for DIVOM calculations, where calculations are not analyzed past the point of CHF; therefore the approval of TRACG04 for DIVOM calculations does not imply the approval of the TRACG04 post-CHF models.

## 2.0 BACKGROUND

### 2.1. Long Term Solutions

Following the March 1988 instability event at a LaSalle County Station boiling water reactor (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 (References 16 and 17). 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. <u>LPRM-Based Detect and Suppress</u>**. 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 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.

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 (2RPT) 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 a 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 the Nine Mile Point 2 event, the adjustable parameters had been set to the least sensitive value to avoid spurious actuations. The event had a very small oscillation amplitude and, because of the settings chosen, the confirmation count value kept on resetting and tripped the reactor later than expected. In spite of stability solution deficiencies that were identified after careful analysis of the event data, Solution III automatically initiated a scram of 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.

## 2.2. <u>DIVOM Methodology</u>

The DIVOM methodology is described in detail in NEDO-32465-A (Reference 2). The DIVOM correlation is used to estimate the delta CPR as a 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 may 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 Solutions I-D, II, and 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 principle, two DIVOM correlations are calculated for each reactor condition: the core-wide mode DIVOM and the regional-mode DIVOM. Under all credible circumstances, the regional-mode DIVOM correlation has a larger slope (i.e., more conservative) than the core-wide mode DIVOM. This is because regional-mode oscillations are always accompanied by larger swings in hot channel flow, which reduce the CPR performance.

To calculate the cycle-specific DIVOM curve, a licensed three-dimensional (3-D) core simulator (e.g., TRACG04/PANAC11) is used to simulate core-wide and regional oscillations at the limiting power/flow state point for a minimum of three cycle exposures. For each exposure time, a growing power oscillation is calculated as illustrated in **Figure 1** through 3.

The TRACG output is parsed to determine the maximum swings in power and CPR in each bundle. The power and CPR amplitudes for each oscillation are plotted against each other, and a piece-wise linear function is plotted to define a region that statistically bounds all oscillations as illustrated in **Figure 4**. For most applications, this piece-wise linear function is a single straight line that defines a single slope, which is known as the DIVOM slope. The original BWROG methodology described in NEDO-32465-A (Reference 2) uses a single DIVOM slope over the expected range of oscillation magnitudes (the Hot Channel Oscillation Magnitude (HCOM) range). However, the BWROG DIVOM methodology allows for a more generic DIVOM curve, where the slope varies with oscillation amplitude. The GEH DIVOM methodology is consistent with the BWROG DIVOM methodology. .

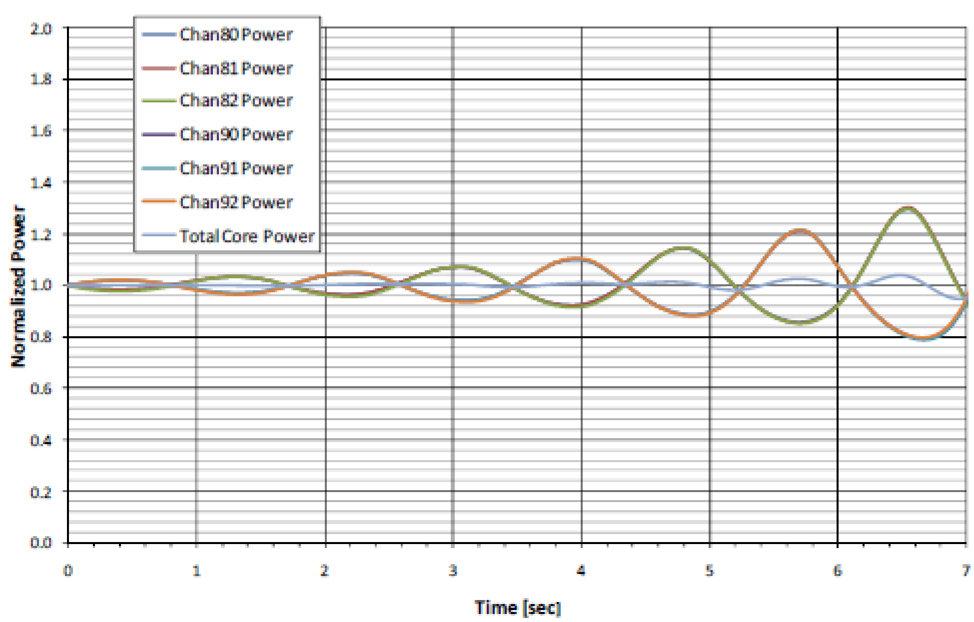



**Figure 1. Typical regional-mode power oscillation calculated by TRACG04/PANAC11**

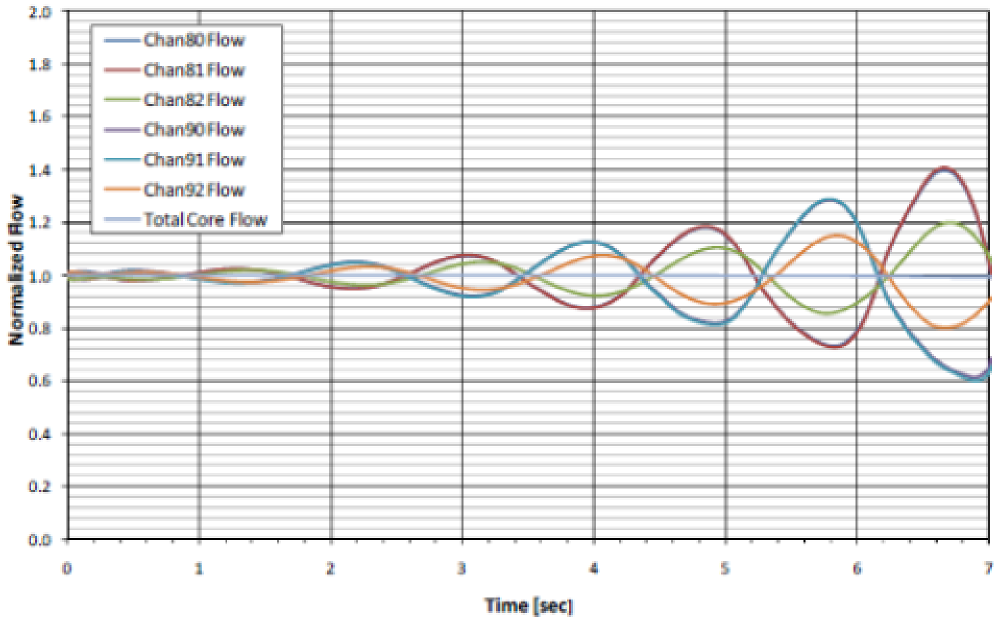



**Figure 2. Typical regional-mode flow oscillation calculated by TRACG04/PANAC11**

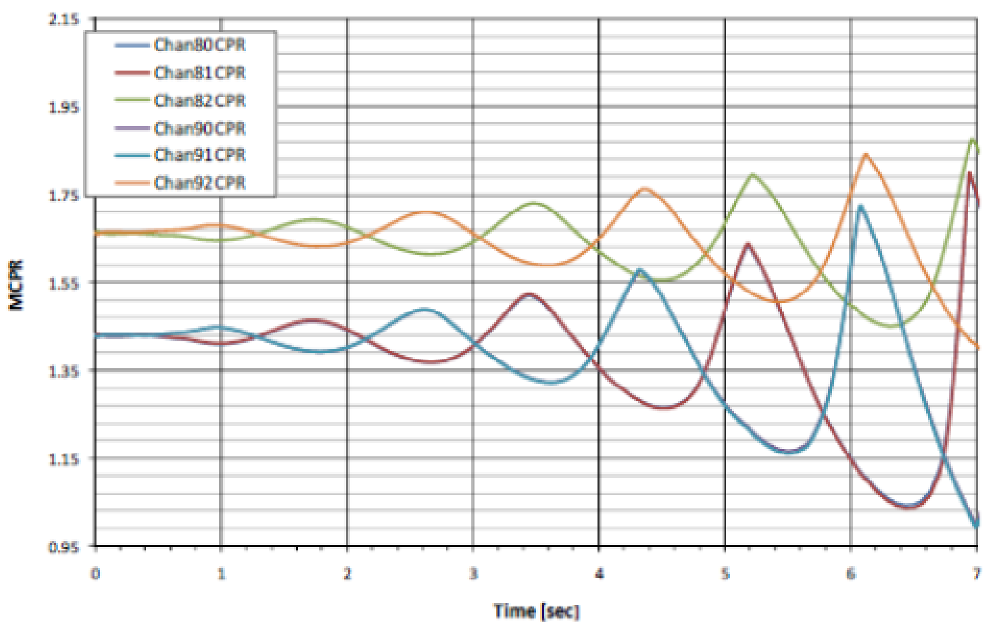



**Figure 3. Typical regional-mode MCPR oscillation calculated by TRACG04/PANAC11**

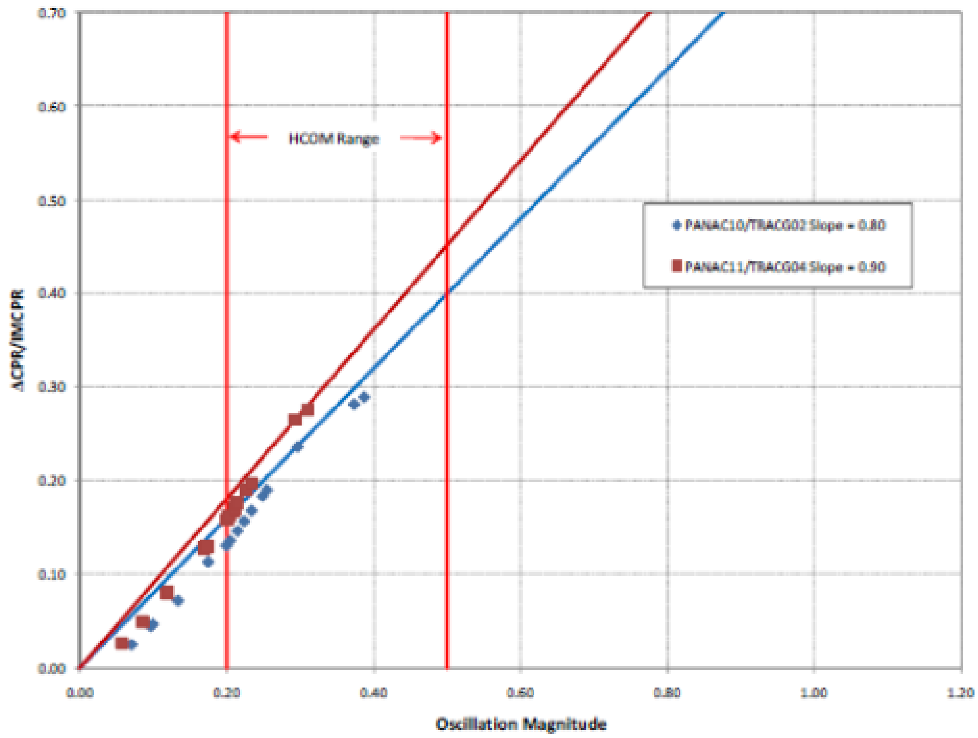



**Figure 4. Typical regional DIVOM slope (TRACG04 vs TRACG02)**

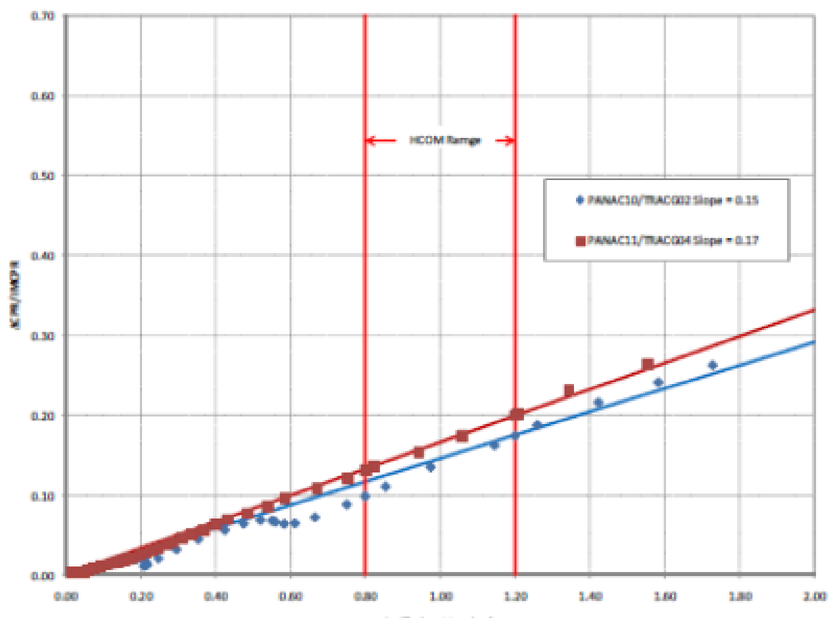



**Figure 5. Typical core-wide DIVOM slope (TRACG04 vs TRACG02)**

## 2.3. <u>TRACG04 Use For DIVOM Calculations</u>

The generic DIVOM analysis performed in NEDO-32465-A (Reference 2) used TRACG02 coupled with PANAC10 (P10). However, most plants have now adopted the PANAC11 (P11)

BWR core simulator methodology coupled with TRACG04 to perform DIVOM analyses. The use of the TRACG04/P11 methodology was originally supported by a 10 CFR 50.59 evaluation. NEDO-32465, Supplement 1 (Reference 1) documents this methodology upgrade. Only the detect and suppress (D&S) part of the Option 1-D, Option II, and Option III Stability LTSs are based on the DIVOM methodology. There are no other changes requested for any of these stability solutions.

### 2.4. TRACG04 Modifications from TRACG02

Appendix A of NEDO-32465, Supplement 1 (Reference 1) documents the 15 main changes made to TRACG02 in the upgrade to TRACG04. Most of these changes affect loss-of-coolant accident calculations (Reference 9). The changes that are most relevant to DIVOM calculations are:

Upgrade to the PANAC11 kinetics model and cross sections generated with the P11/TGBLA06 methodology.

Fuel rod thermal conductivity models are now consistent with the PRIME fuel rod thermal-mechanical code/methodology.

Update of pump homologous curves with data representative of large pumps.

## 3.0 REGULATORY EVALUATION

The DIVOM correlation is used to estimate the delta CPR as a function of oscillation amplitude, and it is required to select the scram set point for D&S solutions. Supplement 1 to NEDO-32465 addresses a code migration from TRACG02/PANAC10 to TRACG04/PANAC11, which had previously been implemented following a GEH evaluation in accordance with 10 CFR 50.59.

The DIVOM correlation and its related licensing basis were developed to comply with the requirements of General Design Criteria 10 and 12 in 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

Criterion 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."

Criterion 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."

To ensure compliance with Criteria 10 and 12, Appendix A, 10 CFR Part 50, the NRC staff will confirm that the licensee performs the plant-specific trip setpoint calculations using NRC-approved methodologies as prescribed in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Chapter 4. The subject TR provides the licensee's application to support its TS license amendment changes.

Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," establishes the minimum quality requirements for the design, fabrication, construction, and testing of structures, systems, and components of nuclear power plants and fuel reprocessing facilities. Nuclear power plants include the structures, systems, and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. These requirements establish the criteria by which the NRC staff review the development of safety system hardware and software for use in nuclear power plants.

The GEH safety system development process has been approved by the NRC staff as a process that is consistent with the requirements of 10 CFR Part 50, Appendix B. The DIVOM correlation and its scram set point for D&S solutions were developed for use in GE-design BWRs using the GEH safety system development process, thereby addressing the requirements of 10 CFR Part 50, Appendix B.

## 4.0 TECHNICAL EVALUATION

In NEDO-32465, Supplement 1 (Reference 1), GEH requests NRC staff review and approval of the Detect and Suppress Solutions Licensing Basis Methodology to use TRACG04/P11 for applications to the Option 1-D, Option II, and Option III Stability LTS.

The supplement (Reference 1) presents a series of comparisons of DIVOM calculations using the old TRACG02/P10 and the new TRACG04/P11 methodologies. Because P10 and P11 use different cross section methodologies, extreme care must be taken to develop the two cross section sets so that both represent the same reactor condition. Nevertheless, small differences are to be expected.

The main results of this benchmark indicate that the DIVOM slopes calculated by both methodologies are essentially identical, with the new TRACG04/P11 methodology being slightly more conservative (larger DIVOM slope) than TRACG02/P10. These benchmarks are reproduced here as **Figure 4** and 5. The NRC staff notes that in these figures the red line (TRACG04/P11) is slightly higher than the blue line (TRACG02/P10), which results in lower values of the scram setpoint and is more conservative.

As stated previously, the changes in TRACG04 relevant to DIVOM calculations are: (1) upgrade from P10 to P11, (2) the use of PRIME for fuel thermal conductivity models, and (3) upgrade of the pump characteristics. These changes are acceptable and do not significantly affect the quality of the DIVOM slope calculation, as demonstrated by the previous benchmarks.

In the response to RAI 14 in Reference 15, GEH provided the results of a benchmark of the TRACG04 code against recent periodic dryout tests for modern fuel bundles. The 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 response to RAI 14 (Reference 15). **Figure 6** thru **Figure 8** show some examples for the most recent tests with GE14 and GNF2 type fuel. [

], and the CPR margin is calculated using the GEXL correlation. Reasonable agreement is observed between the calculated and measured rod temperatures, [

].

Additional oscillatory dryout tests are documented in Section 3.6.1 of the TRACG Qualification Report (Reference 7). Based on this experimental data, the NRC staff concludes that the GEXL correlation implemented in TRACG can predict oscillatory conditions of the kind considered in DIVOM calculations.

[

]

**Figure 6. Test flow oscillations, imposed to TRACG as boundary condition**

[

]

**Figure 7. Fuel temperature oscillation predicted by TRACG compared to measurements**

[

]

**Figure 8. Fuel temperature oscillation predicted by TRACG compared to measurements**

In Sections 3 and 7 of the TRACG Qualification Report (Reference 7), GEH has documented a number of successful TRACG benchmarks against plant stability tests and events, including

1. LaSalle Instability Event
2. Leibstadt Stability Tests
3. Nine Mile Point 2 Instability Event
4. Peach Bottom 2 Stability Tests
5. FRIGG Stability Tests

## 5.0 RAI RESOLUTION

The NRC staff requested additional information from GEH about a number of topics. Most of these RAI questions were for clarifications to the statements in the TR, or requests to define more specifically the methodology for future applications. The detailed responses are documented in (Reference 14). The staff reviewed the responses to the RAI questions and found them acceptable. No open issues remain following this evaluation. Below is a summary of the RAI responses.

### 5.1. RAI-1 - TRACG04 Configuration Options:

*Please specify the required TRACG04 configuration options (where TRACG represents the Transient Reactor Analysis Code – GEH proprietary version) for DIVOM [Delta CPR over Initial MCPR Versus Oscillation Magnitude] calculations (e.g., full-core channel mapping, axial nodalization, semi-implicit method, etc.).*

The RAI question response provides the configuration options for TRACG04 DIVOM calculations, including the channel mapping, axial nodalization, and the requirement to use the **[ ]**.

### 5.2. RAI-2 – Approved Code Versions:

*NEDO-32465, Supplement 1, Revision 0 states that “The NRC has examined the capability and qualification of P11/TGBLA06 through numerous applications” (where P11 represents PANAC11, a boiling water reactor core simulator methodology, coupled with TGBLA06, a fuel lattice physics methodology used to provide lattice input to nuclear design and analysis methods). Please provide a list of references of approved (“-A”) licensing topical reports (LTRs) that use the P11/TGBLA06 methodology.*

The references were provided. Previously approved applications of TRACG04 with the P11/TGBLA06 neutronic models include anticipated operation occurrence (AOO) and anticipated transient without scram (ATWS) overpressure analyses, Economic Simplified BWR (ESBWR) transients, ESBWR stability analyses (Reference 13), and ESBWR ATWS. In addition, TRACG04/P11 was used extensively in the preparation of the TR NEDC-33173, “Applicability of GE Methods to Expanded Operating Domains” (Reference 18).

5.3. RAI-3 – Applicability To New Fuels:

*Please describe the applicability of the DIVOM methodology with TRACG04/P11 (TRACG04 coupled with PANAC11) in NEDO-32465, Supplement 1 to new fuels and fuels from other vendors. Is a review process required for new fuels before application of P11/TGBLA06?*

In the response to the RAI question, GEH clarifies that the DIVOM methodology is plant- and cycle-specific. As such, the TRACG04/P11 analysis includes the detailed bundle design, whether it is from GEH/Global Nuclear Fuel – Americas, LLC (GNF) or from other fuel vendors. Therefore, the TRACG04/P11 DIVOM methodology is applicable to current and new fuel designs from GEH/GNF and/or other fuel vendors. The qualification of P11/TGBLA06 to new fuel designs involves a comparison of key parameters such as the eigenvalue, void coefficient and control rod worth to the corresponding parameters produced with MCNP [Monte Carlo N-Particle code]. The NRC staff finds GEH's evaluation acceptable.

5.4. RAI-4 – Fuel Properties:

*As part of the TRACG04 upgrade, PRIME (a fuel rod thermal mechanical code) is used to calculate fuel properties. What codes or methodologies were used to calculate the fuel properties in the sample cases in Figures 4-18 to 4-23?*

In the RAI question response, GEH clarifies that consistent fuel properties have been used for all calculations. When a calculation is marked as TRACG02/P10, the GESTR thermal mechanical code was used to derive the fuel properties. For calculations marked TRACG04/P11, PRIME was used.

5.5. RAI-5 – Channel Grouping:

*As part of the new TRACG04 methodology, stability calculations are performed with full one-to-one channel mapping; however, old TRACG02/P10 applications used channel grouping (typically approximately 30 thermal-hydraulic channels). What channel grouping was used for the sample cases in Figures 4-18 to 4-23? Please describe any impact on DIVOM slopes of the new channel grouping strategy.*

In the RAI question response, GEH clarifies that the new TRACG04 methodology that uses one-to-one channel mapping only applies to DSS-CD, as described in Reference 9. For Solution III DIVOM calculations, the channel grouping strategy documented in the response to RAI question 1 above is used.

5.6. RAI-6 – Natural Circulation HCOM:

*Section 4.2 of NEDO-32465, Supplement 1 states that HCOM values at natural circulation are typically between 0.8 and 1.0. In Figure 5-4, a single HCOM value of approximately 1.05 is marked in the figure. How can a bounding DIVOM slope be defined with only one HCOM value instead of a range? Please explain the example of Figure 5-4.*

In the RAI question response, GEH clarifies that for normal Solution III applications, a HCOM range would be used. However, for Solution ID applications, a single HCOM value specified by the methodology is used. In the particular case of Figure 5-4 of the TR, the purpose of that calculation was to compare the performance of TRACG02/P10 with TRACG04/P11; for purposes of this comparison, a single known HCOM value was used.

## 6.0 CONCLUSION

Based on its review of the subject TR, as stated above, the NRC staff has reached the following conclusions:

1. The TRACG04/P11 code suite is qualified to model the growing unstable power oscillations that are required for the DIVOM calculation procedures.

2. TRACG04/P11 can correctly predict the onset of dryout conditions during power oscillations representative of instabilities.

3. Therefore, the use of TRACG04 for DIVOM stability calculations is acceptable for BWRs employing the long term stability solutions Option I-D, Option II, or Option III.

4. The TRACG04 DIVOM application may include all power/flow domains and all licensed operational enhancements where the Long Term Solution is applicable.

5. Key fuel parameters are explicitly input to the TRACG04 model. Therefore the applicability of TRACG04 for DIVOM applications is not limited to the fuels demonstrated in NEDO-32465 Supplement 1 (Reference 1). The methodology may be applied to future fuels types, including fuel designs from other vendors.

## 7.0 REFERENCES

1. NEDO-32465 Supplement 1. “Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications,” GE Hitachi Nuclear Energy. September 2011.

2. NEDO-32465-A. “Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications,” GE Nuclear Energy. August 1996.

3. 0000-0115-7421-R0. “TRACG04P DIVOM 10 CFR 50.59 Evaluation Basis,” GE Hitachi Nuclear Energy. April 2010.

4. NEDC-33075P-A, Revision 8. “GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density,” GE Hitachi Nuclear Energy, November 19, 2013.

5. NEDE-33147P-A, Revision 4, “DSS-CD TRACG Application,” GE Hitachi, August 12, 2013.

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

7. NEDE-32177P, Revision 3. “TRACG Qualification,” GE Hitachi Nuclear Energy. August 2007.

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

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

10. 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)

11. Not Used

12. NUREG/CR-5249, “Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large-Break, Loss-of-Coolant Accident,” US NRC. December 1989.

13. NEDE-33083P-A, Supplement 1, Revision 1, “TRACG Application for ESBWR Stability Analysis,” GE Hitachi Nuclear Energy. January 2008.

14. MFN 12-088, “Response to Request for Additional Information RE: GE-Hitachi Nuclear Energy Americas Topical Report (TR) NEDO-32465-A, Supplement 1, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications" (TAC No. ME7104) and DIVOM Process Screen Shots,” GE Hitachi Nuclear Energy. July 27, 2012.

15. 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),” GE Hitachi Nuclear Energy. June 19, 2012.

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

17. TR NEDO-31960-A, Supplement 1, “BWR Owners' Group Long-Term Stability Solutions Licensing Methodology," dated November 1995. (ADAMS Legacy Accession No. 9603130105).

18. TR NEDC-33173P-A, “Applicability of GE Methods to Expanded Operating Domains,” dated January 2008. (ADAMS Legacy Accession No. 083520464).

Attachment: Resolution of Comments

Principal Contributor: Tai Huang, NRR/DSS/SRXB

Date: October 24, 2014

**RESOLUTION OF COMMENTS BY THE OFFICE OF NUCLEAR REACTOR REGULATION**

**ON DRAFT SAFETY EVALUATION FOR TOPICAL REPORT**

**NEDO-32465, SUPPLEMENT 1, "MIGRATION TO TRACG04/PANAC11**

**FROM TRACG02/PANAC10 FOR REACTOR STABILITY DETECT AND SUPPRESS**

**SOLUTIONS LICENSING BASIS METHODOLOGY FOR RELOAD APPLICATIONS**

**(TAC NO. ME7104)**

**Note:** Page numbers shown in this table reflect the page numbers in General Electric – Hitachi (GEH) transmittal letter MFN 14-038, June 26, 2014. Due to suggested changes in the Safety Evaluation (SE) and the addition of a change summary table, these page numbers differ from the page numbers in the draft SE sent to GEH for review.

| Location | Comment | NRC Disposition |
|---|---|---|
| Section 1.0<br>Introduction | Page 6:<br>Last Paragraph: Please replace "DSS-CD" with "DIVOM calculations".<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 2.2<br>DIVOM Methodology | Page 8:<br>1st paragraph:<br>GEH suggests the following changes:<br>"This potential for a non conservative DIVOM curve made Solutions I-D, II, and III invalid as a viable…"<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 2.2<br>DIVOM Methodology | Page 8:<br>3rd paragraph:<br>GEH suggests the following changes:<br>"To calculate the cycle-specific DIVOM curve, a licensed three-dimensional (3-D) core simulator (e.g., TRACG04/PANAC11) is used to simulate core-wide and regional oscillations at the limiting power/flow state point ~~several state points throughout that cycle~~ a minimum of three cycle exposures."<br><br>*This clarifies the way in which DIVOM is calculated.*<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |

| Location | Comment | NRC Disposition |
|---|---|---|
| Section 2.2<br>DIVOM Methodology | Page 8:<br>4th paragraph:<br>GEH suggests replacing the last three sentences with the following text:<br>"The original BWROG methodology described in NEDO-32465-A (Reference 2) uses a single DIVOM slope over the expected range of oscillation magnitudes (the Hot Channel Oscillation Magnitude (HCOM) range). However, the BWROG DIVOM methodology allows for a more generic DIVOM curve, where the slope varies with oscillation amplitude**.** The GEH DIVOM methodology is consistent with the BWROG DIVOM methodology. ~~The GEH DIVOM methodology application procedure is described in detail in NEDO-32465-A (Reference 2). It uses a single DIVOM slope over the expected range of oscillation magnitudes (the Hot Channel Oscillation Magnitude (HCOM) range).~~"<br><br>*NEDO-32465-A is a BWROG document. The text was reorganized in order to reflect that NEDO-32465-A is the original basis and the plant-specific DIVOM guidelines updated the method in order to calculate DIVOM on a cycle-specific basis and to make it clear that the GEH methodology is consistent with the BWROG methodology.*<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 2.3<br>TRACG04 Use For Divom Calculations | Page 11:<br><br>GEH suggests the following change to the section title:<br>"TRACG04 Use For ~~Divom~~ DIVOM Calculations"<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 2.4<br>TRACG04 Modifications from TRACG02 | Page 12:<br>GEH suggests replacing Reference 11 in this section with Reference 9 and deleting Reference 11.<br>"Appendix A of NEDO-32465, Supplement 1 (Reference 1) documents the 15 main changes made to TRACG02 in the upgrade to TRACG04. Most of these changes affect loss-of-coolant accident calculations (Reference 9)."<br><br>*Reference 11 does not discuss TRACG04.*<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |

| Location | Comment | NRC Disposition |
|---|---|---|
| Section 4.0<br>Technical Evaluation | Page 16:<br>Paragraph directly below Figure 8:<br>Change 'Section 7' to 'Sections 3 and 7'.<br><br>*This clarification reflects that FRIGG stability tests are discussed in Section 3 of Reference 7.*<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 6.0<br>Conclusion | Page 19:<br>Item 3:<br>GEH suggests the following change:<br>"Therefore, the use of TRACG04 for DIVOM stability calculations is acceptable for ~~BWR/3-6 plants~~ BWRs employing ~~any approved D&S stability solution like Solutions ID, II or III~~ the long term stability solutions Option I-D, Option II, or Option III."<br><br>*This change is recommended because DIVOM is part of three long-term stability solutions. The applicability of a long-term stability solution to a particular BWR type is dependent on the assessment of that BWR and the long-term stability solution selected. Application of DIVOM with TRACG04/PANAC11 does not impact the assessment of a long-term stability solution to a particular BWR type.*<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |
| Section 7.0<br>References | Page 20:<br>GEH suggests deleting Reference 11 and replacing it with 'Not Used' since it is not used in the SE and a later version of the same LTR is used elsewhere in the SE.<br>Suggested changes shown in the markup. | Comment accepted. Change made in final SE. |

# TABLE OF CONTENTS

# LIST OF FIGURES

## Revision Summary

**Revision 1:**

1. Created '-A' version by adding the NRC's Final Safety Evaluation (Reference 21) and GEH's responses to the NRC's Requests for Additional Information (RAIs) (Reference 20).
2. Added References 20 and 21.

## Acronyms and Abbreviations

| Term | Definition |
|---|---|
| AOO | Anticipated Operational Occurrence |
| ATWS | Anticipated Transient Without Scram |
| BOC | Beginning Of Cycle |
| BWR | Boiling Water Reactor |
| CFR | Code of Federal Regulations |
| CPR | Critical Power Ratio |
| ΔCPR | Delta CPR |
| D&S | Detect and Suppress |
| DIVOM | Delta CPR over Initial MCPR Versus Oscillation Magnitude |
| EOC | End Of Cycle |
| GDC | General Design Criteria |
| GE | General Electric |
| GEH | GE Hitachi Nuclear Energy |
| GESTAR | General Electric Standard Application for Reload Fuel |
| GNF | Global Nuclear Fuel |
| HCOM | Hot Channel Oscillation Magnitude |
| IMCPR | Initial Minimum Critical Power Ratio |
| LOCA | Loss of Coolant Accident |
| LTS | Long Term Solution |
| MCPR | Minimum Critical Power Ratio |
| MOC | Middle Of Cycle |
| NRC | Nuclear Regulatory Commission |
| OLMCPR | Operating Limit MCPR |
| OM | Oscillation Magnitude |
| OPRM | Oscillation Power Range Monitor |
| P10 | PANAC10 |
| P11 | PANAC11 |
| TGBLA | Toshiba, GE Boiling Lattice Analysis |
| TRACG | Transient Reactor Analysis Code (GEH proprietary version) |

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

GEH uses the TRACG04 computer code to perform plant- and cycle-specific DIVOM (Delta CPR over Initial MCPR Versus Oscillation Magnitude) analyses. DIVOM is one component of the Detect and Suppress (D&S) licensing methodology for the Option 1-D, Option II, and Option III Stability Long Term Solutions (LTS).

The generic DIVOM analysis performed in NEDO-32465-A (Reference 1) used TRACG02 and PANAC10 (P10). However, most plants have now adopted the PANAC11 (P11) BWR core simulator methodology coupled with TRACG04 to perform DIVOM analyses. The use of the P11/TRACG04 methodology has been supported by a 10 CFR 50.59 evaluation (Reference 18).

## 1.2 PURPOSE

The purpose of NEDO-32465 Supplement 1 is to replace the 10 CFR 50.59 basis for the use of P11/TRACG04. Supplement 1 extends the applicability of the approved NEDO-32465-A DIVOM methodology to the P11/TRACG04 basis. No other changes to the NEDO-32465-A methodology are included in this supplement. This supplement includes comparisons of TRACG02 and TRACG04 DIVOM cases and additional DIVOM demonstration analyses with TRACG04 taken from recent reload analyses.

The following are the only changes included in this supplement:

1. TRACG04 replaces TRACG02 as the Boiling Water Reactor (BWR) event simulation model (References 2 and 3). A listing of the changes from TRACG02 to TRACG04 is provided in Appendix A.
2. P11 replaces P10 as the three-dimensional kinetics model (Reference 2).

Only the D&S part of the Option 1-D, Option II, and Option III Stability LTS are based on the DIVOM methodology and, hence, are affected by this supplement to NEDO-32465-A. There is no other change to the methodology, software, or hardware for any of these stability solutions.

GEH requests NRC staff review and approval of this supplement to the licensing basis for the D&S Solutions Licensing Basis Methodology (Reference 1) to use P11/TRACG04 for applications to the Option 1-D, Option II, and Option III Stability LTS. This supplement demonstrates that the use of P11/TRACG04 methodology generates a plant- and cycle-specific DIVOM slope that is essentially the same or more conservative than using P10/TRACG02 under "identical" or very similar core design and plant conditions.

# 2.0 LICENSING REQUIREMENT

Stability requirements are set forth in 10 CFR 50 Appendix A, General Design Criteria (GDC) 10 and 12.

Criterion 10 requires that:

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

Criterion 12 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."

All BWRs have selected one of the NRC approved stability LTSs described in References 1, 4, 5, 6, 16 and 17 to meet the GDC criteria. LTSs can be classified as either the prevention type (i.e., power oscillations are not possible), the detect and suppress type (i.e., power oscillations can be reliably and readily detected and suppressed), or a combination of the two types. General Electric Standard Application for Reactor Fuel (GESTAR) II US Supplement, Section S.4 (Reference 8) presents the plant- and cycle-specific process used for each of the NRC approved stability LTSs.

# 3.0 TRACG04/P11 DESCRIPTION

The NRC has accepted TRACG02 (Reference 1) for use in performing DIVOM analyses. TRACG04 implements the NRC approved P11 (Reference 9) kinetics while TRACG02 is implements the NRC approved P10 (Reference 10) kinetics. The transition from TRACG02/P10 to TRACG04/P11 has been approved for Anticipated Operating Occurrence (AOO) and Anticipated Transients Without Scram (ATWS) overpressure transient methodology (Reference 11). The approved ESBWR stability LTS method was also based on TRACG04/P11 (Reference 12).

## 3.1 P11

P11 utilizes TGBLA06 for preparing homogenized nodal constants. TGBLA06 has been used to provide lattice input to nuclear design and analysis methods since it was approved via GESTAR II amendment in November 1999 (Reference 9). Similarly, P11 was approved in the same amendment and has been used since that time. P11/TGBLA06 has been used for the BWR operating fleet, extended power uprates, and the ESBWR.

The NRC has examined the capability and qualification of P11/TGBLA06 through numerous applications. Since the initial NRC approval in 1999, P11/TGBLA06 received substantial NRC focus during the review of References 11, 13, and 14.

## 3.2 TRACG04

Appendix A includes a list of the changes from TRACG02 to TRACG04. These changes expand the scope of TRACG to include the ESBWR, as well as providing new models and upgrades to improve the application of TRACG to AOO, Loss of Coolant Accident (LOCA) and ATWS.

# 4.0 TRACG ANALYSIS

## 4.1 OVERVIEW

TRACG evaluations have been performed to compare the DIVOM slopes calculated by TRACG02 and TRACG04 for both regional and core-wide mode oscillations. Regional and core-wide mode oscillations are considered in the LTS Option III and II, whereas only core-wide mode oscillations are considered in LTS Option 1-D. A summary of the evaluations is provided below.

## 4.2 TRACG04 VERSUS TRACG02 DIVOM COMPARISON

This section contains a comparison of the results of a TRACG regional and core-wide mode DIVOM analysis using TRACG02 and TRACG04.

Because TRACG02 uses a P10 wrap-up and TRACG04 uses a P11 wrap-up it is very important for the two wrap-ups to be comparable for the results to be meaningful. For the regional mode comparison the analysis was performed at Beginning of Cycle (BOC). However, for the core wide mode comparison, it was necessary to perform the analysis at End of Cycle (EOC) where the core is more susceptible to core-wide oscillations. A Haling depletion was performed to ensure that the P10 and P11 cores were similar at EOC.

For Option III plants, in which a range in Oscillation Power Range Monitor (OPRM) amplitude set points are used, a corresponding range in 95/95 Hot Channel Oscillation Magnitude (HCOM) or (P-M)/A are calculated. In establishing the DIVOM slope, only DIVOM data points (ΔCPR/IMCPR vs. Oscillation Magnitude (OM)) within this HCOM range are used. In this example a HCOM range of 0.2 – 0.5 is used, which is typical for most Option III plants. For Option 1-D and II plants, the DIVOM slope is established using DIVOM data points corresponding to the HCOM at natural circulation. In this example a HCOM range of 0.8 – 1.0 is used which is typical for most HCOM's at natural circulation.

### 4.2.1 Regional Mode Oscillation Comparison

The regional mode oscillation comparison was evaluated at the BOC exposure point because depletion to Middle of Cycle (MOC) or EOC might introduce differences in the wrap-ups, which would lessen the value of the comparison of the two codes. The power flow state point analyzed is not typical and was chosen to ensure strong regional oscillations.

For the TRACG comparisons to be meaningful, it is important that the P10 and P11 wrap-ups be nearly identical. Figure 4-1 and Figure 4-2 show a plot of the radial power for the two wrap-ups at off-rated conditions using P10 and P11, respectively. Figure 4-3 shows a comparison of the axial power for the two wrap-ups. The radial and axial power shapes are very similar and consistent with each other. Figure 4-4 and Figure 4-5 show the TRACG channel grouping. The axis of symmetry for the higher harmonic mode is slightly different for the two wrap-ups, but the hot channel designations are the same. Key results for the TRACG transient analysis are plotted in Figure 4-6 through Figure 4-11. A comparison of the TRACG02 and TRACG04 results show that the TRACG04 oscillations have a higher growth rate as expected due to the P11 kinetics implementation.

A comparison of the DIVOM slopes for the P10/TRACG02 and P11/TRACG04 cases are shown in Figure 4-12. Only data points from the limiting channel in which the MCPR is greater than 1.0 are plotted. The results show that even at this highly unstable state point, that the DIVOM slope generated by P11/TRACG04 is greater than the slope generated by P10/TRACG02. The increase in DIVOM slope is expected because TRACG04 directly solves for the spatial distribution of the neutron flux as a function of time for each time step whereas TRACG02 decouples the spatial and temporal components of the neutron flux and solves for the spatial component less frequently than the temporal component. These differences in the solution schemes generally make the TRACG04 solution more responsive than the TRACG02 solution especially for regional stability cases. Therefore, the use of P11/TRACG04 in place of P10/TRACG02 for regional oscillation analyses is acceptable because it produces a DIVOM slope that is higher. A higher DIVOM slope produces higher stability based Operating Limit Minimum Critical Power Ratios (OLMCPRs), which in turn mean lower OPRM amplitude setpoints. This means the P11/TRACG04 methodology produces stability results for regional oscillations that are essentially the same or more conservative than the ones obtained by using P10/TRACG02 methodology.

### 4.2.2 Core-Wide Mode Oscillation Comparison

The core-wide mode oscillation comparison was evaluated at the EOC exposure point because the core is more susceptible to core-wide mode oscillations at EOC. To ensure that both the P10 and P11 wrap-ups were similar at the EOC exposure point, a Haling depletion was performed on each wrap-up.

Figure 4-13 and Figure 4-14 show a plot of the radial power for the two wrap-ups at off-rated conditions using P10 and P11, respectively. Figure 4-15 shows a comparison of the axial power for the two wrap-ups. The radial and axial power shapes are very similar and consistent with each other. Figure 4-16 and Figure 4-17 show the TRACG channel grouping. A comparison of the P10 and P11 grouping show minor differences in the single channels which results from slight differences in the power shapes. Key results for the TRACG transient analysis are plotted in Figure 4-18 through Figure 4-23. A comparison of the TRACG02 and TRACG04 results show that the TRACG02 oscillations begin growing somewhat sooner than TRACG04 but that the growth ratios are essentially identical.

The DIVOM slopes for the P10/TRACG02 and P11/TRACG04 core-wide DIVOM are shown in Figure 4-24. From this figure it can be seen that the DIVOM slope generated using P11/TRACG04 is greater than the slope generated by P10/TRACG02. Therefore the use of P11/TRACG04 in place of P10/TRACG02 for core-wide oscillation analyses is acceptable because it produces a DIVOM slope that is higher. A higher DIVOM slope produces higher stability based OLMCPRs. This means that P11/TRACG04 methodology produces stability results for core-wide oscillation mode that are essentially the same or more conservative than the ones obtained by using P10/TRACG02 methodology.

**Figure 4-1 P10 Regional Radial Peaking Distribution**

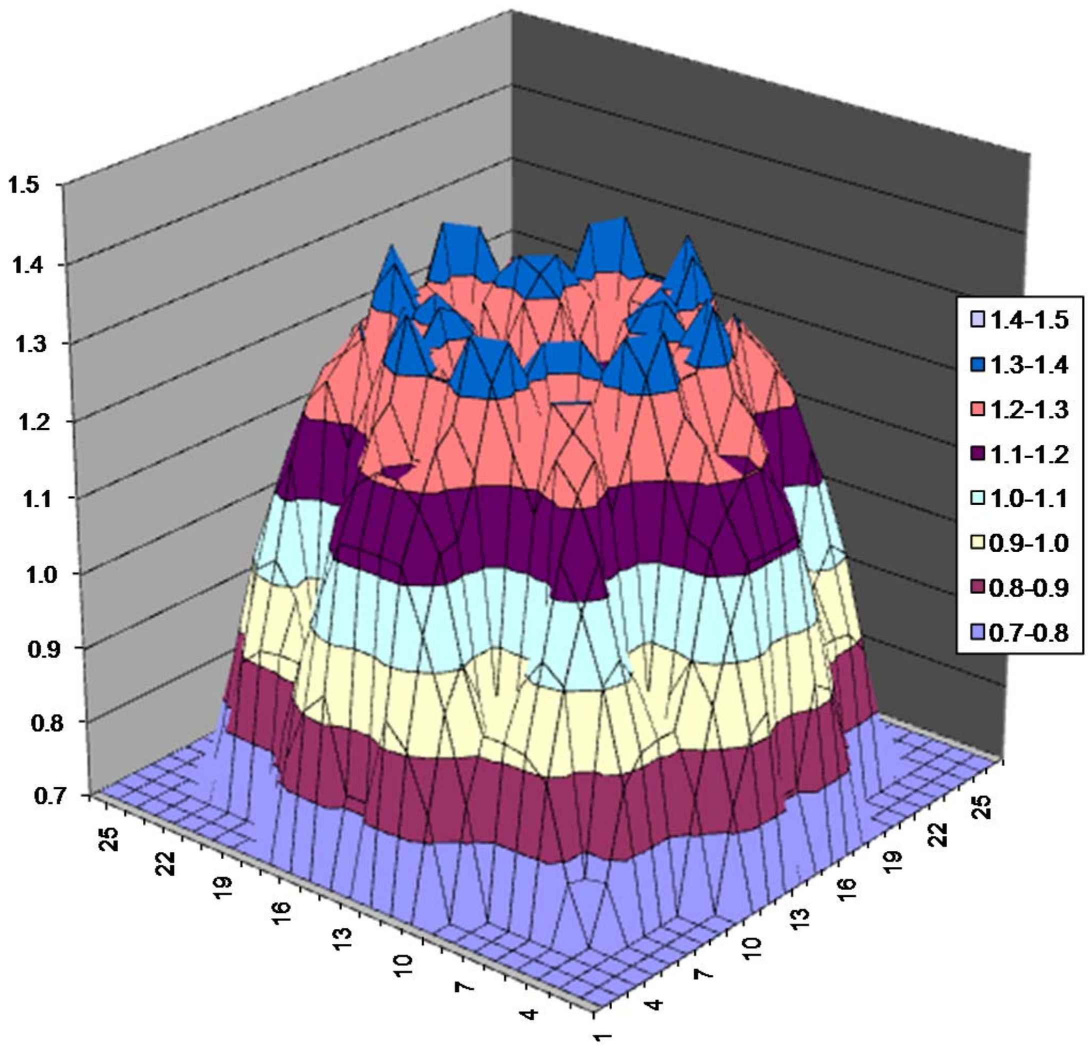


**Figure 4-2 P11 Regional Radial Peaking Distribution**

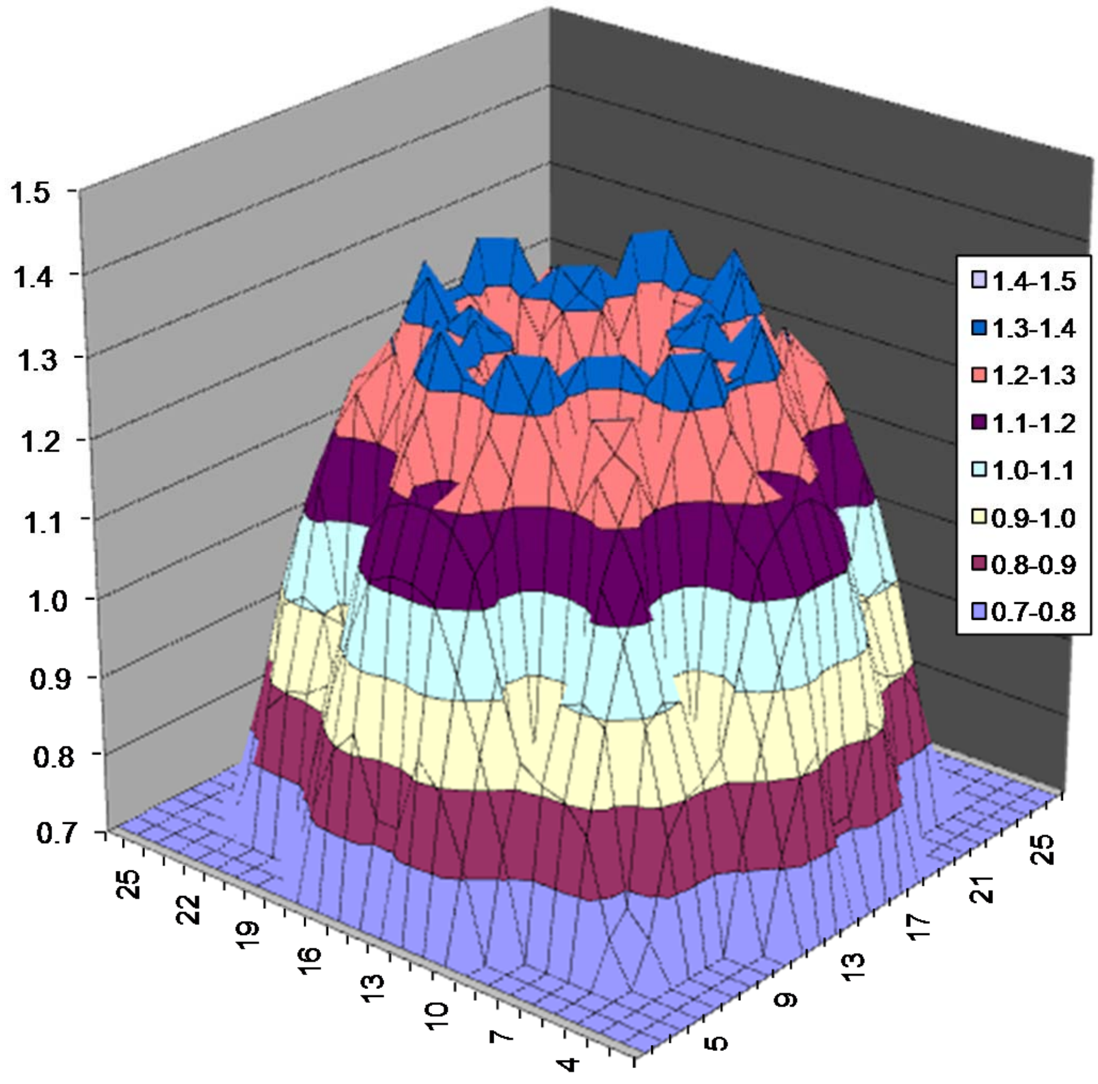


**Figure 4-3 P10 and P11 Regional Axial Power Comparison**

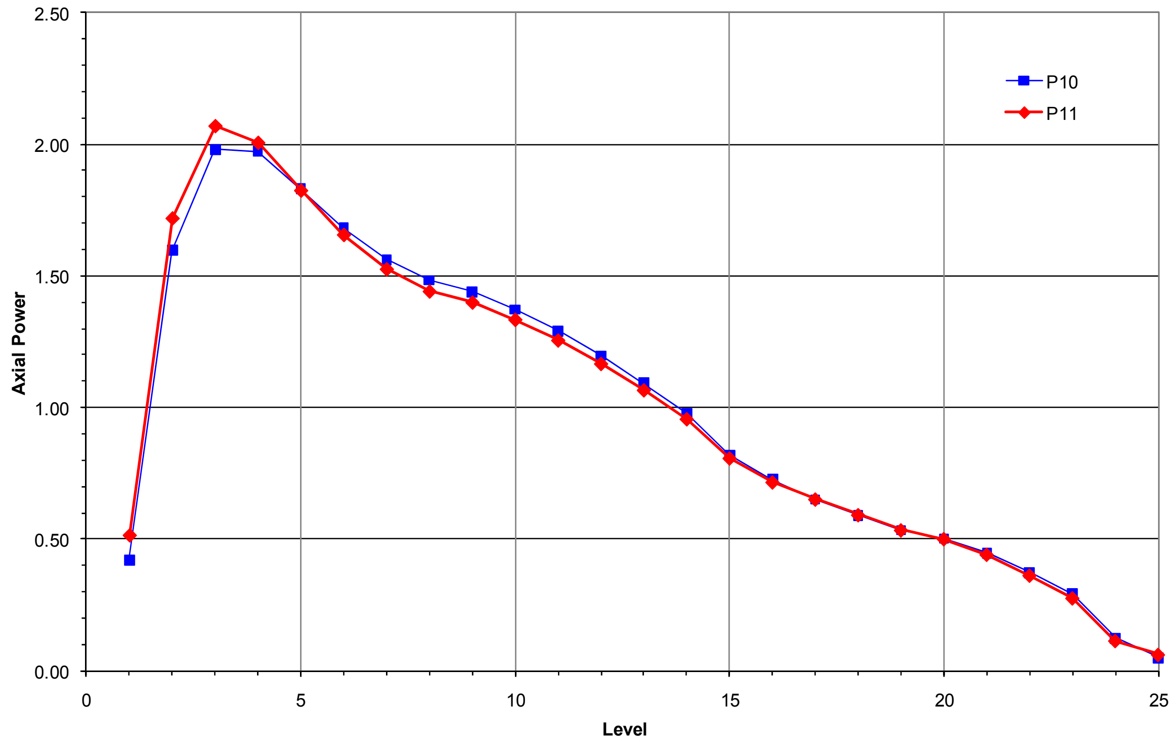


**Figure 4-4 P10/TRACG02 Regional Channel Grouping**

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 26 |
| | | | | | | | 38 | 30 | 31 | 31 | 32 | 31 | 31 | 32 | 32 | 31 | 30 | 38 | | | | | | | | 25 |
| | | | | 38 | 38 | 38 | 30 | 35 | 35 | 36 | 36 | 32 | 32 | 36 | 36 | 36 | 35 | 31 | 38 | 38 | 38 | | | | | 24 |
| | | | 38 | 30 | 31 | 31 | 35 | 35 | 32 | 36 | 33 | 37 | 82 | 33 | 36 | 32 | 35 | 35 | 31 | 31 | 31 | 38 | | | | 23 |
| | | 38 | 30 | 30 | 35 | 35 | 35 | 31 | 35 | 32 | 36 | 32 | 32 | 37 | 32 | 35 | 31 | 36 | 36 | 36 | 31 | 31 | 38 | | | 22 |
| | | 38 | 30 | 35 | 31 | 35 | 31 | 35 | 31 | 36 | 32 | 36 | 36 | 33 | 36 | 31 | 35 | 31 | 36 | 32 | 36 | 31 | 38 | | | 21 |
| | | 38 | 30 | 35 | 35 | 31 | 35 | 31 | 36 | 32 | 81 | 32 | 33 | 80 | 33 | 36 | 32 | 36 | 32 | 36 | 35 | 31 | 38 | | | 20 |
| | 38 | 30 | 34 | 34 | 30 | 35 | 31 | 35 | 31 | 36 | 31 | 36 | 36 | 32 | 37 | 32 | 36 | 32 | 36 | 31 | 35 | 35 | 30 | 38 | | 19 |
| 38 | 30 | 34 | 34 | 30 | 34 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 31 | 36 | 32 | 36 | 32 | 36 | 32 | 35 | 31 | 35 | 34 | 30 | 38 | 18 |
| 28 | 20 | 34 | 30 | 34 | 30 | 34 | 30 | 34 | 30 | 35 | 31 | 35 | 35 | 31 | 36 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 35 | 30 | 38 | 17 |
| 28 | 20 | 24 | 24 | 20 | 34 | 30 | 34 | 30 | 34 | 31 | 35 | 30 | 30 | 35 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 35 | 35 | 30 | 38 | 16 |
| 28 | 20 | 24 | 20 | 24 | 20 | 24 | 30 | 34 | 30 | 34 | 30 | 34 | 34 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 35 | 30 | 38 | 15 |
| 28 | 20 | 20 | 24 | 20 | 24 | 20 | 24 | 20 | 24 | 20 | 34 | 30 | 30 | 34 | 30 | 34 | 30 | 34 | 31 | 34 | 30 | 34 | 30 | 30 | 38 | 14 |
| 28 | 20 | 20 | 24 | 20 | 24 | 21 | 24 | 20 | 24 | 20 | 24 | 20 | 20 | 24 | 30 | 34 | 30 | 34 | 30 | 34 | 30 | 34 | 30 | 30 | 38 | 13 |
| 28 | 20 | 25 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 24 | 24 | 20 | 24 | 20 | 24 | 20 | 34 | 30 | 34 | 30 | 34 | 30 | 38 | 12 |
| 28 | 20 | 25 | 25 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 25 | 20 | 20 | 25 | 21 | 24 | 20 | 24 | 20 | 24 | 30 | 34 | 34 | 30 | 38 | 11 |
| 28 | 20 | 25 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 26 | 21 | 25 | 25 | 21 | 25 | 20 | 24 | 20 | 24 | 20 | 24 | 20 | 24 | 20 | 38 | 10 |
| 28 | 20 | 24 | 25 | 21 | 25 | 22 | 26 | 22 | 26 | 22 | 26 | 21 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 24 | 20 | 24 | 24 | 20 | 28 | 9 |
| | 28 | 20 | 25 | 25 | 21 | 26 | 22 | 26 | 22 | 27 | 22 | 26 | 26 | 21 | 26 | 21 | 25 | 21 | 25 | 20 | 24 | 24 | 20 | 28 | | 8 |
| | | 28 | 21 | 25 | 26 | 22 | 26 | 22 | 26 | 23 | 90 | 23 | 22 | 91 | 22 | 26 | 21 | 25 | 21 | 25 | 25 | 20 | 28 | | | 7 |
| | | 28 | 21 | 26 | 22 | 26 | 21 | 25 | 21 | 26 | 23 | 26 | 26 | 22 | 26 | 21 | 25 | 21 | 25 | 21 | 25 | 20 | 28 | | | 6 |
| | | 28 | 21 | 21 | 26 | 26 | 26 | 21 | 25 | 22 | 27 | 22 | 22 | 26 | 22 | 25 | 21 | 25 | 25 | 25 | 20 | 20 | 28 | | | 5 |
| | | | 28 | 21 | 21 | 21 | 25 | 25 | 22 | 26 | 23 | 92 | 27 | 23 | 26 | 22 | 25 | 25 | 21 | 21 | 20 | 28 | | | | 4 |
| | | | | 28 | 28 | 28 | 21 | 25 | 26 | 26 | 26 | 22 | 22 | 26 | 26 | 25 | 25 | 20 | 28 | 28 | 28 | | | | | 3 |
| | | | | | | | 28 | 20 | 21 | 22 | 22 | 21 | 21 | 22 | 21 | 21 | 20 | 28 | | | | | | | | 2 |
| | | | | | | | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | | | | | | | | | 1 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |

**Figure 4-5 P11/TRACG04 Regional Channel Grouping**

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 26 |
| | | | | | | | 38 | 37 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 37 | 38 | | | | | | | | 25 |
| | | | | 38 | 38 | 38 | 37 | 33 | 33 | 31 | 31 | 35 | 35 | 31 | 31 | 33 | 33 | 37 | 38 | 38 | 38 | | | | | 24 |
| | | | 38 | 37 | 36 | 36 | 33 | 33 | 35 | 31 | 34 | 30 | 82 | 34 | 31 | 35 | 33 | 33 | 36 | 36 | 37 | 38 | | | | 23 |
| | | 38 | 37 | 36 | 33 | 33 | 33 | 36 | 33 | 35 | 30 | 35 | 35 | 30 | 35 | 33 | 36 | 33 | 33 | 33 | 37 | 37 | 38 | | | 22 |
| | | 38 | 36 | 33 | 35 | 31 | 36 | 33 | 36 | 31 | 34 | 31 | 31 | 34 | 31 | 36 | 33 | 36 | 33 | 36 | 33 | 37 | 38 | | | 21 |
| | | 38 | 36 | 33 | 31 | 35 | 31 | 35 | 31 | 34 | 81 | 34 | 34 | 80 | 34 | 31 | 35 | 31 | 35 | 33 | 33 | 37 | 38 | | | 20 |
| | 38 | 37 | 33 | 33 | 36 | 31 | 35 | 31 | 35 | 31 | 35 | 31 | 31 | 35 | 31 | 35 | 31 | 35 | 33 | 36 | 33 | 32 | 37 | 38 | | 19 |
| 38 | 37 | 32 | 32 | 37 | 33 | 36 | 31 | 36 | 33 | 35 | 31 | 36 | 36 | 31 | 35 | 33 | 36 | 33 | 36 | 32 | 37 | 32 | 32 | 37 | 38 | 18 |
| 38 | 37 | 32 | 37 | 32 | 37 | 33 | 36 | 33 | 36 | 33 | 36 | 33 | 33 | 36 | 33 | 36 | 33 | 36 | 33 | 37 | 32 | 37 | 32 | 37 | 38 | 17 |
| 38 | 37 | 32 | 32 | 37 | 33 | 36 | 33 | 36 | 33 | 36 | 33 | 36 | 37 | 33 | 36 | 33 | 36 | 32 | 37 | 32 | 37 | 32 | 32 | 37 | 38 | 16 |
| 38 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 36 | 33 | 37 | 32 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 38 | 15 |
| 38 | 37 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 32 | 37 | 37 | 32 | 37 | 32 | 37 | 32 | 27 | 22 | 27 | 22 | 27 | 27 | 28 | 14 |
| 38 | 37 | 37 | 32 | 37 | 32 | 37 | 22 | 27 | 22 | 27 | 22 | 27 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 27 | 28 | 13 |
| 28 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 22 | 27 | 23 | 26 | 22 | 27 | 22 | 27 | 22 | 27 | 22 | 27 | 28 | 12 |
| 28 | 27 | 22 | 22 | 27 | 22 | 27 | 22 | 26 | 23 | 26 | 23 | 27 | 26 | 23 | 26 | 23 | 26 | 23 | 26 | 23 | 27 | 22 | 22 | 27 | 28 | 11 |
| 28 | 27 | 22 | 27 | 22 | 27 | 23 | 26 | 23 | 26 | 23 | 26 | 23 | 23 | 26 | 23 | 26 | 23 | 26 | 23 | 27 | 22 | 27 | 22 | 27 | 28 | 10 |
| 28 | 27 | 22 | 22 | 27 | 22 | 26 | 23 | 26 | 23 | 25 | 21 | 26 | 26 | 21 | 25 | 23 | 26 | 21 | 26 | 23 | 27 | 22 | 22 | 27 | 28 | 9 |
| | 28 | 27 | 22 | 23 | 26 | 23 | 25 | 21 | 25 | 21 | 25 | 21 | 21 | 25 | 21 | 25 | 21 | 25 | 21 | 26 | 23 | 23 | 27 | 28 | | 8 |
| | | 28 | 27 | 23 | 23 | 25 | 21 | 25 | 21 | 24 | 90 | 24 | 24 | 91 | 24 | 21 | 25 | 21 | 25 | 21 | 23 | 26 | 28 | | | 7 |
| | | 28 | 27 | 23 | 26 | 23 | 26 | 23 | 26 | 21 | 24 | 21 | 21 | 24 | 21 | 26 | 23 | 26 | 21 | 25 | 23 | 26 | 28 | | | 6 |
| | | 28 | 27 | 27 | 23 | 23 | 23 | 26 | 23 | 25 | 20 | 25 | 25 | 20 | 25 | 23 | 26 | 23 | 23 | 23 | 26 | 27 | 28 | | | 5 |
| | | | 28 | 27 | 26 | 26 | 23 | 23 | 25 | 21 | 24 | 92 | 20 | 24 | 21 | 25 | 23 | 23 | 26 | 26 | 27 | 28 | | | | 4 |
| | | | | 28 | 28 | 28 | 27 | 23 | 23 | 21 | 21 | 25 | 25 | 21 | 21 | 23 | 23 | 27 | 28 | 28 | 28 | | | | | 3 |
| | | | | | | | 28 | 27 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 27 | 28 | | | | | | | | 2 |
| | | | | | | | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | | | | | | | | | 1 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |

**Figure 4-6 P10/TRACG02 Regional Transient Results – Channel Power**

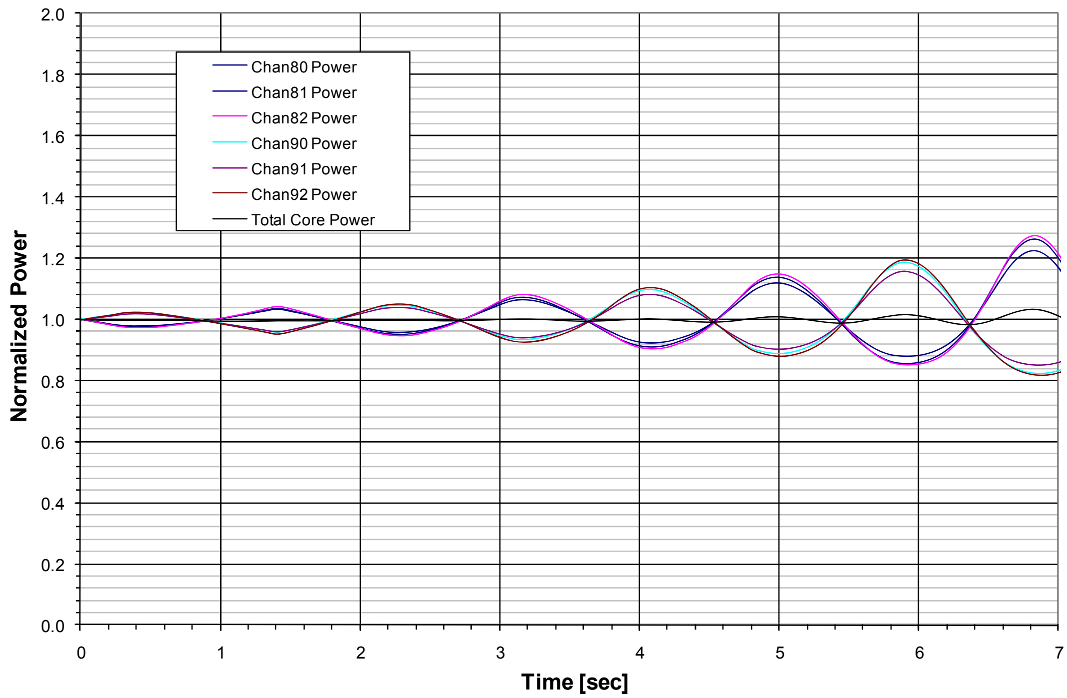


**Figure 4-7 P10/TRACG02 Regional Transient Results – Channel Flow**

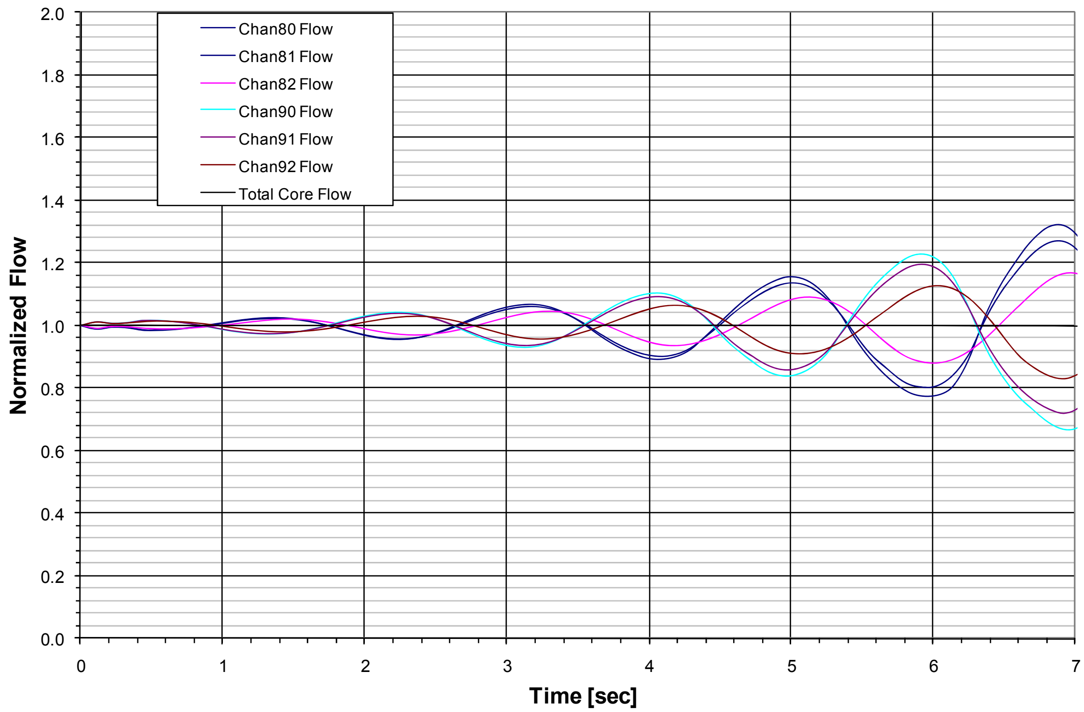


**Figure 4-8 P10/TRACG02 Regional Transient Results – Channel CPR**

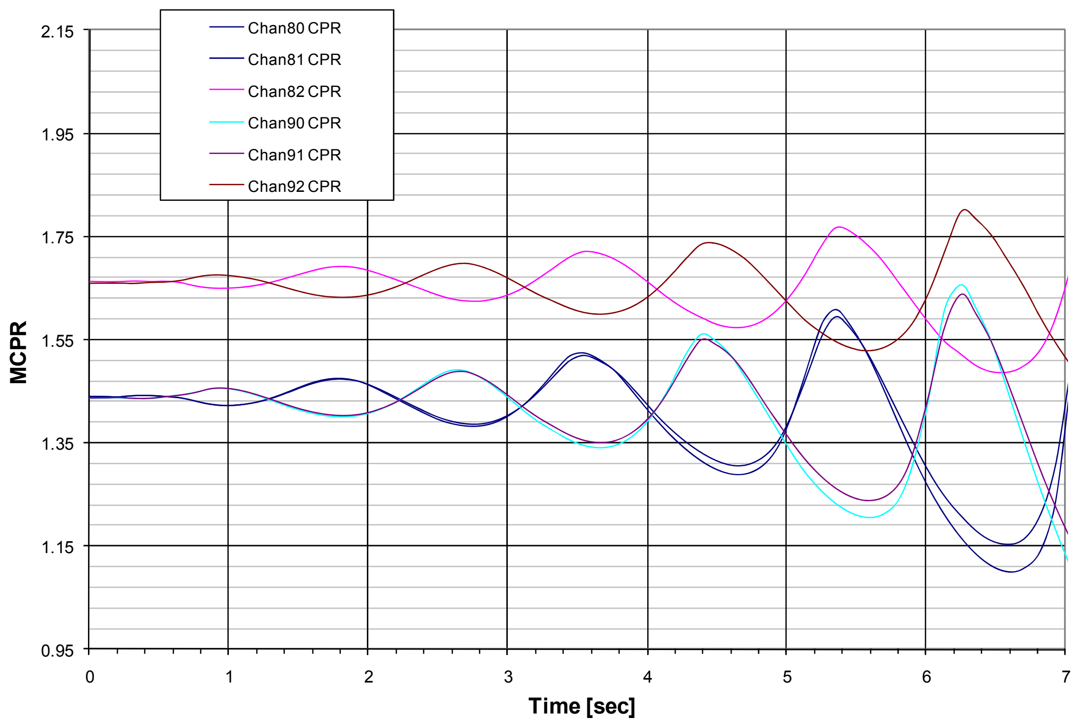


**Figure 4-9 P11/TRACG04 Regional Transient Results – Channel Power**

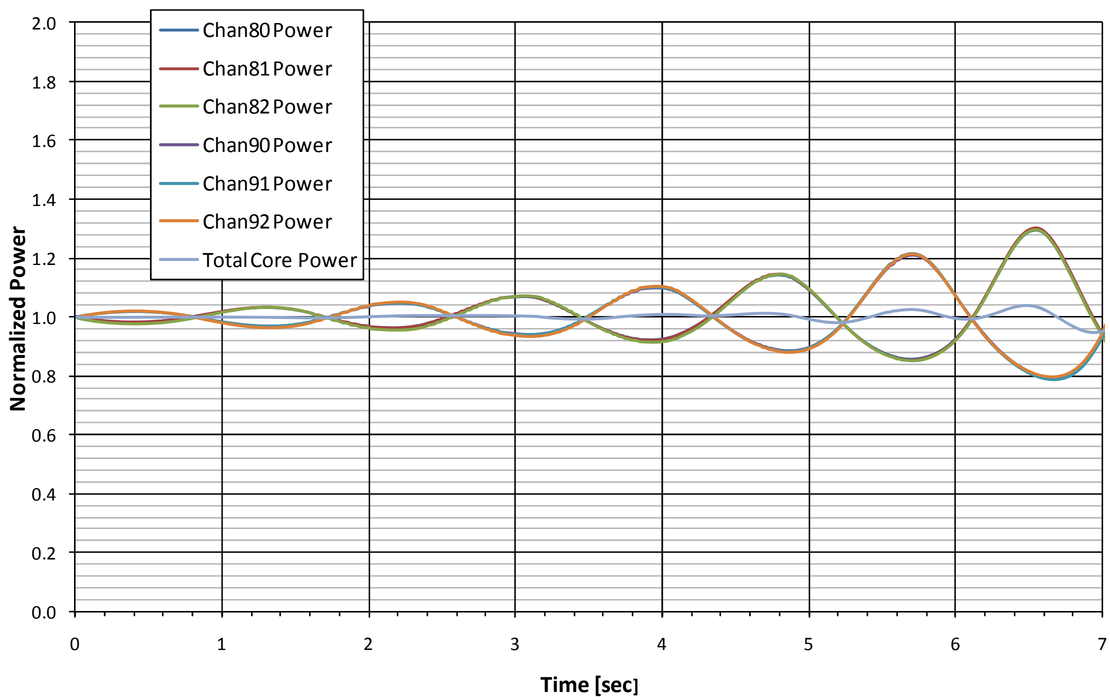


**Figure 4-10 P11/TRACG04 Regional Transient Results – Channel Flow**

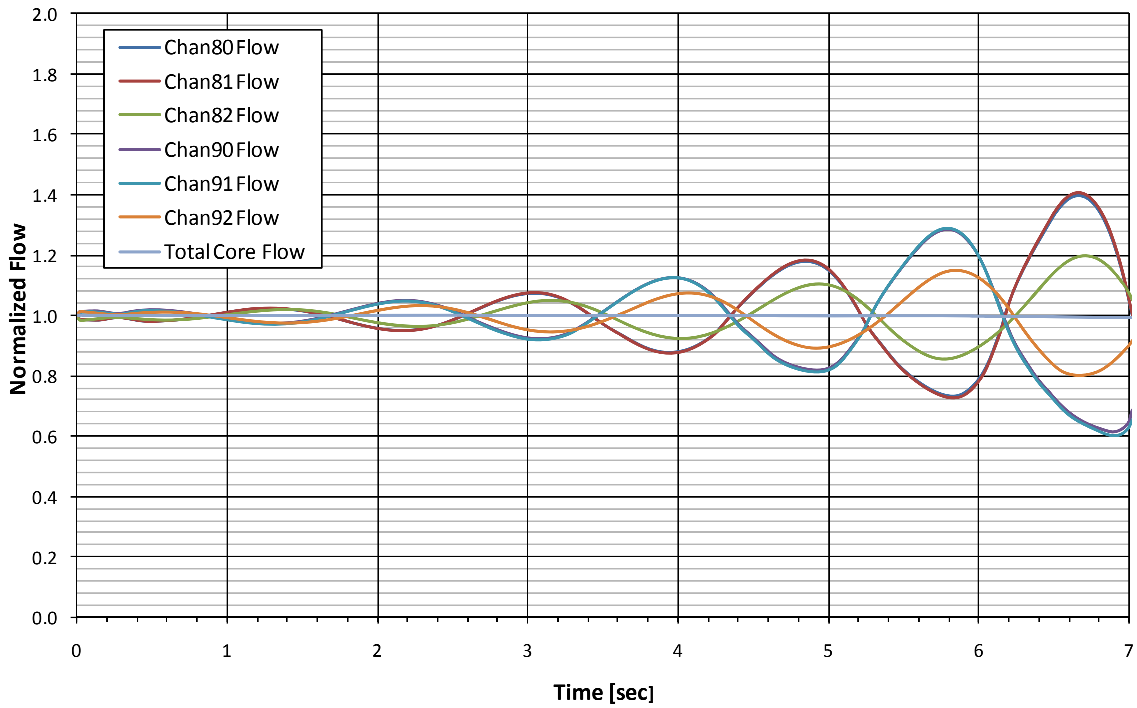


**Figure 4-11 P11/TRACG04 Regional Transient Results – Channel MCPR**

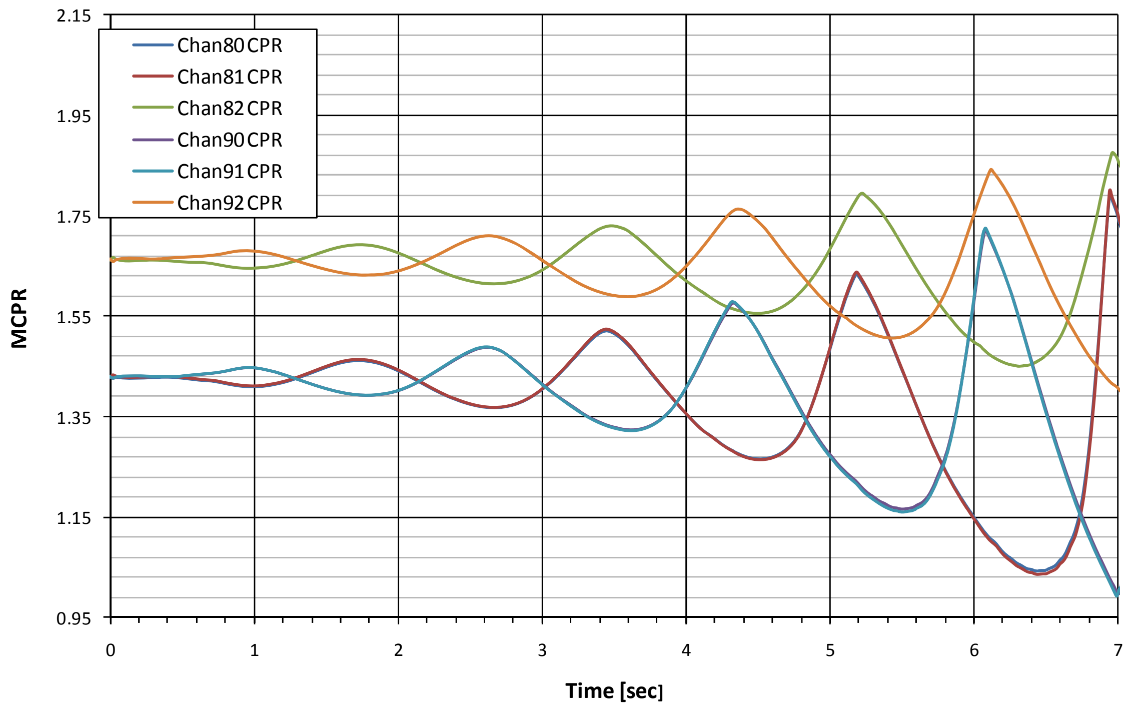


**Figure 4-12 P10/TRACG02 and P11/TRACG04 Regional DIVOM Slope Comparison**

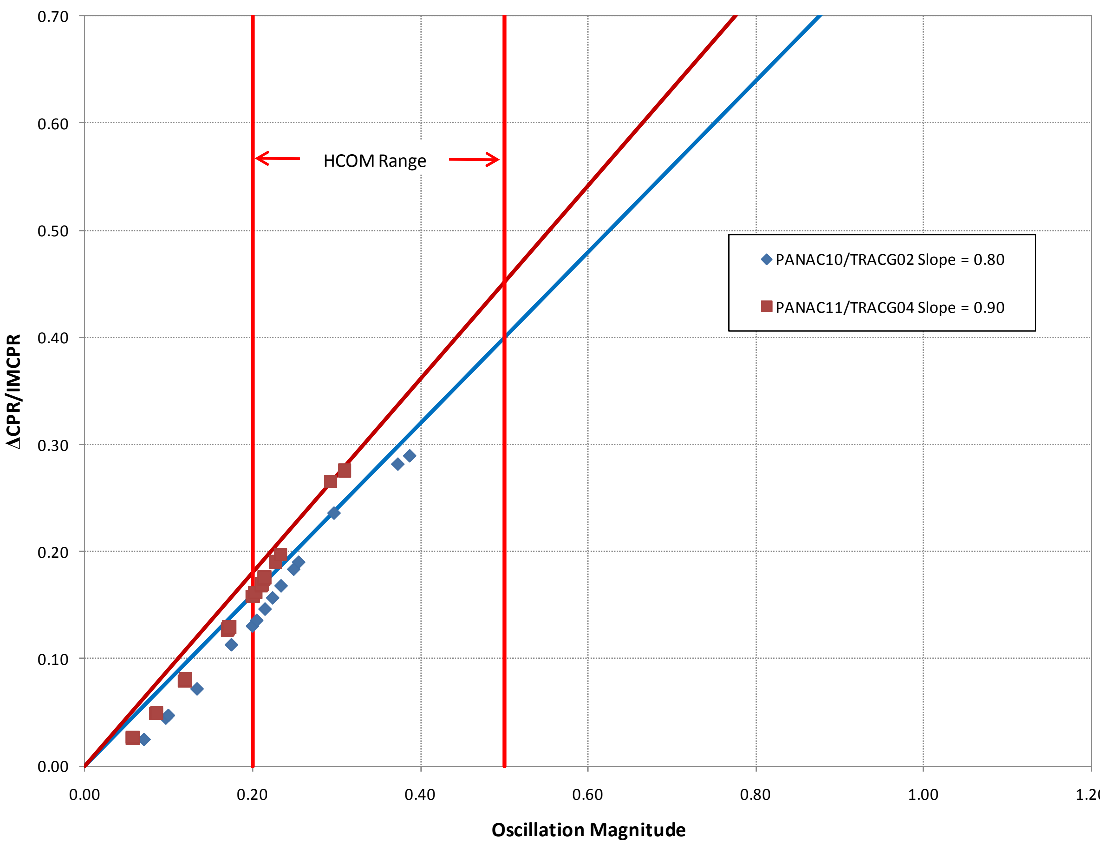


**Figure 4-13 P10 Core-Wide Radial Peaking Distribution**

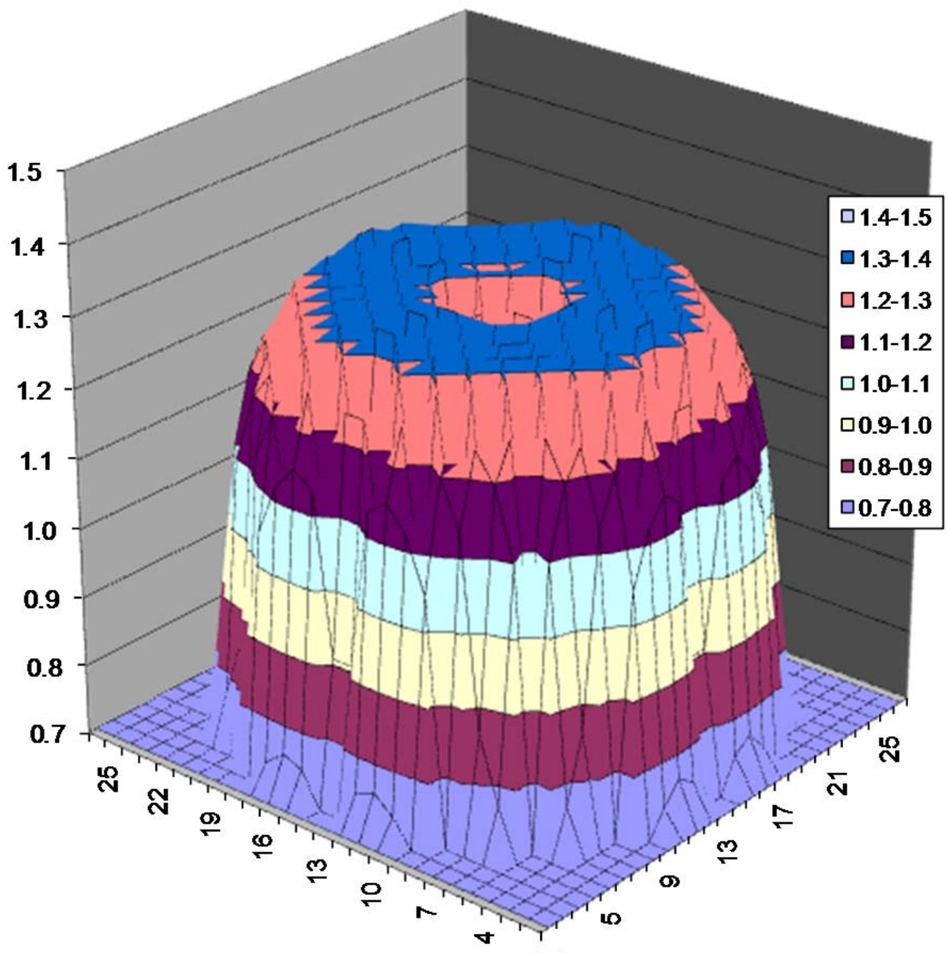


**Figure 4-14 P11 Core-Wide Radial Peaking Distribution**

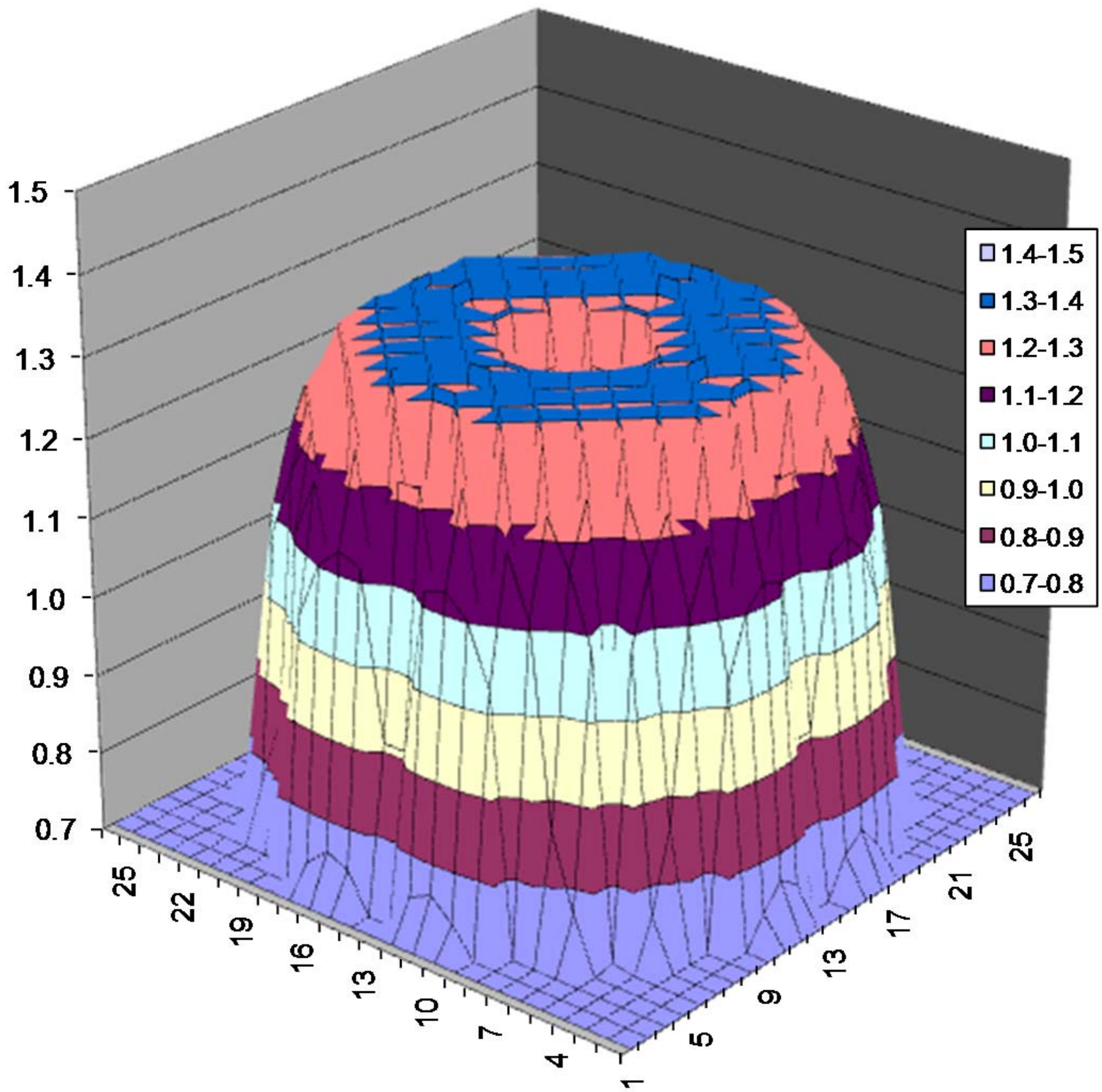
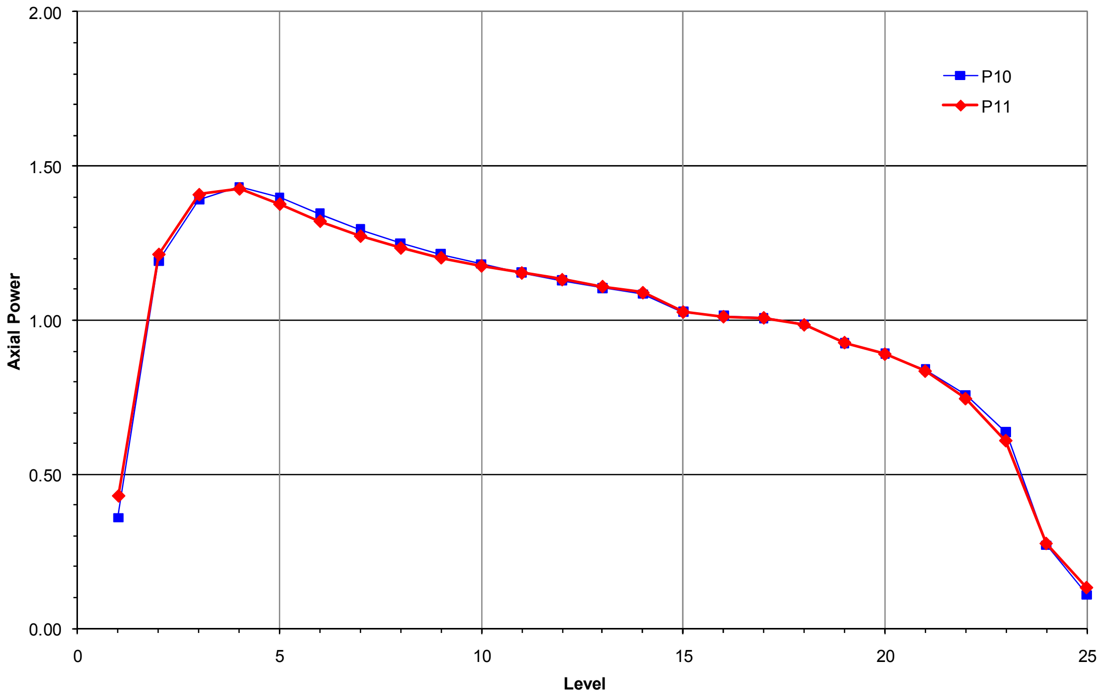


**Figure 4-15 P10 / P11 Core-Wide Axial Power Comparison**



## Figure 4-16 P10/TRACG02 Core-Wide Channel Grouping

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 39 | 39 | 39 | 39 | 39 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 26 |
| | | | | | | | 39 | 37 | 37 | 37 | 37 | 37 | 36 | 36 | 36 | 36 | 36 | 38 | | | | | | | | 25 |
| | | | | 39 | 39 | 39 | 37 | 28 | 28 | 28 | 28 | 35 | 34 | 29 | 29 | 29 | 29 | 36 | 38 | 38 | 38 | | | | | 24 |
| | | | 39 | 37 | 37 | 37 | 28 | 26 | 35 | 26 | 35 | 26 | 27 | 34 | 27 | 34 | 27 | 29 | 36 | 36 | 36 | 38 | | | | 23 |
| | | 39 | 37 | 37 | 28 | 28 | 26 | 35 | 26 | 35 | 25 | 33 | 32 | 24 | 34 | 27 | 34 | 27 | 29 | 29 | 36 | 36 | 38 | | | 22 |
| | | 39 | 37 | 28 | 35 | 26 | 35 | 26 | 33 | 23 | 30 | 21 | 95 | 31 | 22 | 32 | 27 | 34 | 27 | 34 | 29 | 36 | 38 | | | 21 |
| | | 39 | 37 | 28 | 26 | 35 | 25 | 33 | 23 | 30 | 21 | 30 | 31 | 20 | 31 | 22 | 32 | 24 | 34 | 27 | 29 | 36 | 38 | | | 20 |
| | 39 | 37 | 28 | 26 | 35 | 25 | 33 | 25 | 33 | 23 | 33 | 94 | 20 | 32 | 22 | 32 | 22 | 32 | 24 | 34 | 27 | 29 | 36 | 38 | | 19 |
| 39 | 37 | 28 | 28 | 35 | 26 | 33 | 23 | 30 | 25 | 30 | 21 | 30 | 31 | 20 | 31 | 24 | 31 | 22 | 32 | 27 | 34 | 29 | 29 | 36 | 38 | 18 |
| 39 | 37 | 28 | 35 | 26 | 33 | 23 | 33 | 23 | 33 | 21 | 30 | 23 | 22 | 31 | 20 | 32 | 22 | 32 | 22 | 32 | 27 | 34 | 29 | 36 | 38 | 17 |
| 39 | 37 | 28 | 26 | 35 | 21 | 30 | 23 | 30 | 21 | 30 | 25 | 33 | 32 | 24 | 31 | 20 | 31 | 22 | 31 | 22 | 34 | 27 | 29 | 36 | 38 | 16 |
| 39 | 37 | 28 | 35 | 25 | 30 | 21 | 33 | 21 | 30 | 25 | 33 | 25 | 24 | 32 | 24 | 31 | 20 | 32 | 20 | 31 | 24 | 34 | 29 | 36 | 38 | 15 |
| 39 | 37 | 35 | 26 | 33 | 21 | 30 | 92 | 30 | 21 | 33 | 25 | 33 | 32 | 24 | 32 | 22 | 31 | 93 | 31 | 20 | 32 | 27 | 34 | 36 | 38 | 14 |
| 39 | 37 | 37 | 26 | 33 | 21 | 30 | 91 | 30 | 23 | 33 | 25 | 33 | 32 | 24 | 32 | 22 | 31 | 20 | 31 | 20 | 32 | 27 | 36 | 36 | 38 | 13 |
| 39 | 37 | 28 | 35 | 25 | 30 | 21 | 33 | 21 | 30 | 25 | 33 | 25 | 24 | 32 | 24 | 31 | 20 | 32 | 20 | 31 | 24 | 34 | 29 | 36 | 38 | 12 |
| 39 | 37 | 28 | 26 | 35 | 23 | 30 | 23 | 30 | 21 | 30 | 25 | 33 | 32 | 24 | 31 | 20 | 31 | 22 | 31 | 22 | 34 | 27 | 29 | 36 | 38 | 11 |
| 39 | 37 | 28 | 35 | 26 | 33 | 23 | 33 | 23 | 33 | 21 | 30 | 23 | 22 | 31 | 20 | 32 | 24 | 32 | 22 | 32 | 27 | 34 | 29 | 36 | 38 | 10 |
| 39 | 37 | 28 | 28 | 35 | 26 | 33 | 23 | 30 | 25 | 30 | 21 | 30 | 31 | 20 | 31 | 24 | 31 | 22 | 32 | 27 | 34 | 29 | 29 | 36 | 38 | 9 |
| | 39 | 37 | 28 | 26 | 35 | 25 | 33 | 23 | 33 | 23 | 33 | 21 | 20 | 32 | 22 | 32 | 24 | 32 | 24 | 34 | 27 | 29 | 36 | 38 | | 8 |
| | | 39 | 37 | 28 | 26 | 35 | 25 | 33 | 23 | 30 | 21 | 30 | 31 | 20 | 31 | 22 | 32 | 24 | 34 | 27 | 29 | 36 | 38 | | | 7 |
| | | 39 | 37 | 28 | 35 | 26 | 35 | 26 | 33 | 23 | 30 | 96 | 20 | 31 | 22 | 32 | 27 | 34 | 27 | 34 | 29 | 36 | 38 | | | 6 |
| | | 39 | 37 | 37 | 28 | 28 | 26 | 35 | 26 | 35 | 25 | 33 | 32 | 24 | 34 | 27 | 34 | 27 | 29 | 29 | 36 | 36 | 38 | | | 5 |
| | | | 39 | 37 | 37 | 37 | 28 | 26 | 35 | 26 | 35 | 26 | 27 | 34 | 27 | 34 | 27 | 29 | 36 | 36 | 36 | 38 | | | | 4 |
| | | | | 39 | 39 | 39 | 37 | 28 | 28 | 28 | 28 | 35 | 34 | 29 | 29 | 29 | 29 | 36 | 38 | 38 | 38 | | | | | 3 |
| | | | | | | | 39 | 37 | 37 | 37 | 37 | 37 | 36 | 36 | 36 | 36 | 36 | 38 | | | | | | | | 2 |
| | | | | | | | | 39 | 39 | 39 | 39 | 39 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 1 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |

**Figure 4-17 P11/TRACG04 Core-Wide Channel Grouping**

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 39 | 39 | 39 | 39 | 39 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 26 |
| | | | | | | | 39 | 37 | 37 | 37 | 37 | 37 | 36 | 36 | 36 | 36 | 36 | 38 | | | | | | | | 25 |
| | | | | 39 | 39 | 39 | 37 | 29 | 29 | 29 | 29 | 35 | 34 | 28 | 28 | 28 | 28 | 36 | 38 | 38 | 38 | | | | | 24 |
| | | | 39 | 37 | 37 | 37 | 29 | 29 | 35 | 27 | 35 | 27 | 26 | 34 | 26 | 34 | 28 | 28 | 36 | 36 | 36 | 38 | | | | 23 |
| | | 39 | 37 | 37 | 29 | 29 | 27 | 35 | 27 | 35 | 25 | 33 | 32 | 24 | 34 | 26 | 34 | 26 | 28 | 28 | 36 | 36 | 38 | | | 22 |
| | | 39 | 37 | 29 | 35 | 27 | 35 | 27 | 33 | 23 | 31 | 23 | 22 | 30 | 22 | 30 | 26 | 34 | 26 | 34 | 28 | 36 | 38 | | | 21 |
| | | 39 | 37 | 29 | 27 | 35 | 25 | 33 | 23 | 31 | 94 | 31 | 30 | 92 | 30 | 22 | 32 | 24 | 34 | 26 | 28 | 36 | 38 | | | 20 |
| | 39 | 37 | 29 | 27 | 35 | 25 | 33 | 23 | 33 | 21 | 33 | 21 | 20 | 32 | 20 | 32 | 22 | 32 | 24 | 34 | 26 | 28 | 36 | 38 | | 19 |
| 39 | 37 | 29 | 29 | 35 | 27 | 33 | 23 | 31 | 23 | 31 | 21 | 31 | 30 | 20 | 30 | 22 | 30 | 22 | 32 | 26 | 34 | 26 | 28 | 36 | 38 | 18 |
| 39 | 37 | 29 | 35 | 27 | 33 | 23 | 33 | 23 | 33 | 21 | 31 | 25 | 24 | 30 | 20 | 32 | 22 | 32 | 22 | 32 | 26 | 34 | 28 | 36 | 38 | 17 |
| 39 | 37 | 29 | 27 | 35 | 23 | 31 | 21 | 31 | 21 | 31 | 25 | 33 | 32 | 24 | 30 | 20 | 30 | 20 | 30 | 22 | 34 | 26 | 28 | 36 | 38 | 16 |
| 39 | 37 | 29 | 35 | 25 | 31 | 21 | 33 | 21 | 31 | 25 | 33 | 25 | 24 | 32 | 24 | 30 | 20 | 32 | 20 | 30 | 24 | 34 | 28 | 36 | 38 | 15 |
| 39 | 37 | 35 | 27 | 33 | 23 | 31 | 21 | 31 | 25 | 33 | 25 | 33 | 32 | 24 | 32 | 24 | 30 | 20 | 30 | 22 | 32 | 26 | 34 | 36 | 38 | 14 |
| 39 | 37 | 37 | 27 | 33 | 23 | 31 | 21 | 31 | 25 | 33 | 25 | 33 | 32 | 24 | 32 | 24 | 30 | 20 | 30 | 22 | 32 | 26 | 36 | 36 | 38 | 13 |
| 39 | 37 | 29 | 35 | 25 | 31 | 21 | 33 | 21 | 31 | 25 | 33 | 25 | 24 | 32 | 24 | 30 | 20 | 32 | 20 | 30 | 24 | 34 | 28 | 36 | 38 | 12 |
| 39 | 37 | 29 | 27 | 35 | 23 | 31 | 21 | 31 | 21 | 31 | 25 | 33 | 32 | 24 | 30 | 20 | 30 | 20 | 30 | 22 | 34 | 26 | 28 | 36 | 38 | 11 |
| 39 | 37 | 29 | 35 | 27 | 33 | 23 | 33 | 23 | 33 | 21 | 31 | 25 | 24 | 30 | 20 | 32 | 22 | 32 | 22 | 32 | 26 | 34 | 28 | 36 | 38 | 10 |
| 39 | 37 | 29 | 27 | 35 | 27 | 33 | 23 | 31 | 23 | 31 | 21 | 31 | 30 | 20 | 30 | 22 | 30 | 22 | 32 | 26 | 34 | 26 | 28 | 36 | 38 | 9 |
| | 39 | 37 | 29 | 27 | 35 | 25 | 33 | 23 | 33 | 21 | 33 | 21 | 20 | 32 | 20 | 32 | 22 | 32 | 24 | 34 | 26 | 28 | 36 | 38 | | 8 |
| | | 39 | 37 | 29 | 27 | 35 | 25 | 33 | 23 | 31 | 93 | 31 | 30 | 91 | 30 | 22 | 32 | 24 | 34 | 26 | 28 | 36 | 38 | | | 7 |
| | | 39 | 37 | 29 | 35 | 27 | 35 | 27 | 31 | 23 | 31 | 23 | 22 | 30 | 22 | 32 | 26 | 34 | 26 | 34 | 28 | 36 | 38 | | | 6 |
| | | 39 | 37 | 37 | 29 | 29 | 27 | 35 | 96 | 35 | 25 | 33 | 32 | 24 | 34 | 95 | 34 | 26 | 28 | 28 | 36 | 36 | 38 | | | 5 |
| | | | 39 | 37 | 37 | 37 | 29 | 27 | 35 | 27 | 35 | 27 | 26 | 34 | 26 | 34 | 28 | 28 | 36 | 36 | 36 | 38 | | | | 4 |
| | | | | 39 | 39 | 39 | 37 | 29 | 29 | 29 | 29 | 35 | 34 | 28 | 28 | 28 | 28 | 36 | 38 | 38 | 38 | | | | | 3 |
| | | | | | | | 39 | 37 | 37 | 37 | 37 | 37 | 36 | 36 | 36 | 36 | 36 | 38 | | | | | | | | 2 |
| | | | | | | | | 39 | 39 | 39 | 39 | 39 | 38 | 38 | 38 | 38 | 38 | | | | | | | | | 1 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |

**Figure 4-18 P10/TRACG02 Core-Wide Transient Results – Channel Power**

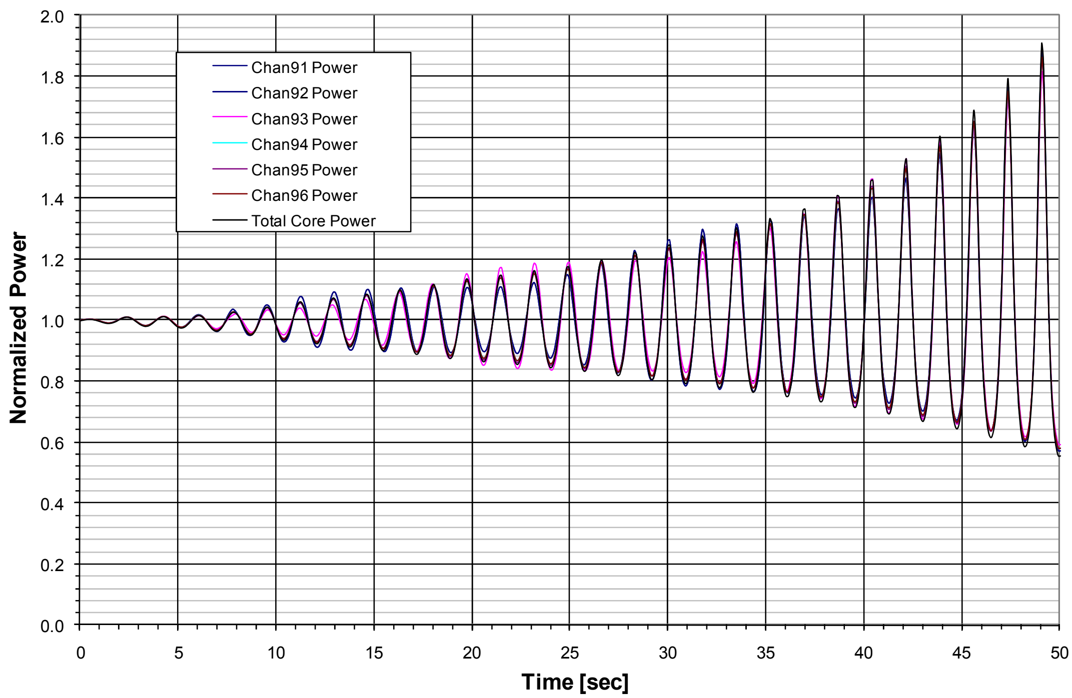


**Figure 4-19 P10/TRACG02 Core-Wide Transient Results – Channel Flow**

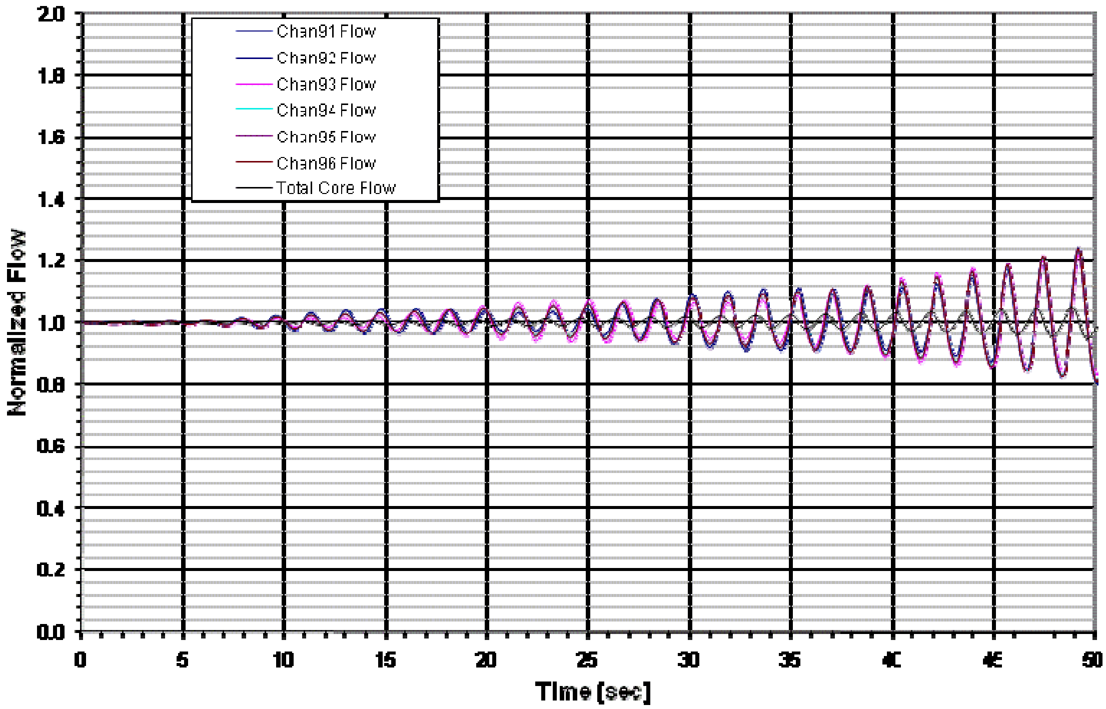


**Figure 4-20 P10/TRACG02 Core-Wide Transient Results – Channel MCPR**

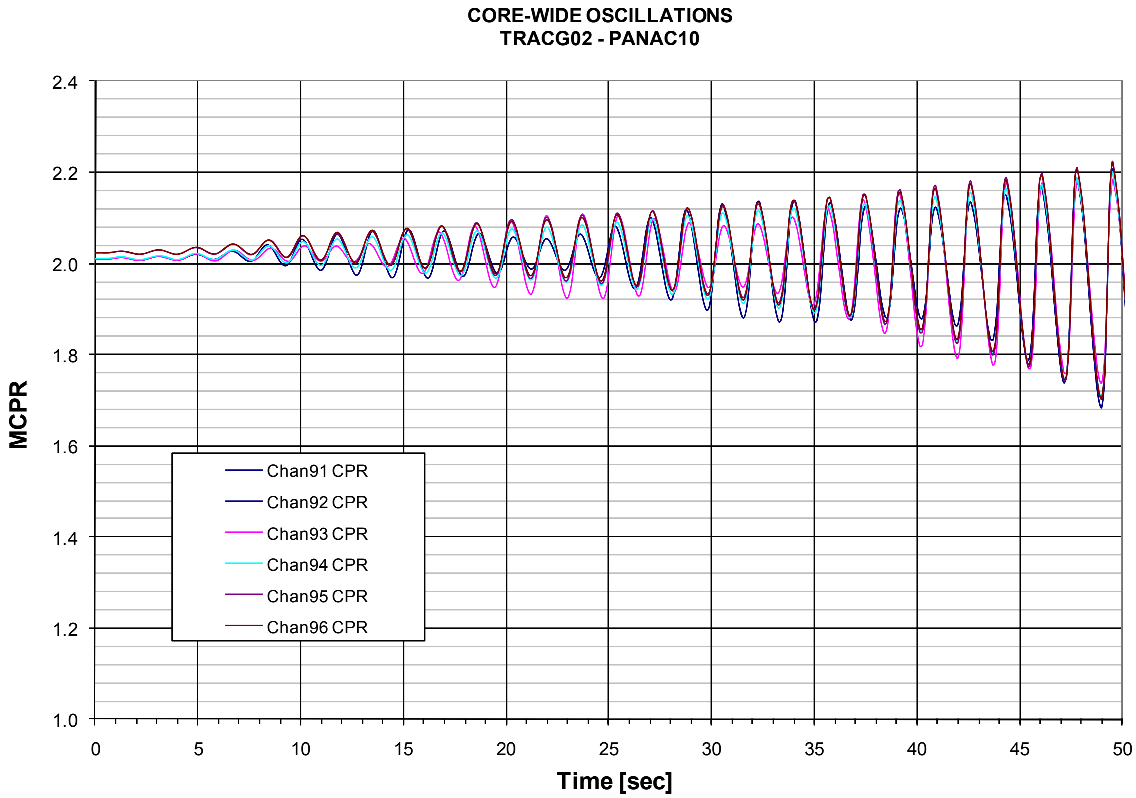


**Figure 4-21 P11/TRACG04 Core-Wide Transient Results – Channel Power**

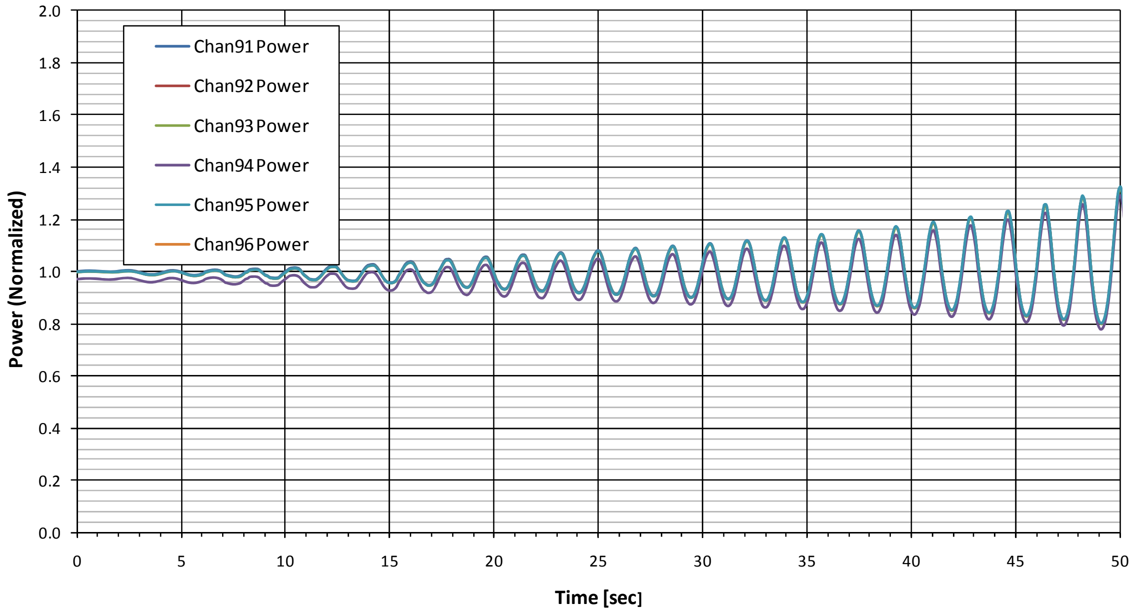


**Figure 4-22 P11/TRACG04 Core-Wide Transient Results – Channel Flow**

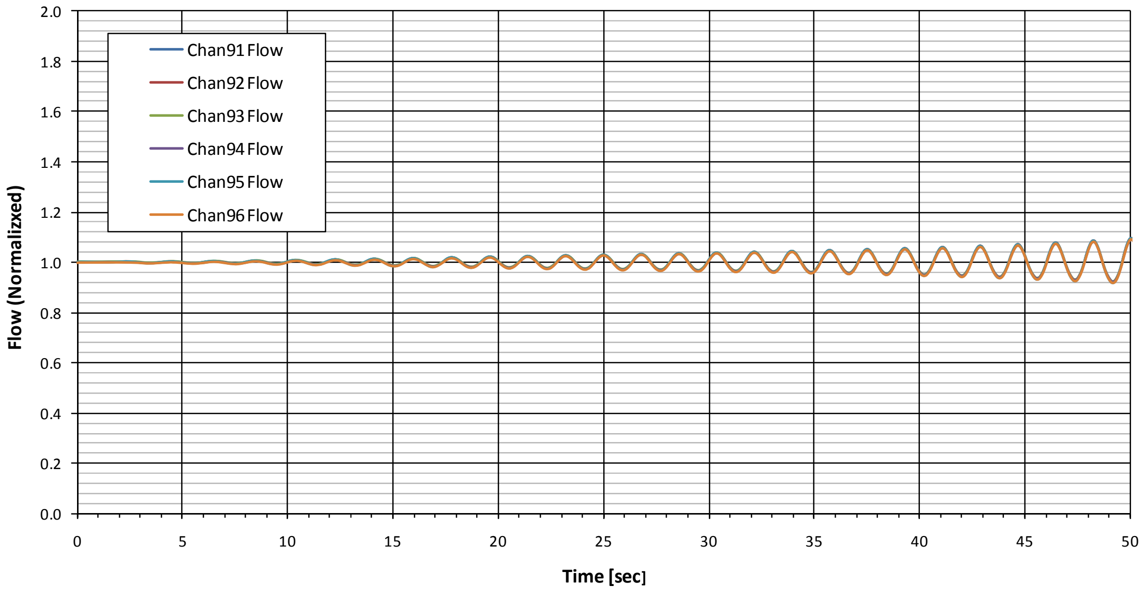


**Figure 4-23 P11/TRACG04 Core-Wide Transient Results – Channel MCPR**

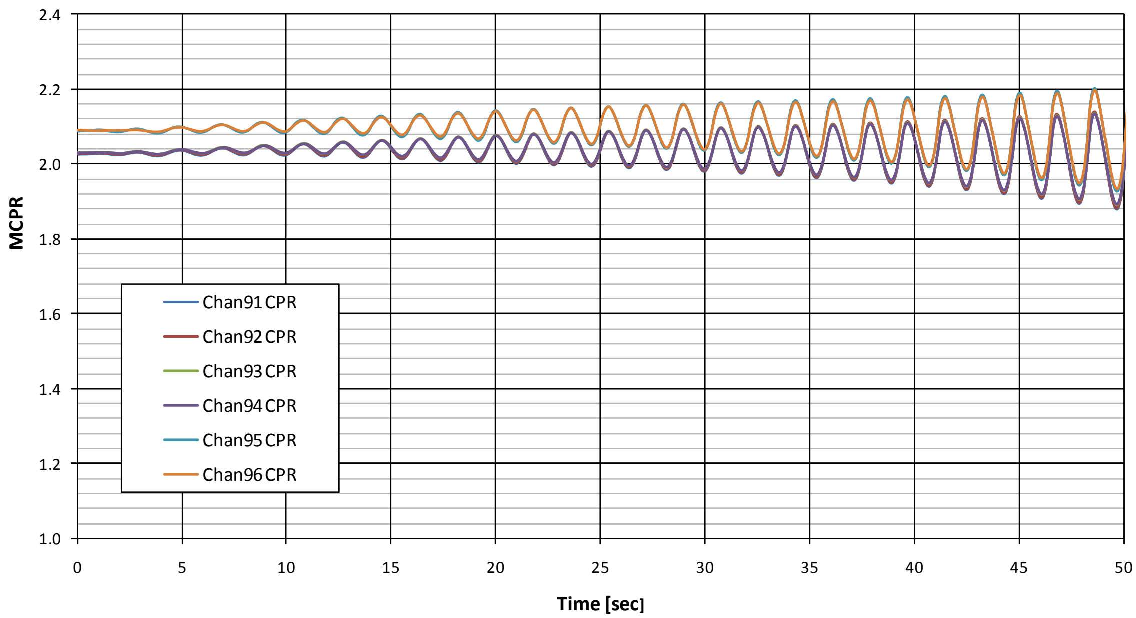
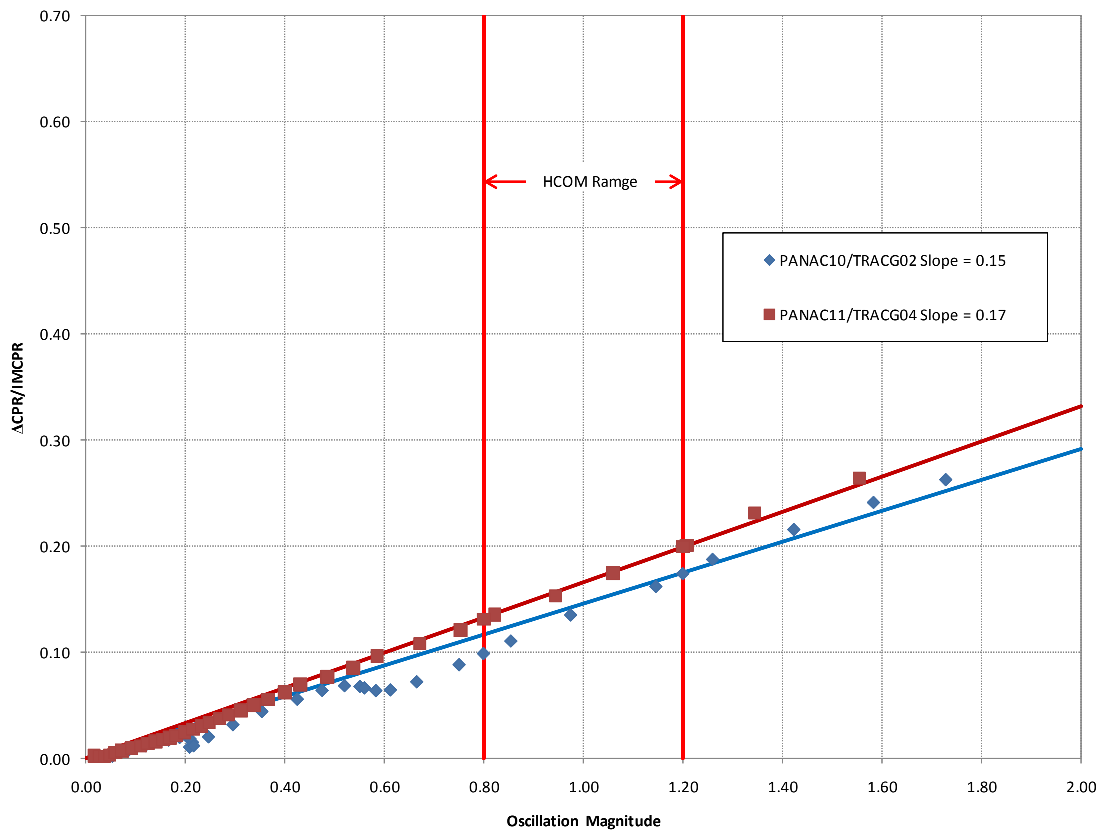


**Figure 4-24 P10/TRACG02 and P11/TRACG04 Core-Wide DIVOM Slope Comparison**



# 5.0 TRACG04 DEMONSTRATION

## 5.1 TRACG APPLICATION

The generic DIVOM slope established in Reference 1 was found to be non-conservative for cores with high bundle power-to-flow ratios. GEH made a Part 21 Notification (Reference 15) and subsequently replaced the generic DIVOM slope with a plant- and cycle-specific analysis to address this issue (References 7 and 8). This analysis addresses the important parameters (e.g., cycle exposure, power/flow conditions, feedwater temperature, radial peaking, xenon concentration) on a plant- and cycle-specific basis. A demonstration of both regional and core-wide plant specific DIVOM analyses are given below.

For Option III plants, in which a range in OPRM amplitude set points are used, a corresponding range in 95/95 HCOM or (P-M)/A are calculated. In establishing the DIVOM slope, only DIVOM data points (ΔCPR/IMCPR vs. OM) within this HCOM range are used. For Option 1-D and II plants, the DIVOM slope is established using DIVOM data points corresponding to the HCOM at natural circulation.

## 5.2 REGIONAL MODE OSCILLATIONS

A typical regional mode DIVOM analysis is shown in Figure 5-1 and Figure 5-2.

Figure 5-1 provides the power and MCPR for the limiting channel. Figure 5-2 provides the DIVOM data points and resultant DIVOM slope. The slope is a line that bounds the data points within the range of HCOM as described in References 7 and 8.

## 5.3 CORE-WIDE MODE OSCILLATIONS

A typical core-wide oscillation analysis is shown in Figure 5-3 and Figure 5-4.

Figure 5-3 provides the power and MCPR for the limiting channel. Figure 5-4 provides the DIVOM data points and resultant DIVOM slope. The slope is a line that bounds the data point nearest the HCOM as described in References 7 and 8.

**Figure 5-1 Regional Analysis – Channel Power and MCPR Results**

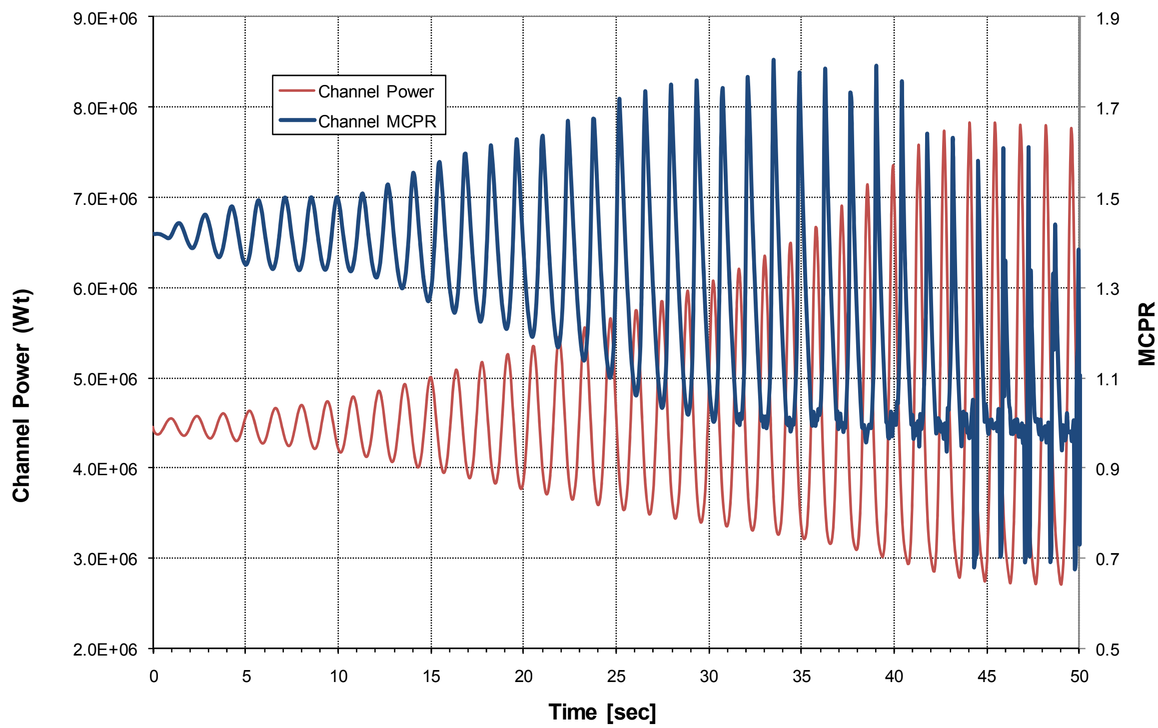


**Figure 5-2 Regional Analysis – DIVOM Results**

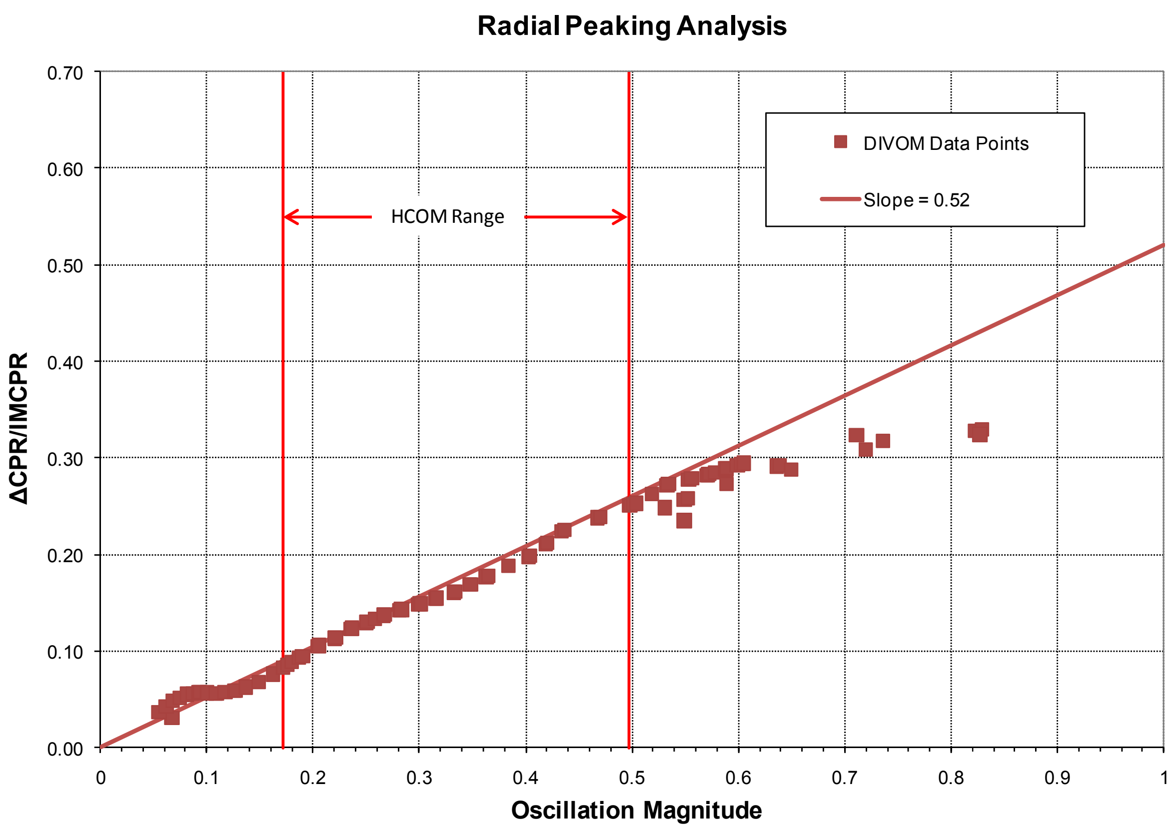


**Figure 5-3 Core-Wide Analysis – Channel Power and MCPR Results**

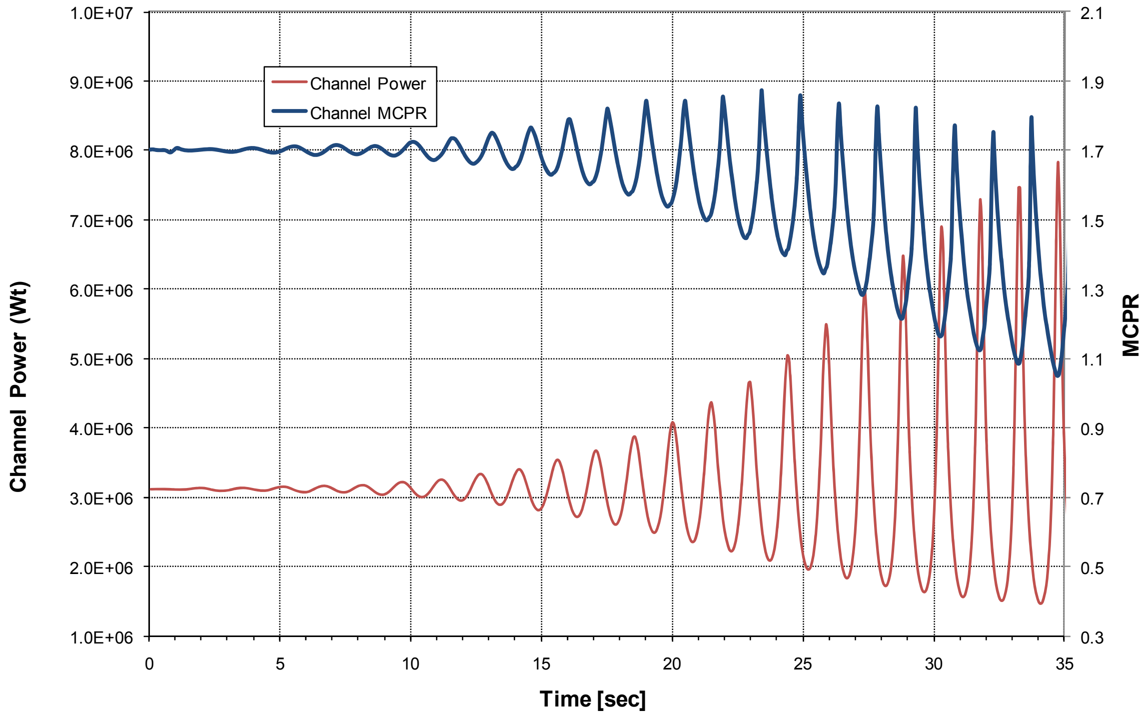
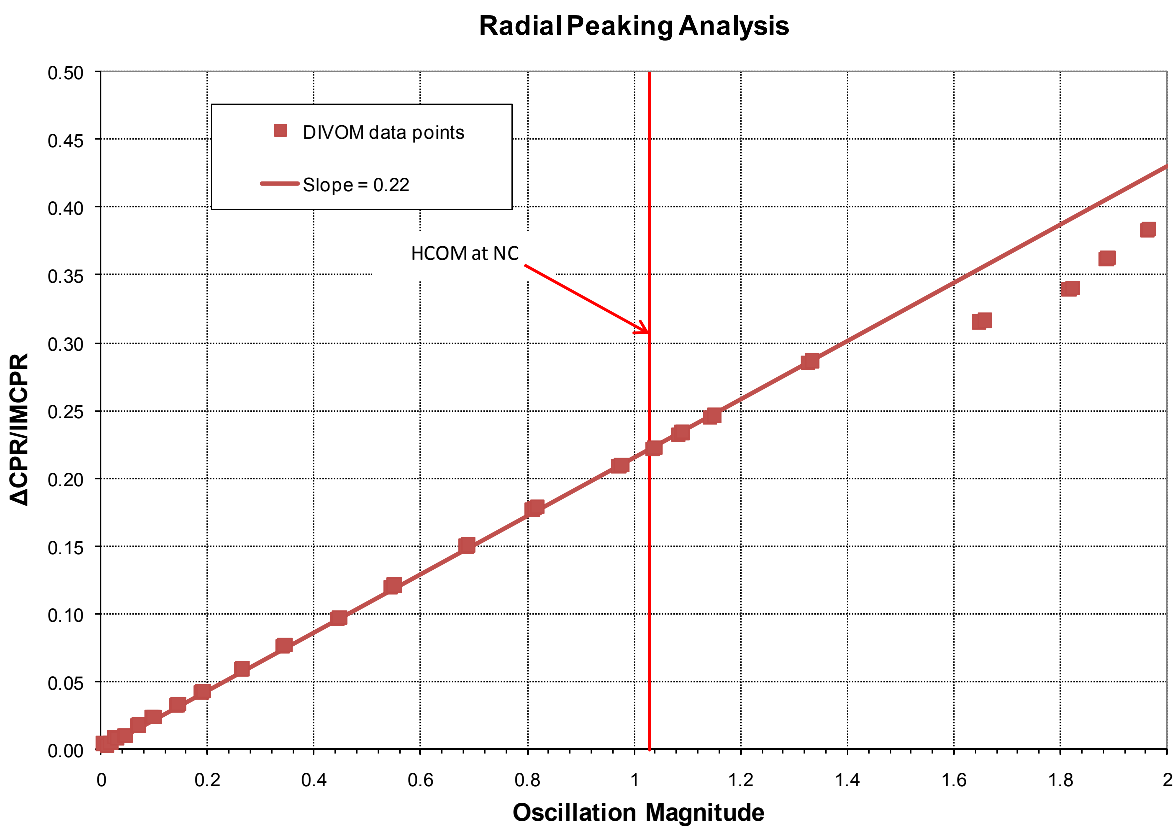


**Figure 5-4 Core-Wide Analysis – DIVOM Results**



# 6.0 CONCLUSIONS

The use of P11/TRACG04 methodology in place of P10/TRACG02 for DIVOM analyses used in Option 1-D, Option II, and Option III Stability LTS is acceptable because it produces essential the same or more conservative results with respect to the currently approved P10/TRACG02 methodology of NEDO-32465-A (Reference 1).

# 7.0 REFERENCES

1. GE Nuclear Energy, “Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications,” NEDO-32465-A, August 1996.

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

3. GE Nuclear Energy, “TRACG Qualification,” NEDE-32177P, Revision 3, August 2007.

4. GE Nuclear Energy, “BWR Owners' Group Long-Term Stability Solutions Licensing Methodology,” NEDO-31960-A, November 1995.

5. GE Nuclear Energy, “BWR Owners' Group Long-Term Stability Solutions Licensing Methodology (Supplement 1),” NEDO-31960-A, Supplement 1, November 1995.

6. GE Hitachi Nuclear Energy, "General Electric Boiling Water Reactor Detect and Suppress Solution - Confirmation Density," NEDC-33075P, Revision 6, January 2008.

7. Global Nuclear Fuel-Americas, “General Electric Standard Application for Reactor Fuel (GESTAR II),” NEDE–24011–P–A–18, Revision 18, April 2011.

8. Global Nuclear Fuel-Americas, “General Electric Standard Application for Reactor Fuel (GESTAR II), (Supplement for United States),” NEDE–24011–P–A–18-US, Revision 18, April 2011.

9. 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),” FLN-1999-011, November 10, 1999.

10. General Electric Company, “Steady State Nuclear Methods,” NEDE-30130P-A, April 1985.

11. GE Hitachi Nuclear Energy, "Migration to TRACG04/P11 from TRACG02/P10 for TRACG AOO and ATWS Overpressure Transients,” NEDE-32906P, Supplement 3-A, Revision 1, April 2010.

12. GE Hitachi Nuclear Energy, “TRACG Application for ESBWR Stability Analysis,” NEDE-33083 Supplement 1-A, Revision 2, September 2010.

13. GE Nuclear Energy, “Applicability of GE Methods to Expanded Operating Domains,” NEDC-33173P-A, Revision 1, September 2010.

14. Global Nuclear Fuel-Americas, "GE14 for ESBWR Nuclear Design Report," NEDC-33239P-A," Revision 5, October 2010.

15. GE Nuclear Energy, "Stability Reload Licensing Calculations Using Generic DIVOM Curve," MFN 01-046, August 31, 2001.

16. GE Nuclear Energy, "Application of Stability Long-Term Solution Option II to Nine Mile Point Nuclear Station Unit 1," GENE-A13-00360-02 Revision 1, November 1998.

17. GE Nuclear Energy, "Application of Stability Long-Term Solution Option II to Oyster Creek," NEDC-33065P, April 2002 as amended by "OC Option II Stability Setpoints Evaluation," GE-NE-0000-0029-0208-R0, June 2004.

18. GE Hitachi Nuclear Energy, "TRACG04P DIVOM 10 CFR 50.59 Evaluation Basis," 0000-0115-7421-R0, April 2010.

19. GE Nuclear Energy, "TRACG Application for Anticipated Operational Occurrences Transient Analysis," NEDE-32906P, Supplement 2-A, March 2006.

20. Letter from James F. Harrison (GEH) to NRC Document Control Desk, "Response to Request for Additional Information RE: GE-Hitachi Nuclear Energy Americas Topical Report (TR) NEDO-32465-A, Supplement 1, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications" (TAC No. ME7104) and DIVOM Process Screen Shots," MFN 12-088, July 27, 2012.

21. Letter from Aby S. Mohseni (NRC) to Jerald G. Head (GEH), "Final Safety Evaluation for General Electric Hitachi Nuclear Energy Americas, LLC Topical Report NEDO-32465, Supplement 1, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications (TAC No. ME7104)," October 24, 2014.

# APPENDIX A

List of changes from TRACG02 to TRACG04 from *Migration to TRACG04 / P11 from TRACG02 / P10 for TRACG AOO and ATWS Overpressure Transients*, NEDE-32906P Supplement 3-A, Revision 1, April 2010 (Reference 11).

1. Replace the existing P10 kinetics model with the P11 kinetics model. (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), FLN-1999-011, November 10, 1999.) (Reference 9)
2. The ANS decay heat model. (American National Standard for Decay Heat Power in Light Water Reactors, ANSI/ANS 5.1-1979. American National Standard for Decay Heat Power in Light Water Reactors, ANSI/ANS 5.1-1994.) The ANS decay heat model is implemented as an optional model in addition to the existing May-Witt model. The ANS model improves the simulation of the effect of exposure on the decay heat and was implemented primarily for applications to LOCA.
3. Implement the quench front model for fuel rods and channel box. The quench front model was not activated in the previous version of TRACG. The model has been activated for application to LOCA, where quench front controlled rewetting is important for the calculation of the peak cladding temperature.
4. A hot rod model for the fuel channel component. The one-dimensional hydraulic model in the TRACG channel component does not simulate the cross sectional variation in void fraction and steam superheat that can exist in a fuel bundle prior to reflooding and quenching during a LOCA. The hot rod model is implemented to capture the effect of cross sectional variations on the peak cladding temperatures.
5. The Shumway model for the minimum stable film boiling temperature. (R. W. Shumway, TRAC-BWR Heat Transfer: Assessment of Tmin, EGG-RST-6781, October 1984.) The Shumway model is implemented as an optional enhancement to the minimum film boiling temperature correlation. This model primarily effects the rewetting during the reflood phase of a LOCA.
6. Enhancement to the entrainment model to give better agreement with data. The models for the interfacial shear in the previous version of TRACG had primarily been qualified for pressure ranges applicable to normal operating conditions and AOO transient and ATWS overpressure analyses. Additional qualification for low pressure was performed to support the expansion of the application of TRACG to LOCA. Minor enhancements to the entrainment model were introduced to improve the application of TRACG at lower

pressures. The enhancements affect the onset of entrainment and primarily the calculation of entrainment when some surfaces (e.g., fuel rods in a channel component) have experienced boiling transition.

7. Enhancement to the flow regime map to give better void fraction predictions for low pressure. The models for the flow regime transitions in the previous version of TRACG had primarily been qualified for pressure ranges applicable to normal operating conditions and AOO transient and ATWS overpressure analyses. Additional qualification for low pressure was performed to support the expansion of the application of TRACG to LOCA. Minor enhancements to the model for transition to annular flow was introduced to improve the application of TRACG at lower pressures.
8. Fuel rod conductivity consistent with PRIME. (J. G. M. Andersen, et. al., TRACG Model Description, NEDE-32176P, Rev. 4, January 2008.) (Reference 2) The fuel conductivity from the PRIME model has been implemented as the default model in TRACG04, while the previous GESTR-based model has been retained as an optional model. The PRIME model improves the effect of temperature, exposure, and Gadolinium on the fuel thermal conductivity.
9. Models for the uncertainty in fuel rod internal pressure, the cladding yield stress, and the cladding rupture stress. These models were implemented for use in the statistical analysis of a LOCA.
10. Modify the Zircaloy oxidation rate to be consistent with the latest version of the Cathcart & Pawel correlation. (J. V. Cathcart and R. E. Pawel, Zirconium Metal-Water Oxidation Kinetics: IV. Reaction Rate Studies, ORNL/NUREG-17, August 1977.)
11. Enhanced default pump homologous curves. The default pump homologous curves, which were based on data from the Semiscale test facility, have been supplemented with curves representative for large pumps.
12. Improved free convection heat transfer. The McAdams correlation correlation for free convection at a liquid surface has been implemented in addition to the current model that was based on Holman.
13. Improved condensation heat transfer. The default correlation for condensation heat transfer in the pressence of noncondensibles was changed from the Vierow-Schrock to the Kuhn-Schrock-Peterson correlation.
14. Optional 6-cell jet pump. One-nozzle jet pumps have a relatively long straight section between the suction inlet and the diffuser. In the standard 5-cell jet pump, a single cell is used for this region. An option to subdivide this region into two cells has been implemented, primarily to improve the accuracy of the calculation of the void profile and

static head in the jet pump for low flow two-phase flow conditions such as during the refill/reflood phase of a LOCA.

15. Improved boron model. The models for solubility of sodiumpentaborate and the $B_{10}$ absorption cross section have been improved to give better agreement with available data.

There is one additional change in the transition of the DIVOM methodology from TRACG02 to TRACG04. The TRACG04 methodology also includes the use of the TRACG04 transient CPR calculation which was approved for application to transients by Reference 19.

# APPENDIX B

## GEH Responses to NRC RAIs on NEDO-32465 Supplement 1

**RAI-1 - TRACG04 Configuration Options:**

Please specify the required TRACG04 configuration options (where TRACG represents the Transient Reactor Analysis Code – GEH proprietary version) for DIVOM [Delta CPR over Initial MCPR Versus Oscillation Magnitude] calculations (e.g., full-core channel mapping, axial nodalization, semi-implicit method, etc.).

**GEH Response:**

The key TRACG04 configuration requirements for the DIVOM stability analyses are the following:

Thermal-Hydraulic Nodalization:

- [[

]]

Neutronics Nodalization:

- [[

]]

Numerics:

- [[

]]

**References:**

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

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

1-3 GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," NEDO-32465, Supplement 1, Revision 0, September 2011.

1-4 GE Hitachi Nuclear Energy, "TRACG Model Description," NEDE-32176P, Revision 4, January 2008.

1-5 GE Nuclear Energy, "TRACG Application for Anticipated Operational Occurrences Transient Analysis," NEDE-32906P-A, Revision 3, September 2006.

1-6 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.

1-7 GE Nuclear Energy, "Steady-State Nuclear Methods," NEDE-30130P-A, April 1985.

1-8 Letter, 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.

**RAI-2 – Approved Code Versions:**

NEDO-32465, Supplement 1, Revision 0 states that "The NRC has examined the capability and qualification of P11/TGBLA06 through numerous applications" (where P11 represents PANAC11, a boiling water reactor core simulator methodology, coupled with TGBLA06, a fuel lattice physics methodology used to provide lattice input to nuclear design and analysis methods). Please provide a list of references of approved ("-A") licensing topical reports (LTRs) that use the P11/TGBLA06 methodology.

**GEH Response:**

TRACG has been reviewed and approved for Anticipated Operational Occurrences (AOOs) for operational boiling water reactors (BWRs) and ESBWRs. The following references used TRACG with P11/TGBLA06 methodology.

| Approved LTR | Application |
|---|---|
| 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. | BWR/2-6 AOO and Anticipated Transient Without Scram (ATWS) Overpressure |
| GE Hitachi Nuclear Energy, "TRACG Application for ESBWR Transient Analysis," NEDE-33083 Supplement 3P-A, Revision 1, September 2010. | ESBWR AOO |
| GE Hitachi Nuclear Energy, "TRACG Application for ESBWR Stability Analysis," NEDE-33083 Supplement 1P-A, Revision 2, September 2010. | ESBWR Stability |
| GE Hitachi Nuclear Energy, "TRACG Application for ESBWR Anticipated Transient Without Scram Analyses," NEDE-33083 Supplement 2P-A, Revision 2, October 2010. | ESBWR ATWS |
| GE Hitachi Nuclear Energy, "Applicability of GE Methods to Expanded Operating Domains," NEDC-33173P-A, Revision 3, April 2012. | Extended Power Uprate (EPU) Application |
| GE Nuclear Energy, "TRACG Application for Anticipated Operational Occurrences (AOO) and Transient Analyses," NEDE-32906P-A, Revision 3, September 2006. | BWR/2-6 AOO |

**RAI-3 – Applicability to New Fuels:**

Please describe the applicability of the DIVOM methodology with TRACG04/P11 (TRACG04 coupled with PANAC11) in NEDO-32465, Supplement 1 to new fuels and fuels from other vendors. Is a review process required for new fuels before application of P11/TGBLA06?

**GEH Response:**

The DIVOM methodology is plant- and cycle-specific. As such, the TRACG04/P11 analysis includes the detailed bundle design, whether it is from GEH/GNF or from other fuel vendors. Therefore, the TRACG04/P11 DIVOM methodology is applicable to current and new fuel designs from GEH/GNF and/or other fuel vendors. The qualification of P11/TGBLA06 to new fuel designs (GEH/GNF or other fuel vendors) involves a comparison of key parameters to the corresponding parameters produced with MCNP (Reference 3-1). These parameters include the infinite multiplication constant or eigenvalue, dynamic void coefficient, the cold control rod worth, the Boron worth, and the fission density distribution. A review process for the new fuels before application of P11/TGBLA06 is required. The requirements of the review process are described in Section 3, Item (1) of Reference 3-2.

**References:**

3-1 GE Nuclear Energy, "Methodology and Uncertainties for Safety Limit MCPR Evaluations," NEDC-32601P-A, August 1999.

3-2 Letter, F. Akstulewicz (NRC) to G. A. Watford (GE), "Acceptance for Referencing of Licensing Topical Reports NEDC-32601P, Methodology and Uncertainties for Safety Limit MCPR Evaluations; NEDC-32694P, Power Distribution Uncertainties for Safety Limit MCPR Evaluation; and Amendment 25 to NEDE-24011-P-A on Cycle-Specific Safety Limit MCPR (TAC Nos. M97490, M99069 and M97491)," MFN-003-99, March 11, 1999.

**RAI-4 – Fuel Properties:**

As part of the TRACG04 upgrade, PRIME (a fuel rod thermal mechanical code) is used to calculate fuel properties. What codes or methodologies were used to calculate the fuel properties in the sample cases in Figures 4-18 to 4-23?

**GEH Response:**

Figures 4-18 through 4-23 (Reference 4-1) show key results for the core-wide TRACG transient analysis. Figures 4-18 through 4-20 show results using TRACG02/PANAC10 with GESTR (Reference 4-2) to calculate fuel properties, whereas Figures 4-21 through 4-23 use TRACG04/PANAC11 with PRIME (Reference 4-3) to calculate fuel properties.

**References:**

4-1. GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," NEDO-32465, Supplement 1, Revision 0, September 2011.

4-2. Letter, C. O. Thomas (NRC) to J. S. Charnley (GE), "Acceptance for Referencing of Licensing Topical Report NEDE-24011-P Amendment 7 to Revision 6, 'General Electric Standard Application for Reactor Fuel," MFN-036-85, March 1, 1985.

4-3. GE Hitachi Nuclear Energy, "The PRIME Model for Analysis of Fuel Rod Thermal – Mechanical Performance Part 1 – Technical Bases," NEDC-33256P-A, Revision 1, "Part 2 – Qualification," NEDC-33257P-A, Revision 1, and, "Part 3 - Application Methodology," NEDC-33258P-A, Revision 1, September 2010.

**RAI-5 – Channel Grouping:**

As part of the new TRACG04 methodology, stability calculations are performed with full one-to-one channel mapping; however, old TRACG02/P10 applications used channel grouping (typically approximately 30 thermal-hydraulic channels). What channel grouping was used for the sample cases in Figures 4-18 to 4-23? Please describe any impact on DIVOM slopes of the new channel grouping strategy.

**GEH Response:**

It is the Detect and Suppress Solution – Confirmation Density (DSS-CD) TRACG04 methodology that implements the full core individual bundle model, in which each fuel bundle is modeled as an individual thermal-hydraulic channel in the system code thermal-hydraulic nodalization (References 5-1 and 5-2). The DIVOM requirements for channel grouping are provided in the response to RAI-1. The channel grouping requirements for TRACG04/PANAC11 DIVOM analyses are consistent with those used for the TRACG02/PANAC10 DIVOM analyses, which were based on studies showing that once the [[ ]] there is little sensitivity in the DIVOM slope. Because the DIVOM methodology, unlike DSS-CD, [[ ]], it is not necessary to run the full core individual bundle model for TRACG DIVOM analyses.

The channel groupings used for the sample cases in Figures 4-18 to 4-23 are shown in Figure 4-16 and Figure 4-17 of Reference 5-3 for TRACG02/PANAC10 and TRACG04/PANAC11, respectively. The channel groupings documented in Figures 4-16 and 4-17 of Reference 5-3 are consistent with the [[ ]].

A consistent methodology for channel grouping is maintained for TRACG04/PANAC11 with respect to TRACG02/PANAC10 applications. Therefore, there is no impact on DIVOM slopes because there is no new channel grouping strategy that is implemented.

**References:**

5-1 GE Hitachi Nuclear Energy, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," NEDC-33075P, Revision 7, June 2011.

5-2 GE Hitachi Nuclear Energy, "DSS-CD TRACG Application," NEDE-33147P, Revision 3, January 2011.

5-3 GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing

Basis Methodology for Reload Applications," NEDO-32465, Supplement 1, Revision 0, September 2011.

## RAI-6 – Natural Circulation Hot Channel Oscillation Magnitude (HCOM):

Section 4.2 of NEDO-32465, Supplement 1 states that HCOM values at natural circulation are typically between 0.8 and 1.0. In Figure 5-4, a single HCOM value of approximately 1.05 is marked in the figure. How can a bounding DIVOM slope be defined with only one HCOM value instead of a range? Please explain the example of Figure 5-4.

## GEH Response:

In the Option III Stability Long Term Solution (LTS) (Reference 6-1), Oscillation Power Range Monitor (OPRM) amplitude set points are established corresponding to a range of Hot Channel Oscillations Magnitudes (HCOMs). Within this range of HCOMs, a DIVOM slope is calculated which bounds all the DIVOM data points. In the Option 1-D Stability LTS, the stability protection is provided by the Average Power Range Monitor (APRM) flow biased SCRAM line. There is only one HCOM value of interest, which is defined by the distance from the 100% Original Licensed Thermal Power (OLTP) rod line at natural circulation to the APRM SCRAM line. Therefore, for 1-D plants, the DIVOM slope is calculated at this specific HCOM value. In Section 4.2, an analysis is provided to compare PANAC10/TRACG02 and PANAC11/TRACG04 methodologies for a plant in which the exact HCOM is not known. Therefore, the DIVOM slope is calculated over a 0.8 - 1.0 range in HCOM for comparison purposes only. In Section 5.3, a demonstration analysis using the PANAC11/TRACG04 methodology is provided for a typical Option 1-D plant in which the HCOM value is known. Therefore, the DIVOM slope is calculated such that it bounds this known HCOM value, which in this case was approximately 1.05.

## References:

6-1. GE Hitachi Nuclear Energy, "Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications," NEDC-32465, Supplement 1, Revision 0, September 2011.