Enclosure 2

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DSS-CD TRACG APPLICATION

LICENSING TOPICAL REPORT

Non-proprietary Information

GE Nuclear Energy
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LICENSING TOPICAL REPORT

DSS-CD TRACG APPLICATION

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The information contained in this document is furnished for the purpose of obtaining NRC approval of the licensing requirements for implementation of the stability Detect and Suppress Solution – Confirmation Density (DSS-CD) to provide automatic detection and suppression of stability related power oscillations. The only undertakings of General Electric Company with respect to information in this document are contained in contracts between General Electric Company 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 that for which it is intended is not authorized; and with respect to any unauthorized use, General Electric Company makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

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EXECUTIVE SUMMARY

Several different stability long-term solution (LTS) options have been developed for BWRs. The Detect and Suppress Solution – Confirmation Density (DSS-CD) is a LTS that consists of hardware and software for the automatic detection and suppression of stability related power oscillations.

DSS-CD uses an enhanced detection algorithm, the Confirmation Density Algorithm (CDA), which reliably detects the inception of power oscillations and generates an early power suppression trip signal prior to any significant oscillation amplitude growth and Minimum Critical Power Ratio (MCPR) degradation. The TRACG code is used to confirm the MCPR margin during reasonably limiting instability event simulations for DSS-CD applications. Licensing topical report (LTR) NEDC-33075P (Reference 1) provides the DSS-CD generic licensing basis for GE BWR/3-6 product lines, and describes a standard procedure for plant-specific confirmations of reload designs and other design changes that may affect the DSS-CD generic licensing basis.

The GE TRACG code model description, qualification, application for anticipated operational occurrences, and use in the DSS-CD process are documented in LTRs NEDE-32176P (Reference 2), NEDE-32177P (Reference 3), NEDE-32906P-A (Reference 4) and NEDC-33075P, respectively. All of these LTRs have been reviewed by the NRC. This LTR incorporates the essential information from the above four LTRs to describe and justify the use of TRACG for modeling instabilities in the DSS-CD process.

ACKNOWLEDGEMENTS

The following individuals contributed significantly to the development, verification, and review of this report:

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ACRONYMS AND ABBREVIATIONS

Term	Definition
AOO	Anticipated Operational Occurrence
BOC	Beginning of cycle
BT	Boiling Transition
BWR	Boiling Water Reactor
CCFL	Counter Current Flow Limitation
CDA	Confirmation Density Algorithm
CHAN	Fuel Channel component in TRACG
CPR	Critical Power Ratio
CSAU	Code Scaling, Applicability and Uncertainty
DSS-CD	Detect and Suppress Solution – Confirmation Density
DVC	Dynamic Void Coefficient
ECCS	Emergency Core Coolant System
EOC	End Of Cycle
EPU	Extended Power Uprate
FMCPR	Final Minimum Critical Power Ratio
FTTC	Fuel Thermal Time Constant
FW	Feedwater
FWTR	Feedwater temperature reduction
GDC	General Design Criteria
GESTAR	General Electric Standard Application for Reload Fuel
GEXL	GE Boiling Transition Correlation
GT	Guide Tube
H	High Importance
HPCS	High Pressure Core Spray
HT	Heat Transfer
ICPR	Initial Critical Power Ratio
IMCPR	Initial Minimum Critical Power Ratio
JP	Jet Pump
L	Low Importance
LOCA	Loss Of Coolant Accident
LPCI	Low Pressure Coolant Injection
LTP	Lower Tieplate
LTR	Licensing Topical Report

Term	Definition
LTS	Long-Term Solution
M	Medium Importance
MCPR	Minimum Critical Power Ratio
MELLLA+, M+	Maximum Extended Load Line Limit Analysis Plus
MG	Motor Generator
MOC	Middle Of Cycle
NA	Not Applicable
NRC	Nuclear Regulatory Commission
OLMCPR	Operating Limit MCPR
OLTP	Original Licensed Thermal Power
Option III	Stability OPRM-Based Detect and Suppress Long Term Solution
PANAC11	PANACEA, GE BWR Core Simulator
PIRT	Phenomena Identification and Ranking Table
PHE	Peak Hot Excess
RFACT	R Factor
SAFDL	Specified Acceptable Fuel Design Limit
SEO	Side entry orifice
SLMCPR	Safety Limit MCPR
TMIN	Minimum Stable Film Boiling Temperature
TRACG	Transient Reactor Analysis Code (GE proprietary version)
UTP	Upper Tieplate
1-D	One Dimensional
1P	Single Phase Pressure Drop
2P	Two Phase Pressure Drop
2RPT	Two Recirculation Pumps Trip
3-D	Three Dimensional

1.0 INTRODUCTION

1.1 Background

Under certain conditions, boiling water reactors (BWRs) may be susceptible to coupled neutronic/thermal-hydraulic instabilities. These instabilities are characterized by periodic power and flow oscillations and are the result of density waves (i.e., regions of highly voided coolant periodically sweeping through the core). If the flow and power oscillations become large enough, and the density waves contain a sufficiently high void fraction, the fuel cladding integrity safety limit could be challenged.

The Detect and Suppress Solution – Confirmation Density (DSS-CD) solution, documented in Reference 1, consists of hardware and software that provide for reliable, automatic detection and suppression of stability related power oscillations. It is designed to identify the power oscillation upon inception and initiate control rod insertion to terminate the oscillations prior to any significant amplitude growth. The combination of hardware, software, and system setpoints provides protection against violation of the Safety Limit Minimum Critical Power Ratio (SLMCPR) for anticipated oscillations. Thus, compliance with General Design Criteria (GDC) 10 and 12 of 10 CFR 50, Appendix A is accomplished via an automatic action.

The DSS-CD is designed to provide adequate automatic SLMCPR protection for anticipated reactor instability events. The existing Option III algorithms are retained (with generic setpoints) to provide defense-in-depth protection for unanticipated reactor instability events. To support DSS-CD implementation, the TRACG code is used to simulate events to confirm the capability of the DSS-CD solution for early oscillation detection and suppression. The purpose of the TRACG qualification review, summarized herein and described in Reference 1 is to provide background in support of the DSS-CD application. The TRACG model description, qualification, and application to transient analyses together with NRC Safety Evaluation Report are documented in NEDE-31176P, NEDE-31177P and NEDE-32906P-A, respectively (References 2-4).

This report provides a generic licensing basis for TRACG analyses in support of Reference 1.

1.2 Purpose and Scope

This report provides the licensing basis and methodology to demonstrate the adequacy of the TRACG analyses as part of the DSS-CD solution. Section 2.0 describes the licensing requirements and the scope of the TRACG application to DSS-CD. Section 3.0 describes the identification and ranking of BWR phenomena for stability. Section 4.0 describes and justifies the applicability of TRACG models to DSS-CD. Section 5.0 describes the model uncertainties. Section 6.0 describes the application uncertainties and biases. Section 7.0 describes the combination of uncertainties. Section 8.0 provides a demonstration analysis.

2.0 LICENSING REQUIREMENTS AND SCOPE OF APPLICATION

2.1 Licensing Compliance

The DSS-CD solution and related licensing basis comply with the requirements of 10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants". The Appendix A criteria related to stability are Criteria 10 and 12.

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."

The DSS-CD hardware and software reliably and readily detect and suppress both core wide and regional mode oscillations prior to violating the SLMCPR for anticipated oscillations. The ability to trip the reactor is automatically enabled at power and flow conditions at which stability related oscillations are possible.

The DSS-CD licensing basis provides a high degree of confidence that power oscillations are terminated at relatively low amplitude by the DSS-CD solution, prior to any significant MCPR degradation, and therefore, obviates SLMCPR violations for anticipated instability events. Thus, the DSS-CD solution complies with GDC 10 and 12. The purpose of the DSS-CD TRACG analysis is to confirm the inherent MCPR margin afforded by the solution design.

2.2 TRACG Analysis Approach For Licensing Compliance

The overall TRACG demonstration analysis approach for DSS-CD is consistent with the Code Scaling, Applicability and Uncertainty (CSAU) analysis methodology (NUREG/CR-5249, Reference 5) and Regulatory Guide 1.157 (Reference 6), and addresses the applicable elements of the NRC-developed CSAU evaluation methodology. As established in Reference 1, Table 2-1 provides a summary of 14 CSAU methodology steps for TRACG.

2.3 Scope of TRACG Application for DSS-CD

The TRACG code is used to simulate reasonably limiting [[ ]] events to confirm the early oscillation detection and suppression capability of DSS-CD solution. [[ ]] The purpose of the TRACG qualification review is to provide background for the code use in support of the DSS-CD application.

2.4 NRC Review Requirements for TRACG Code Updates

In order to effectively manage the future viability of TRACG, GE proposes the following requirements for upgrades to the code to define changes that (1) require NRC review and approval and (2) that will be on a notification basis only.

2.4.1 Updates to TRACG Code

Modifications to the basic models described in Reference 2 that significantly reduce the MCPR margin may not be used for licensing calculations without NRC review and approval. However, modifications to the basic models that add conservatism or are judged to be insignificant would not require NRC review and approval.

Updates to the TRACG nuclear methods to ensure compatibility with the NRC-approved steady-state nuclear methods (e.g., PANAC11) may be used for licensing calculations without NRC review and approval as long as the ΔCPR/ICPR shows less than 1 sigma deviation difference compared to the method presented in this LTR. A typical 2RPT case will be compared and the results from the comparison will be transmitted for information.

Changes in the numerical methods to improve code convergence may be used in licensing calculations without NRC review and approval.

Features that support effective code input/output may be added without NRC review and approval.

2.4.2 Updates to TRACG Model Uncertainties

New data may become available with which the specific model uncertainties described in Section 5 of Reference 4 may be reassessed. If the reassessment results in a need to change specific model uncertainty, the specific model uncertainty may be revised for licensing calculations without NRC review and approval as long as the process for determining the uncertainty is unchanged.

The nuclear uncertainties (void coefficient, Doppler coefficient, and scram coefficient) may be revised without review and approval as long as the process for determining the uncertainty is unchanged. In all cases, changes made to model uncertainties without NRC review and approval will be transmitted for information.

2.4.3 Updates to TRACG Statistical Method

Revisions to the TRACG statistical method described in Section 7 may not be used for licensing calculations without NRC review and approval.

Table 2-1

14 Step CSAU Methodology

CSAU Step	Step Description	DSS-CD
1	Scenario Specification	[[ ]]
2	Nuclear Power Plant Selection	BWR/3-6
3	Phenomena Identification and Ranking	Addressed in Table 3-1
4	Frozen Code Version Selection	TRACG02A
5	Code Documentation	References 2, 3
6	Determination of Code Applicability	Table 4-1
7	Establishment of Assessment Matrix	Table 4-2
8	Nuclear Power Plant Nodalization Definition	Nodalization defined. Plant nodalization study performed. References 1, 3
9	Definition of Code and Experimental Accuracy	References 3, 4
10	Determination of Effect of Scale	Full scale data available, addressed in Section 5.2, Item 10 of Reference 1
11	Determination of the Effect of Reactor Input Parameters and State	Addressed in Tables 3-1 and 6-1
12	Performance of Nuclear Power Plant Sensitivity Calculations	Addressed in Tables 5-1 and 6-1
13	Determination of Combined Bias and Uncertainty	[[ ]]
14	Determination of Total Uncertainty	DSS-CD bounding calculations demonstrate that FMCPR > SLMCPR

3.0 PHENOMENA IDENTIFICATION AND RANKING

The critical safety parameter for stability events is the MCPR. The MCPR value is determined by the governing physical phenomena. The phenomena identification and ranking table (PIRT) is used to delineate the important physical phenomena. PIRTs are ranked with respect to their impact on the critical safety parameters. For example, the MCPR is determined by the reactor short-term response to stability events. The coupled core neutronic and thermal-hydraulic characteristics govern the neutron flux, reactor pressure, and core flow in a stability transient.

All processes and phenomena that occur during a transient do not equally influence plant behavior. Disposition analysis is used to reduce all candidate phenomena to a manageable set by identifying and ranking the phenomena with respect to their influence on the critical safety parameters. The phases of the events and the important components are investigated. The processes and phenomena associated with each component are examined. Cause and effect are differentiated. After the processes and phenomena have been identified, they are ranked with respect to their effect on the critical safety parameters for the event.

PIRTs are developed with only the importance of the phenomena in mind and are independent of whether or not the model is capable of handling the phenomena and whether or not the model shows a strong sensitivity to the phenomena. For example, two phenomena may be of high importance yet may tend to cancel each other so that there is little sensitivity to either phenomenon. Both phenomena are of high importance because the balance between these competing phenomena is important.

Table 3-1 was developed to identify the phenomena that govern BWR/3-6 stability responses, and represents a consensus of GE expert opinions. The stability transient events have been categorized into three distinct groups:

- Channel thermal-hydraulic instability,
- Core-wide instability, and
- Regional instability.

For each event type, the phenomena are listed and ranked for each major component in the reactor system. The ranking of the phenomena is done on a scale of high importance to low importance or not applicable, as defined by the following categories:

- **High importance (H):** These phenomena have a significant impact on the primary safety parameters and should be included in the overall uncertainty evaluation.
- **Medium importance (M):** These phenomena have insignificant impact on the primary safety parameters and may be excluded in the overall uncertainty evaluation.
- **Low importance (L) or not applicable (NA):** These phenomena have no impact on the primary safety parameters and need not be considered in the overall uncertainty evaluation.

The PIRT serves a number of purposes. First, the phenomena are identified and compared to the modeling capability of the code to assess whether the code has the necessary models to simulate the phenomena. Second, the identified phenomena are cross-referenced to the qualification basis to determine what qualification data are available to assess and qualify the code models and to determine whether additional qualification is needed. As part of this assessment, the range of the PIRT phenomena covered in the tests is compared with the corresponding range for the intended application to establish that the code has been qualified for the highly ranked phenomena over the appropriate range.

Table 3-1 also tabulates a number of derived parameters (e.g. ratio of core power to core flow) important to reactor instability.

Using the PIRT table ranking results, the uncertainties for the highly ranked PIRT phenomena are established and evaluated based on a bounding analysis to arrive at the total model uncertainty.

Table 3-1

Phenomena Governing BWR/3-6 Stability Transients

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4.0 APPLICABILITY OF TRACG TO DSS-CD APPLICATIONS

This section demonstrates the applicability of TRACG for the analysis of anticipated instability events in BWRs through a two-step process. First, the identified phenomena are compared to the modeling capability of the code to determine that the code has the necessary models to simulate the phenomena, as shown in Table 4-1.

Second, the capability of the TRACG models to treat the highly ranked phenomena and the qualification assessment of the TRACG code for stability applications are examined.

The capability to simulate an event for a nuclear power plant depends on four elements:

- Conservation equations, which provide the code capability to address global processes,
- Correlations and models, which provide the code capability to model and scale particular processes,
- Numerics, which provide the code capability to perform efficient and reliable calculations, and
- Structure and nodalization, which address the code capability to model plant geometry and perform efficient and accurate calculations.

Consequently, these four elements must be considered when evaluating the applicability of the code to the event of interest for the nuclear power plant calculation. The key phenomena for each event are identified in generating the PIRTs for the intended application. The capability of the code to simulate the key phenomena for AOO applications is addressed, documented and supported by code qualification in Reference 4. A similar demonstration for stability is made in Section 4.1. There are only minor differences between the (H) ranked PIRTs (see Table 3-1) for stability and those for AOOs with the inclusion of:

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4.1 Phenomena vs. Qualification Basis Cross-Reference

The identified phenomena are cross-referenced to the qualification basis to determine what qualification data are available to assess and qualify the code models, and to determine whether additional qualification is needed for some phenomena. As part of this assessment, the range of the PIRT phenomena covered in the tests is compared with the corresponding range for the intended application to establish that the code has been qualified for the highly ranked phenomena over the appropriate range.

The qualification assessment of TRACG models is summarized in Table 4-2. The models are identified so that they may be easily correlated to the model description and qualification reports. For each model, the relevant elements from the Model Description LTR (Reference 2) and the Qualification LTR (Reference 3) are identified.

For each of the governing BWR phenomena, TRACG qualification has been performed against a wide range of data. In this section, the qualification basis is related to the phenomena that are important for the intended application. This is a necessary step to confirm that the code has been adequately qualified for the intended application.

The complete list of phenomena is cross-referenced to the model capabilities in Table 4-1. Similarly, as shown in Table 4-2, the complete list of phenomena is cross-referenced to the qualification assessment basis. Data from separate effects tests, component tests, integral system tests and plant tests as well as plant data have been used to qualify the capability of TRACG to model the phenomena.

4.2 Other Topics Relevant To TRACG Modeling Instability

This section addresses other topics relevant to TRACG modeling of instability, including the selection of numerical integration scheme and nodalization approach for the Channel component, numerical formulations used, and Channel grouping approach used in TRACG stability analysis, which includes the use of harmonic power shape for determining the regional mode channel grouping.

4.2.1 Explicit Integration Scheme for the Channel Component

TRACG uses a fully implicit integration technique for the heat conduction and hydraulic equations when integrating from time step n to time step n+1. In the implicit formulation, the convective terms are calculated based on the new properties at time step n+1. The fully implicit technique is the default option. The governing hydraulic equations in the implicit form are provided in Section 8.2 of Reference 2. For time domain stability calculations, an optional explicit integration technique can be employed. To minimize numerical damping, the use of explicit scheme changes the convective terms to use the current properties at time step n properties in place of the new properties at time step n+1.

Thermal-hydraulic instability caused by density waves can occur in boiling two-phase flow, where there is a mismatch between the power and flow (i.e., high power and low flow). Traditionally, this instability has been analyzed using frequency domain methods. The frequency domain method consists of a first order perturbation at a given frequency to the steady-state solution. Neglecting all second order terms, a linear system of equations is formed, which can be solved for growth rate or damping as a function of frequency. The maximum growth rate characterizes the thermal-hydraulic stability of the channel. Frequency domain methods generally predict the onset of instability well. However, because they are based on a linearized model, they cannot predict what will happen after the system becomes unstable. To capture the nonlinear effects of an unstable system, time domain methods are developed. The TRACG thermal-hydraulic instability modeling has been evaluated for adequacy by comparison to experimental data of the FRIGG facility, as discussed throughout Section 3.7 of Reference 3. Two types of tests were run in the FRIGG facility. One test series used a pseudo random signal imposed on the system to determine the system response as a function of frequency. A second test series provided a more deterministic measurement of the onset of unstable behavior. In these tests, which started from steady-state natural circulation operation, the system power was slowly increased until the onset of unsteady behavior was observed. This second series of tests have been simulated by TRACG. Comparisons of TRACG predictions of the channel power for the onset of limit cycle oscillations to the power measured in the tests is considered the best assessment of the code's ability to predict the onset of unstable operation.

4.2.2 Detailed Nodalization Scheme for the Channel Component

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4.2.3 Coupling of Conduction and Hydraulic Equations

The coupling scheme used for the conduction and hydraulic equations does not change for stability applications, relative to AOOs.

The heat transfer coupling between the structures and the hydraulics is treated implicitly, when the implicit integration technique is used. For this purpose, the heat conduction equation is solved in two steps, and thus integration of the combined equations involves the following steps:

(1) The heat conduction equation for structures is linearized with respect to fluid temperatures. The result of this step is a system of linear equations for structure temperatures and surface heat flow as functions of the fluid temperatures.

(2) The hydraulic equations are solved using an iterative technique. This step results in new values for the fluid pressures, void fraction, temperatures and velocities.

(3) A corrector step is utilized for the hydraulic solution. Due to use of an iterative solution technique, the conservation of the properties is affected by the convergence. The corrector step is employed to correct any lack of conservation due to imperfect convergence.

(4) Back-substitution into the heat conduction equation is performed to obtain new temperatures for structures.

The linearization of the heat conduction equation and subsequent back-substitution (Steps 1 and 4) are described in Section 8.1 of Reference 2. The hydraulic solution (Steps 2 and 3) is described in Section 8.2 of Reference 2.

4.2.4 Coupling of the Vessel and Channel Components

The coupling scheme used between the vessel component and the channel components does not change for stability applications, relative to AOOs. A network solution scheme is applied, as described in Section 8.2.2 of Reference 2.

4.2.5 Coupled 3-D Kinetics and Thermal-Hydraulics Model

The coupled 3-D kinetics and thermal-hydraulics model used does not change for stability applications, relative to AOOs. The 3-D kinetics model is described in Section 9 of Reference 2.

TRACG solves the three-dimensional (3-D) transient neutron diffusion equations using one neutron energy group and up to six delayed neutron precursors groups. The basic formulation and assumptions are consistent with the GE 3-D BWR Core Simulator (Reference 7). This same one-group formulation collapsed radially to one axial dimension is the basis for the NRC-approved ODYN computer code (Reference 8). The formulation described fully in Reference 8 is used in ODYN for BWR transient simulations. The simplifying assumptions made in ODYN to yield a one-dimensional (1-D) transient kinetics model are not used in the TRACG 3-D model. Instead, neutron flux and delayed neutron precursor concentrations at every (i,j,k) node are integrated in time in response to moderator density, fuel temperature, boron concentration or control rod changes. [[
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4.2.6 Channel Grouping for Stability Applications

Individual fuel bundles in the core may be modeled in TRACG as individual channels or may be grouped together into a single TRACG channel. Because of current code limitations within TRACG on the number of components allowed it is not possible to model every fuel bundle as a single TRACG channel. Consequently, it is necessary to group or combine individual fuel bundles. [[
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The channels are grouped based on (a) hydraulic considerations to separate hydrodynamic characteristics and (b) neutron kinetics considerations to separate dynamic power sensitivity characteristics. [[
]]

The channel grouping performed by COLPS is furthered modified for application to TRACG stability analysis. The modifications are made to account for additional TRACG capability in the areas of limiting channel response, peripheral channel grouping, and vessel modeling detail.

In order to capture the most limiting channels in the core, the COLPS generated channel grouping is adjusted manually. Bundles with the criteria shown in Table 4-3 are selected and each assigned to a single TRACG channel. The criteria is based on GE studies which have shown that:

[[

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4.2.7 Instability Solution Uniqueness

This section addresses the solution uniqueness of TRACG analysis results for licensing BWR/3-6 power plants to support the DSS-CD licensing basis. GE has provided information to support the use of TRACG as an extension to the previously approved method of analyzing BWR stability and demonstrating compliance with licensing limits (References 10 and 11). Stability events are analyzed to establish the reactor system response, including the calculation of the CPR. This report addresses TRACG capabilities to confirm that acceptable fuel design limits are not exceeded during specified stability event.

The originally approved TRACG stability application for Option III (Reference 12) evaluated the CPR response versus the hot channel oscillation magnitude based on conservative pre-oscillation initial conditions. The event was assumed to initiate following a steady-state initiation at the least stable point on the power/flow map (i.e. the intersection of the natural circulation line and the highest rod line). This typically resulted in the fastest oscillatory growth due to the off-rated equilibrium feedwater temperature condition and location of the power/flow state point. The type of oscillations that developed, core wide or regional, was predetermined by the grouping method as discussed in Section 4.2.6. However, in the [[

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Table 4-1

Stability Phenomena and TRACG Model Capability Matrix

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[redacted]																							
[redacted]																							

[redacted]

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Table 4-2

Qualification Assessment Matrix For BWR/3-6 Stability Phenomena

ID	REGION or PHENOMENA DESCRIPTION	Channel Thermal Hydraulic Stability	Core wide Stability	Regional Stability	Highest Ranking	Critical Safety Parameter	1. Critical power ratio (CPR). Controlled by heat flux, flow, pressure, and inlet subcooling - Power oscillations - Flow oscillations 2. Decay Ratio - controls stability margin/growth rate of perturbations COMMENTS	Qualification Basis Reference to Section Number in the *TRACG Qualification*, LTR NEDE-32177, (Reference 3)			
								Separate Effects Qualification	Component Performance Qualification	Integral System Qualification	Plant Data Qualification
[redacted]											

ID	REGION or PHENOMENA DESCRIPTION	Channel Thermal Hydraulic Stability	Core wide Stability	Regional Stability	Highest Ranking	Critical Safety Parameter	1. Critical power ratio (CPR). Controlled by heat flux, flow, pressure, and inlet subcooling • Power oscillations • Flow oscillations 2. Decay Ratio - controls stability margin/growth rate of perturbations COMMENTS	Qualification Basis Reference to Section Number in the *TRACG Qualification*, LTR NEDE-32177, (Reference 3)			
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ID	REGION or PHENOMENA DESCRIPTION	Channel Thermal Hydraulic Stability	Core wide Stability	Regional Stability	Highest Ranking	Critical Safety Parameter	1. Critical power ratio (CPR). Controlled by heat flux, flow, pressure, and inlet subcooling - Power oscillations - Flow oscillations 2. Decay Ratio - controls stability margin/growth rate of perturbations COMMENTS	Qualification Basis Reference to Section Number in the *TRACG Qualification*, LTR NEDE-32177, (Reference 3)			
								Separate Effects Qualification	Component Performance Qualification	Integral System Qualification	Plant Data Qualification
[redacted]											
[redacted]											
[redacted]											
[redacted]											

ID	REGION or PHENOMENA DESCRIPTION	Channel Thermal Hydraulic Stability	Core wide Stability	Regional Stability	Highest Ranking	Critical Safety Parameter	1. Critical power ratio (CPR). Controlled by heat flux, flow, pressure, and inlet subcooling - Power oscillations - Flow oscillations 2. Decay Ratio - controls stability margin/growth rate of perturbations COMMENTS	Qualification Basis Reference to Section Number in the *TRACG Qualification*, LTR NEDE-32177, (Reference 3)			
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[redacted]											
[redacted]											
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ID	REGION or PHENOMENA DESCRIPTION	Channel Thermal Hydraulic Stability	Core wide Stability	Regional Stability	Highest Ranking	Critical Safety Parameter	1. Critical power ratio (CPR). Controlled by heat flux, flow, pressure, and inlet subcooling - Power oscillations - Flow oscillations 2. Decay Ratio - controls stability margin/growth rate of perturbations COMMENTS	Qualification Basis Reference to Section Number in the *TRACG Qualification*, LTR NEDE-32177, (Reference 3)			
								Separate Effects Qualification	Component Performance Qualification	Integral System Qualification	Plant Data Qualification
[redacted]											

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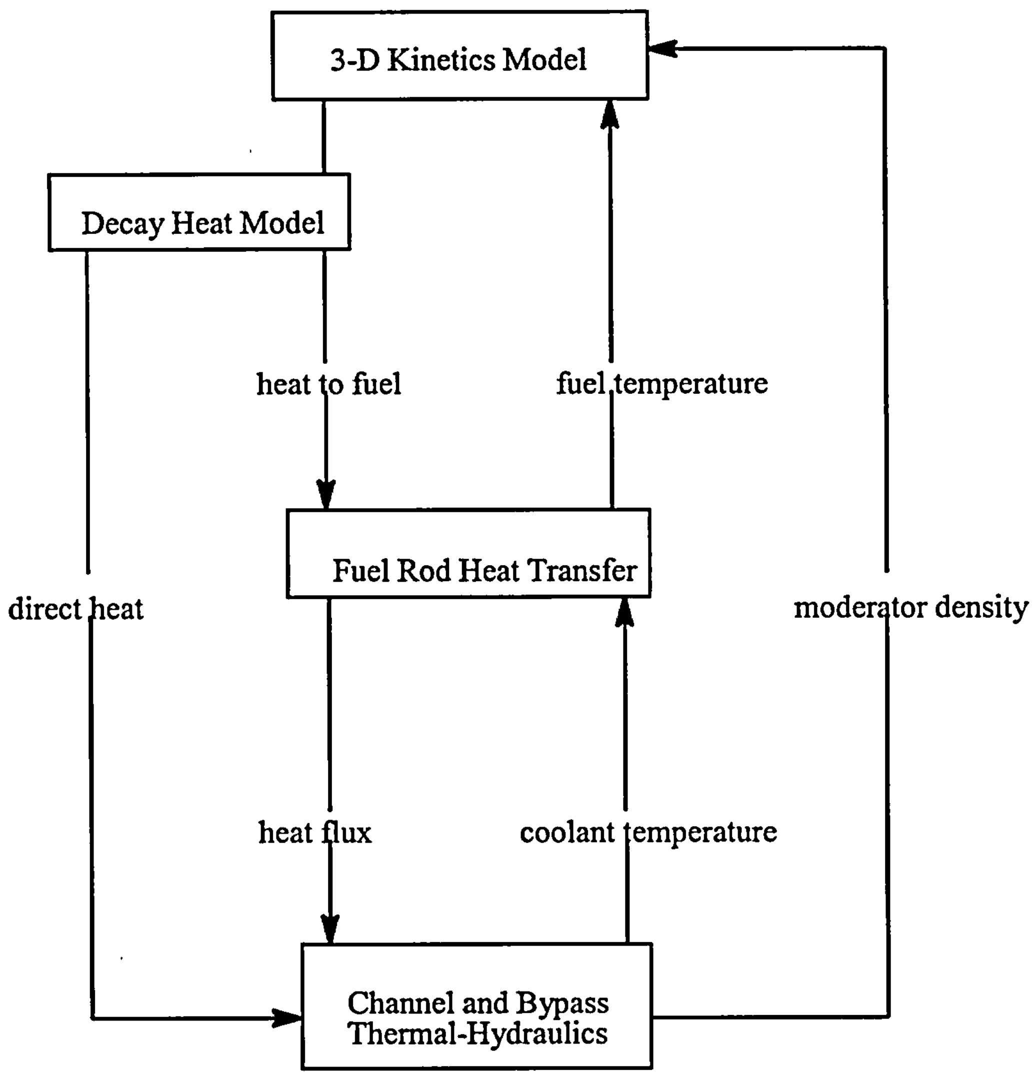
Table 4-3

Single Channel Selection Criteria

Core Wide Mode	Regional Mode	
	Side 1	Side 2
1. Highest radial peaking factor	1. Highest radial peaking factor	1. One channel that is symmetric to the highest radial peaking channel from Side 1. (Note that this channel selection is primarily used to verify symmetrical regional oscillations.)
2. Second highest radial peaking factor	2. Second highest radial peaking factor	
3. Lowest CPR	3. Lowest CPR	
4. Highest gross peaking factor	4. Highest gross peaking factor	
5. Second highest gross peaking factor	5. Second highest gross peaking factor	
	6. Highest product of radial peaking factor and first harmonic flux	
	7. Second highest product of radial peaking factor and first harmonic flux	

Figure 4-1

Data Transfer Between TRACG Models



5.0 MODEL BIASES AND UNCERTAINTIES

The model biases and uncertainties for all items from the PIRT table (Table 3-1), which have been identified as having a high impact on the critical safety parameters, have been evaluated. Overall model biases and uncertainties for the stability application are assessed for each high ranked phenomena by using a combination of comparisons of calculated results to: (1) separate effects test facility data, (2) integral test facility test data, (3) component qualification test data and (4) BWR plant data. Where data is not available, cross-code comparisons or engineering judgment are used to obtain approximations for the biases and uncertainties. For some phenomena that have little impact on the calculated results, it is appropriate to simply use a nominal value or to conservatively estimate the bias and uncertainty. Table 5-1 provides the dispositions of the high ranked stability model parameters from Table 3-1.

Table 5-1

Disposition of High Ranked Stability Model Parameters

[[

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6.0 APPLICATION UNCERTAINTIES AND BIASES

Code inputs can be divided into four broad categories: (1) geometry inputs, (2) model selection inputs, (3) initial condition inputs, and (4) plant parameters. For each type of input, it is necessary to specify the value for the input. If the calculated result is sensitive to the input value, then it is also necessary to quantify the uncertainty in the input.

The geometry inputs specify lengths, areas and volumes. Uncertainties in these quantities are due to measurement uncertainties and manufacturing tolerances. These uncertainties usually have a much smaller impact on the results than do uncertainties associated with the modeling simplifications.

Individual geometric inputs are the building blocks for the spatial nodalization. The spatial nodalization includes modeling simplifications such as the lumping together of individual elements into a single model component. For example, several similar fuel channels may be lumped together and simulated as one fuel channel group. An assessment of these kinds of simplifications, along with the sensitivities to spatial nodalization, is included in the TRACG Qualification LTR (Reference 3).

Inputs are used to select the features of the model that apply for the intended application. Once established, these inputs are fully specified in the procedure for the application and do not change.

A plant parameter is defined as a plant-specific quantity such as a protection system scram characteristic, etc. Plant parameters influence the characteristics of the transient response and have essentially no impact on steady-state operation.

Initial conditions are those conditions that define a steady-state operating condition. Initial conditions may vary due to the allowable operating range or due to uncertainty in the measurement at a give operating condition. The plant Technical Specifications and Operating Procedures provide the means by which controls are instituted and the allowable initial conditions are defined. At a given operating condition, the plant's measurement system has inaccuracies that also must be accounted for as an uncertainty.

Table 6-1 lists the key plant initial conditions/parameters that are high ranked for the stability application.

Table 6-1

Key Plant Initial Conditions/Parameters

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Table 6-1 Notes

[[

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7.0 COMBINATION OF UNCERTAINTIES

The following provides the approach for combining the uncertainties due to model uncertainties, scaling uncertainties, and plant condition or state uncertainties.

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A commonly used approach in traditional conservative analyses is combining the uncertainties linearly, by applying bounding models for the phenomena and by setting plant parameters to values expected to produce the most limiting plant response. [[ ]] Separate calculations were performed to characterize the effect of each response parameter important for stability in order to define the appropriate uncertainty range. The total uncertainty treatment is based on reasonably limiting initial conditions and model uncertainties identified in the previous CSAU steps.

The advantage of this approach is that it requires no more than one computer run for each output parameter of interest. The most significant disadvantage of this method is that it is very conservative. In extreme cases, it can give unrealistic results, and no statistical quantification of the margins to design limits is possible.

8.0 EXAMPLE DEMONSTRATION ANALYSES

8.1 Best Estimate TRACG Simulation

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The simulation results are used to assess the MCPR response and margin to the SLMCPR. The transient responses of key simulation parameters, including core power and flow, core inlet subcooling, hot channel power, hot channel flow and CPR, [[

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8.2 MCPR Uncertainty Assessment

The CSAU bounding approach described in Reference 1 and in this report was applied to the [[

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the bounding approach resulted, as expected, in a significant decrease in CPR margin.

[[

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8.3 MCPR Uncertainty Application to DSS-CD

[[

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Figure 8-1. [[ ]]

Figure 8-2. [[ ]]

Figure 8-3. [[ ]]

Figure 8-4. [[ ]]

Figure 8-5. [[ ]]

Figure 8-6. [[ ]]

Figure 8-7. [[ ]]

Figure 8-8. [[ ]]

Figure 8-9. [[ ]]

Figure 8-10. [[ ]]

Figure 8-11. [[ ]]

Figure 8-12. [[ ]]

Figure 8-13. [[ ]]

Figure 8-14. [[ ]]

Figure 8-15. [[ ]]

Figure 8-16. [[ ]]

9.0 REFERENCES

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Enclosure 3

MFN 04-019

AFFIDAVIT

Enclosure 1

MFN 04-019

NEDE-33147P

DSS-CD TRACG APPLICATION

LICENSING TOPICAL REPORT

GE Proprietary Information