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Proprietary Information Notice
This letter forwards proprietary information in accordance with 10CFR2.390. The balance of this letter may be considered non-proprietary upon the removal of Enclosure 1.

MFN 06-339

Docket No. 52-010

September 22, 2006

U.S. Nuclear Regulatory Commission
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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application – TRACG Application for ESBWR Stability – RAI Numbers 4.4-10 through 4.4-13 & Letter No. 56 - TRACG Application for ESBWR ATWS – RAI Number 21.6-77 B**

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Reference 1 and 2 letters.

Enclosure 1 contains proprietary information as defined in 10CFR2.390. The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 1 has been handled and classified as proprietary to GE. GE hereby requests that the proprietary information in Enclosure 1 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17. A non proprietary version is contained in Enclosure 2.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

References:

1. MFN 06-276, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application*, August 8, 2006
2. MFN 06-316, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 56 Related to ESBWR Design Certification Application*, September 7, 2006

Enclosures:

1. MFN 06-339 – Response to Portion of NRC Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application – TRACG Application for ESBWR Stability – RAI Numbers 4.4-10 through 4.4-13 & Letter No. 56 - TRACG Application for ESBWR ATWS – RAI Number 21.6-77 B – GE Proprietary Information
2. MFN 06-339 – Response to Portion of NRC Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application – TRACG Application for ESBWR Stability – RAI Numbers 4.4-10 through 4.4-13 & Letter No. 56 - TRACG Application for ESBWR ATWS – RAI Number 21.6-77 B – Non Proprietary Version
3. Affidavit – George B. Stramback – dated September 22, 2006

cc: AE Cubbage USNRC (with enclosures)
GB Stramback GE/San Jose (with enclosures)
eDRFs 0057-4126 and 0056-6816

ENCLOSURE 2

MFN 06-339

Response to Portion of NRC Request for

Additional Information Letter No. 49

Related to ESBWR Design Certification Application

TRACG Application for ESBWR Stability

RAI Numbers 4.4-10 through 4.4-13 &

Letter No. 56 - TRACG Application for ESBWR ATWS

RAI Number 21.6-77 B

Non Proprietary Version

NRC RAI 4.4-10

DCD Tier 2, Section 4D.1.1, "Stability Criteria," describes the criteria used to establish stable operation by using a map of core and channel decay ratios. DCD Tier 2, Section 4.3.3.6.2 states that "The ESBWR licensing basis for stability is satisfied by determining a stability criteria map of core decay ratio vs. channel decay ratio to establish margins to stability." During the review of NEDE-33083P, Supplement 1, "TRACG Application for ESBWR Stability Analysis," GE agreed (MFN 06-009) to modify the stability design criteria to include regional decay ratio calculations. Update the DCD accordingly to reflect this.

GE Response

To supply the requested information, Appendix 4D will be modified as shown in the attached markup. The modifications are shown in a "revision mode" with a bar in the right hand column, and will be incorporated in Revision 2 of the Tier 2 DCD.

NRC RAI 4.4-11

Provide a core, channel, and regional stability calculation with fine nodalization in the chimney. Adjust the size of the chimney nodes to obtain a Courant number close to 1.0. The purpose of this calculation is to evaluate the effect of the chimney on the density-wave stability performance.

GE Response

The TRACG model used in the calculations reported in the DCD and Reference 4.4-11-1 was modified to include a fine node structure in the chimney region. For computational efficiency, the chimney was represented by PIPE components instead of the original representation as part of the VSSL. [[

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A base calculation was performed to demonstrate that the PIPE representation of the chimney did not introduce changes relative to the VSSL representation. [[

]] Regional decay ratio calculations were performed with this model following the procedure described in Reference 4.4-11-1. The calculated decay ratio for the limiting channel group of 0.40 agreed exactly with the previously calculated value based on the VSSL model [[ ]] The close agreement verifies that the replacement of the VSSL regions in the chimney by PIPE components is acceptable.

The next step was to implement the fine nodalization in the chimney. The 6 m high chimney was subdivided into 120 5 cm cells. For this cell size, the time step is limited by the vapor velocity in the chimney (i.e., Courant number ~ 1).

The core wide power response to a pressure perturbation was evaluated with the new nodalization. The results are compared with the Reference 4.4-1-1 results in Figure 4.4-11-2. The traces are virtually indistinguishable, indicating that fine nodalization in the chimney has no effect on the core decay ratio. Figure 4.4-11-3 compares the core power response to a flow perturbation. Again, there is close agreement between the responses for the coarse and fine nodalizations in the chimney.

In the adiabatic chimney, void perturbations should theoretically propagate without damping from the bottom to the top. Figure 4.4-11-4 shows the propagation of void perturbations through the chimney as calculated by TRACG. With the Courant number in

the chimney close to 1, the amplitude of the perturbation is not significantly affected as it traverses the height of the chimney.

Figure 4.4-11-5 shows the results of a channel stability calculation for a high power channel. The calculated results for the case with the finely nodalized chimney compare closely with the original calculation in Reference 4.4-11-1.

The results for regional stability shown in Reference 4.4-11-1 [[

]] the regional stability results with the fine nodalization in the chimney have been compared with new coarse node results that do not have this bias. Both sets of calculations used the new PIPE representation of the chimney. [[

]] Figure 4.4-11-6 shows the power response of several channel groups (including those on opposite sides of the axis of symmetry) with the fine nodalization. In Figure 4.4-11-7, results for the fine and coarse nodalizations are shown. The curves are indistinguishable. A maximum decay ratio of 0.40 was calculated for the coarse nodalization for the limiting channel group relative to a value of 0.41 with the fine nodalization.

In summary, the finely nodalized chimney allows for a more accurate representation of void propagation through the chimney, but has no effect on the stability results. The original nodalization used for the stability calculations in Reference 4.4-11-1 and the DCD is adequate for stability analysis.

There is no DCD change related to this RAI.

<u>Reference</u>

4.4-11-1: GE Nuclear Energy, B.S.Shiralkar, et al, "TRACG Application for ESBWR Stability Analysis," NEDE-33083P, Supplement 1, December 2004.

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Figure 4.4-11-1.
Modified TRACG Nodalization (PIPE representation of Chimney)

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Figure 4.4-11-2.
Core Power Response to Pressure perturbation – Original vs. Fine Node Chimney

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Figure 4.4-11-3.
Core Power Response to Core Flow Perturbation – Original vs. Fine Node Chimney

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Figure 4.4-11-4.
Void Propagation through Chimney (Fine nodalization)

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Figure 4.4-11-5.
Channel Stability Results – Original vs. Fine Node Chimney

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Figure 4.4-11-6.
Regional Stability Results for Various Channel Groups –Fine Node Chimney

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Figure 4.4-11-7.
Regional Stability Results – Coarse vs. Fine Node Chimney

RAI 4.4-12

Using the TRACG model developed in RAI 4.4-11, perturb the buoyancy term in the chimney to confirm that buoyancy-driven oscillations do not develop.

GE Response

The TRACG model with the detailed nodalization in the chimney (described in the response to the previous RAI) was utilized for this study.

A buoyancy perturbation was imposed on the system by instantaneously increasing the void fraction in the chimney region and decreasing the void fraction in the downcomer. Simultaneous perturbations were made in the chimney and downcomer masses to keep the total mass in the system constant to see whether manometric (U-tube) oscillations could develop. An artificial case with no neutronic feedback (constant power) was also run to explore the role of the neutronics for loop stability.

Figure 4.4-12-1 shows the case without neutronic feedback. The initial perturbation in the downcomer and chimney masses results in a transient in the circulation flow. The masses and circulation flow are restored to their initial values in about 13 seconds. The response is significantly damped with a single cycle of oscillation showing some undershoot (overshoot). Note that the time period associated with this damped oscillation is of the order of 13 seconds, corresponding to a loop oscillation caused by perturbing the buoyancy in the chimney.

The realistic case with neutronic feedback is shown in Figures 4.4-12-2 and 4.4-12-3. With neutronic feedback, the core voids tend to remain constant for slow oscillations with periods of ~13 seconds. Consequently, the loop oscillation driven by chimney buoyancy perturbations is almost completely damped. In its place, small damped oscillations at a higher frequency, corresponding to density wave oscillations are observed. These are more evident in the core power response shown in Figure 4.4-12-3.

In summary, loop oscillations driven by chimney buoyancy perturbations will not develop in the ESBWR.

There is no DCD change related to this RAI.

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Figure 4.4-12-1.
Response to Chimney Buoyancy Perturbation without neutronic feedback

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Figure 4.4-12-2.
Response to Chimney Buoyancy Perturbation with neutronic feedback

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Figure 4.4-12-3.
Core Power Response to Chimney Buoyancy Perturbation

RAI 4.4-13

Update the DCD Tier 2 documentation to include a TRACG calculation of the ESBWR startup transient including nuclear feedback to confirm that unstable oscillation do not develop during startup.

GE Response

Covered by the response to RAI 4.4-10.

NRC RAI 21.6-77

Provide the following additional information to support the staff's computational fluid dynamics (CFD) modeling of the boron flow paths during an anticipated transient without scram (ATWS) event:

A. *Provide a TRACG nodalization diagram that identifies all volumes that act as sources of mass and energy into or out of the core bypass region along with those volumes or nodes that make up the bypass region. The dimensions (flow areas, volumes, length) and extent (elevation, radial and azimuthal locations) of these volumes is also requested.*

B. *Provide the TRACG output data used to develop the boundary conditions for General Electric's confirmatory CFD analysis of boron mixing in the ESBWR core bypass region.*

GE Response to Part B

The values provided in this response to RAI 21.6-77B represent the ESBWR ATWS MSIVc case.

Entrance Condition (Boron Injection Boundary Condition)

The mass flow rates for the holes in the injection nozzles is given in Table 21.6-77B-1.

Parameter	Value	Units
V_{ave}	30	[m/s]
Flow $Area_{TOTAL}$	0.000904778	[m^2]
Injection Density	1058	[kg/m^3]
Number of Injection Nozzles	16	
Number of Holes per Nozzle	2	
Mass Flow $Rate_{TOTAL}$	28.718	[kg/s]
Mass Flow $Rate_{PER\ HOLE}$	0.897	[kg/s]

Table 21.6-77-1 SLCS Injection Nozzle Parameters

Exit Condition

Pressure at Top of Core: The pressure in the bypass region at the top of the core is [[ ]].

Leakage Flow Rates into Channels: The mass flow rates given in Figure 21.6-77B-1 represent the leakage per channel (bundle). Each bundle has two leakage holes above the lower tie plate. Thus, the leakage per hole is one half of the value given in the Table in Figure 121.6-77B- for a particular bundle. The mass flow rates given are taken from 185 seconds into the transient, just prior to SLCS injection.

As the CFD model represents 1/8 of the core, it is expected that the leakage flow rates selected for the CFD analysis represent the most conservative leakage flow rates with respect to boron distribution in the core. Because the leakage flows at the center of the core are expected to draw boron to the center of the core from the periphery, it would be conservative to use a slice of the core with the lower leakage flow rates at the center of the core. The leakage flow rates between the sectors are very close to one another, so this choice will not have a significant effect on the analysis.

There will be no Tier 2 DCD changes as a result of this RAI response.

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Figure 21.6-77B-1 Leakage Flow Rates for Each Channel in ESBWR Core

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4D. STABILITY EVALUATION

The stability licensing criterion for all nuclear power plants is set forth in 10 CFR 50 Appendix A, General Design Criterion 12 (GDC-12). As discussed in Section 4B.8, this requires assurance that power oscillations, which can result in conditions exceeding specified acceptable fuel design limits, are either not possible or can be reliably detected and suppressed. Because the most limiting stability condition in the ESBWR normal operating region is at the rated power/flow condition, the ESBWR is designed so that power oscillations are not possible (i.e., remains stable) throughout the whole operating region, including plant startup. In addition, the ESBWR is designed to be stable during anticipated operational occurrences (AOOs). As a backup, the ESBWR will implement a Detect and Suppress solution as a defense-in-depth system. The details of the solution will be developed during the ESBWR Construction and Operating License (COL) phase.

This appendix summarizes the stability evaluation of the ESBWR design. Section 4D.1 presents the stability performance during power operation and Section 4D.2 presents the stability performance during plant startup.

4D.1 STABILITY PERFORMANCE DURING POWER OPERATION

4D.1.1 Stability Criteria

Compliance with General Design Criterion 12 is assured by implementing design criteria for the decay ratio. GE uses a stability criteria map of core decay ratio vs. channel decay ratio to establish margins to stability. Stability acceptance criteria for BWRs are established on this map at core decay ratio = 0.8 and limiting channel decay ratio = 0.8, with an allowance for regional mode oscillations in the top right corner of the defined rectangle. These boundaries were established considering model uncertainties of the order of 0.2 in the core and channel decay ratio in the GE analysis methods (FABLE and ODYSY). There is also margin in the regional boundary, which is drawn below available plant regional oscillation data, though the amount of conservatism has not been quantified. The NRC has approved application of ODYSY to the E1A Long Term Stability Solution [4D-1, 4D-2].

The ESBWR core size of 1132 bundles is significantly larger than the largest operating BWR (ABWR with 872 bundles). The sub-criticality of the azimuth harmonic, which is relevant for regional oscillations, decreases with core size. The regional stability boundary is expected to move inwards in the Core Decay ratio vs. Channel Decay Ratio plane as the sub-criticality decreases. Rather than modifying the operating plant stability map, the regional decay ratio will be calculated directly and compared with an acceptance criterion of 0.8. The margin of 0.2 in the calculation of the regional decay ratio is reasonable and consistent with the values for the channel and core decay ratios. Figure 4.D-1 shows the three-dimensional stability map and the design criteria for channel, core and regional stability.

The design goal is for the nominal values of the core, channel and regional decay ratios at rated power and flow to be less than 0.4, or about half the design criteria. This is consistent with the BWR design philosophy of maintaining the decay ratios in the flow control range approximately half of the limiting values.

The design requirement is for the core, channel and regional decay ratios to be less than the acceptance criteria of 0.8 at the 2σ level of uncertainty. Because the ESBWR is a new plant and there are no plant data, the uncertainties includes operating state and model uncertainties, even though there is already an explicit allowance for model uncertainty in the acceptance criteria.

4D.1.2 Analysis Methods

The TRACG computer code is used for the analysis of ESBWR stability margins. TRACG is a General Electric (GE) proprietary version of the Transient Reactor Analysis Code (TRAC). TRACG uses advanced one-dimensional and three-dimensional methods to model the phenomena that are important in evaluating the operation of BWRs. The NRC has approved TRACG for ESBWR LOCA (ECCS and containment) analysis [4D-3]. The application of TRACG for Anticipated Operational Occurrences (AOOs) and for ATWS overpressure calculations for operating BWRs has also been approved by the NRC [4D-4, 4D-5].

TRACG has a multi-dimensional, two-fluid model for the reactor thermal hydraulics and a three-dimensional reactor kinetics model. The models can be used to accurately simulate a large variety of test and reactor configurations. These features allow for realistic simulation of a wide range of BWR phenomena, and are described in detail in the TRACG Model Description Licensing Topical Report [4D-6].

TRACG has been extensively qualified against separate effects tests, component performance data, integral system effects tests and operating BWR plant data. The details are presented in the TRACG Qualification Licensing Topical Report [4D-7]. Specific qualification studies for tests simulating passive BWR design features are reported in References 4D-8 and 4D-9.

The stability analysis statistically accounts for the uncertainties and biases in the models and plant parameters using a Monte Carlo method for the Normal Distribution One-Sided Upper Tolerance Limit (ND-OSUTL) if the output distribution is normal, or the Order Statistics method if it is not. Conservative values are used in place of probability distributions for some plant parameters for convenience. The uncertainties and biases considered include the following:

- Model uncertainties
- Experimental uncertainties and any uncertainties related to test scale-up
- Plant uncertainties
- Process measurement errors
- Manufacturing tolerances

The overall analysis approach followed is consistent with the Code Scaling Applicability and Uncertainty (CSAU) analysis methodology [4D-10].

The application methodology is described in Reference 4D-11.

4D.1.3 Steady State Stability Performance

4D.1.3.1 Baseline Analysis

A baseline analysis was performed for the ESBWR at rated conditions, which are the most limiting from the perspective of stability due to the highest power/flow ratio [4D-11]. Analysis

was conducted for equilibrium GE14 core at various points in the cycle: Beginning of Cycle (BOC), Middle of Cycle (MOC) near the peak reactivity state, and End of Cycle (EOC). The initial conditions are tabulated in Table 4D-1. The core average axial power shapes for the three exposure points are shown in Figure 4D-2.

Channel Stability

Channel stability is evaluated for the highest power channels by perturbing the inlet flow velocity while maintaining constant channel power.

Super Bundle Stability

A super bundle is defined as a group of 16 bundles below a common chimney cell. The hydrodynamic stability of the highest power super bundle was analyzed by perturbing the inlet flow to the group of 16 bundles while maintaining constant power. The calculation was performed at BOC conditions because this is the most limiting for channel hydrodynamic stability.

Core wide Stability

Core stability was evaluated at BOC, MOC and EOC conditions. The calculations were made with the 3-D kinetics model interacting with the thermal hydraulics parameters. The response to a pressure perturbation in the steam line was analyzed to obtain the decay ratio.

Regional Stability

The 'nominal' decay ratio for out-of-phase regional oscillations was calculated by perturbing the core in the out-of-phase mode about the line of symmetry for the azimuthal harmonic mode.

The initial conditions were the same as for the channel and core stability cases. The decay ratio calculations were made at BOC conditions because of the lowest value of the sub-criticality and highest bottom peaking at these conditions. The channel decay ratio is also the highest at BOC because of the bottom peaked axial flux shape. The decay ratio and oscillation frequency were extracted from the responses for the individual channel groups.

Results

The results for channel, super bundle, core and regional stability are tabulated in Table 4D-2. The channel decay ratio was the highest at BOC because of the bottom peaked axial power shape. The channel decay ratios meet the design goal of 0.4. The oscillation time period is approximately twice the transit time for the void propagation through the channel. The transit time through the chimney does not contribute to the oscillation time period. There is pressure equalization at the top of the bypass region, which reduces the importance of the chimney. Moreover, there are insignificant frictional losses in the chimney and the static head does not affect the stability performance.

The super bundle decay ratio was lower than that for the single high power bundle, because of the lower average power for the group of 16 bundles. Again, the transit time through the chimney does not contribute to the oscillation time period. The slightly larger time period relative to the hot bundle is also due to the lower average power level.

The core decay ratio was the highest at MOC conditions due to the combination of axial power shape and void coefficient. The oscillation time period corresponds to twice the vapor transit time through the core region. The core decay ratios meet the design goal of 0.4.

The decay ratio and oscillation frequency for regional stability were extracted from the responses for the individual channel groups. The results for the limiting channel group are tabulated in Table 4.D-2. Several other channel groups were within 0.01 of the highest group. The regional decay ratio meets the design goal of 0.4.

4D.1.4 Statistical Analysis of ESBWR Stability

4D.1.4.1 Channel Decay Ratio Statistical Analysis

A Monte Carlo analysis of channel stability was performed at rated power and flow and BOC conditions that were determined to be limiting. A total of 59 trials were made. In each trial, random draws are made for each of the parameters determined to be important for stability. Some of these parameters are not important for channel stability per se, but the same set of parameters was perturbed for both channel and core stability. These parameters and their individual probability distributions are listed in Reference 4D-11. The value for each of these parameters is drawn from the individual probability distribution for that parameter. A TRACG calculation is made with this perturbed set of parameters to obtain a new steady state. The channel decay ratio for the highest power channel is then calculated by applying a perturbation in inlet velocity. This constitutes one trial in the Monte Carlo process. A One-Sided Upper Tolerance Limit with 95% content and 95% confidence level (OSUTL95/95) is calculated from the Monte Carlo distribution. Table 4D-3 shows the value of the OSUTL95/95 for the channel decay ratio.

4D.1.4.2 Core Wide Decay Ratio Statistical Analysis

The Monte Carlo analysis of core stability was performed at rated power and flow and MOC conditions that were determined to be limiting. As for channel stability, a total of 59 trials were made. In each trial, random draws are made for each of the parameters determined to be important for stability. A TRACG calculation is made with this perturbed set of parameters to obtain a new steady state. The core decay ratio is then calculated by applying a pressure perturbation in turbine inlet pressure. This constitutes one trial in the Monte Carlo process. An OSUTL95/95 is calculated from the Monte Carlo distribution. Table 4D-3 shows the value of the OSUTL95/95 for the core decay ratio.

4D.1.4.3 Regional Decay Ratio Statistical Analysis

The Monte Carlo analysis of regional stability was performed at rated power and flow and BOC conditions that were determined to be limiting. As for core-wide stability, a total of 59 trials were made. In each trial, random draws are made for each of the parameters determined to be important for regional stability. A TRACG calculation is made with this perturbed set of parameters to obtain a new steady state. The regional decay ratio is then calculated by applying an instantaneous inlet velocity perturbation. A positive perturbation is applied to all channel groups on one side of the line of symmetry of the harmonic mode; a negative perturbation is applied to the channel groups on the other side. The decay ratio was extracted for the high power channel group from the transient response. This constitutes one trial in the Monte Carlo

process. An OSUTL95/95 is calculated from the Monte Carlo distribution. Table 4D-3 shows the value of the OSUTL95/95 for the regional decay ratio.

4D.1.4.4 Comparison with Design Limits

Figure 4D-3 shows the stability map with the design criteria. The baseline results for core, channel and regional decay ratios are compared against the design goal. The OSUTL95/95 values for core, channel and regional decay ratios are compared against the design criteria. Note that these values are calculated at different times in the cycle and represent the highest individual values. The combination of these decay ratios at the same time is not possible. Nevertheless, the limiting core, channel and regional decay ratios (OSUTL95/95) are simultaneously compared against the design limits. Figure 4D-3 shows that both the design goals and design limits are satisfied for the ESBWR core.

The demonstration of stability margins has been performed for an equilibrium GE14 core design. The COL applicant will need to verify that the final core design is at least as stable as the GE14 core design used in the analysis in this section. If the nominal decay ratios are higher than the calculated values, the statistical analysis of decay ratios will need to be performed and the results checked versus the design criteria.

4D.1.5 Stability Performance During AOOs

In general, the stability margin reduces when the reactor power increases and/or core flow reduces. Because the ESBWR design relies on natural circulation for core flow circulation, the core flow during full power operation is only dependent upon the vessel water level. Higher water level means higher core flow, and vice versa. During normal operation, the water level is tightly controlled within a pre-set range (between Level 4 and Level 7 setpoints) through the feedwater and level control system. During AOOs, a reactor scram is initiated when the water level is too high (higher than Level 8 setpoint) or too low (below Level 3 setpoint). In addition, high neutron flux scram and high-simulated thermal power scram are initiated to prevent the reactor from operating at high power. Therefore, the stability during AOOs is assured by the scram protection.

Two limiting AOOs were identified based on the above discussion: Loss-of Feedwater Heater (LOFWH), which results in increased power; and Loss of Feedwater Flow (LOFW), which results in a lower flow. The trajectories of the transients in the power – flow map are shown in Figure 4D-4. The curve A-A corresponds to operation with a reduced level in the downcomer. The lower level leads to a reduction in flow. Different points on A – A correspond to changes in control reactivity or changes in core inlet subcooling.

LOFWH is a slow transient, in which the power increases slowly as the feedwater temperature drops. If the operator takes no action, the power would increase until a high thermal power scram occurs at 115% of rated power. The worst operating point would be one where the drop in feedwater temperature is such that the power increases to just below the setpoint (115%) and levels off at that value.

Stability analysis was performed at the pre-scram conditions due to the loss of the feedwater heating at MOC conditions. Decreasing the feedwater temperature simulated the transient. The power increased to approximately 116% (slightly above the scram conditions of 115%) due to

initial flow noise has subsided. At this time the pressure is about 8 bar. Voids propagate to cell 30 at about 8000 s, by which time the system pressure is above 25 bar. The high power level (125 MW) leads to extreme conditions during the heatup. Vapor generation in the core begins early. Figure 4D-19 shows that the high power bundle has an exit void fraction of 15% at 4000 s. Rapid heating of the core leads to conditions that favor condensation-induced oscillations because vapor is generated in the core while the chimney is not yet at saturated conditions. These are the extreme conditions examined in the tests by Aritomi [4D-12] and Kuran, et al [4D-14]. The situation is further illustrated by looking at the flows in individual bundles. The exit flows in the high power and the low power peripheral bundles were examined. Figure 4D-20 depicts the exit flows in the high power bundle for the three cases. These traces follow the core average flow response shown in Figure 4D-13. The exit flows in the peripheral bundles (Figure 4D-21) show a more dramatic distribution. In the two lower power cases, the peripheral bundles are in upflow throughout the transient, despite the noise imposed on the average flow rate. However, at 125 MW, large condensation induced oscillations lead to flow reversals between 3500 to 4000 s.

Margins to thermal limits (CPR) were calculated for the three startup scenarios. The thermal margin for the high power bundles is shown in Figure 4D-22. Large margins are maintained throughout. Figure 4D-23 is the corresponding plot for the peripheral bundles. Again, large margins are maintained throughout the transient. This is true even for the extreme case with 125 MW. Despite the flow reversals, the heat fluxes are low enough that critical heat flux conditions are not approached.

Subsequent to this analysis, a coupled nuclear-thermal hydraulic analysis of the ESBWR startup has been performed [4D-18]. The results are shown in the next section.

4D.2.2.3 TRACG Calculation of ESBWR Startup with Neutronic Feedback

A TRACG simulation of ESBWR startup with the neutronic feedback was performed using the limiting heat up rate. This is an example of a startup transient. The actual startup procedure will be defined at a later stage. Results of this simulation have demonstrated that at the limiting heat up rate, no difficulties and no large power oscillations were encountered during the startup transient.

This TRACG calculation was performed activating the 3D kinetics model. The calculation was initiated at the end of the de-aeration period, similar to the calculations in the previous section. The water level was maintained near the top of the separators. The MSIVs were closed to isolate the RPV. Initially, all control rods are in fully inserted position.

The 269 control rods in ESBWR are divided into 10 groups and the rod group positions are shown in Figure 4D-24. Rod Group # 10 represents the control rods for the 25 control cells. The grouping of control rods and the withdrawal sequence during the startup are similar to those used for operating plants. The withdrawal speeds for each of these groups during the transient are specified as TRACG input to simulate the operator actions to maintain the reactor at power during the startup transient. These rod groups are slowly withdrawn to maintain the total reactivity close to 0.0 and the total power level is maintained at around 85 MW until the reactor is pressurized to the desired value. Subsequently, the MSIVs are opened and the power level is increased in steps (by means of additional rod withdrawals) to achieve rated pressure.

Figure 4D-25 shows the withdrawal fraction for all control rods. After Groups 1, 2 and 3 are fully withdrawn, the control rod withdrawal fraction is 0.37, i.e., 63% of all rods are in fully inserted position. At this time, the reactor is critical. Groups 4 and the next several groups are withdrawn with slower speed to avoid rapid change in total reactivity and reactor power.

Figure 4D-26 shows the total reactor power. For the first 1500 seconds, the total reactor power consists mainly of decay heat. After the core becomes critical, there is a step increase in total reactor power. From this time on, the rod groups are slowly withdrawn to maintain the total reactor power at around 85 MW. The total power is maintained around 85 MW by the continuous withdrawal of the control rods. No significant core void is calculated until the MSIVs are opened, when the temperature and pressure are near the operating conditions. The heatup rate for this case is slightly below the maximum allowed rate considering thermal stress of 55 C/hour.

Figure 4D-27 shows the steam dome pressure response for this case. The RPV pressurizes to 6.3 MPa in 3.6 hours and the MSIVs are opened. With the MSIV open the power is limited by BOP systems not by heatup rate. The control rods are withdrawn further to step up the power and to reach the rated pressure at 4.4 hours. At this time, Rod Groups 1 to 7 are fully withdrawn and Group 8 is 50% withdrawn. Groups 9 and 10 (25 control cell rods) are in fully inserted position.

Figure 4D-28 shows the core inlet subcooling as a function of time. The local inlet subcooling drops as the system pressurizes to 6.3 MPa. The core flow transient response is shown in Figure 4D-29. There are two periods with small flow noise: around 2000 seconds corresponding to the step increase in power (Figure 4D-26) and around 4500 seconds corresponding to some void initiation at the top of separators. Steady void fraction is established at the top of the separators after 9000 seconds. There are no fluctuations in the neutron flux during these periods. The flow result is similar to the case with no reactor kinetics modeled.

Figure 4D-30 shows core void in the highest power bundles. Vapor generation begins at the top of the high power bundles at pressure of about 5 bar. Voids propagate about a quarter of the height into the bundle at 11000 s, by which time the system pressure is above 30 bar. The high power bundle flow follows the core average flow response. The peripheral bundles are in upflow throughout the transient.

Margins to thermal limits (CPR) were calculated for this startup case. Large margins are maintained for all bundles throughout the transient.

Table 4D-2

Baseline Stability Analysis Results

Mode	BOC		MOC		EOC	
	Decay Ratio	Frequency (Hz)	Decay Ratio	Frequency (Hz)	Decay Ratio	Frequency (Hz)
Channel	0.23	0.80	0.09	~0.75	0.05	~0.7
Superbundle	0.14	0.74				
Core	0.26	0.74	0.33	0.74	0.29	0.66
Regional	0.40	0.82				

Table 4D-3

Statistical Stability Analysis Results

	Decay Ratio – One Sided Upper Tolerance Limit (95/95)	**Decay Ratio - Design Criteria**
Core	0.50	0.8
Channel	0.36	0.8
Regional	0.57	0.8

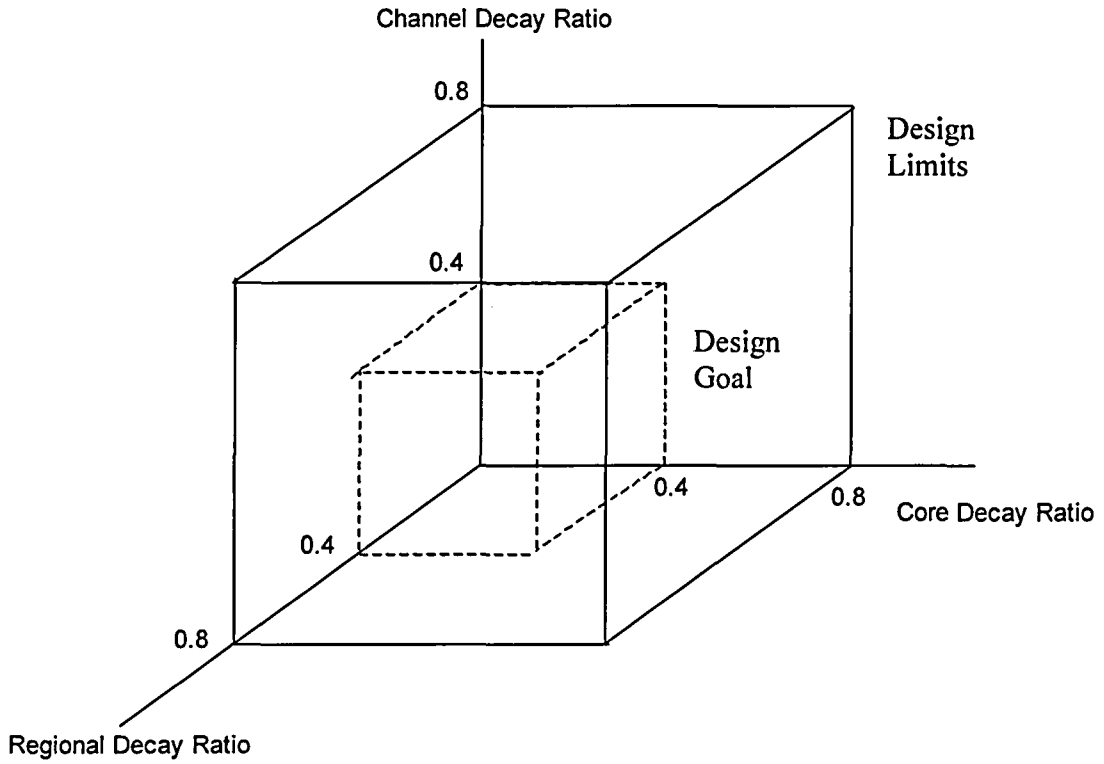

Figure 4D-1. Proposed Stability Map for ESBWR

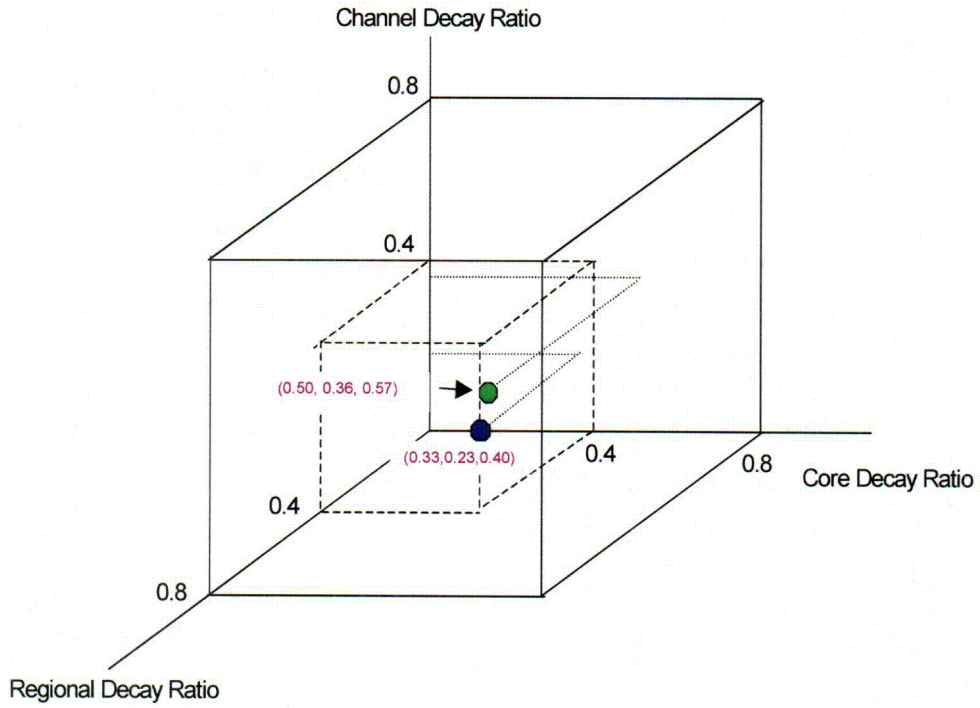

Figure 4D-3. Decay Ratio Results Compared to Design Criteria

Row & Column #	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
1								4	5	3	5	4							
3						5	2	9	1	10E	2	9	1	5					
5					6	4	8	3	8	4	8	3	8	4	6				
7				5	2	9	1	10E	2	9C	1	10E	2	9	1	5			
9			6	4	7	3	8	4	7	3	7	4	8	3	7	4	6		
11		5	2	9	1	10D	2	9B	1	10C	2	9B	1	10D	2	9	1	5	
13		4	8	3	8	4	7	3	8	4	8	3	7	4	8	3	8	4	
15	2	9	1	10E	2	9B	1	10B	2	9A	1	10B	2	9B	1	10E	2	9	1
17	5	3	8	4	7	3	8	4	7	3	7	4	8	3	7	4	8	3	5
19	1	10E	2	9C	1	10C	2	9A	1	10A	2	9A	1	10C	2	9C	1	10E	2
21	5	4	8	3	7	4	8	3	7	4	7	3	8	4	7	3	8	4	5
23	2	9	1	10E	2	9B	1	10B	2	9A	1	10B	2	9B	1	10E	2	9	1
25		3	8	4	8	3	7	4	8	3	8	4	7	3	8	4	8	3	
27		5	2	9	1	10D	2	9B	1	10C	2	9B	1	10D	2	9	1	5	
29			6	3	7	4	8	3	7	4	7	3	8	4	7	3	6		
31				5	2	9	1	10E	2	9C	1	10E	2	9	1	5			
33					6	3	8	4	8	3	8	4	8	3	6				
35						5	2	9	1	10E	2	9	1	5					
37								3	5	4	5	3							

Figure 4D-24. ESBWR Control Rod Groups for Startup Simulation

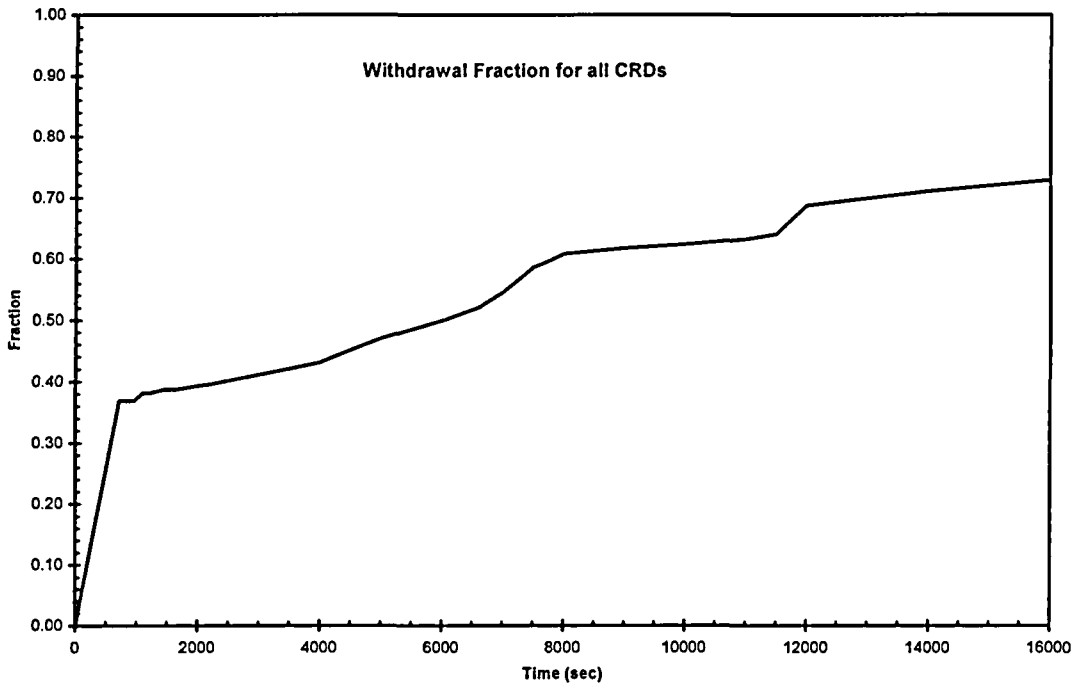

Figure 4D-25. Withdrawal Fraction for all Control Rods

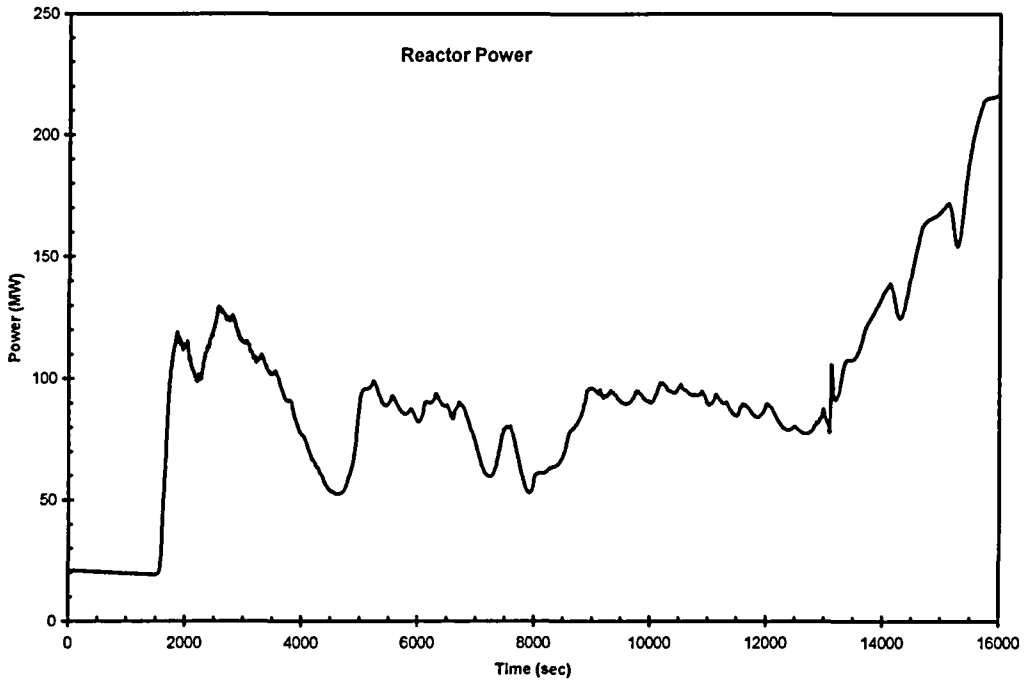

Figure 4D-26. Reactor Power

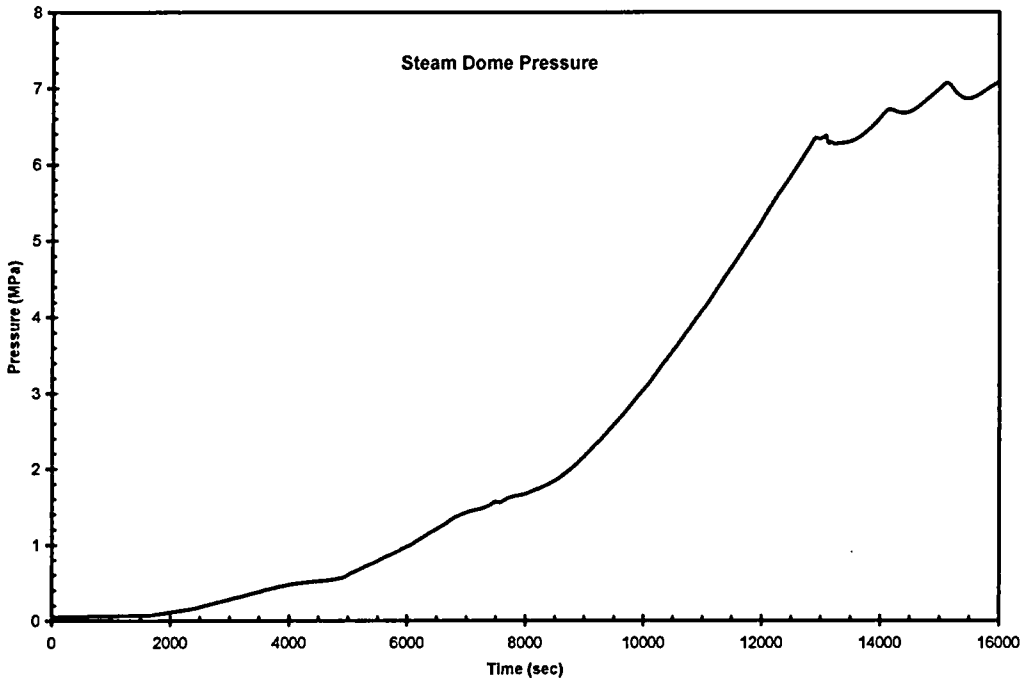

Figure 4D-27. Steam Dome Pressure

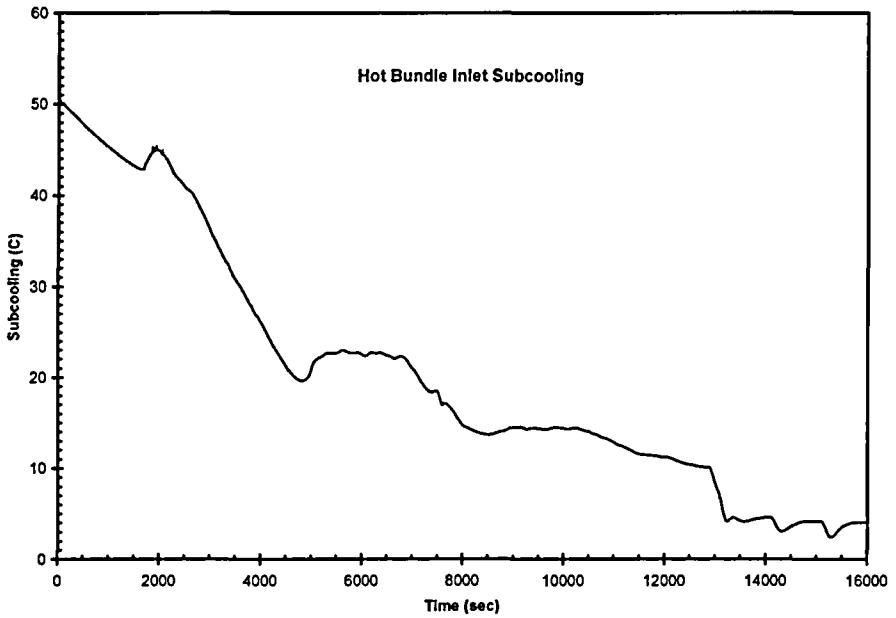

Figure 4D-28. Core Inlet Subcooling

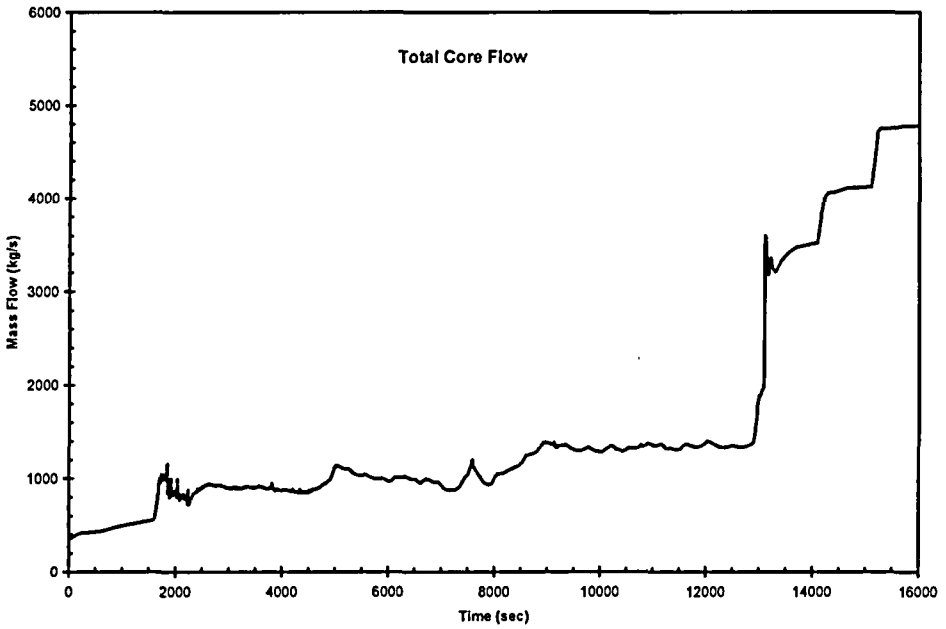

Figure 4D-29. Core Inlet flow

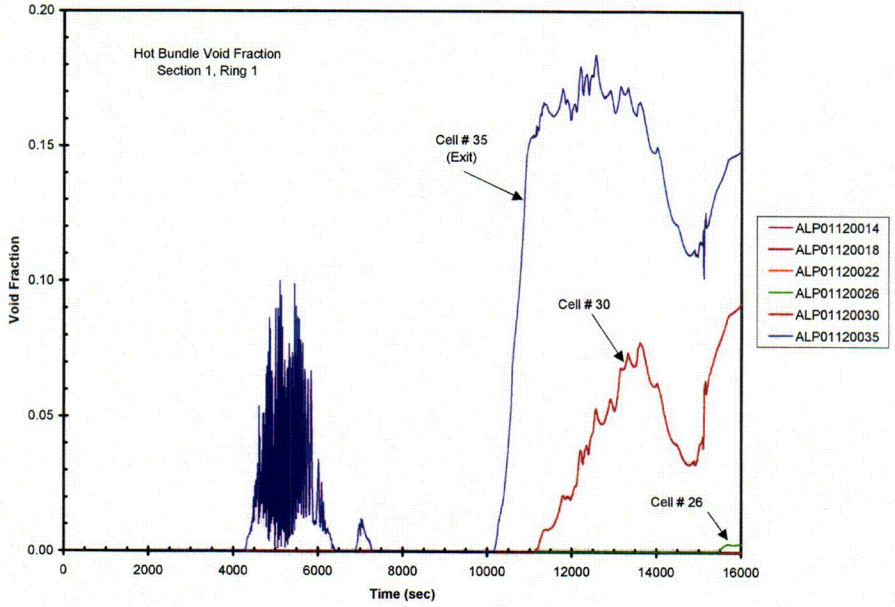

Figure 4D-30. Hot Bundle void Fraction

ENCLOSURE 3

MFN 06-339

Affidavit

General Electric Company

AFFIDAVIT

I, George B. Stramback, state as follows:

(1) I am Manager, Regulatory Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of GE letter MFN 06-339, David H. Hinds to NRC, *Response to Portion of NRC Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application – TRACG Application for ESBWR Stability – RAI Numbers 4.4-10 through 4.4-13 & Letter No. 56 - TRACG Application for ESBWR ATWS – RAI Number 21.6-77 B* dated September 21, 2006. The proprietary information in Enclosure 1, *Response to Portion of NRC Request for Additional Information Letter No. 49 Related to ESBWR Design Certification Application – TRACG Application for ESBWR Stability – RAI Numbers 4.4-10 through 4.4-13 & Letter No. 56 - TRACG Application for ESBWR ATWS – RAI Number 21.6-77 B,* is delineated by a double underline inside double square brackets. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation[{3}] refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.790(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains the results of TRACG analytical models, methods and processes, including computer codes, which GE has developed, and applied to perform Stability and ATWS evaluations for the ESBWR. GE has developed this TRACG code for over fifteen years, at a total cost in excess of three million dollars. The reporting, evaluation and interpretations of the results, as they relate to Stability and

ATWS evaluations for the BWR was achieved at a significant cost, in excess of one quarter million dollars, to GE.

The development of the testing and evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 22nd day of September 2006.

George B. Stramback
General Electric Company