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MFN 08-224

Docket No. 52-010

March 10, 2008

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 98 - Related to ESBWR Design Certification Application – RAI Number 4.4-57**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by the Reference 1 NRC letter. GEH response to RAI Number 4.4-57 is addressed in Enclosures 1 and 2.

If you have any questions or require additional information, please contact me.

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

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NRO

Reference:

1. MFN 07-317, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 98 Related to the ESBWR Design Certification Application*, dated May 29, 2007

Enclosures:

1. MFN 08-224 – Response to Portion of NRC Request for Additional Information Letter No. 98 - Related to ESBWR Design Certification Application – RAI Number 4.4-57
2. MFN 08-224 – Response to Portion of NRC Request for Additional Information Letter No. 98 - Related to ESBWR Design Certification Application – DCD Markups from the Response to RAI Number 4.4-57

cc:	AE Cubbage	USNRC (with enclosure)
	GB Stramback	GEH/San Jose (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRF	0000-0070-3482

Enclosure 1

MFN 08-224

Response to Portion of NRC Request for

Additional Information Letter No. 98

Related to ESBWR Design Certification Application

RAI Number 4.4-57

NRC RAI 4.4-57

Regional mode decay ratio for AOOs

DCD Tier 2, Rev. 3, Table 4D-4 shows that only core and channel decay ratios were calculated for the two limiting AOO's. Provide regional mode decay ratios for these two cases.

GEH Response

To address the question and related questions from a GEH-NRC meeting on November 8, 2007, additional stability analyses have been performed at small exposure increments (i.e., 1,000 MWd/St) in order to determine that the worst exposure level in terms of regional mode instability is captured. Based on the analysis results, it is determined that the limiting exposure is at the Peak Hot Excess (PHE) cycle point for the equilibrium core. Furthermore, in addition to the scram protection for the stability performance during AOOs as discussed in DCD Subsection 4D.1.5, SCRRI/SRI (Selected Control Rod Run-In/Select Rod Insert) is credited upon the detection of feedwater temperature reduction of 30°F or higher during a Loss-of Feedwater Heater (LOFWH) event. The LOFWH event will lead to an increase in power as the feedwater temperature drops. Therefore, the regional mode decay ratio for LOFWH event is evaluated at the limiting PHE exposure condition and at steady state condition, where the drop in feedwater temperature is set to be ~30°F and the power increases to approximately 106%. Following the established methodology as described in DCD Subsection 4D.1.5, the regional mode decay ratio for Loss-of Feedwater Flow (LOFW) event is also evaluated at the determined limiting PHE exposure and at new steady state conditions, where the downcomer collapsed water level is below Level 3 (L3). Table 4.4-57-1 summarizes the results from these studies and shows that adequate margin is maintained to the stability design criteria.

Table 4.4-57-1

AOO	Power (% of Rated)	Regional Decay Ratio
LOFWH with SCRRI/SRI	~106	0.66
LOFW	~100	0.58

DCD Impact

DCD Tier 2, Chapter 4, Subsections 4D.1.3 and 4D.1.5; Tables 4D-1, 4D-2 and 4D-4; and Figures 4D-3 and 4D-5 will be revised in Revision 5 as noted in the enclosure 2 DCD markup.

Enclosure 2

MFN 08-224

Response to Portion of NRC Request for

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Related to ESBWR Design Certification Application

DCD Markups from the Response to RAI Number 4.4-57

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 Reference 4D-11. Analysis was conducted for equilibrium GE14 core at various points in the cycle: BOC, Middle of Cycle (MOC) at ~~near~~ the Peak Hot Excess (PHE) reactivity cycle point~~peak reactivity~~ 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-3. Additional analysis was conducted at points with small exposure increment through the cycle in order to make sure that the limiting exposure level in terms of Regional Stability is identified. Based on the analysis results, it is determined that the limiting exposure is at the Peak Hot Excess (PHE) cycle point for the equilibrium core.

Channel Stability

Channel stability is evaluated for the highest power channels by perturbing the inlet flow velocity while maintaining constant channel power. The calculation was performed at MOC conditions because this is the most limiting exposure.

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 M~~B~~OC 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 at nominal conditions. The decay ratio calculations were made at M~~B~~OC -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 M~~B~~OC 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 MBOC 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 criteria.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 criteria.goal of 0.4.

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. The SCRRI/SRI (Selected Control Rod Run-In/Select Rod Insert) is initiated automatically upon the detection of feedwater temperature reduction of 30°F or higher during AOOs, which may lead to an increase in power as the feedwater temperature drops. Therefore, the stability during AOOs is assured by SCRRI/SRI and 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-5. 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~~ SCRRI/SRI is initiated at 30°F reduction in feedwater temperature. The worst operating point would be one where the drop in feedwater temperature is about 30°F such that the power increases to ~~just below the setpoint~~ a higher value (~106~~15~~%) than rated and levels off at that value.

Stability analysis was performed at new steady state~~the pre-scram~~ conditions due to the loss of the feedwater heating at_ MOC condition~~s~~ that was determined to be the limiting exposure. Decreasing the feedwater temperature simulated the transient. The power increased to approximately 106~~16~~%~~ (slightly above the scram conditions of 115%)~~ due to the feedwater temperature reduction of ~30°F. The circulation flow increased slightly and the average core void fraction stayed almost constant.

Stability analysis was performed for LOFWH AOO at new power/flow/feedwater conditions after a steady state was achieved (Table 4D-4). Under these conditions the feedwater temperature had dropped from ~ 215°C (~420~~19~~°F) to ~200~~174~~°C (~392~~45~~°F) and reactor power had increased from 4500 to ~4780~~5221~~ MWt. ~~The transient response to a pressure perturbation was analyzed to determine the decay ratio. The core decay ratio and channel decay ratio at the pre-scram conditions are shown in Table 4D-4,~~ The decay ratio for the most limiting oscillation mode, which is determined to be regional mode based on the results in Table 4D-2, is shown in Table 4D-4 and are well below the stability design criteria.

Analysis of the LOFW transient turned out to be more complex. The transient is rapid and unless feedwater flow is restored, the reactor scrams in a few seconds on a trip at Level 3 (L3). In this period, the flow, power and subcooling are dropping and pressure is responding to the pressure controller. Rather than imposing a pressure perturbation on top of the transient response to evaluate the decay ratio, the following approach was adopted. When the level had fallen below L3, the feedwater flow was restored to maintain a reduced level. This eventually led to a new steady state where the circulation flow was reduced slightly and the power stabilized close to the initial value with a reduced core inlet temperature. This operating point is more severe than the rated condition as the flow is reduced at the same power level. It provides a conservative evaluation of the LOFW transient, as the power is higher than would occur during a LOFW. Regional stability analysis was performed at the new steady state conditions where level is below L3 at PHE conditions that were determined to be limiting for stability.

Results of stability analysis for the reduced level case are shown in Table 4D-4. The results from these studies show that adequate margin is maintained to the stability design criteria even for these more severe operating states.

Table 4D-1

Initial Conditions for Channel and Core Stability Analysis

Parameter	Value		
	BOC	**MOC**	**EOC**
Core Thermal Power (MWt)	4500	4500	4500
Core Flow (kg/s)*	9,925 (78.77 Mlbm/hr)	9,982~~10,003~~ (79.22~~39~~ Mlbm/hr)	10,153 (80.58 Mlbm/hr)
Feedwater temperature (°C)	215 (~419°F)	215 (419°F)	215 (419°F)
Narrow range water level (m)	21.0 (68.9 ft)	21~~.0~~ (68.9 ft)	21.0 (68.9 ft)
Feedwater flow (kg/s)*	2421 (19.21 Mlbm/hr)	2428~~1~~ (19.27~~1~~ Mlbm/hr)	2421 (19.21 Mlbm/hr)
Core inlet subcooling* (°C)	16.6 (29.9°F)	16.5~~3~~ (29.7~~3~~°F)	16.2 (29.2°F)
Steam dome pressure (MPa)	7.05 (~1022 psia)	7.18~~05~~ (1041~~22~~ psia)	7.05 (1022 psia)
ICPR*	1.40	1.53~~46~~	1.38
Hot Bundle Power (MWt)*	5.10	5.31~~4.94~~	5.09
Hot Bundle flow (kg/s)*	8.6 (68.25 klbm/hr)	8.4~~7~~ (66.67~~9.05~~ klbm/hr)	8.8 (69.84 klbm/hr)

* Calculated parameter

Table 4D-2

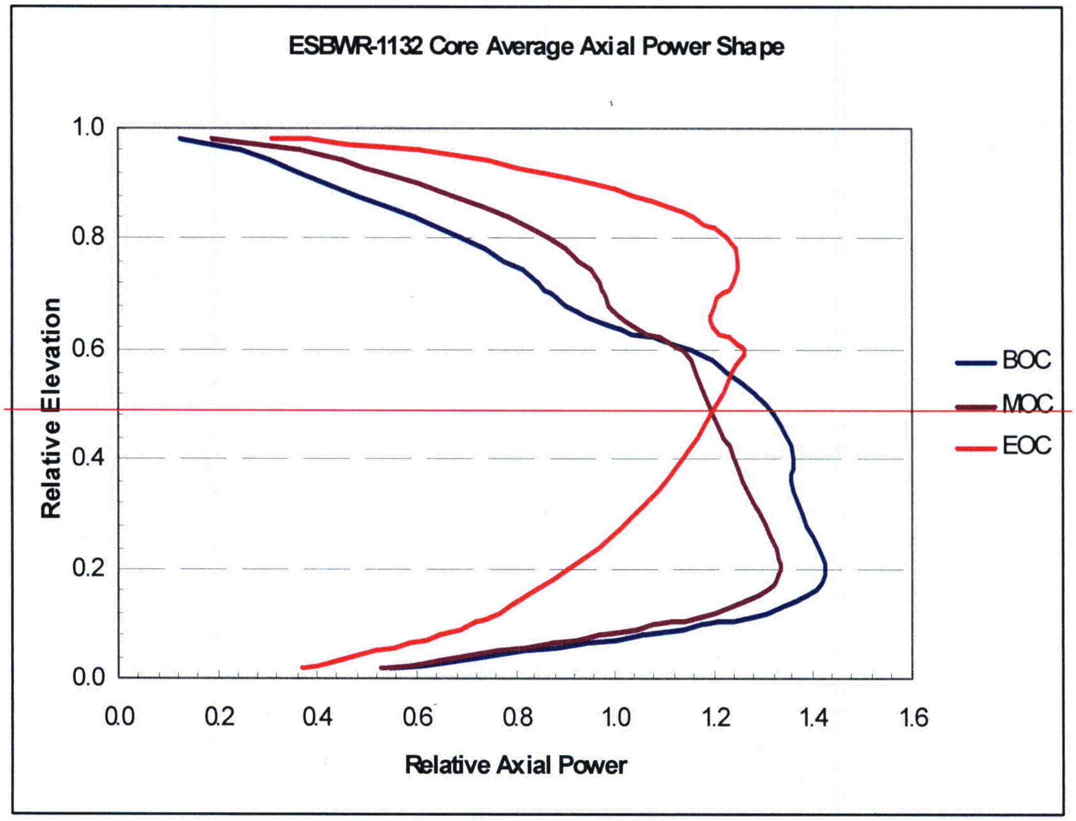
Baseline Stability Analysis Results

Mode	BOC		MOC		EOC	
	Decay Ratio	Frequency (Hz)	Decay Ratio	Frequency (Hz)	Decay Ratio	Frequency (Hz)
Channel	0.23	0.80	0.25~~09~~	0.84~~75~~	0.05	~0.7
Superbundle	0.14	0.74	0.15	0.70		
Core	0.26	0.74	0.44~~33~~	0.80~~74~~	0.29	0.66
Regional	0.40	0.82	0.53	0.87		

Table 4D-4

Limiting AOO Event Results

AOO	Power (% of Rated)	Regional Decay Ratio
LOFWH	106	0.66
LOFW	100	0.58


ESBWR-1132 Core Average Axial Power Shape
1.0
0.8
0.6
0.4
0.2
0.0
Relative Elevation
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Relative Axial Power
BOC
MOC
EOC

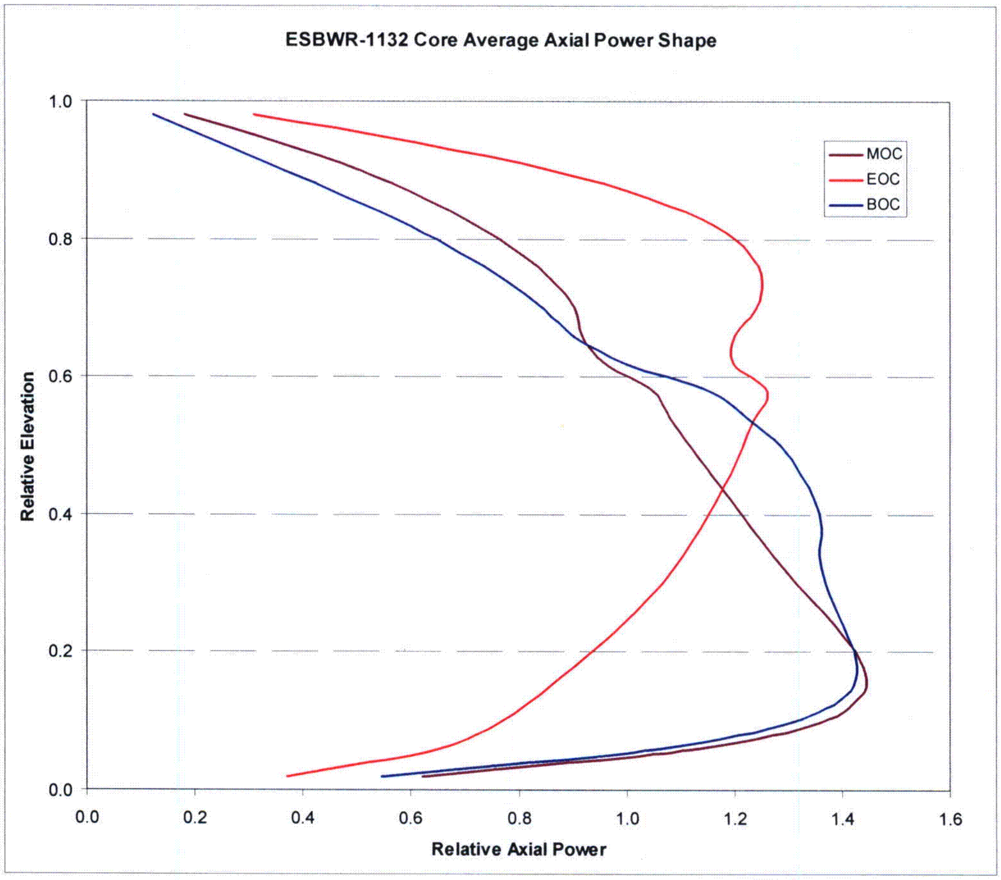


Figure 4D-3. Core Average Axial Power Shape at Different Exposures

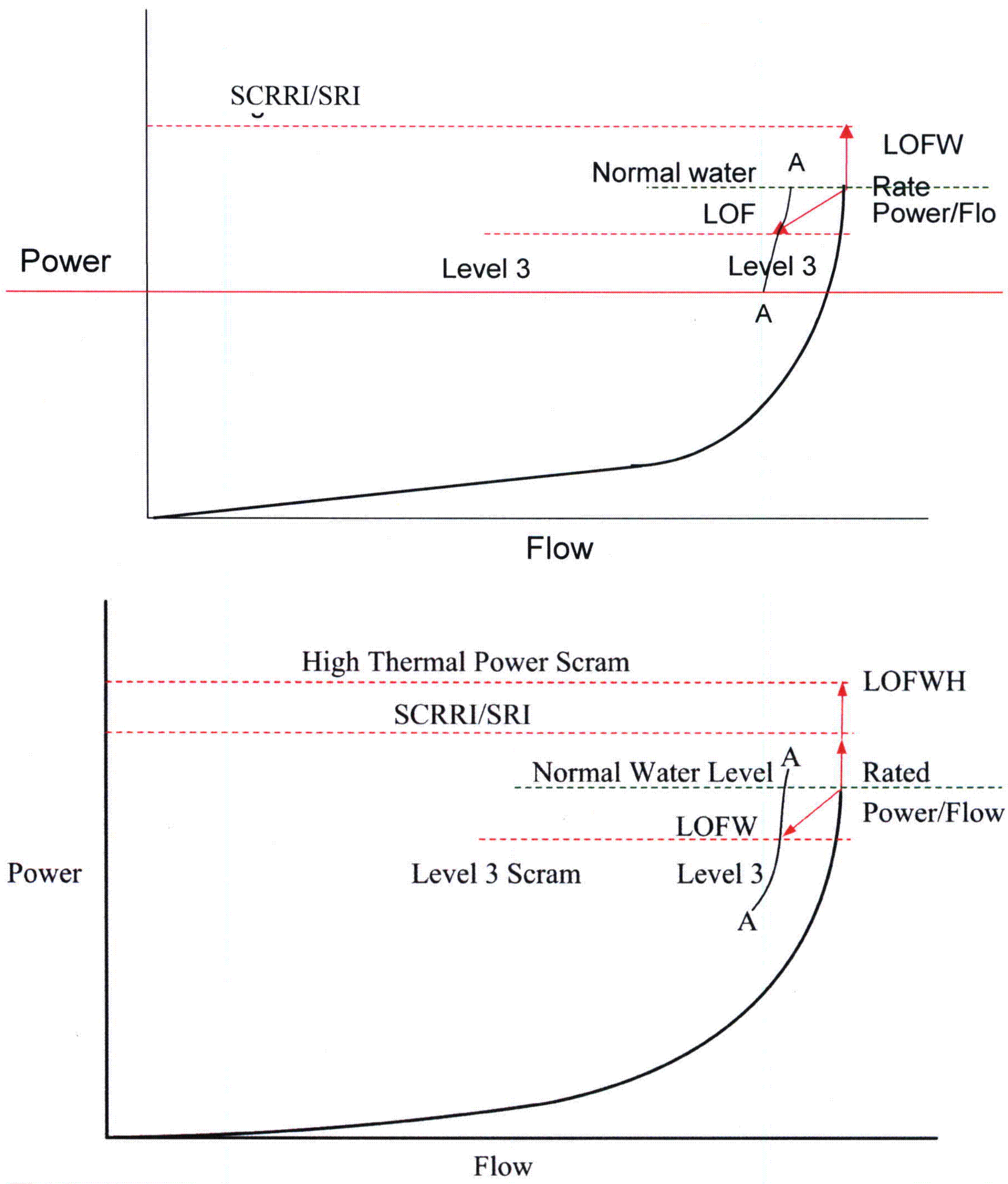


Figure 4D-5. Stability in Expanded Operating Map