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Supplement 2

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Subject: **Response to RAIs 3.9-47 S01, 3.9-48 S01, 3.9-52 S01 and 3.9-75 S01, Related to ESBWR Design Certification Application – DCD Section 3.9**

Enclosure 1 contains GE-Hitachi Nuclear Energy Americas LLC (GEH)'s response to the subject NRC RAIs 3.9-47 S01, 3.9-48 S01, 3.9-52 S01, and 3.9-75 S01, which were transmitted via Reference 1.

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

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

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NRO

Reference:

1. EMail to GEH from Chandu Patel (NRC) 05/15/07
2. MFN 06-464, *Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application – DCD Section 3.9 – RAI Numbers 3.9-4 through 3.9-11, 3.9-17, 3.9-18, 3.9-23, 3.9-26, 3.9-27, 3.9-29, 3.9-32, 3.9-34 through 3.9-36, 3.9-38 through 3.9-40, 3.9-44, 3.9-46 through 3.9-55, 3.9-57, 3.9-59, 3.9-60, 3.9-67, 3.9-72 through 3.9-76, 3.9-79, 3.9-80, 3.9-91 through 3.9-94, 3.9-96 through 3.9-99, 3.9-101, 3.9-102, 3.9-104, 3.9-105, 3.9-108, 3.9- 110, 3.9-132, 3.9-140, 3.9-142, 3.9-147, 3.9-150, 3.9-151, and 3.9-153,* dated November 22, 2006

Enclosure:

1. MFN 06-464, Supplement 2, RAI Response to RAIs 3.9-47 S01, 3.9-48 S01, 3.9-52 S01, and 3.9-75 S01

cc:	AE Cubbage	USNRC (with enclosures)
	RE Brown	GEH/Wilmington (with enclosures)
	GB Stramback	GEH/San Jose (with enclosures)
	eDRF 0000-0070-0632, Revision 1	

MFN 06-464, Supplement 2

Enclosure 1

RAI Response to RAI Numbers 3.9-47 S01, 3.9-48 S01, 3.9-52 S01, and 3.9-75 S01

For historical purposes, the original text of RAIs 3.9-47 S01, 3.9-48 S01, 3.9-52 S01, and 3.9-75 S01 and the GE responses are included. The attachments are not included from the original response to avoid confusion.

NRC RAI 3.9-47

It is stated in DCD Tier 2, Section 3.9.2.3 that in general, the vibration forcing functions for operational flow transients and steady-state conditions are not predetermined by detailed analysis. Discuss GE's detailed analytical methodology to determine vibration forcing functions for obtaining operational flow transients and steady state conditions.

GE Response

The vibration forcing functions for operational flow transients and steady state conditions are determined by first postulating the source of the forcing function, such as forces due to flow turbulence, symmetric and asymmetric vortex shedding, pressure waves from steady state and transient operations. Based on these postulates, prior startup and other test data from similar or identical components are examined for the evidence of the existence of such forcing functions. Based on these examinations, the magnitudes of the forcing functions and/or response amplitudes are derived. These magnitudes are then used to calculate the expected ESBWR responses for each component of interest during steady state and transient conditions.

DCD Impact

No DCD changes will be made in response to this RAI.

NRC RAI 3.9-48

It is stated in DCD Tier 2, Section 3.9.2.3 that special analysis of the response signals measured from reactor internals of many similar designs is performed to obtain the parameters, which determine the amplitude and modal contributions in the vibration responses. Identify the specific parameters which are used to determine amplitude and modal contributions and explain with typical diagrams how these parameters are used in the special analysis.

GE Response

The test data from sensors (accelerometers, strain gages, and pressure sensors) installed on reactor internal components are first analyzed through signal processing equipment to determine the spectral characteristics of these signals. The spectral peak magnitudes and the frequencies at the spectral peaks are then determined. These spectral peak frequencies are then classified as natural frequencies or forced frequencies. If a spectral peak is classified as being from a

natural frequency, its amplitude is then determined using a band-pass filter if deemed necessary. The resultant amplitude is then identified as the modal response at that frequency. This process is used for all frequencies of interest. Thus the modal amplitudes at all frequencies of interest are determined. If a spectral peak is identified are being from a forced frequency, the source (such as a vane passing frequency of a pump) is identified. Again, its magnitude is determined using a band-pass filter if deemed necessary.

The modal amplitudes and the forced response amplitudes are then used to calculate the expected ESBWR amplitudes for the same component. These ESBWR expected amplitudes are determined by calculating the expected changes in the forcing function magnitudes from the test component to the ESBWR component. For example, for flow turbulence excited components, the magnitudes are determined by rationing with the flow velocity squared.

A flow chart of the above process is shown below.

(e.d.: Note: Flow chart not included to avoid confusion.)

<u>DCD Impact</u>
No DCD changes will be made in response to this RAI.

NRC RAI 3.9-47 S01

RAI 3.9-47 S01 Comment on response to RAI 3.9-47:
The staff finds that the applicant has provided the relevant information regarding the forcing functions, as requested. However, the applicant should include this information in the ESBWR DCD.

GEH Response

DCD Section 3.9.2.3 is to be modified with the addition of the sentences as shown below.

NRC RAI 3.9-48 S01

RAI 3.9-48 S01 Comment on response to RAI 3.9-48:
The staff finds that the applicant has provided an explanation of how the various parameters are used in the special analysis, as requested. However, the applicant should include this information in the ESBWR DCD.

GEH Response

DCD Section 3.9.2.3 is to be modified with the addition of the sentences as shown below.

DCD Impact for NRC RAI 3.9-47 S01 and NRC RAI 3.9-48 S01

3.9.2.3 Dynamic Response of Reactor Internals Under Operational Flow Transients and Steady-State Conditions

The major reactor internal components within the vessel are subjected to extensive testing, coupled with dynamic system analyses, to properly evaluate the resulting flow-induced vibration phenomena during normal reactor operation and from anticipated operational transients.

In general, the vibration forcing functions for operational flow transients and steady-state conditions are not predetermined by detailed analysis. The vibration forcing functions for operational flow transients and steady state conditions are determined by first postulating the source of the forcing function, such as forces due to flow turbulence, symmetric and asymmetric vortex shedding, pressure waves from steady state and transient operations. Based on these postulates, prior startup and other test data from similar or identical components are examined for the evidence of the existence of such forcing functions. Special analysis of the response signals measured for reactor internals of many similar

RAI 3.9-47

designs is performed to obtain the parameters which determine the amplitude and modal contributions in the vibration responses. Based on these examinations, the magnitudes of the forcing functions and/or response amplitudes are derived. These magnitudes are then used to calculate the expected ESBWR responses for each component of interest during steady state and transient conditions. This study provides useful predictive information for extrapolating the results from tests of components with similar designs to components of different designs. This vibration prediction method is appropriate where standard hydrodynamic theory cannot be applied due to complexity of the structure and flow conditions. Elements of the vibration prediction method are outlined as follows: RAI 3.9-47

- Dynamic modal analysis of major components and subassemblies is performed to identify vibration modes and frequencies. The analysis models used for Seismic Category I structures are similar to those outlined in Subsection 3.7.2.
- Data from previous plant vibration measurements are assembled and examined to identify predominant vibration response modes of major components. In general, response modes are similar but response amplitudes vary among BWRs of differing size and design.
- Parameters are identified which are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions.
- Correlation functions of the variable parameters are developed which, multiplied by response amplitudes, tend to minimize the statistical variability between plants. A correlation function is obtained for each major component and response mode.
- Predicted vibration amplitudes for components of the prototype plant are obtained from these correlation functions based on applicable values of the parameters for the prototype plant. The predicted amplitude for each dominant response mode is stated in terms of a range, taking into account the degree of statistical variability in each of the correlations. The predicted mode and frequency are obtained from the dynamic modal analyses.

The dynamic modal analysis forms the basis for interpretation of the initial startup test results (Subsection 3.9.2.4). Modal stresses are calculated and relationships are obtained between sensor response amplitudes and peak component stresses for each of the lower normal modes.
Details of the special signal analyses of the vibration sensors are given below: The test data from sensors (accelerometers, strain gages, and pressure sensors) installed on reactor internal components are first analyzed through signal processing equipment to determine the spectral characteristics of these signals. RAI 3.9-48

The spectral peak magnitudes and the frequencies at the spectral peaks are then determined. These spectral peak frequencies are then classified as natural frequencies or forced frequencies. If a spectral peak is classified as being from a natural frequency, its amplitude is then determined using a band-pass filter if deemed necessary. The resultant amplitude is then identified as the modal response at that frequency. This process is used for all frequencies of interest. Thus the modal amplitudes at all frequencies of interest are determined. If a spectral peak is identified as being from a forced frequency, the source (such as a vane passing frequency of a pump) is identified. Again, its magnitude is determined using a band-pass filter if deemed necessary. RAI 3.9-48

The modal amplitudes and the forced response amplitudes are then used to calculate the expected ESBWR amplitudes for the same component. These ESBWR expected amplitudes are determined by calculating the expected changes in the forcing function magnitudes from the test component to the ESBWR component. For example, for flow turbulence excited components, the magnitudes are determined by ratioing with the flow velocity squared.

A flow chart of the above process is shown below.

NRC RAI 3.9-52
It is stated in DCD Tier 2, Section 3.9.2.3 that parameters are identified which are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions. Identify all the parameters which are expected to influence vibration response amplitudes among the reference plants. Also discuss the relative significance of each parameter.

GE Response
The following process parameters have the potential to impact component vibration amplitudes: power, re-circulation flow rates and velocities, feedwater flow rates and velocities, and steam mass flow rates and velocities.

Plant transients are affected by MSIV and turbine stop valve (TSV) closure rates. The following structural parameters have the potential to impact component vibration amplitudes: Structural and fluid damping, structural natural frequencies, and mode shapes. Other parameters that may impact vibration amplitudes are: Frequency of the forcing function, amplitudes and spatial distribution of forcing functions.

In general, the vibration amplitudes are linearly related to the fluid mass and proportional to the square of fluid flow velocities. Transient response amplitudes are generally inversely proportional to the closure rates of MSIV's and TSV's. In general, the vibration amplitudes are inversely proportional to the frequency squared. Also, the lower natural modes generally have higher responses because the generalized forces are normally higher for the lower mode shapes. This is because generalized force is a measure of the energy input into the vibrating system by the applied force. The frequency of the forcing function becomes critical if it is near a natural frequency. This is because resonance or near resonance could occur. At or near resonance, the vibration amplitudes increase exponentially.

DCD Impact
No DCD changes will be made in response to this RAI.

NRC RAI 3.9-52 Supplement 1

RAI 3.9-52 S01 Comment on response to RAI 3.9-52:
The staff finds that the applicant's response to RAI 3.9-52 has provided parameters that are expected to influence vibration response amplitudes among the reference plants with one exception: the relative phases of the forcing functions. The applicant should discuss the importance of the relative phases of the forcing functions and identify any components where relative phase could affect the response significantly

GEH Response

During normal steady state operation, the ESBWR reactor internal components may be subjected to pressure fluctuations due to flow turbulence. These pressure fluctuations do not have identifiable phase. Turbulent pressure fluctuations cause the reactor internal components to respond in their natural modes. Each natural mode response vibrates with a broad-band frequency peaking at the natural frequency. The vibration phase of each mode is different from another. Thus the phases of the peak responses of the modes are such that the peaks do not coincide in time or structural location. This results in lower actual responses when compared to the absolute sum of the peak responses of each mode. On rare occasions, it is possible for the peak of two modes to coincide. Because such occurrences occur infrequently, they do not significantly affect the fatigue usage factor. The square root of the sum of squares method is used to combine these modal responses.

Besides turbulence-induced excitation, reactor internals may also be subjected to pressure fluctuations from active pumping actions from various fluid systems. The recirculation pumps, which are significant sources of pressure fluctuations at the vane passing frequency in other reactor designs, are not a part of the ESBWR design. Thus only minor pressure fluctuations with definite frequency and phase influence reactor internal responses. If these responses are not negligible, they are considered simultaneously with the responses from turbulent flow for fatigue usage calculations in accordance with the ASME code.
Plant transients, such as Main Steam Isolation Valves (MSIV) and turbine stop valve (TSV) closure, results in forcing functions with definite but indeterminate phases. The phase depends on the time of actuation of these valves. Due to this indeterminacy, the stresses are considered simultaneously with the responses from turbulent flow for fatigue usage calculations in accordance with the ASME code.

DCD Impact

No DCD changes will be made in response to this RAI.

NRC RAI 3.9-75

The use of the terms prototype and non-prototype in DCD Tier 2, Section 3.9.9.1 and GE Report MFN 06-012, NEDE-33259P are contradictory. Using Regulatory Guide 1.20, Revision 2, May 1976, revise DCD Tier 2, Section 3.9.9.1, including the information on startup testing that will be provided to the NRC.

GE Response

The term "prototype" in NEDE-33259P applies only to the shroud/chimney and SLC structures. The ESBWR as a whole is classified as Non-Prototype Category II. DCD Tier 2, Subsection 3.9.9.1 commits to providing information on startup testing to the NRC at the time of COL application. Subsection 3.9.9.1 will be modified at that time.

DCD Impact

No DCD changes will be made in response to this RAI.
No changes to the subject LTR will be made in response to this RAI.

NRC RAI 3.9-75 S01

RAI 3.9-75 S01 Comment on response to RAI 3.9-75:
The response of the applicant is acceptable because the use of terms has been made clear and a schedule for providing startup information at the time of COL application has been identified. RAI 3.9-75 is a COL action item. However, classification of the ESBWR, as a whole as Non-Prototype Category II, will not be considered until responses to all the open items are received.

GEH Response

The applicant agrees with the Staff position. GE is completing work to support the Non-Prototype Category II classification.

DCD Impact

No DCD changes will be made in response to this RAI.