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Subject: **Partial Response to NRC RAI Letter No. 330 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.7 – Seismic Design; RAI Number 3.7-74**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) partial response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) letter number 330 sent by NRC letter dated April 13, 2009 (Reference 1). RAI Number 3.7.74 is addressed in Enclosure 1. Enclosure 2 contains the DCD changes as a result of GEH's response to this RAI. Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

Reference:

1. MFN 09-261 Letter from U.S. Nuclear Regulatory Commission to J. G. Head, GEH, *Request For Additional Information Letter No. 330 Related to ESBWR Design Certification* dated April 13, 2009

Enclosures:

1. Partial Response to NRC RAI Letter No. 330 Related to ESBWR Design Certification Application - DCD Tier 2 Section 3.7 – Seismic Design; RAI Number 3.7-74

2. Response to Portion of NRC Request for Additional Information Letter No. 330 Related to ESBWR Design Certification Application - DCD Markup for RAI Number 3.7-74

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0101-4980 (RAI 3.7-74)

Enclosure 1

MFN 09-312

Response to Portion of NRC Request for

Additional Information Letter No. 330

Related to ESBWR Design Certification Application

DCD Tier 2 Section 3.7 – Seismic Design;

RAI Numbers 3.7-74

NRC RAI 3.7-74

Tier 2 Designation*

The staff requests that the text in the sections identified below are marked as Tier 2* information in the ESBWR DCD:

3.7.3.3.1 Piping Systems
"A maximum deflection of 1.6 mm (1/16 in.) is used for normal operating conditions, and 3.2 mm (1/8 in.) is used for abnormal conditions. For other types of supports, either demonstrate that the support is dynamically rigid, or demonstrate that one half of the support mass is less than 10% of the mass of the straight pipe segment of the span at the support location, to preclude amplification. Otherwise, the contribution of the support weight amplification is added into the piping analysis. Piping supports are evaluated to include the impact of self-weight excitation on support structure"

3.7.3.5 Analysis Procedure for Damping
"Damping values for equipment and piping are shown in Table 3.7-1 and are consistent with RG 1.61."

3.7.3.9 Multiple-Supported Equipment and Components with Distinct Inputs
"To use the SRSS method for independent support response spectrum analysis, it is required to include 10% margin in the design requirements for piping stress and piping support loads to address the uncertainties that may exist from the use of the SRSS method rather than the absolute sum method for the group combination method when performing an ISM analysis."

3.7.3.12 Effect of Differential Building Movements
"When the piping analysis is performed using USM analysis, per SRP Section 3.9.2, absolute sum method is used to combine the inertia results and the seismic anchor motion results for piping support design. When the piping analysis is performed by ISM, the piping stresses and pipe support loads are increased by 10% when using the SRSS group combination method. With the additional 10% added to the piping stresses and the pipe support loads, the inertia and the seismic anchor motion are combined by SRSS for piping stresses and pipe support loads."

3.7.3.16 Design of Small Branch and Small Bore Piping
"Branch lines can be decoupled when the ratio of run to branch pipe moment of inertia is 25 to 1, or greater."

GEH Response

The Subsections 3.7.3.3.1, 3.7.3.5, 3.7.3.9, 3.7.3.12, and 3.7.3.16 are designated as Tier 2* information.

DCD Impact

DCD Tier 2, Subsections 3.7.3.3.1, 3.7.3.5, 3.7.3.9, 3.7.3.12, and 3.7.3.16 will be revised as shown in the attached markup.

Enclosure 2

MFN 09-312

Response to Portion of NRC Request for

Additional Information Letter No. 330

Related to ESBWR Design Certification Application

DCD Markup for RAI Number 3.7-74

amplitude not less than one-third of the maximum SSE amplitude) when derived in accordance with Appendix D of IEEE-344.

For equipment seismic qualification performed in accordance with IEEE-344 as endorsed by RG 1.100, the equivalent seismic cyclic loads are five 0.5 SSE events followed by one full SSE event. Alternatively, a number of fractional peak cycles equivalent to the maximum peak cycles for five 0.5 SSE events is used in accordance with Appendix D of IEEE-344 when followed by one full SSE.

3.7.3.3 Procedures Used for Analytical Modeling

The mathematical modeling of equipment and piping is developed according to the finite element technique following the basic modeling procedures described in Subsection 3.7.2.3 for primary systems.

3.7.3.3.1 Piping Systems

Mathematical models for Seismic Category 1 piping systems are constructed to reflect the dynamic characteristics of the system. The continuous system is modeled as an assemblage of pipe elements (straight sections, elbows, and bends) supported by hangers and anchors, and restrained by pipe guides, struts and snubbers. Pipe and hydrodynamic fluid masses are lumped at the nodes and connected by zero-mass elastic elements, which reflect the physical properties of the corresponding piping segment. The mass node points are selected to coincide with the locations of large masses, such as valves, pumps, and motors, and with locations of significant geometry change. All concentrated weights on the piping systems, such as the valves, pumps, and motors, are modeled as lumped mass rigid systems if their fundamental frequencies are greater than the cutoff frequency in Subsection 3.7.2.1.1. On straight runs, mass points are located at spacing no greater than the span which would have a fundamental frequency equal to the cutoff frequency stipulated in Subsection 3.7.2.1.1, when calculated as a simply supported beam with uniformly distributed mass. The torsional effects of valve operators and other equipment with offset center of gravity with respect to the piping center line are included in the analytical model. Furthermore, all pipe guides and snubbers are modeled so as to produce representative stiffness. The equivalent linear stiffness of the snubbers is based on certified test results provided by the vendor.

Pipe supports are designed and qualified to satisfy stiffness values used in the piping analysis. For struts and snubbers, the stiffness to consider is the combined stiffness of strut, snubber, pipe clamp and piping support steel.

In general, pipe support component weights, which are directly attached to a pipe such as a Clamp, Strut, Snubber, and Trapeze are considered in the piping analysis. Frame type supports are designed to carry their own mass and are subjected to deflection requirements. [*A maximum deflection of 1.6 mm (1/16 in.) is used for normal operating conditions, and 3.2 mm (1/8 in.) is used for abnormal conditions. For other types of supports, either demonstrate that the support is dynamically rigid, or demonstrate that one half of the support mass is less than 10% of the mass of the straight pipe segment of the span at the support location, to preclude amplification. Otherwise, the contribution of the support weight amplification is added into the piping analysis. Piping supports are evaluated to include the impact of self-weight excitation on support*

structure and anchorage in detail along with piping analyzed loads where this effect is significant.]*

The stiffness of the building steel/structure (i.e., beyond the NF jurisdictional boundary) is not considered in pipe support overall stiffness. Response spectra input to the piping system includes flexibility of the building structure. When attachment to a major building structure is not possible, any intermediate structures are included in the analysis of the pipe support.

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.7.3.3.2 Equipment

For dynamic analysis, equipment is represented by lumped-mass system, which consists of discrete masses connected by zero-mass elements. The criteria used to lump masses are as follows:

- The number of modes of a dynamic system is controlled by the number of masses used; therefore, the number of masses is chosen so that all significant modes are included. The number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency of Subsection 3.7.2.1.1.
- Mass is lumped at any point where a significant concentrated weight is located. Examples are the motor in the analysis of a pump stand, and the impeller in the analysis of a pump shaft.
- If the equipment has free-end overhang span whose flexibility is significant compared to the center span, a mass is lumped at the overhang span.
- When equipment is concentrated between two existing nodes located between two supports in a finite element model, a new node is created at that location. Alternatively, the equipment mass can be concentrated at the nearest node to either side which tends to shift the natural frequency to the higher amplification region of the input motion response spectrum. When the approximate location of the equipment mass is shifted toward the mid-span between the supports the natural frequency is lowered and when the approximate location is shifted toward either support the natural frequency is increased. Moving the natural frequencies of the equipment into the higher amplification region of the excitation thereby conservatively increases the equipment response level.

  Similarly, in the case of live loads (mobile) and variable support stiffness, the location of the load and the magnitude of the support stiffness are chosen to lower the system natural frequencies. Similar to the above discussion, this ensures conservative dynamic responses because the lowered equipment frequencies tend to be shifted to the higher amplification range of the input motion spectra. If not, the model is adjusted to give more conservative responses.

3.7.3.3.3 Modeling of Special Engineered Pipe Supports

Special engineered pipe supports are not used.

3.7.3.4 Basis for Selection of Frequencies

Where practical, in order to avoid adverse resonance effects, equipment and components are designed/selected such that their fundamental frequencies are less than half or more than twice the dominant frequencies of the support structure. Moreover, in any case, the equipment is analyzed and/or tested to demonstrate that it is adequately designed for the applicable loads considering both its fundamental frequency and the forcing frequency of the applicable support structure.

3.7.3.5 Analysis Procedure for Damping

[*Damping values for equipment and piping are shown in Table 3.7-1 and are consistent with RG 1.61.*]* For ASME Section III, Division 1 Class 1, 2, and 3, and ASME B31.1 piping systems, alternative damping values specified in Figure 3.7-37 is used. For systems made of subsystems with different damping properties, the analysis procedures described in Subsection 3.7.2.13 are applicable.

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3.7.3.6 Three Components of Earthquake Motion

The applicable methods of spatial combination of responses due to each of the three input motion components are described in Subsection 3.7.2.6.

3.7.3.7 Combination of Modal Responses

The applicable methods of modal response combination are described in Subsection 3.7.2.7.

3.7.3.8 Interaction of Other Systems with Seismic Category I Systems

Each non-Category I (i.e., Seismic Category II or non-seismic) system is designed to be isolated from any Seismic Category I system by either a constraint or barrier, or is remotely located with regard to the Seismic Category I system. If it is not feasible or practical to isolate the Seismic Category I system, adjacent non-Category I systems are analyzed according to the same seismic criteria as applicable to the Seismic Category I systems. For non-Category I systems attached to Seismic Category I systems, the dynamic effects of the non-Category I systems are simulated in the modeling of the Seismic Category I system. The attached non-Category I systems, up to the first anchor beyond the interface, are also designed in such a manner that during an earthquake of SSE intensity it does not cause a failure of the Seismic Category I system.

3.7.3.9 Multiple-Supported Equipment and Components with Distinct Inputs

For multi-supported systems (equipment and piping) analyzed by the response spectrum method for the determination of inertial responses, either of the following two input motions are acceptable:

- Envelope response spectrum with USM applied at all support points for each orthogonal direction of excitation; or
- ISM response spectrum at each support for each orthogonal direction of excitation.

When the ISM response spectrum method of analysis (Subsection 3.7.2.1.2) is used, a support group is defined by supports that have the same time-history input. This usually means all supports located on the same floor, or portions of a floor, of a structure. The responses caused by motions of supports in two or more different groups are combined by the SRSS procedure.

[*To use the SRSS method for independent support response spectrum analysis, it is required to include 10 percent margin in the design requirements for piping stress and piping support loads to address the uncertainties that may exist from the use of the SRSS method rather than the absolute sum method for the group combination method when performing an ISM analysis.*]*

In addition to the inertial response discussed above, the effects of relative support displacements are considered. The maximum relative support displacements are obtained from the dynamic analysis of the building, or as a conservative approximation, by using the floor response spectra. For the latter option, the maximum displacement of each support is predicted by $S_d = S_a g/\omega^2$, where S_a is the spectral acceleration in "g's" at the high-frequency end of the spectrum curve (which, in turn, is equal to the maximum floor acceleration), g is the gravity constant, and ω is the fundamental frequency of the primary support structure in radians per second. The support displacements are imposed on the supported systems in a conservative (i.e., most unfavorable combination) manner and static analysis is performed for each orthogonal direction. The resulting responses are combined with the inertia effects by the SRSS method. Because the OBE design is not required, the displacement-induced SSE stresses due to seismic anchor motion are included in Service Level D load combinations.

In place of the response spectrum analysis, the ISM time history method of analysis is used for multi-supported systems subjected to distinct support motions, in which case both inertial and relative displacement effects are already included.

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3.7.3.10 Use of Equivalent Vertical Static Factors

Equivalent vertical static factors are used when the requirements for the static coefficient method in Subsection 3.7.2.1.3 are satisfied.

3.7.3.11 Torsional Effects of Eccentric Masses

Torsional effects of eccentric masses are included for subsystems similar to that for the piping systems discussed in Subsection 3.7.3.3.1.

3.7.3.12 Effect of Differential Building Movements

In most cases, subsystems are anchored and restrained to floors and walls of buildings that may have differential movements during a seismic event. The movements may range from insignificant differential displacements between rigid walls of a common building at low elevations to relatively large displacements between separate buildings at a high seismic activity site.

Differential endpoint or restraint deflections cause forces and moments to be induced into the system. The stress thus produced is a secondary stress. It is justifiable to place this stress, which results from restraint of free-end displacement of the system, in the secondary stress category

because the stresses are self-limiting and, when the stresses exceed yield strength, minor distortions or deformations within the system satisfy the condition which caused the stress to occur.

[*When the piping analysis is performed using USM analysis, per SRP Section 3.9.2, absolute sum method is used to combine the inertia results and the seismic anchor motion results for both piping and piping support design.*

When the piping analysis is performed by ISM, the piping stresses and pipe support loads are increased by 10% when using the SRSS group combination method. With the additional 10% added to the piping stresses and the pipe support loads, the inertia and the seismic anchor motion are combined by SRSS for piping stresses and pipe support loads.]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change.

3.7.3.13 Seismic Category I Buried Piping, Conduits and Tunnels

~~There are no~~ All Seismic Category I utilities (i.e. piping, conduits, or auxiliary system components), that are ~~directly buried~~routed underground are installed in concrete trenches/tunnels or in concrete duct banks in direct contact with soil.

Fire Protection System yard piping with a Seismic Category I classification is installed in ~~covered~~ reinforced concrete ~~trenches~~tunnels and covered concrete trenches near the ground surface with removable covers to facilitate maintenance and inspection access.

There are Seismic Category I conduits in four electrical duct banks from the CB to the RB. The~~se~~ electrical ~~duct banks~~conduit are ~~installed~~ embedded in ~~closed~~ reinforced concrete duct bank ~~trenches covered with backfill~~in direct contact with soil.

~~There are no Seismic Category I tunnels in the ESBWR design.~~ The access tunnel, which includes walkways between and access to RB, CB, TB, SB, and Electrical Building is classified Seismic Category II. Since Seismic Category II structures are designed to the same criteria as Seismic Category I structures there is no impact to adjacent Seismic Category I structures.

The Radwaste Tunnel provides for pipes that transport radioactive waste to the Radwaste Building from RB and TB. The Radwaste Tunnel is classified non-seismic but the structural acceptance criteria are in accordance with RG 1.143 – Safety Class RW-IIa.

In accordance with SRP 3.7.3 (Rev. 3, March 2007), ~~The~~ the following items are considered in the analysis and design of trenches/tunnels or concrete duct banks for Seismic Category I utilities and buried Seismic Category II and radwaste tunnels (RG 1.143 – use 1/2 SSE)~~in accordance with SRP 3.7.3 (Rev. 3, March 2007)~~:

- Two types of ground shaking-induced loadings are considered for design:
  - Relative deformations imposed by seismic waves traveling through the surrounding soil or by differential deformations between the soil and anchor points.
  - Lateral earthquake pressures and ground-water effects acting on structures.
- When applicable, the effects caused by local soil settlements, soil arching, etc., are considered in the analysis.

- Damping values used to determine the spectral acceleration in the impulsive mode are based upon the system damping associated with the tank shell material as well as with the SSI. The SSI system damping takes into account soil damping in the form of stiffness-weighted damping in accordance with Equation 3.7-14 or complex stiffness matrix in accordance with Equation 3.7-16.
- In determining the spectral acceleration in the horizontal convective mode, S_{a2}, the fluid damping ratio is 0.5% of critical damping unless a higher value can be substantiated by experimental results.
- The maximum overturning moment, M_o, at the base of the tank is obtained by the modal and spatial combination methods discussed in Subsections 3.7.2.7 and 3.7.2.6, respectively. The uplift tension resulting from M_o is resisted either by tying the tank to the foundation with anchor bolts, etc., or by mobilizing enough fluid weight on a thickened base skirt plate. The latter method of resisting M_o, when used, must be shown to be conservative.
- The seismically induced hydrodynamic pressures on the tank shell at any level are determined by the modal and spatial combination methods discussed in Subsections 3.7.2.7 and 3.7.2.6, respectively. The maximum hoop forces in the tank wall are evaluated with due regard for the contribution of the vertical component of ground shaking. If the effects of SSI results in higher response then an appropriate SSI method of analysis comparable to Reference 3.7-16 is used. The hydrodynamic pressure at any level is added to the hydrostatic pressure at that level to determine the hoop tension in the tank shell.
- Either the tank top head is located at an elevation higher than the slosh height above the top of the fluid or else is designed for pressures resulting from fluid sloshing against this head.
- At the point of attachment, the tank shell is designed to withstand the seismic forces imposed by the attached piping. An appropriate analysis is performed to verify this design.
- The tank foundation is designed to accommodate the seismic forces imposed on it. These forces include the hydrodynamic fluid pressures imposed on the base of the tank as well as the tank shell longitudinal compressive and tensile forces resulting from M_o.
- In addition to the above, a consideration is given to prevent buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

The seismic SSI analysis of the Firewater Storage Tanks is described in Appendix 3A.

3.7.3.16 Design of Small Branch and Small Bore Piping

(1) Small branch lines are defined as those lines that can be decoupled from the analytical model used for the analysis of the main run piping to which the branch lines attach. [*Branch lines can be decoupled when the ratio of run to branch pipe moment of inertia is 25 to 1, or greater.*]* In addition to the moment of inertia criterion for acceptable decoupling, these small branch lines are designed with no concentrated masses, such as valves, in the first one-half span length from the main run pipe; and with sufficient flexibility to prevent

restraint of movement of the main run pipe. Due to branch decoupling, the thermal displacements at the run pipe are combined with associated pressures and temperatures for the flexibility analyses of the branch pipe. All the stresses must meet the ASME Code requirements. The branch pipe analysis results ensure adequate flexibility and proper design of all the restraints on the branch pipe.

(2) For small bore piping defined as piping 50 mm (2 in.) and less nominal pipe size, and small branch lines 50 mm (2 in.) and less nominal pipe size, as defined in (1) above, it is acceptable to use small bore piping handbooks in lieu of performing a system flexibility analysis, using static and dynamic mathematical models, to obtain loads on the piping elements and using these loads to calculate stresses per equations in NB, NC, and ND-3600 in ASME Code Section III and ASME B31.1 Code, whenever the following are met:

a. When the small bore piping handbook is serving the purpose of the Design Report it meets all of the ASME requirements for a piping design report. This includes the piping and its supports.

b. Formal documentation exists showing piping designed and installed to the small bore piping handbook (1) is conservative in comparison to results from a detail stress analysis for all applied loads and load combinations using static and dynamic analysis methods defined in Subsection 3.7.3, (2) does not result in piping that is less reliable because of loss of flexibility or because of excessive number of supports, (3) satisfies required clearances around sensitive components.

The small bore piping handbook methodology is not applied when specific information is needed on (a) magnitude of pipe and fittings stresses, (b) pipe and fitting cumulative usage factors, (c) accelerations of pipe-mounted equipment, or locations of postulated breaks and leaks.

The small bore piping handbook methodology is not applied to piping systems that are fully engineered and installed in accordance with the engineering drawings.

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3.7.3.17 Interaction of Other Piping with Seismic Category I Piping

In certain instances, Seismic Category II piping is connected to Seismic Category I piping at locations other than a piece of equipment which, for purposes of analysis, could be represented as an anchor. The transition points typically occur at Seismic Category I valves, which may or may not be physically anchored. Because a dynamic analysis must be modeled from pipe anchor point to anchor point, two options exist:

(1) Specify and design a structural anchor at the Seismic Category I valve and analyze the Seismic Category I subsystem.

(2) Analyze the subsystem from the anchor point in the Seismic Category I subsystem through the valve to either the first anchor point in the Seismic Category II subsystem; or for a distance such that there are at least two seismic restraints in each of the three orthogonal directions.

(3) The interface anchor between the seismic and non-seismic category piping is designed for the maximum load using piping reactions from both sides.