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Subject: **Partial Response to NRC RAI Letter No. 330 Related to ESBWR Design Certification Application - DCD Tier 2 Section 3.6 – Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping; RAI Number 3.6-23**

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 3.6-23 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

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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 3.6 – Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping; RAI Number 3.6-23
2. Response to Portion of NRC Request for Additional Information Letter No. 330 Related to ESBWR Design Certification Application - DCD Markup for RAI Number 3.6-23

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
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	eDRF Section	0000-0101-4951 (RAI 3.6-23)

Enclosure 1

MFN 09-326

Response to Portion of NRC Request for

Additional Information Letter No. 330

Related to ESBWR Design Certification Application

DCD Tier 2 Section 3.6 –

Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping;

RAI Number 3.6-23

NRC RAI 3.6-23

Tier 2 Designation*

The staff requests that all of the text in sections 3.6.2.1.1, "Locations of Postulated Pipe Breaks", 3.6.2.1.2, "Locations of Postulated Pipe Cracks," 3.6.2.5, "Pipe Break Analysis Results and Protection Methods" are identified as Tier 2 information in the ESBWR DCD. Also, it should be noted that there are several unresolved RAIs in section 3.6.2 and pending the final resolution of those RAIs, there may be some additional material that would need to be marked as Tier 2*.*

GEH Response

The Subsections 3.6.2.1.1, 3.6.2.1.2, and 3.6.2.5 are designated as Tier 2* information.

DCD Impact

DCD Tier 2, Subsections 3.6.2.1.1, 3.6.2.1.2, and 3.6.2.5 will be revised as shown in the attached markup.

Enclosure 2

MFN 09-326

Response to Portion of NRC Request for

Additional Information Letter No. 330

Related to ESBWR Design Certification Application

DCD Markup for RAI Number 3.6-23

energy fluid systems, pipe failures are limited to postulation of cracks in piping and branch runs; these cracks affect the surrounding environmental conditions only and do not result in whipping of the cracked pipe. High-energy fluid systems are also postulated to have cracks for conservative environmental conditions in a confined area where high and moderate-energy fluid systems are located.

The following high-energy piping systems (or portions of systems) are considered as potential candidates for a postulated pipe break during normal plant conditions and are analyzed for potential damage resulting from dynamic effects:

- all piping which is part of the reactor coolant pressure boundary (RCPB) and subject to reactor pressure continuously during station operation;
- all piping which is beyond the second isolation valve but subject to reactor pressure continuously during station operation; and
- all other piping systems or portions of piping systems considered high-energy systems.

Portions of piping systems that are isolated from the source of the high-energy fluid during normal plant conditions are exempted from consideration of postulated pipe breaks. This includes portions of piping systems beyond normally closed valves. Pump and valve bodies are also exempted from consideration of pipe break because of their greater wall thickness.

3.6.2.1.1 [*Locations of Postulated Pipe Breaks*

Postulated pipe locations are selected as follows:

Piping Meeting Separation Requirements

Based on the HELSA evaluation described in Subsection 3.6.1.3, the high-energy lines which meet the spatial separation requirements, are generally not identified with particular break points. Breaks are postulated at all possible points in such high-energy piping systems. However, in some systems break points are particularly specified according to the following subsections if special protection devices such as barriers or restraints are provided.

Piping in Containment Penetration Areas

No pipe breaks or cracks are postulated in those portions of piping from the containment wall penetration to and including the inboard or outboard isolation valves which meet the following requirements in addition to the requirement of the ASME Code, Section III, Subarticle NE-1120:

- *The following design stress and fatigue limits are not exceeded:*

  For ASME Code, Section III, Class 1 Piping

  – *The maximum stress range between any two load sets (including the zero load set) does not exceed 2.4 S_m, and is calculated by Equation 10 in NB-3653, ASME Code, Section III. If the calculated maximum stress range of Equation (10) exceeds 2.4 S_m, the stress ranges calculated by both Equation (12) and Equation (13) in paragraph NB-3653 meet the limit of 2.4 S_m.*

  – *The cumulative usage factor is less than 0.1.*

For the piping system with reactor water, if the environmental fatigue is included in accordance with RG 1.207, the fatigue usage limit should be ≤ 0.40 as the criteria instead of ≤ 0.10 for determining pipe break locations.

- *The maximum stress as calculated by Equation 9 in NB-3652 under the loadings resulting from a postulated piping failure beyond those portions of piping, does not exceed the lesser of 2.25 S_m and 1.8 S_y except that, following a failure outside containment, the pipe between the outboard isolation valve and the first restraint may be permitted higher stress, provided a plastic hinge is not formed and operability of the valves with such stresses is assured in accordance with the requirement identified in Subsection 3.9.3. Primary loads include those that are deflection limited by whip restraints.*

For ASME Code, Section III, Class 2 Piping

- *The maximum stress as calculated by the sum of Equations 9 and 10 in Paragraph NC-3653, ASME Code, Section III, considering those loads and conditions thereof for which level A and level B stress limits are specified in the system's Design Specification (i.e., sustained loads, occasional loads, and thermal expansion), excluding an earthquake event, does not exceed 0.8(1.8 S_h + S_A). The S_h and S_A are allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III.*
- *The maximum stress, as calculated by Equation 9 in NC-3653 under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping, does not exceed the lesser of 2.25 S_h and 1.8 S_y.*

Primary loads include those that are deflection limited by whip restraints. The exceptions permitted above may also be applied provided that, when the piping between the outboard isolation valve and the restraint is constructed in accordance with the Power Piping Code ASME B31.1, the piping is either of seamless construction with full radiography of all circumferential welds, or all longitudinal and circumferential welds are fully radiographed.

- *Welded attachments, for pipe supports or other purposes, to these portions of piping are avoided except where detailed stress analyses, or tests, are performed to demonstrate compliance with the above mentioned code limits.*
- *The number of circumferential and longitudinal piping welds and branch connections are minimized. Where penetration sleeves are used, the enclosed portion of fluid system piping is seamless construction and without circumferential welds unless specific access provisions are made to permit in-service volumetric examination of longitudinal and circumferential welds.*
- *The length of these portions of piping are reduced to the minimum length practical.*
- *The design of pipe anchors or restraints (e.g., connections to containment penetrations and pipe whip restraints) do not require welding directly to the outer surface of the piping (e.g., flued integrally forged pipe fittings may be used) except where such welds are 100% volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the above mentioned code limits.*

- *Sleeves provided for those portions of piping in the containment penetration areas are constructed in accordance with the rules of Class MC, Subsection NE of the ASME Code, Section III, where the sleeve is part of the containment boundary. In addition, the entire sleeve assembly is designed to meet the following requirements and tests:*
  - *The design pressure and temperature are not less than the maximum operating pressure and temperature of the enclosed pipe under normal plant conditions.*
  - *The Level C stress limits in NE-3220, ASME Code, Section III, are not exceeded under the loadings associated with containment design pressure and temperature in combination with the safe shutdown earthquake (SSE).*
  - *The assemblies are subjected to a single pressure test at a pressure not less than its design pressure.*
  - *The assemblies do not prevent the access required to conduct the in-service examination specified below.*
- *A 100% volumetric in-service examination of all pipe welds is conducted during each inspection interval as defined in IWA-2400, ASME Code, Section XI.*

ASME Code Section III Class 1 Piping in Areas Other Than Containment Penetration

With the exception of those portions of piping identified above, breaks in ASME Code, Section III, Class 1 piping are postulated at the following locations in each piping and branch run:

- *At terminal ends including the locations shown in Figure 3.6-3.*
- *At intermediate locations where the maximum stress range as calculated by Equation 10 in NB-3653, ASME Code, Section III exceeds 2.4 S_m, and either Equation 12 or Equation 13 in Paragraph NB-3653 exceeds 2.4 S_m.*
- *At intermediate locations where the cumulative usage factor exceeds 0.1. As a result of piping reanalysis caused by differences between the design configuration and the as-built configuration, the highest stress or cumulative usage factor locations may be shifted; however, the initially determined intermediate break locations need not be changed unless one of the following conditions exists:*
  - *The dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.*
  - *A change is required in pipe parameters, such as major differences in pipe size, wall thickness, and routing.*

  For the piping system with reactor water, if the environmental fatigue is included in accordance with RG 1.207, the fatigue usage limit should be ≤ 0.40 as the criteria instead of ≤ 0.10 for determining pipe break locations.

ASME Code Section III Class 2 and 3 Piping in Areas Other Than Containment Penetration

With the exceptions of those portions of piping identified above, breaks in ASME Code, Section III, Class 2 and 3 piping are postulated at the following locations in those portions of each piping and branch run:

- *At terminal ends.*
- *At intermediate locations selected by one of the following criteria:*
  - *At each pipe fitting (e.g., elbow, tee, cross, flange, and nonstandard fitting), welded attachment, and valve.*
  - *At one location at each extreme of the piping run adjacent to the protective structure for piping that contains no fittings, welded attachments, or valves.*
  - *At each location where stresses calculated by the sum of Equations 9 and 10 in NC/ND-3653, ASME Code, Section III, exceed 0.8 times the sum of the stress limits given in NC/ND-3653.*

Piping will be designed to minimize the stresses and fatigue usage factors such that piping intermediate pipe break locations are avoided.

As a result of piping reanalysis caused by differences between the design configuration and the as-built configuration, the highest stress locations may be shifted; however, the initially determined intermediate break locations may be used unless a redesign of the piping resulting in a change in the pipe parameters (diameter, wall thickness, routing) is required, or the dynamic effects from the new (as-built) intermediate break location are not mitigated by the original pipe whip restraints and jet shields.

For complex piping systems such as those containing arrangements of headers and parallel piping running between headers, the pipe breaks are postulated pursuant to the applicable criteria identified in this subsection and in conformance with BTP 3-4.]*

The terminal end pipe break locations for high energy lines inside and outside containment are provided in Tables 3.6-5 and 3.6-6. The high energy line breaks at the containment penetration outside of the containment penetration zone are provided in Table 3.6-7. Terminal end break locations in piping systems on both sides of the containment penetration are shown in Figure 3.6-3.

[***Non-ASME Class Piping***

Breaks in seismically analyzed non-ASME Class (not ASME Class 1, 2, or 3) piping are postulated according to the same requirements for ASME Class 2 and 3 piping above. Separation and interaction requirements between seismically analyzed and non-seismically analyzed piping are met as described in Subsection 3.7.3.8.

Separating Structure With High-Energy Lines

If a structure separates a high-energy line from a safety-related component, the separating structure is designed to withstand the consequences of the pipe break in the high-energy line at locations that the aforementioned criteria require to be postulated. However, as noted in Subsection 3.6.1.3, some structures which are identified as necessary by the HELSA evaluation (i.e., based on no specific break locations), are designed for worst-case 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.

3.6.2.1.2 [***Locations of Postulated Pipe Cracks***

Postulated pipe crack locations are selected as follows:

Piping Meeting Separation Requirements

Based on the HELSA evaluation described in Subsection 3.6.1.3, the high- or moderate-energy lines, which meet the separation requirements, are not identified with particular crack locations. Cracks are postulated at all possible points that are necessary to demonstrate adequacy of separation or other means of protections provided for safety-related SSCs.

High-Energy Piping

With the exception of those portions of piping identified above, leakage cracks are postulated for the most severe environmental effects as follows:

- *For ASME Code, Section III Class 1 piping, at axial locations where the calculated stress range by Equation 10 and either Equation 12 or Equation 13 in NB-3653 exceeds 1.2* S_m.
- *For ASME Code, Section III Class 2 and 3 or non-ASME class piping, at axial locations where the calculated stress by the sum of Equations 9 and 10 in NC/ND-3653 exceeds 0.4 times the sum of the stress limits given in NC/ND-3653.*
- *Non-ASME class piping, which has not been evaluated to obtain stress information, has leakage cracks postulated at axial locations that produce the most severe environmental effects.*

Moderate-Energy Piping in Containment Penetration Areas

Leakage cracks are not postulated in those portions of piping from the containment wall to and including the inboard or outboard isolation valves, provided (1) they meet the requirements of the ASME Code, Section III, NE-1120, and (2) the stresses calculated by the sum of Equations 9 and 10 in ASME Code, Section III, NC-3653 do not exceed 0.4 times the sum of the stress limits given in NC-3653.

Moderate Energy Piping in Areas Other Than Containment Penetration

- *Leakage cracks are postulated in piping located adjacent to safety-related structures, systems or components, except:*
  - *Where exempted above.*
  - *For ASME Code, Section III, Class 1 piping the stress range calculated by Equation 10 and either Equation 12 or Equation 13 in NB-3653 is less than 1.2* S_m.
  - *For ASME Code, Section III, Class 2 or 3 and non-ASME class piping, the stresses calculated by the sum of Equations 9 and 10 in NC/ND-3653 are less than 0.4 times the sum of the stress limits given in NC/ND-3653.*
- *Leakage cracks, unless the piping system is exempted above, are postulated at axial and circumferential locations that result in the most severe environmental consequences.*
- *Leakage cracks are postulated in fluid system piping designed to non-seismic standards as necessary to meet the environmental protection requirements of Subsection 3.6.1.1.*

Moderate-Energy Piping in Proximity to High-Energy Piping

*Moderate-energy fluid system piping or portions thereof which are located within a compartment of confined area involving considerations for a postulated break in high-energy fluid system piping, are acceptable, without postulation of through-wall leakage cracks, except where a postulated leakage crack in the moderate-energy fluid system piping results in more severe environmental conditions than the break in the proximate high-energy fluid system piping, in which case the provisions of this subsection are applied.]**

* 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.

3.6.2.1.3 Types of Breaks and Cracks to be Postulated

Pipe Breaks

The following types of breaks are postulated in high-energy fluid system piping at the locations identified by the criteria specified in Subsection 3.6.2.1.1.

- No breaks are postulated in piping having a nominal diameter less than or equal to 25.4 mm (1 inch). Instrument lines 1 in. and less nominal pipe or tubing size meet the provision of RG 1.11. Additionally, the 32 mm (1.25 in) hydraulic control units (HCU) fast scram lines do not require special protection measure because of the following reasons:
  - The piping to the control rod drives (CRDs) from the HCUs are located in the containment under reactor vessel, and in the Reactor Building away from other safety-related equipment; therefore, should a line fail, it would not affect any safety-related equipment but only impact on other HCU lines. As discussed in Subsection 3.6.1.1, a whipping pipe can only rupture an impacted pipe of smaller nominal pipe size or cause a through-wall crack in the same nominal pipe size but with thinner wall thickness.
  - The total amount of energy contained in the 32 mm (1.25 in) piping between the normally closed scram insert valve on the HCU module and the ball-check valve in the control rod housing is smaller than 6 kJ per meter (1348.85 ft. lbf per foot) of 32 mm (1.25 in) line. In the event of a rupture of this line, the ball-check valve would close to prevent reactor vessel flow out of the break.
  - Even if a number of the HCU lines ruptured, the control rod insertion function would not be impaired, because the electrical motor of the fine motion control drive would drive in the control rods.
- Longitudinal breaks are postulated only in piping having a nominal diameter equal to or greater than 102 mm (4 in).
- Circumferential breaks are only assumed at all terminal ends.
- At each of the intermediate postulated break locations identified to exceed the stress and usage factor limits of the criteria in Subsection 3.6.2.1.1, consideration is given to the occurrence of either a longitudinal or circumferential break. Examination of the state of stress in the vicinity of the postulated break location is used to identify the most probable

- Dynamic inertia loads of the moving pipe section, which is accelerated by the blowdown thrust and subsequent impact on the restraint.
- Design characteristics of the pipe whip restraints are included and verified by the pipe whip dynamic analysis described in Subsection 3.6.2.2.
- Because the pipe whip restraints are not contacted during normal plant operation, the postulated pipe rupture event is the only design loading condition.

Strain rate effects and other material property variations have been considered in the design of the pipe whip restraints. The material properties utilized in the design have included one or more of the following methods:

- Code minimum or specification yield and ultimate strength values for the affected components and structures are used for both the dynamic and steady-state events.
- Not more than a 10% increase in minimum code or specification strength values is used when designing components or structures for the dynamic event, and code minimum or specification yield and ultimate strength values are used for the steady-state loads.
- Representative or actual test data values are used in the design of components and structures including justifiably elevated strain rate-affected stress limits in excess of 10%.
- Representative or actual test data are used for any affected component(s) and the minimum code or specification values are used for the structures for the dynamic and the steady-state events.

3.6.2.4 Guard Pipe Assembly Design

The ESBWR does not require guard pipes.

3.6.2.5 [Pipe Break Analysis Results and Protection Methods

The following information shall be provided in a pipe break evaluation report that will be completed in conjunction with closure of ITAAC Tier 1, Table 3.1-1 related to pipe break analysis report:

- *A summary of the dynamic analyses applicable to high-energy piping systems in accordance with Subsection 3.6.2.5 of RG 1.70. This shall include the following:*
  - *Sketches of applicable piping systems showing the location, size and orientation of postulated pipe breaks and the location of pipe whip restraints and jet impingement barriers.*
  - *A summary of the data developed to select postulated break locations including calculated stress intensities, cumulative usage factors and stress ranges as delineated in BTP 3-4.*
- *For failure in the moderate-energy piping systems, descriptions showing how safety-related systems are protected from the resulting jets, flooding and other adverse environmental effects.*
- *Identification of protective measures provided against the effects of postulated pipe failures for protection of each of the systems listed in Tables 3.6-1 and 3.6-2.*

- *The details of how the MSIV functional capability is protected against the effects of postulated pipe failures.*
- *Typical examples, if any, where protection for safety-related systems and components against the dynamic effects of pipe failures include their enclosure in suitably designed structures or compartments (including any additional drainage system or equipment environmental qualification needs).*
- *The details of how the feedwater line check and feedwater isolation valves functional capabilities are protected against the effects of postulated pipe failures.*]*

* 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.

3.6.2.6 Analytic Methods to Define Blastwave Interaction to SSCs

Structures, systems, and components (SSCs) are evaluated for the blast wave effects. The blast wave occurs as a result of a pipe rupture that creates a rapid wave propagation of air surrounding the break due to the differential pressure between the rupture of a pressurized fluid in pipe and the ambient air. The blast effects are evaluated from all break types such as for the circumferential and longitudinal breaks for high and moderate energy piping systems. The wave propagation of the blast wave is dependent on the following conditions:

Blast Wave Due to a Pipe Rupture Occurring in an Open Space

The blast wave in an open space is considered as spherically expanding wave front. The blast wave pressure intensity is determined based on the pressure difference between pipe internal pressure prior to the pipe break and surrounding air at the break point and the pressure attenuation occurs based on the radius cubed of the spherically expanding wave front.

Blast Wave Due to a Pipe Rupture Occurring in an Enclosed Space

Blast wave in an enclosed space experiences the propagation of shock wave and reflected wave effects. As the shock wave continue to propagate outward along the enclosed surface a front known as the Mach front is formed by the interaction of the incident wave and the reflected wave. The reflected wave represents the incident wave that has been reinforced by the surrounding surface. Computational fluid dynamic analysis models analyze these phenomena and blast intensities further from a pipe break location are determined.

3.6.3 (Deleted)

3.6.3.1 (Deleted)

3.6.3.2 (Deleted)

3.6.4 As-built Inspection of High-Energy Pipe Break Mitigation Features

An as-built inspection of the high-energy pipe break mitigation features is performed. The as-built inspection confirms that systems, structures and components, that are required to be functional during and following an SSE, are protected against the dynamic effects associated