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MFN 08-339

Docket No. 52-010

April 16, 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 Number 148 Related to ESBWR Design Certification Application – Seismic Category I Structures – RAI Numbers 3.8-4 S03, 3.8-101 S03, 3.8-102 S03, and 3.8-103 S03**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to a portion of the U.S. Nuclear Regulatory Commission (NRC) Requests for Additional Information (RAIs) received by GEH via Reference 1. Enclosure 1 contains the GEH response to NRC RAI 3.8-4 S03. Enclosure 2 contains the GEH response to NRC RAIs 3.8-101 S03, 3.8-102 S03, and 3.8-103 S03. The RAIs addressed in both Enclosures 1 and 2 were received from the NRC on February 19, 2008, via MFN 08-158 (NRC Letter 148) (Reference 1).

Previously GEH received RAIs 3.8-4 S03, 3.8-101 S02, 3.8-102 S02, and 3.8-103 S02, on May 24, 2007, via an e-mail from the NRC (Chandu Patel) (Reference 4), to which GEH responded to RAI 3.8-4 S03 on November 6, 2007, via MFN 06-298, Supplement 4 (Reference 2); and to which GEH responded to RAIs 3.8-101 S02, 3.8-102 S02, and 3.8-103 S02 on November 28, 2007, via MFN 06-407, Supplement 3 (Reference 3).

GEH created RAIs 3.8-4 S01, 3.8-101 S01, 3.8-102 S01, and 3.8-103 S01, on December 14, 2006, following an NRC audit and subsequent assessment (Reference 7), to which GEH responded to RAI 3.8-4 S01 on January 29, 2007, via MFN 06-298, Supplement 1 (Reference 5); and to which GEH responded to RAIs 3.8-101 S01, 3.8-102 S01, and 3.8-103 S01, on February 1, 2007, via MFN 06-407, Supplement 1 (Reference 6).

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GEH received original RAIs 3.8-4, 3.8-101, 3.8-102, and 3.8-103 on June 23, 2006, via MFN 06-197 (NRC Letter 38) (Reference 10), to which GEH responded to RAI 3.8-4 on August 31, 2006, via MFN 06-298 Reference 8); and RAIs 3.8-101, 3.8-102, and 3.8-103 on November 8, 2006, via MFN 06-407 (Reference 9).

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

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

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

References:

1. MFN 08-158 from Leslie Perkins, Project Manager, ESBWR/ABWR Projects Branch, Division of New Reactor Licensing, Office of Nuclear Reactor Regulation, to Robert E. Brown, *Request for Additional Information Letter No. 148 Related to ESBWR Design Certification Application – Classification of structures, systems, and components*, RAI Numbers 3.8-4 S03, 3.8-101 S03, 3.8-102 S03, and 3.8-103 S03, dated February 19, 2008

2. MFN 06-298, Supplement 4, from James C. Kinsey to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis – RAI Number 3.8-4 S02*, dated November 6, 2007

3. MFN 06-407, Supplement 3, from James C. Kinsey to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.8 – Seismic Category I Structures – RAI Numbers 3.8-101 S02, 3.8-102 S02, and 3.8-103 S02*, dated November 28, 2007

4. E-mail from Chandu Patel, U.S. Nuclear Regulatory Commission to GEH, comment on response to RAI 3.8-101 S01, 3.8-102 S01, and 3.8-103 S01 (MFN 06-308 Supplement 1), dated May 24, 2007

5. MFN 06-298, Supplement 1, from James C. Kinsey to the U.S. Nuclear Regulatory Commission, Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-1 S01, 3.8-2 S01, 3.8-4 S01, 3.8-5 S01, 3.8-7 S01, 3.8-9 S01, 3.8-10 S01, 3.8-12 S01, 3.8-15 S01, 3.8-29 S01, 3.8-30 S01, 3.8-31 S01, 3.8-42 S01, 3.8-52 S01, 3.8-53 S01, 3.8-54 S01, 3.8-58 S01, 3.8-60 S01, 3.8-61 S01, 3.8-67 S01, 3.8-70 S01, 3.8-71 S01, 3.8-72 S01, 3.8-74 S01 & 3.8-98 S01 – Supplement 1, dated January 29, 2007

6. MFN 06-407, Supplement 1, from James C. Kinsey to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-17 S01, 3.8-24 S01, 3.8-28 S01, 3.8-44 S01, 3.8-59 S01, 3.8-62 S01, 3.8-65 S01, 3.8-69 S01, 3.8-76 S01, 3.8-77 S01, 3.8-79 S01, 3.8-80 S01, 3.8-84 S01, 3.8-95 S01, 3.8-97 S01, 3.8-101 S01, 3.8-102 S01 and 3.8-103 S01*, dated February 1, 2007

7. NRC assessment following an NRC audit concluded December 14, 2006. RAIs 3.8-4 S01, 3.8-101 S01, 3.8-102 S01, and 3.8-103 S01 were created by GEH in response to the audit and subsequent assessment

8. MFN 06-298, from David H. Hinds to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-1, 3.8-2, 3.8-4, 3.8-5, 3.8-7 through 3.8-12, 3.8-15, 3.8-16, 3.8-21, 3.8-22, 3.8-29 through 3.8-31, 3.8-39, 3.8-42, 3.8-43, 3.8-45, 3.8-50, 3.8-52 through 3.8-55, 3.8-57, 3.8-58, 3.8-60, 3.8-61, 3.8-66 through 3.8-68, 3.8-70 through 3.8-72, 3.8-74, 3.8-75, 3.8-78, and 3.8-98, dated August 31, 2006*

9. MFN 06-407, from David H. Hinds to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-17, 3.8-24, 3.8-28, 3.8-32, 3.8-33 through 3.8-38, 3.8-44, 3.8-59, 3.8-62, 3.8-65, 3.8-69, 3.8-73, 3.8-76, 3.8-77, 3.8-79, 3.8-80, 3.8-81, 3.8-84, 3.8-85, 3.8-86, 3.8-88, 3.8-89, 3.8-92, 3.8-93 through 3.8-97, 3.8-99, 3.8-101, 3.8-102 and 3.8-103*, dated November 8, 2006

10. MFN 06-197 from Lawrence Rossbach, Project Manager, ESBWR/ABWR Projects Branch, Division of New Reactor Licensing, Office of Nuclear Reactor Regulation, to David H. Hinds, *Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application* [RAI concerning structural analysis, as described in Section 3.8 of the ESBWR design control document], dated June 23, 2006

Enclosures:

1. Partial Response to NRC RAI Letter No. 148 Related to ESBWR Design Certification Application – Seismic Category I Structures – RAI Number 3.8-4 S03

2. Partial Response to NRC RAI Letter No. 148 Related to ESBWR Design Certification Application – Seismic Category I Structures – RAI Numbers 3.8-101 S03, 3.8-102 S03 and 3.8-103 S03

cc:	AE Cubbage	USNRC (with enclosures)
	RE Brown	GEH/Wilmington (with enclosures)
	GB Stramback	GEH/San Jose (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0081-8349, Rev. 0 (RAI 3.8-4 S03)
	eDRF Section	0000-0081-8352, Rev. 1 (RAIs 3.8-101 S03, 3.8-102 S03, and 3.8-103 S03)

ENCLOSURE 1

MFN 08-339

Partial Response to NRC RAI Letter No. 148

Related to ESBWR Design Certification Application

Seismic Category I Structures

RAI Number 3.8-4 S03

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

Original Response, Supplement 1 and Supplement 2 were previously submitted under MFNs 06-298, 06-298, Supplement 1 and 06-298, Supplement 4, respectively, and are included to provide historical continuity during review.

NRC RAI 3.8-4

Described how the jurisdictional boundaries defined in DCD Section 3.8.1.1.3 and Figure 3.8-1 meet the definition of jurisdictional boundaries as specified in the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC), Division 2, Subsection CC. Subsection CC of the Code states that "When a structural concrete support is constructed as an integral part of the containment, it shall be included within the jurisdiction of these criteria." There are a number of structural components in the reactor building (RB), such as the RB concrete floor slabs, that are integrally connected to the containment structure that restrain and provide support to the containment under various loads (e.g., internal containment pressure).

GE Response

ASME III, Division 2, Subsection CC, Section CC-1140, require that the Containment conform to the requirements of ASME III, NCA-3254.2. Furthermore, Section CC-1140 states that NCA-3254.2 is supplemented by the provision below:

"When a structural concrete support is constructed as an integral part of the containment, it shall be included within the jurisdiction of these criteria."

According to the ASME Code Section III, NCA-3254.2, "Definition of Division 2 Boundaries", the support structure that is constructed as an integral part of the concrete containment shall be included within the jurisdiction of Division 2. However, in Interpretation No. 12 (III-2-83-01) of ASME Code Section III, the code committee states that when the containment mat is integral with other building foundations, only the portion of the containment foundation mat directly beneath the containment vessel including any additional peripheral volume for anchoring of the containment shell reinforcement shall be considered within the code jurisdictional boundary and constructed in accordance with the rules of ASME Code Section III Division 2. The portion of the common mat subject to the rules of ASME Section III, Division 2, shall be proportioned for the forces and moments resulting from the consideration of the entire mat. The loads from the portion of the common mat outside the rules of ASME Section III, Division 2, shall be specified in the design specification and applied to the ASME Section III Division 2 mat in combination with those specified for Section III, Division 2 mat. The load combinations specified in CC-3000 and the Design Specification shall be applicable for all loads.

The ESBWR containment pressure boundary, as described in DCD Section 3.8.1 is limited to the cylindrical walls of the containment, the foundation mat directly beneath the containment, and the top slab. This boundary is shown in DCD Figure 3.8-1. The fuel pool girders, RB floor slabs, cylindrical wall supporting the containment wall and suppression pool slab, and the diaphragm floor slab, which are outside of the boundary defined in DCD Figure 3.8-1, participate in carrying loads which act on the containment structure. The fuel pool girders, which are integral with the containment top slab, provide additional strength to resist internal containment pressure acting on the top slab. Similarly, the diaphragm floor slab and the RB floor slabs, which are integral with the containment wall, provide additional strength to resist internal containment pressure acting on the containment wall.

Analogous to the jurisdictional boundary definition per Interpretation No. 12, structural components (RB floor slabs, fuel pool girders etc.), which are integral with the containment are treated the same as the containment only as far as loads and loading combinations are concerned in the design. This is consistent with the USNRC's position shown in Regulatory Guide 1.142 (revision 2) on the design code (ANSI/ACI 349-97) and requirements for the diaphragm floor slab in the ABWR and Mark II design which is integral with the containment wall and participates in resisting a portion of the pressure load on the containment wall. See response to RAI 3.8-101 for additional information.

Interpretation No. 12 (III-2-83-01) of ASME Code Section III is below.

DCD Impact

No DCD change was made in response to this RAI.

Interpretation: III-2-83-01

Subject: Section III, Division 2, CC-3200, Load Criteria Used for Containment Vessel and Auxiliary Building

Date Issued: September 9, 1982

File: NI81-180

Question (1): When a common foundation is used for both the containment vessel and auxiliary building in a nuclear power plant, is it permissible for only the volume of the common foundation directly beneath the Class CC containment vessel, including any additional peripheral volume for anchorage of the containment shell reinforcing, to be subject to the rules of Section III, Division 2?

Reply (1): The specific boundaries of a Section III, Division 2, Class CC containment vessel shall be specified in the Design Specification as required by NCA-3254.2. The portion of the common foundation directly beneath the containment vessel, including any additional peripheral volume for anchoring of the containment shell reinforcing, shall be constructed in accordance with the rules of Section III, Division 2, when required by the Design Specification. The balance of the common foundation outside the jurisdictional boundary of the containment vessel, specified in the Design Specification, is not included in the scope of Section III, Division 2.

Question (2): If the balance of the common foundation is outside the scope of Section III, Division 2, what, if any, consideration should be given to the forces and moments of this portion of the foundation in the design of the Section III, Division 2 portion?

Reply (2): The portion of the common mat subject to the rules of Section III, Division 2, shall be proportioned for the forces and moments resulting from consideration of the entire mat. The loads from the portion of the common mat outside the rules of Section III, Division 2, shall be specified in the Design Specification and applied to the Section III, Division 2 mat in combination with those specified for the Section III, Division 2 mat. The load combinations specified in CC-3000 and the Design Specification shall be applicable for all loads.

NRC RAI 3.8-4, Supplement 1

NRC Assessment Following the December 14, 2006 Audit

Further clarification and discussion needed with GE.

During the audit, GE explained that the loads and load combinations for the entire RB from the ACI 349 and ASME Section III, Division 2 are checked against the acceptance criteria in ASME Section III, Division 2 Code. GE indicated that they have confirmed that the acceptance criteria in the ASME, Section III, Division 2 Code are more conservative than the acceptance criteria in ACI 349. GE was requested to provide the technical basis for this conclusion. Therefore, in effect the entire RB is designed to both the ASME Section III, Division 2, Subsection CC and the ACI 349 Code. In this case, the current boundary shown in DCD Figure 3.8-1 for the ASME jurisdictional boundary for all aspects of design, construction, fabrication, and inspection is acceptable. GE will provide a supplemental response to this RAI and RAIs 3.8-67, 101, 102 and 103 to reflect the above.

GE Response

In the original response submitted under MFN 06-298, the suppression pool slab was inadvertently omitted. The first sentence of the third paragraph is corrected as follows:

The ESBWR concrete containment pressure boundary, as described in DCD Section 3.8.1, is limited to the cylindrical walls of the containment, the suppression pool slab, the foundation mat directly beneath the containment, and the top slab.

Further, the original response submitted under MFN 06-298 is supplemented as follows:

The entire RB is designed to both the ASME Section III, Division 2, Subsection CC code and the ACI 349-01 Code. The acceptance criteria in ASME 2004 Section III, Division 2 are more conservative than the acceptance criteria in ACI 349-01 as shown below. The current boundary shown in DCD Tier 2 Figure 3.8-1 for the ASME jurisdictional boundary for all aspects of design, construction, fabrication, and inspection is acceptable.

Comparison of Acceptance Criteria of ACI 349-01 Vs. ASME 2004 Section III Div. 2 Subsection CC:

Figure 3.8-4 (1) shows the comparison of M-N (bending moment-axial force) interactions that define the relationships between allowable bending moments and axial forces calculated in accordance with ACI 349-01 and ASME 2004 Section III, Division 2 codes (for factored primary and secondary loads).

As shown in Figure 3.8-4 (1), the ASME allowable values are smaller, except in the high axial force (compression) region in which the ASME limit is $0.75f_c'$ for primary plus secondary membrane and $0.60f_c'$ for primary membrane. For additional conservatism, the $0.60f_c'$ limit, which is lower than the ACI 349-01 allowable, is applied to the ESBWR design. Therefore, the use of the ASME acceptance criteria is a conservative design approach for the design of ESBWR concrete structures that are integrated with the containment.

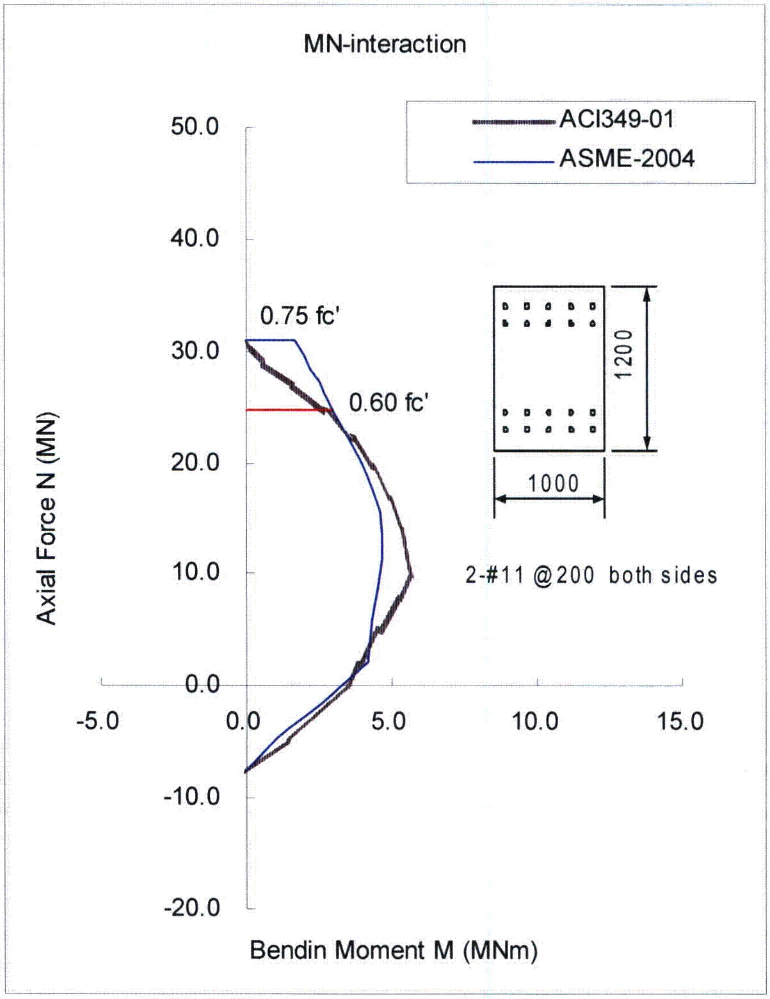

Figure 3.8-4 (1) Comparison in M-N interaction between ACI 349-01 and ASME 2004-Section III, Division 2

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-4, Supplement 2

NRC Assessment from Chandu Patel E-mail Dated May 24, 2007

The staff reviewed the latest supplemental response and finds that additional clarification is needed. The applicant stated that the entire Reactor Building is designed to both the ASME Section III, Division 2, Subsection CC code and the ACI 349-01 Code. Therefore, it is not clear to the staff why there is a need to demonstrate that the acceptance criteria in ASME, Section III, Division 2 are more conservative than the criteria in ACI 349. In addition, the RAI response does not appear to support that conclusion. The comparison between the codes is limited to the case of a member subjected to a combination of axial loading and bending. As indicated in the response, in the high axial force (compression) region the ASME allowable values are not more conservative. The limited comparison presented in the response does not constitute a technical basis for concluding that other acceptance criteria in the ASME Code are also more conservative than the ACI 349-01 Code. The staff requests the applicant to explain the purpose of the comparison, and clarify how ASME Section III, Division 2, Subsection CC and ACI 349-01 Code were used for the design of the RB.

GEH Response

The RB is integral to the Concrete Containment and is designed to the more limiting acceptance criteria of ASME Section III, Division 2, Subsection CC and ACI 349-01. For the design of RB elements integral with the Concrete Containment, the relevant acceptance criteria are load combinations, allowable compressive stress in concrete, allowable tensile and compressive stresses in reinforcing steel, and allowable transverse shear stress. The case of a member subjected to a combination of axial force and bending moment is demonstrated in the response to NRC RAI 3.8-4, Supplement 1 as an example to show that ASME Section III, Division 2, Subsection CC is governing and is applied in the RB design. The acceptance criteria for transverse shear are essentially the same between ASME Section III, Division 2, Subsection CC and ACI 349-01 as shown in the comparison between Tables 7 and 8 of the SSDP-2D validation report in Enclosure 2 to MFN 06-416 in response to NRC RAI 3.8-107. Therefore, the ACI 349-01 acceptance criteria for transverse shear are applied in the RB design. For the load combinations, an envelope of load combinations specified in ACI 349-01 and ASME 2004, Division 2, Subsection CC is used.

This design approach ensures that the RB, which is designed to ACI 349-01 acceptance criteria, also meets the ASME Section III, Division 2, Subsection CC acceptance criteria for the Concrete Containment.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-4, Supplement 3

The staff reviewed the Supplement 2 response to this RAI, transmitted in GEH letter dated November 6, 2007, and finds that the design of the entire RB to the more limiting acceptance criteria of ASME Section III, Division 2, Subsection CC and ACI 349-01 is acceptable. This includes enveloping the loading combinations and the allowable stresses in the concrete and steel reinforcement from both Codes. This approach for the design of the reactor building needs to be described in the appropriate subsections and tables of Sections 3.8.4 and 3.8.5, and Appendix 3G of the DCD.

Based on the above discussion, the ASME Code jurisdictional boundary for design, construction, fabrication, and inspection of the containment discussed in DCD Section 3.8.1 and as shown in DCD Figure 3.8-1 would also need to be revised. As noted in the Supplement 1 response to this RAI, Interpretation No. 12 (III-2-83-01) of ASME Code Section III states that when the containment mat is integral with other building foundations, only the portion of the containment foundation mat directly beneath the containment vessel including any additional peripheral volume for anchoring of the containment shell reinforcement shall be considered within the code jurisdictional boundary and constructed in accordance with the rules of ASME Code Section III, Division 2. Based on this interpretation, Section 3.8.1 of the DCD including Figure 3.8-1 also needs to be revised to indicate that where integral connections from the reactor building exist (i.e., base mat beyond the containment foundation mat directly beneath the containment vessel as well as floor and walls integrally connected to the containment) the additional peripheral volume for anchoring the containment shell reinforcement shall be within the Code jurisdictional boundary, and thus are subject to all of the rules in ASME Code Section III, Division 2.

GEH Response

The design approach described in NRC RAI 3.8-4, Supplement 2 will be incorporated into the appropriate subsections and tables of DCD Tier 2 Subsection 3.8.4 and DCD Tier 2 Appendix 3G.

DCD Tier 2 Subsection 3.8.1, including DCD Tier 2 Figure 3.8-1, will be revised incorporating the statement of Interpretation No. 12 (III-2-83-01) of ASME Code Section III. The boundaries of the additional peripheral volumes are determined based on the required development lengths of containment reinforcements.

As for the design of the additional peripheral volume, the development length of the containment reinforcement in the area is determined in accordance with ASME Section III, Division 2. However, the section design is performed using the same method as other RB areas. As described in NRC RAI 3.8-4, Supplement 2, the RB concrete structures are designed for the envelope of the loading combinations and the allowable stresses specified in ACI 349-01 and 2004 ASME Section III, Division 2, Subsection CC. Therefore, the application of the RB design method is more conservative.

Although the CB and FWSC are not structurally integrated with the containment structure, their section design is conservatively taken to be the more limiting of ACI 349-01 and 2004 ASME Section III, Division 2, Subsection CC requirements, utilizing the existing code conformance check algorithm of the SSDP-2D computer code, and will be clarified in DCD Tier 2 Subsections 3G.2.5.4 and 3G.4.5.4 and Tables 3G.2-6 and 3G.4-6.

DCD Impact

DCD Tier 2 Subsections 3.8.1.1.1, 3.8.4.3.1.2, 3.8.4.3.2, 3.8.4.3.5, 3.8.4.5.1, 3.8.4.5.2, 3.8.4.5.5, 3G.1.5.2.2.4, 3G.2.5.4, 3G.3.5.2.2, 3G.4.5.4, Figure 3.8-1 and Tables 3G.1-11, 3G.2-6, 3G.3-4 and 3G.4-6 will be changed in ESBWR DCD Tier 2, Revision 5 as noted in the attached markups.

3.8 SEISMIC CATEGORY I STRUCTURES

The Seismic Category I structures include the Concrete Containment, Reactor Building (RB), Control Building (CB), Fuel Building (FB) and Fire Water Service Complex (FWSC).

3.8.1 Concrete Containment

The containment structure is designed to house the primary nuclear system and is part of the containment system, whose functional requirement is to confine the potential release of radioactive material in the event of a LOCA. The containment structure is totally enclosed by the Reactor Building. This subsection describes the concrete containment structure. Steel components of the containment that resist pressure and are not backed by structural concrete are discussed in Subsection 3.8.2. A detailed functional description of the containment system is presented in Section 6.2.

3.8.1.1 Description of the Containment

3.8.1.1.1 Concrete Containment

The containment is shown in the summary report contained in Appendix 3G Section 3G.1. Appendix 3G Section 3G.1 contains a more detailed description of the containment and the analytical models, inputs, analytical procedures, figures, results from controlling load combinations, components with controlling concrete stresses, reinforcement stresses, and liner strains for the concrete containment vessel.

The containment is a low-leakage reinforced concrete structure with an internal steel liner in the drywell and wetwell to serve as a leaktight membrane. The containment is a cylindrical shell structure, which consists of the reactor pressure vessel (RPV) pedestal, the containment cylindrical wall, the top slab, the suppression pool slab and the foundation mat. The containment is divided by the diaphragm floor and the vent wall into a drywell (upper and lower) and a wetwell. The top slab of the concrete containment is an integral part of the Isolation Condenser/Passive Containment Cooling (IC/PCC) pools ~~and the services pools for storage of Dryer/Separator and other uses~~(including expansion pools), the buffer pool, which is also used to store the dryer, and the equipment storage pool, which is also used to store the chimney partitions and the separator. The pool girders, which serve as barriers of the pools, rigidly connect the top slab and the Reactor Building (RB) walls. The RB floors that surround the containment walls and walls that are under the suppression pool floor slab are also integrated structurally with the concrete containment. The containment foundation mat is continuous with the RB foundation mat, and the ~~Fuel Building (~~FB~~)~~ as well. The containment and the structures integrated with the containment are constructed of cast-in-place, reinforced concrete.

The configuration of the containment is shown in Figure 3.8-1. Additional peripheral volumes for anchoring of the containment reinforcements are considered within the code jurisdictional boundary and constructed in accordance with the rules of ASME Code Section III, Division 2. The boundaries of the additional peripheral volumes are determined based on the required development lengths of containment reinforcements. The key dimensions of the containment are summarized in Table 3.8-1.

Y_j = Jet impingement equivalent static load on a structure generated by the postulated break and including a calculated dynamic factor to account for the dynamic nature of the load.

Y_m = Missile impact equivalent static load on a structure generated by or during the postulated break, like pipe whipping, and including a calculated dynamic factor to account for the dynamic nature of the load.

W = Wind force (Subsection 3.3.1)

W_t = Tornado load (Subsection 3.3.2) (tornado-generated missiles are described in Subsection 3.5.1.4, and barrier design procedures in Subsection 3.5.3.)

P_a = Accident pressure at main steam tunnel due to high energy line break.

F = Internal pressures resulting from flooding of compartments.

E' = Safe shutdown earthquake (SSE) loads as defined in Section 3.7 including SSE-induced hydrodynamic pressures in pools. The impulsive and convective pressures may be combined by the SRSS method.

T_o = Thermal effects — load effects induced by normal thermal gradients existing through the RB wall and roof. Both summer and winter operating conditions are considered. In all cases, the conditions are considered of long enough duration to result in a straight line temperature gradient. The temperatures are listed in Table 3.8-10. The stress free temperature for the design is 15.5°C (59.9°F).

T_a = Thermal effects (including T_o) which may occur during a design accident.

H = Loads caused by static or seismic earth pressures and water in soil.

3.8.4.3.1.2 Load Combinations for Concrete Members

For the load combinations in this subsection, where any load reduces the effects of other loads, the corresponding coefficient for that load is taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise, the coefficient for that load is taken as zero.

The safety-related concrete structure is designed using the loads, load combinations, and load factors listed in Table 3.8-15. Because a number of concrete structures in the RB are integrally connected with the concrete containment, the load combinations for the concrete containment, which are listed in Table 3.8-2, are additionally considered in the design of the RB concrete structures. The maximum co-directional responses to each of the excitation components for seismic loads are combined by the ~~100/40/40~~SRSS method as described in Subsection 3.8.1.3.6.

3.8.4.3.1.3 Load Combinations for Steel Members

The safety-related steel structure is designed using the loads, load combinations, and load factors listed in Table 3.8-16. The maximum co-directional responses to each of the excitation components for seismic loads are combined by the ~~100/40/40~~SRSS method as described in Subsection 3.8.1.3.6.

In all these load combinations, both cases of L having its full value or being completely absent are checked.

3.8.4.3.2 Control Building

Refer to the loads, notations, and combinations established in Subsection 3.8.4.3.1, except that fluid pressure F, accident pressure P_a, and pipe break loads Y_r, Y_j, Y_m do not exist. In addition, because the CB is structurally separated from the concrete containment, the load combinations for the concrete containment do not apply to the CB design. The live loads and temperature loads are as follows:

- All concrete floors except for HVAC room – 4.8 kPa (100 psf)
- Concrete floors in HVAC room – 2.9 kPa (60 psf)
- Concrete roof – 2.9 kPa (60 psf)
- Construction live load on floor framing in addition to dead weight of floor – 2.4 kPa (50 psf)

The temperatures during normal operating conditions are shown in Table 3.8-11. The temperatures during abnormal operating conditions are shown in Table 3H-10 and are associated with a postulated loss of HVAC function.

3.8.4.3.3 Fuel Building

Refer to the loads, notations, and combinations established in Subsection 3.8.4.3.1, except that fluid pressure F, accident pressure P_a, and pipe break loads Y_r, Y_j, Y_m do not exist. The accident thermal load, T_a, includes the thermal effects in the spent fuel pool which may occur due to loss of FAPCS cooling function. The live loads and temperature loads are as follows:

- All concrete floors except for HVAC room – 4.8 kPa (100 psf)
- Concrete floors in HVAC room – 2.9 kPa (60 psf)
- Concrete roof – 2.9 kPa (60 psf)
- Construction live load on floor framing in addition to dead weight of floor – 2.4 kPa (50 psf)

The temperatures during normal operating conditions are shown in Table 3.8-12.

3.8.4.3.4 Radwaste Building

Loads and load combinations listed in Table 3.8-9 Item 32, Safety Class RW-IIa is used for the design of the RW.

3.8.4.3.5 Fire Water Service Complex

Refer to the loads, notations, and combinations established in Subsection 3.8.4.3.1, except that fluid pressure F, accident pressure P_a, accident thermal T_a, accident pipe reactions R_a and pipe break loads Y_r, Y_j, Y_m do not exist. In addition, because the FWSC is structurally separated from the concrete containment, the load combinations for the concrete containment do not apply to the FWSC design. The live loads and temperature loads are as follows:

- All concrete floors (except FWS areas) - 4.8 kPa (100 psf)
- Concrete roof - 2.9 kPa (60 psf)
- Construction live load on floor framing in addition to dead weight of floor - 2.4 kPa (50 psf)

The temperatures during normal operating conditions are shown in Table 3.8-18.

3.8.4.4 Design and Analysis Procedures

3.8.4.4.1 Reactor Building, Control Building and Fuel Building

The Reactor Building (RB), Control Building (CB) and ~~Fuel Building (~~FB~~)~~ are analyzed using the linear elastic ~~finite element (~~FE~~)~~ computer program NASTRAN described in Appendix 3C.

As described in Subsection 3.8.4.1.3, the RB and FB is integrated into one building. Therefore, the RB/FB structure is analyzed using a common FE model, which includes the RB and FB and also the concrete containment. The model is described in Appendix 3G Subsection 3G.1.4.1.

The FE analysis model of the CB includes the entire structure. The details of the FE model of the CB are described in Appendix 3G Subsection 3G.2.4.1.

The foundation soil is simulated by a set of horizontal and vertical springs in each model. The soil spring constraints are calculated based on the properties of the soil spring used in the Soil – Structure Interaction (SSI) analysis model, which is described in Appendix 3A. The constraints by soil surrounding the buildings are conservatively neglected in the FE models.

3.8.4.4.2 Radwaste Building

The RW is described in Subsection 3.8.4.1.5. The design is in accordance with the criteria in Table 3.8-9 Item 32 for Safety Class RW-IIa.

3.8.4.4.3 Fire Water Service Complex

As described in Subsection 3.8.4.1.4, the FWSC consists of two FWS and a FPE that share a common basemat. Therefore, the FWSC structures are analyzed using a common FE model, which includes the two FWS and a FPE. The model is described in Appendix 3G, Subsection 3G.4.4.1.

The foundation soil is simulated by a set of horizontal and vertical springs in the model. The soil spring constraints are calculated based on the properties of the soil spring used in the Soil-Structure Interaction (SSI) analysis model, which is described in Appendix 3A.

3.8.4.5 Structural Acceptance Criteria

3.8.4.5.1 Reactor Building

The acceptance criteria for the design of the safety-related reinforced concrete structure are included in Table 3.8-15. "U" in Table 3.8-15 is the section strength required to resist design loads based on the strength design method described in Table 3.8-9 item 1 and in SRP 3.8.4 Section II.3. For the acceptance criteria for the load combinations in Table 3.8-2, which is also applicable to the RB concrete design, refer to Subsection 3.8.1.5.

The RB is designed to the more limiting acceptance criteria of the ASME Section III, Division 2, Subsection CC and ACI 349-01. The relevant acceptance criteria are allowable compressive stress in concrete, allowable tensile and compressive stresses in reinforcing steel, and allowable transverse shear stress for the design of RB concrete elements. For a combination of axial force and bending moment, the acceptance criteria of ASME Section III, Division 2, Subsection CC are more limiting than ACI 349-01 and are applied in the RB design. The acceptance criteria for transverse shear are essentially the same between ASME Section III, Division 2, Subsection CC and ACI 349-01. Therefore, the ACI-349-01 acceptance criteria for transverse shear are applied in the RB design. The aforementioned acceptance criteria is also applicable to the additional peripheral volumes for anchoring the containment reinforcement, which are shown in Figure 3.8-1.

The acceptance criteria for the design of the safety-related steel structure are included in Table 3.8-16. Allowable elastic working stress, S, is the allowable stress limit specified in Part 1 of ANSI/AISC N690.

The design criteria preclude excessive deformation of the Reactor Building.

3.8.4.5.2 Control Building

~~The acceptance criteria for the design of the Control Building are same as the Reactor Building in Subsection 3.8.4.5.1.~~The acceptance criteria for the design of the safety-related reinforced concrete structure are included in Table 3.8-15. "U" in Table 3.8-15 is the section strength required to resist design loads based on the strength design method described in Table 3.8-9 item 1 and in SRP 3.8.4 Section II.3.

The acceptance criteria for the design of the safety-related steel structure are included in Table 3.8-16. Allowable elastic working stress, S, is the allowable stress limit specified in Part 1 of ANSI/AISC N690. The design criteria preclude excessive deformation of the Control Building.

3.8.4.5.3 Fuel Building

The acceptance criteria for the design of the Fuel Building are same as the Reactor Building in Subsection 3.8.4.5.1.

3.8.4.5.4 Radwaste Building

Structural acceptance criteria and materials criteria for the RW is in accordance with Item 32 in Table 3.8-9 for Safety Class RW-IIa.

3.8.4.5.5 Fire Water Service Complex

The acceptance criteria for the design of the FWSC are the same as the ~~Reactor~~ Control Building, which is discussed in Subsection 3.8.4.5.~~1~~2.

3.8.4.6 Material, Quality Control and Special Construction Techniques

This subsection contains information related to the materials, quality control and special construction techniques used in the construction of other Seismic Category I structures.

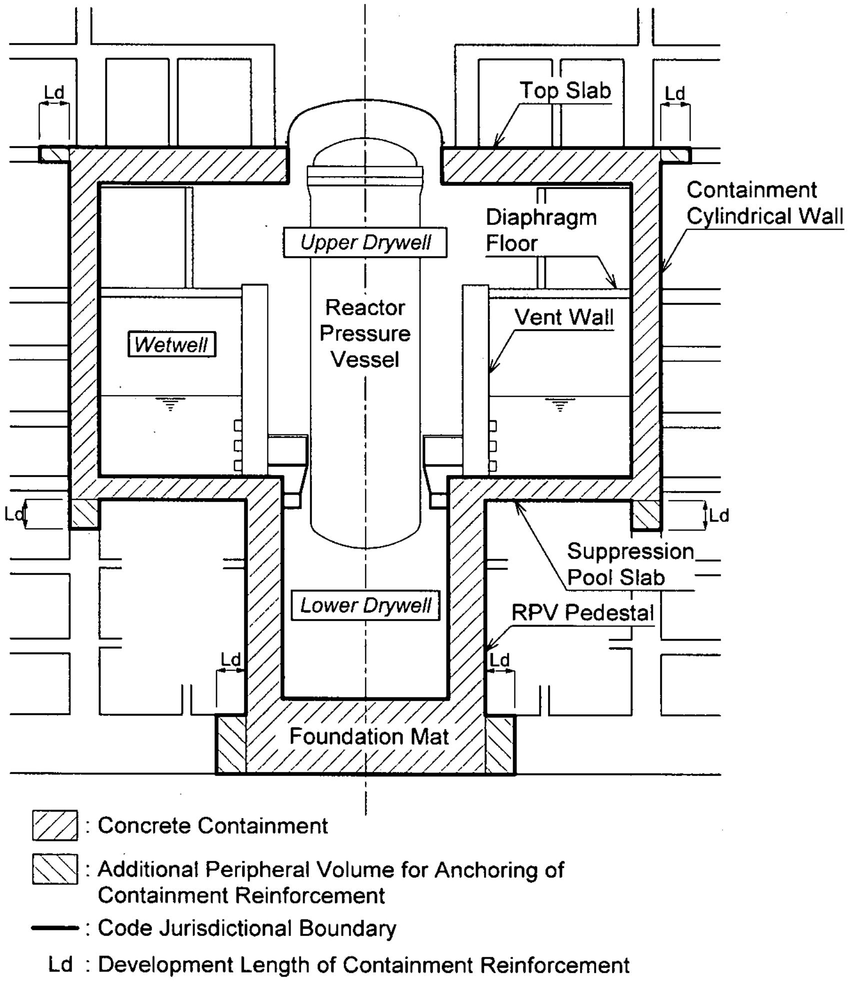

Figure 3.8-1. Configuration of Concrete Containment

3G.1.5.2.2.2 Steel Containment Components

Table 3.8-4 gives a detailed list of various load combinations with acceptance criteria per ASME Section III Division 1, Subsection NE. For the drywell head, the loads of W, W', R_o, R_a and Y are not direct loads and their indirect effects through the supporting RCCV top slab are negligibly small.

3G.1.5.2.2.3 Containment Internal Structures

Table 3.8-7 gives a detailed list of various load combinations with acceptance criteria per ANSI/AISC N690.

3G.1.5.2.2.4 Reactor Building (RB) Concrete Structures Including Pool Girders

~~Table 3.8-15 gives load combinations for the safety-related reinforced concrete structure.~~Load combinations and acceptance criteria for the RB concrete structures are described in Subsections 3.8.4.3.1.2 and 3.8.4.5.1, respectively. Based on previous experience, critical load combinations are selected for the RB design. They are mainly combinations including LOCA loads and seismic loads as shown in Table 3G.1-11. The acceptance criteria for the selected combinations are also included in Table 3G.1-11.

3G.1.5.2.3 Material Properties

3G.1.5.2.3.1 Concrete

Properties of concrete used for the design analyses are shown in Table 3G.1-12.

Concrete has a tendency to change properties when subjected to elevated temperatures. For the ESBWR design, reduction of concrete strength due to high temperature is determined based upon the average value of the following upper bound and lower bound equations excerpted from Reference 3G.1-1.

- Lower bound reduction factor
  - $\phi = 1.0 - 0.0030\ (T-21.1)$ 21.1°C (70°F) ≤ T ≤ 121.1°C (250°F)
  - $\phi = 0.70 - 0.00083\ (T-121.1)$ 121.1°C (250°F) ≤ T
- Upper bound reduction factor
  - $\phi = 1.0$ T ≤ 260.0°C (500°F)
  - $\phi = 1.0 - 0.00081\ (T-260.0)$ 260.0°C (500°F) ≤ T

Young's modulus for concrete is also determined based upon the average value of the following upper bound and lower bound equations excerpted from Reference 3G.1-1.

- Lower bound reduction factor
  - $\phi = 1.0 - 0.0069\ (T-21.1)$ 21.1°C (70°F) ≤ T ≤ 93.3°C (200°F)
  - $\phi = 0.50 - 0.0009\ (T-93.3)$ 93.3°C (200°F) ≤ T
- Upper bound reduction factor
  - $\phi = 1.0 - 0.00056\ (T-21.1)$ 21.1°C (70°F) ≤ T ≤ 204.4°C (400°F)

Table 3G.1-10

Selected Load Combinations for the RCCV

Category	Load Combination											Acceptance Criteria*1
	No.*2	D	L	P_t	P_a	T_a	E'*3	R_a*3	SRV*3	CO*3	CHUG*3	
SIT (maximum pressure)	CV-1	1.0	1.0	1.0								S
LOCA (1.5Pa) 6 minutes	CV-7a	1.0	1.0		1.5	1.0		1.0	1.0	1.5		U
LOCA (1.5Pa) 72 hours	CV-7b	1.0	1.0		1.5	1.0		1.0	1.0		1.5	U
LOCA + SSE 6 minutes	CV-11a	1.0	1.0		1.0	1.0	1.0	1.0	1.0	1.0		U
LOCA + SSE 72 hours	CV-11b	1.0	1.0		1.0	1.0	1.0	1.0	1.0		1.0	U

Note:

*1: S = Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3430 for Service Load Combination.
U = Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination.

*2: Based on Table 3.8-2

*3: In load combinations that combine SSE with SRV, CHUG and CO, the loads are combined by SRSS.

Table 3G.1-11

Selected Load Combinations for the RB

Category	Load Combination												Acceptance Criteria*1
	No.*2	D	L	P_a*3	T_o	T_a*3	E'*4	W	R_a*4	SRV*4	CO*4	CHUG*4	
Severe Environmental	RB-4	1.05	1.3		1.3			1.3					U
LOCA (1.5P_a) 6 minutes	RB-8a	1.0	1.0	1.5		1.0			1.0	1.0	1.5		U
LOCA (1.5P_a) 72 hours	RB-8b	1.0	1.0	1.5		1.0			1.0	1.0		1.5	U
LOCA + SSE 6 minutes	RB-9a	1.0	1.0	1.0		1.0	1.0		1.0	1.0	1.0		U
LOCA + SSE 72 hours	RB-9b	1.0	1.0	1.0		1.0	1.0		1.0	1.0		1.0	U

Note:

*1: U = Envelope of "Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01."

*2: Based on Table 3.8-15

*3: P_a and T_a are accident pressure load within the containment and thermal load generated by LOCA, respectively.
P_a and T_a are indirect loads, but their effects are considered in the RB design.

*4: In load combinations that combine SSE with SRV, CHUG and CO, the loads are combined by SRSS.

3G.2.5.2.3 Material Properties

Properties of the materials used for the CB design analyses are the same as those for the RB, and they are described in Subsection 3G.1.5.2.3.

3G.2.5.3 Stability Requirements

The stability requirements for the CB foundation are same as those for the RB, and they are described in Subsection 3G.1.5.3.

3G.2.5.4 Structural Design Evaluation

The evaluation of the Seismic Category I structures in the CB is performed using the same procedure as the RB, which is described in Subsection 3G.1.5.4.

The locations of the sections that are selected for evaluation are indicated in Figures 3G.2-5 through 11. They are selected, in principle, from the center and both ends of wall and slab, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. Tables 3G.2-7 through 3G.2-11 show the forces and moments at the selected sections from NASTRAN analysis. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.2-16. Tables 3G.2-12 through 3G.2-15 show the combined forces and moments in accordance with the selected load combinations listed in Table 3G.2-6.

Table 3G.2-16 lists the sectional thicknesses and rebar ratios used in the evaluation. The values are retrieved from the outline drawings shown in Figures 3G.2-1 through 3G.2-3.

~~Tables 3G.2-17 through 3G.2-24 show the rebar and concrete stresses at these sections for the representative elements.~~Tables 3G.2-17 through 3G.2-24 compares the rebar and concrete stresses at these sections for the representative elements with the allowable stresses, which are conservatively taken to be the more limiting of ACI 349-01 and ASME Section III Division 2. Table 3G.2-25 summarizes evaluation results for transverse shear in accordance with ACI 349, Chapter 11.

3G.2.5.4.1 Shear Walls

The maximum rebar stress of 338.0 MPa (49.02 ksi) is found in the vertical rebar in the wall at EL -7400 due to the load combination CB-9 as shown in Table 3G.2-24. The maximum horizontal rebar stress is found to be 286.0 MPa (41.48 ksi) also in 2F wall due to the load combination CB-9. The maximum transverse shear force is found to be 1.210 MN/m (6.9 kips/in) against the shear strength of 1.826 MN/m (10.4 kips/in) in the wall at EL -7400.

3G.2.5.4.2 Floor Slabs

The maximum rebar stress of 258.2 MPa (37.45 ksi) is found in the roof at EL 13800 due to the load combination CB-9 as shown in Table 3G.2-23. The maximum transverse shear force is found to be 0.270 MN/m (1.54 kips/in) against the shear strength of 0.734 MN/m (4.19 kips/in).

Table 3G.2-6

Selected Load Combinations for the CB

Category	Load Combination								Acceptance Criteria*1
	No. *2	D	L	T_o	T_a	E'	W	W_t	
Severe	CB-3	1.4	1.7				1.7		U
Environmental	CB-4	1.05	1.3	1.3			1.3		U
Tornado	CB-7	1.0	1.0	1.0				1.0	U
LOCA + SSE	CB-9	1.0	1.0		1.0	1.0			U

*1: U = Conservatively taken as envelope of "Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01."

*2: Based on Table 3.8-15.

temperature distributions for various structural elements of the FB, and Table 3G.3-3 shows the magnitude of equivalent linear temperature distribution.

The evaluation method of temperature effect on the concrete design is based on ACI 349-01 Commentary Figure RA.1.

Two cases, winter and summer, are considered in the analysis.

Stress-free temperature is 15.5°C (60°F).

3G.3.5.2.1.7 Design Seismic Loads

The design seismic loads applied to the FB are provided in Subsection 3G.1.5.2.1.13.

Seismic lateral soil pressure for the FB is provided in Subsection 3G.1.5.2.1.13.

3G.3.5.2.2 Load Combinations and Acceptance Criteria

~~Table 3.8-15 gives load combinations for the safety-related reinforced concrete structure.~~Load combinations and acceptance criteria for the FB concrete structures are described in Subsections 3.8.4.3.3 and 3.8.4.5.3, respectively. Based on previous experience, critical load combinations are selected for the FB design. They are mainly combinations including LOCA loads and seismic loads as shown in Table 3G.3-4. The acceptance criteria for the selected combinations are also included in Table 3G.3-4.

3G.3.5.2.3 Material Properties

Properties of the materials used for the FB design analyses are the same as those for the RB, and they are described in Subsection 3G.1.5.2.3.

3G.3.5.3 Stability Requirements

The stability requirements for the FB foundation are the same as the RB and are described in Subsections 3G.1.5.3 and 3G.1.5.5.

3G.3.5.4 Structural Design Evaluation

The evaluation of the seismic Category I structures in the FB is performed with the same procedure as the RB, which is described in Subsection 3G.1.5.4.

Figure 3G.3-2 shows the location of the sections that are selected for evaluation. They are selected, in principle, from the center and both ends of wall and slab, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. Tables 3G.3-5 through 3G.3-9 show the forces and moments at the selected sections from NASTRAN analysis. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.3-3. Tables 3G.3-10 through 3G.3-12 show the combined forces and moments in accordance with the selected load combinations listed in Table 3G.3-4.

Figures 3G.3-4 and 3G.3-5 present the design drawings used for the evaluation of the FB structural design. Table 3G.3-13 lists the sectional thicknesses and rebar ratios used in the evaluation.

Table 3G.3-4

Selected Load Combinations for the FB

Category	Load Combination											Acceptance Criteria*1
	No. *2	D	L	P_a*3	T_o	T_a*3	E'*4	W	R_a*4	SRV*4	CHUG*4	
Severe Environmental	FB-4	1.05	1.3		1.3			1.3				U
LOCA (1.5P_a) 72 hours	FB-8	1.0	1.0	1.5		1.0			1.0	1.0	1.5	U
LOCA + SSE 72 hours	FB-9	1.0	1.0	1.0		1.0	1.0		1.0	1.0	1.0	U

*1: U = Envelope of "Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01."

*2: Based on Table 3.8-15.

*3: P_a and T_a are accident pressure load within the containment and thermal load generated by LOCA, respectively. T_a includes the thermal effects in the spent fuel pool due to loss of FAPCS cooling function.

P_a and T_a are indirect loads, but their effects are considered in the FB design.

*4: In load combinations that combine SSE with SRV, CHUG and CO, the loads are combined by SRSS.

3G.4.5.2.1.5 Tornado Load (W_t)

The tornado load is applied to the roof slab and external walls above grade and its characteristics are given in Table 3G.1-2. The tornado load, W_t, is further defined by the combinations described in Subsection 3G.1.5.2.1.5.

3G.4.5.2.1.6 Thermal Load (T_o)

Thermal load for the FWSC is evaluated for the normal operating condition. Figure 3G.4-7 shows the section location for temperature distributions for various structural elements of the FWSC, and Table 3G.4-4 shows the magnitude of equivalent linear temperature distribution.

Stress-free temperature is 15.5°C (60°F).

3G.4.5.2.1.7 Design Seismic Loads

The design seismic loads are obtained by soil – structure interaction analyses, which are described in Appendix 3A. The seismic loads used for design are as follows:

- Figures 3G.4-8, 3G.4-9: design seismic shears and moments
- Table 3G.4-5: maximum vertical acceleration

The seismic loads are composed of two perpendicular horizontal and one vertical components. The effects of the three components are combined based on the ~~100/40/40~~SRSS method as described in Subsection 3.8.1.3.6.

3G.4.5.2.2 Load Combinations and Acceptance Criteria

Table 3.8-15 gives load combinations for the safety-related reinforced concrete structure. Based on previous experience, critical load combinations are selected for the FWSC design as shown in Table 3G.4-6. The acceptance criteria for the selected combinations are also included in Table 3G.4-6.

3G.4.5.2.3 Material Properties

Properties of the materials used for the FWSC design analyses are the same as those for the RB, and they are described in Subsection 3G.1.5.2.3.

3G.4.5.3 Stability Requirements

The stability requirements for the FWSC foundation are same as those for the RB, and they are described in Subsection 3G.1.5.3.

3G.4.5.4 Structural Design Evaluation

The evaluation of the Seismic Category I structures in the FWSC is performed using the same procedure as the RB, which is described in Subsection 3G.1.5.4.

The locations of the sections that are selected for evaluation are indicated in Figures 3G.4-3 through 3G.4-6. They are selected, in principle, from the center and both ends of wall and slab, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. Tables 3G.4-7 through 3G.4-11 show the forces and moments at the selected sections from NASTRAN analysis. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.4-10. Tables 3G.4-12 through 3G.4-15 show the combined forces and moments in accordance with the selected load combinations listed in Table 3G.4-6.

Table 3G.4-16 lists the sectional thicknesses and rebar ratios used in the evaluation. The values are retrieved from the outline drawings shown in Figure 3G.4-1.

~~Tables 3G.4-17 through 3G.4-20 show the rebar and concrete stresses at these sections for the representative elements.~~Tables 3G.4-17 through 3G.4-24 compares the rebar and concrete stresses at these sections for the representative elements with the allowable stresses, which are conservatively taken to be the more limiting of ACI 349-01 and ASME Section III Division 2. Table 3G.4-21 summarizes evaluation results for transverse shear in accordance with ACI 349, Chapter 11.

3G.4.5.4.1 Shear Walls

The maximum rebar stress of ~~285.5~~330.2 MPa (~~41.41~~47.89 ksi) is found in the vertical rebar of FWS cylindrical wall due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum horizontal rebar stress is found to be ~~230.7~~154.1 MPa (~~33.46~~22.35 ksi) ~~also~~ in FWS cylindrical wall due to the load combination FWSC-6. The maximum transverse shear force is found to be ~~0.840~~0.525 MN/m (~~4.80~~3.00 kips/in) against the shear strength of ~~1.632~~1.594 MN/m (~~9.32~~9.10 kips/in) in the FWS cylindrical wall.

As for the FPE, the maximum rebar stress of ~~220.3~~224.8 MPa (~~31.95~~32.61 ksi) is found in the horizontal rebar of east wall due to the load combination FWSC-6. The maximum vertical rebar stress is found to be ~~201.5~~191.8 MPa (~~29.23~~27.82 ksi) in ~~south~~ east wall in the same load combination. The maximum transverse shear force is found to be ~~0.838~~0.691 MN/m (~~4.79~~3.95 kips/in) against the shear strength of ~~1.205~~1.322 MN/m (~~6.88~~7.55 kips/in).

3G.4.5.4.2 Roof Floor Slabs

As for the FPE roof slab, the maximum rebar stress of ~~253.4~~252.3 MPa (~~36.75~~36.59 ksi) is found due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum transverse shear force is found to be ~~0.117~~0.231 MN/m (~~0.67~~1.32 kips/in) against the shear strength of ~~0.399~~0.363 MN/m (~~2.28~~2.07 kips/in) in the roof of FPE.

On the FWS roof slab, the maximum rebar stress of ~~177.4~~193.2 MPa (~~25.73~~28.02 ksi) is found due to the load combination FWSC-6. The maximum transverse shear force is found to be ~~0.065~~0.105 MN/m (~~0.37~~0.60 kips/in) against the shear strength of ~~0.386~~0.389 MN/m (~~2.20~~2.22 kips/in).

3G.4.5.4.3 Foundation Mat

The maximum rebar stress is found to be ~~294.8~~293.7 MPa (~~42.76~~42.60 ksi) due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum transverse shear force is found to be ~~2.492~~2.616 MN/m (~~14.23~~14.94 kips/in) against the shear strength of ~~5.394~~4.454 MN/m (~~30.80~~25.43 kips/in).

3G.4.5.4.4 Shear Key

The maximum rebar stress of 74.9 MPa (10.86 ksi) is found in the horizontal rebar of shear key due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum vertical rebar stress is found to be 65.7 MPa (9.53 ksi) in the same load combination. The maximum

Table 3G.4-5

Maximum Vertical Acceleration

Elevation (m)	Node No.	Stick Model	Max. Vertical Acceleration (g)
19.70	10	FWS	1.69
17.25	9	FWS	1.64
15.53	8	FWS	1.58
13.81	7	FWS	1.58
12.10	6	FWS	1.43
11.00	5	FWS	1.23
9.90	4	FWS	1.13
8.81	3	FWS	1.05
6.73	2	FWS	1.00
4.65	8002	FWSC	0.78
2.15	8001	FWSC	0.78
19.70	11	Oscillator	3.26

Elevation (m)	Node No.	Stick Model	Max. Vertical Acceleration (g)
8.25	405	FPE	1.12
6.45	402	FPE	1.09

See Figure 3A.7-7 for the node numbers.

Table 3G.4-6

Selected Load Combinations for FWSC

Category	Load Combination									Acceptance Criteria*1
	No.*2	D	L	H	T_o	E'	W	W_t	R_o	
Severe	FWSC-3	1.4	1.7	1.7			1.7		1.7	U
Environmental	FWSC-4	1.05	1.3	1.3	1.3		1.3		1.3	U
SSE	FWSC-6	1.0	1.0	1.0	1.0	1.0			1.0	U
Tornado	FWSC-7	1.0	1.0	1.0	1.0			1.0	1.0	U

*1: U = Conservatively taken as envelope of "Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01".

*2: Based on Table 3.8-15.

ENCLOSURE 2

MFN 08-339

Partial Response to NRC RAI Letter No. 148

Related to ESBWR Design Certification Application

Seismic Category I Structures

RAI Numbers 3.8-101 S03, 3.8-102 S03 and 3.8-103 S03

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

The Original Response, Supplement 1 and Supplement 2 were previously submitted under MFNs 06-407, 06-407 Supplement 1, and 06-407 Supplement 3, respectively, and are included to provide historical continuity during review.

NRC RAI 3.8-101

DCD Section 3.8.5.2 implies that two separate sets of codes, standards, and specifications were used for the common RCCV/RB/FB foundation. Was the common foundation supporting the RCCV, RB, and FB actually designed to two different sets of codes, standards and specifications, as indicated, or was a uniform design basis employed? If two different design bases were employed, explain how this was implemented and justify the jurisdictional boundary.

Include this information in DCD Section 3.8.5.2. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Section designs of the portions, which are included in the RCCV, are performed in accordance with the ASME code, and other portions outside of containment are designed in accordance with ACI 349.

The loads and load combinations that cover both codes are considered for the whole basemat for conservatism.

See also response to NRC RAI 3.8-4.

No DCD change was made in response to this RAI.

NRC RAI 3.8-101, Supplement 1

NRC Assessment Following the December 14, 2006 Audit

GE's response to RAI 3.8-101 does not adequately address RAIs 3.8-101, -102, and -103. There is no discussion of how jurisdictional boundaries have been evaluated. How are loads and load combinations that cover both codes considered for the whole basemat? Were the code-specific acceptance criteria applied to the whole basemat, for the code-specific load combinations? Was there redundancy of evaluation, to effectively qualify the whole basemat in accordance with both codes?

During the audit, it was agreed that this issue is being addressed under RAI 3.8-4.

GE Response

See response to NRC RAI 3.8-4, Supplement 1 for further clarification of jurisdictional boundaries.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-101, Supplement 2

NRC Assessment from Chandu Patel E-mail Dated May 24, 2007

This RAI relates to the jurisdictional boundary between the containment and other Category I structures. This issue is discussed under RAI 3.8-4, which is currently unresolved. When resolved, DCD Section 3.8.5.2 will need to be revised to reflect the resolution.

GEH Response

Please see the response to NRC RAI 3.8-4, Supplement 2.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-101, Supplement 3

The response, transmitted in GEH letter dated November 28, 2007, refers to RAI 3.8-4, Supplement 2 for resolution of this RAI. While significant progress has been made in resolving RAI 3.8-4, it still remains open; therefore, RAI 3.8-101 must also remain open. When RAI 3.8-4 is fully resolved, then the existing text in DCD Section 3.8.5.2 and other related sections (e.g., Appendix 3G) need to be revised to properly describe the applicable codes, standards and specifications for the foundations of the reactor building and the other Seismic Category I structures. The revised text should not simply refer to Section 3.8.1.2 and 3.8.4.2 as it does now unless the referenced sections clearly explain which specific codes, standards and specifications apply to each foundation covered in DCD Section 3.8.5.

GEH Response

The applicable codes, standards and specifications for the foundations of the RCCV, RB, CB, FB, and FWSC are the same as those for the superstructures consistent with SRP 3.8.5 Section II.2 and will be clarified in DCD Tier 2 Subsection 3.8.5.2.

A reference to DCD Tier 2 Subsection 3.8.1.1.3 for the jurisdictional boundary for application of Section III, Division 2 of the ASME Code to the concrete containment foundation will be added to DCD Tier 2 Subsection 3.8.5.2.

DCD Impact

DCD Tier 2 Subsection 3.8.5.2 will be changed in DCD Revision 5 as noted in the attached markup.

NRC RAI 3.8-102

DCD Section 3.8.5.3 implies that two different sets of loads and load combinations were used for design of the common RCCV/RB/FB foundation. For the common foundation supporting the RCCV, RB and FB, explain how two different sets of loads and load combinations were implemented and justify the jurisdictional boundary.

Include this information in DCD Section 3.8.5.3. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Refer to the response to NRC RAI 3.8-101.

No DCD change was made in response to this RAI.

NRC RAI 3.8-102, Supplement 1

NRC Assessment Following the December 14, 2006 Audit

GE refers to response to RAI 3.8-101. See staff assessment of response to RAI 3.8-101. During the audit, it was agreed that this issue is being addressed under RAI 3.8-4.

GE Response

See response to NRC RAI 3.8-4.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-102, Supplement 2

NRC Assessment from Chandu Patel E-mail Dated May 24, 2007

This RAI relates to the jurisdictional boundary between the containment and other Category I structures. This issue is discussed under RAI 3.8-4, which is currently unresolved. When resolved, DCD Section 3.8.5.3 will need to be revised to reflect the resolution.

GEH Response

Please see the response to NRC RAI 3.8-4, Supplement 2.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-102, Supplement 3

The response, transmitted in GEH letter dated November 28, 2007, refers to RAI 3.8-4, Supplement 2 for resolution of this RAI. While significant progress has been made in resolving RAI 3.8-4, it still remains open; therefore, RAI 3.8-102 must also remain open. When RAI 3.8-4 is fully resolved, then the existing text in DCD Section 3.8.5.3 and other related sections (e.g., Appendix 3G) need to be revised to properly describe the loads and load combinations for the foundations of the reactor building and the other Seismic Category I structures. The revised text should not simply refer to Section 3.8.1.3 and 3.8.4.3 as it does now unless the referenced sections clearly explain which loads and load combinations apply to each foundation covered in DCD Section 3.8.5.

GEH Response

The loads and load combinations for the foundations of the RCCV, RB, CB, FB, and FWSC are the same as those for the superstructures with additional foundation stability requirements consistent with SRP 3.8.5 Section II.3 and will be clarified in DCD Tier 2 Subsection 3.8.5.3.

The additional SRP 3.8.5 Section II.3 requirements for foundation stability are already included in the last paragraph of DCD Tier 2 Subsection 3.8.5.3.

DCD Impact

DCD Tier 2 Subsection 3.8.5.3 will be changed in DCD Revision 5 as noted in the attached markup.

NRC RAI 3.8-103

DCD Section 3.8.5.5 describes the structural acceptance criteria for foundations and states that the containment portion follows DCD Section 3.8.1.5, and the rest of the foundations follow DCD Section 3.8.4.5. Was the common foundation supporting the RCCV, RB, and FB actually designed to two different sets of structural acceptance criteria, as indicated, or was uniform structural acceptance criteria employed? If two different structural acceptance criteria were employed, explain how this was implemented and justify the jurisdictional boundary.

Include this information in DCD Section 3.8.5.5. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Refer to the response to NRC RAI 3.8-101.

No DCD change was made in response to this RAI.

NRC RAI 3.8-103, Supplement 1

NRC Assessment Following the December 14, 2006 Audit

GE refers to response to RAI 3.8-101. See staff assessment of response to RAI 3.8-101. During the audit, it was agreed that this issue is being addressed under RAI 3.8-4.

GE Response

See response to NRC RAI 3.8-4.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-103, Supplement 2

NRC Assessment from Chandu Patel E-mail Dated May 24, 2007

This RAI relates to the jurisdictional boundary between the containment and other Category I structures. This issue is discussed under RAI 3.8-4, which is currently unresolved. When resolved, DCD Section 3.8.5.5 will need to be revised to reflect the resolution.

GEH Response

Please see the response to NRC RAI 3.8-4, Supplement 2.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 3.8-103, Supplement 3

The response, transmitted in GEH letter dated November 28, 2007, refers to RAI 3.8-4, Supplement 2 for resolution of this RAI. While significant progress has been made in resolving RAI 3.8-4, it still remains open; therefore, this RAI 3.8-103 must also remain open. When RAI 3.8-4 is fully resolved, then the existing text in DCD Section 3.8.5.5 and other related sections (e.g., Appendix 3G) need to be revised to properly describe the structural acceptance criteria for the foundations of the reactor building and the other Seismic Category I structures. The revised text should not simply refer to Section 3.8.1.5 and 3.8.4.5 as it does now unless the referenced sections clearly explain which acceptance criteria apply to each foundation covered in DCD Section 3.8.5.

GEH Response

The structural acceptance criteria for the foundations of the RCCV, RB, CB, FB, and FWSC are the same as those for the superstructures with additional foundation stability requirements consistent with SRP 3.8.5 Section II.5 and will be clarified in DCD Tier 2 Subsection 3.8.5.5.

The additional SRP 3.8.5 Section II.5 requirements for foundation stability are already included in DCD Tier 2 Subsection 3.8.5.5.

DCD Impact

DCD Tier 2 Subsection 3.8.5.5 will be changed in DCD Revision 5 as noted in the attached markup.

3.8.5.1 Description of the Foundations

The Reactor Building (RB) including the containment and ~~Fuel Building (~~FB~~)~~ are built on a common foundation mat as described in Subsection 3.8.4. The foundation of the ~~Control Building (~~CB~~)~~ is separated from the foundation of the RB and FB.

The foundation of the RB and FB is a rectangular reinforced concrete mat. Its key dimensions are shown in Table 3.8-13. The foundation mat is constructed of cast-in-place conventionally reinforced concrete. It supports the RB, the FB, the containment structure, and other internal structures. The containment structure foundation is defined as within the perimeter or the exterior surface of the containment structure. The containment foundation mat details are discussed in Subsection 3.8.1.1.1.

The Control Building foundation is rectangular reinforced concrete mat. The key dimensions are included in Table 3.8-13.

The foundation for Category I structures is contained in the summary stress reports for their respective buildings. The Reactor Building foundation is contained in Appendix 3G Section 3G.1, the Control Building foundation is in Appendix 3G Section 3G.2, and the Fuel Building foundation is in Appendix 3G Section 3G.3. The summary stress report contains a section detailing safety factors against sliding, over turning, and floatation.

As described in Subsection 3.8.4.1.4, the FWSC consists of two FWS and a FPE that share a common basemat. The foundation of the FWSC is separated from the foundations of the RB/FB and CB. The foundation of the FWSC is a rectangular reinforced concrete mat. Its key dimensions are shown in Table 3.8-13. The foundation mat is constructed of cast-in-place conventionally reinforced concrete. It supports the two FWS and their contents, FPE and other associated SSCs. Details of the foundation design and analysis for the FWSC, including foundation stability evaluation are contained in Appendix 3G, Section 3G.4.

3.8.5.2 Applicable Codes, Standards and Specifications

The applicable codes, standards and specifications for the containment foundation and for the other Seismic Category I foundations are the same as those for their respective superstructures consistent with SRP 3.8.5 Section II.2.

The applicable codes, standards, specifications and regulations are discussed in Subsection 3.8.1.2 for the containment foundation and in Subsection 3.8.4.2 for the other Seismic Category I foundations.

The jurisdictional boundary for application of Section III, Division 2 of the ASME Code to the concrete containment foundation is discussed in Subsection 3.8.1.1.3.

3.8.5.3 Loads and Load Combinations

The loads and load combinations for the containment foundation and for the other Seismic Category I foundations are the same as those for their respective superstructures with additional foundation stability requirements consistent with SRP 3.8.5 Section II.3.

The loads and load combinations for the containment foundation mat are given in Subsection 3.8.1.3. The loads and load combinations for the other Seismic Category I structure foundations are given in Subsection 3.8.4.3.

This iterative process is continued until there are no more springs in tension. The analysis results confirmed the adequacy of the basemat design. Details are provided in Appendix 3G.1.5.5.1.

The selected waterproofing material for the bottom of the basemat is a chemical crystalline powder that is added to the mud mat mixture forming a water proof barrier when cured. No membrane waterproofing is used under the foundations in the ESBWR.

The standard ESBWR design is developed using a range of soil conditions as detailed in Appendix 3A. The minimum requirements for the physical properties of the site-specific subgrade materials are furnished in Table 2.0-1. Stability of subsurface materials and foundations are addressed in Table 2.0-2, Subsection 2.5.4. Settlement of the foundations, and differential settlement between foundations for the site-specific foundations medium, is calculated, and safety-related systems (i.e., piping, conduit, etc.) designed for the calculated settlement of the foundations. The effect of the site-specific subgrade stiffness and calculated settlement on the design of the Seismic Category I structures and foundations is evaluated.

A detailed description of the analytical and design methods for the foundations of the RB including the containment, CB, FB and FWSC is included in Appendix 3G.

3.8.5.5 Structural Acceptance Criteria

The structural acceptance criteria for the containment foundation and for the other Seismic Category I foundations are the same as those for their respective superstructures with additional foundation stability requirements consistent with SRP 3.8.5 Section II.5.

The main structural criteria for the containment portion of the foundation are to provide adequate strength to resist loads and sufficient stiffness to protect the containment liner from excessive strain. The acceptance criteria for the containment portion of the foundation mat are presented in Subsection 3.8.1.5. The structural acceptance criteria for the RB, CB, FB and FWSC foundations are described in Subsection 3.8.4.5.

The allowable factors of safety of the ESBWR structures for overturning, sliding, and flotation are included in Table 3.8-14. The calculated factors of safety are shown in Appendix 3G for each foundation mat evaluated according to the following procedures.

The factor of safety against overturning due to earthquake loading is determined by the energy approach described in Subsection 3.7.2.14.

The factor of safety against sliding is defined as:

$$FS = (F_s + F_p)/(F_d + F_h)$$

where F_s and F_p are the shearing and sliding resistance, and passive soil pressure resistance, respectively. F_d is the maximum lateral seismic force including any dynamic active earth pressure, and F_h is the maximum lateral force due to loads other than seismic loads.

The factor of safety against flotation is defined as:

$$FS = F_{DL}/F_B$$

where F_{DL} is the downward force due to dead load and F_B is the upward force due to buoyancy.