HITACHI

GE Hitachi Nuclear Energy

Richard E. Kingston
Vice President, ESBWR Licensing

P.O. Box 780
3901 Castle Hayne Road, M/C A-65
Wilmington, NC 28402 USA

T 910.819.6192
F 910.362.6192
rick.kingston@ge.com

MFN 09-279 Revision 1 Docket No. 52-010

January 14, 2010

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

Subject: **Revised Response to NRC RAI Letter No. 299 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Numbers 3.8-107 S03 (Revision 1)**

The purpose of this letter is to submit to the NRC a corrected response to RAI Number 3.8-107 S03 (Revision 1). RAI Number 3.8-107 S03 was originally transmitted to the NRC via Reference 1.

Anatech, a GEH subcontractor, informed GEH of reporting errors in an analysis document used to develop our response to this RAI. This RAI response is being revised for consistency with Anatech's revised report *Thermal Cracking Demonstration Analysis for Use of Thermal Ratios in ESBWR Design* that documents the correction of the Anatech reporting errors. These reporting errors are inconsequential and do not affect any of the results or conclusions reached from the data provided in the RAI response

Enclosure 1 contains GEH's revised response to RAI Number 3.8-107 Supplement 3 (Revision 1). Revision bars in the right hand column and text strike throughs identify the changes to the GEH response to RAI 3.8-107 Supplement 3.

All remaining Enclosures and Attachments contained in Reference 1 remain valid.

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

Sincerely,

Richard E. Kingston
Vice President, ESBWR Licensing

Reference:

1. MFN 09-279 Letter from R. E. Kingston, GEH, to U.S. Nuclear Regulatory Commission *Response to NRC RAI Letter No. 299 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Numbers 3.8-107 S03* dated April 24, 2009

Enclosure:

1. Revised Response to NRC RAI Letter No. 299 Related to ESBWR Design Certification Application - DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Numbers 3.8-107 S03 (Revision 1)

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	HA Upton	GEH/San Jose (with enclosures)
	eDRF Section	0000-0099-3093 R1 (RAI 3.8-107 S03 R1)

ENCLOSURE 1

MFN 09-279 Revision 1

Revised Response to NRC RAI Letter No. 299
Related to ESBWR Design Certification Application

DCD Tier 2 Section 3.8 – Seismic Category I Structures

RAI Number 3.8-107 S03 (Revision 1)

<u>NRC RAI 3.8-107, Supplement 3</u>

As a result of the staff's review of the GEH response transmitted in GEH letter MFN 08-432, Supplement 2, dated September 30, 2008, GEH is requested to address the following two remaining items:

Part (b)(3):

The information provided in the RAI response does not demonstrate that the approach in AIJ Article 15 (provided as Attachment 3.8-107(3) to the RAI response) is the same as the analytical approach in Section 4.2 of the Shimizu SSDP validation report (Enclosure 2 to GEH letter MFN 06-416 dated 11/6/06). While the equations for most of the concrete section properties (e.g., A_e, g, I_g) match, the equations for solving the compressive stress in the concrete, and rebar stresses in tension and compression could not be matched. Furthermore, the equations in the additional Reference 3 (Reinforced Concrete Analysis and Design textbook excerpt provided as Attachment 3.8-107(4)) also do not match the equations in the AIJ Article 15. Therefore, GEH is requested to verify the equations used in the SSDP computer code by comparing the quantitative results for the sample problems performed in Sections 4.2.1 through 4.2.3 of the validation report with the use of the equations presented in the Reference 2 concrete textbook or other conventional concrete textbook. This approach would validate the use of the SSDP computer code for design of reinforced concrete members for the ESBWR.

Part (c):

The study performed demonstrates that the use of uncracked properties for mechanical loads is acceptable for determining the concrete stresses; however, the approach did not adequately demonstrate the approach for stresses in the rebars. This was evident by the fact that so many rebar stress ratios for Case 1/Case 2, in RAI Table 3.8-107(18), were less than 1.0 and in some cases substantially less than 1.0. The RAI response indicates that these locations are "typically" at locations of "relatively" low stress that are "not controlling." This statement alone is not considered sufficient to address the numerous tabulated ratios less than 1.0. Therefore, unless the effects of concrete cracking is considered in the mechanical load analyses, GEH is requested to confirm that in the regions where the rebar stress ratios are less than 1.0, these rebar stresses indeed do not control the design. This could be achieved by confirming that at locations where the stress ratios are less than 1.0 one or more of the following occurs: (1) the section design at the location is based on other sections adjacent to or at a different azimuth where the ratios are equal to or greater than 1.0, (2) the rebar stresses are sufficiently small to compensate for the ratio being less than 1.0, and/or (3) there is sufficient margin between the rebar stress/section design and code limits to accommodate the lower stress ratios.

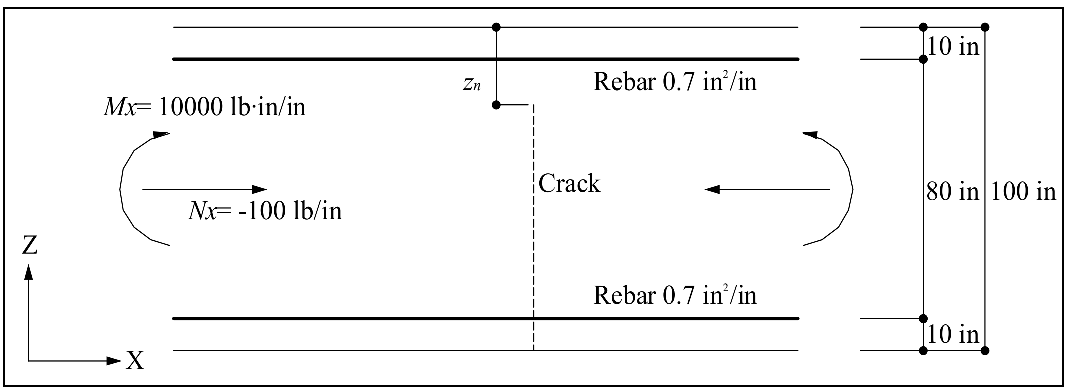
Revised GEH Response

Part (b)(3)

The equations used in the SSDP-2D computer code are verified by comparing the quantitative results for the most representative sample problem for a partially cracked concrete section described in Section 4.2.3 of the SSDP-2D validation report (Enclosure 2 to GEH letter MFN 06-416 dated 11/7/06) with the results from equations presented in Section 1.13.2 of the text book by Mr. S.S. Ray (Attachment 3 to GEH letter MFN 08-432 S01 dated 9/11/08).

The hand calculation using the equations presented in Section 1.13.2 of the textbook by Mr. S.S. Ray is as follows:

1. Problem Descriptions



a. Material Properties

E_c: Young's modulus of concrete (3.61×10^6 psi)

E_s: Young's modulus of rebar (2.90×10^7 psi)

m: Young's modulus ratio

$$\begin{aligned} m &= E_s / E_c \\ &= 2.90\times10^7 / 3.61\times10^6 \\ &= 8.03 \end{aligned}$$

b. Sectional Dimensions

H: Thickness (100 in)

b: Width (1 in)

d: Depth of tensile rebar from compression face (90 in)

d': Depth of cover concrete at tension side (10 in)

c. Rebar Arrangement

A_s: Area of tension rebar (0.7 in^2/in)

A_s': Area of compression rebar (0.7 in^2/in)

d. Applied Forces

N_x: Compressive force (-100 lb/in)

M_x: Bending moment (10000 lb·in/in)

e: $= M_x / |N_x| = 10000/|100| = 100$ (in)

g: Depth of central axis of bending moment from compressive face (in)

$$g = H/2 = 100/2 = 50$$

2. Calculation Details

Find the neutral axis by iterations to satisfy the following equation for solution convergence:

$$x_1 - x_2 = 0.0$$

where, x_1: Initial assumed value

x_2: Depth of neutral axis from compressive face calculated as follows:

$$x_2 = \frac{d}{\left(1 + \frac{f_s}{mf_c}\right)}$$

f_c : Axial Stress of Concrete (psi)

$$f_c = \frac{k_1 N_x}{k_3\left(1 - \frac{d'}{d}\right)A_s' + k_2 bd}$$

f_s : Axial Stress of Tension Rebar (psi)

$$f_s = \frac{f_c(k_3 A_s' + 0.5bx_1) - N_x}{A_s}$$

$$k_1 = \left[\frac{(e-g)}{d} + 1 \right]$$

$$k_2 = \left(\frac{x_1}{2d} \right)\left(1 - \frac{x_1}{3d} \right)$$

$$k_3 = m\left(1 - \frac{d'}{x_1} \right)$$

For $x_1 = 34.1580$ (in), equation for solution convergence is satisfied. Other variables are determined as follows:

$$k_1 = \left[\frac{(100-50)}{90} + 1 \right]$$
$$= 1.5556$$

$$k_2 = \left(\frac{34.1580}{2 \times 90} \right)\left(1 - \frac{34.1580}{3 \times 90} \right)$$
$$= 0.1658$$

$$k_3 = 8.0332 \times \left(1 - \frac{10}{34.1580} \right)$$
$$= 5.6814$$

$$f_c = \frac{1.5556 \times 100}{5.6814 \times \left(1 - \frac{10}{90} \right) \times 0.7 + 0.1658 \times 1.0 \times 90}$$
$$= 8.4282$$

$$f_s = \frac{8.4282 \times (5.6814 \times 0.7 + 0.5 \times 1.0 \times 34.1580) - 100}{0.7}$$
$$= 110.6629$$

f_s' : Axial stress of compression rebar (psi)

$$f_s' = m f_c \frac{x_1 - d'}{x_1}$$
$$= 8.0332 \times 8.4282 \times \frac{34.1580 - 10}{34.1580}$$
$$= 47.8842$$

$$x_2 = \frac{90}{\left(1 + \frac{110.6629}{8.0332 \times 8.4282}\right)}$$

$$= 34.1624$$

$$\approx x_1$$

3. Results

The hand calculation results are in good agreement with the SSDP-2D results as shown in Table 3.8-107(19).

Part (c)

To confirm section design adequacy in the regions where the rebar stress ratios are less than 1.0, the stress results of Case 2 (Thermal + Pressure nonlinear analysis) of the demonstration analysis are first converted to section forces and moments for all section cuts of the RCCV including the RPV Pedestal, Wetwell, Drywell, Suppression Pool (S/P) Slab and Top Slab.

These Thermal + Pressure section forces and moments are then combined with the section forces and moments of other loads calculated by NASTRAN linear elastic analyses for LOCA + SSE load combination (designated as CV-11b in DCD Tier 2 Table 3G.1-10) for stress calculations using SSDP-2D. The resulting stresses are summarized in Table 3.8-107(20).

The rebar stresses at all sections are within the code allowable. The highest ratio of calculated rebar stress to code allowable is 0.84 at element 98104 of the Top Slab. The concrete compressive stresses are also within the code allowable except at one element in the RPV Pedestal (element 5013 at the bottom). The concrete stress at this element is slightly higher (less than 10%) than the code allowable but it is very localized and the whole section is still below general yielding in view of large margins in the rebar stress; the highest rebar stress at this section is only 57% of the code allowable.

Furthermore, ignoring the concrete tensile stress in the design approach tends to result in overestimation of the concrete compressive stress as explained in GEH's response to NRC RAI 3.8-107 S02 (MFNs 08-432, dated 5/1/08 and 08-432 S01, dated 9/11/08) for the demonstration analysis. Therefore, it can be concluded that section design based nonlinear cracked analysis results for thermal loads and linear uncracked analysis results for other loads is an adequate design approach.

Errors have been discovered in the Thermal + Pressure section forces and moments used to determine the resulting stresses summarized in Table 3.8-107(20) provided to the NRC in MFN 09-279, dated 4/24/09.

Table 3.8-107(20A) contains the erroneous values, which are for the horizontal faces at 180º locations for cuts WW3, UW1, UW2 and UW3. The correct section forces and moments are shown in Table 3.8-107(20B) for these locations and are smaller than those in Table 3.8-107(20A); therefore, there is no reduction in the margins reported in Table 3.8-107(20) provided to the NRC in MFN 09-279, dated 4/24/09.

Table 3.8-107(19) Hand Calculation and SSDP-2D Results

Stresses	Hand Calculation	SSDP-2D
Concrete (psi)	-8.43	-8.50
Tension Rebar (psi)	110.7	110.6
Compression Rebar (psi)	-47.9	-47.7

Table 3.8-107(20) Rebar and Concrete Stresses of RCCV
Selected Load Combination CV-11b

Location	Element ID	Concrete Stress (Mpa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
1 RPV	5006	-25.6	-27.9	-54.1	201.0	-126.7	32.5	361.6
Pedestal	5013	-30.3	-27.9	-54.5	204.9	-150.9	87.0	361.6
Bottom	5024	-25.1	-27.9	-43.0	201.1	-121.7	107.7	361.6
2 RPV	6006	-19.5	-27.9	-14.3	174.9	-94.4	113.0	361.6
Pedestal	6013	-26.1	-27.9	-22.7	132.9	-115.2	202.3	361.6
Mid-Height	6024	-27.7	-27.9	27.7	221.5	-104.4	237.1	361.6
3 RPV	6606	-11.3	-27.9	-48.7	105.6	-12.0	72.0	361.6
Pedestal	6613	-17.3	-27.9	-83.0	108.7	82.2	-48.8	361.6
Top	6624	-11.6	-27.9	-54.5	120.6	95.4	11.7	361.6
4 RCCV	1806	-25.0	-28.3	41.4	230.6	-88.1	222.7	364.4
Wetwell	1813	-20.1	-28.3	-21.6	166.6	-85.5	159.9	364.4
Bottom	1824	-22.8	-28.3	25.9	232.3	-86.4	190.9	364.4
5 RCCV	2606	-16.2	-28.2	21.8	216.5	-68.6	161.0	363.8
Wetwell	2613	-17.8	-28.2	18.2	209.4	-81.8	203.3	363.8
Mid-Height	2624	-20.7	-28.2	18.6	204.4	-92.8	207.6	363.8
6 RCCV	3406	-12.5	-28.2	112.3	263.3	89.2	182.6	363.8
Wetwell	3413	-10.3	-28.2	29.8	212.7	81.5	185.6	363.8
Top	3424	-11.9	-28.2	76.3	259.1	-47.0	188.0	363.8
7 RCCV	3606	-18.6	-27.7	55.6	227.2	-58.9	239.7	360.2
Drywell	3613	-13.7	-27.7	24.7	206.1	-47.8	229.3	360.2
Bottom	3624	-19.1	-26.7	33.8	167.1	-76.5	287.8	352.9
8 RCCV	4006	-15.3	-27.7	40.4	289.8	-50.5	177.6	360.2
Drywell	4013	-17.2	-27.7	29.9	260.9	-72.6	193.1	360.2
Mid-Height	4976	-17.9	-26.7	14.6	172.4	-76.7	154.7	352.9
9 RCCV	4406	-13.5	-27.7	33.7	269.3	-38.3	133.5	360.2
Drywell	4413	-13.3	-27.7	-13.1	220.0	-55.5	88.5	360.2
Top	4424	-12.4	-26.7	-25.6	199.6	94.2	48.7	352.9
12 S/P Slab	80003	-14.9	-28.3	141.1	214.5	-57.2	38.6	364.4
@ RPV	80007	-12.5	-28.3	90.6	173.7	-53.6	-15.5	364.4
	80012	-10.9	-28.3	57.8	162.4	-41.8	28.5	364.4
13 S/P Slab	80206	-24.5	-28.3	-15.4	139.8	-73.8	175.2	364.4
@ Center	80213	-24.6	-28.3	-18.0	169.3	-57.7	168.2	364.4
	80224	-23.5	-28.3	16.0	159.6	-65.1	192.1	364.4
14 S/P Slab	83306	-20.3	-28.3	-17.9	259.1	-41.7	99.1	364.4
@ RCCV	83313	-18.8	-28.3	-25.9	214.7	-25.6	49.7	364.4
	83324	-15.9	-28.3	-22.8	166.1	-39.6	67.2	364.4
15 Topslab	83406	-16.5	-26.2	139.7	-24.5	64.5	-30.2	349.2
@ Drywell Head	83413	-17.0	-26.2	249.1	110.0	131.0	-54.1	349.2
Opening	83424	-22.9	-26.2	250.1	-38.0	114.6	-23.3	349.2
16 Topslab	83506	-8.8	-26.6	155.0	17.2	9.3	-31.4	352.0
@ Center	83513	-9.6	-26.6	210.7	34.1	48.6	-36.1	352.0
	83524	-16.9	-27.2	204.2	-16.5	107.5	-26.6	356.6
17 Topslab	98120	-10.1	-26.6	58.5	47.2	44.8	25.5	352.0
@ RCCV	98135	-12.1	-26.6	125.7	32.9	132.2	-40.5	352.0
	98104	-22.2	-27.2	297.8	-24.3	134.4	-17.7	356.6

Note: Negative value means compression.
Note *: RCCV, Pedestal Direction1: Hoop Direction2: Vertical S/P Slab Direction1: Radial Direction2: Circumferential
Top slab Direction1: N-S Direction2 : E-W

Table 3.8-107(20A) ERRONEOUS Section Forces and Moments from Nonlinear Cracking (Thermal + Pressure) Demonstration Analysis

(Units: MN/m, MN-m/m)

Section	Location	Horizontal Face (Vertical Direction)				
		N	M	Q	V	T
WW3	180º	-0.81	-4.15	0.58	-0.17	0.07
UW1	180º	1.04	-9.09	-1.27	-0.15	-0.08
UW2	180º	-5.11	-6.57	-2.73	0.39	-0.03
UW3	180º	-4.08	2.93	-3.83	0.23	0.27

Table 3.8-107(20B) CORRECT Section Forces and Moments from Nonlinear Cracking (Thermal + Pressure) Demonstration Analysis

(Units: MN/m, MN-m/m)

Section	Location	Horizontal Face (Vertical Direction)				
		N	M	Q	V	T
WW3	180º	-0.65	-3.30	0.46	-0.14	0.05
UW1	180º	0.82	-7.22	-1.01	-0.12	-0.06
UW2	180º	-4.06	-5.23	-2.17	0.31	-0.02
UW3	180º	-3.24	2.33	-3.04	0.18	0.22

Legend:

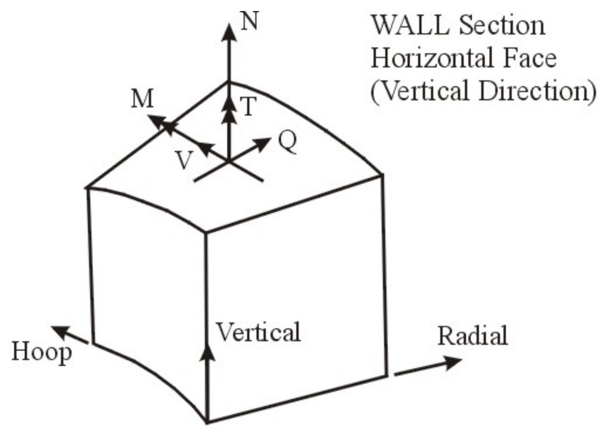
N Force normal to face, positive means tension.

M Moment, positive puts tension on inside surface.

Q Out-of-plane shear, positive as shown.

V In plane shear, positive as shown.

T Torsion, positive is vector along N.



DCD Impact

No DCD change is required in response to this RAI Supplement.