REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**249-8323**
SRP Section:	**03.08.01 –Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**10/14/2015**

Question No. 03.08.01-16

The staff reviewed Sections 3.7 and 3.8 of the APR1400 DCD Tier 2, and identified some editorial errors. The applicant is requested to address the following editorial errors:

a. Subsection 3.8.5.4.3, “Design Summary Report,” refers to Technical Report APR1400-E-S-NR-14006-P, Rev. 0: Stability Check for NI Common Basemat.” The TR should be Revision 1.

b. Subsection 3.8.5.7, “Testing and Inservice Inspection requirements,” last paragraph, “(COL.3.8(10).” should read “(COL 3.8(10)).”

c. Subsection 3.8.6, “Combined License Information,” in COL 3.8(1), “. condits…” should read “...conduits…”

d. Subsection 3.8.6, “Combined License Information,” COL item COL 3.8(10), “COL 3.8.(10)” should read “COL 3.8(10)”

e. Table 3.8.A-5, “Critical Sections of RCB Basemat,” should be associated with Figure 3.8A-15, “Design Sections for Basemat Reinforcement.” Subsection 3.8A.1.4.2.3, “Analysis and Design Procedures,” provides the connection. However, in Figure (b) vertical area, between Sections 5 and 6 was not identified.

f. Subsection 3.8A.1.4.1.3.5, “Design Sections, d2 “Personnel Airlock” should read “2) Personnel Airlocks”

g. Section 3.8.1.1.3.5.1, 3rd sentence, “Figure 3.8-3” does not show the reinforcement, perhaps this should have been Figure 3.8A-10.

h. The HRHF report Page 7, “Table 3-4” should be “Table 3-4 of this report.” The current wording suggests that it is a table in Appendix C of draft SRP 3.7.1, Rev. 4.

i. In DCD Table 3.7-1, the 10% damping CSDRS curve at 25 Hz should be 0.447 (instead of 0.464). Table 2-1 of APR1400-E-S-NR-14001-P, Rev. 0, Seismic Design Bases, has the correct value.

j. In Section 3.5.1 of APR1400-E-S-NR-14004-P, Rev. 1, “Figure 22” should be “Figure 3-16”.

k. In Section 3.7.3.3, the referenced Section 3.7.2.15 should be 3.7.2.14

l. In Section 3.7.3.9, the statement “…free-standing cylindrical tanks anchored to reinforced concrete pads or directly on a building structure.” The term “free-standing” should be deleted because the tanks are anchored.

m. Section 4.2.11 in APR1400-E-S-NR-14002-P states that “Figure 4-10 is another view looking west into the interior modeling, with a vertical cut at column line 19.” In contrast, the description in the figure itself states “… N-S Cutting at Column Line 19 and Looking East”

n. In step (4) and equation 6-1 in Section 6.1 of APR1400-E-S-NR-14003-P, the seismic inertial load sub-vector is duplicated in both sides of the equation. Please verify whether or not the right side of the equation should refer to a sub-vector of absolute acceleration rather than the seismic inertial load sub-vector.

o. Step (13) in Section 6.1 of APR1400-E-S-NR-14003-P referenced step (11) as containing the differential maximum building structure (axial and shear) forces and equation 6-6. The correct reference should be step (12).

p. The paragraph following step (8) in Section 6.3 of APR1400-E-S-NR-14003-P refers to step (5) as providing maximum displacements. However, Step (5) rather than providing maximum displacements, it provides the basemat rotation. Step (8) provides the maximum displacements. Verify whether or not the appropriate step to refer to should be step (8).

q. Note 11 to some tables in Appendix B in APR1400-E-S-NR-14003-P (e.g. Table B-5, B-9, etc…) refer to Table H-64 which does not exist in this report.

r. Section 3.5.1 in APR1400-E-S-NR-14004-P, Rev. 1, refer to Figure 3-16 as showing the intensity envelope function plot. However, the plot is shown on Figure 3-15. Therefore, the reference to Figure 3-16 should be changed to Figure 3-15.

s. The following sentence in Section 6 in APR1400-E-S-NR-14004-P, Rev. 1, as written, describes the opposite of what is shown on Table 6-5. This sentence and Table 6-5 need review to verify and correct any inconsistencies.

   1. Equivalent accelerations from HRHF input ground motion envelop those from the CSDRS except the vertical acceleration of Fuel Handling Area 3 (El. 195'-0" to 213'-0").

t. In DCD Section 3.7.2, the information related to Interaction of Non-Seismic Category I Structures with Seismic Category I Structures, is assigned the Subsection number

3.7.2.7.1. Consistent with the SRP format, verify whether this should be a separate subsection (e.g. 3.7.2.8).

u. Technical Report (TR) APR1400-E-S-NR-14006-P, Rev 1, Section 1, “Introduction,” states “The NI common basemat is a reinforced concrete mat foundation with an area of approximately 99,180 ft Technical Report (TR) APR1400-E-S-NR-14006-P, Rev 1, Section 1, “Introduction,” states “The NI common basemat is a reinforced concrete mat foundation with an area of approximately 99,180 ft2 (348 ft x 285 ft).” However, in Table 4-1, “Uplift Area for NI Common Basemat,” the area of basemat is tabulated as 113,590 ft2. Is this an error? If so, the applicant is requested to correct the error and update the section of the TR accordingly.

Response - (Rev. 1)

a. DCD Tier 2, Subsection 3.8.5.4.3, “Design Summary Report,” will be revised to refer to technical report APR1400-E-S-NR-14006-P, Rev. 1, as shown in Attachment 1 to this response.

b. The last paragraph of DCD Tier 2, Subsection 3.8.5.7, “Testing and Inservice Inspection requirements,” will be revised to replacae “(COL.3.8(10).” with “(COL 3.8(10)).” as shown in Attachment 2 to this response.

c. DCD Tier 2, Subsection 3.8.6, “Combined License Information,” COL 3.8(1) will revise “...condits…” to read “...conduits…” as shown in Attachment 3 to this response.

d. DCD Tier 2, Subsection 3.8.6, “Combined License Information,” COL item COL 3.8(10) will revise “COL 3.8.(10)” to read “COL 3.8(10)” as shown in Attachment 4 to this response.

e. DCD Tier 2, Table 3.8.A-5, “Critical Sections of RCB Basemat,” will be revised to indicate the excluded design sections, indicated in the “Location” column, include Section-07 instead of Section-08. DCD Tier 2, Figure 3.8A-15, “Design Sections for Basemat Reinforcement,” will be revised to identify the vertical area between Sections 5 and 6 as Section 8, as shown in Attachment 5 to this response.

f. DCD Tier 2, Subsection 3.8A.1.4.1.3.5, “Design Sections,” item d2, “Personnel Airlock” will be revised to read “2) Personnel Airlocks,” as shown in Attachment 6 to this response.

g. The reference to Figure 3.8-3 in the third sentence of Section 3.8.1.1.3.5.1 will be revised to refer to Figure 3.8A-10, as shown in Attachment 7 to this response.

h. Page 7 of technical report APR1400-E-S-NR-14004-NP, Rev. 1, “Evaluation of Effects of HRHF Response Spectra on SSCs” will be revised to change “Table 3-4” to “Table 3-4 of this report” for clarity, as shown in Attachment 8 to this response.

i. DCD Tier 2, Table 3.7-1, “Spectral Amplitude of CSDRS for Control Points” will be revised so that the 10% damping CSDRS curve at 25 Hz shows a value of 0.447 (instead of 0.464), as shown in Attachment 9 to this response.

j. The fourth paragraph of Section 3.5.1 of APR1400-E-S-NR-14004-P, Rev. 1, “Evaluation of Effects of HRHF Response Spectra on SSCs” will be revised to replace “Figure 22” with “Figure 3-16,” as shown in Attachment 10 to this response.

k. Because the subsection of DCD Tier 2 numbers are renumbered as described in Subquestion t, the response of Subquestion k is not needed.

l. The term “free-standing” will be deleted from DCD Tier 2, Section 3.7.3.9, “Methods for Seismic Analysis of Above-ground Tanks,” as shown in Attachment 12 to this response.

m. Technical report APR1400-E-S-NR-14002-NP, Rev. 0, “FEM for SSI Analyses of NI Buildings,” Section 4.2.11, “Geometry Plots of ANSYS Fine and Coarse 3-D AB FEM” will be revised so that the last sentence reads “Figure 4-10 is another view looking east into the interior modeling…” as shown in Attachment 13 to this response.

n. Step (4) of Equation 6-1 in Section 6.1 of APR1400-E-S-NR-14003-P will be revised such that the right side of the equation refers to a sub-vector of absolute acceleration rather than the seismic inertial load sub-vector, as shown in Attachment 14 to this response.

o. Step (13) in Section 6.1 of APR1400-E-S-NR-14003-P will be revised to referenced Step (12) as containing the differential maximum building structure (axial and shear) forces and equation 6-6, as shown in Attachment 15 to this response.

p. The paragraph following step (8) in Section 6.3 of APR1400-E-S-NR-14003-P will be revised to reference Step (8) as providing maximum displacements, as shown in Attachment 16 to this response.

q. Note 11 to Table B-5, B-11, B-17, B-23, B-29, B-35, B-41, B-47, B-53, and B-59 in Appendix B of APR1400-E-S-NR-14003-P will be revised to refer to Table B-67, as shown in Attachment 17 to this response.

r. Section 3.5.1 of APR1400-E-S-NR-14004-P, Rev. 1, will be revised to refer to Figure 3-15 as showing the intensity envelope function plot, as shown in Attachment 18 to this response.

s. The third sentence of the sixth paragraph of APR1400-E-S-NR-14004-P, Rev. 1, Section 6 will be revised to state, “Equivalent accelerations from CSDRS input ground motion envelop those from the HRHF except the vertical acceleration of Fuel Handling Area 3 (El. 195'-0" to 213'-0").” Attachment 19 to this response shows the change to be made.

t. DCD Tier 2, Subsection 3.7.2.7.1, “Interaction of Non-Seismic Category I Structures with Seismic Category I Structures,” will be changed to Subsection 3.7.2.8 to be consistent with the format of the SRP. Subsequent subsections of the DCD will be renumbered. Attachment 20 to this response shows the changes to be made.

u. Technical report APR1400-E-S-NR-14006-P, Rev 1, Section 1, “Introduction,” will be revised to state the NI common basemat is a reinforced concrete mat foundation with an area of 113,590 ft^2, as shown in Attachment 21 to this response.

Impact on DCD

DCD Tier 2, Subsections 3.8.5.4.3, 3.8.5.7, 3.8.6, 3.8A.1.4.1.3.5, 3.8.1.1.3.5, 3.7.3.3, 3.7.3.9, 3.7.2.7.1, 3.7.2.8, 3.7.2.9, 3.7.2.10, 3.7.2.11, 3.7.2.12, 3.7.2.13, 3.7.2.14 and Tables 3.8A-5, 3.8A-15, 3.7-1 will be revised as indicated in the attachments associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical reports APR1400-E-S-NR-14004-P/NP, Rev. 1; APR1400-E-S-NR-14002-P/NP, Rev. 0; APR1400-E-S-NR-14003-P/NP, Rev. 0; and APR1400-E-S-NR-14006-P/NP, Rev. 1 will be revised as indicated in the attachments associated with this response.

30. Regulatory Guide 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, April 2013.

31. Regulatory Guide 1.115, "Protection Against Low-Trajectory Turbine Missiles," Rev. 2, U.S. Nuclear Regulatory Commission, January 2012.

32. Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, November 2001.

33. ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineering/Structural Engineering Institute, 2006.

34. GTSTRUDL User Guide, GTSTRUDL Version 31, Georgia Institute of Technology, August 2010.

35. Research Council on Structural Connections, "Specification for Structural Joints Using ASTM A325 or A490 Bolts," 2004.

36. AWS D1.1, "Structural Welding Code," American Welding Society, 2010.

37. ASTM C191, "Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle," American Society for Testing and Materials.

38. ASTM C109, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars," American Society for Testing and Materials.

39. ASTM A36, "Standard Specification for Carbon Structural Steel," American Society for Testing and Materials.

40. APR1400-E-S-NR-14006-P, "Stability Check for NI Common Basemat" Rev. ~~0~~, 1 KHNP, ~~November 2014.~~ February 2015

The COL applicant is to provide testing and inservice inspection programs to examine inaccessible areas of concrete structures for degradation and monitoring of groundwater chemistry (COL 3.8(9)).

The long-term settlement is the site-specific characteristics. The COL applicant is to provide the soil parameters for APR1400 site ~~(COL. 3.8(10).~~ (COL. 3.8(10)).

3.8.6 Combined License Information

COL 3.8(1) The COL applicant is to provide the design of site-specific seismic Category I structures such as the essential service water building and the component cooling water heat exchanger building, essential service water condits, and class 1E electrical duct runs.

COL 3.8(2) The COL applicant is to identify any applicable site-specific loads such as site proximity explosions and missiles, potential aircraft crashes, and the effects of seiches, surges, waves, and tsunamis.

COL 3.8(3) The COL applicant is to determine the environmental condition associated with the durability of concrete structures and provide the concrete mix design that prevents concrete degradation including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.

COL 3.8(4) The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.

COL 3.8(5) The COL applicant is to monitor the safety and serviceability of seismic Category I structures during the operation of the plant and provide the appropriate maintenance.

COL 3.8(6) The COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1 are met or exceeded.

The COL applicant is to provide testing and inservice inspection programs to examine inaccessible areas of concrete structures for degradation and monitoring of groundwater chemistry (COL 3.8(9)).

The long-term settlement is the site-specific characteristics. The COL applicant is to provide the soil parameters for APR1400 site (COL. 3.8(10).

3.8.6 Combined License Information

COL 3.8(1) The COL applicant is to provide the design of site-specific seismic Category I structures such as the essential service water building and the component cooling water heat exchanger building, essential service water ~~condits~~, and class 1E electrical duct runs.
conduits

COL 3.8(2) The COL applicant is to identify any applicable site-specific loads such as site proximity explosions and missiles, potential aircraft crashes, and the effects of seiches, surges, waves, and tsunamis.

COL 3.8(3) The COL applicant is to determine the environmental condition associated with the durability of concrete structures and provide the concrete mix design that prevents concrete degradation including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.

COL 3.8(4) The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.

COL 3.8(5) The COL applicant is to monitor the safety and serviceability of seismic Category I structures during the operation of the plant and provide the appropriate maintenance.

COL 3.8(6) The COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1 are met or exceeded.

COL 3.8(7) The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.

COL 3.8(8) The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.

COL 3.8(9) The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.

COL 3.8(10) The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.

deleted

3.8.7 References

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission.

2. ASME Section III, Subsection NE, "Class MC Components," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

3. ASME Section III, Division 2, "Code for Concrete Containments," Subsection CC, American Society of Mechanical Engineers, 2001 Edition with 2003 Addenda.

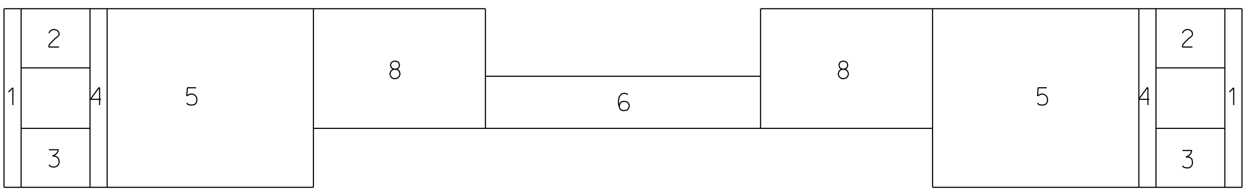
4. Regulatory Guide 1.35, "Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment," Rev. 3, U.S. Nuclear Regulatory Commission, July 1990.

5. Regulatory Guide 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," U.S. Nuclear Regulatory Commission, July 1990.

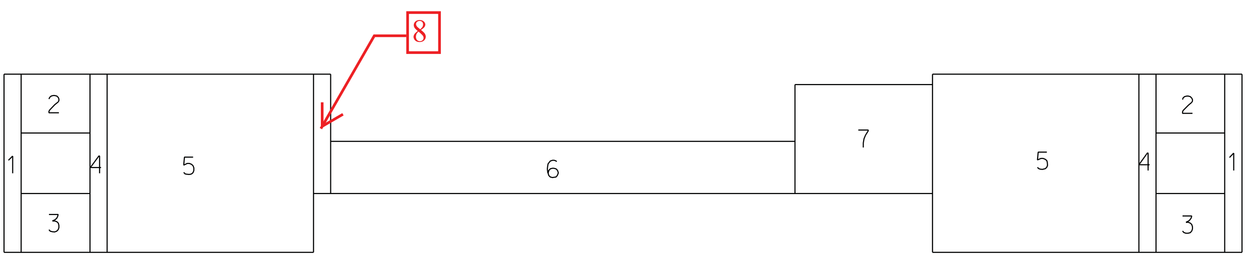
Table 3.8A-5

Critical Sections of RCB Basemat

Design Section	Location	Height (ft)
Section-01	Tendon Gallery Outside Area	33
Section-02	Tendon Gallery Upper Area	10
Section-03	Tendon Gallery Below Area	10
Section-04	R = 63.25′ to 70.5′ at El. 45′ to El. 78′	33
Section-05	R = 42.5′ to 63.25′ Exclude Design Section-06, -07, -08	33
Section-06	Cavity Area at El. 55′ to 66′	11
Section-07	x = 22′ to 39′ and y = 0′ to 18.75′ at El. 55′ to 76′	21
Section-08	x, y = 0′ to 42.5′ Exclude Design Section -06, ~~-08~~ -07	23



(a) Basemat Cross Section for E-W Direction



(b) Basemat Cross Section for N-S Direction

Figure 3.8A-15 Design Sections for Basemat Reinforcement

1) Equipment hatch

2) Personnel ~~airlock~~ airlocks

3.8A.1.4.1.3.6 Rebar Arrangement

Continuous vertical and horizontal reinforcements are placed at the inside and outside faces of the containment wall. The vertical reinforcements of the containment wall are extended and anchored to the basemat. Additional reinforcing bars are provided around the large penetrations in the cylindrical wall as required. Shear ties are also provided where shear reinforcing is required.

Table 3.8A-3 summarizes the reinforcing details for the major design sections of the containment wall. Figures 3.8A-6 through 3.8A-10 show the rebar arrangement for the major design sections of the containment wall. Figure 3.8A-16 and 3.8A-17 show the connection detail between the containment wall and basemat.

The containment dome is also reinforced by two-way orthogonal sets of vertical reinforcing steel and hoop reinforcing steel. The orthogonal reinforcing is the continuation of the vertical reinforcing in the containment wall. Hoop reinforcing is also provided up to 45 degrees above the springline. Radial reinforcements are provided over the entire dome to resist radial tension forces resulting from curved tendons.

3.8A.1.4.1.3.7 Design Results

The design sections of the containment wall and dome are analyzed by the computer program DARTEM to check the stresses of concrete and reinforcing steel in the concrete section. The input of DARTEM consists of section geometry, material properties, section forces and moments, and loading combinations. Table 3.8A-4 presents the rebar stresses and margins of safety for the major design sections of the containment. The margin of safety is the ratio of allowable stress and actual stress of reinforcement in the containment.

Subsections 3.8.2.1.3.1.1 and 3.8.2.1.3.1.2. The penetrations greater than 457.2 mm (18 inches), except the personnel airlocks and equipment hatch, are given in Table 3.8-11.

The penetration sleeves through the containment are fabricated of steel, anchored to the concrete structure, and seal welded to the containment liner plate. The type, size, and location of the penetration, as well as any load that is imposed on the cylindrical wall by the penetration, determine whether any additional reinforcing is required in the wall around the penetration. Post-tensioning tendons are deflected around the penetrations, if required. Minimum bend radius of all deflected tendons is 9.15 m (30.0 ft) between tangent points. Portions of the containment pressure boundary that are steel and not backed by concrete, such as the equipment hatch, personnel airlocks, and Class MC penetration assemblies including the fuel transfer tube penetration sleeve, are designed in accordance with ASME Section III, Division 1, Subsection NE (Reference 2), as described in Subsection 3.8.2.

3.8.1.1.3.5.1 Personnel Airlocks

Access to the containment is provided through two personnel airlocks with a diameter of 3.4 m (11 ft 2 in). The personnel airlocks are located at the plant grade level (Az. 280 degrees and elevation 103 ft 9 in) and the operating floor level (Az. 234 degrees and elevation 159 ft 9 in). The containment wall around the personnel airlocks is thickened, and additional reinforcement is provided for stress concentrations due to the opening, as shown in Figure 3.8-3 and Figure 3.8A-10. The post-tensioning tendons are deflected around the penetrations.

3.8.1.1.3.5.2 Equipment Hatch

The equipment hatch, with a diameter of 7.92 m (26 ft), is located at Az. 280 degrees and elevation 167 ft 6 in. The containment wall around the equipment hatch is thickened, and additional reinforcement is for stress concentrations due to the opening provided around the opening. The post-tensioning tendons are deflected around the opening.

3.8.1.1.3.6 Polar Crane Bracket

The polar crane brackets are spaced equally and embedded in the cylindrical wall to support the polar crane girder. Forces acting on the wall due to bracket loads are accommodated by additional reinforcement in the wall. A thickened liner plate is provided in the bracket rock sites is selected as the 5%-damped horizontal target HRHF response spectrum for application to the APR1400 standard plant design as shown in Figure 3-2.

The 5%-damped vertical target HRHF response spectrum is generated from the 5%-damped HRHF horizontal target response spectrum by multiplying the vertical/horizontal (V/H) ratios for CEUS rock sites recommended in NUREG/CR-6728 (Reference 14). The V/H ratios for the 0.2 to 0.5g range of the peak rock-outcrop horizontal acceleration are used. For all needed frequencies not listed in NUREG/CR-6728, the ratios used follow a log-log amplitude-frequency linear interpolation. The resulting 5%-damped vertical HRHF target response spectrum generated are plotted along with the 5%-damped HRHF horizontal target response spectrum in Figure 3-3.

The digitized values of the HRHF horizontal and vertical target response spectra are given in Table 3-1 and 3-2. The V/H ratios are given in Table 3-3 and plotted in Figure 3-4.

The horizontal HRHF response spectra for damping ratios other than 5% (namely, 2%, 3%, 7%, and 10% damping ratios, which are not available from the EPRI study) are generated from the 5%-damped HRHF horizontal response spectrum by multiplying the 5%-damped spectral values by the spectral ratios for the CEUS rock sites given in Table 3-4 of Appendix C of SRP 3.7.1 (Reference 15). For spectral frequencies not listed in Table 3-4 of this report, the ratios that were used follow a log-log amplitude-frequency linear interpolation. The horizontal HRHF response spectrum for a 4% damping ratio, for which the spectral ratios are not available in Table 3-4 of this report, is generated by interpolating between the spectral values for 3% and 5% damping ratios on a log scale for the damping ratio and a linear scale for the spectral acceleration.

The vertical HRHF response spectra for 2%, 3%, 4%, 7%, and 10% damping ratios are generated by multiplying the V/H ratios for the CEUS rock site conditions given in Table 3-3 by the corresponding HRHF horizontal response spectra.

The resulting horizontal and vertical HRHF response spectra for 2%, 3%, 4%, 5%, 7%, and 10% damping ratios developed in the manner described above are shown in Figures 3-5 and 3-6, respectively. The spectrum curves shown in these two figures are the HRHF horizontal and vertical response spectra selected for the APR1400. The numerical values of the HRHF horizontal and vertical response spectra selected are listed in Tables A-1 and A-2 in Appendix A of this report.

Comparisons of the HRHF response spectra with the CSDRS for 5% damping are shown in Figures 3-7 and 3-8 for the horizontal and vertical directions, respectively.

3.3 Generation of HRHF Response-spectrum-compatible Time Histories

The basic guidelines and criteria to be used for generating a set of three-component design time histories compatible with the HRHF target response spectra follow the guidelines and criteria in NRC SRP Section 3.7.1, for Option 1 ("single time history option"). Since the HRHF response-spectrum-compatible design time histories are to be used for the evaluation of the APR1400 standard plant design, which involves the plant SSCs with different damping ratios, the recommended approach for generating the spectrum-compatible design time history is Option 1, Approach 1. The requirements of Option 1, Approach 1, are summarized below.

3.3.1 Ground Motion Time Histories

The guidelines and criteria in SRP Section 3.7.1, for Option 1, Approach 1, and the desirable spectrum-compatible design time histories are as follows:

(1) Design time histories to be generated are based on recorded seed motion time histories.

Table 3.7-1

Spectral Amplitude of CSDRS for Control Points

Horizontal

Damping Ratio (%)	Amplification Factor for Control Points						
	0.1 Hz	0.2 Hz	0.25 Hz	2.5 Hz	9 Hz	25 Hz	50 Hz
2	0.0276	0.111	0.171	1.275	1.062	0.511	0.300
3	0.0254	0.102	0.159	1.125	0.939	0.498	0.300
4	0.0238	0.096	0.147	1.020	0.852	0.487	0.300
5	0.0226	0.090	0.141	0.939	0.783	0.479	0.300
7	0.0207	0.084	0.129	0.816	0.681	0.464	0.300
10	0.0188	0.075	0.117	0.684	0.570	~~0.464~~ 0.447	0.300

Vertical

Damping Ratio (%)	Amplification Factor for Control Points						
	0.1 Hz	0.2 Hz	0.25 Hz	3.5 Hz	9 Hz	25 Hz	50 Hz
2	0.0184	0.075	0.114	1.215	1.062	0.511	0.300
3	0.0170	0.069	0.105	1.074	0.939	0.498	0.300
4	0.0159	0.063	0.099	0.972	0.852	0.487	0.300
5	0.0151	0.060	0.093	0.894	0.783	0.479	0.300
7	0.0138	0.057	0.087	0.777	0.681	0.464	0.300
10	0.0125	0.051	0.078	0.651	0.570	0.447	0.300

described below.

3.5.1 HRHF Response Spectrum-compatible Target PSDs

The development of the APR1400-HRHF response spectrum-compatible target PSDs in the frequency range of 0.3 to 80 Hz, the time history simulation method described in NUREG/CR-5347 (Reference 24) is used. Applying this method for developing the target PSD involves the following steps:

(1) An ensemble of 30 artificial time histories is generated using a frequency domain response spectrum-compatible time history generation method developed by Gasparini and Vanmarcke and implemented in SIMQKE (Reference 25). Each time history 30 time history ensemble has a total duration of 20.475 seconds and is modulated by the intensity envelope function shown in Figure 3-16. Each time history generated has a 2%-damped time history response spectrum compatible with the 2%-damped horizontal APR1400 HRHF response spectra.

The SIMQKE frequency domain response spectrum-compatible time history generation method starts with synthesizing pure harmonic waves with white noise random phases and with amplitudes generated from an initial response spectrum-compatible target PSD within the frequency range of interest, which for the APR1400 HRHF response spectra is 0.3 to 80 Hz. The initial target PSD at each frequency is derived from the 2%-damped target response spectral value divided by a frequency-dependent "peak factor" derived from the random vibration theory (Reference 25). The peak factor, which relates the target PSD value to the 2%-damped target response spectral value, is a function of frequency and non-exceedance probability of the target response spectra. The initial time history is then modified iteratively by adjusting the initial time history PSD at each frequency using the square of the ratio of the 2%-damped time history response spectral value to the 2%-damped target response spectral value.

The 2%-damped time history response spectra for the ensemble of 30 artificial time histories are computed based on which 2%-damped "ensemble-median" time history response spectrum is derived. This spectrum for the ensemble of 30 artificial time histories is shown in Figure ~~22~~ 3-16 for the horizontal motion and in Figure 3-17 for the vertical motion. The 2%-damped horizontal and vertical "ensemble-median" time history response spectra are then compared with the 2%-damped horizontal and vertical target HRHF response spectra. These comparisons are shown in Figures 3-18 and 3-19.

As indicated in Figures 3-18 and 3-19, the ensemble-median time history response spectra derived from the generated horizontal and vertical 30 time history ensembles compared closely with the horizontal and vertical target horizontal and vertical APR1400 HRHF response spectra. The good comparisons indicate that the ensembles of the 30 generated time histories are compatible with the horizontal and vertical target HRHF response spectra and are therefore representative time history ensembles from which the target PSDs compatible with the horizontal and vertical target APR1400 HRHF response spectra can be developed.

(2) The PSD of each individual time history in each 30 time history ensemble is computed. Because each time history in the ensemble is intensity modulated and is therefore a non-stationary motion, an equivalent stationary duration for the motion must be determined for use in computing the PSD of the individual time history. The PSDs computed for the 30 time history ensemble are shown in Figure 3-20 for the horizontal motion and in Figure 3-21 for the vertical motion.

(3) The "ensemble-average" or "ensemble-mean" PSDs obtained from the horizontal and vertical 30 time history PSDs computed in Step (2) and shown in Figures 3-20 and 3-21 are smoothed in accordance with the PSD smoothing procedure recommended in NUREG/CR-5347 (Reference 24). To simplify the representation of the target PSDs shown in Figures 3-20 and

3.7.3.3 Analysis Procedures for Damping

The analysis procedure used to account for the damping in subsystems conforms with Subsections 3.7.1.2 and 3.7.2.15.

3.7.3.4 Three Components of Earthquake Motion

Seismic responses resulting from analysis of subsystems due to three components of earthquake motions are combined in the same manner as the seismic response resulting from the analysis of building structures as specified in Subsection 3.7.2.6.

3.7.3.5 Combination of Modal Responses

When a response spectrum method of analysis is used to analyze a subsystem, the maximum responses such as accelerations, shears, and moments in each mode are calculated regardless of time. If the frequencies of the modes are well separated, the SRSS method of mode combination gives acceptable results; however, where the structural frequencies are not well separated, the modes are combined in accordance with NRC RG 1.92.

3.7.3.6 Use of Constant Vertical Static Factors

In general, seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Subsection 3.7.3.1. No constant vertical static factors are used for subsystems.

3.7.3.7 Buried Seismic Category I Piping, Conduits, and Tunnels

During an earthquake, buried structures such as piping, conduits, and tunnels respond to various seismic waves propagating through the surrounding soil as well as to the dynamic differential movements of the buildings to which the structures are connected. The various waves associated with earthquake motion are P (compression) waves, S (shear) waves, and Rayleigh waves. The stresses in the buried structure are governed by the velocity and angle of incidence of these traveling waves. However, the wave types and their directions during an earthquake are very complex. For design purposes, the seismicinduced upper-bound strains and corresponding stresses in the buried piping and concrete electrical ducts are calculated using expressions given by ASCE 4-98 (Reference 12).

Seismic design for buried seismic Category I structures takes the effect of wave propagation into consideration, based on the assumption that there is no movement of the buried structure remote from anchor points relative to the surrounding soil referred to in ASCE 4-98, Subsection 3.5.2. That is, the strain of the structure is the same as that of the surrounding soil medium, and the stress of the structure is calculated from the strain. Consideration of relative deformation between anchor points and the adjacent soil is applied to the design using the SRSS method for the three orthogonal stresses calculated from the relative displacements of the seismic analysis results.

The resistance effect of the surrounding soil for deformation or displacement of the buried structures, differential movement of the anchors, and shape or curvature changes of the bent parts is taken into account in the analysis. The structures can be modeled by beam elements supported by an elastic foundation representing the stiffness of the adjacent soil.

Lateral dynamic soil pressure on buried seismic Category I structures is calculated in accordance with elastic theory by Wood referred to in ASCE 4-98, Subsection 3.5.3. The effect of underground water is considered by applying the equation proposed by Matuo and O'Hara based on the theory from Westergaard that is referred to in ASCE 4-98, Subsection 3.5.3.1.

The COL applicant is to perform a seismic analysis of buried seismic Category I piping, conduits, and tunnels (COL 3.7(6)).

3.7.3.8 Methods for Seismic Analysis of Category I Concrete Dams

The COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if required (COL 3.7(5)).

3.7.3.9 Methods for Seismic Analysis of Above-ground Tanks

Above-ground seismic Category I tanks are generally large, flat-bottomed, single-shell, ~~free-standing~~ cylindrical tanks anchored to reinforced concrete pads or directly on a satisfy (1) the 12 ft mesh size requirement for a 50 Hz cut-off frequency and (2) the model size requirement of the ACS SASSI program. Accordingly, a mesh size of 12 ft is determined to be adequate for use in the ANSYS coarse 3-D AB FEM.

4.2.11 Geometry Plots of ANSYS Fine and Coarse 3-D AB FEM

The ANSYS fine and coarse 3-D AB FEMs are created. Table 4-9 summarizes the two FEMs.

Figure 4-7 depicts the ANSYS fine 3-D AB FEM, while Figure 4-8 depicts ANSYS coarse 3-D AB FEM. Figure 4-9 shows a view looking north into the interior modeling with a vertical cut at column line AG (to avoid blocking by the wall at column line AF). Figure 4-10 is another view looking ~~west~~ east into the interior modeling, with a vertical cut at column line 19.

4.2.12 Minimum Frequency of Seismic Wave Passage

For subgrade portions of the structure, the mesh size is controlled by the soil thickness, which is required to satisfy the minimum frequency. A cut-off frequency of 50 Hz is used for seismic wave passage through rock and hard and moderate soil profiles. Cut-off frequencies between 20 and 40 Hz are used for soft soil profiles.

computed by multiplying the mass sub-matrix $[m_{kl}]$ by the seismic ~~inertia load sub-vector~~ absolute acceleration transfer function sub−vector $\{H_{kl}^{\cancel{I}\,a}(f_j)\}_p$, i.e.,

$$\{H_{kl}^{I}(f_j)\}_p = [m_{kl}] \; \{H_{kl}^{\cancel{I}\,a}(f_j)\}_p \qquad (6\text{-}1)$$

(5) The transfer function of seismic response building (axial or shear) force in the direction *"q," q* = X (E-W), Y (N-S), and Z (vertical), due to seismic input in direction *"p," p* = X, Y, and Z, designated by the symbol $V_{kl}^{q}(f_j)_p$, can be computed by multiplying the seismic response inertia load sub-vector $\{H_{kl}^{I}(f_j)\}_p$ by a rigid-body translation sub-vector in direction *"q"* due to seismic input in the direction *"p,"* designated as $\{R_{kl}^{q}\}_p$, i.e.,

$$V_{kl}^{q}(f_j)_p = \{R_{kl}^{q}\}_p^T \; \{H_{kl}^{I}(f_j)\}_p \quad q = X, Y, Z \qquad (6\text{-}2)$$

where $\{R_{kl}^{q}\}_p^T$ is the transpose of the sub-vector $\{R_{kl}^{q}\}_p$. The sub-vector $\{R_{kl}^{q}\}_p$ contains vector coefficients with the value 1 for each nodal DOF in the direction *"q"* and the value of 0 for all other DOFs.

(6) The transfer function of seismic response building (torsional or overturning) moment about the coordinate axis *"q," q* = X, Y, and Z, due to seismic input in direction *"p," p* = X, Y, and Z, designated by the symbol $M_{kl}^{q}(f_j)_p$, can be computed by multiplying the seismic response inertia load sub-vector $\{H_{kl}^{I}(f_j)\}_p$ by a rigid-body rotation sub-vector of moment arms r_q^i about the axis *"q"* between the nodal DOF *"i"* relative to a designated point *"o"* on the plane of the structure cross-section *"l"* due to the seismic input in the *"p"* direction, designated as $\{R_{\theta kl}^{q}\}_p$, i.e.,

$$M_{kl}^{q}(f_j)_p = \{R_{\theta kl}^{q}\}_p^T \; \{H_{kl}^{I}(f_j)\}_p \qquad q = X, Y, Z \qquad (6\text{-}3)$$

where $\{R_{\theta kl}^{q}\}_p^T$ is the transpose of the sub-vector $\{R_{\theta kl}^{q}\}_p$. The sub-vector $\{R_{\theta kl}^{q}\}_p$ contains vector coefficients with the moment arm r_q^i relative to the point *"o"* for each nodal translation DOF *"i"* rotating about the coordinate axis *"q,"* the value of 1 for all nodal rotation DOFs rotating about the axis "q," and the value of 0 for all other DOFs.

(7) The structure force and moment transfer functions, $V_{kl}^{q}(f_j)_p$ and $M_{kl}^{q}(f_j)_p$, obtained from Eqs. (6-2) and (6-3) at each calculated frequency f_j, are interpolated and then convolved with the seismic input time history in the direction *"p"* to generate the time histories of building (axial and shear) forces and (torsional and overturning) moments. The maximum forces and moments, designated as $(V_{kl\,\max}^{q})_p$ and $(M_{kl\,\max}^{q})_p$ for the structure *"k"* at the structure cross-section *"l"* due to the seismic input in direction *"p"* are obtained as the maximum values of the time histories.

(8) The maximum structure forces and moments for the structure *"k"* at the structure cross-section *"l"* due to the seismic input in direction *"p"* obtained in Step (7) above are combined, using SRSS combination rule, to generate the maximum forces and moments due to the seismic inputs in all three (3) directions.

(9) Steps (1) through (8) are repeated for all structure cross-sections of interest of all freestanding structures in the NI structures.

(10) From Step (2) described above, the total mass of the structure *"k"* above the structure cross-section *"l"* in the direction *"q"* due to seismic input in the direction *"p,"* designated as $\left(m_{kl}^{t}\right)_{p}^{q}$, can be computed from the mass sub-matrix $\left[m_{kl}\right]$ and the rigid-body translation sub-vector $\left\{R_{kl}^{q}\right\}_{p}$, as defined in Step (5), as follows:

$$\left(m_{kl}^{t}\right)_{p}^{q} = \left\{R_{kl}^{q}\right\}_{p}^{T} \left[m_{kl}\right] \qquad p,\ q = X, Y, Z \qquad (6\text{-}4)$$

(11) The tributary mass of the structure *"k"* between the structure cross-sections "(*l* -1)" and *"l"* in the direction *"q"* due to seismic input in the direction *"p,"* designated as $\left(\Delta m_{kl}^{t}\right)_{p}^{q}$, can be computed as

$$\left(\Delta m_{kl}^{t}\right)_{p}^{q} = \left(m_{kl}^{t}\right)_{p}^{q} - \left(m_{k(l-1)}^{t}\right)_{p}^{q} \qquad p,\ q = X, Y, Z \qquad (6\text{-}5)$$

(12) From Step (7), the differential maximum building structure (axial and shear) forces in the structure *"k"* above the structure cross-section *"l"* in the direction *"q"* due to seismic input in the direction *"p,"* designated as $\left(\Delta V_{kl\,\max}^{q}\right)_{p}$, can be computed from the maximum build forces computed at the cross-sections "(*l* -1)" and *"l"* as follows:

$$\left(\Delta V_{kl\,\max}^{q}\right)_{p} = \left(V_{kl\,\max}^{q}\right)_{p} - \left(V_{k(l-1)\max}^{q}\right)_{p} \qquad p,\ q = X, Y, Z \qquad (6\text{-}6)$$

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(13) From the tributary mass $\left(\Delta m_{kl}^{t}\right)_{p}^{q}$, computed from Step (11) using Eq. (6-5), and the differential maximum building structure (axial and shear) forces $\left(\Delta V_{kl\,\max}^{q}\right)_{p}$, computed from Step (~~11~~ 12) using Eq. (6-6), the equivalent seismic response acceleration, designated as $\left(a_{kl}\right)_{p}^{q}$, of the structure *"k"* between the cross-sections "(*l* -1)" and *"l"* in the direction *"q"* due to seismic input in the direction *"p,"* can be derived as follows:

$$\left(a_{kl}\right)_{p}^{q} = \left(\Delta V_{kl\,\max}^{q}\right)_{p} / \left(\Delta m_{kl}^{t}\right)_{p}^{q} \qquad p,\ q = X, Y, Z \qquad (6\text{-}7)$$

The equivalent acceleration $\left(a_{kl}\right)_{p}^{q}$ computed from Eq. (6-7) is the acceleration to be used for structural design. The application of the equivalent acceleration so derived will produce the maximum seismic response building (axial and shear) forces computed from Step (7) described above.

Following the steps described above, the maximum building seismic response (axial and shear) forces and (torsional and overturning) moments, along with the equivalent maximum seismic response accelerations derived from the maximum building seismic response forces for structural design, are

(5) The basemat rotation about the coordinate axis *"q"* due to seismic input in the direction *"p,"* designated by the symbol $R_{\theta q}^{p}\left(f_j\right)$, can be computed as follows:

$$R_{\theta q}^{p}\left(f_j\right) = \left[\ H_Z^d\left(f_j\right)_q^A - H_Z^d\left(f_j\right)_q^B\ \right] / D \qquad (6\text{-}10)$$

(6) For a designated nodal point *"i"* on a designated structure elevation *"l"* with height h_l, the transfer function of displacement relative to the basemat, designated as $H_b^d\left(f_j\right)_p^q$, can be computed from the transfer function of displacement relative to the free-field ground surface $H^d\left(f_j\right)_p^q$ computed at frequency f_j as follows:

$$H_b^d\left(f_j\right)_p^q = H^d\left(f_j\right)_p^q - R_{\theta q}^{p}\left(f_j\right)\times h_l \qquad (6\text{-}11)$$

(7) The transfer function of displacement relative to the basemat $H_b^d\left(f_j\right)_p^q$ computed from Eq. (6-11) at calculated frequency f_j can be interpolated and convolved with the seismic input time history in the direction *"p"* to generate the response time history $d_{bp}^q(t)$, from which the maximum absolute response value can be obtained, designated as $d_{bp\ \max}^q$. The maximum displacements relative to the basemat generated for the seismic input in all three directions can be combined using the SRSS combination rule to obtain the maximum displacements relative to the basemat due to all three directions of input, designated as $d_{b\ \max}^q$.

(8) The maximum displacements relative to the basemat $d_{b\ \max}^q$ generated for all nodal points on each designated elevation *"l"* are enveloped to give the enveloped maximum displacement relative to the basemat for the designated elevation for the response direction *"q."*

The maximum displacements relative to the basemat obtained from Step (~~5~~ 8) above for all designated elevations in the RCB are tabulated in Appendix E in a format that is similar to that for the maximum displacements relative to the free-field ground surface.

6.4 Maximum Seismic Response Accelerations

The maximum seismic response absolute accelerations obtained as the zero period acceleration (ZPA) values for the designated structure elevations in the RCB and AB, for twenty (20) individual SASSI analysis cases, are tabulated in Appendix F. The ZPA values tabulated for each designated elevation in the tables in Appendix G are the values enveloped of the ZPA values obtained for all selected nodes on that elevation.

Table B-5 CASE01C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S01C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	0.90	0.88	0.57
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	0.81	0.77	0.51
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.71	0.68	0.48
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.64	0.69	0.47
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.57	0.66	0.38
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.48	0.55	0.42
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.41	0.46	0.39
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.35	0.35	0.35
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.30	0.23	0.32
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.27	0.18	0.29
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.24	0.23	0.27
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.20	0.20	0.24
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.14	0.14	0.20
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.47	0.80	0.29
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.38	0.15	0.29
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.33	0.24	0.30
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.29	0.24	0.29
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.25	0.24	0.28
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.19	0.22	0.27
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.17	0.21	0.26
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.72	0.75	0.39
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.55	0.51	0.31
SSW: 3	136.5	156	7.60E+03	7.59E+03	7.59E+03	0.41	0.23	0.30
SSW: 4	130	136.5	3.96E+03	3.97E+03	3.97E+03	0.34	0.28	0.30
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.30	0.27	0.29
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.25	0.25	0.28
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.20	0.23	0.26
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-11 CASE02C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S02C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE						
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	0.83	0.87	0.63
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	0.74	0.76	0.57
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.65	0.66	0.54
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.60	0.58	0.53
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.54	0.57	0.45
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.45	0.53	0.48
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.39	0.44	0.44
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.33	0.34	0.41
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.28	0.25	0.37
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.24	0.28	0.34
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.22	0.24	0.32
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.18	0.19	0.28
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.13	0.13	0.27
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.49	0.71	0.33
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.40	0.20	0.33
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.35	0.31	0.33
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.32	0.29	0.32
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.27	0.26	0.32
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.22	0.24	0.31
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.19	0.22	0.31
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.72	0.75	0.40
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.58	0.46	0.34
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.44	0.33	0.33
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.37	0.31	0.33
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.33	0.29	0.32
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.29	0.26	0.32
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.23	0.24	0.30
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-17 CASE03C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S03C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.18	1.21	0.59
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.06	1.09	0.54
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.96	0.95	0.51
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.89	0.84	0.50
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.80	0.80	0.43
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.66	0.65	0.45
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.56	0.54	0.41
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.48	0.43	0.38
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.40	0.30	0.34
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.37	0.23	0.31
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.39	0.21	0.29
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.36	0.17	0.25
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.30	0.24	0.23
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.46	0.80	0.36
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.37	0.12	0.36
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.31	0.29	0.36
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.26	0.26	0.36
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.29	0.25	0.35
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.26	0.25	0.34
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.24	0.24	0.34
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.75	1.00	0.49
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.59	0.49	0.39
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.44	0.29	0.37
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.33	0.29	0.37
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.28	0.28	0.36
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.27	0.25	0.35
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.22	0.25	0.33
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B−67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-23 CASE04C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S04C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.20	1.13	0.57
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.07	1.02	0.48
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.97	0.90	0.44
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.90	0.82	0.42
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.82	0.78	0.44
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.69	0.65	0.42
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.58	0.56	0.41
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.48	0.45	0.39
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.39	0.33	0.37
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.34	0.28	0.36
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.30	0.21	0.35
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.27	0.13	0.34
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.29	0.06	0.32
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.44	0.70	0.37
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.34	0.19	0.37
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.29	0.33	0.37
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.26	0.31	0.37
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.22	0.29	0.36
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.23	0.26	0.35
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.25	0.26	0.34
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.74	0.97	0.48
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.58	0.51	0.38
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.43	0.31	0.37
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.33	0.32	0.37
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.29	0.31	0.37
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.24	0.27	0.36
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.18	0.26	0.35
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B−67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-29 CASE05C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S05C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.25	1.37	0.80
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.12	1.22	0.72
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	1.03	1.10	0.66
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.97	1.01	0.64
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.88	0.93	0.53
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.68	0.73	0.57
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.58	0.63	0.53
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.59	0.57	0.48
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.53	0.59	0.43
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.44	0.57	0.40
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.36	0.50	0.37
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.24	0.38	0.33
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.12	0.31	0.29
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.61	1.11	0.48
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.49	0.24	0.48
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.44	0.21	0.49
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.39	0.28	0.46
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.33	0.27	0.44
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.24	0.30	0.40
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.18	0.31	0.38
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	1.06	1.27	0.73
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.80	0.73	0.58
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.59	0.32	0.53
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.48	0.32	0.51
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.42	0.30	0.50
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.37	0.25	0.48
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.26	0.31	0.40
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-35 CASE06C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S06C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.16	1.26	0.63
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.06	1.15	0.56
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.95	1.05	0.52
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.90	0.97	0.50
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.83	0.91	0.46
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.74	0.77	0.46
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.68	0.70	0.43
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.58	0.64	0.40
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.45	0.57	0.37
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.36	0.50	0.36
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.28	0.42	0.34
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.18	0.35	0.32
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.11	0.27	0.29
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.42	0.83	0.45
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.35	0.24	0.44
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.32	0.23	0.44
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.29	0.25	0.43
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.26	0.23	0.42
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.24	0.27	0.41
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.25	0.28	0.39
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.72	0.86	0.58
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.54	0.60	0.50
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.41	0.29	0.47
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.34	0.29	0.45
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.30	0.27	0.44
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.25	0.24	0.42
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.23	0.27	0.38
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-41 CASE07C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S07C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.14	1.25	0.73
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.03	1.12	0.60
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	0.94	1.02	0.55
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.88	0.95	0.53
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.81	0.90	0.48
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.74	0.77	0.51
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.67	0.71	0.49
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.58	0.64	0.45
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.45	0.55	0.42
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.34	0.48	0.39
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.27	0.40	0.38
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.18	0.32	0.37
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.09	0.26	0.34
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.39	0.79	0.42
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.33	0.21	0.41
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.29	0.26	0.41
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.26	0.23	0.40
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.23	0.24	0.40
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.24	0.28	0.39
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.24	0.27	0.36
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	0.65	0.89	0.55
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.45	0.55	0.47
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.35	0.29	0.43
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.29	0.27	0.42
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.27	0.25	0.41
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.24	0.22	0.39
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.24	0.28	0.36
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-47 CASE08C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S08C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.29	1.41	1.03
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.19	1.26	0.88
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	1.09	1.14	0.82
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	1.01	1.06	0.79
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.92	0.97	0.62
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.69	0.75	0.69
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.52	0.59	0.63
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.43	0.45	0.55
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.48	0.42	0.46
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.45	0.40	0.41
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.42	0.48	0.36
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.32	0.40	0.29
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.17	0.28	0.24
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.69	1.27	0.54
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.53	0.22	0.53
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.43	0.13	0.53
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.37	0.29	0.49
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.33	0.32	0.45
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.28	0.33	0.38
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.24	0.33	0.35
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	1.25	1.45	0.79
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.90	0.80	0.63
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.63	0.36	0.58
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.48	0.28	0.55
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.44	0.31	0.52
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.40	0.27	0.49
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.29	0.34	0.39
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-53 CASE09C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S09C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.27	1.38	1.01
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.15	1.23	0.86
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	1.05	1.11	0.82
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.97	1.02	0.80
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.88	0.94	0.63
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.66	0.72	0.70
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.52	0.57	0.64
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.54	0.51	0.56
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.51	0.49	0.47
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.43	0.52	0.41
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.39	0.50	0.38
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.28	0.38	0.41
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.14	0.26	0.36
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.64	1.20	0.46
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.51	0.23	0.46
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.44	0.16	0.47
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.40	0.29	0.44
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.35	0.34	0.41
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.26	0.38	0.37
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.23	0.34	0.35
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	1.11	1.34	0.76
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	0.84	0.75	0.56
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.62	0.36	0.51
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.49	0.26	0.49
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.45	0.31	0.48
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.39	0.26	0.45
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.28	0.37	0.37
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

Table B-59 CASE10C (CRACKED)

Total Equivalent Weight and Seismic Acceleration Summary for RCB

APR1400-RCBAB-B2-R6(0928)-S10C			BUILDING SEISMIC EQUIVALENT WEIGHT AND ACCELERATION SUMMARY TABLE					
ID #	BOTTOM EL. (ft)	TOP EL. (ft)	ΔWx (kips)	ΔWy (kips)	ΔWz (kips)	Acc. X (g)	Acc. Y (g)	Acc. Z (g)
CS: 1	307.5	331.75	8.69E+03	8.69E+03	8.68E+03	1.38	1.38	1.35
CS: 2	281	307.5	9.05E+03	9.05E+03	9.05E+03	1.23	1.23	1.12
CS: 3	254.5	281	6.86E+03	6.86E+03	6.86E+03	1.08	1.09	1.02
CS: 4	241	254.5	4.16E+03	4.16E+03	4.16E+03	0.99	0.99	0.98
CS: 5	220	241	1.17E+04	1.17E+04	1.17E+04	0.92	0.91	0.75
CS: 6	200	220	8.10E+03	8.10E+03	8.10E+03	0.71	0.71	0.83
CS: 7	178	200	8.38E+03	8.38E+03	8.38E+03	0.56	0.57	0.74
CS: 8	156	178	8.47E+03	8.47E+03	8.46E+03	0.44	0.41	0.64
CS: 9	136	156	6.76E+03	6.76E+03	6.77E+03	0.30	0.29	0.53
CS: 10	130	136	2.83E+03	2.83E+03	2.83E+03	0.23	0.21	0.47
CS: 11	125	130	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A
CS: 12	114	125	5.85E+03	5.85E+03	5.85E+03	0.37	0.16	0.41
CS: 13	100	114	5.14E+03	5.14E+03	5.14E+03	0.36	0.10	0.35
CS: 14	78	100	5.81E+03	5.81E+03	5.81E+03	0.29	0.30	0.33
		∑ =	**9.18E+04**	**9.18E+04**	**9.18E+04**			
PSW: 1	156	191	2.71E+03	2.99E+03	2.71E+03	0.81	1.45	0.60
PSW: 2	136.5	156	5.09E+03	5.09E+03	5.09E+03	0.58	0.15	0.58
PSW: 3	130	136.5	2.20E+03	2.21E+03	2.20E+03	0.50	0.31	0.57
PSW: 4	114	130	5.21E+03	5.20E+03	5.21E+03	0.44	0.27	0.52
PSW: 5	100	114	5.62E+03	5.63E+03	5.62E+03	0.35	0.32	0.48
PSW: 6	78	100	6.48E+03	6.48E+03	6.48E+03	0.20	0.29	0.40
PSW: 7	66	78	1.66E+03	1.65E+03	1.66E+03	0.26	0.28	0.36
		∑ =	**2.90E+04**	**2.92E+04**	**2.90E+04**			
SSW: 1	191	200	1.54E+02	1.54E+02	1.54E+02	1.57	1.72	0.91
SSW: 2	156	191	4.76E+03	5.03E+03	4.76E+03	1.05	0.97	0.71
SSW: 3	136.5	156	7.59E+03	7.59E+03	7.59E+03	0.68	0.32	0.63
SSW: 4	130	136.5	3.97E+03	3.97E+03	3.97E+03	0.50	0.25	0.60
SSW: 5	114	130	3.63E+03	3.62E+03	3.63E+03	0.41	0.31	0.57
SSW: 6	100	114	4.38E+03	4.38E+03	4.38E+03	0.31	0.29	0.53
SSW: 7	78	100	2.71E+04	2.71E+04	2.52E+04	0.25	0.33	0.40
		∑ =	**5.16E+04**	**5.19E+04**	**4.97E+04**			

Notes

1. ΔWj = ΔMAX(Fj/j) = The absolute Weight in the j direction between the top and bottom elevations. - (kips)
2. Acc. j = The equivalent acceleration in the j direction calculated between the top and bottom listed elevations. - (g)
3. MAX(Fi/j) = The Maximum Value of the Force in the i direction due to a 1g ground motion in the j direction. - (kips)
4. For the calculation of AB:1, ΔWj includes the differences from shear cuts with ID# 32 and ID# 31 (MCR and FHA structures)
5. The X,Y,Z axes point in the East, North, and vertically upward directions respectively.
6. Moments are calculated about the geometric center of the CS.
7. Moments and Forces due to RCS elements are not included.
8. Hydrodynamic impulsive masses are included.
9. Hydrodynamic convective masses are not included.
10. Accidental Torsion is not included within the calculations.
11. ΔWx, ΔWy, ΔWz are from Table ~~H-64~~ B-67
12. Equivalent accelerations for CS: 11 are not available because the building weight of the CS between elevations 125' and 130' is zero.

described below.

3.5.1 HRHF Response Spectrum-compatible Target PSDs

The development of the APR1400-HRHF response spectrum-compatible target PSDs in the frequency range of 0.3 to 80 Hz, the time history simulation method described in NUREG/CR-5347 (Reference 24) is used. Applying this method for developing the target PSD involves the following steps:

(1) An ensemble of 30 artificial time histories is generated using a frequency domain response spectrum-compatible time history generation method developed by Gasparini and Vanmarcke and implemented in SIMQKE (Reference 25). Each time history 30 time history ensemble has a total duration of 20.475 seconds and is modulated by the intensity envelope function shown in Figure ~~3-16~~ 3-15. Each time history generated has a 2%-damped time history response spectrum compatible with the 2%-damped horizontal APR1400 HRHF response spectra.

The SIMQKE frequency domain response spectrum-compatible time history generation method starts with synthesizing pure harmonic waves with white noise random phases and with amplitudes generated from an initial response spectrum-compatible target PSD within the frequency range of interest, which for the APR1400 HRHF response spectra is 0.3 to 80 Hz. The initial target PSD at each frequency is derived from the 2%-damped target response spectral value divided by a frequency-dependent "peak factor" derived from the random vibration theory (Reference 25). The peak factor, which relates the target PSD value to the 2%-damped target response spectral value, is a function of frequency and non-exceedance probability of the target response spectra. The initial time history is then modified iteratively by adjusting the initial time history PSD at each frequency using the square of the ratio of the 2%-damped time history response spectral value to the 2%-damped target response spectral value.

The 2%-damped time history response spectra for the ensemble of 30 artificial time histories are computed based on which 2%-damped "ensemble-median" time history response spectrum is derived. This spectrum for the ensemble of 30 artificial time histories is shown in Figure 22 for the horizontal motion and in Figure 3-17 for the vertical motion. The 2%-damped horizontal and vertical "ensemble-median" time history response spectra are then compared with the 2%-damped horizontal and vertical target HRHF response spectra. These comparisons are shown in Figures 3-18 and 3-19.

As indicated in Figures 3-18 and 3-19, the ensemble-median time history response spectra derived from the generated horizontal and vertical 30 time history ensembles compared closely with the horizontal and vertical target horizontal and vertical APR1400 HRHF response spectra. The good comparisons indicate that the ensembles of the 30 generated time histories are compatible with the horizontal and vertical target HRHF response spectra and are therefore representative time history ensembles from which the target PSDs compatible with the horizontal and vertical target APR1400 HRHF response spectra can be developed.

(2) The PSD of each individual time history in each 30 time history ensemble is computed. Because each time history in the ensemble is intensity modulated and is therefore a non-stationary motion, an equivalent stationary duration for the motion must be determined for use in computing the PSD of the individual time history. The PSDs computed for the 30 time history ensemble are shown in Figure 3-20 for the horizontal motion and in Figure 3-21 for the vertical motion.

(3) The "ensemble-average" or "ensemble-mean" PSDs obtained from the horizontal and vertical 30 time history PSDs computed in Step (2) and shown in Figures 3-20 and 3-21 are smoothed in accordance with the PSD smoothing procedure recommended in NUREG/CR-5347 (Reference 24). To simplify the representation of the target PSDs shown in Figures 3-20 and

6. EVALUATION

This section describes the results of evaluations of the SSCs subjected to the seismic response demands of the HRHF response spectra. The HRHF response spectra for the following SSCs are evaluated:

- Building structures
  - RCB internal structure
  - RCB containment structure
  - Auxiliary building
  - EDGB/DFOT room
- Reactor coolant system
  - Reactor vessel internals and core
  - Reactor coolant system supports
  - Reactor coolant system nozzles
- Piping systems
- Safety-related equipment

6.1 Building Structures

Maintaining the structural integrity of the NI buildings is important to plant safety. The RCB internal structure, RCB containment structure and auxiliary building are evaluated for the effect of high frequency input ground motion.

The evaluation consists of comparisons of the responses from high frequency input ground motion to those obtained from the APR1400 CSDRS for the building structures.

The comparisons are performed to demonstrate that seismic responses from the CSDRS envelop those from the high frequency input motion. The NI structures are considered to be qualified for the high frequency input ground motion if the seismic responses from the CSDRS envelop those from the high frequency input motion.

To evaluate an effect on the RCB internal structures (i.e., PSW, IRWST, and SSW), seismic forces and moments of these structures are compared as shown in Tables 6-1, 6-2, and 6-3. Although the comparisons of forces and moments from high frequency input motion are greater than the CSDRS, the arrangements of rebar are not changed due to seismic responses from the HRHF seismic input.

Comparisons of the RCB containment structures are presented in Table 6-4. The comparisons of the containment structures show that seismic forces and moments resulting from the CSDRS input motion are greater than forces and moments obtained from high frequency input ground motion.

Equivalent accelerations of auxiliary building to seismic response story forces are evaluated for comparison of equivalent accelerations from the CSDRS and HRHF response spectra. The comparisons for the auxiliary building are presented in Table 6-5. Equivalent accelerations from ~~HRHF~~ CSDRS

HRHF

input ground motion envelop those from the ~~CSDRS~~ except the vertical acceleration of Fuel Handling Area 3 (El. 195'-0" to 213'-0"). The effect due to the increment of equivalent acceleration in the global z direction can be absorbed in the design of the shear walls because each wall member has stiffness enough to resist the additional seismic load due to high frequency seismic input in the axial direction.

Equivalent accelerations of EDGB/DFOT room are also compared in Table 6-6 for the CSDRS and HRHF response spectra. Although some of the equivalent accelerations from HRHF input motion are greater than those from the CSDRS, the arrangements of rebar are not changed.

6.2 Reactor Coolant System

The reactor vessel internals (RVI) support the core which is important to safety. The RVI consists of complicated components whose natural frequencies are in the relatively high frequency range. The RCS component supports are evaluated because they provide the support for the RCS components to maintain their intended safety-related functions. The nozzles are evaluated because piping failures generally occur at high stress locations such as at nozzles of a component and they represent the sensitivity of the reactor coolant loop piping to high frequency excitation. For selected items, the HRHF response is evaluated by comparing the design loads with the loads obtained from the HRHF incoherent analysis. It is concluded that the supports and nozzles are acceptable for the HRHF seismic loads if the design loads from the CSDRS envelop those from the HRHF input ground motion.

6.2.1 Reactor Vessel Internals and Core

The RVI and core were selected because they are important to safety and their analyses are representative of major primary components. Because the natural frequencies of the RVI components are in the relatively high frequency range, the RVI may be sensitive to high frequency excitation.

Detailed analyses were performed to obtain the responses of the RVI and core to HRHF loads. The RVI HRHF analysis was done using the HRHF excitation of the reactor vessel (RV) obtained from the response of the RCB and RCS to HRHF loads. Then, the response of the core was calculated using the detailed core model and the core plate motion obtained from the RVI analysis.

The time history analyses of the RVI and core were performed for each HRHF mode, and the responses of all modes were combined for the resultant response. The maximum response of each mode was used for the combination. The broadening of the input excitation was also considered for the RVI and core analyses by frequency variation as implemented for the CSDRS loads.

The RVI resultant responses of HRHF loads were compared with those of the CSDRS loads. Most forces and moments of the RVI components for HRHF loads were calculated to be less than those for the CSDRS loads. It was already determined that the structural integrities of the RVI and core are maintained for the CSDRS loads. The evaluations were performed for RVI components such as the core support barrel flange and cylinder because the forces and moments on the components from HRHF loads exceeded those from CSDRS loads. The results of the evaluations showed that the increases in component loads due to HRHF loads were insignificant for the structural integrity of the components.

The core resultant responses of HRHF loads were compared with those of the CSDRS loads. The resultant responses for the comparison were grid impact forces. Since the natural frequency of the fuel assembly is in the relatively low range, the core responses for the HRHF loads were predicted to be less than those of the CSDRS loads. The resultant grid impact forces of the HRHF loads were calculated to be less than those of the CSDRS loads. No grid impact of the fuel assemblies occurs for all the modes except the first mode.

Therefore, the effects of HRHF loads on the structural integrity of the RVI and core are insignificant.

$$R_{rI} = \sum_{i=1}^{n} R_{ri} + R_{missmassI}$$

where $R_{missmassI}$ is the residual rigid response of the missing mass modes for the I_{th} component of seismic input motion. The effect of missing mass modes not included in the analysis is accounted for by using the method given in NRC RG 1.92.

Finally, the combined response is calculated as follows:

$$R_I = \left[R_{rI}^2 + R_{pI}^2\right]^{1/2}$$

~~3.7.2.7.1~~ 3.7.2.8 Interaction of Non-Seismic Category I Structures with Seismic Category I Structures

The interfaces between seismic Category I and non-seismic Category I structures are designed for the dynamic loads and displacements produced by both the seismic Category I and non-seismic Category I structures.

To provide reasonable assurance that the failure of a non-seismic Category I structure under the effect of a seismic event does not impair the integrity of an adjacent seismic Category I structure, one of the following procedures is used:

a. Maintenance of sufficient separation between non-seismic Category I structures and seismic Category I structures

b. Analysis and design of non-seismic Category I structures to prevent their failure under SSE conditions in such a manner that the margins of safety of these structures are equivalent to those of seismic Category I structures

c. Design of seismic Category I structures to withstand loads due to the collapse of the adjacent non-seismic Category I structures if sufficient spatial separation is not achieved

The turbine generator building and compound building are classified as non-seismic Category I structures and are located on the west side and south side of nuclear island with a 1.0 m (3 ft) gap on each side. Figures 3.7-40 and 3.7-41 show the FEMs of the turbine generator building and compound building, respectively. To evaluate the structure-soil-structure interaction effects on the nuclear island structures due to presence of adjacent non-seismic Category I structures, the structure-soil-structure interaction analysis using the coupled model for entire structures is performed. The interaction effects of these non-seismic Category I structures on the nuclear island are negligible as provided in Technical Report, APR1400-E-S-NR-14005-P (Reference 20).

The COL applicant is to confirm that the any site-specific non-seismic Category I SSCs are designed not to degrade the function of a seismic Category I SSC to an unacceptable safety level due to their structural failure or interaction (COL 3.7(4)).

~~3.7.2.8~~ 3.7.2.9 Effects of Parameter Variations on Floor Response Spectra

To consider variations in the structural frequencies due to the uncertainties in material properties of the structure and approximations in modeling, the peaks of the computed floor response spectra are broadened by ± 15 percent and smoothed in accordance with NRC RG 1.122, as described in Subsection 3.7.2.5.

The effects of potential concrete cracking on the structural stiffness of reinforced concrete structures are considered as enveloping the floor response spectra for cracked concrete properties with 7 percent damping for the reinforced concrete structures and those for uncracked properties with 4 percent damping for the reinforced concrete structures.

Both uncracked and cracked concrete stiffnesses are considered separately in the seismic analysis models of the seismic Category I structures. For consideration of potential concrete cracking, the cracked concrete stiffness in horizontal and vertical seismic analysis models is reduced by half of the uncracked concrete stiffness except prestressed concrete containment structure and reinforced concrete columns and walls in the vertical models described in ASCE/SEI 43-05 (Reference 21). Therefore, for nine soil profiles and one fixed-base condition, a total of 20 analysis cases are performed in the seismic analysis to generate the floor response spectra of the seismic Category I structures.

The selected locations where the floor response spectra are obtained in analysis models and resultant floor response spectra enveloping the 20 analysis cases for the nuclear island structures are provided in Technical Report, APR1400-E-S-NR-14003-P (Reference 22).

~~3.7.2.9~~ 3.7.2.10 Use of Constant Vertical Static Factors

The safety-related main structural systems are analyzed in the vertical direction using the methods described in Subsection 3.7.2.1. The vertical component is considered to occur simultaneously with the two horizontal components and consistently combined with the horizontal components of the seismic motion as described in Subsection 3.7.2.6. Therefore, a constant vertical static factor is not used for the seismic design of seismic Category I structures.

~~3.7.2.10~~ 3.7.2.11 Methods Used to Account for Torsional Effects

Because the structural models used for seismic Category I structures are constructed with finite elements containing 6 degrees of freedom per node, incorporating torsional effects into the models, the mathematical models include sufficient mass points and corresponding dynamic degrees of freedom to provide a three-dimensional representation of the dynamic characteristics of the structure.

Torsional effects are also accounted for in the structural models used to generate floor response spectra. An additional eccentricity of 5 percent of the maximum building dimension, perpendicular to load direction that results in an accidental torque, is applied to the static finite element structural model to calculate element forces due to accidental torsion. Accidental torsion is considered in both the E-W and N-S directions.

~~3.7.2.11~~ 3.7.2.12 Comparison of Responses

Since only the time-history analysis method based on complex frequency response method, is used for the seismic Category I structures, comparison of the responses between the time-history analysis method and the response analysis spectrum method is not applicable.

~~3.7.2.12~~ 3.7.2.13 Methods for Seismic Analysis of Dams

The COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if necessary (COL 3.7(5)).

~~3.7.2.13~~ 3.7.2.14 Determination of Dynamic Stability of Seismic Category I Structures

The design overturning moments and base shears for seismic Category I structures are determined by time-history analysis based on the complex frequency response method. The seismic motion is input separately to the structural models in three independent orthogonal directions. To check the overturning and sliding, the simultaneous action of horizontal and vertical seismic forces using methods described in Subsection 3.7.2.6 is incorporated.

The procedure to check the stability of seismic Category I structures is described in Subsection 3.8.5.

~~3.7.2.14~~ 3.7.2.15 Analysis Procedure for Damping

For modal superposition method, composite modal damping values are used for structures with components of different damping characteristics. The composite modal damping values are based on weighting the damping factors according to the mass or the stiffness of each element. For the mass-weighted damping, the formulation is as follows:

$$\beta_j = \frac{\sum_{i=1}^{N} \{\phi_j\}^T \beta_i \{M_i\} \{\phi_j\}}{\{\phi_j\}^T [M] \{\phi_j\}}$$

Where:

β_j = composite modal damping for mode j

N = total number of components

β_i = critical modal damping associated with component i

ϕ_j = mode shape vector

$\{M_i\}$ = subregion of mass matrix associated with component i

1 INTRODUCTION

The purpose of this technical report is to present the stability check for the nuclear island (NI) common basemat.

The NI common basemat consists of the reactor containment building (RCB) base area and auxiliary building (AB) base area structures. The RCB is structurally separate from the AB with a seismic gap of 2 in. above the common basemat. The RCB is a seismic Category I structure composed of a pre-stressed concrete cylindrical shell with a hemispherical-type dome and reinforced concrete internal structures. The AB wraps around the RCB, leaving a space for a seismic gap above the common basemat and is a seismic Category I structure. The AB consists of reinforced concrete shear walls and slabs that constitute a lateral load-resisting system.

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The NI common basemat is a reinforced concrete mat foundation with an area of ~~approximately 99,180~~ ft^2 ~~(348 ft × 285 ft)~~. The thickness of the AB basemat is 10 ft. The thickness of the RCB basemat varies from 10 ft at the center to 33 ft at the side, except for transient areas such as the tendon gallery and reactor cavity. The NI common basemat is embedded to a depth of 55 ft below the nominal plant grade of El. 100 ft 0 in.. The bottom of the foundation is at El. 45 ft 0 in.. Figure 1-1 is a plan view of the APR1400 basemat. Figures 1-2 and 1-3 show cross-sectional views at the containment centerline.

This technical report contains five sections. Section 1 is an introduction with background information. Section 2 describes the site profiles for the APR1400 NI common basemat. Section 3 presents the modeling process of the finite element (FE) model for the NI common basemat analysis. Section 4 describes the stability evaluation of the NI common basemat. Section 5 presents the construction sequence analysis of the NI common basemat.