MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

November 30, 2011

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

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-11413

Subject: MHI's Third Responses to US-APWR DCD RAI No. 810-5874 Revision 3 (SRP 03.07.02)

Reference: 1) "Request for Additional Information No. 810-5874 Revision 3, SRP Section: 03.07.02 – Seismic Systems Analysis," dated 8/22/2011.
2) "MHI's Responses to US-APWR DCD RAI No. 810-5874 Revision 3 (SRP 03.07.02)," UAP-HF-11324, dated 9/22/2011 (ML11269A024).
3) "MHI's Responses to US-APWR DCD RAI No. 810-5874 Revision 3 (SRP 03.07.02)," UAP-HF-11402, dated 11/22/2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Third Response to Request for Additional Information No. 810-5874, Revision 3."

Enclosed is the response to RAI 03.07.02-108 contained within Reference 1. The enclosed response is in addition to 17 RAI responses previously provided in References 2 and 3.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

D081
NRO

Enclosure:

1. Third Response to Request for Additional Information No. 810-5874, Revision 3

CC: J. A. Ciocco
C. K. Paulson

Contact Information

C. Keith Paulson, Senior Technical Manager
Mitsubishi Nuclear Energy Systems, Inc.
300 Oxford Drive, Suite 301
Monroeville, PA 15146
E-mail: ck_paulson@mnes-us.com
Telephone: (412) 373-6466

Enclosure 1

UAP-HF-11413
Docket No. 52-021

Third Response to Request for Additional Information No. 810-5874, Revision 3

November, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/30/2011

US-APWR Design Certification
Mitsubishi Heavy Industries
Docket No. 52-021

RAI NO.:	**NO. 810-5874 REVISION 3**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/22/2011**

QUESTION NO. RAI 03.07.02-108:

The Applicant is requested to clarify the following 15 items identified from various sections of DCD (R3).

1. In Subsection 3.7.2.3.7 of DCD (R3), "Shear Stiffness", item "ii" of the fourth paragraph (page 3.7-22) states in part, "To determine which portion of the resulting displacement at each floor is attributable to shear stiffness and which portion is related to bending stiffness, another analytical model in which the vertical DOF is constrained is also prepared separately. The flexibility coefficients for the equivalent beam are evaluated from the results of these analyses."

   The above quoted sentences do not provide enough detail for the staff to perform an evaluation. The Applicant is requested to provide more detailed information that shows how the shear and bending stiffnesses are determined. If desired, a simple example may be used to demonstrate the procedure.

2. In Subsection 3.7.2.4.1 of DCD (R3), "Requirements for Site-Specific SSI Analysis of US-APWR Standard Plant", the eighth paragraph (page 3.7-32) states in part, "FE analyses are employed to evaluate the flexibility of the basemat and the embedded portion of the building. The floor slabs located at and above the ground surface are assumed absolutely rigid."

   The Applicant is requested to verify the accuracy of the second statement in the above quoted statements. In DCD (R3) Subsection 3.7.2.3.10.1. "Validation Method", the item i of the first paragraph (page 3.7-26) states, "A FE model consisting of the portion of the building above the upper level of the basemat, including the walls, columns, and floor slabs, is developed using brick, shell, and beam elements." This paragraph does not mention that the floor slabs located at and above the ground surface are assumed absolutely rigid.

3. In Subsection 3.7.2.7.1 of DCD (R3), "Left-Out-Force Method (or Missing Mass Correction for High Frequency Modes)", the equation given in the third paragraph (page 3.7-38) has a notation "A_m", which is defined as "the maximum spectral acceleration beyond the flexible

modes". Is its value the value of ZPA? If not, the Applicant is requested to provide what its value is and how to obtain that value.

4. In Subsection 3.7.3.1.7.1 of DCD (R3), "Uniform Support Motion Method", the equation for combined displacement response in the normal coordinate for mode i is given by the equation **q_i = d_j time the summation of P_{ij} times d_{ij}** and the corresponding equation in Subsection 3.7.3.1.7.2, "Independent Support Motion Method" is **q_i = the summation of p_{ij} times d_{ij}** The Applicant is requested check the accuracy of these two equations, because, these two equations cannot be both correct unless d_j and d_{ij} are non-dimensional parameters. Also the free index is inconsistent on the two sides of the first equation.

5. In subsection 3.7.1.2 of DCD (R3), "Percentage of Critical Damping Values", the fourth paragraph (page 3.7-9) states in part, "The strain energy dependent modal damping values are computed based on Reference 3.7-18."

   Reference 3.7-18 has been deleted. The Applicant is requested to correct this mistake.

6. In Subsection 3.7.1.1 of DCD (R3),"Design Ground Motion", item "a" of the sixth paragraph under the subtitle "Design Ground Motion Time History" (page 3.7-6) states in part, "The US-APWR artificial time histories have a sufficiently small time increments (Δt =0.005 seconds) and a total duration of 22.005 seconds."

   In MUAP-11002 (R0), "Turbine Building Model Properties, SSI Analyses, and Structural Integrity Evaluation", the time duration is listed as 22.085 seconds. The Applicant is requested to correct or clarify this inconsistency.

7. DCD (R3) Section 3.7.2 provides an eleven step process for developing equivalent static loads from the results of the lumped mass seismic model of the R/B complex. Potentially, the staff has questions on the details of this process, but first, the staff would like the Applicant to clarify if the procedure for developing equivalent static loads from the lumped mass model is obsolete in light of the commitment by the Applicant to use a full three-dimensional finite element model for the SSI analysis of the of the R/B complex. If the procedure is still relevant, the Applicant should describe the situations in which this procedure will be used. The response should also address the relevance of the procedures described in Section 3.7.3.10 of the DCD.

8. In Table 3.7.2-1 of DCD (R3), the analysis method listed for both the SASSI and ANSYS models is "Time History Analysis in the Frequency Domain". The staff requests clarification of this terminology when referring to ANSYS analyses because ANSYS does not use the same methodology as SASSI.

9. In Subsection 3.7.2.1 of DCD (R3), "Seismic Analysis Methods", the third paragraph (page 3.7-15) states in part, "As an alternative option for seismic category I systems and subsystems, it is also acceptable to utilize the composite modal damping method associated with the modal superposition of time history analysis when the equations of motion can be decoupled in accordance with SRP 3.7.2 (Reference 3.7- 16), Section II.13."

   The last sentence in the above quoted paragraph is confusing because the composite modal damping formulations in SRP Section II.13 are appropriate when the subgrade is modeled using a lumped soil spring approach, or for fixed base models. This is inconsistent with the stated approach in the DCD of modeling a frequency-dependent SSI system. The staff requests clarification of the quoted statement from the DCD.

10. In Subsection 3.7.2.3.7.1 of DCD (R3), "Effective Shear Area (A_x, A_y)", (page 3.7- 22), the symbol A_e is referred as "an equivalent shear area" and "the effective cross section area". In Subsection 3.7.2.3.7.2, "Bending Moment of Inertia (I_{yy}, I_{xx})", (page 3.7-23) the symbol I_e is referred as "equivalent moments of inertia" and "effective moment of inertia". The Applicant is requested to explain why one symbol has two different names in each of the instances cited above.

11. In Subsection 3.7.2.5 of DCD (R3), "Development of Floor Response Spectra", the last bullet of the fifth paragraph (page 3.7-34) states, "The broadened response spectra method discussed in Subsection 3.7.3.1 is used or alternatively in some locations, the peak shifting method described in Subsection 3.7.3.1 can be used."

    The staff reviewed Subsection 3.7.3.1.5 of the DCD and notes that there is no description of spectral broadening, but rather a reference back to Subsection 3.7.2.5 of the DCD. The Applicant should delete the circular reference, and make it clear where the description of spectral broadening appears in the document.

12. In Subsection 3.7.2.8.2 of DCD (R3), "T/B", the second bullet of the last paragraph (page 3.7-40) states, "The design of the T/B is based on a static analysis utilizing a three-dimensional FE model, and a seismic dynamic analysis using a three-dimensional lumped mass model." In contrast, MUAP-11002 (R0) describes a full three-dimensional SSI model of the turbine building rather than a lumped mass model, and there is no mention of static analysis in MUAP-11002 (R0) to analyze the turbine building other than a 1g static analysis in the fixed-base condition that is used for model verification.

    The staff requests MHI to clarify in the DCD the approach for designing the turbine building. Also, the last sentence of Section 3.7.2.8.3 of the DCD refers to a stick model of the T/B. This inconsistency with the model description in MUAP-11002 (R0) should be corrected.

13. In Subsection 3.7.2.8.4 of DCD (R3), "A/B", the second bullet of the second paragraph (page 3.7-41) states, "The design of the A/B is based on a static analysis utilizing a three-dimensional FE model, and a seismic dynamic analysis using a three-dimensional lumped mass model." In contrast, MUAP-11001 (R0) describes a full three-dimensional SSI model of the A/B in addition to a lumped mass model.

    The staff requests MHI to clarify in the DCD the models and approach used for designing the A/B building including the use lumped mass vs. distributed mass models and static vs. dynamic methods.

14. In Subsection 3.7.2.12, "Comparison of Responses", the second paragraph (page 3.7-44) states in part, "Since only a time history analysis method is used, comparison of the responses between the response spectrum method and a time history analysis method, as per SRP Section 3.7.2.II.12 (Reference 3.7-16), is not applicable." In contrast, MUAP-11001 (R0) documents a response spectrum analysis of the A/B.

    The staff recognizes that the A/B is an SC-II structure; however, the staff requests that the DCD Subsection 3.7.2.12 reflect the fact that response spectrum analysis was used for the A/B. Also, MHI should state whether there are any SSC's for which the comparison of responses described in SRP 3.7.2.II.12 are applicable.

15. In Subsection 3.7.2.4.1 of DCD (R3), "Requirements for Site-Specific SSI Analysis of US-APWR Standard Plant", the seventh paragraph (page 3.7-32) states, "The depth of the water table must be considered when developing the P-wave velocities of the submerged subgrade materials. Significant variations in the water table elevation and significant variations of the subgrade properties in the horizontal direction are addressed by using additional sets of site profiles."

    The staff requests clarification on the meaning of this statement because variations of subgrade properties in the horizontal direction are not supported by SASSI.

ANSWER:

1. Subsection 3.7.2.3.7 of DCD (R3) has been revised in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) when MHI advised the NRC that they have replaced the previously used Lumped Mass Stick Model (LMSM) with a dynamic three dimensional finite element model (FEM), which is now the design basis. The shear stiffness methodology in DCD (R3) used for the Lumped Mass Stick Model (LMSM) is no longer the seismic design basis and has been deleted from Subsection 3.7.2.3.7. The LMSM is currently used only for studies as documented in Technical Report MUAP-11007 (R1), where the accuracy of the superstructure response is not important.

2. The quoted second sentence has been deleted from Subsection 3.7.2.4.1 of DCD (R3) in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) due to the replacement of the LMSM with a dynamic three dimensional finite element model. See the response to Part 1 above. The present design utilizes dynamic finite element models as the new design basis for which the quoted second sentence is not applicable. Subsection 3.7.2.3.10.1 has also been revised due to the use of dynamic finite element models as the new design basis.

3. As stated in Subsection 3.7.2.7.1 of DCD (R3), "This factor is usually the ZPA of the response spectra for the corresponding direction." As an alternative the acceleration associated with a cutoff frequency can be obtained instead of the ZPA provided the number of modes chosen is such that the responses associated with high frequency modes are included in the total dynamic solution consistent with the methods described in Regulatory Guide 1.92, Revision 2, Regulatory Positions C.1.4 and C.1.5. The notation Am in Subsection 3.7.2.7.1 will be revised to A_m and the last paragraph in Subsection 3.7.2.7.1 will be revised to add the following sentence as the second sentence of the paragraph:

   "As an alternative the acceleration associated with a cutoff frequency can be used instead of the ZPA provided the number of modes chosen is such that the responses associated with high frequency modes are included in the total dynamic solution consistent with the methods described in Regulatory Guide 1.92, Revision 2, Regulatory Positions C.1.4 and C.1.5."

   This is consistent with the acceptance criteria of Section II.1.A.v of SRP 3.7.2 Revision 3.

   Reference:

1. Seismic System Analysis, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants. NUREG 0800, SRP 3.7.2, Rev. 2 and Rev. 3, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

2. Combining Responses and Spatial Components in Seismic Response Analysis, Regulatory Guide 1.92, Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, July 2006.

4. See the response to RAI 799-5877 Question 03.07.03-7 for correction of the typographical error of the equation of Subsection 3.7.3.1.7.1 of DCD (R3), "Uniform Support Motion Method", where the parameter d_{ij} located on the right side of the equation was removed. The equation in Subsection 3.7.3.1.7.2, "Independent Support Motion Method", is correct and does not require revision.

5. The quoted sentence with Reference 3.7-18 in DCD Subsection 3.7.1.2 has been deleted in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251). The revised paragraph now reads as follows:

   "The damping values for systems that include two or more substructures, such as a concrete and steel composite structure, may also be obtained using the strain energy method. This is the same as the stiffness weighted composite modal damping method as provided in to SRP 3.7.2 (Reference 3.7-16)".

   Modeling of stiffness and damping are detailed in report Technical Report MUAP-10001 (R4).

6. The time history representing the CSDRS was generated with a duration of 20 seconds. The initial condition at the start of this time history has zero acceleration at time zero. The initial condition at the start of this time history in the ACS SASSI computer program is automatically set to zero acceleration at time zero and is not an input. The first time history acceleration data point of the input to the ACS SASSI computer program represents the time of the first iterative solution and for the CSDRS time history corresponds to a time of 0.005 seconds.

   In compliance with the requirements of SRP 3.7.1 (Reference 1), Subsection 3.7.1.II.1B, Option 1 Approach 2, the objective is to generate a set of three components of an artificial time history earthquake by adjusting real ground motion recordings from an actual earthquake as the seed. This results in a set of three statistically independent time history components that are compatible with the two horizontal directions and the vertical direction of the US-APWR CSDRS. These adjusted acceleration time histories are used as input ground motion for the SSI analyses described within the Technical Report MUAP-10001 (R4).

   The Nahanni, Canada earthquake recorded at Site 3 on December 23, 1985 is used for the seed motions to develop the time histories with acceleration response spectra matching the CSDRS for the US-APWR. This earthquake has a magnitude of **M**6.76. The depth of the earthquake is listed at 8 km and the epicenter distance to Site 3 at 22.36 km. The recording instrument is located at ground level. The records were obtained from the "The Pacific Earthquake Engineering Research (PEER) Center, University of California at Berkeley" strong motion database.

   The components of the recorded time history earthquake were spectrally matched to the target response spectra at the damping of 5%. In order to achieve this goal, the Fourier amplitudes of the seed acceleration time histories were modified to generate three new acceleration time histories. The final duration of these time histories is 20 seconds with a time step of 0.005 seconds. This Fourier amplitude modification process iterates until the response spectra of the new time histories envelop the target response spectra. These acceleration time histories were base line corrected to ensure that the displacements are zero at the end of the input.

Accordingly, the total duration will be corrected to 20 seconds instead of 22.005 seconds in Subsection 3.7.1.1 of DCD (R3) as shown in the mark-up of DCD (R3) (UAP-HF-11395), page 3.7-7.

Regarding Technical Report MUAP-11002 (R0), the response to RAI 766-5819 Question 03.07.02-61 (ML11215A104) advocated the time history duration incorrectly as 22.080 seconds. Consequently, this RAI response will supersede the commitment in the response of RAI 766-5819 Question 03.07.02-61 to revise the time history total duration to 22.080 seconds. Subsection 5.2.2 of Technical Report MUAP-11002 (R0) has been revised to change the total duration of the time history from 22.085 seconds to 20.

The response to RAI 766-5819 Question 03.07.02-61 (ML11215A104) also made commitments to revise the total duration of the time history from 22.005 to 22.080 seconds in Section 5.1, part (a) on page 5-7 of Technical Report MUAP-10001(R3) and to revise the total duration of the time history from 22.085 to 22.080 seconds in Section 5.1, part (a) on page 5-10 of Technical Report MUAP-10001(R3). Instead, as explained above, MUAP-10001(R4) has recently been issued to the NRC (UAP-HF-11369) and has updated the total duration of the time history to 20 seconds.

7. The eleven step procedure in Section 3.7.2 of DCD for developing equivalent static loads from the results of the lumped mass model of the R/B complex is obsolete since a full three-dimensional finite element model of the of the R/B complex was generated and used for the SSI analysis. See the response to Part 1 above. Section 3.7.2 has been revised as shown in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) due to the use of dynamic finite element models as the new design basis for the seismic analysis of the Reactor Building Complex instead of lumped mass stick models.

   The results obtained from the site-independent SSI analyses for maximum nodal accelerations serve as a basis for development of the seismic loads used for the standard design of the R/B complex and the PS/B structural members. The overall process for development of seismic loading is summarized as follows:

   1. Obtain maximum accelerations at each structural node in each of the 3 response directions due to each of the 3 direction input motions from the SSI analyses.

   2. Apply the square root of the sum of the squares (SRSS) rule to combine the nodal maximum accelerations due to the three directions of the earthquake calculated in Step 1. Envelope the results of the SRSS combined maximum acceleration responses from the SSI analyses for the site soil profiles provided in Table 3.7.1-6. For the containment internal structure, and PCCV, envelope the responses obtained from analyses of models with two levels of stiffness.

   3. For each floor elevation, record the enveloped maximum response accelerations in the three directions calculated in Step 2.

   4. Calculate weighted average accelerations at floor elevation.

5. Determine equivalent seismic quasi-static load at each floor elevation based on the maximum acceleration determined in Step 3 or the weighted average accelerations calculated in Step 4.

6. Determine the out-of-plane seismic demands on slabs and walls with large unsupported areas based on the maximum acceleration plots created in Steps 3.

7. Calculate story shear diagram for the PS/B structure. The total shear at each floor elevation is obtained as the sum of the all nodal inertial forces at and above that elevation. The nodal inertial forces are the product of the nodal mass and the equivalent static acceleration acting on the node.

Please note that the seven step process for developing equivalent static loads as shown above will be transmitted separately in a DCD UTR scheduled to be issued by the end of November 2011.

Subsection 3.7.2.3.10 of DCD (R3) has been changed in the mark-ups of DCD (R3) associated with the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251). The mark-ups reflect the change in methodology from Lumped Mass Stick Models (LMSM) to the use of finite element models (FEM) for the design basis seismic analyses. This change in methodology was to ensure a sufficient number of discrete mass degrees of freedom to adequately represent local vibration modes, such as individual floor slabs and walls, to ensure that the in-structure response spectra include any additional amplification, and to adequately capture responses with frequencies up to 50 Hz. Section 5.3.3 of Technical Report MUAP-10001 (R4) provides the comparison results for purposes of model validation.

Note: The second part of the question to "address the relevance of the procedures described in Section 3.7.3.10 of the DCD" appears to contain a typographical error. Section 3.7.3.10 does not exist in DCD (R3). Section 3.7.2.3.10 seems to be relevant with the first part of the Question 03.07.02-18 Part-7.

8. The analysis method entries listed in Table 3.7.2-1 have been revised for the two ANSYS entries to "1g Static Analysis & Time History Analysis in Time Domain" to reflect the methodology used for the ANSYS analyses.

9. SRP 3.7.2, Section II.13 is not applicable to current methodology of analysis since fixed base LMSM is not utilized. The current analysis involves a dynamic three dimensional finite element model with discretized–halfspace substructuring method and not the lumped parameter (soil spring) method as described in SRP 3.7.2 Section II.13. DCD Subsection 3.7.2.1 will be revised to delete the second quoted sentence of the third paragraph.

10. The two questioned Subsections 3.7.2.3.7.1 and 3.7.2.3.7.2 associated with the use of LMSM are obsolete. As stated in the responses in Parts 1 and 2 above, the present design utilizes dynamic finite element models as the new design basis for which the Subsections 3.7.2.3.7.1 and 3.7.2.3.7.2 have been replaced with Section 3.7.2.3.7 as noted in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251).

11. DCD Tier 2 Subsection 3.7.2.5 describes the envelope broadened response spectra method as stated in the response to RAI Question 3.7.3-05 in RAI 213-1951 (ML090910119) and as stated in DCD Subsection 3.7.3.1.5. The last bullet in the fifth paragraph of DCD Subsection 3.7.2.5 was added to the DCD inadvertently and will be

deleted, thereby eliminating the circular reference. Further, the third bullet in the fifth paragraph of DCD Subsection 3.7.2.5 will be revised to provide a more specific cross-reference to DCD Subsection 3.7.3.1.6 for the peak shifting method.

12. Subsection 3.7.2.8.2 of DCD (R3) has been revised in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) to reflect the same design methodology as in Technical Report MUAP-11002 (R0). As noted in Technical Report MUAP-11002 (R0), SSI of the T/B foundation was performed based on a three dimensional ACS SASSI finite element model and the superstructure was analyzed with a dynamic three dimensional finite element model in GT STRUDL. 1g static analysis was performed with fixed base condition for model verification.

13. Similar to the T/B as noted in part 12 above, the Subsection 3.7.2.8.4 of DCD (R3) has been revised in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) to reflect the same design methodology as in Technical Report MUAP-11001 (R0). The second bullet of the second paragraph in Subsection 3.7.2.8.4 has been revised to read as follows:

    "The design of the A/B is based on two dynamic models. An FE model is used in determination of the maximum accelerations and displacements. A lump mass stick model is used for seismic stability evaluation."

14. The first sentence as stated in the first paragraph in Section 3.7.2.12 is correct. Guidance in SRP Section 3.7.2.II.12 (Reference 3.7-16) and RG 1.206 Section C.I.3.7.2.12 indicates that only Category I structures be discussed. Since this information for the A/B is addressed in Technical Report MUAP-11001, DCD Subsection 3.7.2.12 is not expanded to discuss the fact that response spectrum analysis was used for the A/B.

    There are no seismic category I SSCs for which the comparison of responses described in SRP 3.7.2.II.12 is applicable, since "both time history analysis method and the response spectrum analysis method" are not used for the same analysis of any SSC

15. The observation by the NRC Staff is correct on the modeling limitations of ACS SASSI for the subgrade property variations in the horizontal direction. The seventh paragraph in Subsection 3.7.2.4.1 is deleted and replaced with the following paragraph:

    "Variations in the water table elevations and those in subgrade properties in the horizontal layers are presented in Subsection 3.7.2.4."

    Soil property variations in the horizontal direction is considered as in the first bullet item of the third paragraph of Subsection 3.7.2.4.1 where it is stated "Properties and layering of the soil including fill concrete and backfill modeled depending on its horizontal extent". It should be noted that DCD Subsection 3.7.2.4 has been revised in the supplemental response to RAI 542-4262 Question 03.07.02-35 (ML11188A251) when the use of FEM replaced the LMSM as the new seismic design basis in performing the SSI analysis. Technical Report MUAP-11007 (R1) is referenced in Subsection 3.7.2.4 which provides results of the sensitivity study on water table effects.

Impact on DCD

1. No impact on DCD

2. No impact on DCD

3. See Attachment 1 for the markup of the DCD Tier 2, Section 3.7, changes to be incorporated.

   Subsection 3.7.2.7.1 will be revised to change the notation Am to A_m. Add the sentence "As an alternative the acceleration associated with a cutoff frequency can be used instead of the ZPA provided the number of modes chosen is such that the results of the analysis are within 10 percent of the results of an analysis that considers the additional number of modes." as the second sentence in the last paragraph in Subsection 3.7.2.7.1.

4. No impact on DCD

5. No impact on DCD

6. No impact on DCD

7. No impact on DCD. The seven step process for developing equivalent static loads will included in a DCD UTR which will be separately transmitted to the NRC by the end of November 2011.

8. See Attachment 1 for the markup of the DCD (R3) Tier 2, Sections 3.7 changes to be incorporated.

   Table 3.7.2-1 will be revised for the two ANSYS entries to "1g Static Analysis & Time History Analysis in Time Domain" to reflect the methodology used for the ANSYS analyses.

9. See Attachment 1 for the markup of the DCD (R3) Tier 2, Sections 3.7 changes to be incorporated.

   Subsection 3.7.2.1 will be revised to delete the second sentence of the third paragraph.

10. No impact on DCD

11. See Attachment 1 for the markup of the DCD Tier 2, Section 3.7, changes to be incorporated.

    Subsection 3.7.2.5 will be revised to delete the fourth bullet item in the fifth paragraph. The last sentence of the third bullet item in the fifth paragraph will be revised to read as follows:

    > "Alternatively in some locations, the peak shifting method described in Subsection 3.7.3.1.6 can be used instead of the broadened response spectra method."

12. No impact on DCD

13. No impact on DCD

14. No impact on DCD

15. See Attachment 1 for the markup of the DCD Tier 2, Section 3.7, changes to be incorporated.

The seventh paragraph in Subsection 3.7.2.4.1 is deleted and replaced with the following paragraph:

> "Variations in the water table elevations and variations in the subgrade properties of the horizontal layers are presented in Subsection 3.7.2.4."

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

Subsection 5.2.2 of Technical Report MUAP-11002 (R0) has been revised (UAP-HF-11369) to change the total duration of the time history from 22.085 seconds to 20.

This completes MHI's responses to the NRC's questions.

3.7.2.1 Seismic Analysis Methods

The methods used for the seismic analysis of the US-APWR seismic category I systems conform to the requirements of SRP Subsections 3.7.1 (Reference 3.7-10) and 3.7.2 (Reference 3.7-16). Table 3.7.2-1, as updated by the COL Applicant to include site-specific seismic category I structures,presents a summary of dynamic analysis and combination techniques including types of models and computer programs used, seismic analysis methods, and method of combination for the three directional components for the seismic analysis of the US-APWR standard plant seismic category I buildings and structures.

The seismic response of standard plant seismic category I and II structures is obtained from site-independent analyses performed using three-dimensional SSI models with the program ACS SASSI (Reference 3.7-17) which utilizes time history analysis in the frequency domain with the sub-structuring technique and complex stiffness representation of stiffness and damping properties of the structures and subgrade. The global complex stiffness matrix of the structure is assembled from the stiffness matrices of the finite elements. Table 3.7.2-3 provides stiffness and damping values for seismic category I structures for both uncracked and cracked conditions. With the sub-structuring technique, impedance, load vector, and complex dynamic stiffness matrices are developed separately for the structure and the soil. The flexible volume method, in which all nodes of the excavated soil are set as interaction nodes, is used as reference method for SSI analyses of embedded structures. The input ground motion is transformed into the frequency domain using Fast Fourier Transformation. The equations of motion for the complex SSI system are then developed by combining the equations of motion for the structure with those of the soil in the frequency domain. The seismic response is obtained in the frequency domain from solution of complex algebraic equations for a selected set of frequencies of analysis. The solutions obtained for the selected set of frequencies of analysis are then interpolated and transformed into the time domain using Inverse Fast Fourier Transformation. The entire process is described in Section 2 of the user's guide for ACS SASSI (Reference 3.7-17).

DCD_03.07.02-35

MIC-03-03-00066

As described above, the ACS SASSI program (Reference 3.7-17) analysis method requires solution in the frequency domain of the coupled equations of motion that represent the SSI system. ~~As an alternative option for seismic category I systems and subsystems, it is also acceptable to utilize the composite modal damping method associated with the modal superposition of time history analysis when the equations of motion can be decoupled in accordance with SRP 3.7.2 (Reference 3.7-16), Section II.13.~~

DCD_03.07.02-108 (9)

Analyses of seismic category I and II subsystems are primarily performed using equivalent static load analysis or modal response spectra analysis. ~~The input seismic loads are defined by ISRS that are obtained from the time history analyses of the major seismic category I buildings and structures.~~ Seismic subsystems are discussed in Subsection 3.7.3, and the modal response spectra and equivalent static load analysis methods are discussed in Subsection 3.7.3.1.

MIC-03-03-00066

Seismic anchor motions are taken into consideration for all seismic analysis methods used in the design of seismic category I and seismic category II SSCs. All analysis approaches have been based on linear elastic analysis of SSCs, with allowable stresses within the elastic limits for seismic loads and load combinations as delineated in Section

Up-to-date modeling techniques capable of capturing the various site-specific SSI effects are used for the analysis. The computer program SASSI is used for the site-specific SSI analysis, because it is based on the use of the FE technique and sub-structuring method with frequency-dependent impedance functions to model the interaction of the embedded flexible basemat with the surrounding soil.

The input used for the site-specific analysis must be derived from geotechnical and seismological investigations of the site. ~~The input control motion that is derived from the site-specific GMRS, is applied in the SASSI analysis as within motion at the bottom of the basemat.~~The input control motion derived from the site-specific FIRS is applied in the SASSI analyses at the bottom-of-foundation control point location as motion within a soil column that includes the embedment materials and their strain-compatible properties. DCD_03.07.02-106
Site-specific SSI analyses account for the uncertainties and variations of the subgrade properties by using at least three sets of site profiles that represent the best estimate, lower bound, and upper bound (BE, LB, and UB for equations, respectively) soil and rock properties. If sufficient and adequate soil investigation data are available, the LB and UB values of the initial (small strain) soil properties are established to cover the mean plus or minus one standard deviation for every layer. In accordance with the specific guidelines for SSI analysis contained in Section II.4 of SRP 3.7.2 (Reference 3.7-16), the LB and UB values for initial soil shear modulii (G_S) are established as follows:

$$G_s^{(LB)} = \frac{G_s^{(BE)}}{(1+C_v)} \quad \text{and} \quad G_s^{(UB)} = G_s^{(BE)} \quad (1+C_v)$$

For well investigated sites, the C_V should be no less than 0.5. For sites that are not well investigated, the C_V for shear modulus shall be at least 1.0.

The SSI analysis must use stiffness and damping properties of the subgrade materials that are compatible with the strains generated by the site-specific design earthquake (SSE or/and OBE). However, soil material damping shall not exceed 15% as stipulated in SRP 3.7.1 (Reference 3.7-10). The COL Applicant is to evaluate the strain-dependent variation of the material dynamic properties for site materials. If the strains in the subgrade media are less than 2%, the strain-compatible properties can be obtained from equivalent linear site-response analyses using soil degradation curves. Degradation curves that are published in literature can be used after demonstrating their applicability for the specific site conditions. The strain-compatible soil profiles for the site-specific verification SSI analyses of the major seismic category I structures can be obtained from the results of the site response analyses that are performed to calculate site-amplification factors for the development of GMRS, as described in Subsection 3.7.1.1.

~~The depth of the water table must be considered when developing the P-wave velocities of the submerged subgrade materials. Significant variations in the water table elevation and significant variations of the subgrade properties in the horizontal direction are addressed by using additional sets of site profiles.~~Variations in the water table elevations and variations in the subgrade properties of the horizontal layers are presented in Subsection 3.7.2.4. DCD_03.07.02-108 (15) described in Subsection 3.7.1.3. ISRS developed from the site-independent seismic analyses of the R/B complex and PS/Bs are used for design. ISRS developed at 5% critical damping, which are presented in Technical Report MUAP-10006 (Reference 3.7-48) and referenced in Appendix 3I are used to validate the standard plant ISRS by comparison to site-specific ISRS that are also developed at 5% critical damping. The process for developing enveloped ISRS is described in detail in Section 3.5 of Technical Report MUAP-10006 and is summarized as follows: ÷ DCD_03.07.02-35

- The response spectra are generated for the three components of earthquake by SRSS, following the general guidance of RG 1.122 (Reference 3.7-26) for frequencies up to 100 Hz.

- The maximum spectral acceleration at each frequency obtained from the seismic analysis of any general subgrade conditions is selected for the envelope.

- The enveloped ISRS are smoothed and broadened by +/-15%. The valleys in the enveloped ISRS are filled when necessary to capture potential shifts in the seismic response caused by soil properties that are different from, but bounded by, the generic soil conditions of the standard plant. Alternatively in some locations, the peak shifting method described in Subsection 3.7.3.1.6 can be used instead of the broadened response spectra method. DCD_03.07.02-108 (11)

- ~~The broadened response spectra method discussed in Subsection 3.7.3.1 is used or alternatively in some locations, the peak shifting method described in Subsection 3.7.3.1 can be used.~~ DCD_03.07.02-108 (11)

~~ISRS are not required for~~No safety-related systems and components are present in non-seismic category I building structures, such as the AC/B, A/B and T/B~~, since no safety-relatedsystems and components are present in non-seismic category I buildings and structures~~. The design, installation, and mounting of non safety-related systems and components in these buildings are based on the applicable site-specific building codes and standards. DCD_03.07.02-35

3.7.2.6 Three Components of Earthquake Motion

As previously discussed in Subsection 3.7.1.1, the seismic analyses of the major seismic category I structures are based on one set of three mutually orthogonal artificial time histories, with each of the three directional components being statistically independent of the other two. The acceleration time histories of the horizontal H1 and H2 components of the earthquake are applied in N-S direction and E-W directions respectively. The acceleration time history V is applied in the vertical direction.

The three components of the earthquake are applied on the seismic model separately in ACS SASSI (Reference 3.7-17) for obtaining the maximum accelerations of the response in the three orthogonal directions. The maximum responses of interest of SSCs obtained from the responses of each of the three components of motion are then combined using SRSS or the Newmark 100%-40%-40% method in accordance with RG 1.92, Rev.2 (Reference 3.7-27). The combined maximum accelerations, obtained through the process described previously in Subsection 3.7.2, are then used as basis for development of the

In the response spectra analysis, the total inertia force contribution of higher modes can be interpreted as:

$$\{ Fr \} = A_m [M] [\{ r \} - \sum P_j e_j]$$

where

A_m = the maximum spectral acceleration beyond the flexible modes

[M] = the mass matrix

{ r }= the influence vector or displacement vector due to unit displacement

P_j = participation factor, where

$$P_j = e_j^T [M] \{ r \}, \ \{ Fr \} = A_m [M] \{ r \} [1 - \sum M e_j e_j^T]$$

In the response spectra analysis, the low frequency modes are combined by one of the modal combination methods in accordance with RG 1.92, Rev.2 (Reference 3.7-27) as discussed above. For each support level, there is a pseudo-load vector or left-out-force vector in the X, Y, and Z directions.

These left-out-force vectors are used to generate left-out-force solutions which are multiplied by a scalar amplitude equal to a magnification factor specified by the user. As an alternative the acceleration associated with a cutoff frequency can be used instead of the ZPA provided the number of modes chosen is such that the results of the analysis are within 10 percent of the results of an analysis that considers the additional number of modes. This factor is usually the ZPA of the response spectra for the corresponding direction. The resultant low frequency responses are combined by the SRSS with the high frequency responses (rigid modes results). DCD_03.07.02-108 (3)

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

The locations of all major buildings within the power block are shown on the general arrangement drawings in Section 1.2.

Seismic category II structures have been analyzed for the same seismic loads and using the same seismic analysis methods described for seismic category I SSCs in Subsection 3.7.2.1 to verify that they will not collapse or adversely interfere with seismic category I SSCs or adversely affect the MCR occupants. Seismic category II is defined in Section 3.2. By definition, seismic category II structures are designed to retain their position to the extent necessary to assure that they will not impact the function or integrity of seismic category I SSCs.

NS structures have been located such that, in case of their collapse or failure, they do not have the potential to impact seismic category I SSCs, either directly or indirectly.

~~NS structures that are not located beyond the range of impact are isolated by heavy concrete walls from seismic category I SSCs.~~ DCD_03.07.02-97

Table 3.7.2-1 Summary of Dynamic Analysis and Combination Techniques

Summary of Dynamic Analyses & Combination Techniques					
Model	**Analysis Method**	**Program**	**Three Components Combination (for purposes of dynamic analysis)**	**Modal Combination**	
Three-dimensional R/B-PCCV-containment internal structure SSI Model (1)	Time History Analysis in Frequency Domain using sub-structuring technique	ACS SASSI	SRSS	N/A	DCD_03.07.02-35
Three-dimensional RCL-R/B-PCCV-containment internal structure FE Model (2)	1g Static Analysis & Time History Analysis in ~~Frequency~~Time Domain	ANSYS	N/A(2)	N/A	DCD_03.07.02-108 (8) DCD_03.07.02-108 (8)
Three-dimensional PS/B SSI Model(3)	Time History Analysis in Frequency Domain using sub-structuring technique	ACS SASSI	SRSS	N/A	DCD_03.07.02-35
Three-dimensional PS/B FE models(2)	1g Static Analysis & Time History Analysis in ~~Frequency~~Time Domain	ANSYS	N/A(2)	N/A	DCD_03.07.02-108 (8) DCD_03.07.02-108 (8)

Notes:

1. The three-dimensional RCL-R/B-PCCV-containment internal structure SSI model is addressed in Technical Reports MUAP-10001 and MUAP-10006 (References 3.7-47 and 3.7-48).
2. The FE models for the RCL-R/B-PCCV-containment internal structure on their common basemat and the PS/Bs are used ~~only~~ for validation of the dynamic FE seismic models and for static analysis for design of structural members and components as addressed in Section 3.8. DCD_03.07.02-35
3. The three-dimensional PS/B model is addressed in Technical Reports MUAP-10001 and MUAP-10006 (References 3.7-47 and 3.7-48).