RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/31/2013

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:	**08/22/11**

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:

This answer revises and replaces the previous MHI answer transmitted by letter UAP-HF-11413 (ML11335A269).

1. A dynamic finite element (FE) model has replaced the previous reactor building (R/B) complex lumped mass stick model as the seismic design basis model. Technical Report MUAP-10006, Rev. 3, Sections 02.3.2, 02.4.1, and 02.5.1, describe the development, properties and validation of the R/B complex dynamic FE model. The statement in item ii of DCD Section 3.7.2.3.7 applies to the LSM approach and is no longer applicable and has been removed from the DCD.

2. The approach described in the text previously quoted in the DCD has been revised, and the DCD has been revised accordingly. The previously used lumped mass stick model has been replaced with a dynamic three dimensional FE model in which the floor slabs located at and above the ground surface are not assumed absolutely rigid. Subsection 3.7.2.3.10.1 has also been revised due to the use of dynamic FE models as the new design basis.

3. As stated in Subsection 3.7.2.7.1 of DCD, Rev. 3, "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 zero period acceleration (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 (RG) 1.92, Rev. 2, Regulatory Positions C.1.4 and C.1.5. The notation Am in Subsection 3.7.2.7.1 has been revised to A_m and the last paragraph in Subsection 3.7.2.7.1 has been 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 Rev. 3.

4. The response to RAI 799-5877, Question 03.07.03-7 corrected the typographical error of the equation of Subsection 3.7.3.1.7.1 of DCD, Rev. 3, "Uniform Support Motion Method,"

where the parameter dij 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. The revised paragraph is revised as follows:

   "The damping values for the 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 SRP 3.7.2 (Reference 3.7-16)."

   Modeling of stiffness and damping are detailed in Technical Report MUAP 10006, Rev. 3, Section 02.4.1.1.4.

6. The current time history duration is identified in Technical Report MUAP-10006 Rev. 3, Section 01.4.1.3. Technical Report 11002, Rev. 1 will be consistent with the information presented in Technical Report MUAP-10006, Rev. 3.

7. The eleven step process for determining the equivalent static loads from the results of the lumped mass stick model are no longer relevant for the R/B complex since a full dynamic FE model is used for the SSI analyses. The process for developing the quasi static loads is described in Technical Report MUAP-10006, Rev. 3, Section 03.3.7. With regard to procedures discussed in Subsection 3.7.2.3.10 of the DCD, the validation of the dynamic FE model is addressed separately from the development of quasi-static loads used for design. The validation of the dynamic FE model is addressed in Sections 02.4.1.2 and 02.5.1.3 of Technical Report MUAP-10006, Rev 3.

8. DCD Table 3.7.2-1 has been revised to present the current methodology and design. The table is consistent with the methodology presented in the technical reports.

9. SRP 3.7.2, Section II.13 is not applicable to current methodology of analysis since fixed base lumped mass stick model is not utilized. The current analysis involves a dynamic three dimensional FE 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 has been revised and no longer contains the cited reference.

10. Section 3.7.2.3.7.1 has been deleted in its entirety since the R/B complex is modeled using a FE model in place of the lumped mass stick model.

11. The DCD has been revised to delete the circular reference. DCD Tier 2 Subsection 3.7.2.5 describes the development of in-structure response spectra (ISRS) which includes enveloping and broadening in accordance with RG 1.122.

12. As noted in Technical Report MUAP-11002, Rev. 2, soil-structure interaction of the turbine building foundation was performed based on a three dimensional ACS SASSI FE model and the superstructure was analyzed with a dynamic three dimensional FE model in GT STRUDL. 1g static analysis was performed with fixed base condition for model verification.

13. The auxiliary building (A/B) has been combined on a common basemat with the R/B, prestressed concrete containment vessel, containment internal structure, east and west power source buildings and the essential service water pipe chase to form the R/B complex. The dynamic modeling approach used for the A/B is now the same as that

used for the dynamic R/B complex FE model as described in DCD Tier 2 Section 3.7.2 and as shown in DCD Table 3.7.2-1. The structural design of the R/B complex is addressed in DCD Section 3.8. Lumped mass stick models are not used for the dynamic or structural design of the A/B.

14. Response spectrum analysis is not used for the seismic design of the R/B complex, which includes the A/B, and as such, DCD Subsection 3.7.2.12 has not been updated to include a comparison of time history analysis results with response spectrum analysis results. As stated in DCD Subsection 3.7.3 and DCD Sections 3.9 and 3.12, response spectrum analyses may be used for subsystem seismic design, rather than time history analyses.

15. Consistent with SASSI, there are no horizontal subgrade property variations in the layers below the excavated volume. Within the excavated volume, horizontal variation such as that associated with backfill properties, is modeled as described in Technical Report MUAP-10006, Rev. 3, Section 03.3.4.1. DCD Section 3.7.2.4.5 requires the site-specific SASSI analyses to consider the horizontal extent of any fill concrete and backfill within the excavated volume, however the text quoted in the question has been deleted from the DCD.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the COLA.

Impact on S-COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on a Technical/Topical Report.

This completes MHI's response to the NRC's question.