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**RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION**

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1/31/2013

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

**RAI NO.:** NO. 852-6003 REVISION 3  
**SRP SECTION:** 03.07.02 – Seismic System Analysis  
**APPLICATION SECTION:** 3.7.2  
**DATE OF RAI ISSUE:** 10/24/11

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**QUESTION NO. RAI 03.07.02-138:**

In reviewing the applicant's technical report, MUAP-10001(R3), the staff identified several areas which need further clarification, additional information, or editorial revision. The applicant is requested to address the following requests and questions:

1. In this report, Section 1 "INTRODUCTION," (page 1-2) the last paragraph states, "Refer to Technical Report MUAP-10006, "Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant" (Reference 24), for the results of these SSI analyses."

The staff noticed that Reference 24, MUAP-10006, Revision 1, is dated January 2011. However, this current Report was issued in June 2011. The applicant is requested to verify the accuracy and relevance of Reference 24 for the purpose stated in the report, and if necessary, to revise this reference.

Also, the following two sentences from the end of the Introduction state:

"The validations of the dynamic FE models of the R/B complex and the PS/B are performed following the methodology described in Section 4.3.2, Section 4.4.3 and Section 5.3.3 through 5.3.5 of this Technical Report. The validation of the PS/B Dynamic FE structural model is performed following the methodology and results described in Section 5.4.5 of this Technical Report."

Clarify the methodology and results that are applicable to the PS/B.

2. In Subsection 4.1 of this Report, "CSDRS Compatible Ground Motion Time Histories," Item 3 of the first paragraph in Page 4-4 states, "Repeat these steps as needed to optimize the spectral match of the time series to the target."

The applicant is requested to provide the criteria for the optimization mentioned above.

3. P. 4-15, in Table 4.3.1.1-2 of this Report, "Input Material Properties," Note 4 states, "The PCCV is comprised of prestressed concrete while the R/B and FHA are comprised of reinforced concrete." It is assumed that the ¼ inch steel liner in the PCCV is ignored. The applicant is

requested to confirm this. Also, there appears to be a typo in the last item in the first column: "Steel-Concrete Modulus," should be "Steel-Concrete Modules."

4. P. 4-22, Section 4.3.1.2 of this Report "Discretization Considerations: Mesh Size." There appears to be an incorrect reference number in the 4<sup>th</sup> line: "(Reference 12)" should be "(Reference 2)."

5. P. 4-23, Section 4.3.1.3 of this Report "Modeling of Stiffness and Damping," there appears to be an incorrect reference number in the 3rd line: "(Reference 12)" should be "(Reference 2)."

6. P. 4-46, Section 4.5.3 of this Report "Approach to Address Concrete Cracking in Site-Independent SSI Analyses," there appears to be some missing words in the last sentence between "also provides a" and "describing."

7. P. 5-13 of this Report, the note below Fig. 5.2-1, Sheet 1 of 2 should be placed on Fig. 5.2-1, Sheet 2 of 2.

8. In Table 4.3.1.1-2 of this Report, "Input material Properties," Note (2) of the table (Page 4-15) states, "Steel-Concrete (SC) Modules is for composite sections made of concrete encased by steel plates. The concrete strength is  $f'_c=4,000$  psi and steel yield strength of  $F_y=50$  ksi. Refer to Section 4.3.1.6 for the material properties (stiffness) of the SC Modules used in the Dynamic FE Model."

The staff noticed that Section 4.3.1.6 concerns the stiffness of composite steel-concrete beams and columns in the FH/A. However, there are no SC modules used in the FH/A. The material properties (stiffness) of the SC modules are given in Appendix A. The applicant is requested to correct this mistake (Reference should be to Appendix A instead of Section 4.3.1.6).

9. In Subsection 4.3.1.6 of this Report, "Stiffness of Composite Steel-Concrete Beams and Columns," the second paragraph (Page 4-27) states, "Based on AISC 360-05 Commentary (Reference 26), 75% of the composite transformed moment of inertia is used in calculating the effective moment of inertia of the composite section ( $I_{eff}$ ):"

$$I_{eff} = \min[0.75I_{tr}, I_x + (\text{Square root } (Q_n/C_t)) \cdot (I_{tr} - I_x)]$$

The staff checked AISC 360-05 and believes the equation cited should be:

$$I_{eff} = 0.75 [I_x + (\text{Square root } (Q_n/C_t)) \cdot (I_{tr} - I_x)]$$

The applicant is requested to verify the accuracy of their equation, and, if necessary, to revise the equation and the seismic input parameters in the SSI analysis.

10. In Subsection 4.5.1 of this Report, "Effects of Concrete Cracking on Reinforced Concrete Shear Wall Structures," the first paragraph (Page 4-43) states, "In accordance with ASCE 4-98 (Reference 13), Section 3.1.2, and ASCE/SEI 43-05 (Reference 14), Section 3.1.2, traditional reinforced concrete members and elements are to be modeled as either cracked or uncracked sections ..."

The staff noticed that the section numbers of ASCE 4-98 and ASCE 43-05 given in the above quoted paragraph are incorrect. The correct section numbers should be ASCE 4-98 Section 3.1.3 and ASCE 43-05 Section 3.4.1, respectively. The applicant is requested to correct these mistakes.

11. P. 4-45, in Section 4.5.3 of this Report, "Approach to Address Concrete Cracking in Site-Independent SSI Analyses," the 1st sentence in the 2<sup>nd</sup> paragraph states: "Two sets of analyses

are also performed on the dynamic FE model of R/B complex using full (uncracked concrete) stiffness and reduced (cracked concrete) stiffness.”

The applicant should clarify if the reduced stiffness due to cracking mean that all elements are assumed to be cracked (i.e., a global reduction), or does it apply only to those FE elements in which the analysis indicates that the cracking strength of the concrete is exceeded in those elements?

12. In Subsection 5.1 of this Report, “CSDRS Compatible Ground Motion Time Histories,” the sentence below Table 5.1.2, “Spectra Matching Requirements for Converted Time Histories,” (Page 5-9) states, “The time histories also meet the requirements set forth in Acceptance Criteria 1B, on page 3.7.1-9 of SRP 3.7.1 (Reference 1) as summarized in Table 5.1-2 and further described below.”

The second paragraph of Acceptance Criteria 1B, on page 3.7.1-9 of SRP 3.7.1 states “In addition to the duration, the ratios  $V/A$  and  $AD/V2$  ( $A$ ,  $V$ ,  $D$  are peak ground acceleration, ground velocity, and ground displacement, respectively) should be consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the uniform hazard response spectra.” The staff found that the ratios  $V/A$  and  $AD/V2$  are not listed in Table 5.1-2 of this Report and are not described in this Report elsewhere. The Applicant is requested to provide these ratios in Table 5.1-2 for the CSDRS and for the artificial time histories generated.

13. In Subsection 5.3.1 of this Report, “Development of the R/B Complex Dynamic FE Model,” the fourth paragraph (Page 5-81) states, “To compensate for such a deficiency, all steel sections are assigned an increased moment of inertia in their strong axis to account for their composite behavior.”

The applicant is requested to provide detailed technical information that shows how the moment of inertia is increased.

14. In Table 5.3.2.1-8 of this Report, “Material Properties of RCL Stick Models,” (Page 5-95) the Young’s modulus for P (A/B/C/D)19 to P(A/B/C/D)20 is listed as 0.0000209.

The applicant is requested to provide information that explains why this value is so low.

15. In Figure 5.4.4-2 of this Report, “Ground Floor (EL. 3’-7”) – Dynamic Model - 1<sup>st</sup> Dominant Frequency,” (Page 5-239) the frequency is listed as 39.468. In Figure 5.4.4-4 of this Report, “Ground Floor (EL. 3’-7”) – Dynamic Model – 2nd Dominant Frequency,” (Page 5-240) the frequency is listed as 33.009.

The applicant is requested to check the accuracy of these two figures. Why is the value of the 2<sup>nd</sup> dominant frequency lower than that of the 1st dominant frequency?

16. In Subsection 5.3.3.2 of this Report, “Validation of the CIS,” the paragraph (Page 5-125) states, “Due to the complexity of the CIS, different stiffness and damping values are assigned to different types of structural components for the two bounding stiffness and damping conditions as described in Appendix A.”

The staff noticed that the applicant has recently issued a report, “Containment Internal Structure: Stiffness and Damping for Analysis,” MUAP-11018-P (R0), August 2011. The applicant is requested to confirm that the information presented in Appendix A of MUAP-10001(R3) with regard to CIS stiffness and damping, that is used in the SSI analysis of R/B complex model, is not revised due to the recently issued report otherwise identify all changes made to the CIS stiffness and damping. The staff has not completed its evaluation of MUAP 11018-P(R0); further questions

and requests for additional information may be generated with respect to Appendix A of MUAP 10001 (R3).

The applicant is requested to reference MHI's technical report "Containment Internal Structure: Stiffness and Damping for Analysis," MUAP-11018-P (R0), August 2011 in this Appendix A.

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**ANSWER:**

Technical Report MUAP-10006, Rev. 3 incorporates and updates the modeling and analysis methodology and results from Technical Report MUAP-10001.

RAI 03.07.02-138 item 1:

The power source buildings (PS/Bs) are now part of the reactor building (R/B) complex structure. The methodology and results related to the development and validation of the PS/B dynamic finite element model are described in Sections 02.4.1 and 02.5.1 of Technical Report MUAP-10006, Rev. 3.

RAI 03.07.02-138 item 2:

The approach for developing certified seismic design response spectra (CSDRS) compatible ground motion time histories has changed from Option 1 Approach 2 to Option 1 Approach 1. The criteria for the power spectra density and spectral matching are therefore the criteria of SRP 3.7.1, Option 1 Approach 1. The overall process is now described in Technical Report MUAP-10006, Rev. 3, Sections 01.4.1 and 01.5.1.

RAI 03.07.02-138 item 3:

The ¼ inch steel liner in the prestressed concrete containment vessel (PCCV) is ignored in developing the stiffness properties of the PCCV. However, the additional mass of ¼ inch steel liner is included in the model. This is clarified in Note 4 in Table 02.4.1.1.1-2 of Technical Report MUAP-10006, Rev. 3 (formerly Table 4.3.1.1-2 of Technical Report MUAP-10001), which states, "The PCCV is comprised of prestressed concrete while the R/B and FHA are comprised of reinforced concrete. In developing the stiffness properties of the PCCV, the PCCV liner is not included as a strength element; the additional mass of the ¼ inch steel liner is included in the model."

The typo in the first column of Table 02.4.1.1.1-2 in Technical Report MUAP-10006, Rev. 3, "Steel-Concrete Modulus" is corrected to "Steel-Concrete Modules."

RAI 03.07.02-138 item 4:

The incorrect reference number ("Reference 12") is corrected to "Reference 02-2" in Section 02.4.1.1.2 of Technical Report MUAP-10006, Rev. 3.

RAI 03.07.02-138 item 5:

The incorrect reference number ("Reference 12") is corrected to "Reference 02-2" in Section 02.4.1.1.3 of Technical Report MUAP-10006, Rev. 3.

RAI 03.07.02-138 item 6:

The wording which was present in the last sentence of Section 4.5.3 of Technical Report MUAP-10001, Rev. 3 is not present in Technical Report MUAP-10006, Rev. 3. Sections 02.4.1.1.3 and 02.4.2 of Technical Report MUAP-10006, Rev. 3, address how concrete cracking is taken into account when modeling the stiffness and damping in the soil-structure interaction (SSI) analyses. Technical Report MUAP-10006, Rev. 3, Section 02.4.2.3 states: “The structural material damping values used for these two different stiffness and stress levels are also provided in Table 02.4.1.1.3-1.”

RAI 03.07.02-138 item 7:

Figure 01.5.2-1 of Technical Report MUAP-10006, Rev. 3, is the equivalent of Figure 5.2-1 of Technical Report MUAP-10001. The note regarding the compression wave velocity is no longer on the figure. Sections 01.4.2.1 and 01.5.2 of Technical Report MUAP-10006, Rev. 3 clarify that the development of generic profiles consider a water table located at the plant surface elevation by setting the value of compression wave velocity at or above 5,000 ft/s, which is the compression wave velocity of water.

RAI 03.07.02-138 item 8:

Table 02.4.1.1.1-2 of Technical Report MUAP-10006, Rev. 3 is the equivalent of Table 4.3.1.1-2 of Technical Report MUAP-10001. Note (2) in Table 02.4.1.1.1-2 refers to Table 02.4.1.1.3-2 of Technical Report MUAP-10006, Rev. 3. Table 02.4.1.1.3-2 summarizes the material properties (stiffness and damping) of the steel concrete (SC) modules used in the dynamic models, rather than Appendix A of Technical Report MUAP-10001.

RAI 03.07.02-138 item 9:

Per the AISC 360-05 Commentary for realistic deflection calculations,  $I_{eff}$  should be taken as  $0.75I_{equiv}$ , where  $I_{equiv}$  is based on linear elastic theory for a composite member. For members that are partially composite, AISC 360-05 gives a separate formula. The stiffness formulae are therefore clarified in Section 02.4.1.1.6 of Technical Report MUAP-10006, Rev. 3, as follows:

$I_{eff} = 0.75 I_{tr}$  for a fully composite member and

$I_{eff} = I_x + (\text{Square root } (Q_n/C_f)) \cdot (I_{tr} - I_x)$  for a partially composite member, with  $Q_n/C_f \geq 0.25$

A typographical error in the formula for  $I_{tr}$  in Section 02.4.1.1.6 of Technical Report MUAP-10006, Rev. 3 (formerly Section 4.3.1.6 of MUAP-10001) has also been corrected, and a cross-reference to the stiffness discussion in Section 02.4.1.1.6 of Technical Report MUAP-10006, Rev. 3 (formerly Section 4.3.1.6 of Technical Report MUAP-10001) has been added to Table 02.4.1.1.3-1 of Technical Report MUAP-10006, Rev. 3 (formerly Table 4.5.3-1) for the composite members in the fuel handling area.

RAI 03.07.02-138 item 10:

The text of Section 02.4.2.1 of Technical Report MUAP-10006, Rev. 3 (formerly Subsection 4.5.1 of Technical Report MUAP-10001) now cites the correct ASCE 4-98 and ASCE 43-05 sections noted by the NRC staff.

RAI 03.07.02-138 item 11:

The reduced stiffness due to cracking is applicable globally as now explained in Sections 02.4.2, 02.4.2.1, and 02.4.2.3 of Technical Report MUAP-10006, Rev. 3, except for the containment internal structure as explained in Sections 02.4.2.2 and 02.5.1.3.3, for which different stiffnesses are assigned for different members.

RAI 03.07.02-138 item 12:

The time histories in Technical Report MUAP-10006, Rev. 3, have been generated in accordance with SRP 3.7.1, Option 1, Approach 1. For clarity, the quoted sentence, which was formerly below Table 5.1-2 in Technical Report MUAP-10001, has been deleted from the corresponding Table 01.5.1.2-1 and discussion in Technical Report MUAP-10006, Rev. 3. The  $V/A$  and  $AD/V^2$  ratio information for the ground motion time histories (based on Northridge, Mount Baldy earthquake seed) matching the CSDRS are presented in Table 01.5.1.2-1 of Technical Report MUAP-10006, Rev. 3, and discussed in Section 01.5.1.2. Note that since the  $V/A$  and  $AD/V^2$  ratios for the CSDRS represent the spectral values for a theoretical oscillator responding to the ground input motion, the  $V/A$  and  $AD/V^2$  CSDRS values are considered to be irrelevant, and only the values associated with the ground motion input time histories are presented. Table 01.5.1.2-1 shows that the US-APWR artificial time histories'  $V/A$  and  $AD/V^2$  ratios fall within the ranges defined by the mean ratios  $\pm$  one standard deviation for earthquakes of magnitude bins of M6.5+ with distance bins from 10 to 100 km, based on Table 3-6 of NUREG/CR-6728. DCD COL Item 3.7(6) requires that the Applicant develop site-specific seismic input motion for validation of the standard plant at a particular site, and DCD COL Item 3.7(24) requires the COL Applicant to verify that the site-specific  $V/A$  and  $AD/V^2$  ratios are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the site-specific uniform hazard response spectra.

RAI 03.07.02-138 item 13:

Section 02.4.1.1.6 of Technical Report MUAP-10006, Rev. 3 (formerly Section 4.3.1.6 of Technical Report MUAP-10001) provides the detailed technical information that shows how the moment of inertia is increased to represent the main steel frame in the fuel handling crane support system.

RAI 03.07.02-138 item 14:

A replacement table for Table 5.3.2.1-8, "Material Properties of RCL Stick Models," of Technical Report MUAP-10001, is not included in Technical Report MUAP-10006, Rev. 3. Material properties of the reactor coolant loop (RCL) stick model elements, including Young's modulus, will be presented in Technical Report MUAP-09002, Rev. 3, "Summary of Seismic and Accident Load Conditions for Primary Components and Piping." Technical Report MUAP-09002, Rev. 3, is scheduled to be issued in July 2013 per the updated MHI US-APWR seismic closure plan presented in letter UAP-HF-12280 (ML12290A009).

RAI 03.07.02-138 item 15:

The plot of Figure 5.4.4-2 was inadvertently interchanged with the plot of Figure 5.4.4-4 in Technical Report MUAP-10001. The dynamic responses for validation of the east and west PS/Bs are now presented in Sections 02.5.1.3.4 and 02.5.1.3.5 of Technical Report MUAP-10006, Rev. 3, respectively. Mode shapes for the east PS/B dynamic model are presented in Figures

02.5.1.3.4.2-5, -7, -9, -11, -13 and -15. Mode shapes for the west PS/B dynamic model are presented in Figures 02.5.1.3.5.2-5, -7, -9, -11 and -13.

RAI 03.07.02-138 item 16:

The information with regard to containment internal structure stiffness and damping is contained in Tables 02.4.1.1.3-1 and 02.4.1.1.3-2 of Technical Report MUAP-10006, Rev. 3 instead of the former Appendix A of Technical Report MUAP-10001. Section 02.5.1.3.3 of Technical Report MUAP-10006, Rev. 3 states: "Due to the complexity of the CIS, different stiffness and damping values are assigned to different types of structural components for the two bounding stiffness and damping conditions as described in Table 02.4.1.1.3-2." Table 02.4.1.1.3-1 refers to Table 02.4.1.1.3-2. The stiffness and damping information in Tables 02.4.1.1.3-1 and 02.4.1.1.3-2 is taken from Table 7-1 of Technical Report MUAP-11018, Rev. 1.

**Impact on DCD**

There is no impact on the DCD.

**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**

There is no impact on the Technical/Topical Reports.

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