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TOKYO, JAPAN

November 04, 2010

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-10300

Subject: MHI's Responses to US-APWR DCD RAI No. 625-4924 (SRP 03.07.02)

Reference: 1) "Request for Additional Information No. 625-4924 Revision 0, SRP Section: 03.07.02 - Seismic System Analysis," dated 8/30/2010.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 625-4924, Revision 0."

Enclosed are the responses to 14 RAIs contained within Reference 1. This transmittal completes the response to this RAI.

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,

Atsushi Kumaki for

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

Enclosure:

1. Response to Request for Additional Information No. 625-4924, Revision 0

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

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NRO

Enclosure 1

UAP-HF-10300
Docket No. 52-021

Response to Request for Additional Information No. 625-4924,
Revision 0

November, 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

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

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. RAI 03.07.02-11:

This request for additional information (RAI) is necessary for the staff to determine if the Application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed. On the basis of the staff's review of the spectra comparisons shown in section 5.3.3.3, the staff disagrees with the conclusion in the first paragraph of Section 5.3.3.3 of MUAP-10001, Rev. 1 that the ARS for the PCCV models indicate that the stick model properly captures the structural response in all directions. Provide the acceptance criteria and technical bases are used to justify that the stick model properly captures the structural response in all directions.

Also, the staff understands that the ANSYS lumped mass model and the SASSI lumped mass model are effectively identical models being run in two different codes. If this is the case, provide the reason for the approximately 30% difference in response between the SASSI stick model and the ANSYS stick model at 11 Hz in Figure 5.3.3.3-9. If the models are different, describe the differences in the models.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

a) The R/B complex lumped mass stick model used for soil-structure interaction (SSI) analysis follows the guidelines given in SRP Sections 3.7.2.II.1 and 3.7.2.II.3 to provide sufficient degrees of freedom to properly capture the dynamic response of the structure and to employ acceptable modeling procedures. The stick model is compared to the detailed 3-D finite element (FE) model used for static analysis and design using three methods described in Section 5.3 of the report:

1) 1g static analyses are performed on each model using ANSYS. The displacement results from fixed base static analyses of the two models are used to develop deflection shapes at the corners of the structures. The comparison of the deflection shapes serves to check the consistency of the distribution of stiffness and mass inertia properties of the two models. Parallel deflection shapes indicate that the lumped mass stick model and the detailed FE model have a consistent distribution of the stiffness and mass inertia properties;

2) Modal analyses are performed using ANSYS to obtain the frequencies of the dominant modes of vibrations of the two models. The two models are considered to have consistent overall dynamic properties if the frequencies of the dominant modes of vibration in three directions are within 5%.

3) A SSI analysis is also performed using ACS SASSI with the foundation of the model resting on the surface of a half-space with hard-rock properties in order to simulate the response of the structures under a fixed base condition. Transfer functions at selected nodes are obtained from the SSI analysis. The translation of the lumped mass stick model from ANSYS into SASSI is considered accurate if the frequencies corresponding to the transfer functions peak amplifications are within 5% of the dominant modal frequencies obtained from the ANSYS fixed base modal analyses.

3) A dynamic time-history response analysis using modal superposition is performed on the lumped mass stick model and the finite element model using ANSYS. Acceleration response spectra (ARS) with 5% damping are generated from the time-history analyses of the two models and compared with the 5% damping ARS obtained from the ACS SASSI analysis with hard-rock SSI. The lumped mass stick model is considered consistent with the detailed FE model if the compared ARS meet the following general guidelines based on engineering judgment:

   - The magnitude of lumped mass stick model peak ARS are within 10% of the FE peak ARS response magnitude for significant peaks
   - The frequency of the lumped mass stick model peak ARS are within 5% of the FE peak ARS frequency for significant peaks

When the criteria outlined above are not met, it may be determined that the dynamic properties of the lumped mass stick model and the detailed FE model are consistent if an acceptable technical justification explains the difference.

b) Additional validation will be performed on the lumped mass stick model used for site-independent SSI analyses of R/B complex in order to assess any potential shortcomings and their effect on the SSI analyses and the seismic standard design basis. For that purpose, a 3-D dynamic finite element (FE) SASSI model of the R/B complex structures is under construction and will be used for SSI analyses of the eight generic layered soil profiles. The results from these SSI analyses will be used to further validate the results obtained from the SSI analyses of the R/B complex lumped mass stick model. A detailed FE model of the R/B complex structures used for structural design has also been updated and enhanced. This updated detailed FE model is also being used for a set of fixed base static and dynamic analyses, the results of which will serve as the basis for validation of the lumped mass stick model and new dynamic FE SASSI model. The validation that follows the guidelines given in SRP Sections 3.7.2.II.1 and 3.7.2.II.3 is to be performed as follows:

1) ANSYS analyses performed on three models (detailed FE model, dynamic FE model and lumped-mass stick model) with full stiffness or un-cracked concrete properties that serve as the basis for the validation of the models dynamic properties

2) The models (two FE and one lumped mass stick model) for the PCCV and CIS are isolated from the overall R/B complex FE models and fixed base boundary conditions are established at the nodes where they are attached to the thick central portion of the basemat. Static 1-g, modal and mode superposition time history analyses are performed independently for the PCCV and CIS.

3) Static 1-g and modal analyses are performed on the R/B models that includes the FH/A and the basement, but not the CIS and PCCV. In order to simplify the ANSYS computer runs, the modal superposition time history analysis is performed on reduced models representing the above ground portion of the R/B that is isolated from the overall R/B complex model and fixed at plant grade elevation.

4) The consistency of the effective seismic mass between the models is checked by performing ANSYS 1-g static analyses where each floor of the FE element models is fixed to calculate total reaction at each floor elevation. The models are considered consistent if the weight of the lumped mass inertia assigned at each floor elevation is within 5% of the effective seismic weight obtained from 1-g analyses of FE models.

5) The deflection shapes obtained from 1g static analyses of FE models and lumped mass stick model are compared to check the distribution of the mass inertia and stiffness properties. Smooth and parallel deflection shapes indicate that the different models have consistent distribution of mass and stiffness properties.

6) Dominant modes of vibration are extracted from the results of the ANSYS modal analyses of the three types of models. The models are considered to have consistent overall dynamic properties if the calculated natural frequencies of the dominant modes of vibration in three directions are within 5%. The dominant modes shapes of the lumped mass stick model are checked for smooth mode shapes.

7) For each of the model, 5% damping acceleration response spectra (ARS) are calculated at representative locations from the results of modal superposition time-history analyses. The response obtained from the different types of models is considered consistent if the results for ARS peak frequencies are within 5% and the differences in the calculated peak spectral accelerations are within 20%.

8) The dynamic FE model is then modified to account for the affects of potential cracking. Best estimate dynamic stiffness properties are evaluated for each structure based on the stress/member force results obtained from the static analyses of the detailed FE model under design load combination that include SSE loads. The structural members that experience high level stresses are selected and their stiffness properties in the dynamic models are adjusted to take into consideration the reduction of stiffness due to the cracking of the concrete.

9) Following the methodology described in Section 5.3.4 of MUAP 10001 Rev 1, ANSYS modal analyses are performed on both detailed and dynamic R/B FE models with cracked concrete properties by isolating individual floors. If the mesh refinement of the dynamic R/B FE model is not sufficient to capture all of the out-of-plane vibrations of flexible slabs and walls with natural frequency below 50 Hz, single degree of freedom (SDOF) elements are developed and incorporated in to the dynamic model.

10) Fixed base modal and modal superposition time history analyses are performed in ANSYS on the dynamic FE model with best estimate (cracked) stiffness properties and SDOF's. SSI analysis is performed on this model after being translated in to ACS SASSI with the model resting on the surface of a half-space with hard-rock properties. Transfer functions and 5% damping ARS are calculated at selected nodes.

The translation from ANSYS into ACS SASSI is considered accurate if the frequencies corresponding to the transfer functions peak amplifications are within 5% of the dominant modal frequencies obtained from the ANSYS fixed base modal analyses and if the ARS results for peak spectral accelerations obtained form the two types of analyses are within 20%.

11) A set of site-independent SSI analyses are performed on the SASSI FE model of R/B complex resting on the surface of the eight generic soil profiles considered for the SSI analyses of R/B complex lumped-mass stick model documented in MUAP 10006 Rev. 0. The responses due to the three components of the earthquake are combined using Square Root of Sum of Squares (SRSS) method. The results for maximum acceleration obtained from the analyses eight soil cases are enveloped and used to verify the SSE design loads specified in Tables 4-13, 4-14 and 4-15 of MUAP 10006 Rev. 0. ISRS with 5% damping are developed at representative locations within the SASSI FE model. The ISRS results obtained from the analyses of the eight soil cases are enveloped and then broadened by 15%. The final broadened ISRS are used to verify the ISRS provided in Appendices C, D and E of MUAP 10006 Rev. 0.

In order to ensure an adequate modeling of the dynamic properties of the R/B complex structures, a technical justification must be provided to explain the difference when any of the above criteria are not met.

c) A review of Figure 5.3.3.3-9 of Technical Report (TR) MUAP-10001 Rev. 1 revealed that the results from the ANSYS time history analysis of the lumped mass stick model were plotted incorrectly. The data labeled in the figures as 'Stick Model – Nd. 9_CV03' was actually the response spectra calculated for the node CV02, located at elevation below CV03. See the detailed response to RAI 603-4666 Rev. 0, Question 03.07.02-10 Item #4 for resolution of this issue.

Impact on DCD

There is no impact on the DCD. A future revision of TR MUAP-10001 will include a) discussion of acceptance criteria and technical bases and b) revised Figure 5.3.3.3-4 and 5.3.3.3-9. A future revision of TR MUAP-10006 will include any required updates due to modeling enhancements implemented in TR MUAP-10001.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-12:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

Based on the staff's review of stiffness comparison plots in section 5.3.4.1, the staff disagrees with the conclusion in the first paragraph of Section 5.3.4.1 of MUAP-10001, Rev. 1 that the comparisons of stiffness between the R/B stick model and the distributed mass are acceptable. Please explain the acceptance criteria and technical bases are used to justify this conclusion and how do the acceptance criteria meet the guidance provided in SRP 3.7.2.II.A.iv.

As an example, in Figure 5.3.4.1-5, the difference in stiffness is approximately 100% at an elevation of 25 ft. Explain the basis for which this difference is determined to be acceptable.

Also, explain why the upper elevation limits in Figures 5.3.4.1-1 through 5.3.4.1-8 vary from approximately 100 feet to approximately 155 feet.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

The dynamic properties of the detailed FE model and lumped mass stick model of the reactor building (R/B) and fuel handling area (FH/A) were reviewed as described in RAI 625-4924 Rev. 0, Question 03.07.02-11 response a. In order to reduce the size of the model and simplify the ANSYS analyses, the detailed FE model of R/B was separated from the overall detailed model of the R/B complex, and fixed boundary conditions were established at the nodes where the walls and slabs of the R/B basement are connected to the R/B complex basemat. The static and dynamic analyses of lumped mass stick model were performed in ANSYS by fixing the nodes of the model at the basemat bottom elevation.

The results from 1-g analyses of the lumped mass stick model and detailed finite element (FE) model for lateral displacements in NS (x) and EW (y) direction at the four corners of the building were compared. Although the displacements vary in magnitude due to the different boundary conditions, the shape of the diagrams of the lateral deformations obtained from the ANSYS analyses of the lumped-mass stick model and the detailed FE model presented in Figures 5.3.4.1-1 to 8 are used as an indicator of the ability of the lumped-mass stick model to represent the stiffness of the structure. The comparison of the results presented in Figures 5.3.4.1-1 to 4 indicate that the displacements in NS direction are consistent in shape for all but the NE corner of the fuel handling area (FH/A) located above R/B operational floor elevation. The comparison of the shapes of the deformations in EW direction calculated from the ANSYS analyses of both models indicates that they are consistent for all areas of the building but the FH/A portion. For the FH/A, the stiffness of the crane steel support and concrete exterior walls in the SASSI stick model is lumped together in a single stick element, so the local effects are not explicitly captured when modeling the overall lateral stiffness of the FH/A.

It is recognized that the lumped mass stick model capability to capture local effects such as the response of the FH/A exterior walls is limited. A 3-D FE SASSI model of the R/B complex structures is under development that will capture the local effects more effectively than the lumped-mass stick models enhanced with SDOF models. As described above in the response to question 03-07-02-11b, the FE SASSI model of R/B complex structures is being validated using results of ANSYS fixed base analyses of a new updated detailed FE model of the building that employs enhanced modeling of the FH/A stiffness and mass inertia.

The elevation of the R/B roof varies in different areas. In the NW corner of the R/B the roof elevation is at 101'-0", the SW roof is at 115'-6", the NE roof is at 154'-6", and the SE roof is at 115'-6". This is reflected in the upper elevation limit of Figures 5.3.4.1-1 through 5.3.4.1-8 of Technical Report MUAP 10001 Rev. 1.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-13:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed. Based on the staff's review of Figures 5.3.4.3-1 through 5.3.4.3-25, of MUAP-10001, Rev. 1, the staff disagrees with the conclusion in Section 5.3.4.3 that the lumped mass models of the R/B properly capture the structural response to dynamic loads in all directions because in numerous cases the ISRS from the stick models show significantly different responses in both frequency and magnitude compared to the distributed mass model. As an example, in Figure 5.3.4.3-1 the peak spectral acceleration at 6 Hz from the distributed mass model is 3.4*g*, while for the lumped mass stick model the peak acceleration is 1.9*g*, which is approximately 45% lower than the target. Similar discrepancies hold for other figures in this section. It is also evident from Figures 5.3.4.3-22 and 5.3.4.3-23 that the stick models respond to frequencies that that are not predicted by the distributed mass model.

Provide the acceptance criteria used to support the conclusion that the stick models are adequate to capture the structural response to dynamic loads in all directions and how do the acceptance criteria meet the guidelines of the SRP. The applicant should resolve the differences in responses of the lumped mass and distributed mass models of the R/B and develop a lumped mass stick model that adequately captures and predicts distributed mass model seismic responses in both frequency and in magnitude.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13,2010; ML101400073

ANSWER:

a) The lumped mass stick model used for soil-structure interaction (SSI) analysis was reviewed to confirm the model has sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

b) It is acknowledged that the comparison of the ARS results from the detailed FE model and the R/B lumped-mass stick model do not demonstrate the ability of the lumped mass stick model to accurately capture the local responses at all locations within the R/B. The methodology used for development of design ISRS, where the responses at lumped mass locations and outrigger locations are enveloped together with the SDOF model responses, are intended to compensate for these modeling shortcomings of the lumped mass stick model. As discussed in the response to question 03.07.02-11 part (b) of this RAI, a 3-D finite element (FE) SASSI model of the R/B complex structures is under construction and will be used for site independent SSI analyses. The results from the SSI analyses of SASSI FE model of the R/B complex will be used to validate that the ISRS generated from the lumped-mass-stick model envelope all of the local vibration responses.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-14:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

Based on the staff's review of comparisons of the stiffness between the CIS stick model and the distributed mass model, the staff disagrees with the conclusion in the first paragraph of Section 5.3.5.1 of MUAP-10001, Rev. 1 that the comparisons of stiffness between the CIS stick model and the distributed mass are acceptable. As an example, differences of stiffness of approximately 30% between the lumped mass model and the distributed mass model are shown in Figures 5.3.5.1-2 and 5.3.5.1-4.

Please explain the acceptance criteria and technical bases used to justify the conclusion that the comparisons of the CIS stick model stiffness and the distributed mass model are acceptable. Also explain how the acceptance criteria for the statement above meet the guidance provided in SRP 3.7.2.II.A.iv.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

a) The lumped mass stick model used for soil-structure interaction (SSI) analysis was reviewed to confirm the model has sufficient accuracy of stiffness to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

b) A comparison of the shapes of lateral deformations presented in Figure 5.3.5.1- 1 to 4 shows that they are consistent in shape in almost all locations. Discrepancies can be noticed in the lateral displacements of IC00-IC61 branch at elevations below elevation 25 ft corresponding to the elevation of the lumped mass node IC02. The detailed FE model of the containment internal structure (CIS) uses two types of elements to represent the stiffness of the bottom 25 ft of the structure, shell elements in purple representing the steel/structure walls at the CIS periphery and solid elements in red representing the CIS central portion. The CIS lumped-mass stick model uses only one stick element between two floor elevations to represent the overall stiffness of the structure. Figures 5.3.5.1-1 through 5.3.5.1-4 of MUAP 10001 Rev. 1 show a variation in the results obtained from the analysis of the detailed FE model for the displacements of the periphery of the model that are due to variation of the local stiffness of the CIS part of the structure modeled with shell elements. The discrepancies in the deformation results can be explained by the local effects that are not captured by the stick elements of the CIS lumped mass stick model. As discussed in the response of Question 03.07.02-11 part b of this RAI, a 3-D FE SASSI model of the R/B complex structures is under construction that will provide a better representation of the local stiffness distribution of the CIS structure.

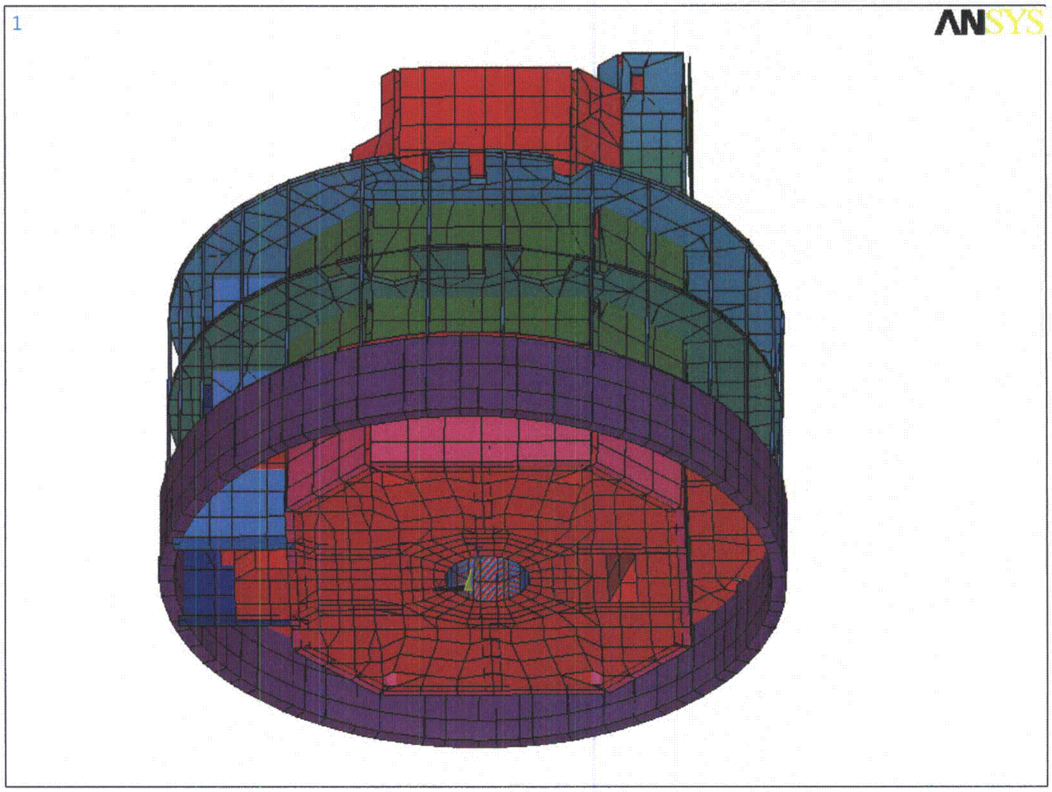


Figure ANSYS Detailed Model of CIS

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-15:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed.

Table 5.3.5.2-1 of MUAP-10001, Rev. 1 shows the modal properties of the detailed distributed mass CIS finite element model in the N-S direction. The first three natural frequencies of the CIS in the N-S direction are shown as 6.2 Hz, 8 Hz, and 11.3 Hz. In Figure 5.3.5.2-1, the first two peaks in the transfer functions occur at approximately 5 Hz and 7.5 Hz. Specifically, the amplifications in the transfer functions at the frequencies in Table 5.3.5.2-1 are significantly lower than the peak amplifications.

Explain how MHI propose to resolve such discrepancies and account for the fact that the natural frequencies in the N-S direction as calculated from the detailed distributed mass model fall in "valleys" and not on the 'peaks' of the transfer functions from the lumped mass stick model. The applicant should resolve the differences in responses of the lumped mass and distributed mass models of the CIS and develop a lumped mass stick model that adequately captures and predicts distributed mass model seismic responses in both frequency and in magnitude.

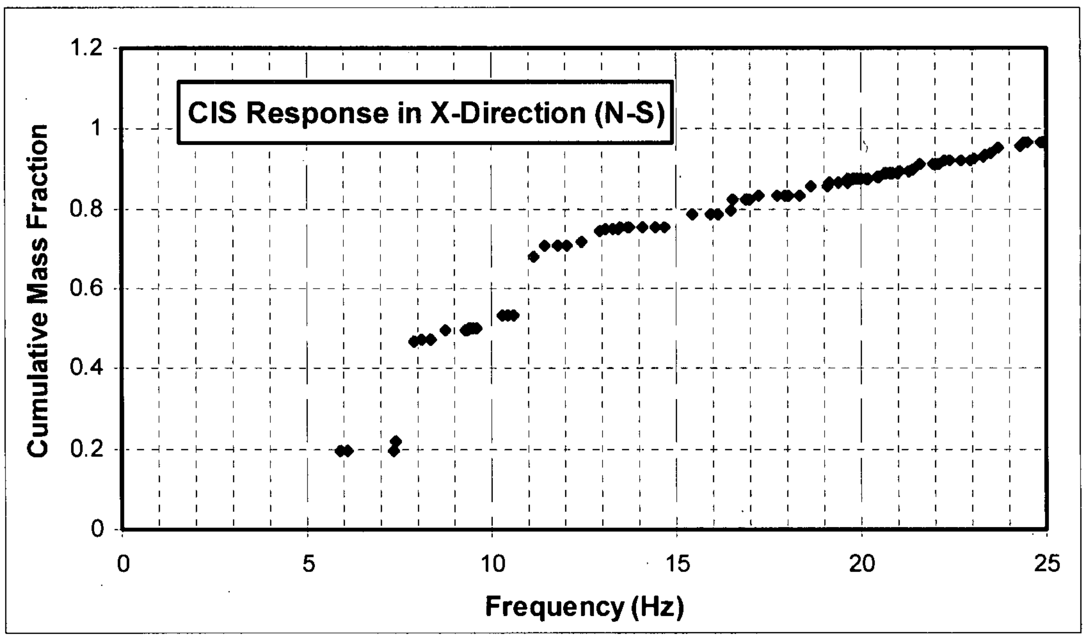
Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

a) The lumped mass stick model used for soil-structure (SSI) analysis is reviewed to confirm the model has sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

b) Section 5.3.5.2 of MUAP 10001 Rev. 1 presented the results of modal analysis of the detailed finite element (FE) model of the containment internal structure (CIS) with full stiffness (uncracked concrete) conditions that was decoupled from the reactor coolant loop (RCL) model. The transfer function results presented in Figures 5.3.5.2-1 to 5.3.5.2-3 of MUAP 10001 Rev. 1 were obtained from the hard rock SSI analysis of the lumped-mass stick model that is coupled with the RCL model and has reduced stiffness (cracked concrete) properties. The first figure provided in this response presents the preliminary results of modal analysis of the coupled detailed FE model with full stiffness (uncracked) properties in terms of the mode cumulative mass fraction in N-S direction and modal frequency. The steep increases in the graph of the cumulative mass fraction indicate significant modes of vibration in N-S direction. The table below summarizes the frequencies of the first three dominant modes of vibration of the CIS in N-S direction that were obtained from the ANSYS modal analysis of the coupled detailed FE model with full stiffness (uncracked) properties. The second figure provided in this response presents the transfer function results obtained from the hard rock SSI analyses of the coupled CIS lumped-mass stick model with full stiffness (uncracked) properties resting on the surface of a half-space with high (hard rock)stiffness properties.

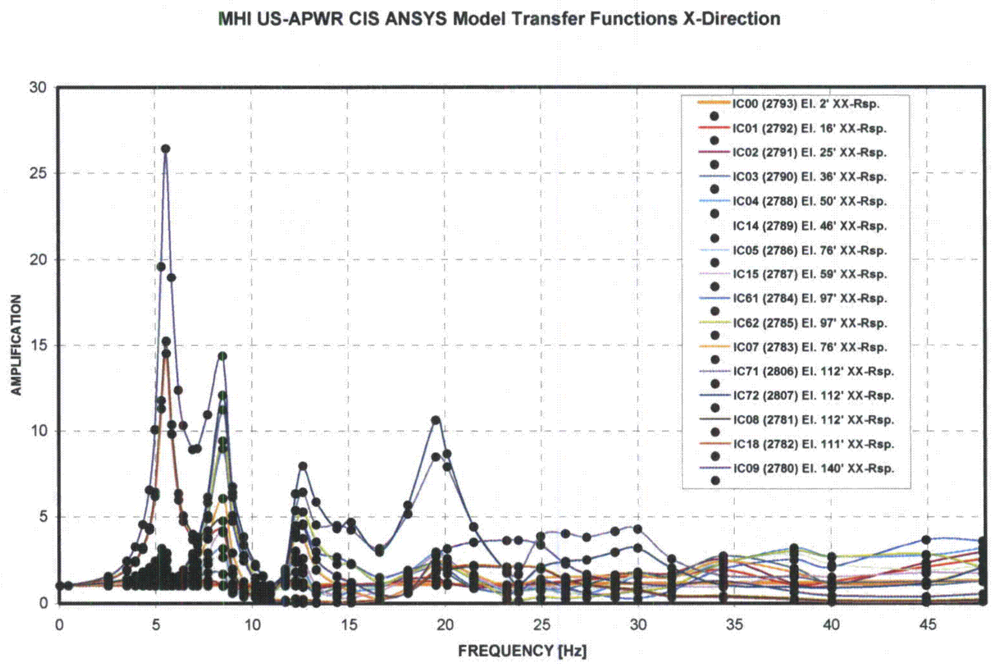
The comparison of the results for the response of the CIS model in the N-S direction shows that the difference between the frequency of the peak transfer function amplification obtained from the ACS SASSI SSI analyses of the lumped mass stick model and the natural frequency of the first two dominant modes obtained for the ANSYS modal analysis of the detailed FE model is 6%. These results indicate acceptable correlation of the dynamic properties between the two models. As described in the response to Question 03.07.02-11 part b of this RAI, the 3-D dynamic FE SASSI model of the R/B complex structures that is under construction will be used to further investigate the effect of the higher local modal responses of the CIS on the SSI results.



Preliminary Revised Table 5.3.5.2-1 Modal Properties of First 3 Modes, X-Direction (NS)

MODE	FREQUENCY (HZ)	PERIOD (sec)	PARTIC.FACTOR	EFFECTIVE MASS (lbs*sec^2/ft)

1	5.90	0.169	199.81	39926.0
5	7.91	0.126	226.04	51094.7
20	11.14	0.0898	-174.96	30611.3



Preliminary Revised Figure 5.3.5.2-1 ANSYS Dynamic Model Transfer Functions, X-Direction

Impact on DCD

There is no impact on the DCD. The next revision of report TR MUAP-10001 will incorporate a revised figure and table in Section 5.3.5.2 for the CIS in the N-S direction as discussed above. Further validation using a SASSI FE will be documented in a future revision of TR MUAP-10001.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

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RAI NO.:	**NO. 625-4924 REVISION 0**
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DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-16:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed.

Table 5.3.5.2-2 of MUAP-10001, Rev. 1 shows the modal properties of the detailed distributed mass CIS finite element model in the E-W direction. The first three natural frequencies of the CIS in the E-W direction are shown as 6.4 Hz, 7.6 Hz, and 11.7 Hz. In Figure 5.3.5.2-2, the first two peaks in the transfer functions occur at approximately 5.25 Hz and 7.5 Hz. Specifically, the amplification at 6.4 Hz in the transfer functions is significantly lower than the peak amplification at 5.25 Hz. Also, it appears that the third natural frequency at 11.7 Hz does not appear at all in the transfer functions shown in Figure 5.3.5.3-2.

Explain how MHI propose to resolve such discrepancies and account for the discrepancies in the dynamic response of the lumped mass stick model and the distributed mass model of the CIS in the E-W direction. The applicant should resolve the differences in responses of the lumped mass and distributed mass models of the CIS and develop a lumped mass stick model that adequately captures and predicts distributed mass model seismic responses in both frequency and in magnitude.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

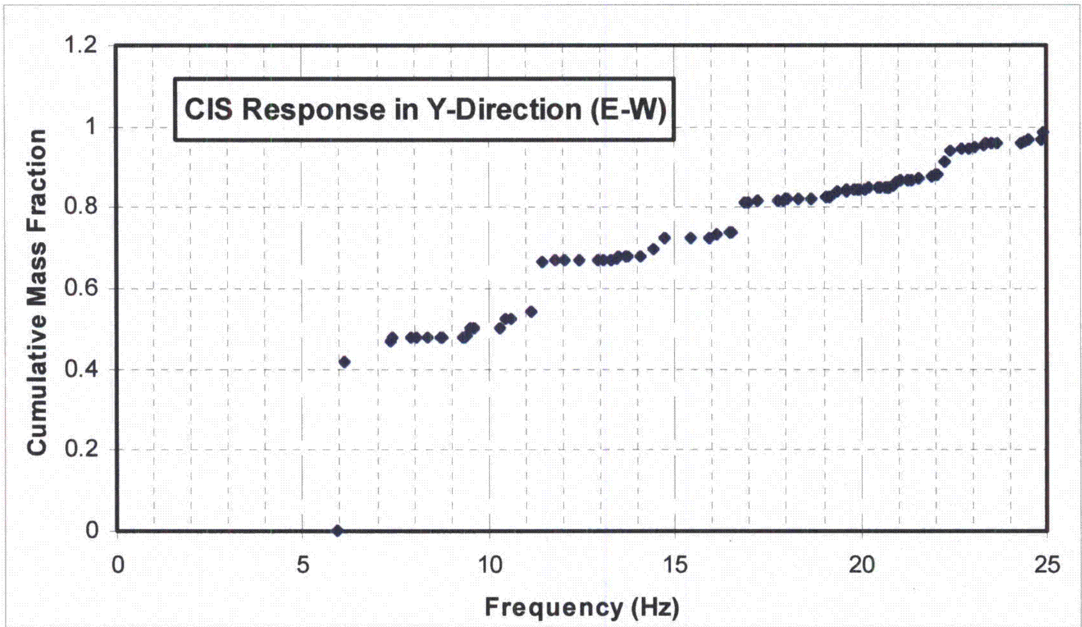
a) The lumped mass stick model used for soil-structure (SSI) analysis is reviewed to confirm the model has sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

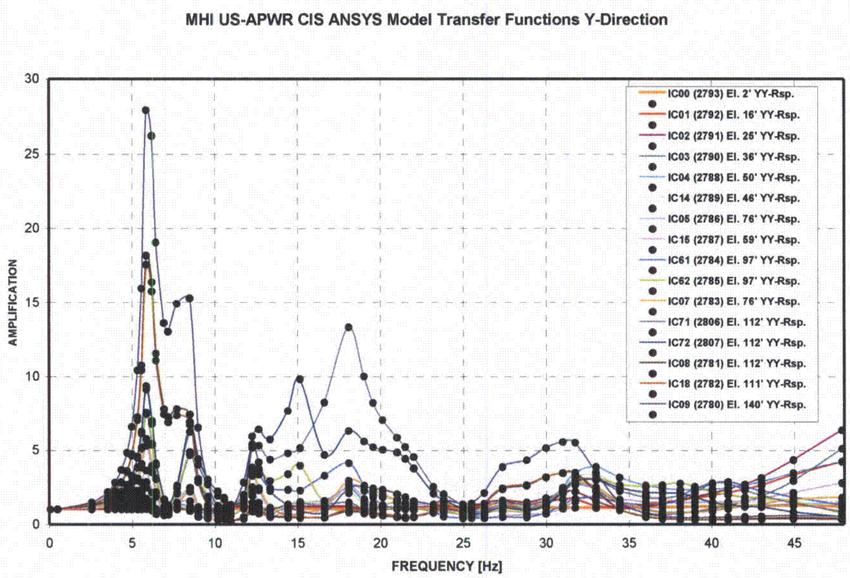
b) As noted in the response to Question 03.07.02-15 part b of this RAI, the detailed finite element (FE) model of the containment internal structure (CIS) considered full (uncracked concrete) stiffness properties while the lumped mass model used for the SSI analyses incorporated reduced (cracked concrete) stiffness properties. The dominant frequencies reported in the MUAP-10001 Rev 0 and 1 technical reports were obtained from the modal analysis of the detailed FE model that was decoupled from the reactor coolant loop (RCL) model. The first figure provided in this response presents the preliminary results of modal analysis of coupled detailed FE model with full stiffness (uncracked) properties in terms of the mode cumulative mass fraction in E-W direction and modal frequency. The steep increases of cumulative mass fraction indicate significant modes of vibration in E-W direction. The table below presents the frequencies of the first three dominant modes of vibration of the CIS in E-W direction that were obtained from the ANSYS modal analysis of the coupled detailed FE model with full stiffness (uncracked) properties. The figure below presents the results of the SSI analysis for the transfer functions for the response in E-W direction that were obtained from the hard rock SSI analyses of the coupled CIS lumped-mass stick model with full stiffness (uncracked) properties.

The comparison of the results for the response of the CIS model in the E-W direction shows that the difference between the frequency of the peak transfer function amplification obtained from of the ACS SASSI SSI analyses of the lumped mass stick model and the natural frequency of the first dominant mode obtained for the ANSYS modal analysis of the detailed FE model is 4%. These results indicate acceptable correlation of the dynamic properties between the two models. As described in the response to Question 03.07.02-11 part b of this RAI, the 3-D dynamic FE SASSI model of the R/B complex structures that is under construction will be used to further investigate the effect on the SSI results of the higher modal responses of the CIS.

Preliminary Revised Table 5.3.5.2-2 Modal Properties of First 3 Modes, Y-Direction (EW)

MODE	FREQUENCY (HZ)	PERIOD (sec)	PARTIC.FACTOR	EFFECTIVE MASS (lbs*sec^2/ft)
2	6.12	0.163	302.85	91717.6
3	7.35	0.136	102.48	10502.6
21	11.43	0.0875	-165.13	27267.4





Preliminary Revised Figure 5.3.5.2-2 ANSYS Dynamic Model Transfer Functions, Y-Direction

Impact on DCD

There is no impact on the DCD. The next revision of report TR MUAP-10001 will incorporate a revised figure and table in Section 5.3.5.2 for the CIS for the E-W direction as discussed above. Further validation using a SASSI FE will be documented in a future revision of TR MUAP-10001.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-17:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed.

Table 5.3.5.2-3 of MUAP-10001, Rev. 1 shows the modal properties of the detailed distributed mass CIS finite element model in the vertical direction. The first three natural frequencies of the CIS in the vertical direction are shown as 13.3 Hz, 17.2 Hz, and 19.7 Hz. In Figure 5.3.5.2-3, there is no indication that the first vertical frequency at 13.3 Hz is captured in the transfer functions.

Explain how MHI propose to resolve such discrepancies and account for the discrepancies in the dynamic response of the lumped mass stick model and the distributed mass model of the CIS in the vertical direction. The applicant should resolve the differences in responses of the vertical lumped mass and distributed mass models of the CIS and develop a lumped mass stick model that adequately captures and predicts distributed mass model seismic responses in both frequency and in magnitude.

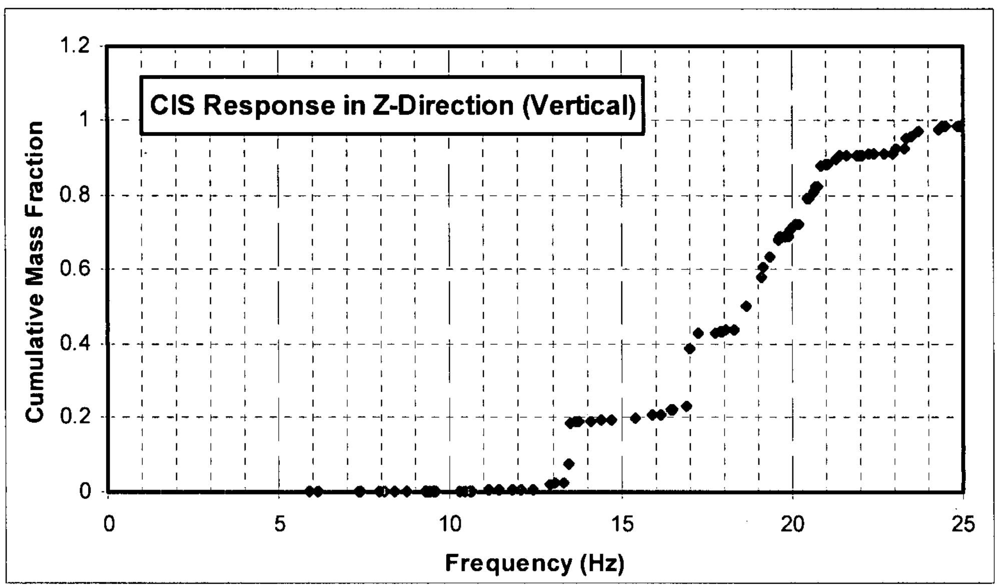
Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

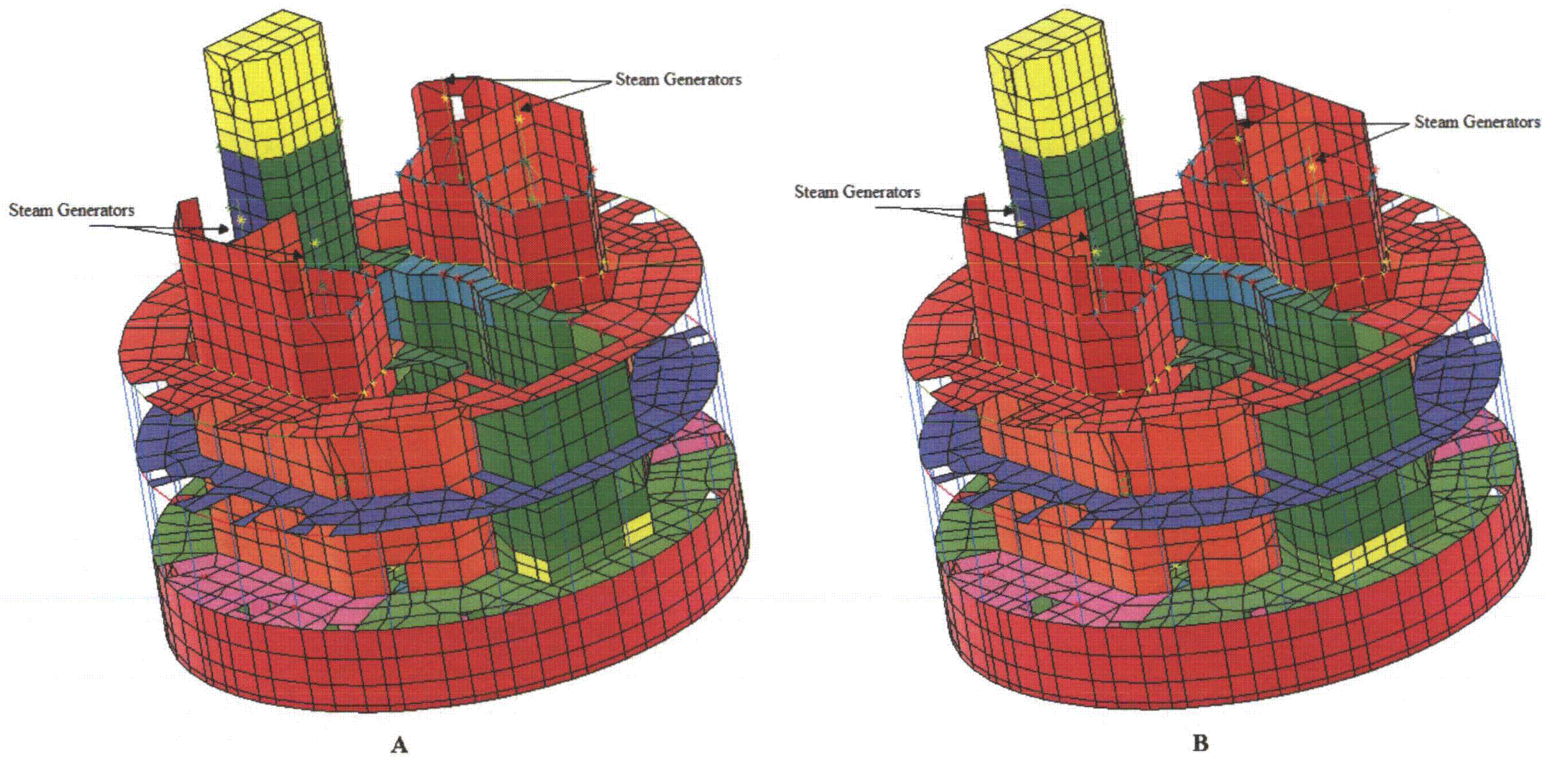
ANSWER:

a) The lumped mass stick model used for soil-structure (SSI) analysis is reviewed to confirm the model has sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

b) As noted in the response to Question 03.07.02-15 part b of this RAI, the detailed finite element (FE) model of the containment internal structure (CIS) considered full (uncracked concrete) stiffness properties while the lumped mass model used for the SSI analyses incorporated reduced (cracked concrete) stiffness properties. The dominant frequencies reported in the MUAP-10001 Rev 0 and 1 technical reports were obtained from the modal analysis of the detailed FE model that was decoupled from the reactor coolant loop (RCL) model. The first figure provided in this response presents the preliminary results of modal analysis of coupled detailed FE model with full stiffness (uncracked) properties in terms of the mode cumulative mass fraction in vertical direction and modal frequency. The steep increases of cumulative mass fraction indicate significant modes of vibration in vertical direction. The second figure provided in this response presents the mode shape of the first mode with significant mass participation in the vertical direction which is at a frequency of 13.5 Hz. The mode shape shows that the first mode in vertical direction represents the vertical vibration of the steam generators and their response. The mode shapes of the higher modes of vibrations indicated that the vertical response of the structure is characterized by multiple modes in the frequency range of 17 Hz to 22 Hz. The table below presents the preliminary updated frequency values for the dominant modes of vibration of the CIS in the vertical direction that were obtained from the ANSYS modal analysis of the coupled detailed FE model with full stiffness (uncracked) properties. The last figure that is included in this response presents the results of the SSI analysis for the transfer functions for the response in the vertical direction that were obtained from the hard rock SSI analyses of the coupled CIS lumped-mass stick model with full stiffness (uncracked) properties.

The first dominant vertical modal frequency obtained from the modal analysis of the CIS detailed FE model is not evident in the transfer functions generated from the results of the hard rock SSI analysis of the lumped mass stick model because this mode represents the vertical vibrations of the equipment included in the RCL lumped mass stick model that is coupled to the CIS. The vertical response of the CIS itself in the detailed model is characterized by multiple modes with a wider variety of frequencies. On the other hand, the vertical response captured by lumped-mass stick model is concentrated to fewer modes of vibration. As described in the response to Question 03.07.02-11 part b of this RAI, the 3-D dynamic FE SASSI model of the R/B complex structures that is under construction will be used to investigate the effect of the multiple higher frequency vertical modes of vibration of the CIS on the SSI results.

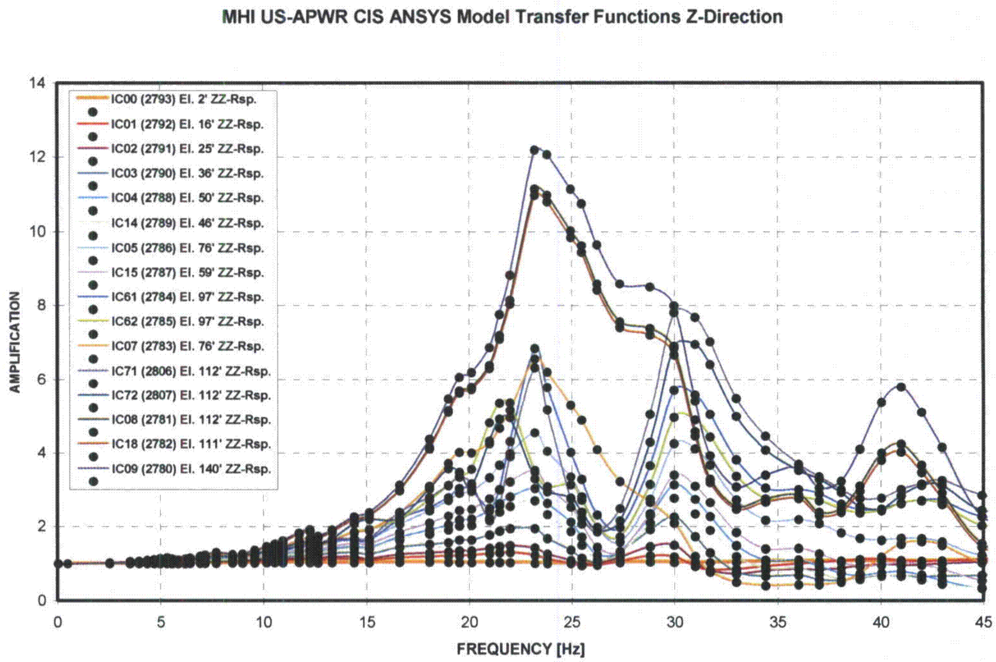




Shape of Mode 29 with Frequency 13.5 Hz

Preliminary Revised Table 5.3.5.2-3 Modal Properties of First 3 Modes, Z-Direction (Vertical)

MODE	FREQUENCY (HZ)	PERIOD (sec)	PARTIC.FACTOR	EFFECTIVE MASS (lbs*sec^2/ft)
29	13.51	0.0740	143.21	20508.4
42	17.00	0.0588	169.96	28887.0
49	18.67	0.0536	110.06	12112.4



Preliminary Revised Figure 5.3.5.2-3 ANSYS Dynamic Model Transfer Functions, Z-Direction

Impact on DCD

There is no impact on the DCD. The next revision of report TR MUAP-10001 will incorporate a revised figure and table in Section 5.3.5.2 for the CIS vertical direction as discussed above. Further validation using a SASSI FE will be documented in a future revision of TR MUAP-10001.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

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

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-18:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed. Based on Figures 5.3.5.3-1 through 5.3.5.3-12, of MUAP-10001, Rev. 1, the staff disagrees with the conclusion that the lumped mass models of the CIS properly capture the structural response to dynamic loads in all directions because in numerous cases the ISRS from the stick models show significantly different responses in both frequency and magnitude compared to the distributed mass model.

As an example, in Figure 5.3.5.3-3 the peak spectral acceleration at 16 Hz from the distributed mass model is 1.6*g*, while for the lumped mass stick model the peak acceleration is 0.82*g*, which is approximately 50% lower than the target. Similar discrepancies hold for other figures in this section. It is also evident from Figure 5.3.5.3- 2 that the distributed mass model responds to frequencies that are not predicted by the lumped mass model.

Provide the acceptance criteria used to support the conclusion that the stick models are adequate and how do the acceptance criteria meet the guidelines of the SRP. The applicant should resolve the differences in response from the lumped mass and distributed mass models of the CIS and propose a lumped mass stick model that adequately captures and predicts distributed mass model seismic responses in both frequency and in magnitude.

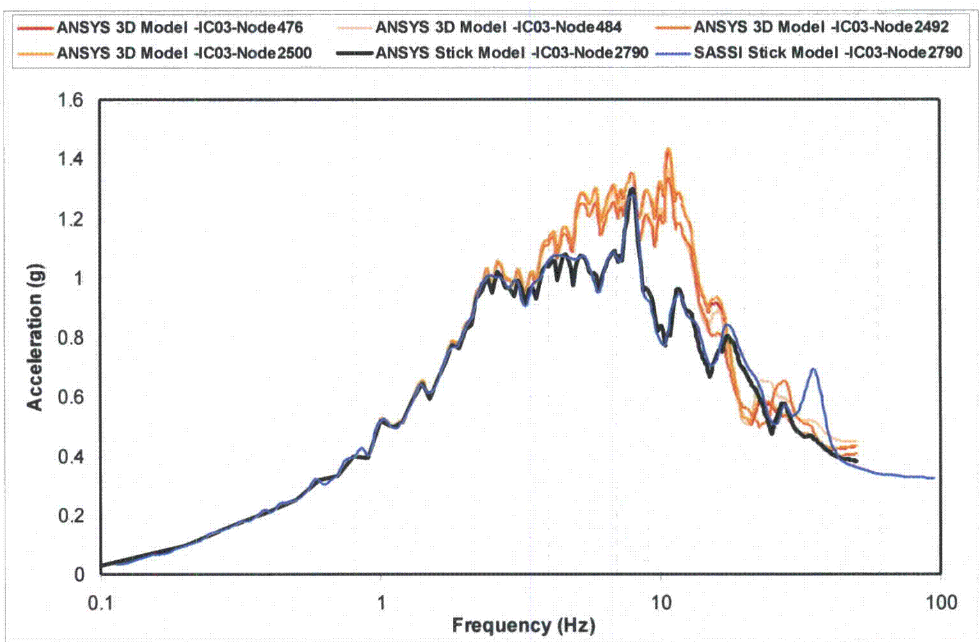
Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

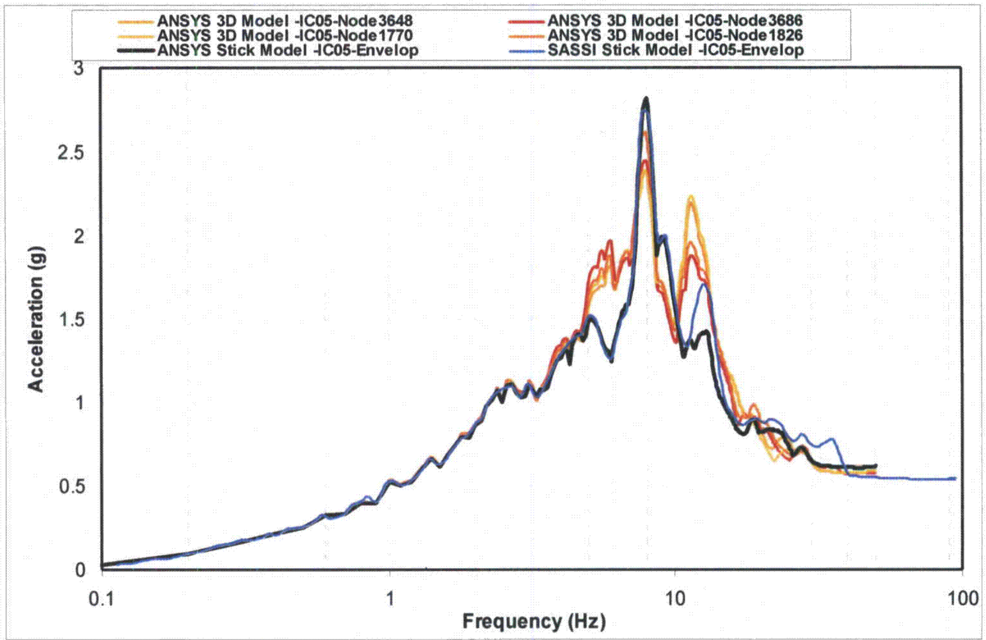
a) The lumped mass stick model used for soil-structure (SSI) analysis was reviewed to confirm the model has sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed per above RAI 625-4924 Rev. 0, Question 03.07.02-11 response a.

b) The review of the acceleration response spectra (ARS) results presented in the figures of Section 5.3.5.3-1 of MUAP 10001 Rev. 1 revealed that the ARS representing the response of the lumped mass stick model in N-S direction were obtained from the ANSYS modal superposition time history of the lumped-mass stick model with reduced stiffness (cracked) concrete properties. The ARS obtained from the ANSYS time history analysis of finite element model and the hard rock SSI analyses of lumped mass stick model for the CIS considered full stiffness (uncracked concrete) properties of CIS structure. The figures below present comparison of the ARS results obtained from the three types of analyses with models with consistent full stiffness properties. The comparison shows close matching between the ARS results obtained from the ANSYS time history and SSI analysis.

It is acknowledged that the lumped-mass stick model has a limited ability to capture higher frequency local responses at all locations as shown by the comparison of the 5% damping ARS results in Figure 5.3.5.3-3 of MUAP 10001 Rev. 1. As described in the response to Question 03.07.02-11 part b of this RAI, a 3-D FE SASSI model of the R/B complex structures is under construction and will be used for site independent SSI analyses. The results from the SSI analyses of SASSI FE model of the R/B complex will be used to validate that the ISRS generated from the lumped-mass-stick model envelope all of the local vibration responses, including such responses as given in Figure 5.3.5.3-3.



Revised Figure 5.3.5.3-1 Acceleration Response Spectrum Node IC03, NS Direction



Revised Figure 5.3.5.3-4 Acceleration Response Spectrum Node IC05, NS Direction

Impact on DCD

There is no impact on the DCD. The next revision of report TR MUAP-10001 will incorporate revised figures and tables in Section 5.3.5.3 for the CIS resulting from the ANSYS time history analyses of lumped mass stick model with full stiffness (uncracked concrete) properties.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-19:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

SRP Subsections 3.7.2.II.1 and 3.7.2.II.3 contain guidelines for determining if lumped mass models have sufficient degrees of freedom to properly capture the dynamic response of the structure of interest and if acceptable modeling procedures are employed.

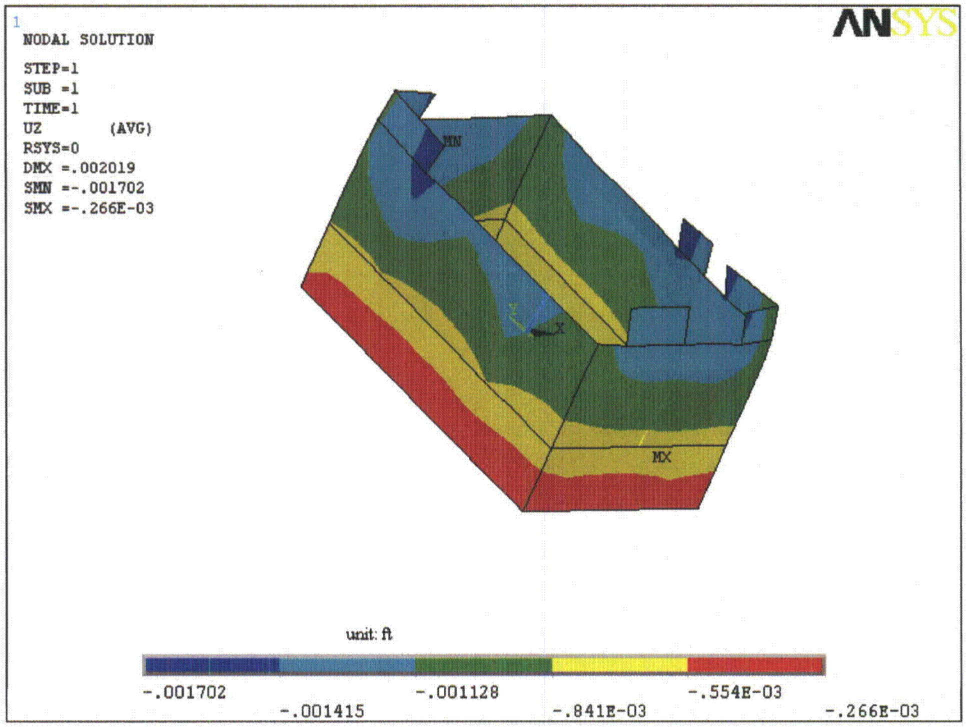
Figure 5.4.2-3 of MUAP-10001, Rev. 1 shows that the vertical displacement at the northwest corner of the PS/B stick model decreases between the 30 foot and 40 foot elevations. Explain the physical interpretation of this result with regards to the safety function of this structure.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

The detailed static model and the dynamic structural model discussed in the report are both 3D finite element models. The detailed static model was used for structural design of the Power Source Buildings. It has a more refined mesh and geometry than the dynamic structural model used for SSI analysis. Figure 5.4.2-3 indicates that the vertical displacements at the northwest corner of the PS/B for both models decrease when approaching the top of the wall/roof. The decrease in the displacement is more pronounced in the dynamic model than in the detailed static model because of differences in accuracy introduced by the structural discretization. The decrease in the vertical displacement at the northwest corner indicates a stretching effect from the roof slab corner reaction. As pointed out by Timoshenko when discussing the boundary condition for downward loaded rectangular plate (Timoshenko, Theory of Plates and Shells, Second Edition, Page 86): "... the corners in general have a tendency to rise, and this is prevented by the concentrated reactions at the corners,..." The tendency to rise at four corners of the roof under 1-g static loads imposes a stretching effect on the wall. The stretching stress on the wall decreases at lower elevations because of the stress spreading/distribution, and the effect of stretching is eventually offset by the increase of the gravity load at some elevation. The figure below shows the vertical displacement contour of dynamic structural model under 1-g static load. The roofs are not shown in the figures. The figure indicates that the vertical displacements at wall corners above a certain elevation are much smaller than the displacement at the central portion of the wall. This verifies the existence of the stretching effects.

It should be noted that the stretching effects as shown by FE discretized model represent upper bound effects. The real effect on the structure is much less than the one shown for the dynamic model case. For the dynamic model case, as shown in Figure 5.4.2-3, the decrease in vertical displacement from el.30 ft to 40 ft is on the order of 0.0004 inch and as such it is considered to be negligible. As far as structural design is concerned, since the detailed static model was used for design, the stretching effect was captured in the design analysis and therefore there is no effect on the safety function of the structure. The comparison of the results obtained from the dynamic analyses of detailed FE model in ANSYS and the dynamic structural model in ANSYS and ACS SASSI show that this discrepancy in modeling local strain and stress distributions have almost no effect on the ability of the dynamic structural model to accurately represent the dynamic behavior of the building.



Vertical Displacement Contour: 1-g Vertical Load on ANSYS Dynamic Model

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-20:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

The staff, based on its review of MUAP-10001, Rev. 1 finds that the applicant has used inconsistent approaches, qualitatively and quantitatively to account for concrete cracking in the seismic models, as noted below.

1. On p. 3-3, is the third sentence in the second paragraph intended to mean that concrete cracking is accounted for by broadened ISRS.
2. On p. 3-3, it is stated that the stiffness of the CIS lumped mass stick model is reduced by 25% to account for concrete cracking resulting from thermal loads,
3. On p. 4-14, it is stated that the elastic modulus of selected slabs in the R/B reduced by 50% to simulate a cracked condition.
4. On p. 4-15, it is stated that the FH/A shear wall areas reduced by 50% for concrete cracking.
5. On p. 4-22, a factor of 0.5 is used for the reduction of flexural stiffness of shell elements in the PS/B lumped mass model..
6. On p. 4-23, it is stated that the stiffness of the lumped mass stick model of the CIS is reduced by 25% to address potential effects due to cracking of the SC modules.

Explain the overall methodology for addressing concrete cracking and explain how the qualitatively and quantitatively different methods of accounting for cracking that are given above result in a consistent approach for accounting for cracking.

Also, when the structural models are analyzed with assumed cracked section properties, the potential for load redistribution relative to the results from the models with uncracked section properties exists due to changes in modal frequencies and corresponding changes in input spectral acceleration. This redistribution has the potential for some sections that had acceptable demand-to-capacity ratios in the uncracked model to have unacceptable demand-to-capacity ratios in the cracked model. Describe how the models will be checked or modified to ensure that the final configuration of the model results in acceptable demand-to-capacity ratios at all sections.

The assumption of cracked or uncracked concrete member used in the final configuration of the cracked concrete seismic models should be validated by the final combined stresses in concrete members.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

In accordance with Technical Report (TR) MUAP-10001, Rev. 1, Section 4.5, traditional reinforced concrete members and elements are modeled as either cracked or uncracked sections, depending on their stress level due to the most critical load combinations in accordance with ASCE 4-98, and ASCE/SEI 43-05. For the uncracked sections/elements, the stiffness is directly obtained from the concrete linear elastic properties and the section or element geometric dimensions. For the cracked concrete, a reduction to the uncracked concrete stiffness is taken into account. The reduction factors shown in Table 3-1 of ASCE/SEI 43-05 are used in linear elastic analysis to address the effects of concrete cracking on the seismic response of the US-APWR seismic Category I structures. Where appropriate, the flexural stiffness of elements is adjusted without changing the axial and shear stiffness or mass of the element as described in TR MUAP-10001 Section 4.5.2.

As documented in TR MUAP-10001, the stress level of Seismic Category I structures are reviewed and the element stiffness of members found to crack being adjusted as follows:

- The out-of-plane flexural stiffness of the R/B elements (excluding the FH/A walls) is reduced by 50% to address out-of-plane bending stress levels in compliance with Table 3-1 of ASCE 43-05; the shear and axial stiffness of the slabs, as well as their mass, are not reduced.
- The in-plane and out-of-plane flexural stiffness and axial/shear areas of the FH/A wall elements are reduced by 50% to address cracking of the FH/A walls.
- The in-plane and out-of-plane stiffness of the CIS elements is reduced by 25% to address potential effects due to cracking of the SC modules. Once cracking has occurred, the SC modules exhibit an asymptotic reduction in stiffness which is a function of the magnitude of the applied load and corresponding stress levels. Based on a review of the stress and strain levels present in the SC modules under SSE loading, 25% was determined to be a best estimate of the reduction amount. The stress levels resulting from the analysis of the more detailed dynamic finite element seismic model will be used to review and confirm the 25% stiffness reduction factor.
- The out-of-plane flexural stiffness of the PS/B elements is reduced by 50% to address out-of-plane bending stress levels; the shear and axial stiffness of the slabs are not reduced.

Based on the above discussion, items 1 through 6 are addressed as follows:

1. The ISRS are broadened to account for uncertainties in the structural frequencies due to uncertainties in such parameters as the material properties of the structure, damping values, soil-structure interaction techniques and the approximations in the modeling techniques used in seismic analysis. While cracking effects are included in this uncertainty, the effects of cracking are addressed more rigorously as described above based on the level of stresses

and strains that the structure experiences under combination of design loads that include the SSE loads.

2. The CIS lumped mass stick in-plane and out-of-plane stiffness is reduced by 25% to account for concrete cracking as described above.

3. Section 4.3.2 of TR, MUAP-10001 provides the methodology to develop single degree of freedom (SDOF) models to capture the out-of-plane flexibility of the slabs and walls. As the development of the SDOF model is concerned only with the out-of-plane effects of the slabs and walls, it is appropriate to reduce the stiffness of the slab 50% by reducing the elastic modulus by 50%.

4. The FH/A lumped mass stick in-plane and out-of-plane shear wall areas are reduced by 50% to account for concrete cracking as described above.

5. The PSB element out-of-plane flexural stiffness is reduced by 50% to account for concrete cracking as described above.

6. The CIS lumped mass stick in-plane and out-of-plane stiffness is reduced by 25% to account for concrete cracking as described above.

The R/B complex and the PS/B are analyzed in a conservative manner that accounts for various uncertainties, including cracking. Element stiffnesses are assigned based on a best estimation of anticipated levels of cracking as described above and in more detail in TR MUAP-10001. The considered variation of soil layering/properties used in the standard plant profiles, the broad-band nature of the ground motion input response spectra, and the resulting broadened ISRS all act in conjunction with the consideration of cracking effects to provide broad frequency band design ISRS. Further, design SSE loads are developed in a conservative manner and rounded up to provide additional margin to allow for eventual changes in the seismic response due to possible changes of stiffness in the structures due to cracking of the concrete. The best estimate of anticipated levels of cracking will be validated based on the stress/member force results obtained from the static analyses of the detailed FE model under final combined stresses, which include loads resulting from the SSI analysis.

MHI is also in the process of preparing and analyzing a more detailed dynamic finite element seismic model will be used to validate the results obtained from the current model used for the standard plant SSI analyses, and which will also used to confirm that the standard plant structures have adequate demand-to-capacity ratios at all sections for all loading conditions. The reinforced concrete design will be based on demands obtained from the static analyses of detailed model. The demands will be generated in a conservative manner in order to address the possible effects of load redistribution among the different structural elements due cracking of the concrete.

Impact on DCD

There is no impact on the DCD. For clarity, the sentence cited on page 3-3 will be revised to read "The ISRS capture the effects of potential concrete cracking on structural stiffness and local vibration modes, which was noted in RAI 212-1950, Questions 3.7.2-15."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-21:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

Per SRP 3.7.1.II.3 Acceptance Criteria, the description of the Supporting Media for Seismic Category I structures must include the design groundwater elevation. On p. 4-6 of MUAP-10001, Rev. 1, it is stated that the DCD specifies a water table depth of 1 foot below the foundation. This is inconsistent with the information in Table 2.0-1 of DCD Rev. 2, Tier 2 (and also Table 2.1-1 of DCD Rev.2, Tier 1) that specifies the maximum groundwater as 1 foot below plant grade.

The common foundation of the R/B complex is located at a depth of 38'-10" from the plant grade. Clarify the upper elevation up to which saturated soil properties have been used in the seismic analysis and explain how the seismic analysis is consistent with the '1 foot below grade' statement in Tier 1 of the DCD.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

The statement on page 4-6 of MUAP-10001 is a typographical error. The intent was to state that the DCD states that the water table depth of 1 foot below plant grade which, for the development of vertical motions, is equivalent to the surface. The next revision of this report will correct this error. Further explanation follows.

The US-APWR DCD standard plant seismic analysis treats the standard plant structures as surface foundations and neglects to consider the effect of the embedment on the response of the seismic structures. The SSI seismic analyses use input soil properties of the subgrade that are strain compatible and based on responses of full profiles that include the effect of the embedment soil above the foundation base elevation. The input motion acceleration time histories that are compatible to the CSDRS are applied at the bottom of the common foundation. The location of the design groundwater considered in the site response analyses is at 1 ft below the grade of the plant. The site-independent SSI analyses consider the support media under the common foundations to be saturated. This approach is consistent with the information in DCD Rev. 2 Table 2.0-1 (Tier 2), and Table 2.1-1 (Tier 1).

The US APWR DCD requires the applicant to perform site-specific SSI analyses and calculate the seismic response of the structures using as input site-specific values for the soil properties and the nominal water table elevation. It is also required that the COL applicant includes the effect of embedment into site-specific SSI analysis of US APWR standard plant structures.

Impact on DCD

There is no impact on the DCD. The next revision of the report will correct the typographical error discussed above.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

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

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-22:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

On p. 4-14 of MUAP-10001, Rev. 1, it is stated that the lumped mass stick model of the R/B complex includes SDOF oscillators for slabs and walls that contain out-of-plane frequencies below the cut-off frequency of 40 Hz. The 40 Hz cut-off frequency is in conflict with the guidance of ISG-01, which recommends that models be sufficiently refined to transmit frequencies up to 50 Hz.

Provide the technical basis for the lower cut-off frequency of 40 Hz and explain how the use of the lower cut-off frequency meets the intent of ISG-01 and how the response due to the ground input spectrum (that is defined up to 50 Hz) are calculated beyond the cutoff frequency.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

See the detailed response to RAI 603-4666 Rev. 0, Question 03.07.02-10 Item #1 for detailed resolution of this issue.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-23:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

The first sentence of Section 5.2.2 of MUAP-10001, Rev. 1 refers to the nine combinations of soil profile categories and depths to hard or soft rock material that are shown in Table 5.2-1. In that table, only eight combinations are shown. Explain why the combination of V_{s30}=100 m/sec, and depth to rock=100 feet is not shown in Table 5.2-1.

Clarify whether the soil profiles used in the SSI analysis are consistent with the nine combinations of soil profiles developed for the analysis, and also determine if the description and implementation of the Supporting Media for Seismic Category I Structures is acceptable per the guidelines of SRP 3.7.1.II.3.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

Section 4.2.1 of the report describes how the profiles for analysis are initially selected. Table 5.2.1 of the report presents the final selection of eight profiles used for the standard design and analysis. The soft soil (270 m/s) with a depth of 100 feet initially considered was not included in the final profiles used for SSI analysis listed in Table 5.2.1 because it was deemed not to be representative of conditions at candidate sites within the continental United States. This is due to the rather unusual condition of soft soil present for only a very shallow depth over a very stiff rock. At sites where such conditions might occur, it is anticipated that the relatively shallow layer of soft soil below the plant foundations to the top of hard rock would be removed due to the potential for a shallow-depth impedance mismatch created by these conditions.

Section 5.2 of the report will be revised to add this clarification. Table 5.2-2 will be revised to delete the 270-100 profile. Section 5.2.2 of the report will be revised to refer to eight not nine profiles. Table 5.2-3 and Figure 5.2-8 will be deleted from the report and the text discussion and references in Section 5.2.2 and other sections of the report will be updated accordingly.

The description and implementation contained in Technical Report (TR) MUAP-10001 for the final profiles representing the Supporting Media for the standard plant Seismic Category I structures are determined to be acceptable per the guidelines of SRP 3.7.1.II.3. TR MUAP-10001 presents the depth of soil over bedrock, soil layering characteristics, discusses how groundwater is accounted for in the profile development and SSI analyses, and presents soil properties such as shear and compression wave velocity, shear modulus, Poisson's ratios, and density as a function of depth. TR MUAP-10001 will be used to update and supplement the DCD. DCD Table 3.7.1-3 provides the foundation embedment depths and dimensions of the structural foundations, and structure height. DCD Table 2.0-1 specifies the maximum groundwater level.

Impact on DCD

There is no impact on the DCD. The next revision of report TR MUAP-10001 will include the following:

- Section 4.2.1, first paragraph: add "The soft soil (270 m/s) with a depth of 100 feet was deemed not to be representative of conditions at candidate sites within the continental United States and therefore was not considered for SSI analysis."

- Section 4.2.1, first paragraph: add "Due to the steep velocity gradient the depth range for soft rock profiles (900 m/s) is restricted to 100 feet and 200 feet.

- Table 5.2-2, remove the "270-100" row

- Section 5.2.2, first sentence: modify to read "For the eight combinations of profile categories….."

- Section 5.2.2, second sentence: modify to read "The strain compatible properties are summarized in Tables 5.2-4 to 5.2-11….."

- Table 5.2-3, remove table

- Figure 5.2-8, remove figure

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/04/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 625-4924 REVISION 0**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**8/30/10**

QUESTION NO. 03.07.02-24:

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.2, 'Seismic Design Parameters.

According to SRP Subsection 3.7.2.II.1.A.iv, simple 1*g* static analyses of lumped mass stick models should be performed for each of the three excitation directions and compared to the results from the distributed mass model. Figures 5.3.3.1-1 and 5.3.3.1- 2 of MUAP-10001, Rev. 1 show elevation vs. displacement results under 1*g* static loads for the vertical and horizontal (X) directions, but results are not shown for the Y-direction. Also, the caption for Figure 5.3.3.1-2 indicates that the horizontal displacements correspond to vertical loading rather than horizontal loading.

Clarify whether or not the horizontal displacement results in Figure 5.3.3.1-2 are actually due to vertical loading, or if they are from horizontal loading in the X-direction per the guidelines of SRP Subsection 3.7.2.II.1.A.iv. Also, provide the results from 1*g* static loading in the Y-direction per guidelines of SRP 3.7.2.

Reference: USAPWR Seismic Design Report MUAP-10001, rev 1; dated May 13, 2010; ML101400073

ANSWER:

The PCCV stick model is symmetric in the X and Y directions. Therefore the Y-direction response was not included in Technical Report (TR) MUAP-10001 Rev. 1 as it would be redundant with the X-response shown in Figure 5.3.3.1-2.

The horizontal displacements shown in TR MUAP-10001 Rev. 1 Figure 5.3.3.1-2 are under 1g horizontal load. This typographical error in the figure title will be corrected in the next revision to TR MUAP-10001.

Impact on DCD

There is no impact on the DCD. The typographical error in the figure title will be corrected in the next revision to TR MUAP-10001.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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