REQUEST FOR ADDITIONAL INFORMATION 852-6003 REVISION 3

10/24/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.07.02 - Seismic System Analysis
Application Section: 3.7.2

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

03.07.02-110

Section 1 of MUAP-10001(R3), "INTRODUCTION," states"the development of the generic layered site profiles consistent with the CSDRS are documented in this technical report." That statement is not clear to the staff. For design certification, the applicant specifies the CSDRS and the generic site profiles that will be analyzed. Please explain the meaning of "generic layered site profiles consistent with the CSDRS."

On Page 1-1, the applicant identified four issues that are addressed in the seismic response analysis reported in MUAP-10001(R3). However, the applicant did not address how the effects of water table location, embedment, and structure-soil-structure interaction (due to structures in close proximity) are included in the updated SSI analyses of the USAPWR standard plant structures.

Although in Subsection 3.2 of the MUAP 10001(R3), "Generic Layered Soil Profiles and Strain Compatible Properties," (Page 3-1) the applicant states that the SSI analyses will consider the effect of the elevation of the water table." The staff is unable to find a description in MUAP-10001(R3) of the approach used by the applicant in considering the effect of water table in the SSI analyses. However, the staff noticed that the effect of high water table is addressed in an MHI technical report recently submitted to the staff, MUAP-11007(R0). The applicant is requested to provide a section in MUAP 10001 (R3) describing the approach for considering the effect of high water table in the SSI analyses. The description should address the following questions:

- How many soil profiles are used in the analyses?
- How are these soil profiles generated?
- How are the strain-compatible soil properties obtained? What degradation curves for soil modules and hysteretic damping curves are used?
- What hysteretic damping values for the shear waves and the compression waves are used in the analyses? Provide the rationale and justifications for using these damping values.
- Provide a technical basis and justification of the applicability of conclusions with regard to the effect of water table on the SSI analysis in MUAP 11007 (RO) that utilizes a different SSI model.

This information is required by the staff in order to assess the effects of these parameters on the seismic response of the SSCs and the results of the SSI analyses.

03.07.02-111

In Section 3.3 of MUAP-10001(R3), “Dynamic Finite Element Model of R/B Complex,” the third paragraph (Page 3-2) states, “The resulting dynamic FE …to provide input design parameters that appropriately address the effects of … scattering of input ground motion.”

The applicant is requested to provide information that shows how the scattering of input ground motion is addressed.

Also, the applicant is requested to clarify the following two sentences and differentiate the specific information that is being conveyed in each sentence in Sections 3.3 and 3.4.

> “The ISRS capture the effects of potential concrete cracking on structural stiffness and local vibration modes as described in Section 3.5. The effects of potential concrete cracking on structural stiffness and local vibration modes are also taken into account in these SSI analyses.”

03.07.02-112

With reference to Section 4.1 of MUAP 10001 (R3), “CSDRS Compatible Ground Motion Time Histories,” the applicant is requested to provide the following additional information.

(A) “the BAL (Mt Baldy, CA) recording of the January 14, 1994, Northridge earthquake (magnitude M6.7), is used as the seed ground motion for generating the time history motions. The Northridge BAL recording was selected because it has the required duration and correlation (statistical independence among the three components comprising the time history earthquake).” The staff noted that many record sets possess appropriate duration and independence characteristics. The results of a recent study (see reference cited below) demonstrate that the computed seismic response of structures is sensitive to the seed record selected during the development of the synthetic time histories which are used as input to SSI analyses. In order to reduce the potential for underpredicting the computed response of the structure, it is generally recommended that when a single seed ground motion is used, a comparison of spectral shapes at 2% and 20% damping is also made to ensure that the resulting artificial records are appropriate for use in SSI analyses that are typically associated with high values of radiation damping. Thus, the applicant is requested to provide comparisons between the CSDRS spectra and the spectra generated from the synthetic time histories for both 2% and 20% damping and discuss the quality of the matches at 2% and 20%.

Reference: “Investigation of the Impact of Seed Record Selection on Structural Response;” PVP2010-25919; Proceedings of the ASME 2010 Pressure Vessels & Piping Division / K-PVP Conference, July 18-22, 2010, Bellevue, Washington, USA. [www.osti.gov/servlets/purl/1019557-1rQA93/]

(B) “the method used here to generate the time history motions is also appropriate to generate other multiple time history motions to perform non-linear analyses.” The purpose of this statement is not clear to the staff. The applicant is requested to describe the characteristics of the spectral matching process that are specifically appropriate for performing non-linear analysis. In addition, the applicant is requested to clarify if the nonlinear analyses are included in the design-basis methodology and describe the specific applications of non-linear analysis and how the analysis results are used in the design of standard plant SSCs.

Also, from the review of MUAP-10001(R3), the staff could not identify at what elevation the CSDRS are applied. It is the staff's understanding from the DCD (R3) that the CSDRS are applied at the foundation level in the superseded lumped mass stick model SSI analyses. The Applicant is requested to define the elevation (e.g., surface, bottom of foundation, other) at which the CSDRS are applied in the updated SSI analyses.

03.07.02-113

With respect to Section 4.3 of MUAP 10001 (R3), "ACS SASSI Dynamic Finite Element Model of R/B Complex," and Section 4.4 of MUAP 10001 (R3), "ACS SASSI Dynamic Finite Element Model of PS/B, " the applicant is requested to provide the following additional information:

(i) Section 4.3.1 of MUAP 10001(R3), the applicant discussed the SASSI problem of connecting different element types having differing end conditions together at a common node. It has been found that the improper definition of constraint conditions at the free degrees-of-freedom can lead to potential improper restraint to the entire model when considering SSI responses. The Applicant is requested to provide descriptions of the connectivity used in SASSI between beam and shell elements and between beam and brick elements, and examples of computed responses using the defined connectivity.

(ii) In Figures 4.3.1.1-6 and 4.3.1.1-7, massless rigid beams and massless surface beams are used to connect structural beams to shell elements. It appears that the rigid beams would be adequate for this purpose. Explain why surface beams are needed and how the stiffness of these surface beams is determined.

(iii) In section 4.3.1.2, the maximum mesh size for concrete was determined to be 20 ft, in order to transfer a shear wave up to 70 Hz, based on a calculation of shear wave propagation. This is not necessarily adequate to accurately capture local out-of-plane vibration modes of walls and floors up to 70 Hz. How have the local out-of-plane modes been incorporated in the dynamic model? Is the detailed model refined enough to adequately represent these modes up to 70 Hz? Have the dynamic and detailed models been compared to confirm the sufficiency of the dynamic model?

(iv) On page 4-28, it is stated that "the effective width of concrete (before transformation to steel section) is based on AISC 360-05, Section I3. The requirements in AISC 360-05 are applicable when the flange of the composite section is in compression. When the flange is in tension, smaller values of 'b_e' could be used.

Since the flange (concrete slab of the composite floor) may be in both tension and compression during earthquake excitation, a smaller 'b_e' would appear to be appropriate. AISC 360-05, Section A1 refers to the provisions of ANSI/AISC N690 or ANSI/AISC N690L for nuclear safety- related structures.

The applicant is requested to confirm whether it has considered provisions of ANSI/AISC N690 or ANSI/AISC N690L in the calculation of 'b_e'.

03.07.02-114

On P. 4-12, in Section 4.3 of this MUAP 10001 (R3), "ACS SASSI Dynamic Finite Element Model of R/B Complex," the third step in the procedure states:

> "Step 3: Translate the Dynamic FE Model into ACS SASSI format and verify the accuracy of the translation.
> The translator built into the ACS SASSI code serves as the platform for the translation of the dynamic FE model from ANSYS to ACS SASSI house module format. In order to validate the translation of the model, validation SSI analyses are performed on the ACS SASSI dynamic FE model resting on a very rigid elastic half space. The dynamic properties of the model revealed by the resulting amplification transfer functions (ATFs) and 5% or 7% damping ARS at selected locations are compared to the fixed base dynamic properties and responses obtained from ANSYS modal and time history analyses to ensure the translation is competed correctly."

The applicant is requested to define the term "very rigid" in this Step 3, and to provide the rationale that explains why it is necessary to qualify the term "rigid." Also, there appears to be a typo in the last line: the word "competed" should be "completed."

03.07.02-115

In Subsection 4.3.1.2 of this MUAP 10001 (R3), "Discretization Considerations: Mesh Size," the last paragraph (Page 4-23) states, "The table shows that for the SSI analyses of harder subgrade profiles, the dynamic FE model of R/B Complex is sufficiently refined to transmit waves with frequencies up to 50 Hz through the soil-foundation interface. The SSI analyses of softer soil profiles for which the wave passage frequencies of dynamic FE model are lower than 50 Hz provide responses that are enveloped in the high frequency range by the responses obtained from analyses of harder soil profiles. Therefore, the SSI analyses of all eight generic soil profiles provide adequate envelope responses up to 50 Hz as required by ISG- 01."

The staff noticed that the applicant's conclusions are not supported by the data presented in the report, as discussed below:

1. The first sentence in the above quoted paragraph states that the FE model of R/B Complex is sufficiently refined to transmit waves with frequencies up to 50Hz through the soil-foundation interface; however, the data shown in Table 4.3.1.2-1 do not support this claim. The values of f_{FE_max} shown in the last column of Table 4.3.1.2-1 are the maximum frequencies for wave passage from the subgrade to the structure. Five out of eight frequencies are less than 50Hz. The applicant is requested to provide technical rationale and data to support the cited statement in this report.
2. The last sentence in the above quoted paragraph states that the SSI analyses of all eight generic soil profiles provide adequate envelope responses up to 50Hz. However, the applicant did not provide the appropriate data to show that the SSI responses of softer soil profiles in the frequency range of f_{FE_max} to 50Hz are enveloped by those of harder soil profiles. The Applicant is requested to provide technical rationale and data to support the cited statement in this report.

The staff also noticed that the applicant has made similar claims for the mesh size used for the dynamic model of the PS/B which is presented in Subsection 4.4.1.2. The applicant is requested to provide the requested data for the PS/B model to confirm that their response to the questions raised above for the R/B complex model also apply to the PS/B model.

03.07.02-116

In Subsection 4.3.1.3 of MUAP-10001(R3), “Modeling of Stiffness and Damping,” the first paragraph (Page 4-23) states “The ACS SASSI house module introduces the stiffness and damping properties of the structure into SSI analysis in the form of a frequency-independent complex stiffness matrix.”

The staff noticed that the damping values listed in Table 4.3.1.1-2 of this report for the OBE and SSE are taken from Regulatory Guide 1.61, and they are viscous modal damping. The corresponding damping forces are thus frequency-dependent real numbers. The applicant is requested to provide technical information that shows how to convert the frequency-dependent real numbers to frequency-independent complex numbers used in ACS SASSI. Additionally, the applicant is requested to provide numerical values of the complex damping used in the ACS SASSI input and numerical value of the shear wave velocity used in ACS SASSI to simulate a rigid elastic half-space.

This information is required by the staff in order to assess the effects of these damping parameters on the seismic response of the SSCs and the results of the SSI analyses.

03.07.02-117

In Subsection 4.3.1.4 of MUAP-10001(R3), “Modeling of Mass,” the last paragraph (Page 4-24) states, “Liquid masses contained in the Spent Fuel Pit, Emergency Feed Water Pits, and Refueling Water Storage Pit are applied as impulsive mass to walls and slabs. The direction of the mass is perpendicular to the surface of the walls or slabs as shown in Figure 4.3.1.4-1.”

The applicant did not provide sufficient details for the staff to evaluate the modeling of the fluid mass. The applicant is requested to provide the following additional information:

- Provide technical information that shows how the impulsive mass is calculated.
- Provide information for the locations of Nodes i and j.
- Is the convective effect (including the surface sloshing wave height) considered for these liquid masses? If not, provide the rationale for not including the convective effects.
- Does the mass used for the new fuel and spent fuel storage pits include the mass of the fuel and the fuel storage racks contained within the pool? If not, provide the rationale for not including these masses.
- Provide a breakdown of masses considered in the 3D seismic SSI model for the new and spent fuel, fuel storage racks, pool water, and the fuel storage pool structure including the pool liner plate.

Also, the fuel storage pool will experience a rocking motion at its base in addition to the horizontal excitation due to SSI. Thus, the applicant is requested to describe how this rocking effect is considered in the analyses, or to provide numerical data to show that this rocking effect is negligible.

03.07.02-118

In Subsection 4.3.1.9 of MUAP 10001(R3), "Adjustment of Dynamic Properties of SC Modules," the second sentence states that "Stiffness and mass properties of elements modeling some of the SC walls of the CIS are adjusted in order to calibrate the dynamic response of the simplified dynamic FE model to match the actual response of the CIS as represented in the Detailed FE Model. The adjustments of the unit density and the elastic moduli of the shell elements are introduced to capture the actual distribution of mass and stiffness."

The applicant is requested to provide detailed technical information that shows how the stiffness and mass properties of elements modeling some of the SC walls of the CIS are adjusted. This information should indentify which SC walls are adjusted and the technical basis supporting the selection of these walls.

This information is required by the staff in order to assess the effects of these parameters on the seismic response of the CIS and associated SSCs, and on the results of the SSI analyses.

03.07.02-119

In Section 4.3.3 (p. 4-33) of MUAP 10001 (R3), four guidelines with numerical criteria are laid out to confirm the accuracy of the translation from the ANSYS model to the ACS SASSI model. However, immediately following these guidelines, the applicant stated that the comparison of the results can indicate larger deviation than specified in the guidelines but did not provide the acceptance criteria used to confirm a sufficiently accurate translation. The applicant is requested to provide additional information in items (i) through (iv) below:

(i) It is stated on page 4-34 that "ACS SASSI uses a mixed mass matrix (average lumped and consistent masses to represent the mass of the structure. The mode superposition analyses in ANSYS are performed using either a lumped or consistent mass matrix." If the mesh is fine enough, the use of lumped, consistent, or mixed mass does not have significant effect on responses. Explain why the mesh cannot be refined to eliminate this as a cause for differences.

(ii) It is stated on page 4-34 that "The ANSYS modal superposition time history analysis uses analysis time integration scheme to solve the decoupled dynamic response equations. ACS SASSI frequency domain solution is based on the convolution of the complex Fourier spectra of the input motion and the complex acceleration transfer functions computed for a limited number of selected frequencies, not at all Fourier points." Explain why additional frequencies cannot be added in the SASSI solution to eliminate this as a cause for differences.

(iii) It is stated on page 4-34 that "ANSYS uses constant value modal damping ratio to account for the dissipation of energy due to structural damping. ACS SASSI uses the complex damping approach in which the dissipation of energy due to structural damping is accounted for in the complex stiffness matrix of the system that is assembled from the complex stiffness matrices of the finite elements. The ACS SASSI analyses allow different structural damping to be used to account for the dissipation of energy in different structural components." The staff notes that (1) ANSYS allows mode-dependent damping; (2) ANSYS also allows material-dependent damping; and (3) complex damping is a mathematical representation and should not contribute to response differences. Explain why the SASSI and ANSYS damping representations cannot be made as equivalent as possible, within the constraints of the two codes, to eliminate this as a cause for differences.

(iv) Based on the ARS comparisons presented in Section 5 of MUAP-10001(R3), discuss the extent to which the guidelines have been satisfied, and also discuss the extent to which the factors that may lead to violations of the guidelines actually affected the results.

03.07.02-120

In Subsection 4.5.3 of MUAP-10001(R3), "Approach to Address Concrete Cracking in Site-Independent SSI Analyses," on page 4-45, it is stated that "Responses obtained from the models with two different levels of stiffness and damping are enveloped in order to develop ISRS for design of the seismic category I and II equipment and components. The SSE loads used for the PCCV and the CIS design are also developed based on the responses obtained from the analyses of models with two different level of stiffness in order to ensure that the design uses seismic loads enveloping both normal operating and accident loading conditions. Responses obtained from models with reduced (cracked concrete) stiffness and SSE damping are used to develop SSE loads for the design of shear walls or reinforced concrete structures since this condition corresponds to the ultimate stress conditions. This approach is consistent with Section 1.2 of RG 1.61."

The Applicant is requested to:

(i) Explain this apparent inconsistency in approach. Clarify where the envelope is used and where only the cracked conditions and SSE damping are used. Provide the technical basis for this dual approach.

(ii) Show that the responses of models with uncracked stiffness and OBE damping do not control the design of the concrete structural members.

03.07.02-121

In Table 4.5.4-1 of MUAP-10001(R3), "Material Properties of Models used for Seismic Response Analyses," (Page 4-47) there are four blank cells under the column heading of "SSE Load" for the full (uncracked) stiffness level.

The applicant is requested to provide the technical rationale for not considering these four cases.

03.07.02-122

In Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” the first sentence (Page 5-80) states: “Built using the ANSYS preprocessor, the R/B Complex Dynamic FE model is an integrated 3-D model of the R/B-FH/A, PCCV and CIS structures resting on top of a common 9’-11” thick basemat.”

The 9’-11” thick basemat is much thicker (38’-2”) in its central region. The applicant is requested to describe how the thicker portions of the basemat in the R/B Complex Dynamic Model are implemented. If the thicker portions of the basemat are not modeled, the applicant is requested to provide the technical basis and justification for ignoring these thicker portions of the basemat in the R/B Complex Dynamic Model.

03.07.02-123

In Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” Step 4 in the 2nd paragraph (Page 5-80) states: “Modifications are implemented as needed to make the model more consistent with the Detailed FE model.”

The applicant is requested to describe the attributes or parameters that are compared, the criteria used, including its basis and justification, to ensure consistency between the Dynamic Model and the Detailed FE Model.

03.07.02-124

In Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” the 2nd sentence in the 4th paragraph (Page 5-80) states: “Wall shell elements are extended into the basemat solid elements to ensure a proper transfer of bending moment between them.”

The applicant is requested to describe the criteria used to achieve the assurance of fully transferring the bending moments.

03.07.02-125

In Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” the 6th paragraph (Page 5-81) states, in part: “The thickness of the PCCV is also simplified for ease of modeling. Only the large equipment hatch is modeled and the elements modeling the buttresses on the East and West sides of the structure are not offset with respect to adjacent elements.”

To help the staff better understand the development of the R/B complex model, the applicant is requested to provide information to the following questions: What is the actual thickness of the PCCV used in the FE model? Are the wall shell elements modified to reflect the increased thickness of the PCCV at the equipment hatch? How does this change (in stiffness) affect the design forces in the PCCV, equipment hatch, and associated SSCs responses? Also, would deleting the equipment hatch from the Dynamic Model altogether be acceptably accurate for the current purpose, and simplify the model? Or, is the inclusion of the equipment hatch intended to allow evaluation of local effects in that area?

03.07.02-126

With respect to Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” the applicant is requested to provide the following information in order for the staff to determine the adequacy of the dynamic model and the results of the SSI analyses of the R/B complex.

(i) Figures 5.3.1-2, -3, -5, -6 seem to indicate that one to three layers of solid elements are used for the basemat. ANSYS recommends the use of at least 4 solid elements for adequate moment capability. Please clarify the modeling of the basemat, and if applicable, provide technical justification for using fewer than 4 elements.

(ii) In Table 5.3.2.1-1, “Concentrated Mass of RV Model,” explain the differences between vertical mass and horizontal mass.

(iii) Explain the large difference in Figure 5.3.3.1.2-3, “R/B Modal Analysis Results – Cumulative Mass in the Vertical Direction (Z),” and discuss how it affects the responses.

(iv) Explain the 33% difference in Figure 5.3.3.2.3-7, “CIS ARS Results – Comparison at Top of Reactor Vessel, X-direction (Uncracked Analyses),” between the detailed and dynamic FE models. Identify the frequency at which it occurs. Provide comparable information for Figures 5.3.3.2.3-11, -12, -14, -16,-17.

(v) Explain the large difference in Figure 5.3.4.1-3, between SASSI and ANSYS Dynamic model analyses.

03.07.02-127

In Section 5.3 of MUAP-10001 (R3), “Development of the R/B Complex Dynamic FE Model,” the 6th paragraph (Page 5-81) states: “The thickness of the PCCV is also simplified for ease of modeling. Only the large equipment hatch is modeled and the elements modeling the buttresses on the East and West sides of the structure are not offset with respect to adjacent elements. Also, the personnel airlocks as well as the Main Steam and Feed Water penetrations are not modeled in the Dynamic FE Model. Figure 5.3.1-4 shows the Dynamic PCCV Model.”

The applicant did not discuss how the polar building crane is modeled in the PCCV Dynamic Model (shown on Figure 5.3.1-4) including the effects of the mass of the crane (with its maximum load lift) on the PCCV model. The applicant is requested to provide the details of the de-coupling criteria (including the actual mass ratios and frequency ratios) and justification for dynamic de-coupling of the polar crane’s seismic response from the building response.

03.07.02-128

In Section 5.3 of MUAP-10001(R3), “Development of the R/B Complex Dynamic FE Model,” the 8th paragraph (Page 5-81) states: “The Dynamic CIS model utilizes numerous simplifications to preclude meshing difficulties. The geometry of some of the CIS components is simplified, and the various small openings throughout the structure are neglected. In order to maintain the dynamic properties of the detailed CIS model, the material properties of some of the CIS members are modified.”

The last sentence referring to modifications of material properties in the detailed CIS model is vague. What is meant by “maintain the dynamic properties” and why should these dynamic properties be maintained? The applicant is requested to provide a description of which properties are modified and the criteria or rationale that guides such changes in material properties. The applicant is also requested to demonstrate that these modifications have conservative effect on the response of CIS and other SSCs.

03.07.02-129

In Subsection 5.3.4.2 of MUAP-10001 (R3), “Validation of the CIS,” the first paragraph (Page 5-189) states, “Please note that the ARS produced by ACS SASSI demonstrate higher peak responses due to the additional amplification from slight variations in the models used for analysis (variations present in both cracked and uncracked models). The fixed base analysis for the ANSYS model considers fixed boundary conditions at the base of the CIS structure. The SSI validation analysis with hard rock soil conditions considers the entire R/B complex with fixed base boundary conditions at the bottom of the basemat. As discussed in Section 4.3.3, this difference in support elevation creates amplifications at the base of the CIS as presented in the transfer functions provided in Figure 5.3.4.2-1 and Figure 5.3.4.2-2.”

The Applicant is requested to address the following:

1. The transfer functions presented in Figure 5.3.4.2-1 and Figure 5.3.4.2-2 are for x and y directions. The applicant is requested to present the corresponding transfer function in the z direction to assist the staff to better understand the ARS shown in Figures 5.3.4.2-13 and 5.3.4.2-14 (Pages 5-202 to 5-203) where the results of SASSI model in z direction have a second distinct peak around 28 Hz.
2. The transfer function in the x direction shown in Figure 5.3.4.2-1 is amplified above 1.5 in the frequency range from 25 Hz to 37 Hz. However, the ARS at top of pressurizer compartment in the x direction shown in Figure 5.3.4.2-3 does not show any amplification in the same frequency range. The applicant is requested to provide a technical explanation for this phenomenon and what changes are made to the FE model to rectify this discrepancy.

03.07.02-130

In Figure 5.3.3.2.1-3 of MUAP-10001(R3), “CIS 1g Static Analysis Results – NS Direction (X) at Reactor Vessel (Uncracked Analyses),” (Page 5-128) and Figure 5.3.3.2.1-4, “CIS 1g Static Analysis Results – EW Direction (Y) at Reactor Vessel

(Uncracked Analyses)," (Page 5-129) the curves shown in these figures have negative slopes.

The applicant is requested to provide an explanation for why the deflection curves have negative slopes. A similar trend is also observed for the curves presented in Figure 5.3.3.2.1-11 (Page 5-136) and Figure 5.3.3.2.1-12 (Page 5-137).

03.07.02-131

With respect to Section 5.4 of MUAP-10001(R3), "Dynamic FE Model of the PS/B," staff noticed that the ANSYS dynamic model is translated into ACS SASSI model for the SSI analysis and that there are large differences in the response from both the ANSYS and ACS SASSI models. The applicant is requested to discuss what actions are planned to improve the accuracy of the seismic model translation from ANSYS to ACS SASSI in order to conform to the guidance provided in Section 4.3.3 of the report (page 4-33). The applicant is also requested to provide the following information in order to determine the adequacy of the dynamic model and the results of the SSI analyses of the PS/B.

(i) In Figure 5.4.1.-7, "PS/B Dynamic FE Model (Beams and Columns)," the beams and columns appear to be modeled using solid elements, in a manner that cannot represent flexural behavior. Explain this figure, and describe how flexural behavior of the beams and columns is modeled.

(ii) Figures 5.4.3-12 through 5.4.3-20 present ARS comparisons between the detailed model and the dynamic model, at locations in the PS/B. The spectral acceleration peak in Figure 5.4.3-20 in the vertical (Z) direction is significantly higher for the dynamic model (6.5g), than for the detailed model (5.2g). Explain the large difference in results.

(iii) Figure 5.4.3-20 "PS/B ARS Results – Comparison at Elev. 39'-6" Interior, Z-direction," the dynamic model result has a 6.5g peak at 18.5 Hz. In Figure 5.4.5-9 "PS/B ACS SASSI Results – ARS Comparison at Elev. 39'-6", Z-direction," the dynamic model result has a 4g peak at 18.5 Hz; and there is a double peak not shown in Figure 5.4.3-20. Explain why there is a large difference in the peak spectral acceleration in the Z direction and also changes in the spectral shape around 20 Hz.

(iv) Figures 5.4.4-1 through 5.4.4-4 present comparisons between the detailed and dynamic models, for local out-of-plane vibration modes of slabs in the PS/B. It appears that Figures 5.4.4-2 and 5.4.4-4 need to be switched for proper comparison of these dynamic model results to the comparable detailed model results. The applicant is requested to confirm this and make this correction in the next revision of MUAP-10001.

(v) The staff noted that the Sections 5.4.5 through 5.4.8 should be Sections 5.4.1 through 5.4.4**.** Figures and tables are numbered correctly. Make this correction in the next revision of MUAP-10001.
(vi) Figures 5.4.4-1 through 5.4.4-4 do not demonstrate good correlation of local modes between the detailed model and the dynamic model at the 70 Hz level as stated on page 5-238.The applicant is requested to provide evidence of the good correlation of local modes at the 70 Hz level.

(vii) The last paragraph on page 5-220 states "It is noted that the Detailed PS/B Model utilizes uncracked concrete material properties. Therefore, for comparison and validation purposes, uncracked concrete material properties are also assigned to the Dynamic PS/B Model." This statement implies that the ISRS developed for design of SSCs attached to the PS/B are based solely on a model with uncracked reinforced concrete stiffness and 4% viscous damping. Confirm this is the correct interpretation, and provide the technical basis for concluding that only the uncracked stiffness case needs to be analyzed, for generating the ISRS and for structural design. Also confirm that the same generic soil profiles are used for SSI analysis of the PS/B as are used for SSI analysis of the RB complex, or explain any differences including technical justification.

(viii) Table 5.4.3-2 PS/B Roof Lateral Displacement Comparison, on page 5-226, compares roof displacements in the NS and EW directions for 1g static loading. The comparison between the detailed model and dynamic model for this simple loading is very good in the EW direction, but less accurate than would be expected in the NS direction. Explain this discrepancy in the NS direction.

(ix) In Figure 5.4.3-14 of MUAP-10001(R3), "PS/B ARS Results – Comparison at Elev. 3'-7" Interior, Z-direction," (Page 5-232) the curve corresponding to the ARS obtained from the dynamic model misses the second peak (about 18 Hz) of that obtained from the detailed model. The difference of the two curves at about 18 Hz shown in Figure 5.4.3-14 is about 30% in magnitude. Explain why there is a large difference in magnitude.

03.07.02-132

In Subsection 5.4.9 of MUAP-10001(R3), "ACS SASSI Validation," the first paragraph (Page 5-241) states, "The comparison shows that the ACS SASSI model accurately represents the structural response of the validated Dynamic FE Model. Differences are observed from the figures for the analysis results using two different codes. They are acceptable based on acceptance criteria and justifications discussed in Section 4.3.3 of this report."

One of the acceptance criteria listed in Section 4.3.3 of MUAP-10001(R3) states, "The ARS results obtained for the ACS SASSI validation analyses shall be within 10% of those obtained from the time history analyses of the dynamic FE model." The staff noticed that the ARS comparison shown in Figure 5.4.5-9 (Page 5-250), the difference of the ARS at the peak about 27 Hz is more than 10%. The applicant is requested to provide numerical data for the ARS at that location to show that the result meets the acceptance criteria.

03.07.02-133

In Figure 5.3.3.1.1-4 of MUAP-10001(R3), "R/B 1g Static Analysis Results – NS Direction (X) at Location H," (Page 5-106) the two curves shown in the figure bend to the left at the top.

The curves shown in the figure represent the structural displacement in the x direction subjected to a 1g static force. Since the 1g forces are all applied in the same direction the displacement curves should not bend to the left on the top. The applicant is requested to make appropriate corrections to the structural model or provide a technical basis and justification for these inconsistent displacements in Figure 5.3.3.1.1-4.

03.07.02-134

In Figure 5.3.3.1.3-2 of MUAP-10001R3), "R/B ARS Results – Comparison at Exterior Wall Location B Roof Level, Y-direction," (Page 5-111) the ARS corresponding to the seismic model has a lower value (difference as large as 66%) than that of the detailed model in the frequency range of 12Hz to 30Hz.
The staff concluded that this discrepancy indicates that the seismic model lacks the vibration modes in the frequency range from 12Hz to 30Hz. The applicant is requested to address the vibration modes in the frequency range from 12Hz to 30Hz in the seismic model and discuss what actions are planned to improve the accuracy of the seismic model to ensure the design of SSCs is based on adequate seismic response in that frequency range.

03.07.02-135

In Figure 5.3.4.1-3 of MUAp-10001(R3), "R/B ARS Results – Comparison at Slab S38A1 (EL. 35'-2"), Z-direction," (Page 5-181) the second peak (around 40 Hz) of ARS from the SASSI model has a much lower value (50% lower) than that of the ANSYS model.

The applicant is requested to discuss what actions are planned to capture the missed second peak in order to demonstrate the adequacy of the SASSI model.

03.07.02-136

In Appendix A of MUAP-10001(R3), "Methodology for Modeling Stiffness and Damping of the CIS," the Category 2 under the subtitle of "Structural Categories in the CIS," (Page A-2) states, "Non-primary shielding walls with T > 56" (e.g. the 67"-thick single-celled walls) are to be treated as concrete walls with no additional stiffness imparted by the steel plates. This category comprises less than 10% of the walls in the CIS."

The staff noticed that Category 2 is actually a SC wall. However, in the above quoted sentence, Category 2 wall is treated as a concrete wall in the analysis. It is not clear to the staff if the Category 2 wall is treated as an ordinary reinforced concrete wall in its design. The applicant is requested to confirm whether the same rebar layout for concrete shear wall specified in ACI 349 is used for Category 2 wall. According to the above quoted sentences, the additional stiffness from steel plates is not considered in the analysis. As a result, the seismic force for Category 2 wall obtained from the analysis will be less than the actual force it experiences because its actual stiffness is larger than that used in the analysis. Thus, the applicant is requested to estimate the actual seismic force this thick wall experiences and demonstrate that the potentially under-designed Category 2 wall is safe. Also, is there a possibility that the Category 2 wall is over-reinforced?

03.07.02-137

In Appendix A of MUAP-10001(R3), "Methodology for Modeling Stiffness and Damping of the CIS," the paragraph under the subtitle of "Category 4, Condition B," (Page A-4) states, "In-plane shear stiffness of the reinforced concrete slabs for this condition shall also be that of the gross concrete section (G_cA_c)."

Per Table 3-1 of ASCE 43-05 (Reference A6 of this Report), shear stiffness for cracked diaphragms is 50% of the gross concrete section. The applicant is requested to provide the rationale for using the full gross concrete section.

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 4th 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 Fy=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 + (Square root (Q_n/C_f)) . ($I_{tr} - I_x$)]

The staff checked AISC 360-05 and believes the equation cited should be:
I_{eff} = 0.75 [I_x + (Square root (Q_n/C_f)) . ($I_{tr} - I_x$)]

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 2nd 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/V^2 (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/V^2 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 - 1st 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 2nd 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.