REQUEST FOR ADDITIONAL INFORMATION 212-1950 REVISION 1

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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)

03.07.02-1

RAI 3.7.2-1

The seismic analysis methods described in section 3.7.2.1 of the DCD state that the methods conform to the requirements of SRP Subsections 3.7.1 and 3.7.2 and generally to industry standard ASCE 4-98. The staff has not reviewed and endorsed ASCE 4-98 for this application. Currently this ASCE standard is under revision. The applicant need to provide justification independent of ASCE 4-98 in all instances where this standard is relied upon as the basis for seismic analysis. The lumped mass stick models described in Section 3.7.2.1 of the DCD use frequency-independent impedance functions for the half-space modeling of the soil media. The SRP acceptance criteria 3.7.2.II.4 state that for the half-space modeling of the soil media, the lumped parameter (soil spring) method and the compliance function method are acceptable provided that frequency variation and layering effects are incorporated. Provide justification including studies and test data for using frequency-independent impedance functions for the half-space modeling of the soil media.

RAI 3.7.2-2

In section 3.7.2.2 of the DCD it is stated that the results obtained from the seismic analysis of the coupled model are reconciled, as necessary, with those results obtained from the current seismic analysis. Provide clarification to this statement and provide details of the various seismic analysis (e.g., current) being referenced.

RAI 3.7.2-3

Section 3.7.2.3.10 of the DCD addresses the validation of various lumped mass stick models. The lumped mass models are nominally validated by comparing static deformations and ISRS at arbitrarily selected nodal locations from the lumped mass models to those from more detailed distributed mass models. In order to verify if the dynamic properties of the stick model conform to those of the detailed finite element model, in accordance with the SRP Section 3.7.2.II.A.iv, provide comparisons of natural frequencies, mode shapes, modal participation factors and total seismic response obtained from the two models by using the identical seismic input motion.

RAI 3.7.2-4

SRP Sections 3.7.2.I.2 and 3.7.2.II.2 A and B state that ISRS at support locations of Seismic Category I equipment should be provided. Section 3.7.2.3.10.1 indicates that the in-structure response spectra (ISRS) are extracted from the lumped mass models at arbitrarily selected nodes that represent main floor levels. Provide the criteria used to select the locations of the ISRS shown in Appendices 3H and 3I and References 3.7-18 and 3.7-33. If the ISRS presented are used solely for model validation, provide the ISRS corresponding to Seismic Category 1 equipment support points.

RAI 3.7.2-5

It is stated in Section 3.7.2.8 of the DCD that the phenomenon of structure-to-structure interaction through the soil is neglected in the soil-structure interaction (SSI) analysis and instead the variations of the site properties considered by the four general subgrade conditions are deemed sufficient to address the uncertainties related to possible structure-to-structure interaction effects. Provide justification for this position other than the reference to ASCE 4-98.The staff has not reviewed and endorsed ASCE 4-98 for the SSI application. Currently this ASCE standard is under revision.

RAI 3.7.2-6

Section 3.7.2.8 of the DCD addresses the interaction of non-category I structures with Category I SSCs in accordance with Section 3.7.2.II.8 of the SRP. It is indicated in the DCD that the maximum displacements of the T/B and A/B have been calculated in order to determine the minimum size of the expansion joints between adjacent buildings. Clarify whether the maximum displacements calculated in analysis of the T/B and A/B include SSI effects, or whether the maximum displacements are determined from fixed-base models. Also, provide a detailed description of the analyses for the ESWPT, (SC I), the T/B, and A/B (SC II) and the AC/B (NS) structures.

RAI 3.7.2-7

Section 3.7.2.8 of DCD indicates that structure-to-structure interaction effects will be further addressed if warranted by specific site conditions. Describe the methodology and acceptance criteria that will be used to determine if structure-to-structure interaction analysis is required and how the analysis will be performed if required.

RAI 3.7.2-8

SRP Section 3.7.2 II.3.C (iii) states that local vibration modes should be adequately represented in the dynamic response model in order to ensure that the in-structure response spectra include the additional amplification. Discuss how the spectra (horizontal and vertical) for each of the lumped mass stick models described in the DCD and in References 3.7-18 and 3.7-33 were benchmarked, validated, or otherwise determined to have sufficient resolution to adequately represent the local dynamic response of the structure being modeled.

RAI 3.7.2-9

Section 3.7.2.5 of the DCD indicate that the ISRS for the Seismic Category 1 structures and design spectra for the RCL system are required to be developed from a coupled model of the RCL-R/B-PCCV-CIS. However, it appears that the spectra that form the basis for the standard plant design are from Appendix 3I of the DCD, which is based on an uncoupled model rather than from the results of the coupled model that are documented in the technical report MAUP-08005, April 2008 (Ref. 3.7-18). Describe the role of the two models and how the results (forces, displacements, accelerations, ISRS) from each of the models were used in the US-APWR standard plant design. Clarify whether the coupled or uncoupled model is the basis for the seismic analysis and design of the standard plant.

RAI 3.7.2-10

Section 3.7.2.5 of the DCD indicates that the ISRS for the Seismic Category I structures and design spectra for the RCL system are to be developed from a coupled model of the RCL-R/B-PCCV-CIS. Appendix 3I of the DCD describes the uncoupled lumped mass stick model of the RCL-R/B-PCCV-CIS and Ref. 3.7-18 in the DCD describes the coupled lumped mass stick model of the RCL-R/B-PCCV-CIS. Describe the criteria used to support the conclusion in Section 9.0 of the technical report for coupled model, MAUP-08005, April 2008 (Ref. 3.7-18) that no significant differences were observed in the results between the coupled RCL-R/B-PCCV-CIS model and the uncoupled R/B complex model. It is noted that in some cases, the spectral accelerations from the coupled model are higher than those from the uncoupled model (which appears to have been used as the design basis). For example, the ISRS at the frequency of 10 Hz in the north-south direction at PCCV (El 50'-2") has a peak value of 1.9g and 1.3g from the coupled and uncoupled model respectively. This difference of 46% at the frequency of design interest is significant. Provide a comparison of the ISRS from the coupled and uncoupled models. From this comparison, provide justification for the ISRS selected for the standard plant design basis.

RAI 3.7.2-11

Section 3.7.2.5 of the DCD indicates that the ISRS for the Seismic Category 1 structures and design spectra for the RCL system are to be developed from a coupled model of the RCL-R/B-PCCV-CIS. Table 3H.3-4 of the DCD and Table 8-4 of Ref. 3.7-18 show differences in the modal properties for the coupled and uncoupled lumped mass stick models of the R/B-PCCV-CIS for the case of soil with a 6,500 ft/s shear wave velocity (the last two rows of the Tables show different frequencies and participation factors). Explain how the results from these two tables are used and what impact the differences will have on the ISRS for the US-APWR standard plant design.

RAI 3.7.2-12

In Section 3.2.2.7 of the DCD, for the seismic response spectra analysis, three methods are proposed for calculating residual rigid response - the static ZPA method, the missing mass method, and the left-out-force method. SRP Section 3.7.2 II.7 references RG 1.92 regarding acceptable methods for calculating residual rigid response. The first two methods above are acceptable according to RG 1.92, but the third method above has not been reviewed and accepted by the staff in RG 1.92, or in the SRP. Provide a

comparison of the responses calculated from the left-out-force method with the other two acceptable methods and demonstrate that the results are conservative in comparison with the other two accepted methods.

RAI 3.7.2-13

It is stated in Section 3.7.2.8 of the DCD that dynamic increases in seismic lateral earth pressure on below-grade exterior walls were accounted for in the design of the US-APWR Seismic Category I structures by applying conservative maximum static and dynamic lateral pressure profiles in accordance with ASCE 4-98. The staff has not reviewed and endorsed ASCE 4-98 for this application. Currently this ASCE standard is under revision. Describe the pressure distribution profiles and the application of these pressure profiles to below-grade exterior walls in the seismic models, and what models are affected. Explain the basis for determining the lateral pressure distribution profiles to be conservative.

RAI 3.7.2-14

It is stated in Section 3.7.2.4.1 of the DCD and in COL action item COL 3.7(23) that the lateral soil pressures on the basement walls determined from a site-specific SSI analysis will be verified to be enveloped by the US-APWR standard design. However, the only SSI models described in the DCD have a basemat resting on the surface of a uniform elastic half-space exclusive of any basement walls. Describe how the lateral soil pressures on the basement walls calculated from a site-specific SSI analysis will be compared to those from the US-APWR standard design.

RAI 3.7.2-15

The SRP acceptance criteria 3.7.2 II.9 states that the effects of potential concrete cracking on structural stiffness should be specifically addressed when determining the effects of parameter variations on floor response spectra. Describe how and where the effect of potential concrete cracking is accounted for in the determination of floor spectra.

RAI 3.7.2-16

Provide a listing or table indicating which analysis method is used for each of the Seismic Category I, Seismic Category II, and non-seismic SSCs, or justify why such a description is not provided in the DCD. SRP Subsections 3.7.2 II.1 through 3.7.2.II.14 provide acceptance criteria for the seismic system analysis, but the acceptability of the SSCs cannot be evaluated without descriptions of the methodologies used. It is noted that the applicant has provided such information in Table 3.7.2-1 of the DCD for a subset of the structures. It is stated in Sections 3.7.2.8.2 and 3.7.2.8.4 that the design of the turbine building (T/B) and Auxiliary building (A/B) are based on a seismic dynamic analysis using a three-dimensional lumped mass model. Provide detailed description of these models and analysis results.

RAI 3.7.2-17

Model properties and seismic analysis results for lumped mass stick models are presented in Appendix 3H of the DCD. Dynamic responses from the lumped mass stick and finite element distributed mass models have been compared. However, it is not clear what data are being presented, how the data are being used, what acceptance criteria apply for the comparisons, and what conclusions are drawn. For example, in subsection 3H.3 of the appendix it is stated that comparison is made with responses obtained from the frequency domain time history analysis of the fixed base detailed finite element model. Provide the details and technical basis of the frequency domain time history analysis method. 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. Describe how the lumped mass and distributed mass models meet the guidelines in the SRP Subsection 3.7.2.II.3C. Provide a clear explanation of the purpose of the Appendix 3H, data presented therein, conclusions drawn, and the technical basis for the conclusions.

RAI 3.7.2-18

Section 2.3.1 of the technical report 'Enhanced Information for PS/B design' (Reference 3.7-33) describes the criteria for determining if the lumped mass stick models of the PS/B have adequate degrees of freedom. SRP Section 3.7.2 II.1.A.iv provides guidelines for determining whether a lumped mass model has adequate degrees of freedom for dynamic modeling. Provide the basis of the statement that additional DOFs do not result in more than a 10% increase in response, and describe how the proposed criteria that additional DOFs do not result in more than a 10% increase in response, or the number of DOFs equals or exceeds twice the number of modes with frequencies less than 33 Hz meet the intent of SRP Section 3.7.2 II.1.A.iv. If the highest structural frequency is limited to 33 Hz, explain how the high frequency responses will be captured. Also, provide a comparison of seismic responses from the lumped mass stick model of the PS/B and the distributed mass finite element model.

RAI 3.7.2-19

In Section 3.7.2.3.1 of the DCD it is stated that the NASTRAN finite element models are used for validation of the dynamic lumped mass stick models and the NASTRAN results are validated by comparison to the results of separate ANSYS finite element model analyses. Provide results and details of the NASTRAN and ANSYS validations. Describe how the various finite element models that were developed for validation meet the guidelines of SRP Sections 3.7.2.II.3.C.ii and iii.

RAI 3.7.2-20

Section 3.7.2.4 of the DCD states that the SSI analysis conservatively neglects the effects of embedment of the common R/B and PCCV basemat. The natural frequency of the structure is sensitive to the embedment effect and the seismic response of subsystem and equipment can be lower or higher depending on the seismic input ground motion and the frequency of subsystem or equipment of interest. Provide a technical basis including studies or test data to demonstrate that neglecting the effects of embedment results in conservative results.

RAI 3.7.2-21

In Tier 1 Table 2.1-1 and Tier 2 Table 2.0-1 of the DCD, it specifies maximum ground water level is 1ft below plant grade; however the SSI analysis discussed in section 3.7.2.4 is based on four soil profiles that are all linear elastic half-space uniform dry materials (no layer and water table considered). Provide justification for not considering soil layering and location of water table in the SSI analysis.

Also, clarify the last paragraph in Section 3.7.2.4 of the DCD. What model is used for SSI analysis that takes into account the site-specific conditions? What does the lumped parameter model consists of - a stick model of a building on layered soil media, or a stick model that uses lumped impedance parameters for the soil? If it is the former, how are the damping characteristics of the layered media compared to impedance function values?

RAI 3.7.2-22

The last two paragraphs of Section 3.7.2.4.1 of the DCD describe a criterion under which a fixed-base analysis is acceptable per ASCE 4-98. The staff has not reviewed and endorsed ASCE 4-98 for this application. Currently this ASCE standard is under revision. Provide bases and technical justification for the criterion. Discuss how the proposed criterion meets the provision of SRP Section 3.7.2.II.4 for assuming a fixed-base condition.

RAI 3.7.2-23

In Section 3.7.1.1 of the DCD it is stated that the essential service water pipe tunnel (ESWPT), the power source fuel storage vaults (PSFSVs), and the ultimate heat sink related structures (UHSRS) are Seismic Category I buildings and structures, but are not included as part of the standard plant. Provide a detailed description of the seismic input, modeling procedure, and seismic analysis methods for each of the structures in order to review their adequacy in accordance with the SRP section 3.7.2 guidelines.

RAI 3.7.2-24

Section 3.7.2.8 of the DCD states that for the purposes of site-specific SSI analysis and for subgrade dynamic bearing capacity confirmation, it is acceptable to use maximum pressure distributions below the basemats of adjacent structures. Provide bases and technical justification for the position and describe how such pressure distributions will be determined and applied in an analysis.

RAI 3.7.2-25

Provide a list of the buildings and structures that will be analyzed for site-specific soil-structure interaction effects and indicate the method of SSI analysis for each –finite element or impedance approach.

RAI 3.7.2-26

Section 3.7.2.7 of the DCD presents equations for two grouping methods for combining modal responses in a response spectrum method of analysis. However, the nomenclature and equations in the DCD appear inconsistent with those in RG 1.92, Rev. 1 and Rev. 2. Demonstrate that the equations given in the DCD are equivalent to those in RG 1.92, or else explain the differences between the approaches and provide justification for the proposed approach.

RAI 3.7.2-27

In Section 3.7.2.11 of the DCD, clarify the second bulleted item. It seems to state that the eccentricities between the mass centers and centers of rigidities for each floor are included to account for accidental torsion. However, the methodology is consistent with determining the torsional effects due to the known asymmetries in the distribution of mass and stiffness of the building rather than accidental torsion as implied in the DCD.

RAI 3.7.2-28

Based on the information in Section 3.7.2.12 of the DCD, it appears that the DC Applicant may have misinterpreted the intent of SRP Section 3.7.2.II.12. The SRP acceptance criteria state that if both the time history analysis method and the response spectrum analysis method are used to analyze an SSC, the peak responses obtained from these two methods should be compared, to demonstrate approximate equivalency between the two methods. The DC Applicant should clearly state whether any SSCs are analyzed using both the time history method and the response spectrum method, and document the comparisons of the two methods.