REQUEST FOR ADDITIONAL INFORMATION 909-6315 REVISION 3

3/5/2012

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)

03.07.02-180

In MUAP-11002(R1), in the listing “Revision History,” the 6th item in the list is “Updated report per NRC Request for Additional Information 766-5819 Revision 3 and 767-5821 Revision 3.”

In the Applicant’s response to the RAIs cited in the Revision History list, several questions in the RAIs were not addressed in any form in the Applicant’s formal response. Specifically, no response was provided for Questions 03.07.02-42, -43, -45, -48, -49, -51, -54, -55, -57, -59, and 63. The Applicant is requested specifically to identify if Revision 1 to MUAP-11002 address any (or all) of the previously unanswered questions and also identify specific sections in the report where the responses to these unanswered questions are provided.

Additionally, the Applicant is requested to describe whether and where changes were made reflecting these previously unanswered questions. If the unanswered questions have not been addressed in this revision, the Applicant is requested to provide specific responses for these unanswered questions.

03.07.02-181

In MUAP-11002(R1), Section 1.0, "Introduction," the 7th sentence in the 5th paragraph (Page 14) states “The six generic layered subsurface profiles were modified for SSI [soil structure interaction] analysis on the TI [Turbine Island] structures.”

The Applicant is requested to describe the modifications and reasons for the modifications made to the subsurface profiles and, if applicable, to describe how they differ from those used in MUAP-10001(R4), “Seismic Design Bases of the US-APWR Standard Plant.” The Applicant is requested to identify if further modifications (reductions) in the number of soil profiles are planned for the standard plant, and how will this modified set of profiles affect the design of the Turbine Building.

03.07.02-182

In MUAP-11002(R1), Section 1.0, "Introduction," the last sentence of the 5th paragraph (Page 14) states “The potential effects of ignoring the embedment are not evaluated in this report.”

The Applicant is requested to provide the reference report that evaluates the embedment effects or a study that concludes that ignoring the effects of embedment is conservative for the design of the Turbine Building.

03.07.02-183

In MUAP-11002(R1)), Section 1.1.2, “Electrical Room,” (page 16), the first paragraph states, in part, “The T/B [Turbine Building] and Electrical Room are separate distinct structures with an engineered clearance between the superstructures and substructures.”

The above quoted sentence states that the T/B and Electrical Room are separate distinct structures. However, the data presented in Table 3-2 (Page 51) are mass properties of the combined T/B and Electrical Room. In order for the staff to assess the seismic eccentricity considered in the analysis, the Applicant is requested to present mass properties of the T/B and Electrical Room separately.

03.07.02-184

In MUAP-11002(R1), Section 1.1.4, “Turbine Generator (T/G) Pedestal,” the next to last sentence (Page 18) states, “The movement of the T/G Pedestal basemat and tabletop and the gap between the T/G pedestal basemat and tabletop and the T/B substructure and superstructure floors will be evaluated in the site-specific design.”

The Applicant is requested to provide the magnitude of the designed gap between the T/G pedestal basemat and tabletop; and the T/B substructure and superstructure floors, and include a COL item in the US-APWR DCD which requires the COL applicant to perform the referenced evaluation described above.

03.07.02-185

In MUAP-11002(R1), Section 2.2, “Material Properties,” (Page 20), the first bullet in the last paragraph give the compressive strength of the heavy concrete as f'_c = 6,000 pounds per square inch. The applicant is requested to discuss the reasons for using this higher value as opposed to 4,000 lbs/in^2 used for the normal weight of concrete, and the basis for the mechanical properties listed in Section 2.2.

03.07.02-186

In Section 2.2 of MUAP-11002(R1), “Material Properties,” (page 21), the 3rd paragraph states, “Since the equation for Young’s modulus in ACI 349-01 (Reference 7) only applies to reinforced concrete with a unit weight up to 155 pounds per cubic foot, this upper bound unit weight is used in calculating Young’s modulus for heavy concrete." The Applicant did not provide any rationale for this assumption that will indicate whether or not this assumption leads to conservative results. Thus, the Applicant is requested to provide a justification for this assumption, or to require the COL Applicant to perform tests in accordance with ASTM C469, “Standard Test Method for Static Modulus of

Elasticity and Poisson's Ratio of Concrete in Compression," to determine the appropriate Young's modulus for the heavy concrete.

03.07.02-187

In Section 2.3.1 of MUAP-11002(R1), "Structural Discretization and Finite Element (FE) Types," the last paragraph (Page 23) states, in part, "In order to include the effects of the T/G [Turbine Generator] Pedestal in the SSI analyses, a simplified lumped mass stick model (LMSM) for the T/G Pedestal was developed in GT STRUDL. Natural frequency and displacement values in the transverse, longitudinal and vertical directions were developed to be representative of the preliminary T/G Pedestal design, and the GT STRUDL T/G Pedestal LMSM closely matches these values."

The LMSM for the T/G Pedestal is not presented in MUAP-11002(R1). The Applicant is requested to provide description of this model in the report, including the development of natural frequency and displacement values in the transverse, longitudinal and vertical directions, and a comparison of the dynamic data demonstrating that simplified LMS Model is representative of the preliminary T/G Pedestal design. The applicant is also requested to describe how it intends to address the final T/G pedestal design in the seismic analysis and when the report on the final seismic analysis of the Turbine Building will be provided to the staff for review.

03.07.02-188

In Section 2.3.2.1 of MUAP-11002(R1), "Consideration of Concrete Cracking Effects," (Page 24), the last sentence states, "Therefore, no attempt to characterize the response of a more rigid, concrete foundation is deemed necessary."

The staff notices that this approach is inconsistent with that used in Subsection 4.5.1 of MUAP-10001 (R4), in which two analyses are performed. One analysis assumes that the concrete is cracked, and the other analysis assumes that the concrete is not cracked. The responses obtained from these two analyses are then enveloped to develop the basis for the seismic analyses and design. The Applicant is requested to provide a rationale for not using a similar dual approach for the T/B analyses, and, also, to provide numerical data that shows that the approach taken in MUAP-11002(R1) is conservative.

03.07.02-189

In Section 3.2 of MUAP-11002(R1), "Modal Analysis," the second paragraph (Page 29) states, in part, "The dominant modal properties for both the fine and coarse mesh ANSYS models up to 50 Hz for the X, Y and Z direction vibrations for the combined T/B and Electrical Room, are shown on Tables 3-3 through 3-5, respectively."

In Section 1.1.2 of MUAP-11002(R1) (Page 16), it is stated that the T/B and Electrical Room are separate distinct structures with engineered clearance between the superstructures and substructures. The modal properties presented in Tables 3-3 through 3-5 are, however, for combined T/B and Electrical Room. The staff is not able to identify whether the modal properties shown in the tables are those of the T/B or of the

Electrical Room. The Applicant is requested to provide additional data in Table 3-3 through 3-5 to clearly identify which building the modal properties represent.

03.07.02-190

In Section 4.0 of MUAP-11002(R1), “Soil-Structure Interaction Analysis,” (Page 31) there is no reference that considers the effects that the high water table in the US-APWR standard plant design may have on the SSI analysis results for the Turbine Island (TI).

The Applicant is requested to address the effects of variations in the water table in the SSI analyses for the TI, including a water table level from the bottom of the TI foundation up to one foot below finished grade.

03.07.02-191

In Section 4.3.1 of MUAP-11002(R1), “Approaches for Developing Maximum Relative Displacement,” the first sentence in the first paragraph (Page 34) states, “The relative displacements of select TI nodes with respect to the ground surface motion in the free-field were calculated using the ACS SASSI RELDISP module.”

In Section 4.2.1 of MUAP-11002(R1), “Subsurface Profile/Properties,” (Page 32), the Applicant indicates that the cut-off frequency used for SSI analysis is 50 Hz. The data shown in Figures 3-10, 3-11, and 3-12 indicate that up to 50 Hz there is only 70% of the mass participation in the x direction and y direction, and only 40% of the mass participation in the z direction. The Applicant is requested to include the missing mass effect in the evaluation; otherwise, the Applicant needs to provide data to show that ignoring the effect of missing mass is conservative in the evaluation of the relative displacement.

03.07.02-192

In Section 5.1 of MUAP-11002(R1), “Loads and Load Combinations for Seismic Structural Integrity Evaluation of TI,” (Pages 37-40), the loads considered in the analyses are listed.

The staff notices that the Wind load (including tornado and hurricane wind per RG 1.221, “Design-Basis Hurricane and Hurricane Missiles from Nuclear Power Plants"), the crane stop forces, and the dynamic lateral earth pressure are not included in this list. The Applicant is requested to provide technical rationales for not considering these loads, and to show that such omissions result in a conservative design. Notice that the wind load may be important for the metal wall panel and insulation fasteners used in the T/B steel frames. Further, the dynamic lateral earth pressure is needed in the design of basement walls and the evaluation of the foundation sliding stability.

03.07.02-193

In Section 5.1.1 of MUAP-11002(R1), “Dead Loads,” the second sentence on top of Page 38 states, “If the weight of the equipment is less than the applicable live load, then

the equipment weight shall be neglected in the dead load determination and shall be accounted for by the area live load."

The staff disagrees with the Applicant that the weight of the equipment which is dead load can be replaced by live load. Dead load and live load are two different types of loads and cannot be interchanged. The Applicant is requested to provide the basis for this assumption and justify that the assumption will result in a conservative design.

03.07.02-194

In Section 5.1.5 of MUAP-11002(R1), "SSE Loads," the first sentence in the second paragraph (Page 40) states, "Accidental torsion is applied in the models per NUREG-0800 SRP 3.7.2 (Reference 8) Acceptance Criteria 11."

However, the staff notices that in Section 7.0 of MUAP-11002(R1), "Turbine Building and Electrical Room Gap Evaluation," (Page 46), the effect of accidental torsion is not considered in the evaluation of the gap between T/B and the Electrical Room. The Applicant is requested to include the effects of accidental torsion in the evaluation.

03.07.02-195

In Section 5.2 of MUAP-11002(R1), "Time History Analysis Methodology," the second paragraph (Page 41) states, "All three components of ground motion will be applied simultaneously and combined algebraically by GT STRUDL at each time step to obtain the combined response time history. The Newmark Beta implicit integration technique will be used for the time history analysis."

The Applicant is requested to address the following questions:

1. Is the model used in time history the coarse model or the fine model?
2. What is the value for beta used in the Newmark Beta integration? In addition, the applicant is requested to provide technical details that show how the damping effect is considered in the direct integration.

03.07.02-196

In Section 5.2 of MUAP-11002(R1), "Time History Analysis Methodology," the third paragraph (Page 41) states, in part, "The member forces that will be obtained using the dynamic time history analysis are calculated at each time step and cannot be combined directly with the static results. Therefore, a pseudostatic load will be created which captures the maximum values of the forces from the time history analysis in order to combine with the static results."

The Applicant is requested to provide a technical description that shows how the pseudostatic load was created and how it is combined with the static results.

03.07.02-197

In Section 5.4 of MUAP-11002(R1), "Structural Integrity Evaluation Methodology," the second paragraph (Page 42) states, "In addition, superstructure member end forces and moments are extracted from the SSI results. These forces and moments are used in lieu of the GT STRUDL calculated seismic forces and moments and substituted back into the controlling load combination for each member. A separate calculation is performed in order to determine the steel superstructure member stress ratios including the SSI results. These member stress ratios are also compared to the AISC N690-1994 (R2004) (Reference 6) allowable stress ratios to confirm the adequacy of the steel members."

The forces and moments obtained from ACS SASSI analyses may not be accurate due to the missing mass effect (see the 12th question of this RAI). The Applicant is requested to consider the missing mass effect in the evaluation of forces and moments, or to provide numerical data to show that the missing mass effect is negligible and conservative. Also, the staff is not able find any numerical results in MUAP-11002(R1) for the evaluation of the member stress ratios. The Applicant is requested to present those results.

03.07.02-198

Section 6.0 of MUAP-11002(R1), "Stability Evaluation of TI," (Page 43) does not include the flotation stability evaluation of the TI. The Applicant is requested to provide analyses that demonstrate the flotation stability of the TI.

03.07.02-199

In Section 6.1 of MUAP-11002(R1), "Sliding Stability Evaluation Methodology," the second paragraph (Page 43) states, in part, "The seismic responses due to an SSE [safe shutdown earthquake] event include 25 percent of the floor live load and 75 percent of the snow load as inertia mass as discussed in Subsection 5.1.5. Therefore, it is reasonable to include the same amount of live and snow loads in calculating the net vertical forces for sliding evaluation."

The staff disagrees with the Applicant. The load combination for sliding stability evaluation is specified in SRP Acceptance Criteria Item 3 of the SRP 3.8.5 Section II. Only the dead load can be considered in the vertical forces. Floor live load and snow load are not dead load; therefore, they should not be included. The Applicant is requested to perform the sliding evaluation without including any live load and snow load in the vertical forces. Note, however, 25 percent of the floor live load and 75 percent of the snow load should be included in the SSE load for the horizontal shear force calculation.

03.07.02-200

Section 6.2 of MUAP-11002(R1), "Sliding Stability Evaluation Results," (Page 44) states, "The minimum sliding factor of safety for each subsurface profile is shown on Table 6-1. Since the factor of safety for all subsurface profiles for both the T/B and Electrical Room are greater than 1.1, the sliding stability is adequate for the T/B and the Electrical Room.

The sliding resistance required for the minimum factor of safety of 1.1 is based on the static coefficient of friction and no mobilization of passive soil resistance. Therefore, the displacement due to sliding is negligible."

1. It is not clear to the staff which direction of the sliding stability (x or y) that the data in Table 6-1 represent. The Applicant is requested to present the factor of safety for sliding stability in both the x direction and y direction in separate rows.
2. The Applicant is requested to specify the coefficient of friction used in calculating the resistance force for sliding. The applicant based its calculation for the minimum factor of safety of 1.1 on the static coefficient of friction. The Applicant is requested to provide the technical basis for using the coefficient of friction.

The embedment of T/B is 27 feet 2 inches, and not all four sides of the basement are in contact with the soil. This will cause unbalanced lateral earth pressure acting on the basement wall during a seismic event. Is this unbalanced lateral static and dynamic earth pressure considered in the sliding stability evaluation? If not, the Applicant is requested to provide justification for not considering it; otherwise, the Applicant is requested to consider it in the sliding stability evaluation.

03.07.02-201

In Section 6.3 of MUAP-11002(R1), "Overturning Stability Evaluation Methodology," the third paragraph (Page 44) states, in part, "In the calculation of the seismic responses, 25 percent of the floor live load and 75 percent of the snow load are used as inertia mass as discussed in Subsection 5.1.5. Therefore, it is reasonable to include the same amount of live and snow loads in calculating the total resisting moments."

The staff disagrees with the above statement. The load combination for overturning stability evaluation is specified in SRP Acceptance Criteria Item 3 of the SRP 3.8.5 Section II. Only the dead load can be considered in the evaluation. Floor live loads and snow loads are not dead loads; therefore, they should not be included. The Applicant is requested to perform the overturning stability evaluation without including any floor live loads and snow load in the resistant moments.

03.07.02-202

Section 6.4 of MUAP-11002(R1), "Overturning Stability Evaluation Results," (Page 45) states, "The minimum overturning factor of safety for each subsurface profile is shown on Table 6-2. Since the factors of safety for all subsurface profiles for both the T/B and Electrical Room are greater than 1.1, the overturning stability is adequate for the T/B and the Electrical Room."

The Applicant is requested to provide numerical data in Table 6-2 for the overturning stability with respect to the x-axis and y-axis in separate rows.

03.07.02-203

In Section 7.0 of MUAP-11002(R1), "Turbine Building and Electrical Room Gap Evaluation," the third paragraph (Page 46) states, in part, "The maximum tilt slopes from settlement analysis of the T/B and Electrical Room are listed in Table 7-2."

In Table 7-2, the Applicant presents the data for the maximum construction tilt slope. It is 0.069 percent for the T/B and 0.269 percent for the Electrical Room. The Applicant is requested to check whether or not the values presented are correct. Also, the Applicant is requested to provide technical details that show how the maximum construction tilt slope and maximum operation tilt slope are estimated.

03.07.02-204

In reviewing this technical report, MUAP-11001(R1), the staff found several areas which need further clarification, additional information, or editorial revision. The applicant is requested to address the following requests and questions:

1. In MUAP-11002 (R1), in the Acronyms/Symbols List (Page 13), NUREG is defined as "US Nuclear Regulatory Commission Regulation." NUREG documents are "*Reports or brochures on regulatory decisions, results of research, results of incident investigations, and other technical and administrative information."* They are not regulations. The Applicant is requested to modify this definition.
2. In MUAP-11002(R1), Section 1.0, "Introduction," (Page 14) there is no mention of the structural integrity evaluation which is included in the report. The Applicant is requested to include such a citation in this introduction and purpose section.
3. In Section 1.1.2 of MUAP-11002(R1), "Electrical Room," (page 16), the last paragraph states, in part, "There is a minimum 3 feet 1 inch gap between the NI [Nuclear Island] structures and the north face of the Electrical Room superstructure, as depicted in Figure 1-7." Depicted in Figure 1-7 is the Turbine Building foundation not the Electrical Room foundation. The Applicant is requested to correct this mistake.
4. In Section 2.2 of MUAP-11002(R1), "Material Properties," the last paragraph (Page 21) states, "The corresponding shear wave velocity of lean concrete was calculated based on the cracked modulus of lean concrete as shown in the following:" The numerical value of $E_{cracked}$ used in the first equation to calculate the shear modulus of lean concrete, 410,000 ksf, is that of uncracked concrete not the cracked concrete. The Applicant is requested to correct this mistake.
5. In Section 4.3.3, "Results of Maximum Relative Displacements," the second sentence in the first paragraph (Page 36) states, "The relative displacements in the Y direction (North-South) range from 0.06 inch at the bottom of the Electrical Room substructure along the north wall at node 933 to 7.95 inches at node 3242 located at the top of the southwest corner of the T/B superstructure." In the above quoted sentence, 0.06 inch at node 933 is incorrect. Based on Table 4-10, it should be 1.67 inches. The Applicant is requested to correct this mistake.
6. In Section 5.1.1 of MUAP-11002(R1), "Dead Loads," the fourth paragraph (Page 38) states, in part, "See Figures 5-1 through 5-4 for equipment load maps for each superstructure level in the T/B and Electrical Room." The quality of the Figures 5-1 through 5-4 is poor and the text is blurred. The staff notes that Figures 5-5 through 5-12, while generally better, also contain unreadable portions. The Applicant is requested to improve the resolution of these figures.

7. In Figure 3-16 of MUAP-11002(R1) (Page 108), the caption of the figure states that the figure is Acceleration Transfer Functions at Node 51581. Node 51581 should be Node 1581. The Applicant is requested to correct this mistake.
8. In Figure 3-22 and Figure 3-23 of MUAP-11002(R1) (Page 114 and 115), the captions of the figures state that the figures are Acceleration Transfer Functions at Node 2569. Node 2569 should be Node 2659. The Applicant is requested to correct this mistake.
9. In Section 8.0 of MUAP-11002(R1), "Conclusions," the last sentence of the 3rd paragraph states "Displacement to mobilize the required sliding resistance is negligible." The meaning of this sentence is not clear to the staff. The Applicant is requested to provide more detailed information that explains the meaning of this sentence.

03.07.02-205

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-44, the Applicant stated that the element size of the coarse mesh model meets the criterion in SRP 3.7.2 by making comparisons of the several response quantities of the coarse mesh model with those of the fine mesh model. However, the staff does not consider the fine mesh model to be a "valid" model for the comparison because the fine mesh model can only represent the dynamic property of the structure up to 21 Hz which is far less than the zero period acceleration (ZPA) of 50 Hz. The fine mesh model, therefore, does not meet the SRP Acceptance Criteria 1.A.iv.(1) of SRP 3.7.2 which states in part, that "It is important to ensure that, for each excitation direction (2 horizontal and vertical), all modes with frequencies less than the ZPA (or PGA [peak ground acceleration]) frequency of the corresponding spectrum are adequately represented in the dynamic solution." As a result of this, the staff finds the Applicant's response to be unacceptable. Further, the Applicant referred its answer, in part, to RAI 03.07.02-57 which was not included in this response package.

The Applicant is requested to provide information that show that its approach for the fine mesh model meets the SRP Acceptance Criteria 1.A.iv.(1) of SRP 3.7.2. In addition, the Applicant is requested to provide its response to RAI 03.07.02-57 for the staff's review.

03.07.02-206

In the response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-47, the Applicant indicated that the values of the radius of central zone considered in the parametric study were 3.3 feet and 11.0 feet, and in general, the maximum displacements obtained using 3.3 feet is about 1 to 60 percent higher than the maximum displacements obtained using 11.0 feet. The staff considers that a study which considers only two values for a parameter is not a valid parametric study. Further, the Applicant did not provide the basis for selecting the values of 3.3 feet and 11.0 feet. The large difference shown in Figure 14 in MUAP-11002(R0) indicates that the response spectra have not converged for the two values considered.

The Applicant is requested to provide the technical rationale for choosing values for the radius of central zone of either 3.3 feet or 11.0 feet; otherwise, the Applicant is

requested to consider a greater number of values for the radius of central zone in the parametric study to demonstrate convergence of the response quantities.

03.07.02-207

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-53, the Applicant stated that the spurious spikes have no significant impact on the response estimation in the SSI analyses by comparing the maximum relative displacement at Node 1473 in the Y-direction using interpolation options 0 and 1 for two subsurface profiles. The staff considers that the data shown in the response to be limited to only one case, and, therefore, are not sufficient to support the argument that the spurious spikes have no significant impact on all the response estimation in the SSI. Spurious spikes may be removed by increasing the number of selected frequencies in transfer function un-interpolated (TFU) or use a different interpolation option.

The Applicant is requested to either increase the number of selected frequencies in the TFU, or use a different interpolation option to remove the spurious spikes in computing the SSI responses.

03.07.02-208

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-58 , the Applicant indicated that the joint ties are used to tie the displacement normal to the concrete wall or slab with those in the fill. In SSI analysis, the joint ties were used to create rigid links (very stiff linear springs). Each link connects a joint in the fill with the corresponding joint in the structure, tying a single translational degree of freedom (DOF). Ideally each link would be compression only. However, nonlinear links are not permitted in ACS SASSI, so the links may also transfer tension. This was judged by the Applicant to be acceptable.

The staff disagrees with the Applicant in allowing links to take tension. For common practice, the soil is assumed to take compression only. If the tension is not too large, one could accept the result of the analysis. However, if the tension is large, the structural model needs to be revised by removing the links having high tension, and performing the analysis again.

The Applicant is, therefore, requested to examine the tension developed at these tie links and revise the model as appropriate in accordance with the staff's comments above.

03.07.02-209

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-61, the Applicant clarified that the duration of the time history is 22.080 seconds. The Applicant also concluded that the 18.875 seconds for the quiet zone is long enough to damp out the transient response to ensure appropriate SASSI evaluation. The staff considers this conclusion to be incorrect. The purpose of the quiet zone is to capture the transient response correctly, not to damp out the transient response. The Applicant is requested

to demonstrate, by showing the convergence of the response graphically, that the periodic nature of the discrete fourier transform (DFT) is not leading to erroneous results in the SASSI evaluation.

03.07.02-210

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-62, the Applicant indicates that there are nine relative displacement time histories generated at each node from the SSI analyses. The staff disagrees with this statement, since for each horizontal motion there are two possible cases that need to be considered--- the results with either positive or results with negative signs. So, there are total of 15 relative displacement time histories.

The Applicant is requested to provide a rationale for not considering the + and – sign for the horizontal motions; otherwise, the Applicant is requested to consider all 15 cases.

03.07.02-211

In its response to RAI No. 766-5819, Revision 0, Question No. 03.07.02-65, the Applicant refers to the answer to RAI 03.07.02-62 and states that the methodology used implicitly accounts for the appropriate treatment of positive and negative displacements. However, in the response to RAI 03.07.02-62, the Applicant did not indicate that this is the case.

The Applicant is requested to provide information that shows that the positive and negative displacements are indeed considered in the combination.