REQUEST FOR ADDITIONAL INFORMATION 856-6094 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)

03.07.02-164

In MUAP-11011 (R0), Figure 2.0-1, Plant Layout of the US-APWR Standard Plant (Page 3), it is shown that the US-APWR Standard Plant consists of R/B, T/B, PS/B and A/B. However, in Table 1.0-1, this combination is not included in the cases considered. The applicant is requested to include “R/B+T/B+PS/B+A/B” in SSI/SSSI Model columns. If this is not feasible to include this case, the applicant is requested to justify the omission of this case. The applicant is also requested to address if it considered the use of a lumped mass stick model for PS/B to determine if the analysis for this case would be feasible.

03.07.02-165

In Section 2.0 of MUAP-11011 (R0), “Description of the US-APWR Standard Plant Layout,” the second paragraph (Page 4) states, “If the assessment in the initial phase indicates that the SSSI effects among the R/B Complex, West PS/B, and A/B are significant (based on guidelines provided in Sections 3.3.1 and 3.3.2 in this report), then further assessment of SSSI effects among the R/B Complex, T/B, and East and West PS/B will be made in the subsequent phases, as indicated in Table1.0-1.”

The staff finds the logic presented in the above quoted sentence as not convincing. The applicant did not provide rationale for including the auxiliary building (A/B) in the initial phase but omitting it from consideration in the subsequent phases. The applicant is requested to provide technical basis to justify that the presence of A/B has a negligible SSSI effect on the design basis of standard plant SSCs in these later phases. Otherwise, the applicant is requested to include the A/B in the subsequent phases.

03.07.02-166

In Subsection 3.1 of MUAP-11011 (R0), “SSSI Analyses Methodology,” the first paragraph (Page 5) states, “The main focus of the analyses is to assess the effect of SSSI on the in-structure response spectra (ISRS) used for the design of Seismic Category I and II systems and components located in the West PS/B. For that purpose, the SSSI analyses will use the same dynamic finite element (FE) model of PS/B as that used for generating the seismic responses from the site-independent SSI analyses of the standalone PS/B that serve as the basis for development of the standard plant design input. To develop the combined SSSI model in a manageable size, the lumped

mass stick (LMS) models of the R/B Complex and A/B are coupled through soil with the PS/B dynamic FE model, to represent the global dynamic properties of the adjacent buildings. The development and calibration of LMS models against the dynamic FE models for R/B Complex and A/B to be used for these SSSI analyses are documented in MUAP-11006 (Reference 3) and MUAP-11001 (Reference 4) respectively."

The first sentence in the above quoted sentences states that the ISRS will be used to assess the effect of SSSI; however, in the NRC public meeting for US-APWR DCD Chapter 3 held on 3/31/2011, the applicant acknowledged that LMS models of R/B and CIS have a limited ability to capture high frequency responses. Therefore, the calculated ISRS will potentially miss the high frequency responses and, therefore, are not appropriate to assess the SSSI effect. The applicant is requested to provide technical rationale to show that the effect of SSSI is negligible in the high frequency range. Otherwise, the applicant is requested to explain how the models will be modified to assure that they capture these higher frequencies.

03.07.02-167

In Subsection 3.1 of MUAP-11011(R0), "SSSI Analysis Methodology," the 2nd paragraph (Page 5) states "The analyses of SSSI effects of the PS/B, R/B Complex and A/B use surface-supported foundation models that neglect the effect of foundation embedment. Due to the large coupled ACS SASSI (Reference 6) models involved, neglecting the embedment effect is currently the only viable approach that can be used to study such SSSI effects."

However, the applicant did not address the effects of certain physical plant parameters (i.e., embedment and high water table) explicitly in the proposed approach. The applicant is requested to explain the potential impact of neglecting the effect of these physical parameters on the accuracy of the SSSI effects on the design basis of standard plant SSCs.

03.07.02-168

In Subsection 3.1 of MUAP-11011 (R0), "SSSI Analyses Methodology," the third paragraph (Page 5) states, "The results from the site-independent SSI analyses of the standalone PS/B dynamic FE model with different stiffness and damping levels for these soil cases will be evaluated to determine which structural stiffness level governs the response. The stiffness properties of the PS/B model in the combined SSSI model will be based on the most critical stiffness level determined from this evaluation."

The applicant is requested to provide more detailed information for the study mentioned in the above quoted first sentence. The staff is not able to find this study presented in the report. If the study will be presented in Revision 1, the applicant is requested to clarify this. Also, the applicant is requested discuss the criteria used to select the most critical stiffness level mentioned in the above quoted sentences.

03.07.02-169

In Subsection 3.1 of MUAP-11011 (R0), “SSSI Analyses Methodology,” the third paragraph (Page 5) states, in part, that “reduced (cracked concrete) structural stiffness properties will be used for the SSSI analyses for the softer generic site profiles, and full (uncracked concrete) stiffness properties will be used for the harder generic rock profiles.”

The applicant is requested to provide technical rationale for using cracked concrete structural stiffness for the softer generic site profiles and using uncracked concrete stiffness for harder generic rock profiles. There are eight soil profiles considered in the US-APWR DCD. The applicant is also requested to identify each of the eight soil profiles as to whether it is either the softer generic site profile or the harder generic rock profile, and to provide a rationale for this categorization.

03.07.02-170

In Subsection 3.2 of MUAP-11011 (R0), “Combined Model of PS/B, R/B Complex and A/B,” the second paragraph (Page 6) states, “Figure 3.2-1 presents the configuration of the combined SSSI model to be used for initial-phase SSSI analyses of the PS/B, R/B Complex and A/B. ACS SASSI is used for the time history frequency domain seismic response analyses of the combined model.”

The staff is not able to find any analyses mentioned in this report that uses the model presented in Figure 3.2-1, nor is the staff able to find the ACS SASSI time history frequency domain seismic response analyses mentioned in the second sentence above quoted. The applicant is requested to provide information as to where these analyses are presented.

03.07.02-171

In Subsection 3.3 of MUAP-11011 (R0), “SSSI Analysis Methodology for the US-APWR Standard Plant Design,” the first paragraph (Page 8) states, “The SSSI effects on the Seismic Category I structures that are not part of the US-APWR standard plant design are addressed on a site-specific basis in the Combined License (COL) application.”

The staff is not able to find any COL item listed in Section 3.7.5, “Combined License Information,” of US-APWR DCD (R3) that addresses this statement in the above quoted paragraph. The applicant is requested to add this COL item in US-APWR DCD.

03.07.02-172

In Subsection 3.3 of MUAP-11011 (R0), “SSSI Analysis Methodology for the US-APWR Standard Plant Design,” the third paragraph (Page 8) states, “The two different aspects of SSSI effects investigated are:

1. Effect on Ground Motion at Adjacent Structure Foundations (kinematic SSSI effect) : The influence of the SSI response of a standalone building on the ground motions at the adjacent structure foundations is assessed in the first step, and

2. Coupled Dynamic SSSI effect: A coupled SSSI model, formed as an integral dynamic system, is used to generate coupled seismic responses of adjacent structures, taking into account their mutual interaction through the supporting subgrade. The coupled dynamic SSSI effect combines the kinematic SSSI effect and the inertial SSSI effect."

In Subsection 3.3.1 of MUAP-11011 (R0), "Effect on Ground Motion at Adjacent Building Foundation Locations," the first paragraph (Page 8) states "The first step in assessing SSSI effects is to investigate how the R/B Complex, which is the heaviest building (approximately 870,000 kips) among the US-APWR plant buildings, affects the near-field site response ground motions at the foundation locations of the adjacent standard plant buildings." Further, the second paragraph (Page 8) states, "The dynamic FE model of the standalone R/B Complex includes interaction nodes at the surface of the adjacent ground (near-field) located at 10 feet or more from the foundation of the R/B Complex as shown in Figure 3.3.1-1."

Also in Subsection 3.3.1, the third paragraph (Page 9) states, "The comparisons of the field response ARS results with the ARS for the input motion provide the basis for assessing the kinematic SSSI effects." It further states "The significance of the kinematic SSSI effects for a particular generic site profile is determined based on the following guideline:

> *The effects on ground motion are considered insignificant if the amplifications of the seismic input motion due to SSI response of the standalone building are such that the 5%-damped ARS of the near-field site response motions at the near-field ground surface locations within the footprint of the adjacent structure foundation are not more than 10% higher than the corresponding 5%-damped ARS of the input ground motion for any frequency window of ± 10% centered on the frequency.*"

The applicant is requested to provide information that addresses the following relating to the above quoted paragraphs:

1. The applicant is requested to provide a formal definition of "kinematic SSSI effect" mentioned in item 1 in the first paragraph quoted above and how this information is used in SSSI analyses. Also, the applicant is requested to provide technical details that show how the dynamic SSSI analyses for the combined kinematic SSSI effect and inertia SSSI effect are performed to evaluate the design basis of standard plant SSCs.

2. In Subsection 3.1 of MUAP-11011 (R0), the first paragraph (Page 5) states that "The first priority in assessing the coupled dynamic SSSI effects is to investigate the effect of the heavier A/B and R/B Complex buildings on the seismic response of the nearby West PS/B which has much smaller dimensions and less weight." The beginning of the second paragraph quoted above states "The first step in assessing SSSI effect is to investigate how the R/B Complex …" The staff is confused by these two statements. The applicant is requested to clarify which one of these statements represents the first step in assessing the SSSI effect on the design basis of standard plant SSCs.

3. In Subsection 3.1 of MUAP-11011 (R0), the applicant indicates that the embedment effect is neglected. Therefore, the R/B Complex is modeled as a surface supported structure. The applicant is requested to provide information that shows the elevation where the input motion to the R/B is specified. If it is not specified at the ground surface, the applicant is requested to provide technical rationale for not specifying it at the ground surface. If it is specified at the ground surface, the near-field ground motion should be the same as that of the free-field input motion because the input motion is assumed to be uniform horizontal vertically propagated waves. If the applicant determined that the near-field ground motion is different from the free-field input motion, the applicant is requested to provide technical rationale that explains why, for the surface supported structures, the near-field ground motion is not the same as that of the free-field input motion.

4. The applicant is requested to verify that, indeed, the dynamic FE model of the R/B complex is used in the analysis; since Figure 3.2-1 shows that the lumped-mass stick model is used for the R/B complex.

5. Since the R/B complex is assumed to be a surface supported structure, the surface ground motion is the same as the free-field input motion used for the SSI analyses. The applicant is requested to provide the reason(s) for the study of the surface supported structure presented in Item 3 above.

6. If the input motion is specified at the ground surface and is assumed to be a uniform horizontal motion propagating vertically, then the motions at the ground surface are the same at any two locations. As a result of this, any two corresponding ARS at two locations are the same. The applicant is requested to provide technical basis and supporting data to justify how can two identical ARS provide the basis for assessing the kinematic SSSI effects.

7. Generally, the ‘kinematic interaction’ is associated with determination of the input motion to the rigid, massless foundation (kinematic interaction) subjected to the free field ground motion. The staff considers the calculations of the near-field ground motions and their ARS to be of no value, and should not be carried out since the model described in MUAP-11011 (R0), and the motion considered, has no kinematic interaction. The applicant is requested to provide technical information that shows why the free-field surface ground motion differs from the near-field surface ground motion. Also the applicant is requested to provide technical details that show how the near-field ground motions are used in determining the SSSI effect on the design basis of standard plant SSCs.

03.07.02-173

In Subsection 3.3.1 of MUAP-11011 (R0), “Effect on Ground Motion at Adjacent Building Foundation Locations,” the second paragraph (Page 8) states, “The 5%- damped Amplified Response Spectra (ARS) results at these near-field ground surface interaction nodes, obtained from the site-independent SSI analyses of the eight generic layered soil profiles, are computed and compared with the 5%-damped ARS of the free-field input motion and the 5%-damped US-APWR Certified Seismic Design Response Spectra (CSDRS).”

The results of the above quoted sentence are presented in Figures 3.3.1-3 through 3.3.1-19. There are ten (10) curves mentioned in the above quoted sentence. However, there are only nine (9) curves shown in Figures 3.3.1-3 through 3.3.1-19. The missing one is the 5%-damped ARS of the free-field input motion. The applicant is requested to revise these figures to include the missing curve.

Also, as indicated in these comparisons cited above, the kinematic SSSI effects on the horizontal near-field ground surface site response motions are relatively small at the locations near the centers of the East and West PS/B, A/B, and T/B. However, the effects on the vertical near-field ground surface site response motions are more significant. The applicant is requested to explain why the vertical effects are significant, while the horizontal effects are not significant.

03.07.02-174

In Subsection 3.3.1 of MUAP-11011 (R0), “Effect on Ground Motion at Adjacent Building Foundation Locations,” the fourth paragraph (Page 9) states, “Figure 3.3.1-2 presents a comparison of the 5%-damped ARS of the CSDRS compatible acceleration time histories in two orthogonal horizontal directions (H1 and H2) that are used for the site-independent SSI analyses. The plots show that the differences between the 5%-damped ARS of the two horizontal components can be more than 20%.”

The applicant presents the difference between the 5%-damped ARS of H1 and H2 in Figure 3.3.1-2. The staff considers this information to be of no value since these two horizontal components are statistically independent, per RG 1.208. Hence, the difference between the 5%-damped ARS does not carry any meaningful information. The applicant is requested to provide information that discuss the significance and relevance of the difference between the 5%-damped ARS of two statistically independent horizontal components and how it affects the SSSI analysis of standard plant SSCs.

03.07.02-175

In Subsection 3.3.2 of MUAP-11011 (R0), “Coupled Dynamic SSSI Effect,” the fifth paragraph (Page 29) states, “The results of the ACS SASSI analysis of R/B Complex dynamic FE model resting on a hard rock subgrade are used to illustrate the uncertainty in the calculated structural response that are due to the variations in the frequency content of the input acceleration time histories.”

The applicant is requested to address the following comments concerning this paragraph quoted above:

1. The applicant is requested to verify that, indeed, the dynamic FE model of the R/B complex is used in the analysis, because in the second paragraph of this Subsection (3.3.2), the applicant indicates that the lumped-mass stick model is used for the R/B complex.
2. In the sentence quoted above, the applicant indicates that the results of ACS SASSI analysis of R/B Complex are used to illustrate the uncertainty in the calculated structural response that is due to the variations in the frequency

content of the input acceleration time histories. The staff is not able to comprehend the significance and relevance of this information on the SSSI effect in the design basis of standard plant SSCs and the applicant is requested to clarify this issue.

03.07.02-176

In Subsection 3.3.2 of MUAP-11011 (R0), "Coupled Dynamic SSSI Effect," the fifth paragraph (Page 30) states, "The comparison of the 5%-damped ARS calculated using different acceleration time histories shown in Figures 3.3.2-1a through 3.3.2-1d, indicate that differences in the ISRS resulting from the variations of the frequency content of the input acceleration histories, can be more than 30%. This demonstrates that the selected guideline for assessing the significance of the SSSI effects is well within the uncertainty introduced in the seismic design of standard plant due to the variations in the CSDRS-compatible input ground acceleration histories."

The ARS shown in Figures 3.3.2-1a through 3.3.2-1d are for the fixed base condition. The SSI effect is not included. The staff is not able to comprehend the significance and relevance of the information presented in these figures with the SSSI effect. The differences presented in these figures are meaningless because the motions in the x direction and y direction are statistically independent. The applicant is requested to provide more detailed information that shows how it will use the information presented in Figures 3.3.2-1a through 3.3.2-1d to assess the SSSI effect in the design basis of standard plant SSCs. Also, the applicant is requested to provide a sketch that shows the locations in the structure where ARS (presented in Figures 3.3.2-1a through 3.3.2-1d) are generated.

03.07.02-177

In reviewing this technical report, MUAP-11011(R0), 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-11011(R0), the "Abstract" (Page II) states "The purpose of this report is to investigate the seismic response of the structure-soil-structure interaction (SSSI) effects among the US-APWR standard plant structures."

The applicant is requested to further clarify the purpose of these SSSI analyses by enumerating the expected specific physical and/or analytical effects and potential impact of any significant structure-soil-structure interaction on the seismic response of any of the standard plant structures. This information should describe both the types of physical impact that SSSI can have on the plant structures, and on the possible modifications of the seismic demands placed on each of these structures which may occur because of the SSSI.

2. In MUAP-11011(R0), "List of Acronyms" (Page VI), ARS is defined as "Amplified Response Spectra." In other technical reports (and the DCD) ARS is defined specifically as the "Acceleration Response Spectra."

The applicant is requested to choose a single consistent definition to avoid confusion.

3. In MUAP-11011 (R0), Section 1, “INTRODUCTION” (page 1) the first paragraph states “The focus of the initial phase of the investigation is on the seismic SSSI effects among the smallest and lightest US-APWR West Power Source Building (PS/B), the heaviest Reactor Building (R/B) Complex, and their adjacent Auxiliary Building (A/B). From the analyses results and assessment conclusions obtained from this initial investigation, the need for further investigations of the SSSI effects among the West and East PS/B, R/B Complex, A/B, and Turbine Building (T/B) will be determined and further SSSI analyses and result assessments will be made in subsequent phases, as required. The proposed analysis steps, in phases for assessment of SSSI effects on the US-APWR standard plant structures are outlined in Table 1.0-1.”

The staff noticed that the initial investigation mentioned in the sentences above quoted is actually the “Analysis Step No. 2” in Table 1.0-1. The very first analysis listed in Table 1.0-1 involves only R/B and A/B. The applicant is requested to clarify this inconsistency.

4. In Section 2.0 of MUAP-11011 (R0), “Description of the US-APWR Standard Plant Layout,” the second paragraph (Page 3) states, “From the SSSI effects perspective, it is anticipated that the seismic response of the larger and heavier structure will have a more significant effect on the seismic response than that of the smaller and lighter adjacent structures.”

The staff finds the above quoted sentence confusing and its meaning unclear. The applicant is requested to revise this sentence to make the meaning clear.

5. In MUAP-11011(R0), Figure 2.0-1 (Page 3) shows the overall US-APWR standard plant layout (with North not defined). Later in the report, in Figure 3.3.1-1, the plant layout is the reverse of what is shown here, and the North direction is indicated. The applicant is requested to correct one or the other of these figures to make them consistent to avoid any possible confusion.

6. In Subsection 3.1 of MUAP-11011 (R0), “SSSI Analyses Methodology,” the second paragraph (Page 5) states, “Due to the large coupled ACS SASSI (Reference 6) models involved, neglecting the embedment effect is currently the only viable approach that can be used to study such SSSI effects.”

The applicant is requested to address whether or not the feasibility of including the embedment effect was considered in the SSSI study for a combined model of R/B and PS/B with both structures modeled by lumped mass stick models.

7. In Subsection 3.3.2 of MUAP-11011 (R0), “Coupled Dynamic SSSI Effect,” the sixth paragraph (Page 30) states, “The results of the assessment of kinematic and dynamic SSSI effects described in this report are used as the basis to identify the critical generic site profile cases for which the SSSI effects is significant. The responses of PS/B obtained from the SSSI analyses of the identified critical site profile cases are enveloped with those of the SSI analyses of the standalone PS/B model.”

   Further, in Subsection 3.3.2 of MUAP-11011 (R0), the last paragraph (Page 30) states, “The findings of this initial study serve as a basis to determine whether

additional assessments of SSSI effects are necessary between the R/B Complex and A/B, between T/B and PS/B, and between R/B Complex and T/B, in accordance with the phased approach as indicated in Table 1.0-1."

The staff is not able to identify the results of the dynamic SSSI effects described in this report, nor has the staff been able to locate the "…findings of this initial study…" (as in the second paragraph quoted above) in this report. The applicant is requested to provide section numbers in the current report where these results are presented. If the results are to be presented in Revision 1 of the Report, the applicant is requested to clarify this.