REQUEST FOR ADDITIONAL INFORMATION 854-6088 REVISION 3

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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)

03.07.02-151

During the staff's review of MUAP-11007(R0), the staff identified several items in need of clarification. The applicant is requested to provide clarification to the following items:

(a) The title of MUAP-11007 (R0) "Results of Evaluation Using LMSM for R/B Complex" is misleading on a number of levels. The staff notes that Revision 0 of the report does not include any analysis results, but only presents the methodology to be followed. It is stated that the results, when available, will be incorporated in a subsequent Revision 1. In addition, the report not only discusses the analysis of the R/B complex, but also analyses of the PS/B and the Aux Bldg. Finally, the report not only discusses the LMSM but also the design-basis dynamic FE model that will be used for the ground water table elevation evaluation of the R/B complex as stated in section 3.4.2. The applicant is requested to consider using a more appropriate title for this report to avoid confusion.

(b) The applicant did not state clearly whether the evaluation results of the embedment and ground water table elevation effects will become part of the design basis, and will be included in the design envelope, or whether these analyses are intended solely to justify prior assumptions of neglecting these effects. The staff considers these effects to be part of the design basis and therefore these effects should be included in the design envelope unless it is demonstrated that the effects are negligible and do not provide additional contribution to and are bounded by the design envelope. The applicant is requested to clarify how the embedment and ground water table elevation effects will be considered in the design basis of standard plant SSCs.

(c) In the second to last sentence of Subsection 1.3 of MUAP-11007 (R0), it is stated that the SSE ground motion is applied in the three orthogonal directions simultaneously. However, in the last sentence of Subsection 3.1, it is stated that the three components of the earthquake are applied to the models separately. Per Subsection 4.3.2, the staff understands that the sliding and overturning stability calculations are to be performed using ACS SASSI, which is inconsistent with the statement that the ground motion components are applied simultaneously. The applicant is requested to explain clearly how the SSE ground motion is applied in the three orthogonal directions for each of the studies reported in MUAP -11007 (R0).

(d) There appears to be a number of instances where the information provided in MUAP-11007 (R0) is inconsistent with the information provided in MUAP-10001(R3) "Seismic Design Bases of the US-APWR Standard Plant." In several RAIs, the staff has requested

the applicant to address specific inconsistencies. To assist the staff's review, the applicant is requested to identify any additional instances, not highlighted by the staff, where the methodology and analysis assumptions described in MUAP-11007(R0) deviate from those in MUAP-10001(R3).

(e) In Section 3.2 "Site Conditions," it is stated that "the modeled soil half space is represented vertically by 10 viscoelastic layers to simulate the dynamic properties of the subgrade layers that are located 650 feet and 250 feet below the foundation elevations for the R/B and PS/B, respectively." The applicant is requested to clarify its use of the term "viscoelastic" in describing the soil layers. The staff understands that SASSI is a linear elastic analysis code, and is not capable of modeling time-dependent creep and stress relaxation.

(f) In Section 4.2.2, "Development of the Unsaturated Soil Profiles," it is stated that below groundwater table elevation, the P-wave velocity of the saturated soil is set to be equal to or greater than the 5,000 fps. The Poisson ratio of the softer strata of saturated soil is approaching values close to 0.5. If the S-wave velocity of the soil is determined by P-wave velocity and Poisson ratio, then the calculated S-wave velocity may not be realistic because (a) the S-wave velocity will not change much after the soil is saturated and (b) the assumed Poisson ratio value of close to 0.5 cannot give realistic S-wave velocity values. The applicant is requested to clarify how the S-wave velocity profile is determined, and the technical basis for the approach.

(g) In Section 4.3.1, "Design Basis," an URS report (reference 7.8) is cited as providing the design basis for sliding and overturning stability. The design basis should reference criteria in the DCD, not in a contractor document. Alternatively, the URS report could be converted into a technical report and incorporated by reference into the DCD. The applicant is requested to clarify the design basis for sliding and overturning stability.

03.07.02-152

Section 3.1 of MUAP 11007(R0) indicates that the finite element meshes for the various buildings and sites are defined to provide adequate frequency transmission capability in the SSI calculations. In addition, the DC/COL-ISG-01, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," guidelines indicate that the meshes used should have a minimum transmission frequency of 50 Hz. Specific finite element meshes are shown for the various buildings in the plots provided on pages 9-6 and 9-7. However, the frequency transmission capability of the building meshes embedded in the various profiles defined for the SSI calculations is not provided. Section 3.1 only indicates that the embedded system is checked to ensure that the mesh used will capture the critical frequency of response. For complicated problems with high frequency modes, specific cutoff frequencies for each building and each profile need to be identified, in conformance the DC/COL-ISG-01.

MUAP-10001(R3), Tables 4.3.1.2-1 and 4.4.1-2 provide the wave passage frequencies for the basemat FE mesh for the R/B Complex and PS/B respectively. The applicant is requested to confirm that the values included in MUAP-10001(R3), Tables 4.3.1.2-1 and 4.4.1-2 for the R/B complex and PS/B dynamic models, respectively, are valid for the

MUAP-11007(R0) analyses. Also, provide the same information for the LMSMs of the R/B complex and the Aux Bldg.

03.07.02-153

(a) Section 3.1 in MUAP 11007 (R0) indicates that the seismic input ground motions are input at the elevation of the bottom of the foundation, presumably as in-column motions. Section 3.3 indicates that these motions are obtained from MUAP-10001(R3) and are the enveloping motions compatible with the CSDRS. In MUAP-10001(R3), however, the definition of the CSDRS at the bottom of foundation or at the ground surface or plant grade is equivalent because surface-mounted conditions are assumed. This is not the case for the MUAP-11007(R0) analyses because embedded conditions are assumed. Therefore, the applicant is requested to confirm consistency between the assumption in MUAP-11007(R0) and the assumption used in the MUAP-10001(R3) SSI analyses.

(b) Section 4.1.3 in MUAP 11007 (R0) indicates that the input motions will be developed using both the BNL and NEI methods outlined in DC/COL-ISG-017. In Section 4.1.3, the development of these in-column motions are based on probabilistic site response evaluations, using multiple realizations of the site profiles. These approaches are not compatible with the deterministic SSI evaluations used in SSI analyses, where only a single profile for a given generic site is defined. Therefore, the applicant is requested to clearly define the input motions used in the MUAP-11007(R0) calculations.

03.07.02-154

Section 3.2 in MUAP 11007 (R0) states that in MUAP-10001(R3), “the profiles are compatible with the strains generated by the input ground motion and are also representative of the effects of geological, geotechnical, and hydrological site parameters for representative nuclear power plant sites.” In fact, the strains computed in MUAP-10001(R3) are not compatible with the CSDRS surface response, but at best can only be considered approximations associated with those profiles. Of more importance, however, it is not clear that the strain-iterated velocities in MUAP-10001 (R3) are in any way related to the eight generic velocity profiles used in MUAP-11007 (R0).
The eight generic site profiles described in MUAP-11007(R0) are not obviously consistent with the velocity profiles described in MUAP-10001(R3), Figures 4.2-1 and 5.2-1, where profiles of variable velocity with depth are shown.

Therefore, the applicant is requested to provide the following information:

(a) Clarify the relation between the eight generic shear wave velocity profiles used in MUAP 11007 (R0) and the strain-iterated shear wave velocities in MUAP 10001(R3). Explain whether the profiles described in MUAP-11007(R0) are consistent with the profiles described in MUAP-10001(R3). If they are not consistent, explain the basis for any differences, and how conclusions relevant to the MUAP-10001(R3) profiles are reached using the MUAP-11007(R0) profiles.

(b) Provide complete definitions of the velocity profiles (Vs and Vp as a function of depth) for the eight generic profiles described in MUAP-11007(R0).

03.07.02-155

The lumped mass stick model (LMSM) shown in MUAP 11007 (R0), Fig. 3.4.1-1, appears to indicate that all sticks representing the R/B complex superstructure (R/B, PCCV, CIS) connect into one plan location on the basemat. The applicant is requested to confirm this, and explain how such a model can account for any bending effects of the basemat on the walls and diaphragms of the superstructure, and how it can be used to justify the design of the standard plant SSCs or to develop bounding estimates of ISRS that includes the effect of embedment. The staff notes that coupling of the superstructure with the basemat cannot be accommodated in these analyses.

03.07.02-156

Section 3.4.1 in MUAP 11007 (R0) states that “The LMSM will be employed for the embedment evaluation and the sliding and overturning stability evaluation.” Section 3.4.2 indicates that the dynamic FE model of the R/B complex will be used in the water table evaluations. According to MUAP-10001(R3), the dynamic FE model is the design-basis RB complex model for SSI analysis. The applicant is requested to explain why the LMSM (and not the dynamic FE model) will be used for the embedment evaluation and the sliding and overturning stability evaluation.

03.07.02-157

Section 4.1.1 in MUAP 11007 (R0) indicates that neglecting the effect of embedment will lead to conservative response calculations. However, in the paragraphs following, it is stated that the assumptions associated with neglecting embedment cause potential SSI frequency shifts, modify effective motion input to the structural models, and can be expected to result in variations in computed transfer functions. In addition, none of the eight profiles considered for SSI include velocity inversions in the profile (i.e., a stiff layer with relatively high shear wave velocity overlaying a softer soil layer with lower shear wave velocity). Also, the last paragraph of Section 4.1.2 indicates that the responses at the extreme outer corners of the basemat are different from the general response. The applicant is requested to explain whether the embedment evaluation is intended to provide additional results to be included in the design-basis envelope, or is only intended to justify that neglecting the effects of embedment is conservative. If the latter is the case, the applicant needs to provide substantive comparisons of results (e.g., at multiple locations of peak structural demands and ISRS) that support this contention.

03.07.02-158

Table 4.1.3-1 in MUAP 11007 (R0) indicates that the cracked concrete models will be used for soft site conditions, and uncracked concrete models will be used for stiff site conditions. The report does not indicate the basis for this approach. The applicant is requested to provide the technical basis for this approach and to discuss if the demands on concrete been evaluated for each site condition to see if cracking will occur.

03.07.02-159

The last paragraph of Section 4.1.3 in MUAP 11007 (R0) indicates that backfill properties used for the SSI analyses will be taken from the Comanche Peak COL application. However, the applicant did not indicate where such backfill will be used in the SSI response analysis. In addition, it is stated that strain-dependent degradation curves will be used to determine the strain compatible properties for the backfill. However, it is not clear how such applications will be made since these site response calculations are deterministic with an undetermined seismic environment. If deconvolution of the CSDRS is used, for example, to obtain in-column response with equivalent linear 1D site response methods, this process does not satisfy recommendations in SRP Section 3.7.2. The Applicant is requested to clearly explain (a) what parameters from the Comanche Peak backfill (i.e., soil material properties) will be used and (2) why it is appropriate to use the Comanche Peak backfill properties in the embedment evaluation of the SSI response of standard plant structures.

03.07.02-160

Section 4.2.1 in MUAP 11007 (R0) addresses the effects of water table elevation raised in RAI 660-5134 Question No. 03.07.02-60 and refers to the RAI response as the. "previous RAI evaluation." Section 4.2.1 in MUAP 11007 (R0) states that “In the updated evaluation presented in this report, the generic unsaturated soil profiles used in the previous RAI evaluation are revised in order to more realistically represent the porosity characteristics of typical soil materials represented by the generic profiles 270-200 and 560-100.” However, porosity is not a property incorporated into the SSI or site response calculations and is not relevant in the context of this description of SSI. Therefore, the applicant is requested to explain the relevance of this statement or delete it from the report.

03.07.02-161

Section 4.2.2 in MUAP 11007 (R0) indicates that Poisson’s ratio values close to 0.5 will be used without stating what limiting value will be used. Of more importance is the fact that the effective values of Poisson’s ratio used in the site response calculations (especially for soft sites) of MUAP-10001(R3) are not related to values from data for real soil, since the P-wave velocities are obtained from low strain shear moduli, while S-wave velocities are obtained from high or iterated strain values. The approach in MUAP-10001(R3) appears to be incompatible with the discussion in this section of MUAP-11007(R0). Section 4.2.2.1 indicates that P-wave velocities for the unsaturated cases will be selected at 20% to 30% of the saturated velocities. The applicant is requested to provide the basis for these assumptions, which should be correlated with the results in MUAP-10001(R3).

03.07.02-162

The staff requests that the content and purpose of Section 4.2.3 of MUAP-11007 (R0) be clarified. The staff does not understand the relevance of this information to the performance of a parametric study of the effect of groundwater level on the SSI response. Specific concerns about this information are:

- Section 4.2.3 generally overstates the appropriateness of the process used to treat saturation in analyses where only one-phase constitutive approximations are used. For example, using a P-wave velocity of 5,000 fps for the soil matrix and water two-phase material is a serious approximation considering that most ground water contains entrapped air, especially near the top of the ground water table and in the perched zones above which seriously degrades the P-wave velocity. The staff considers most of this discussion to be inappropriate and the process does not follow procedures used for SSI analyses. The assumption that water movement is in fact independent of movement of the soil skeleton at the frequencies of interest to the SSI problem is a not a commonly held viewpoint in the SSI community.
- In Section 4.2.3 (2), it is stated that "Reference 7.19 concluded that the ACS SASSI assumption provides a reasonable representation for the real part of the impedance, for values of the dimensionless frequency of foundation vibration (a_0) up to approximately three (3)." It then states that $a_0 = 3.0$ is consistent with a frequency of 8.1 Hz for R/B Complex foundation, and this frequency is much higher than the natural frequencies of R/B Complex structures as well as its SSI frequency for 270-200 soil profile. However, the staff notes that the applicant did not clarify what ACS-SASSI assumption is justified by Reference 7.19. This reference was published in 1999, long before the existence of ACS-SASSI. Also, in the calculation of a_0, the S-wave velocity of soil directly beneath the foundation should be used, not the value 200 ft below the foundation. Therefore, the calculated frequency of 8.1 Hz for R/B Complex foundation is questionable, and the actual frequency may not be higher than the fundamental frequency of R/B Complex structure and the SSI system frequency. The applicant is requested to provide the technical basis for calculated frequency of 8.1 Hz for R/B Complex foundation.
- In Section 4.2.3 (2), it is stated that "The comparison of the impedance functions indicates that the equivalent dry soil assumption is valid in the low frequency range." It is the staff understanding that the low frequency range is estimated to be frequencies up to 8.1 Hz. This implies that the equivalent dry soil assumption is not valid for frequencies higher than 8.1 Hz. In view of this frequency limitation, the applicant is requested to justify the validity of the ground water table elevation sensitivity studies.

03.07.02-163

Section 4.2.5 in MUAP 11007 (R0) indicates that locations for comparison of ISRS will be selected, but does not identify the locations or the basis for their selection. The staff expects the applicant to select the locations based on their importance to the design. Therefore, the applicant is requested to identify locations that are significant for determining peak structural demands (moments and shears) and ISRS.