US-APWRRAIsPEm Resource

From: Ciocco, Jeff
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To: us-apwr-rai@mhi.co.jp; US-APWRRAIsPEm Resource
Cc: Jain, Bhagwat; Shams, Mohamed; Galvin, Dennis; Snyder, Amy; Hamzehee, Hossein
Subject: US-APWR Design Certification Application RAI 960-6709 (3.7.2)
Attachments: US-APWR DC RAI 960 SEB1 6709.pdf

MHI,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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United States Nuclear Regulatory Commission
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REQUEST FOR ADDITIONAL INFORMATION 960-6709

Issue Date: 9/24/2012

Application Title: US-APWR Design Certification - Docket Number 52-021

Operating Company: Mitsubishi Heavy Industries

Docket No. 52-021

Review Section: 03.07.02 - Seismic System Analysis
Application Section: DCD R3

QUESTIONS

03.07.02-212

The staff notes that Section 1.0 of MHI TR MUAP-12002 (R0), "Sliding Evaluation and Results," discusses structural gaps between buildings, but provides no details. To assist the staff in its evaluation of the sliding stability methodology, the staff requests the applicant to provide the following additional information related to structural gaps:

a) In order to judge the adequacy of the gaps, to document which structures are adjacent to each other, and to document the structures that share a common basemat, the applicant is requested to provide a figure that shows those information. The figure should include all of the Seismic Category I structures and non-Seismic Category I structures at the plant site, the boundary of the separate concrete basemats, and the magnitude of the gaps between adjacent basemats (below grade and above). The structures should include those within the MHI US-APWR design certification and those that are within the COL application scope.

b) Explain how the adequacy of gaps between the adjacent structures will be determined in view of the magnitude of sliding that may occur.

c) Describe how the seismic building response is combined with the potential sliding displacement, and how the total response of the two adjacent structures is compared (assuming out of phase motion) to ensure sufficient gaps exist with some factor of safety.

03.07.02-213

SRP Sections 3.8.4 I.10 and 3.8.4 III.9 indicate that COL Action Items should be identified in the Design Certification (DC) application and reviewed by the staff. The staff notes that MHI TR MUAP-12002 (R0), "Sliding Evaluation and Results," only discusses the sliding evaluation for the Reactor Building (R/B) Complex and the Turbine Building (T/B). The COL Applicant is responsible for several Seismic Category I structures (e.g., Essential Service Water Pipe Tunnel (ESWPT), Ultimate Heat Sink Related Structures (UHSRS), and Power Source Fuel Storage Vaults (PSFSVs)) and adjacent Non-Seismic Category I structures. The applicant is requested to identify the COL Action Item that describes the evaluation and acceptance criteria for the sliding stability of these other Seismic Category I structures.

03.07.02-214

The acceptance criteria in SRP Section 3.8.4 II.4, states that cracking of concrete needs to be considered in the design and analysis of structures. The staff notes that Section 2.0 of MHI TR MUAP-12002 (R0), "Sliding Evaluation and Results," indicates that both cracked and uncracked concrete properties are considered for the Reactor Building (R/B) Complex, while only cracked concrete properties are considered for the Turbine Building (T/B) structures. The staff requests the applicant to provide the technical basis and justification for not considering uncracked concrete properties for the T/B structures.

03.07.02-215

Section 3.0 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," states that one of the objectives of this report is to, "Demonstrate acceptable seismic sliding of the Reactor Building (R/B) Complex and the Turbine Building (T/B) structures." It also states that possible sliding will be calculated during the safe-shutdown earthquake (SSE) using nonlinear time history analyses which will demonstrate that the amount of sliding, if any, is too small to cause any physical damage to the R/B Complex and T/B structures or to the structural connections. Currently, the criterion in SRP 3.8.5 indicates that there should be a factor of safety of 1.1 against sliding, rather than an evaluation of the effects of sliding on physical damage to structures and structural connections. The guidance in the SRP is intended to show that there is no sliding, including the consideration of the factor of safety. Therefore, the applicant is requested to provide the technical basis and justification for allowing some small displacement. The staff notes that the report does not include acceptance criteria for sliding. The staff requests the applicant to define the acceptance criteria it will use to evaluate sliding, and to provide the technical basis and justification for the acceptance criteria.

03.07.02-216

Section 4.0 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," describes the methodology utilized to perform the sliding stability analyses. To assist the staff in evaluating whether the assumptions and modeling approach are consistent with the guidance in SRP Section 3.8.5; and can predict the magnitude of the sliding response, the staff requests the applicant to provide the following additional information:

a) In Section 4.1, "Assumptions," under Assumption number 1, the applicant stated that sliding is assumed to occur in some cases under safe-shutdown earthquake (SSE) but did not identify those cases. The applicant is requested to identify those cases and provide the basis for the assumption.

b) In Section 4.1, under Assumption number 2, the applicant indicated that it is assumed that a small amount of sliding will not modify the ground motion in the vicinity of the basemat. The applicant is requested to provide a quantitative measure of "small amount of sliding." The applicant also stated that, "this assumption is the accepted industry practice for such analyses." The applicant is requested to provide appropriate basis and references to demonstrate the industry practice for such analyses and that it has been accepted by the staff.

c) Regarding the use of the time histories from the SASSI soil-structure interaction (SSI) analyses and applying them in all three directions, the applicant is requested to provide a technical basis and justification for neglecting the rocking motions in relation to the two horizontal axes.

d) Since the soil ground motions from the SASSI SSI analysis is proposed to be used in the lumped-mass stick model (LMSM) sliding stability analysis, the dynamic characteristics between these two models should be consistent or conservative in the LMSM approach. Therefore, the applicant is requested to explain whether the ground motions from the SASSI SSI analyses to be used as input to the LMSM analyses will be based on the embedment case with no connection between the building side wall foundation and the vertical edge of the side soil or based on the connected case. In addition, the applicant is requested to confirm that the two model dynamic characteristics (SASSI and LMSM) are equivalent or that the more

conservative ground motion (side soil/wall connection vs. no side soil/wall connection) will be used.
e) Based on the description presented in Sections 4.2.3 and 4.3 of the TR, the subgrade is modeled as a rigid surface and the basemat is modeled as a rigid surface. Contact elements are used between these two surfaces. The applicant is requested to discuss how the effect of dead weight is included in the nonlinear analysis to consider the potential uplift of the basemat; and to provide a technical basis and justification for the sliding stability model and the analysis results.
f) Assumption 4 in the TR indicates that embedment effects (active and passive pressures) are neglected during sliding. The applicant is requested to explain how the effects of surcharge loads due to adjacent structures will be considered in the sliding stability analyses.
g) The applicant in Assumption 5 stated that the maximum ground water level is considered for the sliding analysis. The applicant is requested to justify this assumption and demonstrate that the maximum ground water level case is conservative and will result in the minimum factor of safety (i.e., maximum seismic sliding force and minimum resistance).
h) Assumption 6 in the TR indicates that, “Dynamic soil pressures acting on basement walls before the initiation of sliding are assumed to be compensated by the difference between static and kinetic friction forces acting at the basemat level.” Section 4.2.4 of the TR also discusses this item; however, it is not clearly explained. Therefore, the applicant is requested to describe this behavior, explain how the effects of these pressures are considered to be compensated by the difference between static and kinetic friction forces, and describe how this assumption is conservative and will be demonstrated, as stated in Section 4.2.4 of the TR.

03.07.02-217

Section 4.2.1 of MHI’s TR MUAP-12002 (R0), "Sliding Evaluation and Results," describes the selection of the static and kinetic (sliding) coefficients of friction. To assist the staff in evaluating whether appropriate static and kinetic coefficient of friction values are utilized in accordance with the guidance in SRP Section 3.8.5, the staff requests the applicant to provide the following additional information:
a) Section 4.2.1 of the TR states, “The governing friction occurs between the mud mat and the underlying granular soil where a thin soil layer exists that is interlocked with the bottom of the mud mat.” The applicant is requested to provide the technical basis and justification for the conclusion that the sliding interface would not be at the concrete to soil interface.
b) The TR indicates that any fine grain materials within a few feet below the basemat will be replaced by engineered fill. Engineered fill will be specified in the DCD as a well drained granular backfill with a minimum friction angle of $\Phi = 35°$. The applicant states that the minimum angle of internal friction will be specified in DCD Table 2.0-1 as a site requirement. The staff notes that, regardless whether materials below the basemat are replaced by engineered fill, the DCD needs to specify the minimum angle of internal friction. Therefore, the applicant is requested to confirm that the minimum angle of internal friction for the in-situ soil, and any engineered fill, will be specified in DCD Tier 2, Section 2; and that in-situ soil will also be specified in DCD Tier 1.
c) Another potential sliding interface is at the location of any waterproofing material (e.g., waterproofing material between the mud mat and soil or between the basemat and mud mat). Therefore, the applicant is requested to explain where waterproofing material is used; the type of waterproofing material; the coefficient of friction of the waterproofing material with respect to the adjacent material; and the basis for the coefficient of friction.
d) The TR indicates that the cold joint at the mud mat to bottom of foundation contact will be “raked” with a very rough surface (minimum amplitude greater than ¼ inch - as recommended

in the Commentary to ACI 349-06 to maintain a minimum friction coefficient of 0.7. The applicant is requested to include this commitment in the DCD.
e) The kinetic coefficient of friction used for the sliding stability analysis is given as 0.5 for all subgrades. The value of the kinetic coefficient of friction is based on laboratory soil tests with samples from seven different types of sands. The applicant is requested to confirm that the kinetic coefficient of friction used for the design basis sliding stability analysis bounds the types of soils and soil properties/conditions considered for the US-APWR standard design.
f) Reference 13 in the TR could not be located. To complete its review, the staff requests the applicant to submit a copy of Reference 13: “Constant Volume Cyclic Simple Shear Testing, Proceedings of the 2nd International Conference on Microzonation, San Francisco, CA, Finn, W.D.L., Laid, Y.P. and Bhatia, S.K., pg 839-851, 1978

03.07.02-218

Section 4.2.2 of MHI’s TR MUAP-12002 (R0), "Sliding Evaluation and Results," indicates that Rayleigh damping, using the alpha-d and beta-d coefficients that multiply the mass matrix and the stiffness matrix, respectively will be used in the ANSYS analysis. Since the alpha and beta coefficients are frequency dependent, the TR indicates that the relevant frequencies for sliding analysis will have a range between the lowest fundamental frequency in the horizontal direction and the fundamental frequency in the vertical direction. This statement is not clear. Since the damping coefficients should correspond to the lowest and highest frequency range of interest, the applicant is requested to explain why the damping coefficients are not determined based on the range corresponding to the lowest fundamental frequency from all three directions and the highest frequency that contributes to sliding demand forces. The applicant is also requested to identify the lowest and highest frequency of interest including the quantitative values with adequate justification and a plot of the resulting total damping as function of frequency.

03.07.02-219

Section 4.2.3 of MHI’s TR MUAP-12002 (R0), "Sliding Evaluation and Results," indicates that five sets of acceleration time histories will be used in the nonlinear sliding analyses for each of the six soil profiles, and these will be performed for the cracked and uncracked condition of the concrete members. The criteria in SRP Section 3.7.1.II.1.B Option 2 (for multiple sets of time histories) indicates that for nonlinear structural analyses, the number of time histories must be greater than four and the technical basis for the appropriate number of time histories are reviewed on a case-by-case basis. This review also includes the adequacy of the characteristics of the multiple time histories.
Therefore, the staff requests the applicant to (i) provide the technical basis for selection of 5 time histories, (ii) discuss whether the results from the use of the 5 time histories will be enveloped in the sliding evaluation, (iii) describe the approach used to develop the 5 sets of synthetic time histories, and provide the technical basis and the justification if different from the approach used in developing synthetic time histories for the design-basis seismic soil-structure interaction (SSI) analyses, (iv) confirm that the 5 time histories are based on real recorded ground motions, and (v) discuss whether the approach follows the guidance in SRP 3.7.1II.1.B, and identify any departures from that guidance.

03.07.02-220

Sections 4.3 and 4.4 of MHI’s TR MUAP-12002 (R0), "Sliding Evaluation and Results," describe the development of the finite element models and the lumped-mass stick model (LMSM). To assist the staff in evaluating whether the LMSM is equivalent to the more detailed finite element model, the staff requests the applicant to provide the following additional information:

a) Section 4.3.1 of the TR states, "There are two FE models for the R/B Complex considered: one detailed FE model which is used to validate the dynamic model; and one dynamic FE model, which is used for dynamic analyses in ANSYS, and these two models have correlation with each other. The dynamic FE model is the basis for correlation with the LMSM. Contact (or sliding) elements and a rigid basemat are added to the dynamic FE model for nonlinear sliding analyses. The dynamic FE model customized for sliding analyses is referred to herein as the FEM."

From this information, it appears to the staff that there are three models – 2 finite element models (FEMs) and 1 LMSM. The applicant is requested to provide a clear description (with figures, modal frequencies, and corresponding modal participation factors for the two horizontal and one vertical motions) of all the three models referred to in the above quoted paragraph, and clearly indicate the differences between them.

b) In addition, the applicant is requested to provide information which demonstrates that the LMSM is equivalent to the design basis seismic SSI model. This should include similar model information as described in Item a) above.

c) Section 4.2.1 of the TR appears to indicate that a static friction coefficient (μs) of 0.7 will be used and a kinetic friction coefficient of (μk) equal to 0.5 will be used. However, Section 4.5 of the TR indicates that one of the conclusions for the methodology is: "Use of the kinetic friction coefficient under static conditions (before initiation of sliding)." From the above, it is not clear which coefficient of friction values are used in the analyses. Therefore, the applicant is requested to clarify and provide a technical basis and justification whether both the static and kinetic coefficient of friction values will be used or if only the kinetic coefficient of friction will be used.

d) The applicant is requested to describe the specific ANSYS friction element type that will be used and define the quantitative values for the various parameters for this element.

e) To verify that the development of the LMSM is appropriately based on the first modes in the horizontal directions and the development of an equivalent fundamental frequency in the vertical direction from the FEM, the staff requests that the applicant provide a table showing the results of the modal analysis for the finite element model. The table should include for each mode the frequency, direction, effective mass, and percentage effective mass (of the total). The selection of the modes for matching in the LMSM should be shown to capture sufficient effective mass when compared to the total mass.

f) To confirm that the final (calibrated and fine-tuned) LMSMs for the Reactor Building (R/B) and Turbine Building (T/B) are adequate, the staff requests that the applicant provide a comparison of overall seismic demands predicted by the LMSMs and the detailed finite element models. The comparison should include the two shear forces, vertical (axial) force, and the two over-all bending moments at the base of the models, for a fixed base case with flat response spectral input.

g) To assist the staff in evaluating whether the base shear force from the LMSM for each of the 5 input motions is equivalent to the more detailed finite element model, the staff requests that the applicant compare the maximum forces at the base of the LMSMs with those from the SASSI soil-structure interaction (SSI) analyses used to develop each of the 5 input motions for the sliding stability analyses. In this study, sliding and lift off needs to be prevented in the LMSM analyses, for comparison to the SASSI results.

03.07.02-221

Section 4.5 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," indicates that, based on the conservative sliding stability analyses, it is appropriate to use a factor of safety (FOS) of 2 times the calculated maximum sliding for the design of umbilicals. The TR references ASCE 43-05 for the FOS of 2 to 3 applied to sliding analyses. However, ASCE 43-05 indicates that a FOS of 3.0 be used for sliding and a FOS of 2.0 for rocking when using median-centered analysis techniques to predict "best-estimate" values. The staff notes that the applicant has not adopted the FOS of 3.0 for the sliding as recommended in ASCE 43-05. Thus, the applicant is requested to provide a technical basis and justification for not considering a FOS of 3.0 for calculating the maximum sliding for the design of umbilicals, and discuss how the inherent uncertainties in the nonlinear analysis have been accounted for. Also, the FOS should not be limited to just design of umbilicals, but should include the design of all aspects related to interaction between adjacent structures and components (e.g., structural gaps, structural connections such as buried tunnels, buried commodities). In addition, the applicant is requested to discuss the FOS that will be considered in such cases.

03.07.02-222

In section 4.5.1 of MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," the applicant committed to perform a sensitivity analysis for four parameters but did not discuss how the results of the sensitivity analysis will be implemented in the design and analysis for seismic stability. Thus, the applicant is requested to provide such details and criteria for implementing the results of the sensitivity analysis in the design and analysis.

03.07.02-223

MHI's TR MUAP-12002 (R0), "Sliding Evaluation and Results," did not provide the load combination that will be used in the sliding stability analysis. Therefore, the applicant is requested to identify and describe what loads will be included along with the seismic load. Also, because this is a nonlinear analysis, where superposition cannot be used, describe at what point in the analysis the loads will be applied and describe how they will be applied. If there are any deviations from the load combination identified in the acceptance criteria of SRP 3.8.5 for sliding stability analysis, provide the technical basis and justification.

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