**REQUEST FOR ADDITIONAL INFORMATION 498-3782 REVISION 0**

12/1/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
Application Section: 3.9.2

QUESTIONS for Engineering Mechanics Branch 1 (AP1000/EPR Projects) (EMB1)

03.09.02-59

The staff reviewed the response to RAI 3.9.2-10 (#205-1584, dated 4/30/2009, ML091240113, MHI Ref: UAP-HF-09184) and noted that the equivalent static load method of analysis is the preferred method for use in seismic analysis of subsystems such as equipment and piping anchorages. The staff also notes that SRP Section 3.9.2, Revision 3, SRP Acceptance Criteria 2.A.(ii) states, "An equivalent static load method is acceptable if: (1) There is a justification that the system can be realistically represented by a simple model and the method produces conservative results in responses. ... (2) The design and simplified analysis account for the relative motion between all points of supports. (3) To obtain an equivalent static load of equipment or components which can be represented by a simple model, a factor of 1.5 is applied to the peak acceleration of the applicable floor response spectrum. A factor of less than 1.5 may be used with adequate justification." The applicant did not provide detailed technical information to demonstrate how these three criteria were being satisfied.

The applicant is requested to provide detailed technical information to demonstrate how the three SRP Section 3.9.2, SRP Acceptance Criteria 2.A.(ii) are satisfied. In accordance with the MHI commitment in the response to Question 3.9.2-10, include in a future DCD Revision a list which would summarize the method for determining the stiffness, the related assumptions, and the procedure for verification of the assumptions for all of the anchorage types considered for use on the US-APWR. A copy of the list should be provided, and the DCD revision which will contain this list should be identified, in your response.

03.09.02-60

In its review of the MHI response to RAI 3.9.2-12 (#205-1584, dated 4/30/2009, ML091240113, MHI Ref: UAP-HF-09184) the staff finds the applicant has presented a reasonable explanation of how the coupled lumped mass model of the RCL was validated, including comparison of analytical calculations and with the results of the testing done at the large seismic shake table at the well known Tadotsu Engineering Laboratory in Japan. However, the applicant did not give any specific data as to the frequency inputs for these tests and did not present any rationale that shows that these comparisons will apply to sites with high frequency inputs. Furthermore, the applicant did not provide any technical information to validate the lumped mass stick models. For the staff to accept fully the response to this question, the applicant is requested to explicitly state that this coupled model has been validated for these high frequencies.

03.09.02-61

In its review of the MHI response to RAI 3.9.2-15 (#205-1584, dated 4/30/2009, ML091240113, MHI Ref: UAP-HF-09184) the staff noted that the applicant provided a generic answer to the question regarding the methodology for response spectrum broadening and smoothing and the clarification for "filling the valleys between all peaks". The applicant indicated the "filling valleys approach is used selectively" and the word "all" will be deleted from the DCD. The staff finds that although the applicant's response may resolve the staff's concerns in question 3.7.3-05 of RAI 213-1951, it did not clearly answer the staff's concerns in RAI 3.9.2-15. Specifically, it is not clear whether the ISRS presented in Fig. 3.7.2-13 of the DCD and Fig. 8.1, 8.2, 8.3 of MHI technical report MUAP-08005 is representative of broadening "all" valleys or for just "selected" valleys. If they do not, will these ISRS need to be changed in Revision 2 of the DCD. Or, does the COL Applicant need to know which ISRS are the "selected" valleys before they are compared with the site-specific ISRS. Therefore, the applicant is requested to provide information that addresses issues raised in the above evaluation. In addition, a confirmatory action will be needed to assure that as stated by the applicant in its response the necessary information would be included in Revision 2 of the DCD.

03.09.02-62

In response to this RAI 3.9.2-17 (#205-1584, dated 4/30/2009, ML091240113, MHI Ref: UAP-HF-09184) the applicant stated that in APWR DCD Tier 2, Revision 2, consideration of the effects of wall and floor slab flexibility on seismic anchor motions will be addressed. However, the applicant did not present any data to demonstrate that its approach is conservative. Therefore, the applicant's response to this question is not acceptable. The applicant is requested to provide data and rationale that shows that the approach used is conservative.

03.09.02-63

In the response to RAI 3.9.2-19 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant dealt with the dynamic analysis of the steam generator upper internals and did not address the lower components such as the tube bundles and the U-tubes. MHI is therefore requested to provide appropriate vibration analysis for the steam generator lower internals, including the tube bundles and the U-tubes which are exposed to cross and axial flows. If the design of the SG lower internals is not prototypical, it suffices to refer to in-service SGs with similar design, size and flow conditions.

03.09.02-64

The applicant is requested to revise the DCD to include and to refer to information provided in the response to RAI 3.9.2-20 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), concerning the similarity between the steam delivery system

of the US-APWR and existing plants which have been in operation for more than 20 years. Provide specific references from existing operating reactors.

03.09.02-65

In the response to RAI 3.9.2-21 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant addressed the global differences between the US-APWR and the 1/5 SMT. In doing so, they did not clarify other differences which may appear small but can have important effect on the test results. For example, Fig. 3-2 in Report MUAP-07023-P indicates that the scale model has a lower core plate and a lower support plate, whereas Fig. 2.1-1 in Report MUAP-07027-P shows that the US-APWR has one plate only (lower core support plate). Such discrepancies between documents are not acceptable. The applicant is therefore requested to explain the reasons for these differences (and others which may not be apparent in the above noted figures), and to clarify the effect of these differences on the test results, structural modeling and forcing functions. The applicant is also requested to update SMT Report MUAP-07023-P so that it reflects the true geometry of the tested model and to include in the report any differences from the US-APWR and the effects of these differences on the test results.

03.09.02-66

In the response to RAI 3.9.2-21 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant stated:

> "The validation of the method of structure modeling was conducted by the comparing the computed natural frequencies of the J-APWR SMT with the measured data, as discussed in Subsection 3.2.1 of the Vibration Assessment Program Report MUAP-07027-P."

The staff finds this validation procedure inadequate because it does not take into account the frequency response functions (FRFs) which express the relationship between the structural response and the forcing functions. In addition, the structural modeling of the US-APWR should be validated from measurements on other full size installations. SRP 3.9.2 recommends that uncertainties and bias errors in FE simulations be estimated from comparisons with measurements made on structures similar in construction to the reactor internals being modeled. The staff appreciates that the validated model will not be that of the US-APWR. However, the procedure for modeling boundary conditions, structural tolerances, damping, welds, etc..., and the resulting bias and uncertainty errors can be validated.

The applicant is therefore requested to provide additional information to assure the staff that:

(a) the structural modeling approach has been adequately validated, and

(b) the bias error and uncertainties have been adequately assessed and incorporated in the dynamic analysis of the reactor internals. In addressing the bias error and uncertainties, the applicant is requested to address how the systematic bias and the random uncertainties are separately estimated.

03.09.02-67

In the response to RAI 3.9.2-21 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant provided a comparison between the empirical normalized forcing function (PSD) in the downcomer and that of the 1/5 SMT. In this comparison, the turbulence PSD in the upper portion of the downcomer is about an order of magnitude higher than the upper bound of the empirical PSD. The applicant is requested to explain how this large difference is accounted for in estimating the forcing function of the US-APWR. In particular, the applicant is requested to elaborate on the axial and circumferential distributions of the forcing function.

03.09.02-68

In the response to RAI 3.9.2-24 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant provided inadequate information. As a result, the original request for information is repeated. As previously stated, the applicant has used the SYSNOISE model to describe the acoustic forcing function within the reactor vessel of the US APWR. Therefore, additional information about the validation of this model and its associated uncertainty and bias errors is needed to complete the review process.

In MHI Technical Report MUAP-07027-P, "*Comprehensive Vibration Assessment Program for US-APWR Reactor Internals*," the applicant used very simple geometries (an annulus and a cylinder) to validate the SYSNOISE model. The staff reviewed the technical report and found this “validation” approach inadequate because the geometry of the reactor and cooling system is much more complex than an annulus or a cylinder. According to SRP 3.9.2 and RG 1.20, the applicant is expected to validate the analytical tools by measurements made on structures similar in construction to the reactor internals being modelled. The staff needs this information to complete the review of the models that are used to describe the acoustic forcing functions and the resulting acoustic and structural responses. The applicant is requested to explain the method used to validate the SYSNOISE model of the reactor acoustic environment. Discuss the bias and uncertainty errors in the model predictions. The validation procedure may include comparisons of SYSNOISE predictions with in-plant measurements of existing 4-loop reactors and with tests of the 1/5 scale model of the APWR. Clarify any differences between the predicted and measured values of acoustic resonance frequencies and frequency response functions. Provide the requested comparisons for various locations within the reactor vessel. Review of these issues is needed to assure conformance with GDC-1 and 4. Revise the comprehensive vibration report to include the requested information.

03.09.02-69

In the response to RAI 3.9.2-32 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the applicant explained the acceptance criteria to be 10 percent in the natural frequency for the fundamental mode and the lowest shell mode and a factor of 3 in random response displacement and stress. Regarding the factor of 3 in the random response, the applicant is requested to clarify the implication that the actual stresses of the reactor internals can be up to a factor of 3 higher than the computed stresses. If this

is indeed the case, how is this factor accounted for in the bias error and random uncertainties? With respect to the acceptance criterion of 10 percent in the resonance frequency, the applicant is requested to explain how the analysis accounts for an unanticipated coincidence between a resonance frequency and an excitation frequency that are within 10 percent of each other.

03.09.02-70

In the response to RAI 3.9.2-33 (#272-1585, dated 5/13/2009, ML091460116, MHI Ref: UAP-HF-09228), Report No. MUAP-07027-P (R1) was revised with additional information to clarify many aspects of the vibration assessment program. However several issues are still unclear. Section 3 of Report No.MUAP-07023-P (R1) indicates that the designs of the fuel assembly, the radial support of the core barrel, and the holes in the neutron reflector were modified in the scale model for the sake of simplicity. However, the details of these modifications are not addressed. It is requested that these modifications and their effects on the test results be discussed and documented in the DCD.

03.09.02-71

In the response to RAI 3.9.2-33 (#272-1585, dated 5/13/2009, ML091460116, MHI Ref: UAP-HF-09228), several issues are still unclear. The applicant is requested to confirm how the dynamic analysis of the reactor internals was benchmarked by means of the SMT. Section 6.1 of the revised Report MUAP-07023-P (R1) suggests that the SMT results were scaled up to the J-APWR and the dynamic analysis was performed on the J-APWR. However, in MHI's response to RAI 3.9.2-33, and in the revised version of MHI Report MUAP-07027-P (R1), the applicant explained that in the FIV analysis program, the measured responses of the J-APWR scale model tests were compared with those estimated by the dynamic analysis applied to the SMT size and test conditions. Also, in Figs. 3.2.1-3 to -12 of Report MUAP-07027-P (R1), the figure captions refer to "actual dimensions" without indicating whether these dimensions are those for the SMT or the full-scale reactor. The applicant is therefore requested to explain this apparent contradiction. In particular, was the dynamic analysis performed on the size and flow conditions of the small scale model or the full-scale J-APWR? The applicant is also requested to modify the necessary documents to eliminate this apparent contradiction.

03.09.02-72

In the response to RAI 3.9.2-33, several issues are still unclear. Table 3.1 of the revised Report MUAP-07023-P (R1) indicates that no scaling is needed to convert the strain and stress from the SMT measurements to the J-APWR. This does not seem appropriate since the SMT and J-APWR are not identical in size or flow conditions. In Tables 6.8 to 6.14 of the same report, the method of strain and stress conversion is not clear, and in Tables 6.2 and 6.3, the conversion of measured displacement to the J-APWR is not explained. In addition, the source of the stress equation for high cycle fatigue, which is cited in page 4, is not given. The applicant is requested to substantiate the methods

used to convert/scale the displacement, the strain and the stress from the SMT data to the full-scale J-APWR.

03.09.02-73

In the response to RAI 3.9.2-33, several issues are still unclear. Several parameters and definitions are not clear in Table 6.4 of the revised Report MUAP-07023-P (R1). The applicant is requested to explain:

(a) The procedure of converting the moment from the SMT to the J-APWR
(b) The meaning of the term "design load", especially when this design load is lower than that measured from the SMT
(c) When and how the design load will be determined for the bottom mounted instrumentation nozzle.

03.09.02-74

In the response to RAI 3.9.2-33, several issues are still unclear. In Section 6.1 of the revised Report MUAP-07023-P (R1), MHI states:

> "These natural frequencies, after scaling up to the J-APWR reactor internals in water were shown in Table 6-1, then test results were compared with the J-APWR pre-analysis results to confirm the adequacy of the J-APWR 1/5 test models".

The NRC Staff believes that one of the objectives of the SMT is to validate the dynamic analysis, and not to use the dynamic analysis to confirm the adequacy of the small-scale test models. The applicant is requested to explain what is meant by the above cited statement.

03.09.02-75

In the response to RAI 3.9.2-33, several issues are still unclear. Report No. MUAP-07027-P (R1) indicates that substantial uncertainties exist in the dynamic analysis. For example, in the revised SYSNOISE analysis, the RCP pulsation amplitude is reduced by a factor of 5, and the response of the reactor internals to this RCP pulsation increases by a factor of 5 when the simulation time step is refined. Moreover, when comparing the SMT random response with the response obtained from the dynamic analysis, a ratio of 3 between the measured and predicted values is considered acceptable.

Despite these substantial uncertainties indicated above, the applicant considers a margin of safety of 30 percent acceptable for the high cycle fatigue analysis as indicated in Table 3.3.3-4 of the above mentioned report. The applicant is requested to explain why this margin of safety (30 percent) is considered conservative despite the existing much wider range of uncertainty.

03.09.02-76

In the response to RAI 3.9.2-33, several issues are still unclear. The power spectral density (PSD) of the turbulence excitation in the downcomer is stronger near the inlet nozzles and becomes weaker as the flow progresses along the downcomer, as illustrated, for example, in Fig. 3.2.2-3 of the revised Report MUAP-07027-P (R1). The applicant is requested to explain the axial and circumferential distributions of the turbulence excitation PSD which are used in the dynamic analysis of the reactor internals.

03.09.02-77

In the response to RAI 3.9.2-33, several issues are still unclear. In the introduction of the revised Report MUAP-07027-P (R1), as well as at several other sections of the report, the applicant states:

> In the first version of the report "measured data in the J-APWR scale model test was used for the forcing functions due to the downcomer flow turbulence. After the completion of Revision 0 of this report at the end of 2007, new data pertinent to the US-APWR configuration was obtained in the US-APWR Reactor Vessel Lower Plenum 1/7 Scale Model Flow Test".

The applicant is requested to explain why the SMT of the J-APWR in the revised reports was not entirely replaced by the available SMT of the US-APWR. It is also appropriate to revise the DCD document to include and to refer to the results of the 1/7 scale model tests of the US-APWR.

03.09.02-78

In RAI 3.9.2-35, the applicant was asked to discuss the analysis performed and the tests planned to demonstrate that adverse flow effects will not cause unanticipated excessive flow-induced vibrations or structural damage to the reactor *piping systems and the internal structures in the upper core plenum near the exit nozzles.* In the response (#272-1585, dated4/9/2009, ML091040693, MHI Ref: UAP-HF-09149) to this RAI, MHI addressed the upper core plenum internals only and did not discuss the reactor piping systems. Therefore, RAI 3.9.3-35 still stands for the piping system and MHI is requested to discuss the analysis performed to assess adverse flow effects on the reactor piping system due to the increase in the flow velocity represented by the vessel outlet nozzle as identified in Table 2.1-1 of MUAP-07027-P (R1). The applicant may refer to other sections of the DCD or to technical reports which address the concerns expressed in this RAI.

03.09.02-79

The staff finds this response to RAI 3.9.2-40 (#206-1576, dated 3/27/2009, ML090910123, MHI Ref: UAP-HF-09116) acceptable and agrees that since similar steam generators have been in use in existing plants for many years without any vibration problems, there is no need to perform startup testing of the steam generators.

However, contrary to the statement in the response, the staff could not find any reference in DCD Subsection 3.9.2.4.1 to Subsection 5.4.2.1.2.10 that addresses the SG dynamic response. The applicant is, therefore, requested to add the cross reference to Subsection 3.9.2.4.1 mentioned above.

The applicant is also requested to include a reference to the statement that the design of the US-APWR steam delivery system, including the SG upper internals, the safety relief valves, and the steam lines, has been operating in the USA for more than 20 years in sizes and flow rates that bound those of the US-APWR. These additions are requested so that the DCD document meets the expectations of US NRC RG 1.20 and SRP 3.9.2.

03.09.02-80

In the response to RAI 3.9.2-70 (#207-1577, dated 3/27/2009, ML090910120, MHI Ref: UAP-HF-09117), MHI states that it is acceptable to have a factor of 2 between the measured damping ratios during the pre-operational tests and the damping values used in the prediction analysis. The staff finds it excessively unconservative if the damping ratios, used in the prediction are twice the actual ratios determined during the pre-operational tests. To maintain sufficient conservatism in the analysis, the applicant is requested to use damping ratios which are equal or smaller than those determined from measurements.

03.09.02-81

In its review of the applicant's response to RAI 03.09.02-35 (#272-1585, dated 4/9/2009, ML091040693, MHI Ref: UAP-HF-09149), the staff noted that the description of the models is adequate. There are two items that need further discussion: (a) how local SG shell flexibility at piping nozzles is considered in the model for SG component supports, and (b) how the decoupling criteria in SRP 3.7.2 was considered and applied to the separate analysis of the upper structure from the steam generator (SG) model. Therefore, the staff requests the applicant to provide the following information:

**(a) Provide a description of how the steam generator (SG) shell flexibility was considered in the analysis in the vicinity of piping nozzle penetrations.**

**(b) Provide a description of how the decoupling criteria in SRP 3.7.2 SRP Acceptance Criteria II.3.B was considered and applied to justify the analysis of the upper internal structure separately from the SG shell model. If any deviations were made from the SRP 3.7.2 criteria provide the rationale for such deviations.**

03.09.02-82

In MHI's response to US-APWR DCD RAI No. 03.09.02-37, 214-1920, dated April 30, 2009 (MHI Ref: UAP-HF-09190, ML091240403), the applicant stated that this question was answered in the responses to RAI 212-1950, RAI 3.7.2-26 (dated March 30, 2009, MHI Ref: UAP-HF-09113, ML090930727). In its response to RAI 3.7.2-26 the applicant stated that it is the intent of the US-APWR design to always meet the requirements of RG 1.92, Rev.2 or 1 (when permitted) for combining modal responses. The applicant also stated that DCD Section 3.7.2.7 will be revised to clarify this issue. In its review, the

staff noted that to resolve the staff's concerns in RAI 3.7.2-26 the applicant needs to provide data to show that their approach is conservative.

03.09.02-83

In MHI's response to US-APWR DCD RAI No. 03.09.02-39, 214-1920, dated April 30, 2009 (MHI Ref: UAP-HF-09190, ML091240403), the applicant stated that a list of damping values used for each of the major mechanical components analyzed is provided in US-APWR DCD Tables 3.7.3-1(a) and (b). The SSE analysis for the CRDM used a damping value of 4 percent, and not 5 percent. The staff finds the applicant's response acceptable because the applicant stated that SSE analysis for the CRDM used a damping value of 4 percent, and not 5 percent. However, the applicant did not mention in its response that in the DCD Table 3.7.3-1(a) the damping value for the control rod drive mechanism (CRDM) will be changed. The applicant is requested to revise the CRDM damping value in DCD Table 3.7.3-1(a) and submit the revised DCD for staff review.

03.09.02-84

**Based on the evaluation of the applicant's response to the RAIs on Subsection 3.9.2 of the DCD, the staff is still concerned about the differences between the scale model geometry and the US-APWR. Some of these differences have already been addressed by the applicant, but others seem to exist in the submitted drawings but are not addressed by the applicant, e.g. the second follow-up RAI to question 3.9.2-21, ninth question of this RAI. The staff is also concerned that additional differences may exist which cannot be seen in the scale model drawings. The applicant is therefore requested to provide a list of all the differences between the US-APWR and the geometry of the scale model, which is used in the vibration testing. The applicant is also requested to demonstrate that the effect of each of these differences on the estimated vibration response of the US-APWR is conservative.**