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December 28, 2010

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-10357

Subject: MHI's Responses to US-APWR DCD RAI No. 661-5129 Revision 2 (SRP 03.08.01)

Reference: 1) "Request for Additional Information No. 661-5129 Revision 2, SRP Section: 03.08.01 - Concrete Containment," dated 11/15/2010.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 661-5129, Revision 2."

Enclosed are the responses to 3 RAIs contained within Reference 1. This transmittal completes the response to this RAI.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Atsushi Kumaki for

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Response to Request for Additional Information No. 661-5129, Revision 2

CC: J. A. Ciocco
C. K. Paulson

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Enclosure 1

UAP-HF-10357
Docket No. 52-021

Response to Request for Additional Information No. 661-5129, Revision 2

December, 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/28/2010

US-APWR Design Certification
Mitsubishi Heavy Industries
Docket No. 52-021

RAI NO.:	**NO. 661-5129 REVISION 2**
SRP SECTION:	**03.08.01 – Concrete Containment**
APPLICATION SECTION:	**3.8.1**
DATE OF RAI ISSUE:	**11/15/10**

QUESTION NO. RAI 03.08.01-24:

In the answer to Part (b) of Question 03.08.01-5, MHI states that the soil springs are calculated consistent with the Theory of Elasticity and experimental observations. The staff agrees with this approach; however, the applicant did not address the impact of this change on the structural design of the prestressed concrete pressure vessel (PCCV) basemat. MHI is requested to provide a description of the impact of the above change on the design of the basemat.

In the answer to Part (c), MHI states that the use of springs with compression capacity only in the analyses is not non-linear. The staff considers this answer to be unacceptable unless the analyses show that the foundation partial uplift will not take place. The 100-40-40 combination method is for linear response only. For nonlinear response, the earthquake motions in three directions have to be applied to the structure simultaneously. MHI is requested to provide additional information that supports the assumption that partial uplift will not occur.

ANSWER:

Regarding the answer to Part (b) of RAI 490-3732 Question 03.08.01-5, the impact of soil subgrade stiffness under the Reactor Building basemat is considered in the design of the basemat. The soil subgrade stiffness was referred to previously in the response to Question 03.08.01-5 as soil springs, but currently is being addressed through full continuum finite element analysis. This approach is addressed in a Technical Report REF-13-05-160-005 that is currently scheduled to be issued in January 2011. Subsection 3.8.5.4.3 of the DCD will be modified to clarify that a representative volume of the subgrade will be included in the ANSYS static models. This analysis of the structure–subgrade system more accurately accounts for the translational and rotational stiffnesses of the under laying subgrade. Further, a future Technical Report RBF-13-05-160-002, "Design Report for the Basic Design of the US-APWR R/B Foundation" that is currently scheduled to be issued in March 2011, will provide the results of the reevaluation and describe the impact of the subgrade stiffnesses on the design of the basemat.

Regarding the answer to Part (c) of Question 03.08.01-5, it is agreed that the use of springs with compression capacity only in the analyses is non-linear where uplift can occur. Partial uplift of the mat will occur when subject to full earthquake loading. The 100-40-40 combination method applicable to linear response will not be used. For the nonlinear uplift analysis of the mat, the earthquake motions in three directions will be applied to the structure simultaneously. For the basemat uplift analysis, the magnitudes of the three static equivalent components for each of the three directions will be obtained from time history analysis and will be applied simultaneously to the combined finite element model of the Reactor Building, PCCV and CIS. Seismic loads will be based on the most severe combinations that occur at any time during the SASSI time history analyses of the combined seismic model structure.

Impact on DCD

See Attachment 1 for a mark-up of DCD Revision 2, Tier 2, Subsection 3.8.5.4.3, for changes to be incorporated.

- Revise the paragraph in DCD Subsection 3.8.5.4.3 to read as follows:

  "The basemat subgrade is included in the detailed static FE models used for structural design by meshing a sufficiently large volume of soil/rock below and around the basemat. The stiffness of the backfill around the below-grade walls is not considered in the model. The properties of the subgrade layers used in the FE model of the subgrade are established based on several profiles selected from the generic layered soil profiles described in Technical Report MUAP-10001 (Reference 3.7-47) to cover the entire range of soil/rock conditions at representative nuclear power plant sites within the central and eastern US. To increase computational efficiency, the subgrade part of the FE model is condensed into a super-element. A detailed description of the analysis method is presented in Technical Report REF-13-05-160-005 (Reference 3.7-49)."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 661-5129 REVISION 2**
SRP SECTION:	**03.08.01 – Concrete Containment**
APPLICATION SECTION:	**3.8.1**
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QUESTION NO. RAI 03.08.01-25:

In the response to question 03.08.01-6, MHI states that plate elements will be placed at the centerline of the buttress, and shell elements with variable thickness at nodes will be used to represent the continuity of the wall to the buttress. The staff does not agree with this approach because it changes the configuration of the structure. In ANSYS Release 12, ANSYS will automatically account for the discontinuity effects due to the offset of the centerlines. MHI is requested to re-analyze this area using ANSYS Release 12 for the analyses.

ANSWER:

MHI has applied classic ANSYS shell elements with variable-thickness transition elements located between the edge of buttress and wall of the containment due to the sloping face at the tendon anchors, which results in an accurately predicted response for the discontinuity at the buttress. MHI does not believe that there would be an advantage to re-analyze this area using ANSYS Release 12. Further detail of the current modeling of the structure and a displaced shape are presented in this RAI response to demonstrate that the current modeling accurately respresents the configuration of the structure without "changing" its configuration.

As an alternative to the use of ANSYS Modeler [(1)], the capability to represent offsets was previously available using historical features of ANSYS classic, Release 11.0 [and earlier versions] by use of constraint equation commands. Theoretically, the new option of Release 12.0 consists of generating translation matrices for forces and displacements which then are used to modify the shell stiffness matrix [by transpose and multiplication matrix manipulations similar to the use of constraint equations] to enable rigid offsets at the four corners of the element. The "new" feature of Release 12.0 perhaps could therefore be characterized as more of an option of input convenience rather than a purely new feature, and this is why MHI does not believe that use of the "new" feature is required to model the buttress region.

(1) According to Release Notes of ANSYS Release 12.0 [http://www1.ansys.com/customer/content/documentation /120/ai_rn.pdf] ANSYS advises that a new feature in Design Modeler is applicable for beam modeling including user defined offsets. In addition, for Design Modeler, new features also allow definition of offsets for surface bodies. However, for Release 12.0 there does not appear to be new features for offsets for ANSYS classic which is the QA computer program in use to model the static analysis of the US-APWR Reactor Building, PCCV, and CIS on a common mat.

The constraint equation commands are more appropriate for use with beam elements because the beams can be connected entirely at single nodes. For shell and plate finite elements there is a compatibility of displacement on the sides of the SHELL181 elements that represents a curved pattern of deformation between corner nodes of the elements. The use of offsets defeats this deformation compatibility effect making the solution less accurate. A transition element is required between the edge of buttress and wall of the containment due to the sloping face at the tendon anchors. This transition element is not in a radial plane through the wall. Figure 1 below is a plot of a buttress cross section through the PCCV ANSYS model. The transition elements need to reflect the variable thickness of the wall on the cylindrical wall side as it becomes thicker on the buttress side. If rigid offsets are used instead of this transition element with variable thicknesses at the buttress and wall sides, no density from the transition elements would be available for adding the transition element weight. More computations and input of the lumped masses by other commands would be necessary to account for the transition element weight. The alternative use of rigid links alone would artificially stiffen the buttress to wall connection at the offset nodes over the transition element width because the offsets would be required in the tangential direction in addition to the radial direction of this cylindrical configuration. For these reasons the use of offsets instead of transition element would be expected to result in less accurate analysis responses, and therefore MHI has not applied the use of offsets.

Using the ANSYS classic shell elements with variable thicknesses at this transition element results in a well behaved response at the discontinuity region. See Figure 2 and 3 below for plots of the geometry configuration and deflected shape which show reasonable deformation continuity in the vicinity of the buttress to wall transition elements. Therefore, it is not necessary to procure the Release 12.0 Design Modeler module to perform the analysis of the PCCV structure.

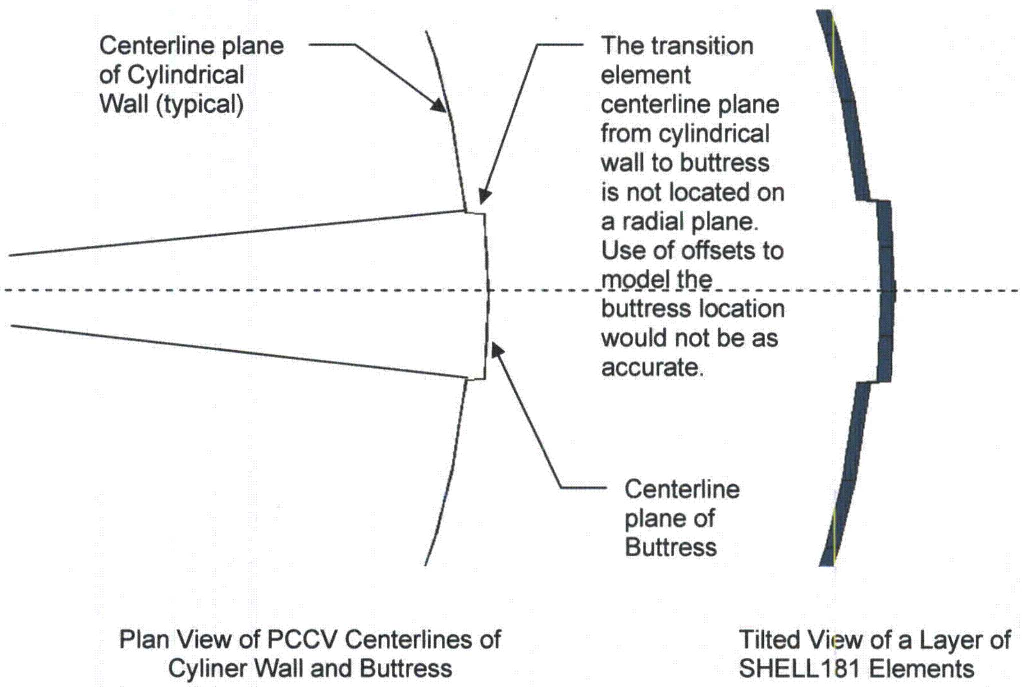

Figure 1 - Cross Section through PCCV ANSYS Model at Buttress Plot

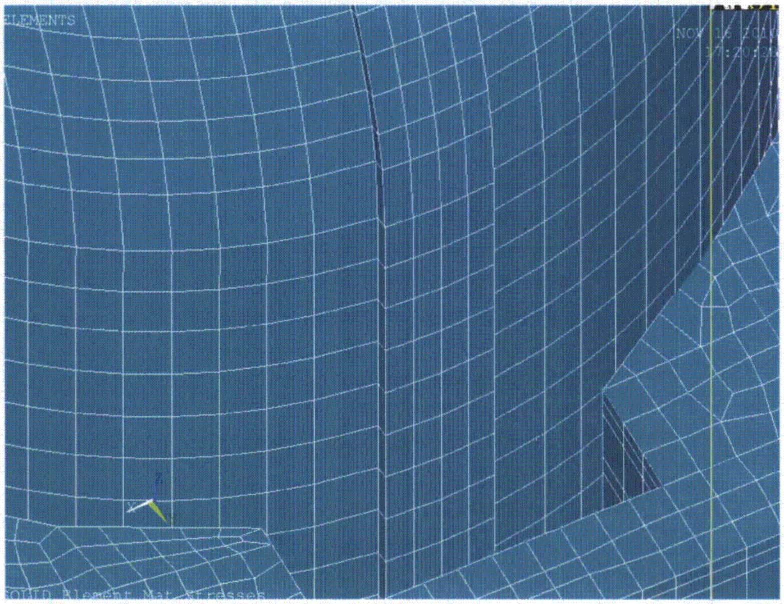

Figure 2 - Geometry Configuration Plot

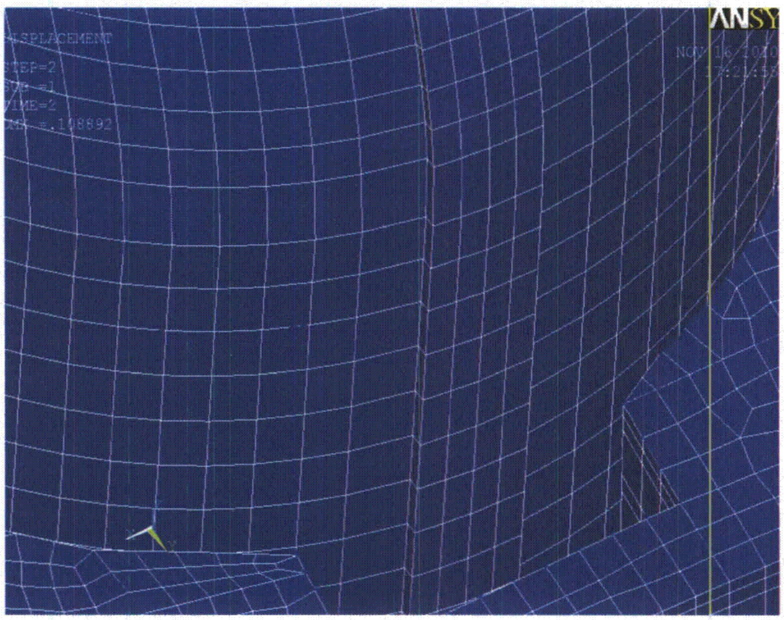

Figure 3 - Deflected Shape Due to North-South Earthquake Plot

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/28/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

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APPLICATION SECTION:	**3.8.1**
DATE OF RAI ISSUE:	**11/15/10**

QUESTION NO. RAI 03.08.01-26:

In the response to Question 03.08.01-8, MHI states that the stress analyses of the PCCV show that besides small localized areas, the prestressed concrete of the PCCV remains in compression under mechanical loads. Cracking of the PCCV occurs due to accidental thermal loading; however, the maximum Safe Shutdown Earthquake (SSE) and the maximum thermal load are not considered to act concurrently in the analyses which is permitted by American Society of Mechanical Engineers (ASME) Section III CC-3230(c), which states that "the maximum effects of Pa, Ta, Ra, Rr, and G shall be combined unless a time-history analysis is performed to justify the lower combined values". The staff is not entirely convinced by the Applicant's statement that the lower combined values can be justified. MHI is requested to provide the actual timelines for each of the loads, and to provide the rationale supporting the assumptions for the timelines.

MHI further states that the effect of the possible shift of fundamental frequency of the PCCV due to concrete cracking will enveloped by the wide range of different subgrade conditions considered. The staff disagrees with this statement. The effect of concrete cracking and the different subgrade conditions are two different factors. They should not be mixed. MHI is requested to provide information that supports their assumption that the fundamental frequency shift is accounted for by using the wide range of subgrade conditions.

ANSWER:

MHI agrees with the NRC Staff's position that seismic SSE must be combined concurrently with LOCA effects such as P_a, T_a, R_a, R_r, etc. from a design basis accident. MHI's commitment to this ASME Section III requirement is already documented in the following fifth sentence of the first paragraph in the response to RAI 490-3732 Rev. 0, Question 03.08.01-8:

> "SSE, accident pressure, and accident thermal loads are considered concurrently as required by Table CC-3230-1 of ASME Section III."

It is MHI's intention to comply with the design requirement in ASME Section III CC-3230(c) so that the conservative design requirement of combining the maximum SSE with maximum P_a and maximum T_a is not required. It should be emphasized that the effects from SSE and LOCA (P_a, T_a, etc.) on the PCCV design are considered concurrently. In the unlikely event of a LOCA, the peak maximum value of P_a occurs quite rapidly after the initiation of the design basis accident but it takes considerable time for the concrete of the PCCV to heat up from the effect of the maximum temperature T_a of the design basis accident on the interior surface of the PCCV. Therefore, the maximum pressure value of P_a and the maximum temperature value of T_a cannot occur at the same instant in time. The Abnormal/extreme environmental load combination of Table CC-3230-1 would result in the following subset of load combinations:

1. maximum SSE + maximum pressure P_a + temperature T_a + other applicable loads
2. maximum SSE + pressure P_a + maximum temperature T_a + other applicable loads
3. maximum SSE + pressure P_a + temperature T_a + other applicable loads

The intermediate values of pressure P_a and temperature T_a in Item 3 above are from time-history analyses.

The R/B Complex design basis seismic and thermal analyses are to be documented in Technical Report PCCV-13-05-113-001 which is currently scheduled to be issued in March 2011. Please note Technical Report PCCV-13-05-113-001 is intended to fulfill the technical report commitment discussed in previous RAI 491-3733 Questions 03.08.01-8, 03.08.01-9, and 03.08.01-10.

To respond to the NRC request to provide information that supports the position that the fundamental frequency shift is accounted for by using a wide range of subgrade conditions, a study will be performed to assess the effects of concrete cracking on the seismic response of the PCCV. The results of the study will be documented in a future technical report.

The extent of concrete cracking and degree of stiffness reduction due to the cracking will be estimated for the PCCV under the critical abnormal/extreme environmental load combination. The stiffness properties of the PCCV lumped-mass stick model will be adjusted based on the stiffness reduction factors obtained from the estimate, and site-independent soil-structure interaction (SSI) analyses will be performed for the adjusted lumped-mass stick model of the PCCV to calculate 5%-damped acceleration response spectra (ARS) at selected representative locations. The ARS results obtained with uncracked and cracked properties will be compared to assess the effect of the concrete cracking on the seismic response of the PCCV.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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area of the basemat that is uplifted. Minimum area of steel reinforcement is calculated from the section forces for the most critical load combinations.

The required reinforcement steel for the portion of the basemat under the R/B (other than PCCV) is determined by considering the reinforcement envelope for the full non-linear iteration of the most critical load combinations.

3.8.5.4.2.1 Global Three-Dimensional FE Modeling of Basemat

The stress conditions of the basemat are generated by numerous types of loads from the superstructure. The modeling of the basemat therefore involves evaluating the interaction between the basemat and the superstructures to determine the stress conditions at the interface. The global FE model is analyzed utilizing the FE computer program ANSYS (Reference 3.8-14).

Regarding the R/B, the element division in a horizontal direction inside the secondary shield walls of containment internal structure is made in a rectangular grid and that outside the secondary shield wall is made in a polar pattern. Peripheral areas of the basemat are divided in a rectangular grid.

The upper portion of tendon gallery is considered with concentrated stresses created by the connection with the PCCV. This region is divided into four elements in the radial direction to better evaluate the stresses.

The basemat below the PCCV and the lower portion of containment internal structure are simulated with hexahedral solid elements. The elements below the PCCV are divided into three to fifteen parts in thickness, and elements in peripheral areas are divided into three parts. The FE modeling of the PS/Bs is provided in Subsection 3.8.4.4.

3.8.5.4.3 Boundary Conditions of Basemat

The basemat subgrade is included in the detailed static FE models used for structural design ~~is represented by translational spring elements that are attached to the bottom of the basemat~~ by meshing a sufficiently large volume of soil/rock below and around the basemat. The stiffness of the backfill around the below-grade walls is not considered in the model. The properties of the subgrade layers used in the FE model of the subgrade are established based on several profiles selected from the generic layered soil profiles described in Technical Report MUAP-10001 (Reference 3.7-47) to cover the entire range of soil/rock conditions at representative nuclear power plant sites within the central and eastern US. ~~Subgrade coefficients, determined based on the SSI lumped parameter values listed in Table 3H.2-14 of Appendix 3H, are used to assign spring values to the individual nodes of the FE model. These subgrade coefficients are multiplied by the basemat nodal point tributary areas to compute the spring constants assigned to the nodal points. The vertical spring stiffnesses are also developed in a manner such that the cumulative vertical stiffness is equivalent to the vertical SSI spring constant value in Table 3H.2-14.~~ To increase computational efficiency, the subgrade part of the FE model is condensed into a super-element. A detailed description of the analysis method is presented in Technical Report REF-13-05-160-005 (Reference 3.7-49).