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TOKYO, JAPAN

April 30, 2009

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-09190

Subject: MHI's Response to US-APWR DCD RAI No. 214-1920

References: 1) "Request for Additional Information No. 214-1920 Revision 0, SRP Section: 03.09.02 – Dynamic Testing and Analysis of Systems Structures and Components, Application Section: DCD, Tier 1 – Section 3.9.2.2," dated 2/25/2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Response to Request for Additional Information No. 214-1920 Revision 0."

Enclosed are the responses to questions 34 through 41 of the RAI (Reference 1).

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,

Y. Ogata

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

Enclosures:

1. Response to Request for Additional Information No. 214-1920, Revision 0

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

D081
NRO

Contact Information

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Enclosure 1

UAP-HF-09190
Docket No. 52-021

Response to Request for Additional Information No. 214-1920,
Revision 0

April, 2009

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

4/30/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 214-1920**
SRP Section:	**03.09.02 – Dynamic Testing and Analysis of Systems Structures and Components**
APPLICATION SECTION:	**3.9.2.2**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-34

In DCD Tier 2, Section 3.9.2.2.2, MHI states that the stiffness of the seismic subsystem anchorage must be determined and the assumptions made in the seismic analysis must be verified as accurately reflecting the mounting condition. The staff requests the applicant to address the following:

(1) Discuss how the dynamic characteristics of the support anchorages, including base plate and anchor bolts or through bolts, connecting to the building structure is determined. Discuss how the equipment seismic analysis account for the dynamic characteristics of the support anchorage, especially for heavy equipment.

(2) Anchor bolt torque relaxation may occur after years of operation and cause reduction in the natural frequency of the equipment and support assembly, and increase in its seismic response. Provide the plant-specific compensatory measures or quality control/assurance programs used to alleviate the effects of anchor bolt torque relaxation.

(3) Clarify whether, and explain why, expansion anchor bolts will or will not be used for safety-related systems and components.

ANSWER:

(1) The flexibility of the equipment support anchorages, which includes the base plate and anchor bolts or through bolts, may affect the natural frequency of the equipment and support assembly and therefore may affect the equipment seismic analysis results. To account for the support anchorage flexibility effects, the stiffness of the anchorage system is considered in the equipment seismic analysis when significant. The stiffness of the anchorage can be determined either by a hand calculation method for a simple anchorage (anchor bolt flexibility only) or by a finite element analysis method for a complicated anchorage arrangement (base plate and anchor bolt flexibility).

When SSCs can be designed using simplified analyses such as the equivalent static method, stiffness of the support anchorage is considered for purposes of appropriate force and moment to load-resisting elements. However, consideration of stiffness of the support anchorage is not necessary to determine the seismic response of the SSC when the peak acceleration from the applicable in-structure response spectra (ISRS) is used as the basis of the seismic design load. In cases where the equivalent static method is used, but the design accelerations are not based on the peak accelerations from the applicable ISRS, then the stiffness of the anchorage is considered to determine if the support frequency is significantly affected by the anchorage stiffness.

For more complicated anchorages, computer programs which employ a finite element analysis model can be employed. The finite element analysis model includes the base plate elements, anchor bolt tension only springs and compression-only springs to simulate the contact between concrete and base plate. Since the model consists of non-linear springs such as compression-only springs for concrete, an iterative analysis method is employed. This model is used to derive the stiffness (spring rate) of the base plate anchorage system by applying each unit load/moment in a given direction individually one at a time. The spring rate in the direction of the applied load/moment will be calculated by the applied load/moment divided by the resulting displacement/rotation in the applied load/moment direction. One example of such a computer program is E/PD STRUDL referenced in DCD Subsection 3.12.4.1.1, which is designed to perform analysis of the pipe support structure, including the base plate flexibility per NRC IE Bulletin 79-02.

For the US-APWR, supports of heavy equipment are modeled as spring elements in the dynamic analysis of the RCL-R/B-PCCV-containment internal structure coupled model that is presented in MHI Technical Report, MUAP-08005. In the coupled model, the spring elements representing the supports are assigned stiffnesses for the three translational (x, y, z) and the three rotational (Rx, Ry, Rz) degrees of freedom. The stiffnesses of the support spring elements include consideration of the support structure and anchorage. Anchorage consists of the anchor bolt, baseplate, and other structural elements. The supports are designed and analyzed such that the stresses remain within the elastic range of the materials. Calculated spring values for various support locations such as the lower pressurizer support and RV, SG and RCP supports are shown in Tables 6-4 and 6-7 of the coupled model technical report. Where supports are investigated and determined to be essentially rigid, the spring values used in the coupled model are set high enough to simulate "infinite" spring values. Therefore the connection point between the anchorage and structure (operation floor, base floor, etc.) for heavy equipment in the coupled model accurately reflects the mounting conditions.

(2) For expansion type of anchors, anchor bolt torque relaxation may occur if the torque value is not properly specified in their design and/or torque is not properly applied during their installation. The US-APWR standard design for the concrete expansion anchor will comply with the requirements of IE Bulletin 79-02, Revision 2 as stated in Subsections 3.9.3.4.5 and 3.12.6.4 of the DCD. The design of expansion anchors will consider the effects of base plate flexibility and the required minimum safety factors among other requirements per IE Bulletin 79-02. QC documentation for the installation of expansion anchors will include the proper torque values and preload testing, and a record confirming that the specified design size and type is correctly installed. The design and installation of the expansion anchors per IE Bulletin 79-02 requirements will alleviate the effects of anchor bolt torque relaxation.

(3) It is intended, for the US-APWR standard plant design, that embedded plates or cast-in-place anchor rods be used as the anchorage for safety-related systems and components. However, where necessary, post-installed expansion anchors conforming to the requirements and provisions of ACI 349 Appendix B, RG 1.199, and IE Bulletin 79-02 are used. ACI 349 Appendix B defines an expansion anchor as follows:

"A post-installed anchor inserted into hardened concrete that transfers loads into or from the concrete by direct bearing or friction or both. Expansion anchors may be torque-controlled, where the expansion is achieved by a torque acting on the screw or bolt; or displacement-controlled, where the expansion is achieved by impact forces acting on a sleeve or plug and the expansion is controlled by the length of travel of the sleeve or plug."

For the US-APWR, post-installed expansion anchor bolts such as wedge-type or sleeve-type anchors which rely on friction will not be used for the systems or components subject to the vibratory motion in the normal operation conditions, since the anchor bolt torque relaxation may occur under this condition. Wedge-type or sleeve-type expansion anchors will also not be used for heavily loaded supports or equipment where limited by their allowable load capacities. Instead a surface mounted base plate with direct-bearing undercut anchor bolts or post-installed through-bolts, or anchorage with grouted embedment can be used. Expansion anchors may be used in the safety-related conduit supports and smaller piping supports that are lightly loaded and not subject to vibrations.

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

4/30/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 214-1920**
SRP Section:	**03.09.02 – Dynamic Testing and Analysis of Systems Structures and Components**
APPLICATION SECTION:	**3.9.2.2**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-35

In DCD Tier 2, Section 3.9.2.2.2, MHI states that two models are used for the RCL seismic analysis. One for RCL seismic analysis, which consists of stick mass spring model of steam generator (SG), reactor coolant pump (RCP), reactor pressure vessel (RPV), loop piping, and building. The other is for seismic analysis of internal components of SG itself. The staff requests the applicant to address the following:

(1) For the SG and its internals, discuss their isolated structural model in detail. This should include SG pressure boundary and its upper internals, such as feedwater headers, platforms, separators, dryers; as well as lower internals, such as tubesheet, tubes, tube support plates, anti-vibration bars, bundle wrappers, and seismic stops.

(2) Discuss how the hydrodynamic coupling of the SG shell to the tubes and other SG internals is simulated in the SG isolated structural model.

(3) Discuss how local flexibility of the SG shell at the primary nozzle connections is accounted for in the model.

(4) Discuss how SG component supports are modeled.

(5) Provide the natural frequencies and mode shapes (including their graphical representation) obtained for the SG and its internals, and, based on that, discuss the adequacy of their respective modeling.

ANSWER:

(1) Separate models are used for the SG and its internal structures. The seismic response of SG is evaluated using the stick mass spring model. The internal structures of SG are evaluated using the two separate models, one for the tube bundle, and the other for the upper shell internal structure. These models are described below:

a) Tube Bundle
The seismic model for tube bundle is shown in Figure1(a). In the model, seven tube groups of different radii represent the upper bundle. The tube elements are coupled for out-of-plane motion in the U-bend tube region and not coupled for in-plane motion, to allow the relative sliding between U-bend tube columns.

b) Upper Shell Internal Structure

The seismic model for the SG upper internals is a three dimensional three-stick model shown in Figure1(b). The first stick represents the stiffness and mass properties of the primary moisture separator and wrapper assembly. The second stick represents the moisture separator downcomer barrel assembly, and the third stick represents the steam dryer and its drain pipe assembly. These 3 stick models are interconnected by the deck plates.

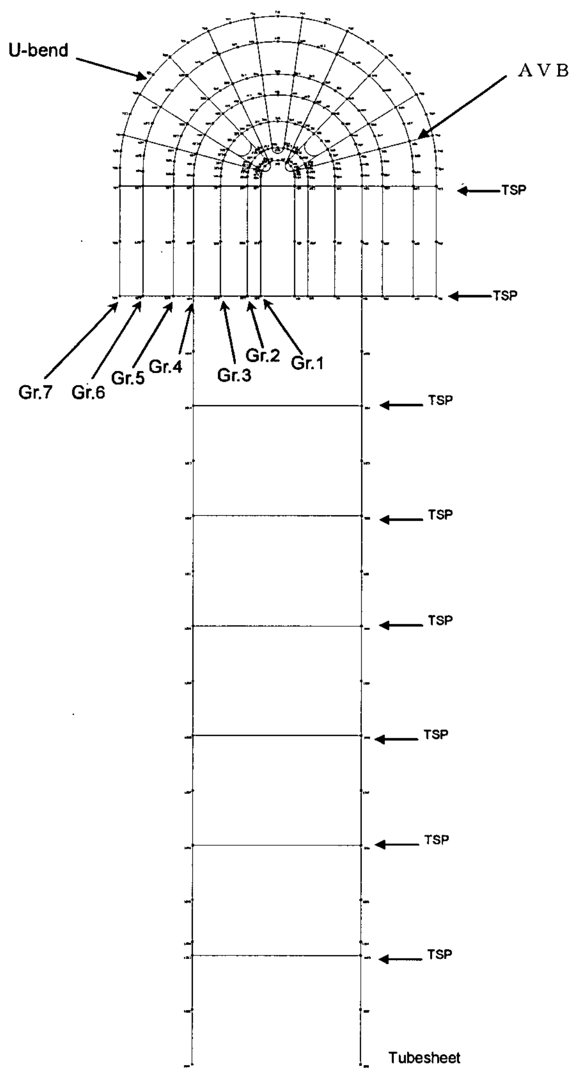

Figure 1(a) - Tube bundle model

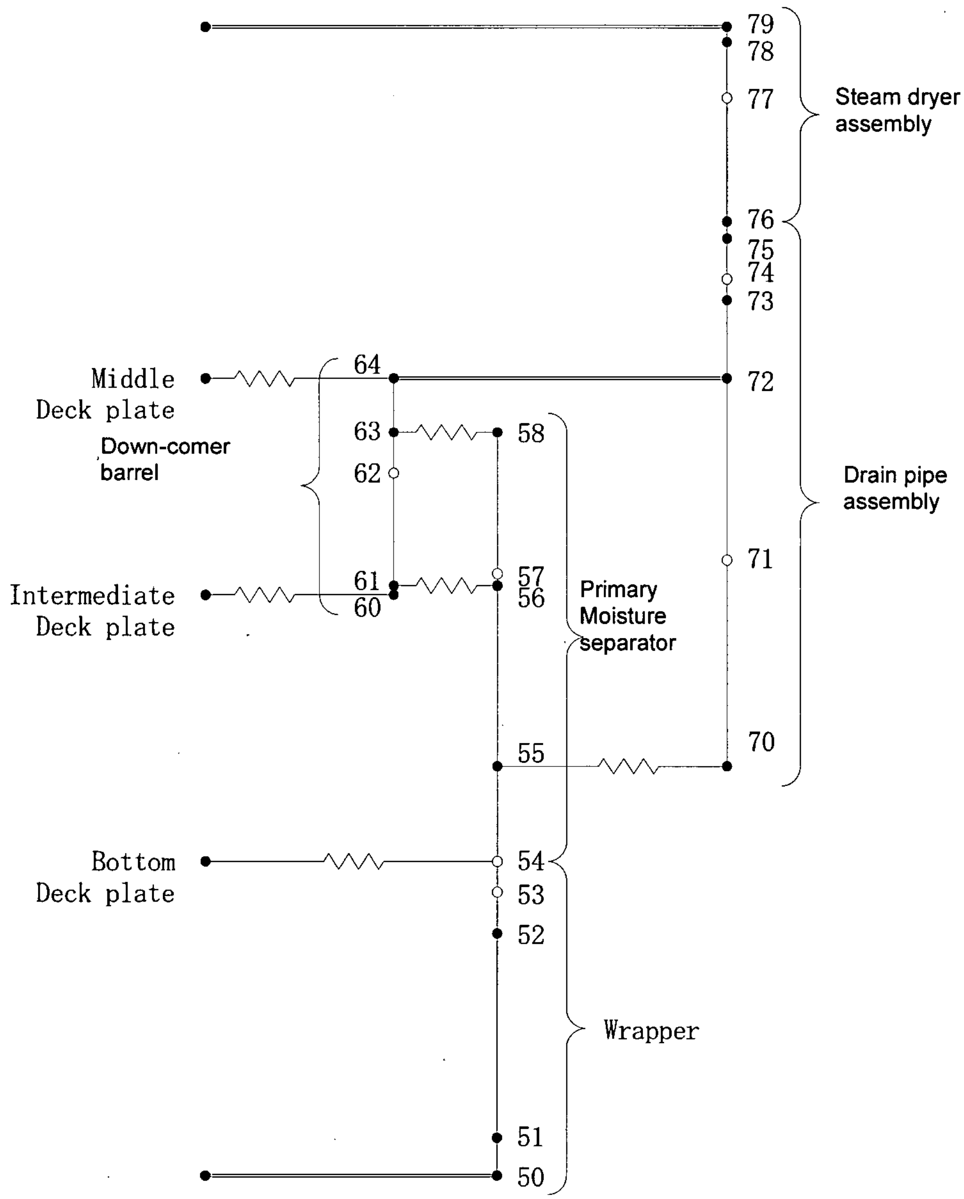

Figure 1(b) - Upper shell internal model

(2) The fluid-structure interaction (FSI) of the tube elements are represented by the tube mass, the mass of fluid inside the tube, and the added virtual mass of water outside the tube. The following formulas are used:

$$M_{total} = M_{tube} + M_{water} + M_{vm} \qquad (1)$$

$$M_{vm} = \frac{\pi}{4} D^2 L \rho \qquad (2)$$

where:

M_{total} = total mass of one tube element

M_{tube} = tube mass

M_{water} = mass of fluid inside the tube element

M_{vm} = additional virtual mass due to FSI effects

ρ = density of secondary side fluid

D = tube outer diameter

L = element length of the tube

(3) Attached Figures 1 and 2 (below) show the finite element (FE) models utilized to develop the support stiffness of the upper and intermediate shell supports of the SG. Horizontal loads assumed by this FE analysis are adequate, but the shell model of the SG and spring model of snubber cause deformation. Based on the results of this analysis, the spring value included in the support model includes local flexibility of the SG shell.

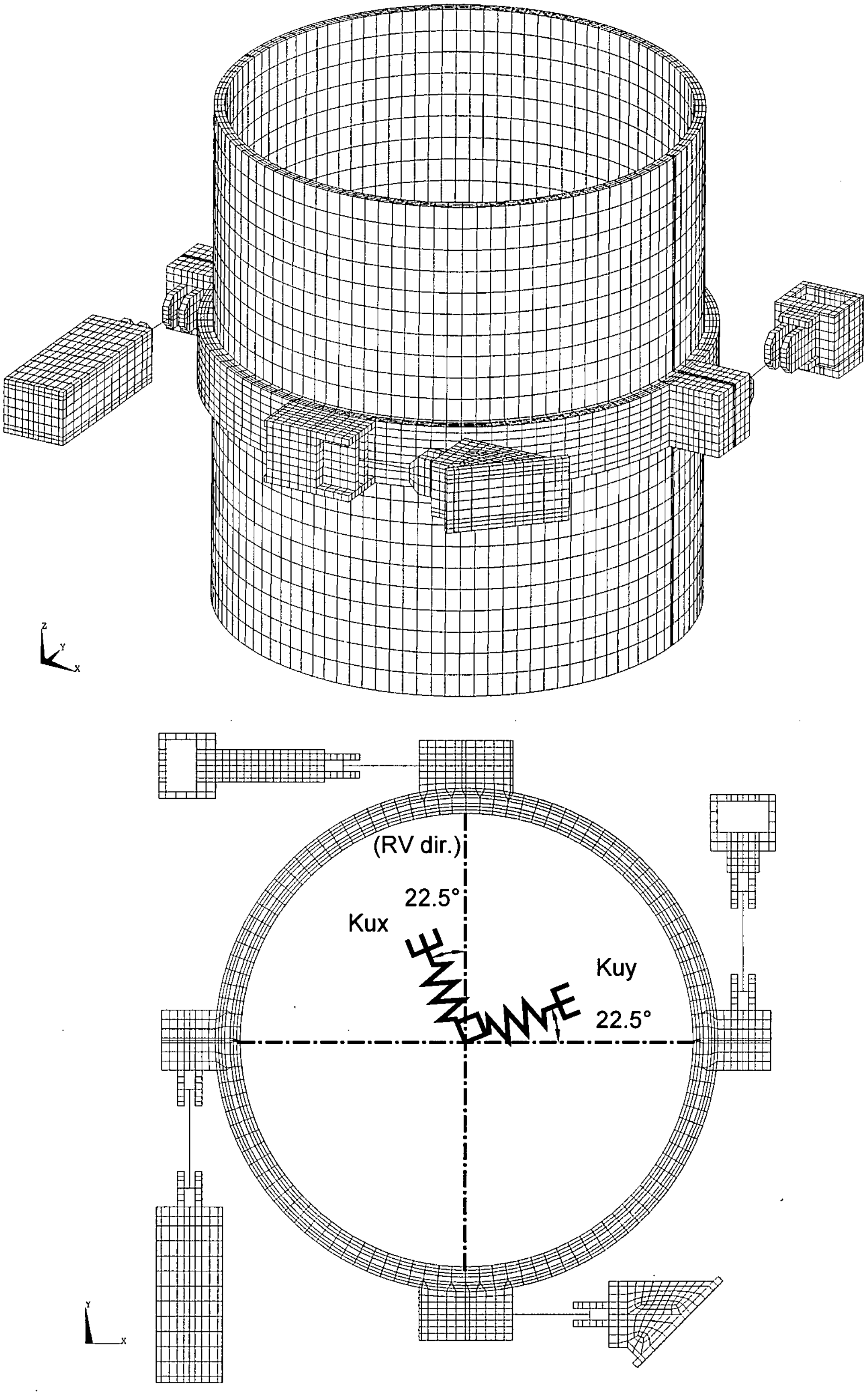

Figure 1 - Spring Model of SG Upper Shell Support

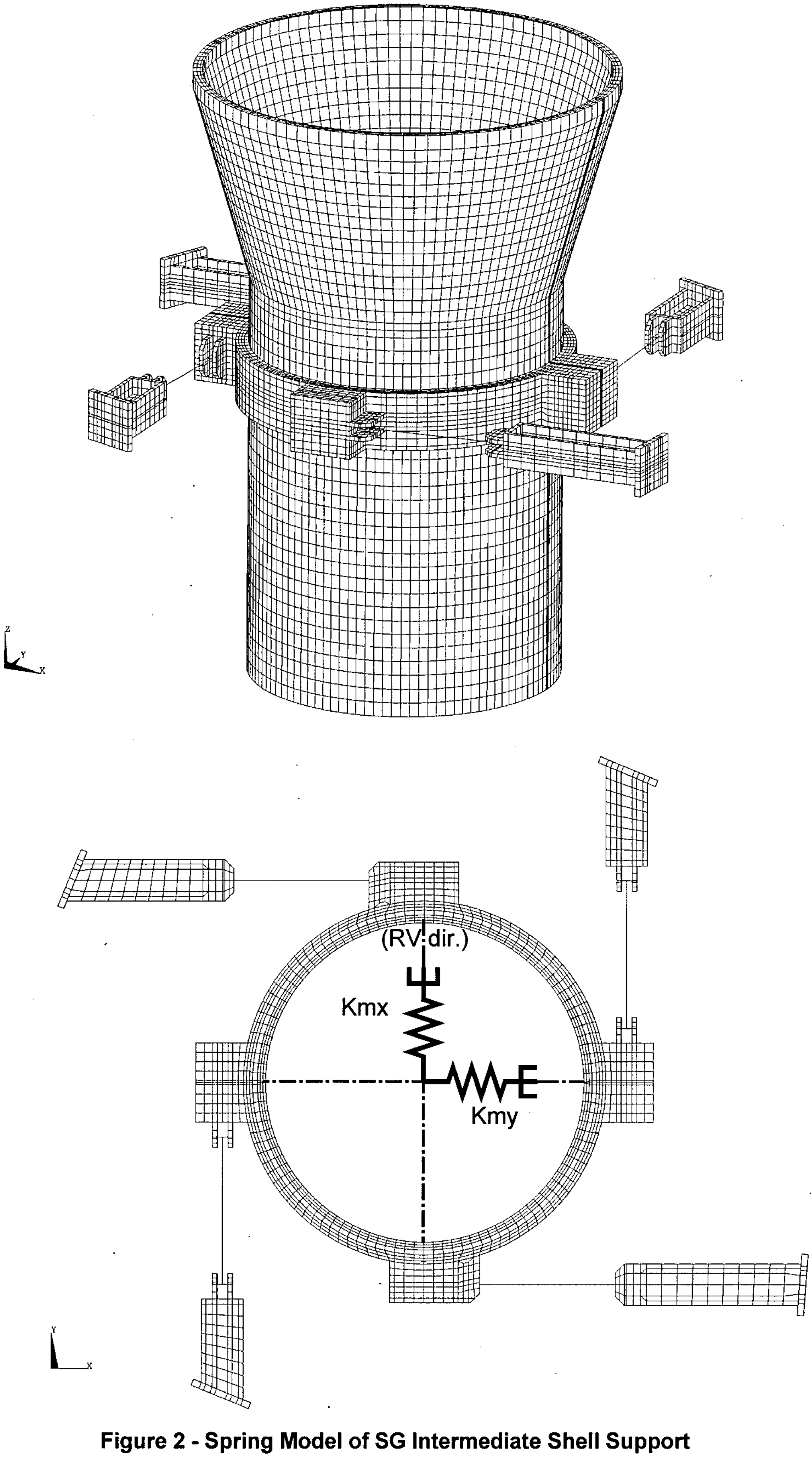

Figure 2 - Spring Model of SG Intermediate Shell Support

(4) The procedure and methodology of modeling the SG component supports is provided in Technical Report, MUAP-08005, Dynamic Analysis of the Coupled RCL-R/B-PCCV-CIS Lumped Stick, Rev. 0, Section 6.2.

(5) The natural frequency of the SG shell is 10.58 Hz in the NS direction and 10.73 Hz in the EW direction. These are presented in Table 8-3 of Technical Report, MUAP-08005, Rev. 0. The dominant frequencies of the tube bundle are lower than this. Relative to the dominant frequencies of the upper internals structure, they are greater than the SG shell. This allows the SG upper internals structure to be evaluated using a model that is decoupled from the SG shell. The compatibility of the decoupling criteria of SRP 3.7.2 may be discussed in more detail during the planned NRC visit to MHI.

Impact on DCD

There is no impact to 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

4/30/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 214-1920**
SRP Section:	**03.09.02 – Dynamic Testing and Analysis of Systems Structures and Components**
APPLICATION SECTION:	**3.9.2.2**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-36

In reference to DCD Tier 2, Section 3.9.2.2.2, regarding RCL seismic analysis, the staff requests MHI to address the following, in regard to a seismic analysis of the RPV and its internals:

(1) Clarify whether a separate seismic analysis for the RPV and its internals is performed. If not, explain why it is not needed. If yes, provide additional information for items (2) through (6).

(2) For the RPV and its internals, discuss their isolated structural model in detail. This should include RPV pressure boundary, CRDMs, CRDM nozzles, closure head equipment (CHE), lower internals, upper internals, and fuel assemblies.

(3) Discuss how the hydrodynamic coupling of the RPV shell to the core barrel (CB) shell and of the CB to the heavy reflector (HR) is simulated in the RPV isolated structural model.

(4) Discuss how local flexibility of the RPV shell at the primary nozzle connections is accounted for in the model.

(5) Discuss how RPV component supports are modeled.

(6) Provide the natural frequencies and mode shapes (including their graphical representation) obtained for the RPV and its internals, and, based on that, discuss the adequacy of their respective modeling.

ANSWER:

MHI responses to the sub-questions (1) through (6) on RCL seismic analysis are as follows:

(1) The seismic analysis of the reactor vessel and the reactor internals was performed as described in Subsection 3.9.2.5 of the DCD.

(2) through (6): The analysis model and its validation is described in DCD Subsection 3.9.2.5 and is also addressed in the responses to RAI 207-1577.

Impact on DCD

There is no impact to the DCD.

Impact on COLA

There is no impact on COLA.

Impact on PRA

There is no impact on PRA.

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DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-37

In DCD Tier 2, Section 3.9.2.2.6, MHI states that modal responses are combined by the methods described in DCD Section 3.7.3.5, when the response spectrum method of analysis is used. The staff requests the applicant to confirm that for mechanical components, modal responses are combined by one of the RG 1.92, Rev. 2, methods. Demonstrate also that the 10% grouping method (using SRSS) for combining closely-spaced modes, in the seismic and dynamic analysis of APWR mechanical components, complies to the guidelines provided in RG 1.92, Rev. 2, Section C.1.1.1.

ANSWER:

This question was answered in the response to RAI 212-1950, question 3.7.2-26.

Impact on DCD

Please see the response to RAI 212-1950, question 3.7.2-26.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.9.2.2**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-38

In DCD Tier 2, Section 3.9.2.2.8, MHI states that generally the equipment supported at two or more locations with distinct seismic input uses upper bound of envelop of all the individual response spectra for those locations. The staff requests the applicant to clarify if the uniform support motion (USM) method of analysis used for USAPWR equipment and components is in accordance with the requirements of SRP 3.9.2.II.2.G.

ANSWER:

SRP 3.9.2.II.2.G addresses the response spectrum envelope method and time history approach to multiple-supported systems. It describes the application methods of response spectra and maximum relative support displacement.

As stated in Subsection 3.9.2.2.8, equipment supported at two or more locations with distinct seismic input, uses the upper bound of the envelop of all individual response spectra for these locations. This Uniform Support Motion method is also described in Subsection 3.7.3.1.7.1.

As discussed in Subsection 3.12.3.2.6, the analysis of seismic anchor motions (i.e., maximum relative support displacement), is performed as a static analysis with all dynamic supports active and the results of this analysis are combined with the piping system seismic inertia analysis results by absolute summation. This approach for piping systems is the same for equipment and components.

Subsections 3.9.2.2.8 and 3.7.3.1.7 will be revised as described below to provide clarification with respect to the application of the time history approach used for select equipment (e.g., RCS components).

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.9, Revision 2, changes to be incorporated:

- Change the text after the first sentence of the second paragraph of Subsection 3.9.2.2.8 to read: "The analysis of seismic anchor motions (i.e., maximum relative support displacement), is performed as a static analysis with all dynamic supports active and the results of this analysis are combined with the piping system seismic inertia analysis results by absolute summation. For select equipment (e.g., RCS components), the time history approach using a coupled model with supported structures is applied."

See Attachment 2 for the mark-up of DCD Tier 2, Section 3.7, Revision 2, changes to be incorporated:

- Add the following paragraph after the last sentence in Subsection 3.7.3.1.7:

  "For select equipment (e.g., RCS components), the time history approach using a coupled model with supported structures is applied."

- Insert the following text after the third sentence of the first paragraph of Subsection 3.7.3.1.7.1: "The analysis of seismic anchor motions (i.e., maximum relative support displacement), is performed as a static analysis with all dynamic supports active and the results of this analysis are combined with the piping system seismic inertia analysis results by absolute summation."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-39

In DCD Tier 2, Section 3.9.2.2.13, MHI states that the damping values used for seismic analysis are consistent with RG 1.61, Rev. 1. The staff requests the applicant to provide a list of damping values used for each of the major mechanical components analyzed, and justify that the damping values used are consistent with the recommendation of RG 1.61, Rev. 1. Provide the basis of assigning a 5% damping value for control rod drive mechanisms, as shown in DCD Tier 2, Table 3.7.3-1(a).

ANSWER:

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%, not 5%.

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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APPLICATION SECTION:	**3.9.2.2**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-40

In DCD Tier 2, Section 3F.1.2, for seismic Category II conduit systems, MHI states that these conduit systems, including support anchorages, are analyzed and designed by the COL applicant for the site SSE using the same methods and stress limits specified for seismic Category I structures and subsystems, except structural steel in-plane stress limits are permitted to reach 1.0 F_y. Clarify where in DCD this COL information item is described.

ANSWER:

Site-specific seismic category II (and I) structures, systems, and components (SSCs) are designed by the COL Applicant. These include subsystems such as conduits, cable trays, and ducts whose design is dependent on the in-structure response spectra developed for the building structure to which the subsystems are mounted. This process is described collectively by COL items 3.7(3), 3.7(4), 3.7(21), 3.7(26), 3.8(15), and 3.8(19).

The site-specific SSE is developed by the COL Applicant from the site-specific ground motion response spectra (GMRS) and foundation input response spectra (FIRS). The site-specific SSE is increased if necessary to envelope the minimum response spectra required by 10 CFR 50 Appendix S. This process is described collectively by COL items 3.7(5), 3.7(6), 3.7(22), 3.7(24), 3.7(26), and 3.7(30). Note that for conduit, cable tray, and duct subsystems located in standard plant buildings, the in-structure response spectra (ISRS) used will be based on the CSDRS. If located in site-specific buildings and structures, the conduit, cable tray, and duct subsystem seismic design will be based on the site-specific SSE.

The terminology "reach 1.0 F_y" may be misinterpreted, and the DCD has been revised to clarify this statement in Section 3F.1.2, and similar statements in Sections 3A.1.2 and 3G.1.2, in the response to related question 3.8.1-14, item 3 in RAI 223-1996. The response to RAI 223-1996 revises Table 3.8.4-4 of the DCD to state that the stress limit coefficient applicable to axial and bending stresses is 1.7, with the allowable stress not to exceed 1.0 F_y for structural steel of seismic category II subsystems (such as conduit, cable tray, and duct subsystems) for load combinations 7 through 11 in Table 3.8.4-4. This general acceptance criterion is sufficient to demonstrate position retention, has been applied to all seismic category II SSCs, and does not differentiate between standard versus site-specific designs.

Impact on DCD

See the response to RAI 223-1996, question 3.8.1-14, item 3, for the 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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DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO.: RAI 03.09.02-41

In DCD Tier 2, Section 3F.4.2 and Section 3G.4.2, respectively, for response spectrum modal analysis of conduit systems and cable tray systems, MHI states that the conduit systems and cable tray systems can be analyzed using the envelope broadened response spectra methods, considering uniform support motion, or the independent support motion method. The staff requests MHI to address the following:

(1) Clarify whether the proposed USM and ISM methods of analysis conform to the guidance provided in SRP 3.9.3.II.2.G and NUREG-1061, Vol.4, respectively.

(2) For the design analysis of conduit and cable tray systems, using the damping values as proposed in DCD Tier 2, Table 3.7.3-1(a), demonstrate that the modal combination methods used, including that for closely-spaced modes, are in accordance with the guidance of RG 1.92, Rev. 2.

ANSWER:

(1) The proposed USM method of analysis for conduit system and cable tray systems as stated in DCD Tier 2 Subsections 3.F.4.2 and 3G.4.2, respectively, conform to the guidance provided in SRP 3.9.2.II.2.G and SRP 3.7.3.II.9 (referenced by SRP 3.9.2.II.2.G for additional design criteria).

A similar, related question on the ISM method of analysis was made by the NRC Staff in RAI 213-1951, Revision 1, question 3.7.3-01. The proposed ISM method of analysis, if used on the US-APWR for conduit and cable tray systems as stated in DCD Tier 2 Subsections 3.F.4.2 and 3G.4.2, respectively, conform to the guidance and criteria provided in NUREG-1061, Vol. 4. The acceptance criteria in SRP 3.9.2.II.2.G and SRP 3.7.3.II.9 referenced this document, NUREG-1061, Vol. 4, Chapter 2 for requirements/ recommendations when the ISM method is used. MHI's commitment for compliance to NUREG-1061, Vol. 4 ISM requirements/ recommendations was made in our response to NRC Staff's original submitted question on the ISM method via question 3.7.3-01.

(2) The NRC in their previously submitted related RAI 212-1950 Question 3.7.2-26 requested additional information on combining modal responses in a response spectrum method of analysis. The following provided response to Question 3.7.2-26 is also applicable to the design analysis of conduit and cable tray systems using the response spectrum method:

> "It is the intent of the US-APWR DCD to always meet the requirements of RG 1.92 Revision 2 or Revision 1 (where permitted by Revision 2) for combining modal responses. As stated in the third paragraph of Section 3.7.2.7, when response spectra methods of analysis are used, the combination of modal responses is done by one of the methods in Regulatory Guide 1.92 Revision 2 or by the 10% grouping method (as contained in Revision 1 of RG 1.92 and as permitted in Revision 2 of RG 1.92). In some applications, the more conservative methods contained in Revision 1 of RG 1.92 are also used as permitted in Revision 2 of RG 1.92."

Impact on DCD

See MHI's responses to RAI 213-1951, Revision 1, question 3.7.3-01 and RAI 212-1950, question 3.7.2-26 for impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

This completes MHI's responses to the NRC's questions.

3.7.1.1 and Subsection 3.10.2. For piping analysis, the guidance in SECY-93-087 is used and the number of earthquake cycles to consider is defined in Section 3.12, Table 3.12-2, Note 3.

3.9.2.2.4 Basis for Selection of Frequencies

To avoid resonance, the fundamental frequencies of components and equipment should be preferably less than one half or more than twice the dominant frequencies of the forcing frequencies of the support structure. When the equipment frequencies are within this range, the equipment must be designed for the applicable loads.

3.9.2.2.5 Three Components of Earthquake Motion

The combination of three components of earthquake motion is dependent on the method used in the seismic analysis and is in accordance with "Combining Modal Responses and Spatial Components in Seismic Response Analysis", RG 1.92, Rev.2 (Reference 3.9-18) as discussed in Subsection 3.7.3.4.

For piping analysis, the three sets of mutually orthogonal components of earthquake motion are combined by the SRSS method per RG 1.92, Rev.1 (Reference 3.9-19), as discussed in Subsection 3.12.3.2.

3.9.2.2.6 Combination of Modal Responses

Combination of modal responses is applicable when the response spectrum method of analysis is used, because the phase relationship between various modes is lost and only the maximum responses for each mode are determined. Modal responses are combined by the methods described in Subsection 3.7.3.5.

For piping analysis, the guidance on combining the individual modal results in RG 1.92, Rev. 1 (Reference 3.9-19) is used as discussed in Subsection 3.12.3.2.

3.9.2.2.7 Analytical Procedures for Piping

For seismic category I piping and seismic category II piping, the seismic analysis methods are provided in Subsection 3.12.3.

3.9.2.2.8 Multiple-Supported Equipment Components with Distinct Inputs

For equipment and components supported at several points by either a single structure at different elevations, or by two separate structures, the methods used to account for the different input motions are described in Subsection 3.7.3.1.

Generally, equipment supported at two or more locations with distinct seismic input uses upper bound of envelop of all the individual response spectra for these locations. The analysis of seismic anchor motions (i.e., maximum relative support displacement), is performed as a static analysis with all dynamic supports active and the results of this analysis are combined with the piping system seismic inertia analysis results by absolute summation. For select equipment (e.g., RCS components), the time history approach using a coupled model with supported structures is applied.~~For some equipment (e.g., RCS components), a coupled model with supported structures is used.~~

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The results of these separate seismic analyses are then enveloped to obtain the final result desired (e.g., stress, support loads, acceleration) at any given point in the system. If three different ISRS curves are used to define the response in the two horizontal and the vertical directions, then the shifting of the spectral values, as defined above, may be applied independently to these three response spectra curves.

3.7.3.1.7 Multiple Support Response Spectra Input Methods

The uniform support motion method and the independent support motion methods use multiple-input response spectra which account for the phasing and interdependence characteristics of the various support points. These methods are based on the guidelines provided by the "Pressure Vessel Research Committee Technical Committee on Piping Systems" (Reference 3.7-38) and have been most often applied to plant piping subsystems but are also applicable to other subsystems with multiple support points.

For select equipment (e.g., RCS components), the time history approach using a coupled model with supported structures is applied.

3.7.3.1.7.1 Uniform Support Motion Method

For analyzing plant SSCs supported at multiple locations within a single structure, a uniform response spectrum is defined that envelopes all of the individual response spectra at the various support locations. The uniform response spectrum is applied at all support locations to calculate the maximum inertial responses of the plant SSCs. This is referred to as the uniform support motion method. Modal combinations for this method including missing mass computations must be performed in accordance with RG 1.92, Rev. 2 (Reference 3.7-27). The analysis of seismic anchor motions (i.e., maximum relative support displacement), is performed as a static analysis with all dynamic supports active and the results of this analysis are combined with the piping system seismic inertia analysis results by absolute summation. The seismic response spectrum, which envelopes the supports, is used in place of the spectra at each support in the envelope uniform response spectra. The contribution from the seismic anchor motion of the support points is assumed to be in phase and is added algebraically as follows:

$$q_i = d_j \Sigma P_{ij} d_{ij}$$

where

q_i = combined displacement response in the normal coordinate for mode i

d_j = maximum value of d_{ij}

d_{ij} = displacement spectral value for mode i associated with support j

P_{ij} = participation factor for mode i associated with support j

Σ = summation for support points from j = 1 to N

N = total number of support points

The enveloped response spectra are developed as the seismic input in three perpendicular directions of the coordinate system to include the spectra at all floor elevations of the attachment points and the piping module or equipment, if applicable.