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April 24, 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-09189

Subject: MHI's Responses to US-APWR DCD RAI No. 213-1951

Reference: 1) "Request for Additional Information No. 213-1951 Revision 1, SRP Section: 03.07.03 – Seismic Subsystem Analysis, Application Section: 03.07.03," dated 2/25/2009.
2) "MHI's Responses to US-APWR DCD RAI No. 213-1951, UAP-HF-09114, dated 3/27/2009.

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. 213-1951, Revision 1."

Enclosed are the responses to the remaining 6 RAIs contained within Reference 1. Nine additional RAI responses contained within Reference 1 were previously provided in Reference 2.

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.

Enclosure:

1. Responses to Request for Additional Information No. 213-1951, Revision 1

D081
NRO

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

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Enclosure 1

UAP-HF-09189
Docket No. 52-021

Responses to Request for Additional Information No. 213-1951,
Revision 1

April, 2009

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

4/24/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 213-1951 REVISION 1**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**03.07.03**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.3-03:

In Section 3.7.3.1.2 of the DCD reference is made to ASCE 4-98 for determining equivalent static load base shear and moment for structures that are modeled as cantilever beams with uniform mass distribution. The staff has not reviewed and endorsed ASCE 4-98 for this application. Currently this ASCE standard is under revision. Provide bases and technical justification for the proposed factors used to determine base shear and base moment.

ANSWER:

The seismic response of cantilever beams with uniform mass distribution is dominated by a single mode such that multi-modal effects do not significantly contribute to the overall response amplitude. The equivalent static base shear factor of 1.0 and base moment factor of 1.1 for cantilever beams with uniform mass distribution, which are proposed in Section 3.7.3.1.2 of the DCD and cited in ASCE 4-98, are based on previous research and analysis. The following references provide justification for use of equivalent static factors that are either less than or equal to those discussed in ASCE 4-98:

> Stevenson, J. D. and W. S. Lapay, "Amplification Factors to be used in Simplified Seismic Dynamic Analysis of Piping System," Proceedings, American Society of Mechanical Engineers, 1974
>
> Czarnecki, R. M., et al, "Justification for a Static Coefficient of 1.0," in Seismic Verification of Nuclear Plant Equipment Anchorage, EPRI NP-5228-SL, Revision 1, Volume 1, 1991
>
> Niehoff, Dennis and Gurbuz, Orhan, "Multi-Mode Factor for Cantilevered Structures with Variable Mass and Stiffness," Bechtel Technical Paper, Bechtel Corporation, San Francisco, California, 2007

The above references provide the basis for the DCD reference to ASCE 4-98 for this particular application. For clarification, the text of Subsection 3.7.3.1.2 will be modified in Revision 2 of the DCD to add the term "single mode dominant" since the discussion also applies to structures and components that are single mode dominant.

Impact on DCD

See Attachment 1 for a mark-up of DCD Tier 2, Section 3.7, Revision 2, changes to be incorporated:

- Change the heading for Subsection 3.7.3.1.2 to the following:

  "**3.7.3.1.2 Single DOF, Single Mode Dominant, or Rigid Structures and Components**"

- Change the first paragraph of Subsection 3.7.3.1.2 to the following:

  "For rigid structures and components, single DOF structures and components, or for cases where the response is such that the response of the system is single mode dominant, the following procedures may be used:"

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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4/24/2009

US-APWR Design Certification

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Docket No. 52-021

RAI NO.:	**NO. 213-1951 REVISION 1**
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APPLICATION SECTION:	**03.07.03**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.3-04:

In Section 3.7.3.1.2 of the DCD, provide bases and justification for using a factor of 1.0 for the equivalent static seismic load for simply-supported, fixed-simply supported, or fixed-fixed beams configurations independent of their frequency calculations.

ANSWER:

Application of the factor of 1.0 to determine equivalent static load for single mode dominant simply-supported, fixed-simply supported, and fixed-fixed beams, regardless of their frequency, is based on the provisions discussed in Section 3.7.3.1.2 of the DCD. Further discussion of this application and its bases and justification is provided as follows.

The equivalent static load is computed using a factor 1.0 multiplied by an appropriate acceleration value. The acceleration value is taken as the acceleration value from the applicable in-structure response spectra (ISRS) that corresponds to the frequency of the beam. However, if the frequency of the beam is calculated to be below the frequency corresponding to the peak ISRS acceleration, then the peak ISRS acceleration times the 1.0 factor is used. If the beam frequency is not calculated, then the peak acceleration obtained from the applicable ISRS times the 1.0 factor is also used. The third bullet of DCD Section 3.7.3.1.2 will be changed to provide clarify this process.

The justification of the factor 1.0 for all the above conditions of simply-supported, fixed-simply supported, and fixed-fixed beams, regardless of frequency, is based on the DCD References 3.7-36 and 3.7-37 cited in the third bullet of Subsection 3.7.3.1.2. This justification is similar to the justification discussed in the response to Question RAI 3.7.3-03 above, where several references for equivalent static factors are cited. Using an equivalent static factor less than 1.5 is justified when the response is dominated by a single mode such that multi-modal effects do not significantly contribute to the overall response amplitude.

Impact on DCD

See Attachment 1 for a mark-up of DCD Tier 2, Section 3.7, Revision 2, changes to be incorporated:

- Change the last two sentences of the third bullet in Subsection 3.7.3.1.2 to the following: "If the frequency of a structure, equipment, or component is not determined, the peak acceleration from the applicable ISRS times a factor of 1.5 is used, unless a lower factor is applicable as discussed herein or otherwise justified. Any structures, equipment, or components which have been determined to have natural frequencies less than the frequency corresponding to the peak floor acceleration (i.e., whose natural frequencies are to the left of spectra peak on an acceleration versus the frequency spectra plot) also utilize the peak acceleration times a factor of 1.5 unless a lower factor is applicable as discussed herein or as otherwise justified."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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Docket No. 52-021

RAI NO.:	**NO. 213-1951 REVISION 1**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.3-06:

In Section 3.7.3.1.6 of the DCD, a seismic response peak shifting method is discussed. This method is not addressed in the SRP guidance or in RG 1.122. Provide bases and technical justification for the use of the seismic response peak shifting method.

ANSWER:

The peak shifting method in Subsection 3.7.3.1.6 of DCD is the same method as discussed in subparagraph N-1226.3 of non-mandatory Appendix N of the ASME Code, Section III. ASME Code Case N-397 addresses alternative rules to spectral broadening including the peak shifting method. RG 1.84 Table 4 states that Code Case N-397 is acceptable for specific plant applications on a case-by-case basis pending revision to RG 1.122. The technical justification of the peak shifting method instead of the peak broadened method is also provided in the Pressure Vessel Research Council in WRC Bulletin 300, "Technical Position on Response Spectra Broadening."

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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Docket No. 52-021

RAI NO.:	**NO. 213-1951 REVISION 1**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.3-12:

Provide details of the methods used to consider torsional effects in the seismic analysis of category I subsystems. This information is required in accordance with SRP Section 3.7.3.I.11 to review the design adequacy of subsystems and equipment.

ANSWER:

US-APWR DCD Subsection 3.7.3 deals only with the seismic category I SSCs, except for mechanical piping design and mechanical systems. Torsional effects affecting the mechanical piping design and mechanical systems, components and equipment are described and addressed in the US-APWR DCD Subsections 3.12.4.2 and 3.9.2.2.10, respectively. This RAI response addresses only torsional effects on seismic category I SSCs covered by Subsection 3.7.3.

The major subsystems where torsional effects may need to be considered are the following:

- HVAC ducts and duct supports. The design of HVAC ducts and duct supports is addressed in Appendix 3A of the US-APWR DCD.
- Conduits and conduit supports. The design of conduits and conduit supports is addressed in Appendix 3F of the US-APWR DCD.
- Cable trays and tray supports. The seismic qualification of cable trays and tray supports is addressed in Appendix 3G of the US-APWR DCD.
- Structures such as miscellaneous steel platforms, which serve as maintenance platforms or support structure for small miscellaneous equipment.

These subsystems are accounted for in the global seismic models of the seismic category I building structures described in Subsection 3.7.2.3 by considering the mass and mass distribution of the subsystems in the models. However, seismic analysis of the subsystems has generally been performed separately from the building model at a second level because the subsystems do not significantly contribute to the building stiffness and because the seismic responses of the buildings serve as the seismic design input load (ISRS or time-history) for the subsystems. The torsional effects of the subsystems are accounted for at this second level when a detailed seismic subsystem analysis is conducted.

One of the following three methods is used to perform the seismic analysis of the above subsystems:

- Equivalent static method (described in Section 3.7.3.1.1 of the US-APWR DCD)
- Response spectrum method (described in Sections 3.7.3.1.3, 3.7.3.1.4, 3.7.3.1.5 and 3.7.3.1.7 of the US-APWR DCD.)
- Time-history method (described in Section 3.7.3.1 of the US-APWR DCD)

Due to the practical considerations, the time-history method is seldom used. The equivalent static method is often used but when more accurate analysis is desired, the response spectrum method is employed.

The torsional effects of commodities (HVAC ducts, cable trays, conduits, etc.) supported as subsystems are accounted for in their design. The analysis is performed in such a way that it accounts for various torsional effects:

(i) *Structure-Commodity Interaction:* It accounts for the effects of the eccentricity caused by the commodity and its supports. This can be achieved in various ways depending upon the commodity and the structural configuration; for example, transferring seismic forces at interface points, creating link(s) between the centroid of the commodity and effected structural member(s) of the mathematical model, etc.

(ii) *Torsional Effects Due to Shear Center Eccentricity:* Torsional effects due to eccentricity between applied load and shear center of the supporting structural member is accounted for in the mathematical model.

(iii) *Torsional Effects of Eccentric Masses:* The eccentricity caused by attached concentrated masses of auxiliary items (or accessories). These torsional effects, in general, are caused by accessories (e.g., pressure sensors, temperature sensors, dampers, etc.) attached to commodities and their supports. The torsional effect, if insignificant due to small accessory weight or eccentricity, can be neglected.

The DCD will be clarified by discussing the torsional effects on seismic category I subsystems. A new paragraph will be added in Subsection 3.7.3.1 during Revision 2 of the DCD.

Impact on DCD

See Attachment 1 for a mark-up of DCD Tier 2, Section 3.7, Revision 2, changes to be incorporated:

- Insert the following as the fourth paragraph in Subsection 3.7.3.1:

  "Torsional effects due to the significant effect of eccentric masses connected to a subsystem are included in the subsystem analysis. For rigid components (i.e., those with natural frequencies greater than the ZPA cutoff frequency of 50 Hz), the lumped mass is modeled at the center of gravity of the component with a rigid link to the appropriate point in the subsystem. For flexible components having a frequency less than the ZPA, the subsystem model is expanded to include an appropriate model of the component."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. RAI 3.7.3-14:

Describe the criteria used to confirm the adequacy of the number of discrete mass degrees of freedom for the reactor coolant loop (RCL) subsystem model discussed in Appendix 3C and in Reference 3.7-18 of the DCD. The SRP Subsection 3.7.2.II.1.A (iv) provides an acceptable method to the staff.

ANSWER:

The seismic analysis of the US-APWR reactor coolant loop (RCL) is conducted using the standardized modeling methodology that is verified by the seismic proving test program sponsored by the Ministry of International Trade and Industry (MITI) of Japan. As part of this seismic proving test program on the seismic reliability for the PWR primary coolant loop system (RCS) (Reference: ASME PVP- Vol. 182, Seismic Engineering, Coordinating Editors: T.H. Liu, and F. Hara, Book No. H00497-1989), shaking table tests were performed on scale physical models of the PWR RCS at the Nuclear Power Engineering Test Center (NUPEC) Tadotsu Engineering Laboratory in Japan. The test results include measurements of vibration modes and various levels of seismic responses obtained from shaking table tests with four input earthquake motions. The correlation of these test results to the dynamic model analyses results confirms that the RCL lumped mass stick model used for seismic response analyses adequately captures the dynamic response of the RCL and therefore meets the intent of SRP 3.7.2.II.1.A (iv).

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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QUESTION NO. RAI 3.7.3-15:

In DCD Section 3.7.3.1.3, the applicant proposed that subsystems with multiple dynamic degrees of freedom (MDOF) can be analyzed by an equivalent static load method in which the seismic demand is determined using 1.5 times the peak acceleration from the applicable ISRS. The concern is the potential for misapplication of the equivalent static load method. This typically arises during equipment qualification when the dynamic models of subsystems do not contain sufficient detail to produce an applicable ISRS at an appropriate point (e.g., valve) in the system. Moreover, the static methodology does not check for closely-spaced modes that can cause additional amplification in the MDOF system. The guidelines in SRP Section 3.7.2.II.1.B, state that in order to use an equivalent static load method to calculate seismic demands on SSCs, justification must be provided that the system or subsystem can be realistically represented by a simple model, and that the method produces conservative results in terms of responses.

Provide the criteria and justification for MDOF subsystems that will be analyzed by an equivalent static load method, and demonstrate that this method will produce conservative results. Also, in the absence of any ISRS for these subsystems, discuss the methodology to analyze the seismic response of the safety-related components (such as valves, electrical equipment) in such subsystems.

ANSWER:

For the purposes of equivalent static analysis, simple models can be considered to be simple linear frame-type structures/components consisting of members that are physically similar to beams and columns. When obtaining an equivalent static load for a SSC, the DCD Subsection 3.7.3.1.3 states to use a static load factor of 1.5 applied to the peak accelerations of the applicable In-Structure Response Spectra (ISRS) unless a lower factor is justified, which is permitted by SRP subsection 3.7.2.II.1.B. Examples of using the equivalent static analysis method are presented in Appendices 3A, 3F and 3G for seismic qualifications of HVAC ducts and their supports, conduits and their supports, and cable trays and their supports respectively. In these Appendices, the equivalent static loads are determined using 1.5 times the peak acceleration from the applicable ISRS. Similarly, the equivalent static load method of analysis is used for small-bore piping as described in DCD Subsection 3.12.3.6.

When the in-line safety-related component is rigid (larger than 50 Hz) and can be seismically qualified by analysis, the equivalent static loads determined by using 1.5 times the peak acceleration of the ISRS applicable to the subsystems or the acceleration at the mounting location from the dynamic analysis of the subsystem can be used for the in-line equipment seismic qualification. Otherwise, ISRS at the equipment mounting location is required for equipment seismic qualification in accordance with DCD Section 3.10.

In the absence of ISRS for subsystems such as piping or duct, line-mounted equipment may be seismically qualified for generic levels of required input motion (RIM) of 6.0g horizontal and 6.0g vertical, as discussed in Subsection 3.10.2.1.1 of the DCD. Where this generic RIM is used for equipment qualification, its suitability for the specific application will be confirmed during the detailed design.

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.

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

aboveground tanks, and the like, which are exterior to the R/B, PCCV, PS/Bs, and the ESWPT.

Seismic and dynamic qualification of mechanical and electrical equipment and subsystems performed by testing is discussed in Section 3.10 and Appendix 3D. Mechanical subsystems include mechanical equipment, piping, vessels, tanks, heat exchangers, valves, and instrumentation tubing and tubing supports. The seismic analysis of mechanical subsystems is addressed in Sections 3.9 and 3.12. The RCL analysis is discussed in Appendix 3C.

A list of seismic category I mechanical and fluid systems, components, and equipment is given in Table 3.2-2. Seismic analysis of civil structural items related to those subsystems is discussed in this subsection.

3.7.3.1 Seismic Analysis Methods

Modal response spectra analysis, time history analysis, or equivalent static load analysis methods may be used for seismic analysis of seismic category I subsystems. The methods are the same as those discussed in Subsection 3.7.2.1 and conform to the requirements of SRP 3.7.1 and SRP 3.7.2 (References 3.7-10 and 3.7-16).

Time history analysis of seismic systems is discussed in Subsection 3.7.2. The time-history seismic analysis of a subsystem can be performed by simultaneously applying the displacements and rotations at the interface point(s) between the subsystem and the system. These displacements and rotations are the results obtained from a model of a larger subsystem or a system that includes a simplified representation of the subsystem.

The choice of applied seismic analysis method depends on the desired level of precision and the level of complexity of the particular subsystem being designed. The equivalent static load method of analysis is predominantly used for civil structure-related seismic subsystems and is generally the preferred method because it is relatively simple and at least as conservative as the other more detailed methods. For example, the equivalent static load analysis method is generally used for miscellaneous steel platforms, stairs, and walkways, reinforced masonry block walls and enclosures, HVAC ducts and duct supports, electrical tray and tray supports, and conduits and conduit supports.

Torsional effects due to the significant effect of eccentric masses connected to a subsystem are included in the subsystem analysis. For rigid components (i.e., those with natural frequencies greater than the ZPA cutoff frequency of 50 Hz), the lumped mass is modeled at the center of gravity of the component with a rigid link to the appropriate point in the subsystem. For flexible components having a frequency less than the ZPA, the subsystem model is expanded to include an appropriate model of the component.

The equivalent static load method of analysis and the various modal response spectra analysis methods are described in the following subsections.

3.7.3.1.1 Equivalent Static Load Method of Analysis

The equivalent static load method involves the use of equivalent horizontal and vertical static forces applied at the center of gravity of various masses. The equivalent force at a mass location is computed as the product of the mass and the seismic acceleration value applicable to that mass location. Loads, stresses, or deflections obtained using the equivalent static load methods are adjusted to account for the relative motion between points of support when significant.

3.7.3.1.2 Single DOF, Single Mode Dominant, or Rigid Structures and Components

For rigid structures and components, single DOF structures and components, or for cases where the response is such that the response of the system ~~has a~~ is single ~~DOF~~ mode dominant, the following procedures may be used:

- For rigid SSCs (fundamental frequency greater than 50 Hz), an equivalent seismic load is defined for the direction of excitation as the product of the component mass and the ZPA value obtained from the applicable ISRS.
- A rigid component (fundamental frequency greater than 50 Hz), whose support can be represented by a flexible spring, can be modeled as a single DOF model in the direction of excitation (horizontal or vertical directions). The equivalent static seismic load for the direction of excitation is defined as the product of the component mass and the seismic acceleration value corresponding to the natural frequency of the support from the applicable ISRS. If the frequency is not determined, the peak acceleration from the applicable ISRS times a factor of 1.5 is used. Supports which have been determined to have natural frequencies less than the frequency corresponding to the peak floor acceleration (i.e., whose natural frequencies are to the left of spectra peak on an acceleration versus the frequency spectra plot) also utilize the peak acceleration times a factor of 1.5.
- If the structure, equipment, or component has a distributed mass whose dynamic response is single mode dominant, the equivalent static seismic load for the direction of excitation is defined as the product of the component mass and the seismic acceleration value at the component natural frequency from the applicable ISRS times a factor of 1.5, with exceptions noted as follows. A factor of less than 1.5 may be used if justified, such as using a factor of 1.0 when the component natural frequency is in the rigid range (greater than 50 Hz), such that no dynamic amplification will occur. A factor of 1.0 is used for structures or equipment that can be represented as simply supported, fixed-simply supported, or fixed-fixed beams as discussed in References 3.7-36 and 3.7-37. In accordance with ASCE 4-98, Subsection 3.2.5.2 (Reference 3.7-9), for cantilever beams with uniform mass distribution, the equivalent-static-load base shear is determined using the peak acceleration, and the base moment is determined using the peak acceleration times a factor of 1.1. If the frequency of a structure, equipment, or component is not determined, the peak acceleration from the applicable ISRS times a factor of 1.5 is used, unless a lower factor is applicable as discussed herein or otherwise justified. Any structures, equipment, or components which have been determined to have natural frequencies less than the frequency corresponding to the peak floor acceleration (i.e., whose natural frequencies are to the left of spectra peak on an acceleration versus the frequency spectra plot) also utilize the peak acceleration times a factor of 1.5 unless a lower factor is applicable as discussed herein or as otherwise justified.

3.7.3.1.3 Multiple DOF Response