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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-11347

Subject: Second MHI's Response to US-APWR DCD RAI No. 799-5877 Revision 3 (SRP 03.07.03)

Reference: 1) "Request for Additional Information No. 799-5877 Revision 3, SRP Section: 03.07.03 – Seismic Subsystem Analysis," dated 08/05/2011
2) "MHI's Response to US-APWR DCD RAI No. 799-5877 Revision 3," UAP-HF-11297, dated 09/07/2011

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. 799-5877, Revision 3."

Enclosed are the responses to 3 RAIs contained within Reference 1. This transmittal, in addition to three RAI response previously provided in Reference 2, 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,

Y. Ogata

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

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NRO

Enclosure:

1. Response to Request for Additional Information No. 799-5877, Revision 3

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-11347
Docket No. 52-021

Response to Request for Additional Information No. 799-5877,
Revision 3

October, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/07/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 799-5877 REVISION 3**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**8/5/2011**

QUESTION NO. RAI 03.07.03-7:

In Subsection 3.7.3.1.7.1 of DCD (R3), "Uniform Support Motion Method", the first paragraph (page 3.7-50) states, "The contribution from the seismic anchor motion of the support points is assumed to be in phase and is added algebraically as follows:..." According to SRP Acceptance Criteria 9 of SRP 3.7.3, when analyzing equipment with multiple support points, the support displacements should be imposed on the supported equipment in the most unfavorable condition. The Applicant should demonstrate that assumption that the motion of the various support points is in phase is consistent with considering the effects of the various support points in the most unfavorable condition.

ANSWER:

NUREG 0800 SRP Acceptance Criteria 9 of SRP 3.7.3 addresses equipment and components supported at several points by either a single structure or two separate structures. In the Criteria 9 for two separate structures, the Uniform Support Motion method (USM) of DCD (R3), where support groups are in phase, does not apply. Alternatively, the Independent Support Motion method described in DCD Subsections 3.7.3.1.7.2, 3.12.3.3, and 3.12.3.2.6 may be used where support groups are combined by the absolute sum method. DCD Tier 2 Subsection 3.7.3.1.7.1 addresses analyzing plant SSCs supported at multiple locations within a single structure only. DCD Subsection 3.7.3.1.7.1 states that for the USM, 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 seismic anchor motion combinations of a particular mode of a single structure the response of the various support points is assumed in phase, consistent with the behavior of a mode. Thus, algebraically combining the responses from all of the supports in computing a modal response is realistic where the combinations of modal responses and spatial components is performed consistent with the methods of R.G. 1.92 as stated in DCD 3.7.3.1.7.1. Therefore, the USM is consistent with considering the effects of the various support points in the most unfavorable condition.

During the development of this response, a typographical error in the equation of Subsection 3.7.3.1.7.1 of DCD (R3), "Uniform Support Motion Method", was noted and will be corrected to remove the parameter d_{ij} located on the right side of the equation. It also is noted that RAI 810-5874 Question 03.07.03-108 item 4 identified the error in the Uniform Support Motion method formula of the DCD in Section 3.7.3.1.7.1.

Impact on DCD

See Attachment 1 for the markup of the DCD (R3) Tier 2, Sections 3.7 and 3.12, changes to be incorporated.

The formula within Subsection 3.7.3.1.7.1 of the DCD (R3) will be revised as indicated on the attached markup to remove the parameter d_{ij} located on the right side of the equation.

The first sentence of the third paragraph of Subsection 3.12.3.2.6 is revised to read as follows:

> "For piping supported by a single concrete building, the SAM at all elevations above the foundation basemat are considered to be out of phase unless justification is provided to show them to be in phase, or unless analyzed using the USM method or ISM method."

The first sentence of the fourth paragraph of Subsection 3.12.3.2.6 is revised to read as follows:

> "When supports are attached to different structures (within a building), the relative phasing characteristics retained from the building seismic analysis are used in the piping analysis considering the maximum relative movements between various supports to be out of phase, unless otherwise justified."

Impact on R-COLA

There is no impact on the COLA.

Impact on S-COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on a Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/07/2011

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

RAI NO.:	**NO. 799-5877 REVISION 3**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**8/5/2011**

QUESTION NO. RAI 03.07.03-10:

In Subsection 3.7.3.1 of DCD (R3), "Seismic Analysis Methods", the fourth paragraph (page 3.7-46) states in part, "The new translational time history at the interface location is generated by algebraic summation of the translational acceleration time history at the reference location and the time-history contribution arising from the rocking and torsional effects of the intervening structural element."

The Applicant is requested to explain how algebraic summation is performed for the translational time history and for the rocking and torsional time histories. If the different directions of excitation are analyzed separately, how will the results of the translational time histories be summed algebraically. The Applicant's response should address the analyses approach used with both the computer codes SASSI and ANSYS.

ANSWER:

This sentence was inserted into DCD (R3) as a response to RAI 493-3983 Revision 1 Question 03.07.03-5. This response supersedes that response by replacing its answer as follows:

The Applicant is fully aware of the fact that the effect of an intervening structural element has to be considered to appropriately use ISRS when the subsystem's support location is a distance away from the reference location of the ISRS. Depending on the degree of flexibility of the intervening structural element, the following basic approaches are adopted:

a) When the intervening structural element (e.g., wall between floors) is rigid (i.e., frequency > 50 Hz), the transformation effect due to the rigid body motion of the intervening structure can be taken into account at intermediate attachment locations by linear interpolation of upper and lower ISRS for the attachment location of the subsystem, provided the intervening structure between those locations (wall in this example) is rigid. Similarly, the transformation effect due to the rigid body motion of an intervening structure such as a slab can be taken into account by linear interpolation from responses at the slab corners or outrigger locations provided the slab is rigid. Alternatively, when the intervening structural element (e.g., consisting of a structure supporting a subsystem such as line-mounted equipment) is rigid (i.e., frequency > 50 Hz), the transformation effect due to the rigid body motion of the intervening structure can be taken into account by adding a rigid link to the subsystem model from its support locations to the reference location of the ISRS. Enveloping ISRS are provided at sufficiently close proximity to the subsystem attachment locations for walls and floors such that contributions arising from the structural rocking and torsional effects at the reference location of the ISRS have insignificant effect on the subsystem. Thus, for cases where the intervening structure is rigid, no translational time history will be obtained by algebraic summation of the translational acceleration time histories at the reference location with time history contributions arising from the structural rocking and torsional effects. In addition, if time histories are not available for cases where the intervening structure is rigid, no translational response spectra will be obtained by absolute summation of the translational accelerations at the reference location with contributions arising from the structural rocking and torsional effects.

b) When the intervening structural element is flexible (i.e., frequency < 50 Hz) or a time history input for analysis of a rigid or flexible SSC away from the reference location of the ISRS is preferred, a new time history and/or associated ISRS at the interface can be generated from a time history analysis of a decoupled model that includes the effects of mass and flexibility of the intervening structural element, provided the applicable decoupling criteria of SRP 3.7.2 Acceptance Criteria 3B or NOG1-2004 are met for the subsystem. The time history ANSYS analysis of a detailed decoupled model of the intervening structural element is performed using time history inputs from the SASSI analysis of the structure. When time histories of in-structure motions from dynamic analysis of the supporting soil-structure system are used frequency content of the time histories are varied to be consistent with the broadening of ISRS. An acceptable method to vary the frequency content of the in-structure accelerations time histories for the best estimate soil properties is by expanding and shrinking the time history within 1/(1 ± 0.15) so as to change the frequency content within ± 15%. For cases where the decoupling criteria of SRP 3.7.2 Acceptance Criteria 3B or Section 4153.2 of NOG1-2004 are not met, the seismic dynamic analysis of the subsystem is expanded to include the intervening structural element. Alternatively, instead of generating a new time history or new ISRS, the seismic dynamic analysis of the subsystem also can be expanded to include the intervening structural element. The response generated via modal superposition coupled with a missing mass correction ensures that the rigid mode effect is included.

Impact on DCD

See Attachment 1 for the markup of the DCD (R3) Tier 2, Section 3.7 changes to be incorporated.

- Add the following to replace the fourth paragraph in Subsection 3.7.3.1:

  "The time history or response spectra generated at the support locations of the subsystem are utilized as the input motion for performing the seismic dynamic analysis of the subsystem. However, where these input motions are not readily available, the input motions generated at the closest distances away from the structural support location can be adapted for use. The structural linkage (i.e., intervening structural element) between these two locations, and the additional amplification of the response due to the presence of the intervening structural element are considered in the analysis. For cases where the intervening structure is rigid (i.e., frequency > 50 Hz), the transformation effect due to the rigid body motion of the intervening structure can be taken into account by linear interpolation of the ISRS at the reference locations adjacent to the structural supported locations of the subsystem. Alternatively, the effect can be represented by adding a rigid link in the subsystem model from the reference location associated with the input motion to the support of subsystem location.

For places where the intervening structural element is flexible (i.e., frequency < 50 Hz), the seismic dynamic analysis of the subsystem model can be expanded to include the mass and stiffness of the flexible intervening structural element to analyze the subsystem response. Alternatively, the subsystem seismic input amplified time history and, if necessary, additional ISRS at the subsystem support locations can be generated by using a detailed de-coupled model of the flexible intervening structure provided the applicable de-coupling criteria of SRP 3.7.2 Acceptance Criteria 3B (Reference 3.7-35) or Section 4153.2 of NOG1-2004 (Reference 3.7-22) for cranes are met for the subsystem. When time histories of in-structure motions from dynamic analysis of the supporting soil-structure system are used, frequency content of the time histories is varied to be consistent with the broadening of ISRS. An acceptable method to vary the frequency content of the in-structure accelerations time histories for the best estimate soil properties is by expanding and shrinking the time history within 1/(1 ± 0.15) so as to change the frequency content within ± 15%."

Impact on R-COLA

There is no impact on the COLA.

Impact on S-COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on a Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/07/2011

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

RAI NO.:	**NO. 799-5877 REVISION 3**
SRP SECTION:	**03.07.03 – Seismic Subsystem Analysis**
APPLICATION SECTION:	**3.7.3**
DATE OF RAI ISSUE:	**8/5/2011**

QUESTION NO. RAI 03.07.03-11:

In Subsection 3.7.3.1 of DCD (R3), "Seismic Analysis Methods", the fourth paragraph (page 3.7-46) states in part, "The new translational response spectra are obtained by absolute sum of the translational response spectra at the reference location and the contributions arising from the rocking and torsional effects of the intervening structural element."

The Applicant is requested to explain how the absolute sum for the translational response spectra and rocking and torsional response spectra is performed. The Applicant's response should address analyses with both SASSI and ANSYS.

ANSWER:

The quoted sentence in this question and another similar sentence cited in RAI 5877 Question 03.07.03-10 were inserted into DCD (R3) as a response to RAI 493-3983 Revision 1 Question 03.07.03-5. As described in the response to RAI 5877 Question 03.07.03-10, the two quoted sentences will be removed and the added paragraph in the response to RAI 493-3983 Revision 1 Question 03.07.03-5 will be revised as indicated on the attached markup to the response to RAI 5877 Question 03.07.03-10.

Impact on DCD

For impact on the DCD, see the response to this RAI Question 03.07.03-10.

Impact on R-COLA

There is no impact on the COLA.

Impact on S-COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on a Technical/Topical Report.

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

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.

~~The time history or response spectra generated at the support point of the subsystem are utilized as the input motion for performing the seismic dynamic analysis of the subsystem. However, where these data are not readily available, the data generated for a distance away from the structural support point may be used. To account for the structural linkage (i.e., intervening structural element) between these two locations, the additional amplification of the response due to the presence of the intervening structural element can be calculated and the remote input motion can be transformed. For cases where the intervening structure is rigid (i.e., frequency > 50 Hz), the transformation can be achieved by adding the effect due to the rigid body motion of the intervening structure to the existing input motion at the remote location. The new translational time history at the interface location is generated by algebraic summation of the translational acceleration time history at the reference location and the time history contribution arising from the rocking and torsional effects of the intervening structural element. The new translational response spectra are obtained by absolute sum of the translational response spectra at the reference location and the contributions arising from the rocking and torsional effects of the intervening structural element. For places where the intervening structural element is judged to be flexible, the new ISRS are generated by incorporating the flexibility of the intervening structural element. Or alternatively, the seismic dynamic analysis of the subsystem shall be expanded to include the flexibility of the intervening structural element.~~ DCD_03.07.03-10

The time history or response spectra generated at the support locations of the subsystem are utilized as the input motion for performing the seismic dynamic analysis of the subsystem. However, where these input motions are not readily available, the input motions generated at the closest distances away from the structural support location can be adapted for use. The structural linkage (i.e., intervening structural element) between these two locations, and the additional amplification of the response due to the presence of the intervening structural element are considered in the analysis. For cases where the intervening structure is rigid (i.e., frequency > 50 Hz), the transformation effect due to the rigid body motion of the intervening structure can be taken into account by linear interpolation of the ISRS at the reference locations adjacent to the structural supported locations of the subsystem. Alternatively, the effect can be represented by adding a rigid link in the subsystem model from the reference location associated with the input motion to the support of subsystem location.

For places where the intervening structural element is flexible (i.e., frequency < 50 Hz), the seismic dynamic analysis of the subsystem model can be expanded to include the mass and stiffness of the flexible intervening structural element to analyze the subsystem response. Alternatively, the subsystem seismic input amplified time history and, if necessary, additional ISRS at the subsystem support locations can be generated by using a detailed de-coupled model of the flexible intervening structure provided the applicable de-coupling criteria of SRP 3.7.2 Acceptance Criteria 3B (Reference 3.7-35) or Section 4153.2 of NOG1-2004 (Reference 3.7-22) for cranes are met for the subsystem. When time histories of in-structure motions from dynamic analysis of the supporting soil-structure system are used, frequency content of the time histories is varied to be consistent with the broadening of ISRS. An acceptable method to vary the frequency content of the in-structure accelerations time history for the best estimate soil properties is by expanding and shrinking the time history within 1/(1 ± 0.15) so as to change the frequency content within ± 15%. DCD_03.07.03-10

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.

Regardless of the method chosen, to avoid resonance, the fundamental frequencies of components and equipment are preferably selected to be less than one half or more than twice the dominant frequencies of the support structure. If this is not practical, equipment and components with fundamental frequencies within this range are designed for any associated resonance effects in conjunction with all other applicable loads.

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 is single 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 adequatelyrepresented 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 supported component from the applicable ISRS. If the frequency of the supported component is not determined, the peak acceleration from the applicable ISRS ~~times a factor of 1.5~~ of the supported DCD_03.07.03-6 DCD_03.07.03-6

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}~~ DCD_03.07.03-7

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. The mode shapes and frequencies below the cut-off frequency are calculated in the response spectra analysis. The modal participation factors in each direction of the earthquake motion and the spectral accelerations for each significant mode are calculated. Based on the calculated mode shapes, participation factors, and spectral accelerations of individual modes, the modal inertia response forces, moments, displacements, and accelerations are calculated. For a given direction, these modal inertia responses are combined based on the consideration of closely spaced modes and high frequency modes to obtain the resultant forces, moments, displacements, For piping supported by a single concrete building, the SAM at all elevations above the foundation basemat are considered to be out of phase unless justification is provided to show them to be in phase, or unless analyzed using the USM method or the ISM method. Support movements relative to the foundation basemat are used in the analysis. DCD_03.07.03-7

~~If the above can not be justified or when~~When supports are attached to different structures (within a building)~~ on the same foundation basemat~~, the relative phasing characteristics retained from the building seismic analysis are used in the piping analysis ~~using~~considering the maximum relative movements~~ (considering phase)~~ between various supports to be out of phase, unless otherwise justified. DCD_03.07.03-7 DCD_03.07.03-7

Alternatively, data can be used based on the building seismic analysis modes having significant seismic movements. For each building mode, the movements of support attachment locations are tabulated. Using those tabulated movements for each mode and each spatial direction, separate static analyses are performed. Intermodal combinations followed by interspatial combinations are performed using the SRSS rule to obtain the cumulative effect of support displacements.

Where supports are located within different structures or buildings on different foundation mats, the seismic motions at these locations are assumed to move 180 degrees out-of-phase in the most unfavorable combination.

The results of USM floor response spectra analysis and the SAM analysis are combined by absolute summation method for use in various load combinations in the design and/or analysis of pipe supports and piping.

When piping is analyzed using the ISM method, the methodology of Volume 4, Section 2, paragraph 2.4 of NUREG-1061 (Reference 3.12-40) is used. In this method, the analysis is performed assuming that when one group of supports is moving, the other groups of supports are at rest. For each spatial direction, responses from movement of each group are combined by the absolute summation method. The combination of interspatial responses is performed by the SRSS rule to obtain the cumulative effect of support displacements. The results of ISM floor response spectra analysis and SAM analysis are combined by the SRSS rule for use in various load combinations in the design and/or analysis pipe supports and piping.

When the one piping system is supported by different buildings, the part of piping supported by one building is treated as one group including the piping portion supported by different floors in the building.

The relative displacements between groups are assumed to move 180 degrees out-of-phase as specified in NUREG-1061 (Reference 3.12-40).

3.12.3.3 Response Spectra Method (or Independent Support Motion Method)

ISM may be used when piping systems are supported by multiple support structures or at multiple levels within a structure.

The supports are divided into support groups. Each support group is made up of supports that have similar time-history input. Each support group is considered to be in a random-