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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-09184

Subject: MHI's Response to US-APWR DCD RAI No. 205-1584

References: 1) "Request for Additional Information No. 205-1584 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. 205-1584 Revision 0."

Enclosed are the responses to questions 10 through 18 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. 205-1584, Revision 0

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

D081
NRO

Contact Information

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Enclosure 1

UAP-HF-09184
Docket No. 52-021

Response to Request for Additional Information No. 205-1584, 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. 205-1584**
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 3.9.2-10

The applicant stated in Subsection 3.9.2.2.2 of the DCD that the stiffness of the seismic subsystem anchorage must be determined and the assumptions made in the analysis must be verified as accurately reflecting the mounting condition.

The DCD does not provide sufficient information to allow the review of the seismic subsystem analysis. The stiffness of the anchorage can affect natural frequencies of the subsystem significantly. The applicant is requested to provide a list of anchorage type, the method for determining their stiffness, the related assumptions, and the procedure for verification of the assumptions. The staff needs this information to ensure conformance with GDC-2. Revise the DCD to include the requested information.

ANSWER:

As stated in DCD Subsection 3.7.3.1, seismic subsystem analysis for the US-APWR design predominantly uses the equivalent static load method of analysis and is the preferred method because of its simplicity and its results are at least as conservative as those that are obtained from the other more detailed methods. For subsystems that are seismically qualified using equivalent static load method of analysis per Subsection 3.7.3.1.1, it is not necessary to consider the stiffness of the support anchorage in determining the seismic response of the SSC if the peak acceleration from the applicable in-structure response spectra (ISRS) is used. 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 stiffness of the anchorage is considered to determine if the support frequency is significantly affected by the anchorage stiffness. In all cases where SSCs are designed using the equivalent static method, stiffness of the support anchorage is considered for purposes of appropriate force and moment to load-resisting elements to capture such effects as prying action, regardless of whether the amplitude of the seismic response is affected by the anchorage stiffness.

For dynamic analysis methods where more exact results are required, the stiffness of the anchorage system is included in the subsystem seismic analysis to account for the support anchorage flexibility and its effects on the natural frequency of the subsystem. The approach to determine the stiffness of support anchorage is described as follows:

> 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 (base plate and anchor bolt flexibility). 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, an iteration analysis method is employed. This model is used to derive the stiffness (spring rate) of the base plate anchorage system by applying a 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.

The following list of anchorage types is anticipated to be used on the US-APWR with the preference starting from top to bottom:

1. Embedded plate with cast-in-place anchors
2. Surface mounted plate with cast-in-place anchor bolts
3. Surface mounted plate with direct-bearing undercut expansion anchors, through-bolts, and/or grouted embedment
4. Surface mounted plate with wedge-type or sleeve-type expansion anchors (where not excluded from use due to vibratory motion under normal operating conditions)

The method for determining stiffnesses, the related assumptions, and the procedures for verification of the assumptions is based in part on testing and verification that is required to be performed in accordance with ACI 349 Appendix B, and will vary from manufacturer to manufacturer based on the proprietary nature of the anchor design. For most direct-bearing undercut expansion anchors (depending on the manufacturer's design), for through-bolts, and for cast-in-place anchors, stiffness is directly dependent on the anchorage length and cross-sectional area.

A list which summarizes the method for determining the stiffness, the related assumptions, and the procedure for verification of the assumptions for the anchorage types listed above will be added to the DCD in its Revision 2.

See the response to question 3.9.2-34 of RAI 214-1920 for further discussion.

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.

4/30/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	NO. 205-1584
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 3.9.2-11

In the Mitshubishi Heavy Industries, Ltd. (MHI) technical report MUAP-08005 the applicant described the development of the coupled model, modeling method and assumptions, the analysis approach, and analysis results such as frequencies and mode shapes of dominant modes, acceleration and displacement responses of the structure, and in-structure response spectra (ISRS). The applicant stated in Sections 3.3 and 6.3 of the technical report that the lumped mass model considers a rigid base mat resting on the surface of a uniform elastic-half-space. Six sets of two parameters, one for stiffness and the other for damping, are developed in accordance with Subsection 3.3.4.2 of American Society of Civil Engineers (ASCE) 4-98 to represent the properties of the SSI in each of the six degrees of freedom (DOF). The values of the SSI soil damping in the two horizontal directions are conservatively set at 60% of the theoretical dash pot values based on ASCE 4-98. The MHI technical report does not address any reduction of the theoretical dashpot value in the vertical direction. Furthermore, Section 3.7.1 of the SRP states that the maximum soil damping value acceptable to staff is 15%.

The staff's review of the technical report MUAP-08005 indicated that the report did not address whether the soil damping in all three directions used in the coupled SSI seismic analysis is consistent with the maximum soil damping value of 15% in Section 3.7.1 of the SRP. The soil damping greatly affects the ISRS for subsystem seismic analysis. The applicant is requested to confirm that the soil damping values in all three directions used in the coupled soil-structure interaction (SSI) seismic analysis are consistent with the 15% damping value limit of SRP Section 3.7.1. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

SRP Section 3.7.1 (2) specifies that the material soil damping must be based on laboratory data considering variation of properties, strain levels, and ground water effects; and limits its maximum value to 15% of the critical damping of the soil material. The seismic response analyses of the US-APWR standard plant that are documented in Subsection 3.7.2 of the DCD and Technical Report MUAP-08005 as well as the requirements for site-specific soil-structure interaction (SSI) analysis specified in Section 3.7 of the DCD are consistent with the 15% limit set for the soil damping. The soil-structure interaction (SSI) lumped parameters used for the seismic analyses described in the DCD and Technical Report MUAP-08005 represent only the dissipation of energy in the subgrade media due only to geometrical damping and neglect the effect of the soil material damping. The SSI damping coefficients representing the geometrical damping in horizontal directions of vibration are set to 60% of their theoretical values specified in Subsection 3.3.4.2 of ASCE 4-98. The values of the SSI damping coefficients in vertical direction are not reduced.

The lumped SSI parameters that model the SSI in the lumped mass stick models of the US-APWR standard plant are developed using the closed-form solutions for vibration of a rigid foundation resting on an uniform elastic half-space specified in Subsection 3.3.4.2 of ASCE 4-98. Two separate mechanisms characterize the dissipation of energy in the elastic-half-space: (1) geometrical damping that represents the energy lost in the process of transmission of elastic-waves from the foundation to infinity; and (2) soil material damping that represent the energy that is lost due to internal friction of the subgrade material. The closed form solutions for damping SSI lumped parameters in Subsection 3.3.4.2 of ASCE 4-98 are derived by considering only the dissipation of energy in the semi-infinite half-space due to geometrical damping and neglect the loss of energy due to the material damping of the uniform subgrade. For item (1) above, geometrical damping is limited to 60% of the theoretical dashpot values computed based on ASCE 4-98. For item (2), since the loss of energy due to the material damping of the subgrade is neglected, the design conforms to the 15% limit on soil damping mandated in SRP Section 3.7.1.

As discussed in Subsections 3.7.2.4 and 3.7.2.4.1 of the DCD, the COL Applicant is responsible to perform site-specific SSI analyses to address effects of site-specific conditions on the seismic response of Category I SSCs including the effects of the soil material damping. The requirement for ACS-SASSI analysis of the R/B-PCCV-containment internal structure on a common mat, in order to address site-specific conditions, is covered by COL Item 3.7(25) and the requirement to address/consider site-specific conditions is also collectively addressed by COL items 3.7(2), 3.7(20), 3.7(22), and 3.7(23). The numerical models and the input design ground motions used for the site-specific SSI analysis are developed using input soil properties based on laboratory soil test data and considering the non-linear constitutive behavior of the soil. Values for the soil material damping are used in the site-specific SSI analyses that are compatible to the level of strains produced in the soil media by the input design ground excitation but are limited to maximum value of 15%. For clarification, the 15% limit on soil damping for site-specific SSI analyses will be cited in Subsection 3.7.2.4.1 of the DCD.

As specified in Subsection 3.7.1.1 of the DCD, the site-specific GMRS and FIRS that define the input ground motion used as input for the site-specific SSI analysis, are developed based on the results of site response analyses that consider the non-linear constitutive behavior of the soil but limit the maximum material damping of the soil materials to maximum value of 15%. Similarly, the site-specific SSI analyses use soil damping profiles that are compatible with the strains generated within the soil by the design ground motion but are limited to 15% as specified in SRP 3.7.1 (2). For clarification, the 15% limit on soil damping for site-specific SSI analyses will be cited in the discussion titled "Site-Specific GMRS" in Subsection 3.7.1.1 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:

- Add the following statement at the end of the second paragraph of the discussion titled "Site-Specific GMRS" in Subsection 3.7.1.1:

  "However, the strain-compatible soil material damping shall not exceed 15% as stipulated in SRP 3.7.1 (Reference 3.7-10)."

- Modify the last sentence of Subsection 3.7.1.2 to state:

  "Damping values associated with site-specific SSI analyses are addressed in Subsection 3.7.2.4.1."

- Modify the last paragraph of Subsection 3.7.2.4 to state:

  "The site-specific SSI analyses take into account site-specific conditions such as soil layering, location of water table and embedment of the basemat and, thus, validate the results of the site-independent SSI analysis and assumptions contained in the US-APWR standard plant design. This is accomplished through site-specific SSI analysis as explained below."

- Add the following statement after the first sentence of the sixth paragraph of Subsection 3.7.2.4.1:

  "However, soil material damping shall not exceed 15% as stipulated in SRP 3.7.1 (Reference 3.7-10)."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

4/30/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	NO. 205-1584
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 3.9.2-12

The applicant stated in Section 4.1 of the MHI technical report MUAP-08005 that both the reactor building (R/B) Complex and reactor coolant loop (RCL) are represented by an adequate number of DOF to represent significant modes in the range of frequencies up to 50 Hz.

The staff reviewed the MHI technical report MUAP-08005 and found that the report does not include sufficient information to allow the review of the coupled lumped mass models. Future sites in eastern US could experience high-frequency seismic loading. The applicant is requested to provide additional information to justify that the coupled lumped mass models are detailed enough, i.e., have sufficient dynamic degree of freedom, to amplify high frequency inputs to as high as 50 Hz. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

The seismic response is evaluated by the coupled lumped mass stick model of the reactor building (R/B) complex that includes the reactor building prestressed concrete containment vessel (PCCV) and containment internal structure (CIS) and reactor coolant loop (RCL) as described in the Technical Report MUAP-08005. The coupled RCL-building modeling and the methodology implemented for the seismic response analysis provide sufficient dynamic solution capability to capture the high-frequency components of the seismic loadings including those specific to the rock sites in the central and eastern US.

The refinement of the lumped mass stick models representing R/B, PCCV and CIS are validated by comparing the dynamic characteristics of the discrete lumped mass stick model with those of the detailed finite element model as discussed in the response to RAI 211-1946, Question 3.7.1-6 (UAP-HF-09187). The RCL lumped mass stick model includes the stiffness and mass inertia properties of the individual components of the four loops and the supports representation, which are connected to the building model with rigid links. The seismic analysis of the US-APWR 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. These test results are used to confirm the validity of the lumped mass stick modeling of the RCL. The seismic design method including RCL modeling, response analysis was compared directly to the test results, such as vibration characteristics, various levels of seismic responses as discussed in the response to RAI 213-1951, Question 3.7.3-14 (UAP-HF-09189). The same standardized modeling methodology used for domestic PWR plants in Japan is applied to the stick mass spring model of the US-APWR RCL.

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. 205-1584**
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 3.9.2-13

The applicant stated in Section 6.2 of the MHI technical report MUAP-08005 that for RCL analysis, the four loops of the RCL are modeled as combination of reactor vessel, steam generator (SG), RCP, and main coolant piping (MCP). These combined system models include both the translational and rotational stiffness, mass characteristics of the RCL piping and components, and the stiffness of supports. The stiffness and mass effects of auxiliary line piping are considered when they affect the system.

The staff's review indicates that the MHI technical report does not address the location of snubber support and modeling of the snubber stiffness. The applicant is requested to provide additional information whether the location of snubber support and the snubber stiffness are addressed in the RCL analysis model. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

In the RCL model of the US-APWR described in MHI Technical Report, MUAP-08005, R0, snubbers are installed at the SG upper supports and intermediate supports. The location and stiffness of snubbers are provided in Table 6-7 and Table 6-8 of Technical Report, MUAP-08005, R0. The outline sketches of component supports are provided in DCD Figure 3.8.3-1 for the reactor vessel support system, Figure 3.8.3-2 for the steam generator support system, Figure 3.8.3-3 for the reactor coolant pump support system, and Figure 3.8.3-4 for the pressurizer support system.

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

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Docket No. 52-021

RAI NO.:	**NO. 205-1584**
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 3.9.2-14

The applicant described in the MHI technical report MUAP-08005 the coupled lumped mass stick model, modeling method and assumptions, and the analysis approach and results. Section 3.7.2 of the SRP states that in developing a lumped mass model it is necessary to consider the local regions of the structures, such as individual slabs or walls. They may have fundamental vibration modes that can be excited by the seismic loading.

The DCD Tier 2, Section 3.7.2, or the technical report MUAP-08005 do not give a detailed description of the method for addressing wall and floor flexibility. The applicant is requested to provide additional information regarding the method for addressing wall and floor flexibility to ensure that the additional amplification due to local vibration is included in the generation of floor response spectra for the subsystem seismic analysis. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

As committed in the response to RAI 212-1950, Revision 1, question 3.7.2-8; the in-structure response spectra (ISRS), considering local vibration modes, (i.e., wall and floor flexibility) and the description of the analysis method will be provided in Revision 2 of the DCD.

Impact on DCD

A description of the ISRS local vibration modes and the analysis method will be provided in DCD Tier 2, Section 3.7, Revision 2.

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. 205-1584**
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 3.9.2-15

In DCD Tier 2, Subsection 3.7.2.9, the applicant stated that to account for variations in the structural frequencies due to the uncertainty in parameters, such as material and mass properties of the structures, damping values, and soil properties, SSI analysis techniques, and the seismic modeling methods, the computed ISRS are smoothed by filling valleys between peaks. In addition, the applicant stated in Subsection 3.7.3.1.5 of the DCD that the ISRS were developed by filling-in the valleys between "all" peaks. Because the design ISRS is developed by enveloping the ISRS of the four types of soil sites with shear wave velocity of 304.8, 1066.8, 1981.2, and 2438.4 m/s (1000, 3500, 6500 and 8000 ft/s), filling the valleys between the peaks could take into consideration these soil sites with shear wave velocity between the four sites.

The staff reviewed Sections 3.7.2 and 3.7.3 of the DCD and the MHI technical report MUAP-08005, and found that in Fig. 3.7.2-12 of the DCD the smoothed ISRS still shows valleys between peaks. Also, the ISRS in the MHI technical report MUAP-08005 show many valleys between peaks; examples include: Fig. 8.1, sheets 1- 4, 15-20, and 27-30, Fig. 8.2, sheets 1-4, 12-20, 24-26, and 29-31, and Fig. 8.3, sheets 21-23, and 31-32. It is not clear under what circumstances the ISRS are smoothed. The applicant is requested to provide (a) the criteria by which the computed ISRS are smoothed by filling the valleys between peaks, (b) a clarification whether all valleys are filled or just some of the valleys, and (c) explain why in the examples of ISRS given below, the valleys have not been filled. The staff needs this information to ensure conformance with GDC-2. Revise the DCD to include the requested information

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ANSWER:

Please see the response to RAI 213-1951, Revision 1, question 3.7.3-05.

Impact on DCD

Please see the “Impact to DCD” to RAI 213-1951, Revision 1, question 3.7.3-05.

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

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Docket No. 52-021

RAI NO.:	**NO. 205-1584**
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 3.9.2-16

In DCD Tier 2, Subsection 3.7.2.4, the applicant stated that four types of soil site are considered in the lumped mass soil-structure interaction analysis. The four type soil sites are soft soil site, medium rock site 1 and 2, and hard rock site. The shear wave velocity, Vs, of these four sites is 304.8, 1066.8, 1981.2, and 2438.4 m/s (1000, 3500, 6500 and 8000 ft/s), respectively. The applicant further stated that the hard rock site is treated as fixed base in the SSI analysis model.

The staff reviewed relevant sections of the DCD and found that the applicant did not provide sufficient information regarding SSI effects in the seismic analysis of seismic Category I equipment and components. The applicant is requested to provide the ISRS generated by using shear wave velocity Vs=2438.4 m/s (8000 ft/s) in some important locations to demonstrate that the difference between the ISRS obtained using Vs=2438.4 m/s and the fixed base case has negligible impact on the supported subsystems. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

Please see the response to RAI 213-1950, Revision 1, question 3.7.2-22. This response refers to SRP 3.7.2, Section II.4, which gives the criterion for performing a fixed-base analysis. SRP Section 3.7.2.II.4 states:

> "For structures founded on materials having a shear wave velocity of 8000 feet per second or higher, under the entire surface of the foundation, a fixed base assumption is acceptable."

Therefore, a comparison of the ISRS generated using V_s=8000 ft/s and the ISRS from the fixed base criteria is not required.

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

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

QUESTION NO.: RAI 3.9.2-17

The applicant stated that for piping analysis, the three sets of mutually orthogonal components of earthquake motion are combined in accordance with RG 1.92, Rev.1, by the SRSS method; details are discussed in DCD Subsection 3.12.3.2. In Subsection 3.12.3.2.6 of the DCD the applicant stated that where supports are located within different structures, the seismic motions at these locations are assumed to move 180 degree out-of-phase (i.e., the most unfavorable condition) in the analysis. Where supports are located within a single structure, the seismic motions are considered to be in-phase and the relative displacement between the support locations is considered in the analysis. Section 3.7.3 of the SRP states that support displacements are imposed on the supported item in the most unfavorable combination for item supported by either a single structure or two separate structures.

The staff reviewed relevant sections of the DCD and found that the applicant's assumption of in-phase motion for item supported in a single structure might not be conservative. Out-of-phase vertical motion could exist due to their frequency difference and local vibration. Also, out-of-phase horizontal motion could occur also to walls due to their local flexibility. The applicant is requested to provide additional information to justify the assumption of in-phase motion for items supported in a single structure. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

The Seismic Anchor Motions (SAMs) are determined from seismic deflections obtained from the seismic analysis of the structures. Where the seismic model is represented as a lumped mass stick model, the seismic deflections are calculated at each mass point which represents the total mass at a floor location. The deflections of the lumped masses are considered to be in-phase because of the predominant influence of the first mode.

Where a component is supported at multiple points within a structure, additional deflections may be imposed on the support due to local flexibility of the sub-system (walls and slabs). These local deflections will be determined by the structural analysis of the building. The local seismic deflections are considered out-of-phase with respect to the lumped mass deflections mentioned above.

The local deflections (at walls and slabs) are often small as compared to lumped mass deflections since the latter are limited by structural criteria and the structure is often stiffer than the component. Consequently, local deflections at walls and slabs can generally be ignored for seismic displacement analysis of traditionally routed smaller diameter pipes up to 4 inch diameter.

However, for larger diameter pipes or pipes with restrained configurations, the in-phase and out-of-phase deflections will either be combined in a way to provide the most un-favorable effect on the supported system or considered in-phase if justified by detailed review of the dynamic model response.

Consideration of the effects of wall and floor slab flexibility on SAMs will be addressed in the DCD Revision 2.

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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4/30/2009

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

QUESTION NO.: RAI 3.9.2-18

In DCD Tier 2, Subsection 3.12.3.2.3, the applicant stated that piping systems supported by structures located at multiple elevations within one or more buildings maybe analyzed using uniform support motion (USM). This analysis method applies a single set of spectra at all support locations, which envelops all of the individual response spectra for these locations. The enveloped response spectrum is developed and applied in the two mutually perpendicular horizontal directions and the vertical direction. Floor response spectrum curves used for USM may be generated using damping values identified in Table 3 or the frequency-dependent damping values of Fig. 1 from RG 1.61, Rev. 1. The applicant stated in DCD Section 3.12.5.1 that if any piping is laid out in the yard, the COL Applicant is to generate site-specific seismic response spectra, which can be used for the design of these piping systems or portions of piping system.

However, the applicant does not provide sufficient details in the DCD regarding the seismic analysis methods. Also, the exact definition of "portions of the piping" is not clear. The applicant is requested to provide the seismic analysis methods (including support displacements) for a piping that is partly laid out in the yard and partly supported by a building, equipment, or components. The staff needs this information to ensure conformance with GDC-2.

ANSWER:

Any safety-related, seismic category I underground piping for the US-APWR standard plant, and for site-specific applications, will be enclosed in and supported by a pipe tunnel, trench, or similar structure and will not be in direct contact with soil. Therefore, the seismic analysis methods (including support displacements) described in the DCD for piping supported by buildings, equipment, or components, are applicable for all piping design. The DCD will be revised to clarify this point.

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 sentence of the last paragraph in part (c) of "Design Ground Motion Time History" of Subsection 3.7.1.1 to: "These non-exceedances would need to be considered if the CSDRS were used to design site-specific pipe tunnels or similar buried SSCs."
- Change the first sentence of the next to last paragraph of Subsection 3.7.2.8 to: "The COL Applicant is to assure that the design or location of any site-specific seismic category I SSCs, for example pipe tunnels or duct banks, will not expose those SSCs to possible impact due to the failure or collapse of non-seismic category I structures, or with any other SSCs that could potentially cause impact, such as heavy haul route loads, transmission towers, non-safety-related storage tanks, etc."
- Change COL item 3.7(9) to :

  COL3.7(9) *The COL Applicant is to assure that the design or location of any site-specific seismic category I SSCs, for example pipe tunnels or duct banks, will not expose those SSCs to possible impact due to the failure or collapse of non-seismic category I structures, or with any other SSCs that could potentially impact, such as heavy haul route loads, transmission towers, non-safety-related storage tanks, etc.*

- Change the first sentence in the second paragraph of Section 3.7.3 to: "In addition to the above, civil structure-related subsystems also include those seismic category I and II SSCs such as pipe tunnels, conduit tunnels, dams, dikes, aboveground tanks, and the like, which are exterior to the R/B, PCCV, PS/Bs, and the ESWPT."

See Attachment 2 for a mark-up of DCD Tier 2, Section 3.12, Revision 2, changes to be incorporated:

- Change the second paragraph of Subsection 3.12.5.1 to:

  "If any piping is routed in tunnels or trenches in the yard, the COL Applicant is to generate site-specific seismic response spectra, which may be used for the design of these piping systems."

- Change COL item 3.12(2) to:

  COL 3.12(2) *If any piping is routed in tunnels or trenches in the yard, the COL Applicant is to generate site-specific seismic response spectra, which may be used for the design of these piping systems.*

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.

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Site-specific GMRS are developed at a sufficient number of frequencies (at least 25) that adequately represent the local and regional seismic hazards using the site-specific geological, seismological, and geophysical input data. A probabilistic seismic hazard analysis is performed that is based either on the reference-probabilistic approach as outlined in RG 1.165 (Reference 3.7-2) or on the performance-based approach outlined in RG 1.208 (Reference 3.7-3). Horizontal GMRS are developed using a site amplification function obtained from site response analyses performed on site-specific soil profiles that include the layers of soil and rock over the generic rock defined as the rock with shear wave velocity exceeding 9,200 ft/s. The site-specific soil profiles account for the uncertainties and variations of the site soil and rock properties. If materials are present at the site in which the initial (small strain) shear velocity is less than 3,500 ft/s [which corresponds to rock material for the purpose of defining input motion in accordance with Section 1.2 of ASCE 4-98 (Reference 3.7-9)], the site response analysis has to address probable effects of non-linearity of the subgrade materials. Equivalent linear methodology can be utilized with soil stiffness and damping degradation curves that represent the stiffness and damping properties of the subgrade materials as a function of strain. However, the strain-compatible soil material damping shall not exceed 15% as stipulated in SRP 3.7.1 (Reference 3.7-10).

Vertical GMRS are developed by combining the horizontal GMRS and the most up-to-date vertical/horizontal response spectral ratios appropriate for the site obtained from the most up-to-date attenuation relationships.

FIRS

The site-specific GMRS serves as the basis for the development of FIRS that define the horizontal and vertical response spectra of the outcrop ground motion at the bottom elevation of the seismic category I and II basemats. Free-field outcrop spectra of site-specific horizontal ground motion are derived from the horizontal GMRS using site response analyses that consider only the wave propagation effects in materials that are below the control point elevation at the bottom of the basemat. The material present above the control point elevation can be excluded from the site response analysis.

Appendix S (IV)(a)(1)(i) of 10 CFR 50 (Reference 3.7-7) requires that the SSE ground motion in the free-field at the basemat level must be represented by an appropriate response spectra with a PGA of at least 0.1 g. This requirement is met on a site-specific basis by considering minimum horizontal response spectra that are tied to the shapes of the US-APWR CSDRS and anchored at 0.1g. Since the CSDRS are based on modified RG 1.60-spectra, this assures that there is sufficient energy content in the low-frequency range. The COL Applicant is to assure that the horizontal FIRS defining the site-specific SSE ground motion at the bottom of seismic category I or II basemats envelope the minimum response spectra required by 10 CFR 50, Appendix S (Reference 3.7-7), and the site-specific response spectra obtained from the response analysis. The same requirements apply to the vertical FIRS, which are developed from the horizontal FIRS by using vertical/horizontal response spectral ratios appropriate for the site.

The COL Applicant is to perform an analysis of the US-APWR standard plant seismic category I design to verify that the site-specific FIRS at the basemat level control point of the CSDRS are enveloped by the site-independent CSDRS. If the verification analysis proves the site-independent seismic design to be inadequate, a reanalysis of the

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there is not more than one data point in any particular window that is below 90% of the CSDRS, and the lowest value for any particular data point is 87.7%, which is a very minor non-exceedance. These non-exceedances also occur at very low frequencies that are not significant for the design of US-APWR standard plant SSCs. These non-exceedances would need to be considered if the CSDRS were used to design site-specific pipe tunnels ~~buried piping~~ or similar buried SSCs.

(d) In lieu of the power spectral density requirement of Approach 1 in NUREG-0800, SRP 3.7.1 (Reference 3.7-10), Approach 2 specifies that the computed 5% damped response spectra of each artificial ground motion time history does not exceed its target response spectra at any frequency by more than 30% (a factor of 1.3) in the frequency range of interest. For the US-APWR, the response spectra derived from the artificial time histories are checked to assure that they do not exceed the corresponding target spectra (CSDRS) by more than 30% at any frequency range measured as described in item (b) above. The results of this check are presented in Table 3.7.1-4.

The cross-correlation coefficients between the three components of the design time histories are as follows:

$$\rho_{12} = -0.0729,\ \rho_{23} = -0.0614,\ \text{and}\ \rho_{31} = -0.1289$$

where 1, 2, and 3 are the three global directions corresponding to north-south, east-west, and vertical directions for the US-APWR standard plant.

Since the absolute values of the cross-correlation coefficients of the US-APWR artificial time histories are less than 0.16, as demonstrated above, in accordance with NUREG/CR-6728 (Reference 3.7-14), the time histories are considered statistically independent of each other.

Duration of Motion

Each time history of the set of three statistically independent time histories which are developed for design of the US-APWR seismic category I buildings has a strong duration of motion of 8.91 seconds and a total duration of motion of 22.09 seconds. The strong duration of motion meets the acceptance criterion of 6 seconds minimum for strong motion duration as given in SRP 3.7.1 (Reference 3.7-10) for design time histories. The duration of motion has been determined using random phase characteristics. The total duration of motion meets the acceptance criterion of 20 seconds minimum as given in SRP 3.7.1 (Reference 3.7-10) design time histories, Option 1, Approach 2 Part (a).

For the linear structural analyses, which are based on the synthesized time histories and used to design US-APWR seismic category I buildings and structures, the total duration of the artificial ground motion time histories has been demonstrated to be long enough such that adequate representation of the Fourier components at low frequency is included in the time history.

The corresponding stationary phase strong-motion duration is consistent with the longest duration of strong motion from the earthquakes defined in SRP 2.5.2 (Reference 3.7-8) at low and high frequency and as presented in NUREG/CR-6728 (Reference 3.7-14).

affected SSCs is performed based on a site-specific SSE defined by the site-specific FIRS. In this case, the scoping re-design analysis may focus on affected SSCs rather

The damping values for systems that include two or more substructures, such as a concrete and steel composite structure, can be obtained using the strain energy method. The strain energy dependent modal damping values are computed based on Reference 3.7-18, which is the same as the stiffness weighted composite modal damping method, and acceptable to SRP 3.7.2 (Reference 3.7-16).

The stiffness weighted modal damping ratio h_j of the j^{th} mode is obtained from the following equation:

$$h_j = \frac{\vec{\phi}_j^{\,T}\left[\overline{K}\right]\vec{\phi}_j}{\vec{\phi}_j^{\,T}\left[K\right]\vec{\phi}_j}$$

where

$[K]$	= the stiffness matrix of the combined soil-structure system
$\vec{\phi}_j$	= the j^{th} normalized mode shape vector
$\left[\overline{K}\right]=\sum[k_i]\cdot\xi_i$	= the modified stiffness matrix constructed from the products of the element stiffness matrices $[k_i]$ and the applicable damping ratio ξ_i

Formulation of damping values for the seismic analysis models which incorporate the combined soil-structure damping is discussed in Subsection 3.7.2.1. Damping values associated with site-specific SSI analyses are addressed in Subsection 3.7.2.4.1.

3.7.1.3 Supporting Media for Seismic Category I Structures

A range of soil parameters of the basemat supporting media are considered in the seismic design of seismic category I building structures for the US-APWR standard plant. The overall basemat dimensions, basemat embedment depths, and maximum height of the US-APWR R/B, PCCV, and containment internal structure on their common basemat are given in Table 3.7.1-3 and as updated by the COL Applicant to include site-specific seismic category I structures.

The required allowable static bearing capacity for seismic category I building structure basemats, including the R/B-PCCV-containment internal structure on their common basemat, is 15 ksf. The dynamic bearing loads for seismic category I structure basemats are dependent upon the magnitude of the seismic loads that can be obtained from a site-specific seismic analysis that considers FIRS. The COL Applicant is to determine the allowable dynamic bearing capacity based on site conditions, and to evaluate the bearing load to this capacity. A minimum factor of safety of 2 is suggested for the ultimate bearing capacity versus the allowable dynamic bearing capacity; however, a different value may be justified based on site-specific geotechnical conditions.

The site-independent seismic design of seismic category I and seismic category II SSCs uses lumped parameter representation to model the interaction of seismic category I structures with the supporting media. The lumped parameter model considers a rigid

The site-independent SSI analyses of US-APWR standard plant are performed by assuming an absolutely rigid basemat that rests on uniform linear-elastic half-space. A viscous damping represents the dissipation of energy in the elastic-half space that is due to radial damping in the subgrade media. This assumption allows the use of simple closed solutions in terms of frequency-independent lumped parameters that describe the stiffness and the dissipation of energy in the SSI system in the six DOF. Three DOF represent the translations of the basemat in two orthogonal horizontal directions and in the vertical direction. Two DOF represent the rocking of the basemat about two horizontal axes, and one rotational DOF describes the torsional vibrations of the basemat. The lumped parameters representing the stiffness and damping properties of the SSI are calculated from the formulas presented in Table 3.3-3, Subsection 3.3.4.2 of ASCE 4-98 (Reference 3.7-9). The values of the lumped SSI parameters for damping in two horizontal translational DOF are conservatively set at 60% of the theoretical dashpot values obtained from formulas in Table 3.3-3.

The ratio of basemat depth-to-equivalent-radius for the R/B-PCCV basemat is less than 0.3 (the embedded depth is 38'-10"), which indicates a shallow embedment basemat for purposes of SSI as defined in ASCE 4-98, Subsection 3.3.4.2 (Reference 3.7-9). SSI analysis performed as part of the site-independent US-APWR standard plant design conservatively neglects the effects of embedment of the common R/B and PCCV basemat. Therefore, the R/B-PCCV seismic models are not coupled with any subgrade or backfill material at the sides of the basemat or along the faces of below-grade exterior walls, and no credit is taken in the seismic analysis for restraint due to the presence of these materials.

The use of frequency independent SSI impedance parameters is based on the assumption that the subgrade conditions are relatively uniform up to a depth of one equivalent basemat diameter below the bottom of the basemat of the major seismic category I structures. Dry soil conditions are assumed in order to simplify the analysis. The following values for shear wave velocity V_s, density γ and Poisson's ratio ν are assigned to the uniform elastic half-space to simulate the general subgrade conditions:

- Soft soil site, V_s = 1,000 ft/s, γ = 110 pcf, ν = 0.40
- Rock site (Medium 1), V_s = 3,500 ft/s, γ = 130 pcf, ν = 0.35
- Rock site (Medium 2), V_s = 6,500 ft/s, γ = 140 pcf, ν = 0.35
- Hard rock site, V_s = 8,000 ft/s, γ = 160 pcf, ν = 0.30

A fixed base analysis considers the hard rock case listed above. The values used for the soil shear wave velocities are considered to be compatible to the strain level corresponding to the site-independent SSE. Table 3.7.2-3 summarizes the US-APWR standard plant seismic SSI analysis cases, with respect to the input time histories applied to the stick models resting on the uniform elastic half-space having the different subgrade conditions listed above.

The site-specific SSI analyses take into account site-specific conditions such as soil layering, location of water table and embedment of the basemat and, thus, validate the results of the site-independent SSI analysis and assumptions contained in the US-APWR standard plant design. ~~Using a lumped-parameter model, SSI damping is based on the characteristics of the site-specific subgrade conditions, not to exceed the values~~

~~specified by the ASCE 4-98 code (Reference 3.7-9).~~ This is accomplished through site-specific SSI analysis as explained below.

3.7.2.4.1 Requirements for Site-Specific SSI Analysis of US-APWR Standard Plant

The COL Applicant referencing the US-APWR standard design is required to perform a site-specific SSI analysis for the R/B-PCCV-containment internal structure utilizing the program ACS-SASSI SSI Version 2.2 (Reference 3.7-17) which contains time history input incoherence function capability. The SSI analysis using SASSI is required in order to confirm that site-specific effects are enveloped by the standard design. After the SASSI analysis is first performed for a specific unit, subsequent COLAs for other units may be able to forego SASSI analyses if the FIRS and GMRS derived for those subsequent units are much smaller than the US-APWR standard plant CSDRS, and if the subsequent unit can also provide justification through comparison of site-specific geological and seismological characteristics.

SSI effects are also considered by the COL Applicant in site-specific seismic design of any seismic category I and II structures that are not included in the US-APWR standard plant. Consideration of structure-to-structure interaction is discussed in Subsection 3.7.2.8. The site-specific SSI analysis is performed for buildings and structures including, but not limited to, to the following:

- Seismic category I ESWPT
- Seismic category I PSFSV
- Seismic category I UHSRS

The site-specific seismic response analysis of R/B-PCCV building structure addresses factors that affect the response of the combined soil-structure dynamic system that include, but are not limited to, the following:

- Properties and layering of the soil, including fill concrete and backfill modeled depending on its horizontal extent
- Depth of the water table
- Basemat embedment
- Flexibility of the basemat
- Presence of nearby structures

Up-to-date modeling techniques capable of capturing the various site-specific SSI effects are used for the analysis. The computer program SASSI is used for the site-specific SSI analysis, because it is based on the use of the FE technique and sub-structuring method with frequency-dependent impedance functions to model the interaction of the embedded flexible basemat with the surrounding soil.

The input used for the site-specific analysis must be derived from geotechnical and seismological investigations of the site. The input control motion that is derived from the site-specific GMRS, is applied in the SASSI analysis as within motion at the bottom of the basemat. Site-specific SSI analyses account for the uncertainties and variations of the subgrade properties by using at least three sets of site profiles that represent the best estimate, lower bound, and upper bound (BE, LB, and UB for equations, respectively) soil and rock properties. If sufficient and adequate soil investigation data are available, the LB and UB values of the initial (small strain) soil properties are established to cover the mean plus or minus one standard deviation for every layer. In accordance with Subsection 3.3.17 of ASCE 4-98 (Reference 3.7-9), the LB and UB values for initial soil shear modulii (G_s) are established as follows:

$$G_s^{(LB)} = \frac{G_s^{(BE)}}{(1+C_v)} \quad \text{and} \quad G_s^{(UB)} = G_s^{(BE)} \quad (1+C_v)$$

where C_v is a variation factor. ASCE 4-98 (Reference 3.7-9) mandates that value of C_v must be greater than 0.5. When insufficient data are available to address uncertainties in properties of deep soil layers, C_v must be greater than 1.0.

The SSI analysis must use stiffness and damping properties of the subgrade materials that are compatible with the strains generated by the site-specific design earthquake (SSE or/and OBE). <u>However, soil material damping shall not exceed 15% as stipulated in SRP 3.7.1 (Reference 3.7-10).</u> The soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3,500 ft/s or higher. The COL Applicant is to institute dynamic testing to evaluate the strain-dependent variation of the material dynamic properties for site materials with initial shear wave velocities below 3,500 ft/s. If the strains in the subgrade media are less than 2%, the strain compatible properties can be obtained from equivalent linear site-response analyses using soil degradation curves. Degradation curves that are published in literature can be used after demonstrating their applicability for the specific site conditions. The strain-compatible soil profiles for the site-specific verification SSI analyses of the major seismic category I structures can be obtained from the results of the site response analyses that are performed to calculate site-amplification factors for the development of GMRS, as described in Subsection 3.7.1.1.

The depth of the water table must be considered when developing the P-wave velocities of the submerged subgrade materials. Significant variations in the water table elevation and significant variations of the subgrade properties in the horizontal direction are addressed by using additional sets of site profiles.

To assure the proper comparability, the site-specific verification SSI analyses must use the same verified and validated lumped mass stick models of the building super-structure as those used for the US-APWR standard plant design. FE analyses are employed to evaluate the flexibility of the basemat and the embedded portion of the building. The floor slabs located at and above the ground surface are assumed absolutely rigid. In order to verify the converted structural model, a site-specific SSI analysis is performed with hard rock site profile that simulates fixed base conditions. The results of the SSI analysis with hard rock site profile are to match closely with the results from the analysis of fixed base stick model. In accordance with requirements of Section with adjacent structures. Maximum lateral earth pressure due to the backfill, surcharge due to live load or adjacent basemat bearing pressures, groundwater, and other such static-load effects on below-grade exterior walls are discussed in Section 3.8. The design of US-APWR seismic category I structures takes into account any dynamic increases of these loads due to a seismic event. This is accomplished through the use of conservative maximum static and dynamic lateral pressure distribution profiles on exterior below-grade walls.

The COL Applicant is to assure that the design or location of any site-specific seismic category I SSCs, for example ~~buried yard piping~~ pipe tunnels or duct banks, will not expose those SSCs to possible impact due to the failure or collapse of non-seismic category I structures, or with any other SSCs that could potentially impact, such as heavy haul route loads, transmission towers, non safety-related storage tanks, etc. Alternately, site-specific seismic category I SSCs are designed for impact loads due to postulated failure of the non-seismic category I SSCs.

Following is a discussion of major structures in the power block area with respect to potential interaction with seismic category I structures.

3.7.2.8.1 AC/B

The AC/B is structurally designed as a NS structure on reinforced concrete foundation located at the west side of the A/B (seismic category II). The AC/B is not located adjacent to any seismic category I SSCs. If the AC/B were to fail or collapse, it could impact the A/B which is a seismic category II structure. AC/B is smaller, shorter, and much less massive than the reinforced concrete A/B. In the unlikely event of impact, there would not be sufficient kinetic energy transfer to cause the A/B to displace beyond acceptable limits. Specifically, the A/B would not displace enough to impact the R/B, PS/Bs, or any other seismic category I SSCs.

The design philosophy of the AC/B is stated as follows.

- The seismic design is in accordance with the International Building Code (Reference 3.7-30) with an Importance Factor of 1.0.
- The structure is designed in accordance with applicable building codes.

3.7.2.8.2 T/B

The T/B is structurally designed as seismic category II, such that its integrity will not be impacted by a design basis seismic event; that is the T/B will not fail or collapse due to seismic loading. The T/B is located on the south sides of the R/B and the PS/Bs, and is separated from these structures with an expansion joint at all above-grade interface locations. The expansion joints are sized prevent contact between buildings, even if the maximum translational and rotational displacements due to a seismic loading (and other loading) were to occur. The minimum sizes of expansion joints must be obtained by considering, at all potential contact locations, the absolute summation of the T/B deflection and the adjacent structures' deflection (R/B, PS/Bs, and ESWPT) obtained from the response spectra or time history analysis results for those structures. The nominal horizontal clearance between the T/B structure above grade to adjacent structures is 4 inches.

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be greater than 1/3 of the site-specific SSE for the design of site-specific seismic category I structures, then load combinations involving the site-specific OBE must have a minimum factor of safety of 1.5 against overturning and sliding.

The US-APWR standard plant design is based on the assumption, as discussed in Chapter 2, that there is no potential for liquefaction of the supporting media. In order to verify the dynamic stability of US-APWR standard plant and site-specific seismic category I structures, site-specific investigations are performed of the supporting media as described in Subsection 2.5.4.8 to verify that there is no potential for liquefaction. The site-specific factor of safety against liquefaction is determined to confirm the dynamic stability of seismic category I structures for the US-APWR standard design with respect to liquefaction.

3.7.2.15 Analysis Procedure for Damping

The analysis procedure of damping in the various elements of the soil-structure system model has been discussed in Subsections 3.7.1.2, 3.7.2.3, and 3.7.2.4.

3.7.3 Seismic Subsystem Analysis

This section addresses seismic analysis of civil structure-related seismic category I subsystems, which are analyzed in accordance with NUREG-0800, SRP 3.7.3 (Reference 3.7-35). The civil structure-related 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 because the subsystems do not contribute to the building stiffness and because the seismic responses of the buildings (ISRS as discussed in Subsection 3.7.2.5) serve as the seismic design input motion for the subsystems. SSCs that are seismically analyzed as civil structure-related subsystems include:

- Structures such as miscellaneous steel platforms, stairs, and walkways.
- Structures such as reinforced masonry block walls and enclosures.
- HVAC ducts and duct supports. The design of HVAC ducts and duct supports is addressed further in Appendix 3A.
- Conduits and conduit supports. The design of conduits and conduit supports is addressed further in Appendix 3F.
- Cable trays and tray supports. The seismic qualification of cable trays and tray supports is addressed in Appendix 3G.
- Pipe racks and pipe support framing. These structures may also be analyzed as part of mechanical piping subsystems as discussed in Section 3.12.
- Pipe whip restraints. See Section 3.6 and Appendix 3B for a discussion of the design of pipe whip restraints for dynamic loads due to pipe rupture and Appendix 3E for discussion of high energy piping design.
- Equipment cabinet structural framing and/or mounting.

In addition to the above, civil structure-related subsystems also include those seismic category I and II SSCs such as pipe tunnels~~direct buried piping~~, conduit tunnels, dams, dikes, aboveground tanks, and the like, which are exterior to the R/B, PCCV, PS/Bs, and the ESWPT.

COL3.7(6) *The COL Applicant is to develop site-specific GMRS and FIRS by an analysis methodology, which accounts for the upward propagation of the GMRS. The FIRS are compared to the CSDRS to assure that the US-APWR standard plant seismic design is valid for a particular site. If the FIRS are not enveloped by the CSDRS, the US-APWR standard plant seismic design is modified as part of the COLA in order to validate the US-APWR for installation at that site.*

COL3.7(7) *The COL Applicant is to determine the allowable dynamic bearing capacity based on site conditions, and to evaluate the bearing load to this capacity.*

COL3.7(8) *The COL Applicant is to institute dynamic testing to evaluate the strain-dependent variation of the material dynamic properties for site materials with initial shear wave velocities below 3,500 ft/s.*

COL3.7(9) *The COL Applicant is to assure that the design or location of any site-specific seismic category I SSCs, for example ~~buried yard piping~~ pipe tunnels or duct banks, will not expose those SSCs to possible impact due to the failure or collapse of non-seismic category I structures, or with any other SSCs that could potentially impact, such as heavy haul route loads, transmission towers, non-safety-related storage tanks, etc.*

COL3.7(10) *It is the responsibility of the COL Applicant to further address structure-to-structure interaction if the specific site conditions can be important for the seismic response of particular US-APWR seismic category I structures, or may result in exceedance of assumed pressure distributions used for the US-APWR standard plant design.*

COL3.7(11) *It is the responsibility of the COL Applicant to confirm the masses and frequencies of the PCCV polar crane and fuel handling crane and to determine if coupled site-specific analyses are required.*

COL3.7(12) *It is the responsibility of the COL Applicant to design seismic category I below- or above-ground liquid-retaining metal tanks such that they are enclosed by a tornado missile protecting concrete vault or wall, in order to confine the emergency gas turbine fuel supply.*

COL3.7(13) *The COL Applicant is to set the value of the OBE that serves as the basis for defining the criteria for shutdown of the plant, according to the site specific conditions.*

constraint. As such, restraints on the branch line should not be located close to the actual pipe run connection.

Seismic analysis of the decoupled branch line is performed using applicable envelope response spectra for the decoupled branch line considering the connection point as an anchor. The envelope response spectra also include amplified response spectra at the connection point to the supporting piping run as a component response spectra. The movements (displacements and rotations) of the pipe run from the thermal, SAM or pipe break analyses is applied as anchor movements with their respective load cases in the decoupled branch line analysis.

If amplified response spectra at the connection point can not be developed, movements of the connection point from the seismic inertia analysis of the pipe run are analyzed as anchor movements and the solution is added to the seismic analysis of the decoupled branch line by absolute summation. The envelope floor response spectrum used for the seismic analysis of the decoupled branch line includes floor response spectra applicable for the connection point or the nearest restraints on the pipe run as a component response spectrum.

The pipe run seismic analysis is performed without the decoupled branch. However, the mass effect is considered when the mass of half the span of the branch pipe is greater than 10% of the mass of the pipe run span.

In the analysis of the pipe run, as well as the decoupled branch pipe, the effects of the applicable stress intensification factors and/or stress indices of the branch connection are incorporated.

3.12.5 Piping Stress Analysis Criteria

3.12.5.1 Seismic Input Envelope vs. Site-Specific Spectra

The development of floor response spectra for the US-APWR design is described in Subsection 3.7.2.5, “Development of Floor Response Spectra”.

If any piping is ~~laid out~~ <u>routed in tunnels or trenches</u> in the yard, the COL Applicant is to generate site-specific seismic response spectra, which may be used for the design of these piping systems ~~or portions of piping system~~.

3.12.5.2 Design Transients

ASME Code, Section III, Class 1 (Reference 3.12-2) piping system and support component experience the RCS transients identified in Table 3.9-1. On the other hand, Class 1 piping experiences the specific transient caused by the flow injection or discharge through this piping. These transient are listed in Table 3.12-6.

3.12.5.3 Loadings and Load Combination

3.12.5.3.1 Pressure

The internal design pressure, P, is used in the design and analysis of ASME Code, Section III, Class 1, 2 and 3 piping (Reference 3.12-2). The wall thicknesses are

The friction force F cannot be greater than the product of the pipe movement and the stiffness of the pipe support in the direction of movement.

3.12.6.11 Pipe Support Gaps and Clearances

All rigid supports have a cold condition gap of 1/16th inch all around the pipe surface in the restrained direction. These small gaps allow the rotation of the pipe and also allow for radial thermal expansion of the pipe.

In the unrestrained direction, the gaps are greater than the expected maximum movement of the pipe.

Stiff pipe clamps, which are preloaded to prevent themselves from lifting off the piping under dynamic loading conditions, are not used for ASME Code, Section III, Class 1 (Reference 3.12-2) piping.

3.12.6.12 Instrumentation Line Support Criteria

The acceptance criteria for instrumentation line supports are from ASME Code, Section III, Subsection NF for seismic category I (Reference 3.12-32) and seismic category II instrumentation lines. Non-seismic instrumentation lines are designed per the rules of "Manual of Steel Construction, 9th Edition", AISC (Reference 3.12-23).

The applicable loading combinations for these supports are those used for normal and faulted conditions in Table 3.12-4.

3.12.6.13 Pipe Deflection Limit

Manufacturer's recommendations for the limitations in its hardware are followed for those piping supports that utilize standard manufactured components. Such limitations include travel limits for variable and constant support spring hangers, swing angles for rod hangers, struts, and snubbers. The variability check of variable support spring hangers is performed per applicable Codes.

3.12.7 Combined License Information

COL 3.12(1) *Deleted*

COL 3.12(2) *If any piping is ~~laid out~~ <u>routed in tunnels or trenches</u> in the yard, the COL Applicant is to generate site-specific seismic response spectra, which may be used for the design of these piping systems ~~or portions of piping system~~.*

COL 3.12(3) *If the COL Applicant finds it necessary to lay ASME Code, Section III (Reference 3.12-2), Class 2 or 3 piping exposed to wind or tornado loads, then such piping must be designed to the plant design basis loads.*

COL 3.12(4) *The COL Applicant is to screen piping systems that are sensitive to high frequency modes for further evaluation.*