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TOKYO, JAPAN

March 25, 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-09112

Subject: MHI's Response to US-APWR DCD RAI No. 211-1946

Reference: 1) "Request for Additional Information No. 211-1946 Revision 1, SRP Section: 03.07.01 – Seismic Design Parameters, Application Section: 3.7.1, 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. 211-1946, Revision 1."

Enclosed are the responses to 3 RAIs contained within Reference 1. Of these RAIs in Reference 1, 4 will not be answered within this package. They are:

RAI 3.7.1-3, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 3.7.1-5, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 3.7.1-6, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 3.7.1-7, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

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.

D081
NRO

Enclosure:

1. Response to Request for Additional Information No. 211-1946, Revision 1

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

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Enclosure 1

UAP-HF-09112
Docket No. 52-021

Response to Request for Additional Information No. 211-1946,
Revision 1

March, 2009

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/25/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 211-1946 REVISION 1**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**03.07.01**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.1-1:

In Section 3.7.1.1 (c) of the DCD, the artificial response spectrum for 5% damping generated from artificial ground motion time histories fall short of the acceptance criteria provided in Section 3.7.1 of the SRP. Section 3.7.1 of the SRP requires that the computed 5% damped response spectrum of the accelerogram not fall more than 10% below the target response spectrum at any one frequency and that it should not fall below the target spectrum for more than 9 adjacent frequency points. The applicant has justified variance (non-exceedances) from the SRP acceptance criteria on the basis of its judgment that the non-exceedances occurred at low frequencies that are not significant for the design of the US-APWR standard plant SSCs. Provide a technical basis of the judgment including a list of SSCs that were considered to conclude that the non-exeedances will not have a significant effect on the seismic analysis of structures, systems, and components in the US-APWR standard plant. Also, describe the steps that will be taken to ensure that the seismic input used to calculate the hydrodynamic loads on liquid-containing tanks contains sufficient energy in the low-frequency region associated with the convective response of the tanks.

ANSWER:

The applicable acceptance criteria are described in Paragraph (c) of Option 1: Single Set of Time Histories - Approach 2, under SRP Section 3.7.1, subsection II B (Revision 3 – March 2007). The relevant part of the second sentence of Paragraph (c) states: "..., the response spectra within a frequency window of no larger than +/- 10% centered on the frequency shall be allowed to fall below the target spectrum." The actual frequency sampling rate at the low frequencies in question is higher than the minimum "100 points per frequency decade" requirement in the paragraph preceding Paragraph (c), and consequently this frequency-window criterion is actually satisfied for all frequency windows where the 5% damped response spectra were below the target spectrum. There is only one frequency in each of the 5% damped response spectra where the ratio of the spectral acceleration ordinate is less than 90 % of the target spectrum, and that ratio is only slightly smaller than 90 % (i.e., 89.36 % at 0.357 Hz for the Ha component; 88.82 % at 0.364 Hz for the Hb component; and, 87.72 % at 0.519 Hz for the Vertical component). These small differences are considered insignificant.

To place these three very small non-exceedances in context, we compare the response spectral shapes of the modified Regulatory Guide 1.60 response spectra for horizontal and vertical

components at 5% damping ratio with the corresponding response spectral shapes computed from current ground-motion models, and with the response spectral shapes of strong motion recordings in central and eastern North America. The current ground-motion models include those for response spectral shape developed by Risk Engineering (2001) in NUREG/CR-6728, and ground-motion prediction equations developed by Toro et al. (1997) and Atkinson and Boore (2006). All of the models and recordings are for hard rock site conditions.

Risk Engineering (2001) developed response spectral shape models for two different earthquake source spectral models: a one-corner frequency model, and a two-corner frequency model. We show comparisons with both models. The horizontal component spectral shapes for these models were computed from Equation (4-9) and Table 4-3 in NUREG/CR-6728 by first substituting the values of moment magnitude (M) and fault distance (R) for the strong motion record into the appropriate coefficient expressions in Table 4-3, and then substituting the coefficient values into Equation (4-9). The vertical-component (V) spectral shapes were computed by multiplying the horizontal component (H) spectral shapes by the frequency-dependent V/H ratios in the column labeled, 0.2 – 0.5g*, in Table 4-5 of NUREG/CR-6728.

The Toro et al. (1997) and Atkinson and Boore (2006) ground-motion prediction equations are based on the stochastic model and apply to horizontal components only. Response spectral shapes were computed for these equations by first substituting the values of moment magnitude (M) and fault distance (R) for the strong motion record into the equations and then normalizing the resulting response spectra by the computed peak ground acceleration, which was assumed to equal the spectral acceleration at 100 Hz.

The strong motion recordings, listed in Table 1 (below), are from the only two moderate-to-large magnitude earthquakes that have been recorded in regions of North America that are remote from plate boundaries. They include rock site recordings of the December 23, 1985 M6.8 Nahanni earthquake and of the November 25, 1988 M5.8 Saguenay earthquake (Somerville et al., 1990; Munro and Weichert, 1989). The three Nahanni recordings are at distances ranging from approximately 5 to 10 km. The distances listed in Table 1 for this event are closest distances from the recording stations to the fault rupture and were taken from a metadata file for the ground-motion database included in the Next Generation Attenuation (NGA) project (Power et al., 2008). The Nahanni records were chosen because they are representative of earthquake source, wave propagation and site characteristics in a region of North America that is remote from plate boundaries. These characteristics are considered to be representative of those in the Central and Eastern United States (Risk Engineering, 2001). The seven Canadian Saguenay recordings, selected to exclude late triggers and high noise levels, are at epicentral distances ranging from 43 to 149 km. They were chosen because they are representative of earthquake source and wave propagation characteristics in eastern North America.

The Regulatory Guide 1.60 response spectrum scaled to 0.3g is a generic representation of ground motion characteristics that are not related to a specified earthquake magnitude and distance. The magnitude and distance combinations of the selected recordings are considered to be relevant to conditions in the eastern United States.

Figures 1 through 4 (below) compare the normalized response spectra of these recordings and of the ground-motion models with the normalized target response spectrum (modified Regulatory Guide 1.60 spectrum), and the normalized response spectra of the artificial time histories. Figures 1 and 3 show, respectively, the horizontal-component and vertical-component comparisons for the Nahanni earthquake, while Figures 2 and 4 show similar comparisons for the Saguenay earthquake. At frequencies lower than approximately 3 Hz in each of these figures, the normalized target response spectrum and associated normalized response spectra of the artificial time histories are generally much larger than the normalized response spectra predicted by the ground motion models and the normalized response spectra of the recorded ground motions. In most cases, the normalized target response spectrum exceeds the normalized response spectra

of the models and recordings by a factor of 2 to 3 or more at frequencies below 1 Hz.

Figure 5 (below) compares the normalized target response spectrum (modified Regulatory Guide 1.60 spectrum) with the normalized response spectra of the single corner model of Risk Engineering (2001) for a wide range of earthquake magnitude and distance combinations. The normalized single corner model has larger ground motion levels than the normalized double corner model at low frequencies. In all cases, the normalized target response spectrum exceeds the normalized response spectra of the Risk Engineering (2001) single corner model by a factor of about 2 or more at frequencies below 1 Hz.

Conclusion

Figures 1 through 5 demonstrate the conservatism of the modified Regulatory Guide 1.60 response spectral shape at frequencies below about 3 Hz. There is only a single frequency at which the 5% damped response spectral ordinate of each of the three artificial time-history components does not satisfy the applicable SRP acceptance criteria, and those frequencies are within this low frequency band. At these three frequencies the spectral ordinates are only 0.6% to 2.3% percent below the allowable level, i.e., below 90% of the modified Regulatory Guide 1.60 spectrum. This difference is not significant, particularly when it is recognized that the modified Regulatory Guide 1.60 spectrum may be approximately 200% to 300% or more above a realistic estimate of the response spectral level at those low frequencies.

Based on the very minor nature of these three non-exceedances, and the very large degree of conservatism that exists in the shape of the modified Regulatory Guide 1.60 spectrum at the low frequencies at which they occur, we conclude that the non-exceedances do not have a significant effect on the seismic analysis of structures, systems, and components in the US-APWR standard plant, and that the seismic input used to calculate the hydrodynamic loads on liquid-containing tanks contains sufficient energy in the low-frequency region associated with the convective response of the tanks.

References

Atkinson, G.M. and Boore, D.M. 2006. Earthquake ground-motion prediction equations for eastern North America. *Bull. Seism. Soc. Am.*, **96**, 2181-2205.

Munro, P. and D. Weichert (1989). The Saguenay earthquake of Nov. 25, 1988: processed strong motion records, Geol. Surv. Canada *Open-file Rept. 1996.*

Risk Engineering, Inc. (2001). Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines. *NUREG/CR-6728.*

Power, M., B. Chiou, N. Abrahamson, Y. Bozorgnia, T. Shantz, and C. Roblee (2008). An overview of the NGA project. *Earthquake Spectra*, **24**, 3-21.

Somerville, P.G., J.P. McLaren, C.K. Saikia, and D.V. Helmberger (1990). The November 25, 1988 Saguenay, Quebec earthquake: source parameters and the attenuation of strong ground motion. *Bull. Seism. Soc. Am.,* **80**, 1118-1143.

Toro, G.R., Abrahamson, N.A. and Schneider, J.F. 1997. Model of strong ground motions from earthquakes in central and eastern North America: best estimates and uncertainties. *Seismological Research Letters*, **68**, 41-57.

Table 1. Strong Motion Recordings used in Comparisons

Earthquake	Magnitude	Recording Station	Distance (km)
Nahanni 23 Dec 1985	6.8	1	9.60
		2	4.93
		3	5.32
Saguenay 25 Nov 1988	5.8	1	114
		2	149
		8	93
		9	123
		10	114
		16	43
		17	64

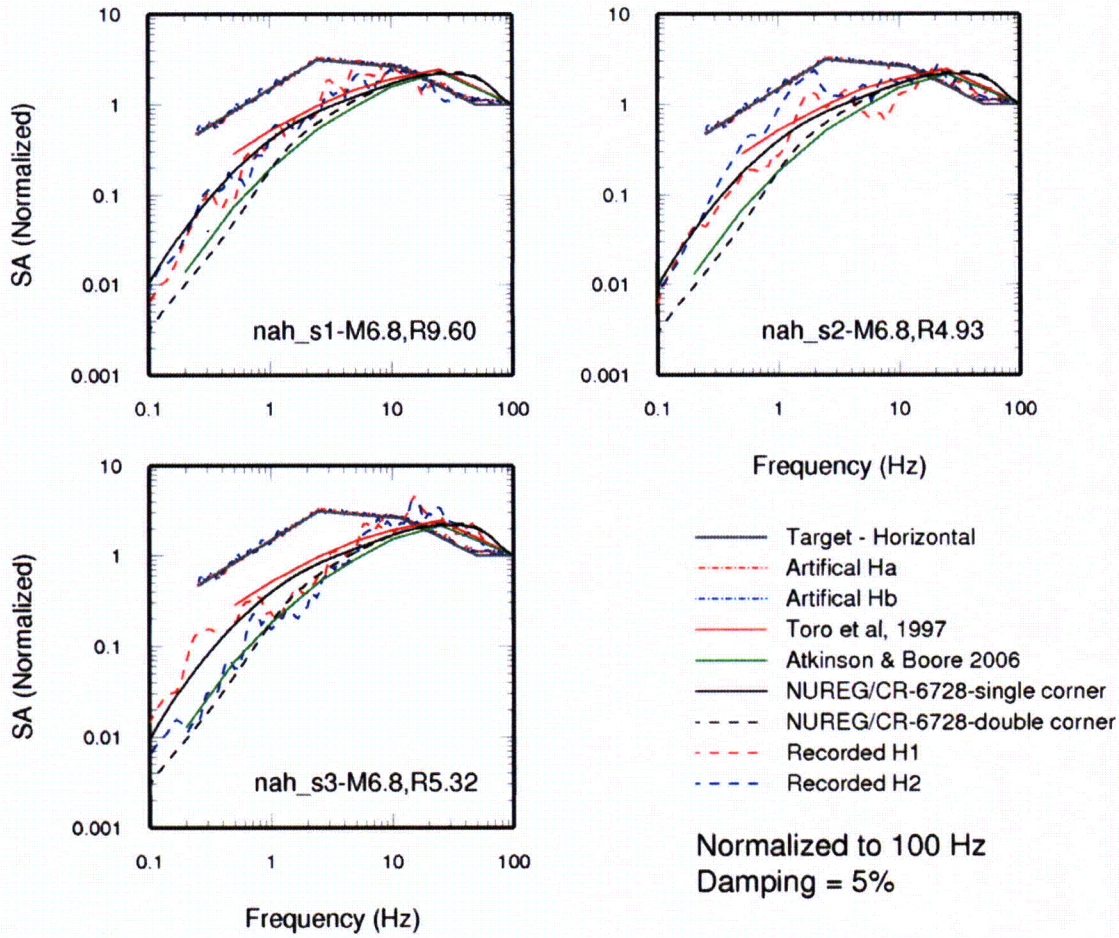


Figure 1. Comparison of the normalized target response spectrum and the normalized response spectra of the artificial time histories with the normalized model response spectra and the normalized response spectra of strong motion recordings, Nahanni earthquake, horizontal component.

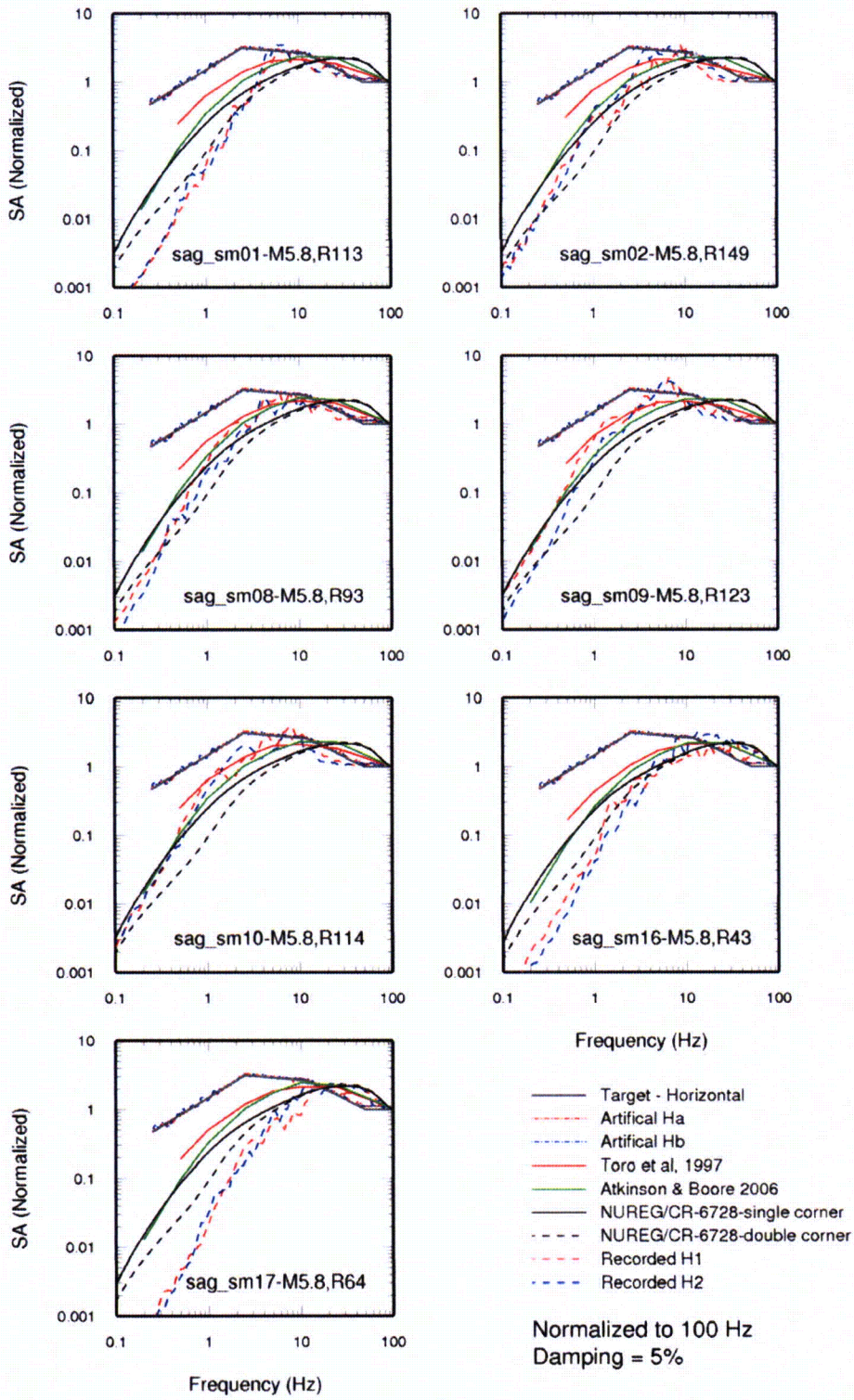


Figure 2. Comparison of the normalized target response spectrum and the normalized response spectra of the artificial time histories with the normalized model response spectra and the normalized response spectra of strong motion recordings, Saguenay earthquake, horizontal component.

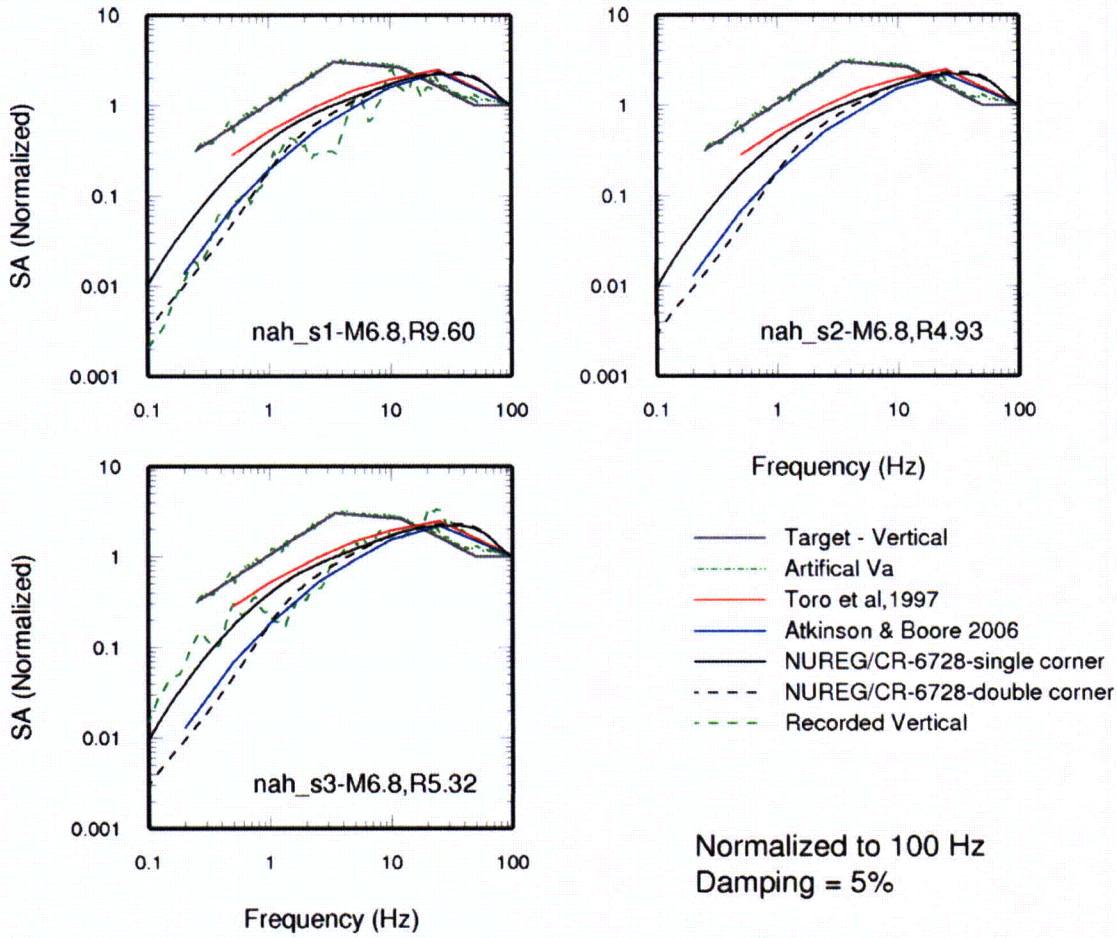


Figure 3. Comparison of the normalized target response spectrum and the normalized response spectra of the artificial time histories with the normalized model response spectra and the normalized response spectra of strong motion recordings, Nahanni earthquake, vertical component.

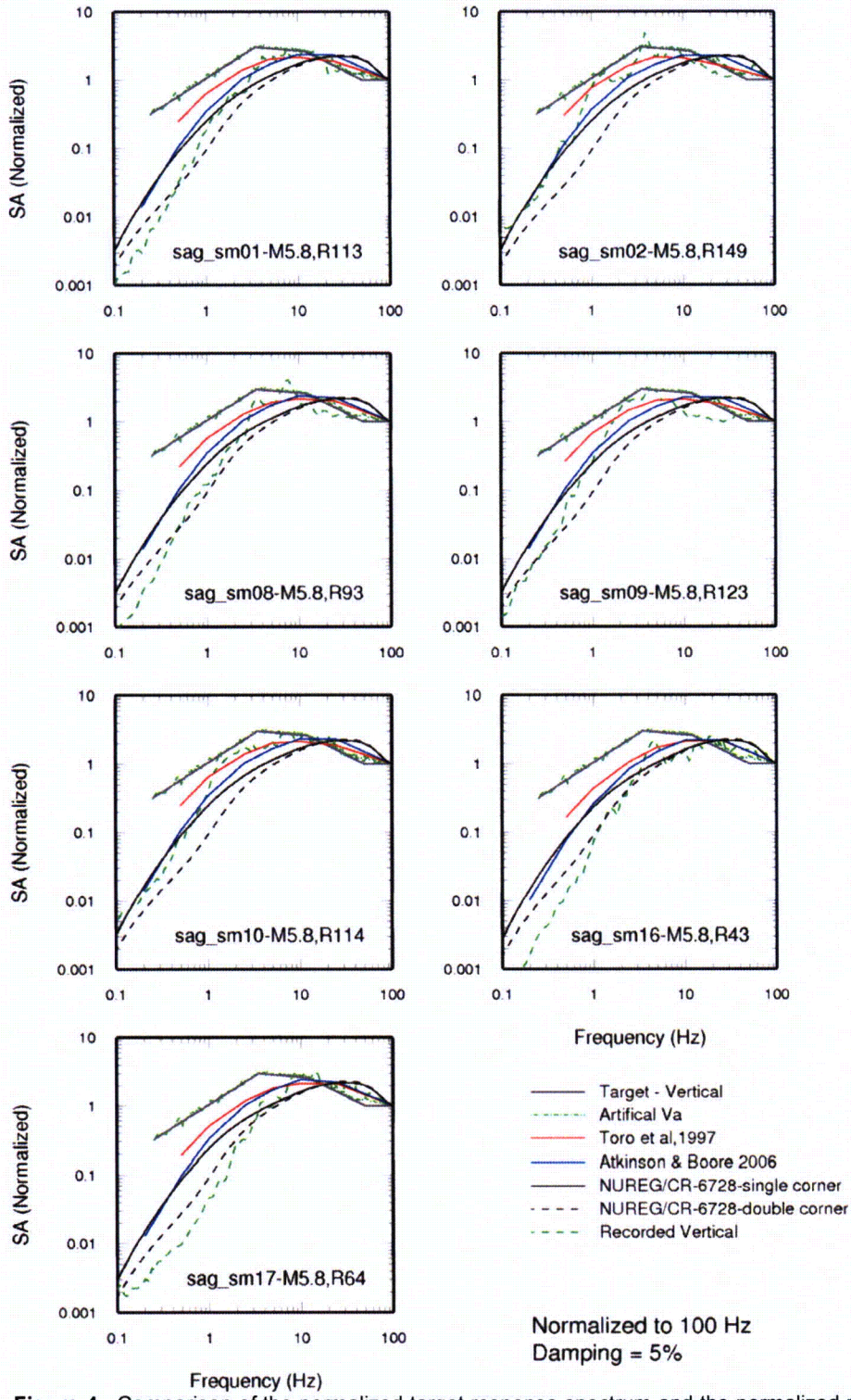


Figure 4. Comparison of the normalized target response spectrum and the normalized response spectra of the artificial time histories with the normalized model response spectra and the normalized response spectra of strong motion recordings, Saguenay earthquake, vertical component.

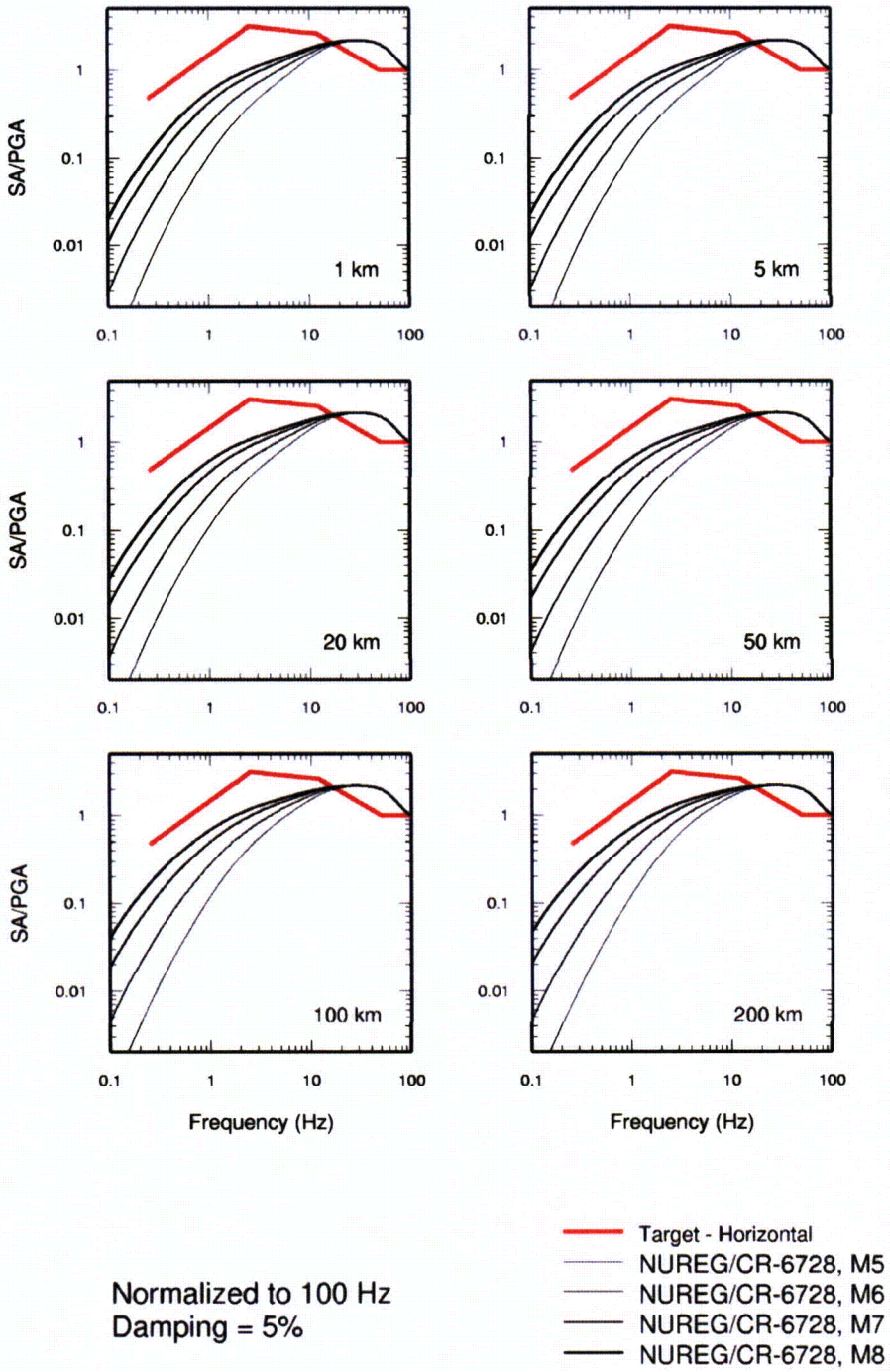


Figure 5. Comparison of the normalized target response spectrum with the normalized response spectra of the Risk Engineering Inc. (2001) single corner model for a wide range of magnitude and distance combinations.

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

3/25/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 211-1946 REVISION 1**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**03.07.01**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.1-2:

Figures 3.7.1-6 through 3.7.1-8 in the DCD provide a comparison of two horizontal and a vertical 5% damped response spectrum obtained from artificial ground motion time histories with the design response spectra. The SRP subsection 3.7.1.B requires that the response spectra obtained from artificial ground motion time histories should envelop the design response spectra for all damping values. Provide a comparison of design spectra with the spectra obtained from artificial ground motion time histories for all design damping values to demonstrate that the response spectra obtained from the artificial time histories of ground motion envelop the design response spectra.

ANSWER:

The requested comparisons are provided for the two horizontal components for damping values of 0.5%, 2%, 5%, 7% and 10% in Figures 1 through 5 (below), and for the vertical component in Figures 6 through 8 (below). These damping values include all that are relevant to analyses using the ground motions. The figures show that the response spectra of the artificial ground motion time history set generally envelop the target response spectra for all values of damping as recommended in Section I.1.B of SRP 3.7.1.

It is our understanding that Option 1, Approach 2 of the Standard Review Plan (Revision 3, March 2007), unlike Option 1, Approach 1, requires the response spectrum of the time history to envelop the target spectrum only for damping of 5%, and does not require that it envelop the design response spectra for other damping values.

The agreement between the response spectra of the time history and the target response spectrum for 5% damping is described in our response to RAI 3.7.1-01.

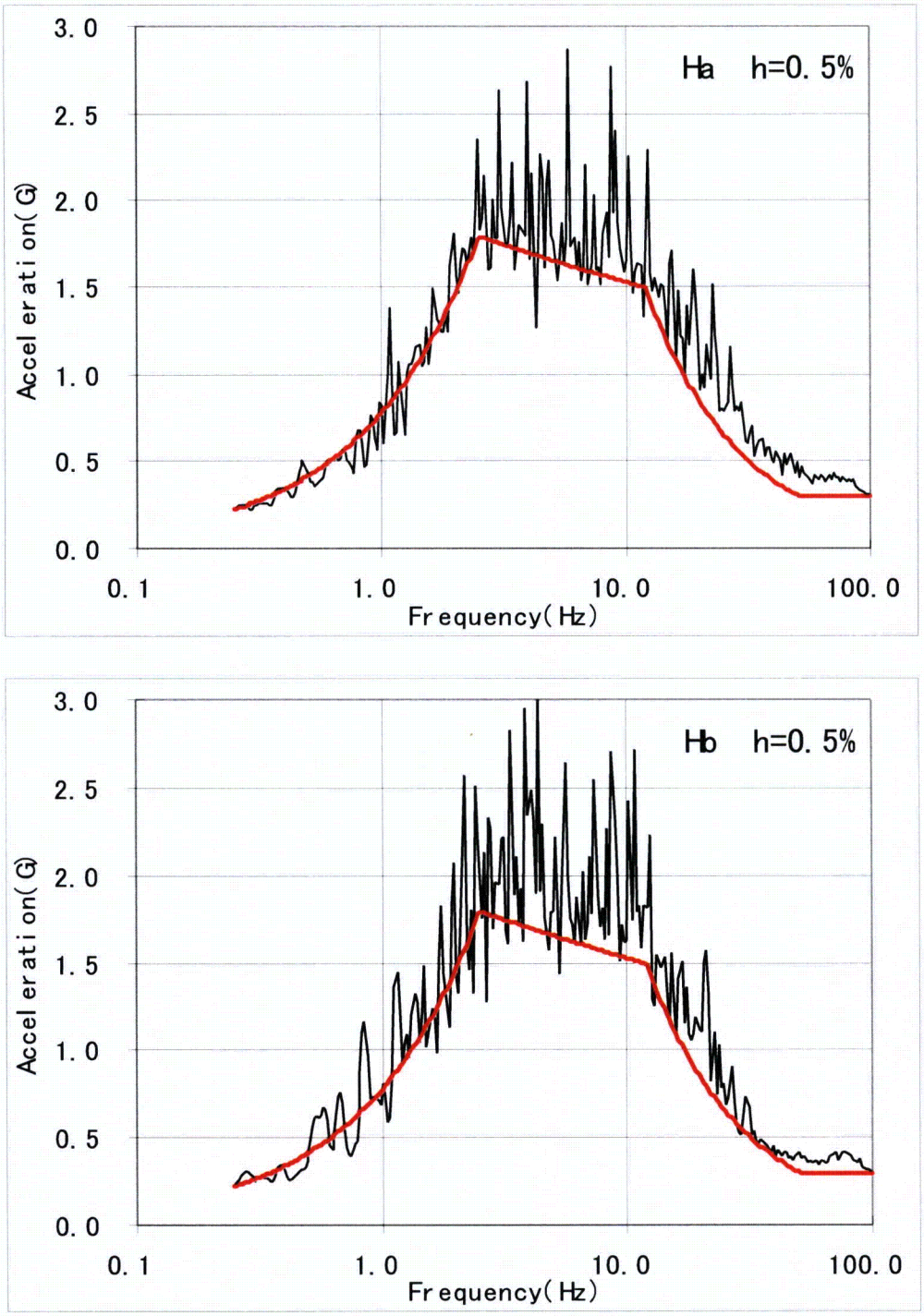
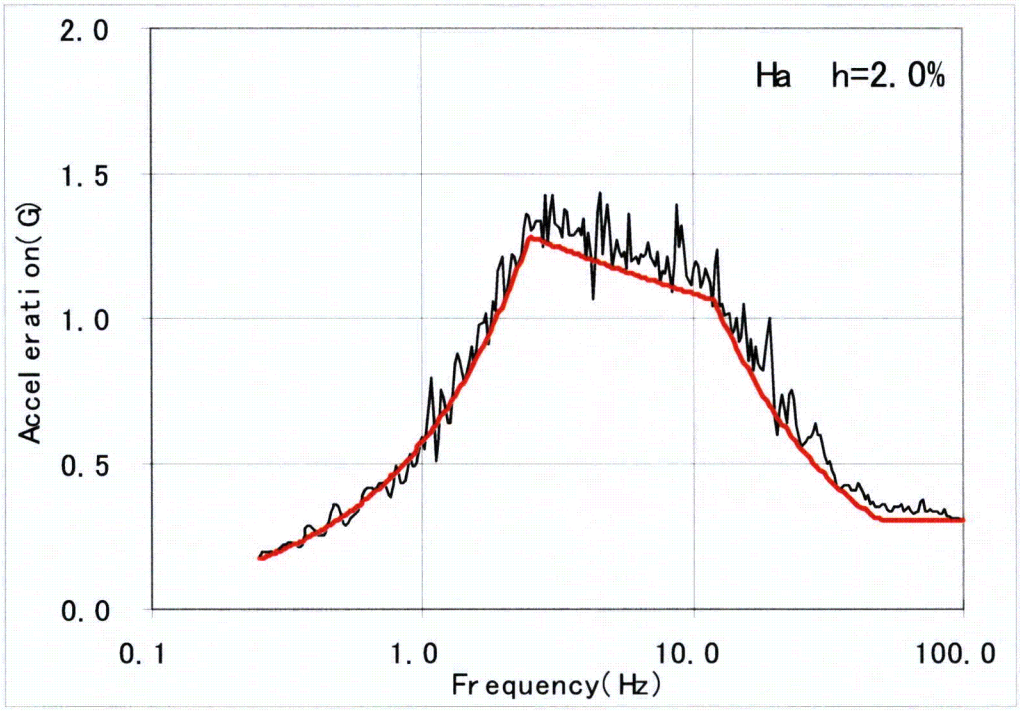


Figure 1. Comparison of target response spectrum (red) with the response spectrum of the two horizontal components of the artificial time history at 0.5% damping (black).



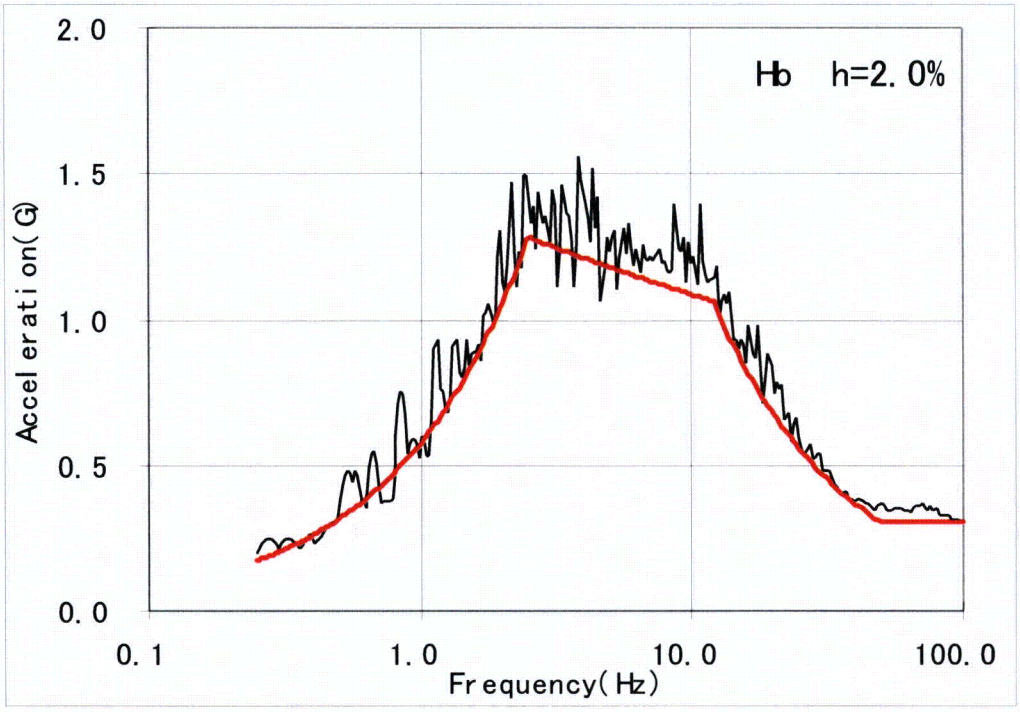
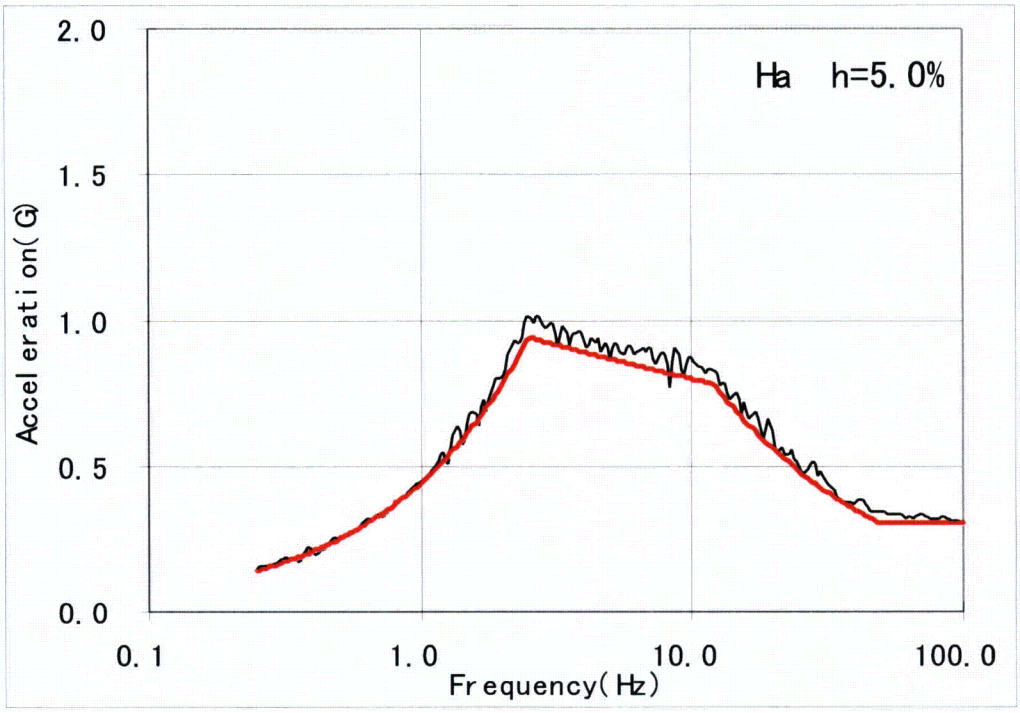


Figure 2. Comparison of target response spectrum (red) with the response spectrum of the two horizontal components of the artificial time history at 2% damping (black).



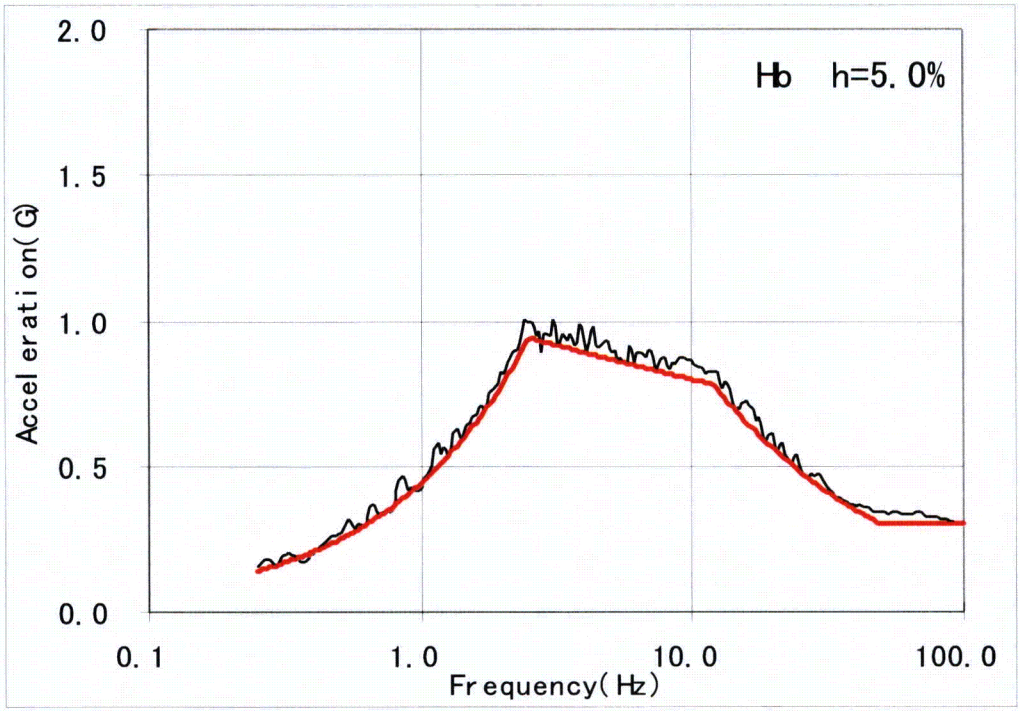
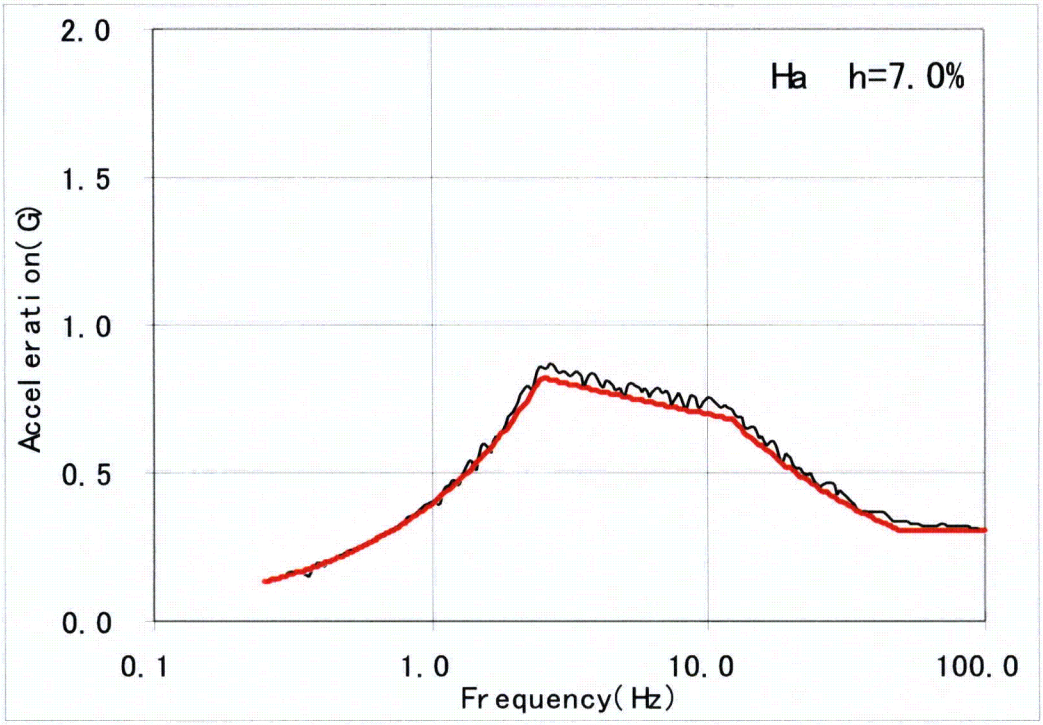


Figure 3. Comparison of target response spectrum (red) with the response spectrum of the two horizontal components of the artificial time history at 5% damping (black).



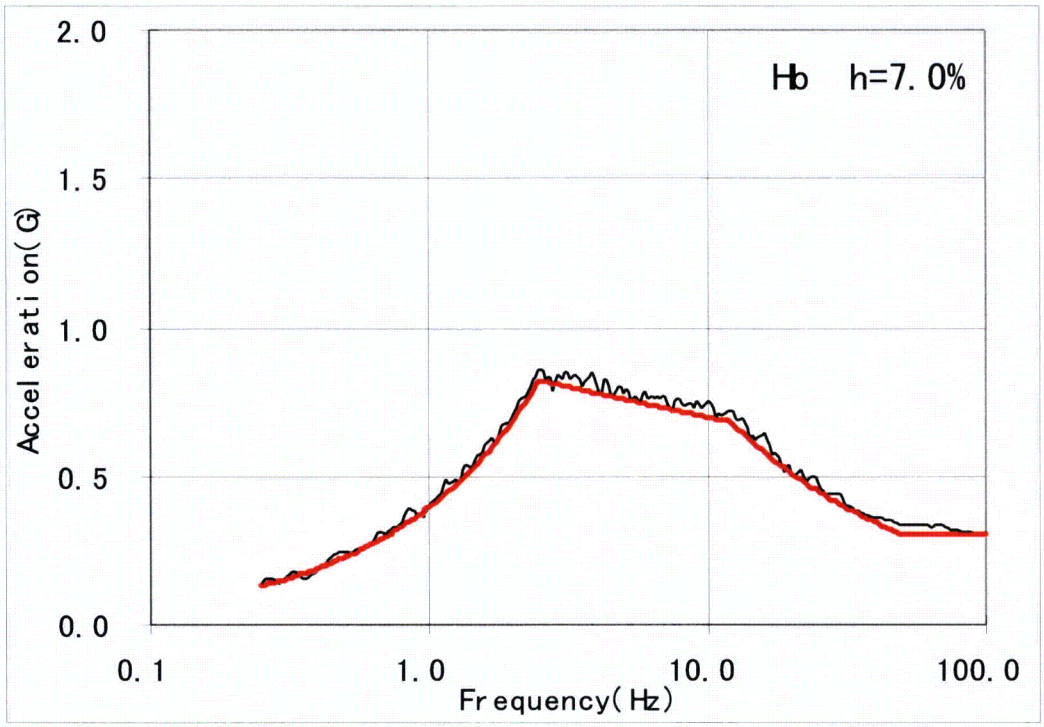
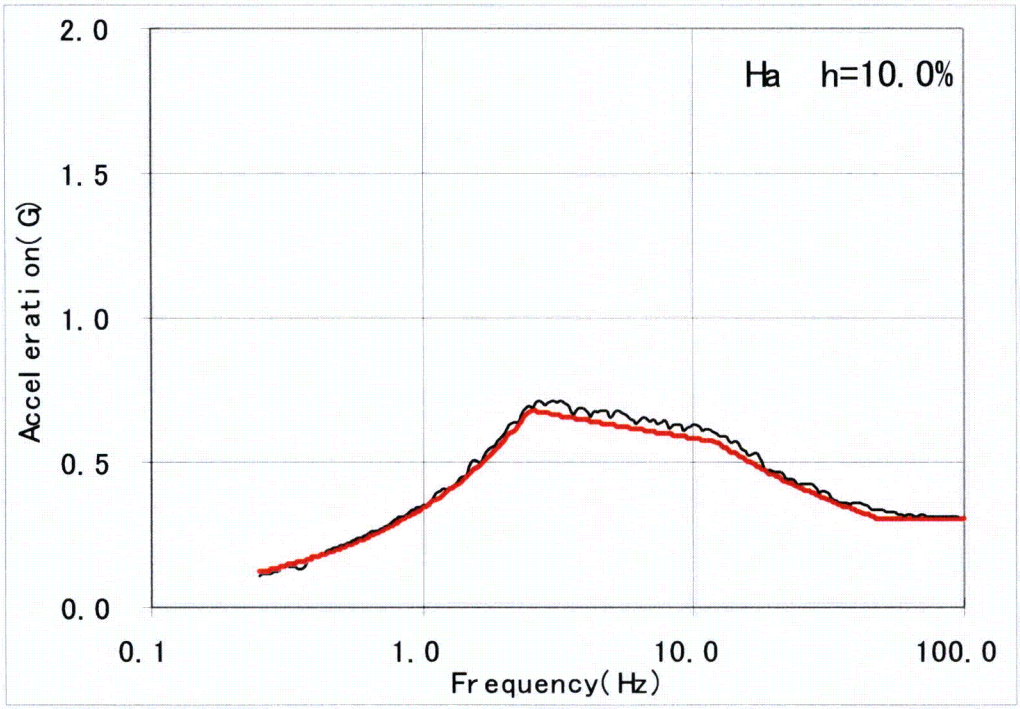


Figure 4. Comparison of target response spectrum (red) with the response spectrum of the two horizontal components of the artificial time history at 7% damping (black).



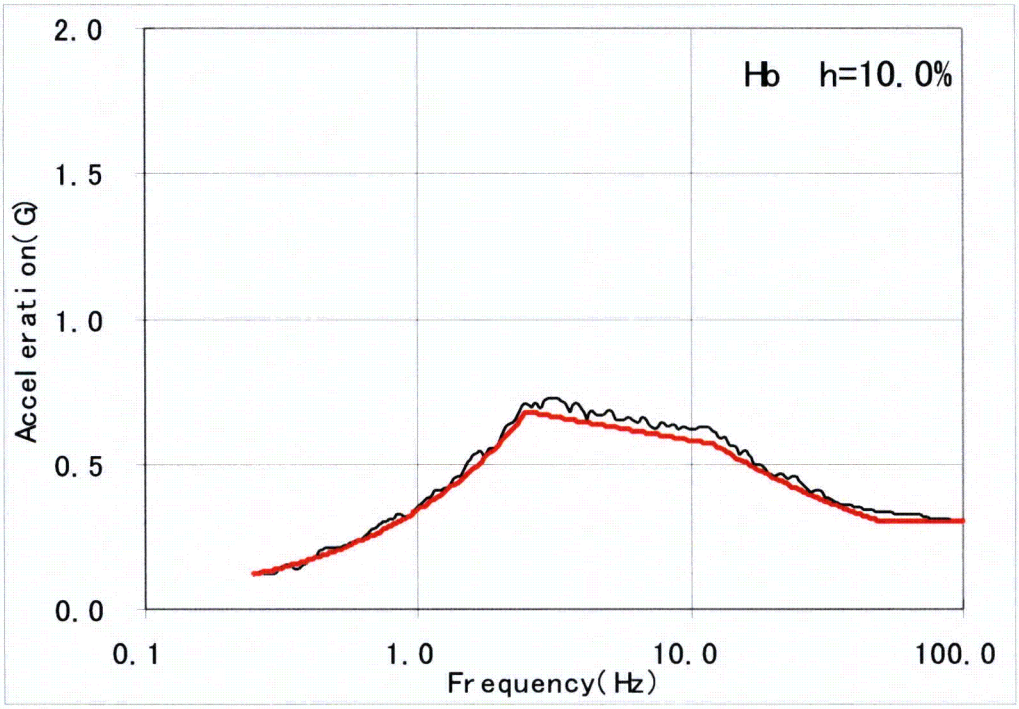
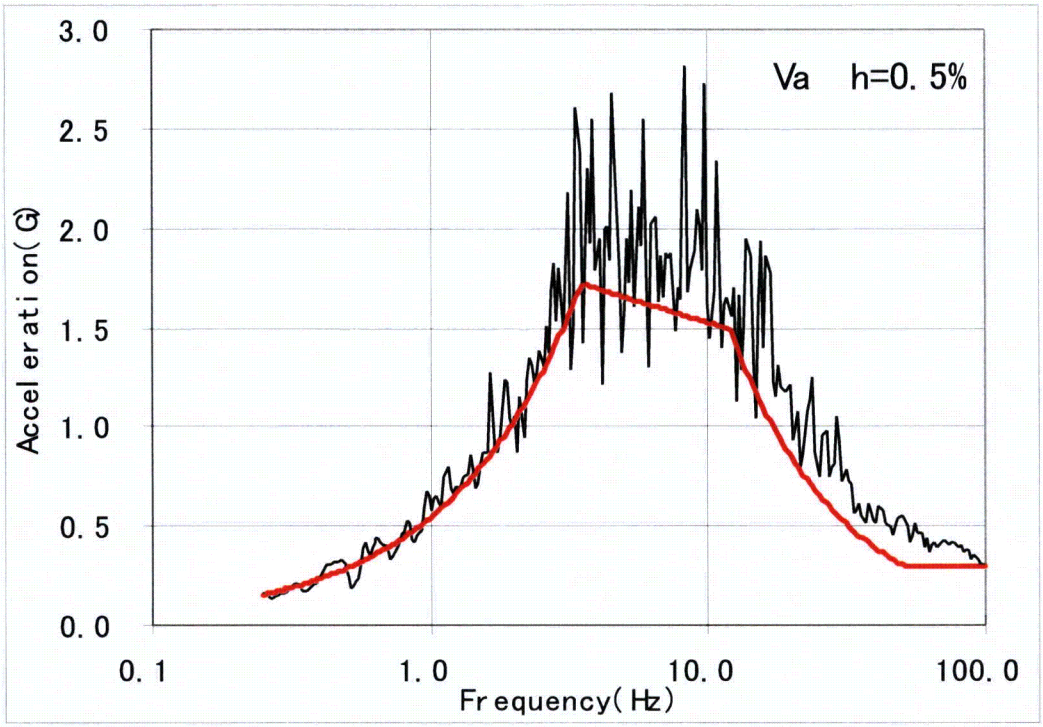


Figure 5. Comparison of target response spectrum (red) with the response spectrum of the two horizontal components of the artificial time history at 10% damping (black).



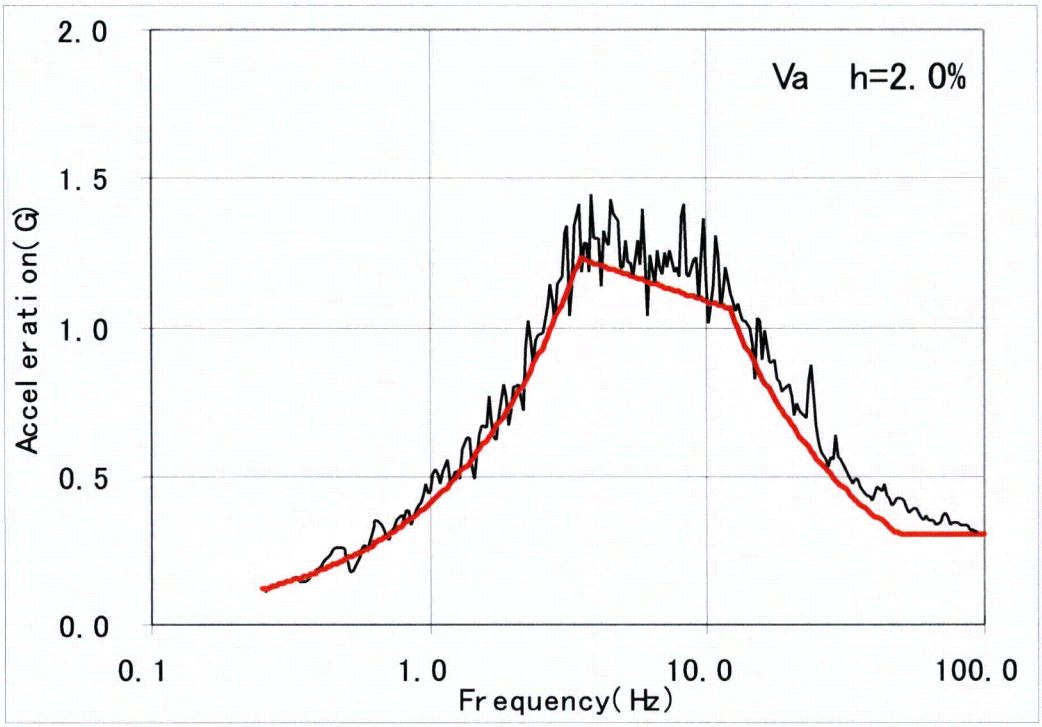
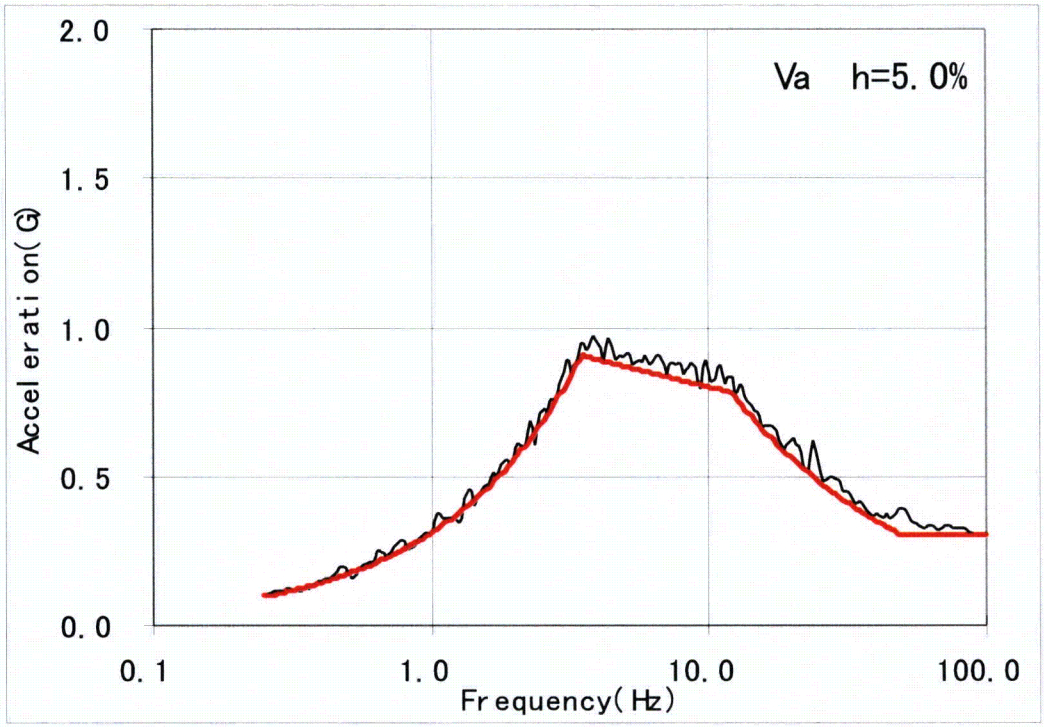


Figure 6. Comparison of target response spectrum (red) with the response spectrum of the vertical component of the artificial time history at 0.5% and 2% damping (black).



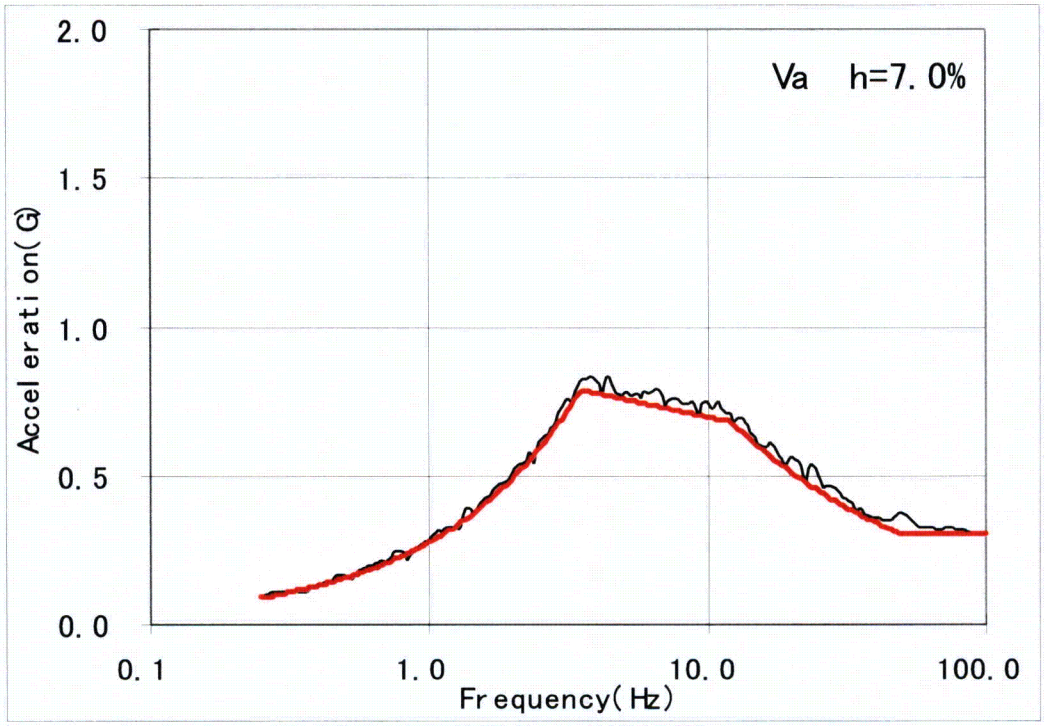


Figure 7. Comparison of target response spectrum (red) with the response spectrum of the vertical component of the artificial time history at 5% and 7% damping (black).

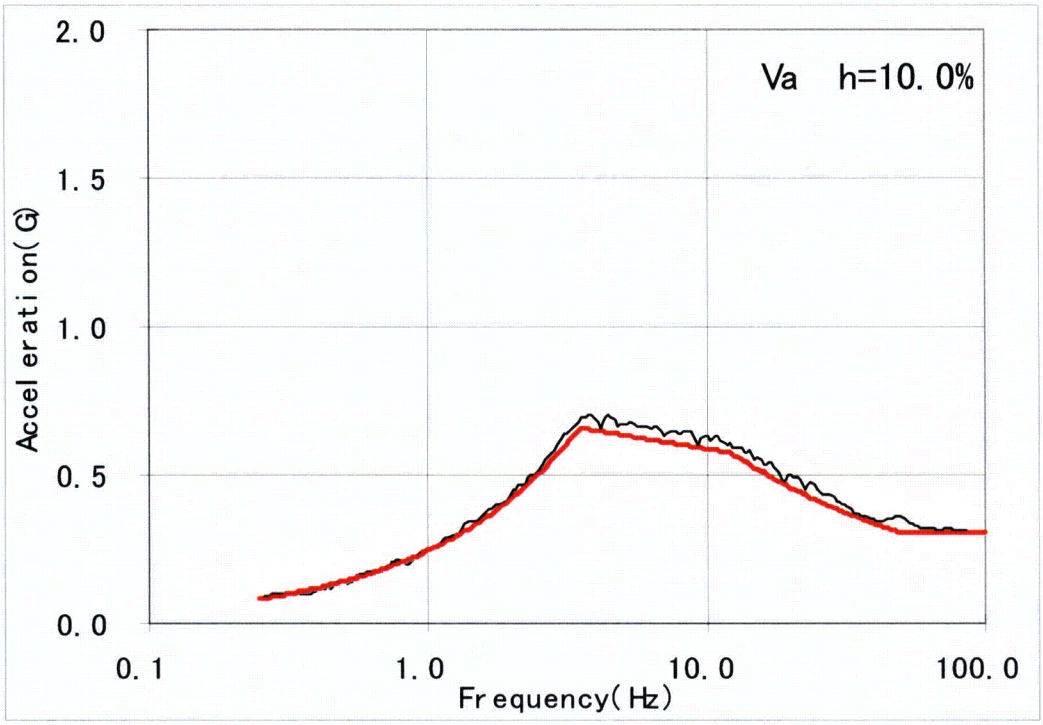


Figure 8. Comparison of target response spectrum (red) with the response spectrum of the vertical component of the artificial time history at 10% damping (black).

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

3/25/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 211-1946 REVISION 1**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**03.07.01**
DATE OF RAI ISSUE:	**02/25/09**

QUESTION NO. RAI 3.7.1-4:

In Section 3.7.1.1of the DCD, a methodology to develop site specific horizontal GMRS is described that refers to the industry standard ASCE 4-98 as the basis for defining the shear wave velocity for rock material. The staff has not reviewed and endorsed ASCE 4-98 for the SSI application. Currently this ASCE standard is under revision. Provide the bases and justification including appropriate test data to support the shear wave velocity of 3500 ft/s for rock material. Also, provide justification for the position that non-linearities of the subgrade material need not be addressed if the initial (small strain) shear wave velocity of the material is 3,500 ft/s or greater.

ANSWER:

Since the NRC staff has not reviewed and endorsed ASCE 4-98 for the SSI application, the reference to ASCE 4-98 will be deleted with respect to the 3,500 ft/s limit for considering effects of non-linearity of the subgrade materials. The DCD discussion in Section 3.7.1.1 "Site-Specific GMRS" will be expanded to state that engineering properties of the site-specific subsurface materials must be determined by the COL Applicant to assure consistency with DCD Section 3.7.2, as discussed in DCD Section 2.5.4. A similar change to the DCD discussion in Section 3.7.2.4.1 "Requirements for Site-Specific SSI Analysis of US-APWR Standard Plant" will also be made.

Explanation for the bases and justification for this approach are provided as follows. The discussion of the site-specific GMRS in DCD Tier 2 Section 3.7.1.1 is intended to briefly describe the process by which seismic input motion is developed for use in various site-specific seismic designs to be performed by the COL Applicant. In that process, site measurements of small-strain shear wave velocity for materials that have shear wave velocities below 3,500 ft/s can serve as the primary indication that the site-specific response behavior may be dependent on the strains induced by the design ground motion. The justification for the use of 3,500 ft/s as the limit below which non-linear behavior <u>must</u> be addressed for the purpose of defining the design input motion was based on the ASCE 4-98 definition of such material as rock, considering that the strain-dependent behavior of materials with lower shear wave velocities would more likely have an impact on the site-specific seismic response. It can also be noted that, historically, a material shear wave velocity value of 3,500 ft/s served as a condition for setting the lower boundary of a

soil-structure interaction model and also as an indication that a fixed-base analysis assumption might be justifiable (refer to discussion in part II, item 4 of SRP 3.7.2, Rev. 2, on page 3.7.2-10). Although new reactor license applications (including the US-APWR) are no longer using 3,500 ft/s as an indicator for those considerations, the DCD discussion considered the approach that the 3,500 ft/s limit could still serve as a general basis for delineation of whether the material seismic response is significantly affected by strain rate, contingent upon site-specific confirmation of soil properties.

Since the occurrence of non-linear subgrade behavior is also a function of the magnitude of seismic acceleration, a site-specific investigation is required by the US-APWR DCD to determine if the effects of non-linearity of the subgrade materials can be neglected and if linear-elastic behavior can be used for the purpose of defining input motion (regardless of subgrade material shear wave velocity). DCD Tier 2 Section 2.5.4 requires the COL Applicant to discuss the site-specific acceptability of soil materials to be addressed to "assure the consistency between the assumptions made in Section 3.7.2 and the site specific conditions identified" within Section 2.5.4 of the COLA. Further, it is the responsibility of the COL Applicant to conduct detailed site-specific geological and geotechnical engineering investigations to assess specific characteristics of all soil and rock formations in the site area, as described in DCD Section 2.5.4.2 and as required by the general COL item 2.5(1). Based on the results of those site investigations, it will be conclusively determined whether the behavior of stiff rock and rock-like materials present at the site remains unaffected by the strains induced by the site-specific SSE.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Subsection 3.7, Revision 2, changes to be incorporated.

- Change the 5th and 6th sentences of the 2nd paragraph of **Site-Specific GMRS** in Subsection 3.7.1.1 to the following: "If materials are present at the site in which the initial (small strain) shear velocity is less than 3,500 ft/s, the site response analysis will address probable effects of non-linearity due to strain-dependence of the subgrade materials' response. 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 function of strain."

- Change the 3rd paragraph of **Site-Specific GMRS** in Subsection 3.7.1.1 to the following:

  "With respect to determining the site-specific GMRS, note that Section 2.5.4 requires site-specific characterization of subsurface materials and investigation of the associated engineering properties to assure consistency with Section 3.7.2. Further, 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."

- Change the 2nd and 3rd sentences of the 6th paragraph in Subsection 3.7.2.4.1 to the following: "The soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3,500 ft/s or higher, to be confirmed by the COL Applicant as part of the site-specific subsurface material investigations discussed in Section 2.5.4. However, the COL Applicant must 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."

- Change Combined License Information statement of *COL3.7(8)* in Subsection 3.7.5 to the following:

"COL3.7(8) The soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3,500 ft/s or higher, to be confirmed by the COL Applicant as part of the site-specific subsurface material investigations discussed in Section 2.5.4. However, the COL Applicant must 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."

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.

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~~ will address probable effects of non-linearity due to strain-dependence of the subgrade materials' response. 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.

With respect to determining the site-specific GMRS, note that Section 2.5.4 requires site-specific characterization of subsurface materials and investigation of the associated engineering properties to assure consistency with Section 3.7.2. Further, ~~V~~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

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). The soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3,500 ft/s or higher, to be confirmed by the COL Applicant as part of the site-specific subsurface material investigations discussed in Section 2.5.4. However, ~~T~~the COL Applicant must ~~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 1.2 of RG 1.61 (Reference 3.7-15), the lower OBE damping values in Table 3.7.3-1(b) are assigned to the structural model as complex damping.

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 soil properties may be considered strain-independent for subgrade materials with initial shear wave velocities of 3,500 ft/s or higher, to be confirmed by the COL Applicant as part of the site-specific subsurface material investigations discussed in Section 2.5.4. However, ~~T~~the COL Applicant ~~is to~~ must 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 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.*