MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

September 21, 2012

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-12265

Subject: **MHI's Amended Responses to US-APWR DCD RAI No. 939-6334 Revision 3 (SRP 03.07.01) and No. 940-6532 Revision 3 (SRP 03.07.01)**

References: **1)** "Request for Additional Information No. 939-6334 Revision 3," dated June12, 2012
2) "Request for Additional Information No. 940-6532 Revision 3," dated June 12, 2012

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") two documents entitled "Amended Response to Request for Additional Information No. 939-6334 Revision 3" and "Amended Response to Request for Additional Information No. 940-6532 Revision 3."

Enclosed are revised responses to Question 03.07.01-36 contained within Reference 1, and Questions 03.07.01-40 and 03.07.01-41 contained within Reference 2, respectively. The responses to the other questions from RAI sets 939-6334 and 940-6532 submitted previously remain unchanged.

Also enclosed is CD 1, "Northridge Time Histories (09/12/2012)," that transmits digital data in support of the time histories used in response to the related RAI questions.

As indicated in the enclosed materials, the enclosed CD contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential.

This letter includes the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all materials designated as "Proprietary" in the enclosed CD be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).
Please contact Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittal. His contact information is below.

D081
NRO

Sincerely,

Y. Ogata

Yoshiki Ogata,
Director, APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosures:

1. Affidavit of Yoshiki Ogata

2. Amended Response to Request for Additional Information No. 939-6334 Revision 3

3. Amended Response to Request for Additional Information No. 940-6532 Revision 3

4. CD 1: Northridge Time Histories (09/12/2012)
   -Version containing proprietary information

The files contained on CD 1 are listed in Attachment 1.

CC: J. A. Ciocco
J. Tapia

Contact Information
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Enclosure 1

Docket No. 52-021
MHI Ref: UAP-HF-12265

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Yoshiki Ogata, state as follows:

1. I am Director, APWR Promoting Department, of Mitsubishi Heavy Industries, LTD ("MHI"), and have been delegated the function of reviewing MHI's US-APWR documentation to determine whether it contains information that should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4)as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the information in the enclosed CD, September 2012, and have determined that the CD contains proprietary information that should be withheld from public disclosure. All information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The information identified as proprietary in the enclosed CD has in the past been, and will continue to be, held in confidence by MHI and its disclosure outside the company is limited to regulatory bodies, customers and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and is always subject to suitable measures to protect it from unauthorized use or disclosure.

4. The basis for holding the referenced information confidential is that it describes the unique design information and analysis of Seismic Design, developed by MHI and not used in the exact form by any of MHI's competitors. This information was developed at significant cost to MHI, since it required the performance of Research and Development and detailed design for its software and hardware extending over several years.

5. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of information to the NRC staff.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information. Other than through the provisions in paragraph 3 above, MHI knows of no way the information could be lawfully acquired by organizations or individuals outside of MHI.

7. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without incurring the costs or risks associated with the design of the subject systems. Therefore, disclosure of the information contained in the referenced CD would have the following negative impacts on the competitive position of MHI in the U.S. nuclear plant market:

   A. Loss of competitive advantage due to the costs associated with development of the US-APWR Seismic Design. Providing public access to such information permits competitors to duplicate or mimic the Seismic Design information without incurring the associated costs.

B. Loss of competitive advantage of the US-APWR created by benefits of enhanced US-APWR Seismic Design development costs associated with the Seismic Stability Design.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information and belief.

Executed on this 21st day of September, 2012.

Y. Ogata

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

Enclosure 2

UAP-HF-12265
Docket No. 52-021

Amended Response to Request for Additional Information No. 939-6334 Revision 3

September 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

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

RAI NO.:	**NO. 939-6334, REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-34:

In its response to RAI 850-6002, Question No. 03.07.01-25, the applicant in its justification of the artificial ground motion time history that matched only a single-damping target spectrum, presented comparisons between the CSDRS spectra with the spectra generated from the artificial time histories for three component directions, for 0.5%, 2%, 5%, 7%, and 10% damping. The staff noticed that the 0.5% and 2% damping response spectrum (on pages 3.7-16 through 21) generated from the artificial time histories is not bounded by the 0.9 to 1.3 band which is specified in SRP 3.7.1. Additionally, the applicant stated in its response that, "The re-generated time histories for the US-APWR are generated in accordance with the guidance of Option I, Approach 2 of SRP 3.7.1 (R3). Unlike the guidance for Option 1, Approach 1; Option 1, Approach 2 only requires enveloping of the computed 5% damping response spectrum of the accelerogram (see items ii.c and ii.d of the SRP)."

The staff noted that the last paragraph of SRP 3.7.1 Option 1, Approach 2 (Page 3.7.1- 12) states, "Artificial ground motion time histories defined as described above shall have characteristics consistent with characteristic values for the magnitude and distance of the appropriate controlling events defined for the uniform hazard response spectrum (UHRS)." The technical basis for SRP 3.7.1 Option 1, Approach 2 is provided in NUREG/CR-6728 that was developed to provide guidance on generating time histories for site specific hazard- and risk-consistent ground motion spectra.

In Section 3.7.1.1 of the USAPWR DCD (R3), the site-independent CSDRS is specified as a modified RG 1.60 spectra and not an UHRS spectrum. Therefore, the use of SRP 3.7.1 Option 1, Approach 2 in generating the artificial time history for the site-independent CSDRS is not appropriate.

The staff requests the applicant to develop the design basis synthetic time histories for all three directions of the CSDRS in the DCD (R3), that satisfy the spectral matching criteria and PSD matching criteria of the SRP 3.7.1, Option 1, Approach 1.

ANSWER:

MHI has revised the time history methodology used to develop the time history for structural design and in-structure response spectra (ISRS) development to satisfy the SRP 3.7.1 Option 1, Approach 1 criteria. (The terminology used here for time history refers to all three components, i.e., North South, East West and vertical.) The design basis time history in Technical Report MUAP-10006, Rev. 3 is being developed to satisfy the spectral matching criteria and power spectral density (PSD) matching criteria of the SRP 3.7.1, Option 1, Approach 1. The approach utilized for developing the time history is summarized in the response to RAI 939-6532, Rev. 3, Question 03.07.01-40.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334, REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-35:

In its response to RAI 850-6002, Question No. 03.07.01-22, the applicant provides Table 1 which is taken from a source of standard statistical tables. Table 1 shows the sample size required for a given percent error in the standard deviation for a normal distribution, which the applicant purports to support their assertion that using 30 realizations in the analyses provides sufficient stable estimates of means and standard deviations. Further, the applicant states that increasing the sample size to 60 realizations reflects, at best, only an unnecessary and marginal improvement.

The staff considers that the evidence provided in Table 1 to be inadequate for supporting the applicant's argument. The staff is requesting that the applicant use actual data generated from the soil profiles in the US-APWR DCD; provide a table that shows conclusively the convergence as the number of realizations is increased; and provide the rationale to support the claim that 30 realizations instead of 60 realizations as specified in RG. 1.208 is adequate for the analyses.

ANSWER:

MHI's position is that increasing the sample size from 30 to 60 reflects a marginal improvement to the accuracy of the strain compatible properties that are developed as median value of the results obtained from site response analyses of 30 realizations.. In order to illustrate the numerical stability in strain compatible properties between 30 and 60 realizations, Figure 1 compares median strain compatible property estimates computed for the two sample sizes for the deep (500 ft) generic profile 560 - 500. Figure 2 provides ratios of the property estimates, i.e., 30 realizations/60 realizations for all properties (shear-wave and compressional-wave velocities and corresponding damping). The maximum difference is about 5% and occurs over shallow and narrow depth ranges. Over the deeper portion of the profile, beyond a depth of about 150 ft, the difference is about 2% in shear-wave and compressional-wave velocity and about 4% in shear-wave damping.

A similar stability of 30 versus 60 realizations is provided for the standard deviation. Figure 3 is a plot, corresponding to the plot in Figure 1, for the Standard Deviations (sigmas) of the strain compatible properties. The percent difference between 30 verses 60 realizations is slightly larger for sigma compared to the mean (Figures 1 and 2), as expected from standard statistical tables. These results support the position, based on standard statistical tables, that the difference in estimates of means and standard deviations is not significant between sample sizes of 30 and 60. The guidance in RG 1.208 for 60 realizations refers to the standard deviation of the simulated response spectra, which is not used in developing the strain compatible properties. The demonstration of stability of the strain compatible properties sigma estimates with respect to sample sizes of 30 versus 60 is offered to provide additional clarity in the process of developing the strain compatible properties.

As illustrated in the figures below, there are marginal improvements in increasing the sample size from 30 to 60. Therefore using 30 realizations is sufficient to provide reasonable estimates for the mean generic strain compatible properties used as input for the site-independent soil-structure interaction (SSI) analyses.

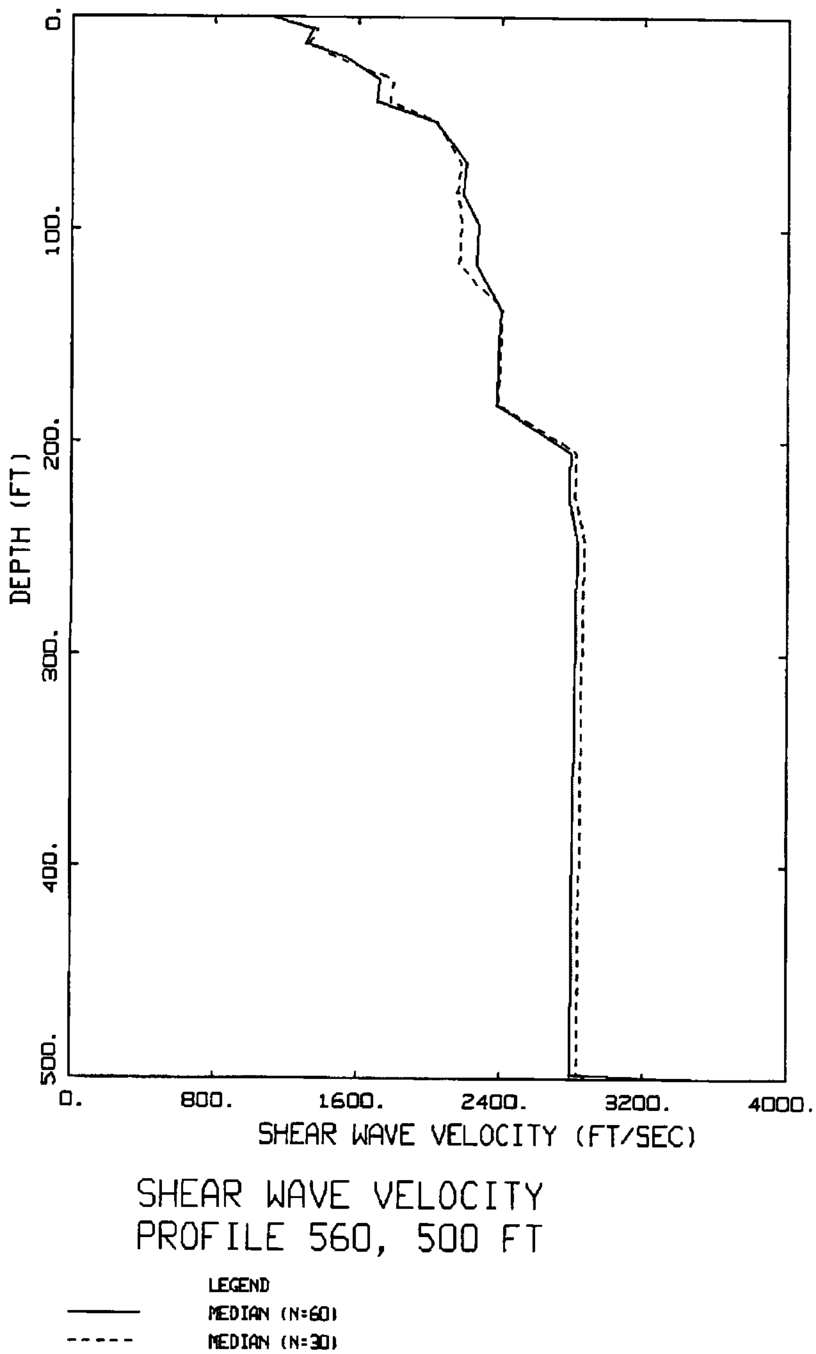


Figure 1, Comparison of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

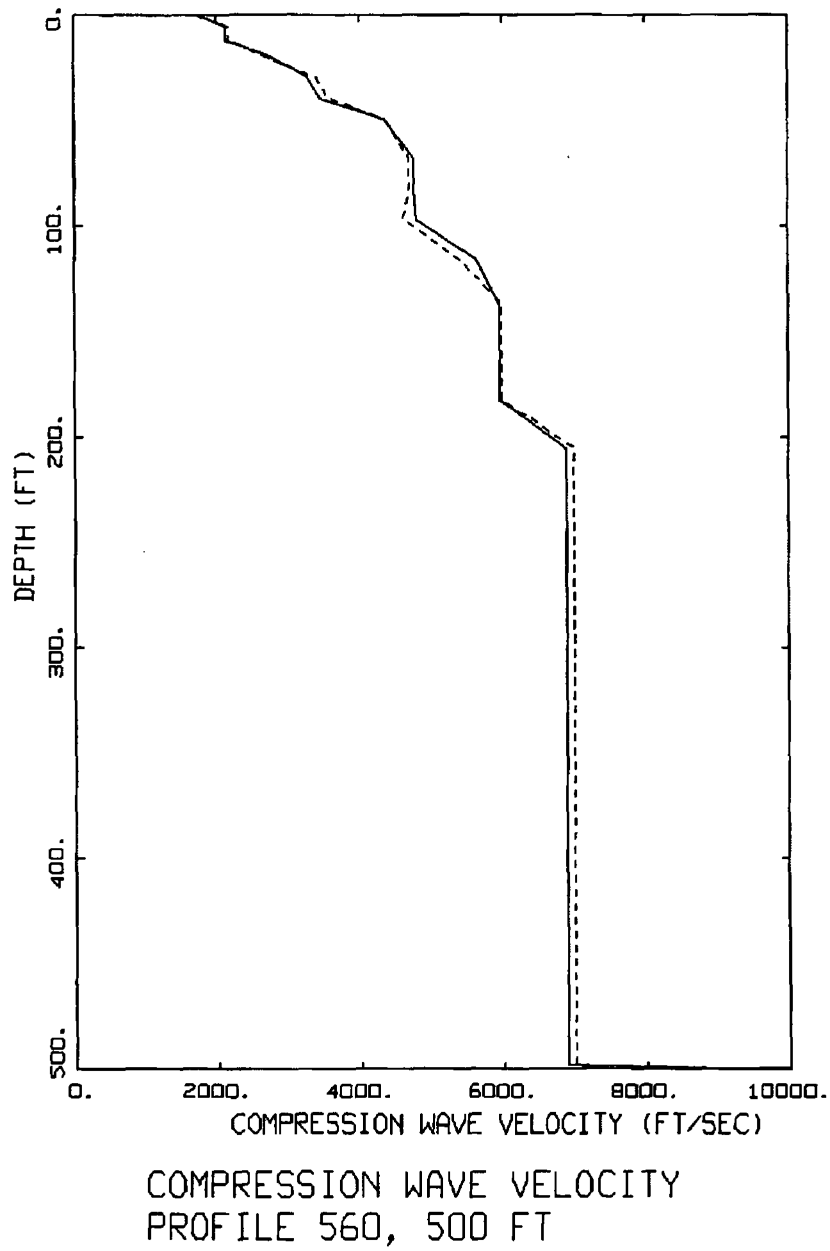


Figure 1 (continued), Comparison of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

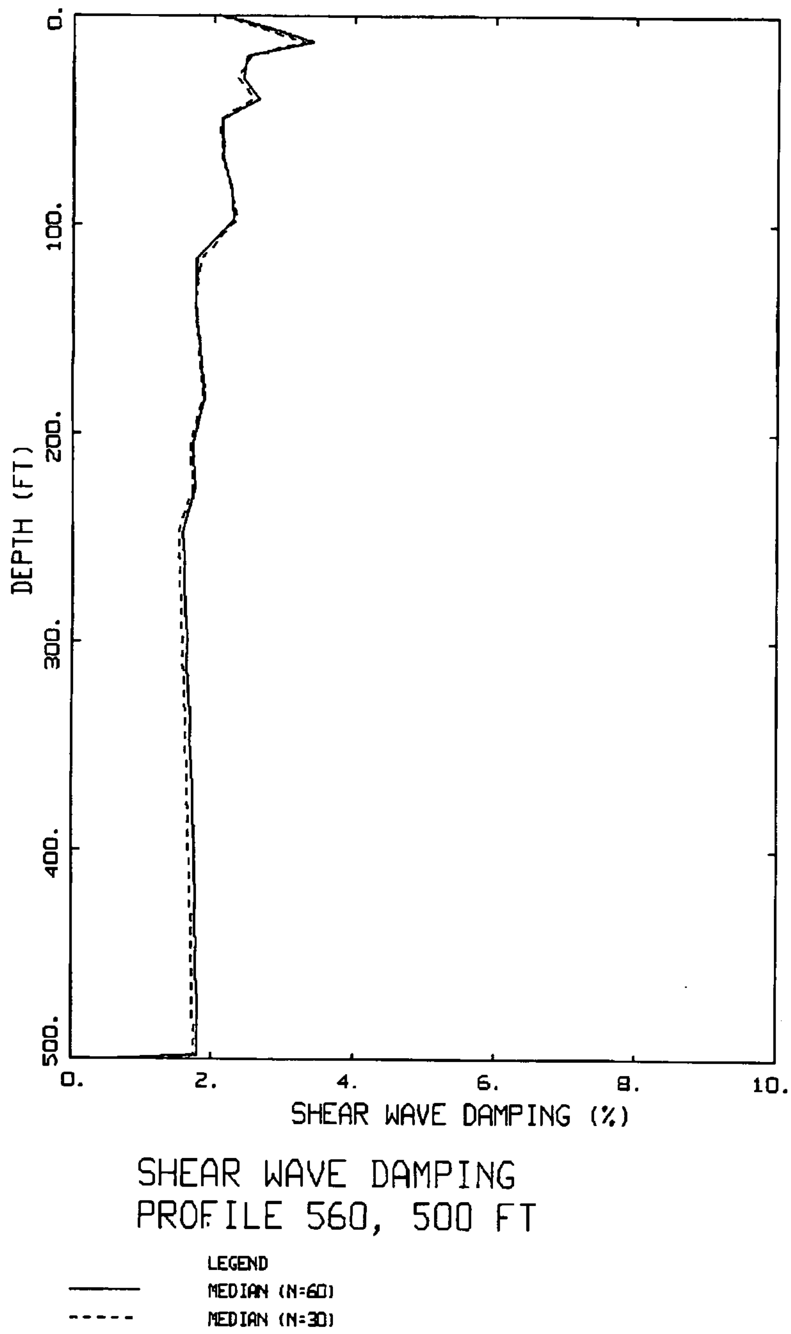


Figure 1 (continued), Comparison of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

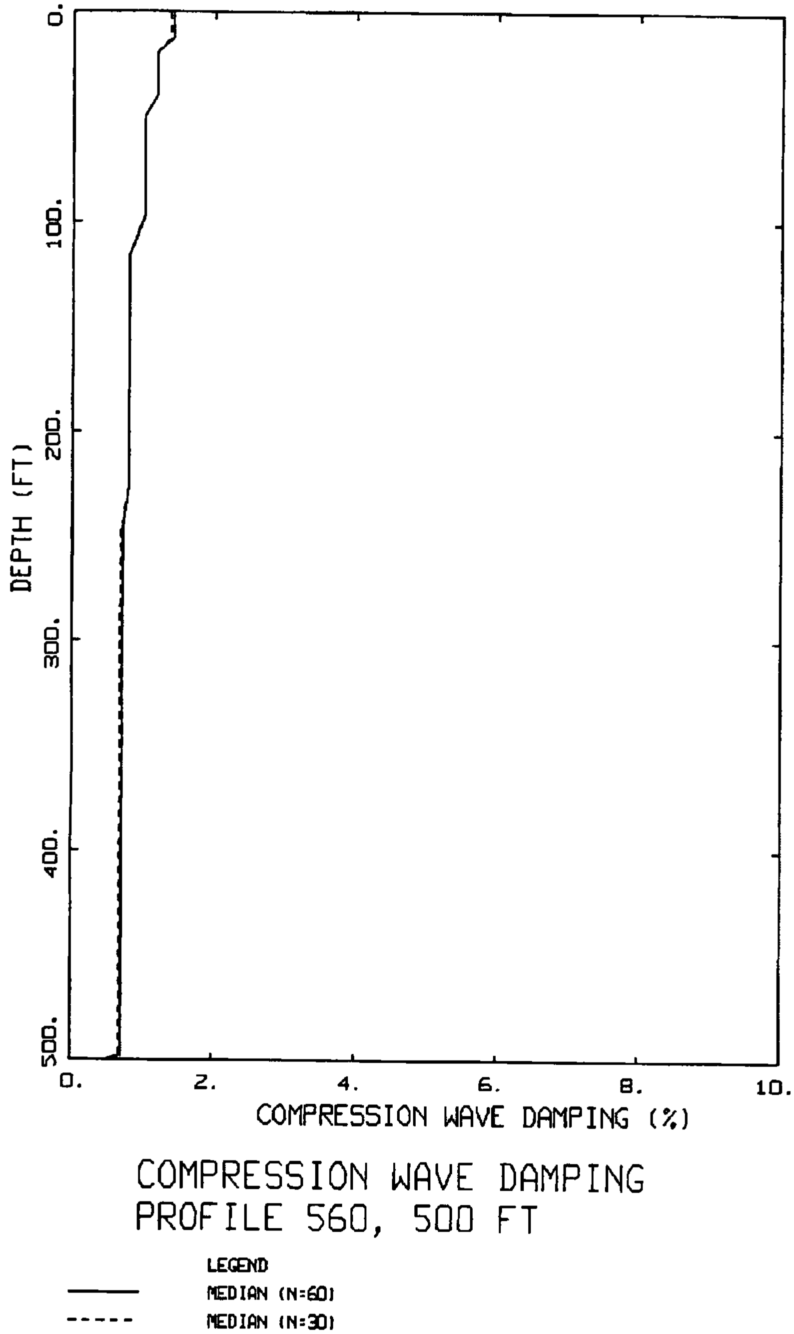


Figure 1 (continued), Comparison of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

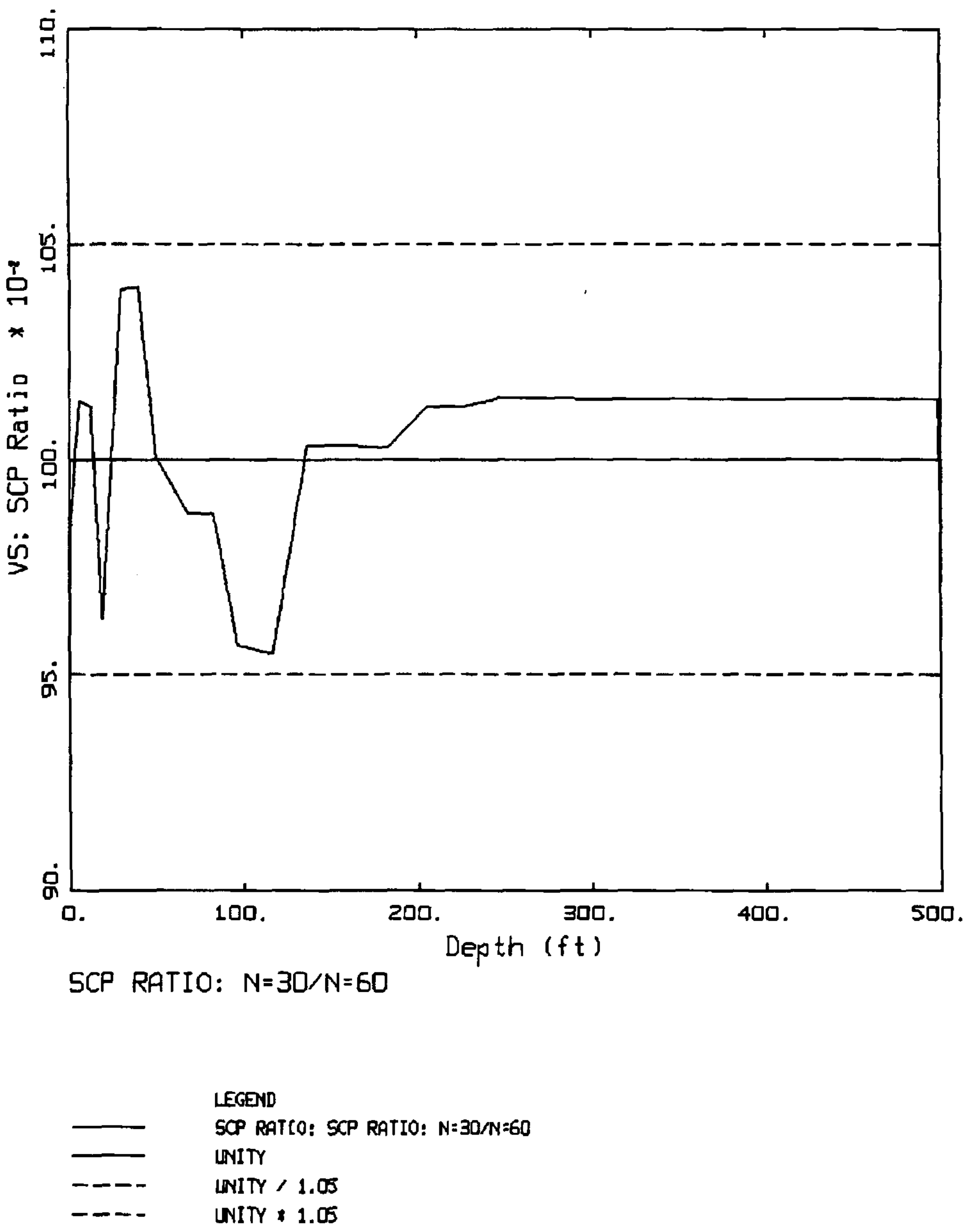


Figure 2, Ratios (30 realizations/60 realizations) of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

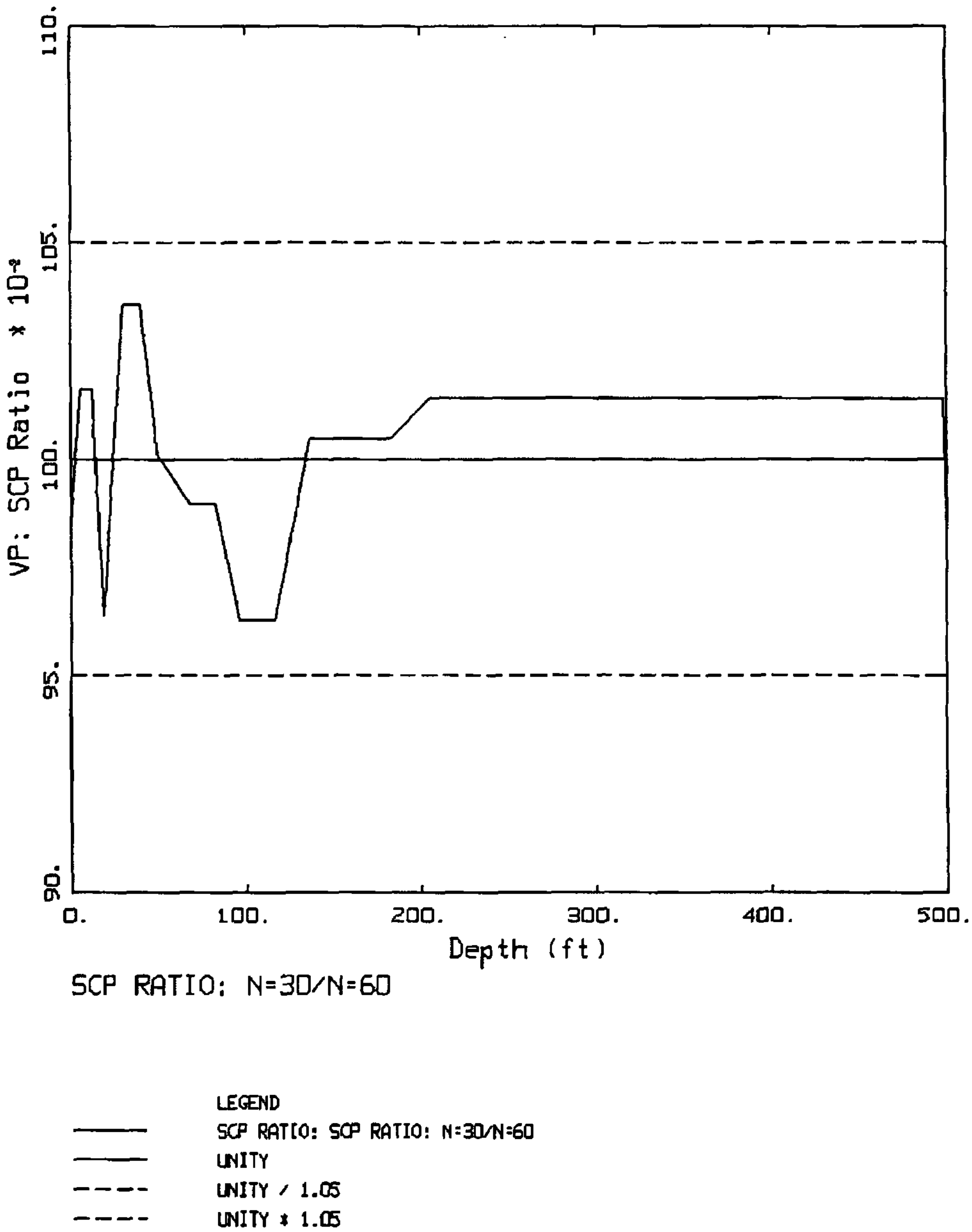


Figure 2 (continued), Ratios (30 realizations /60 realizations) of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

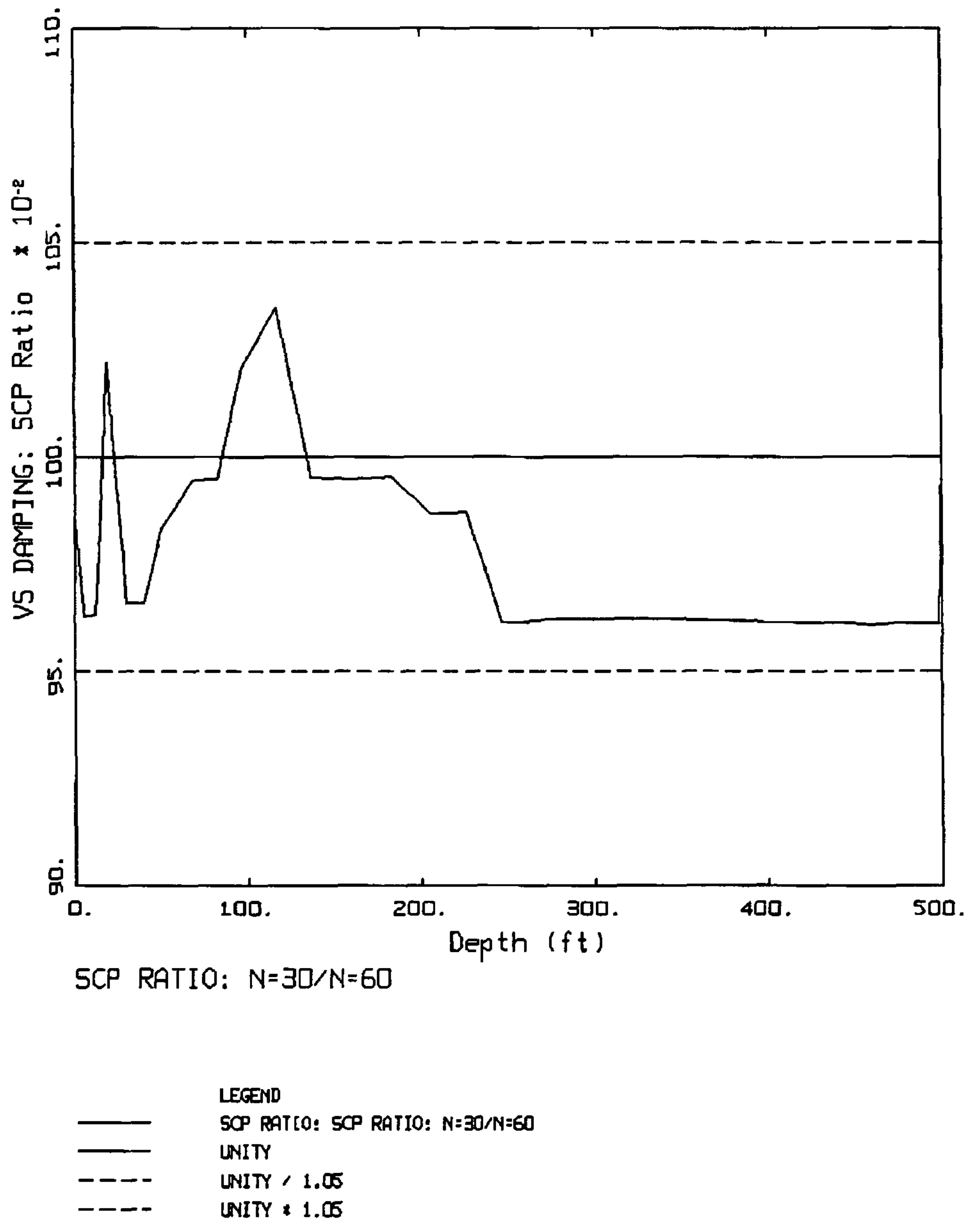


Figure 2 (continued), Ratios (30 realizations /60 realizations) of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

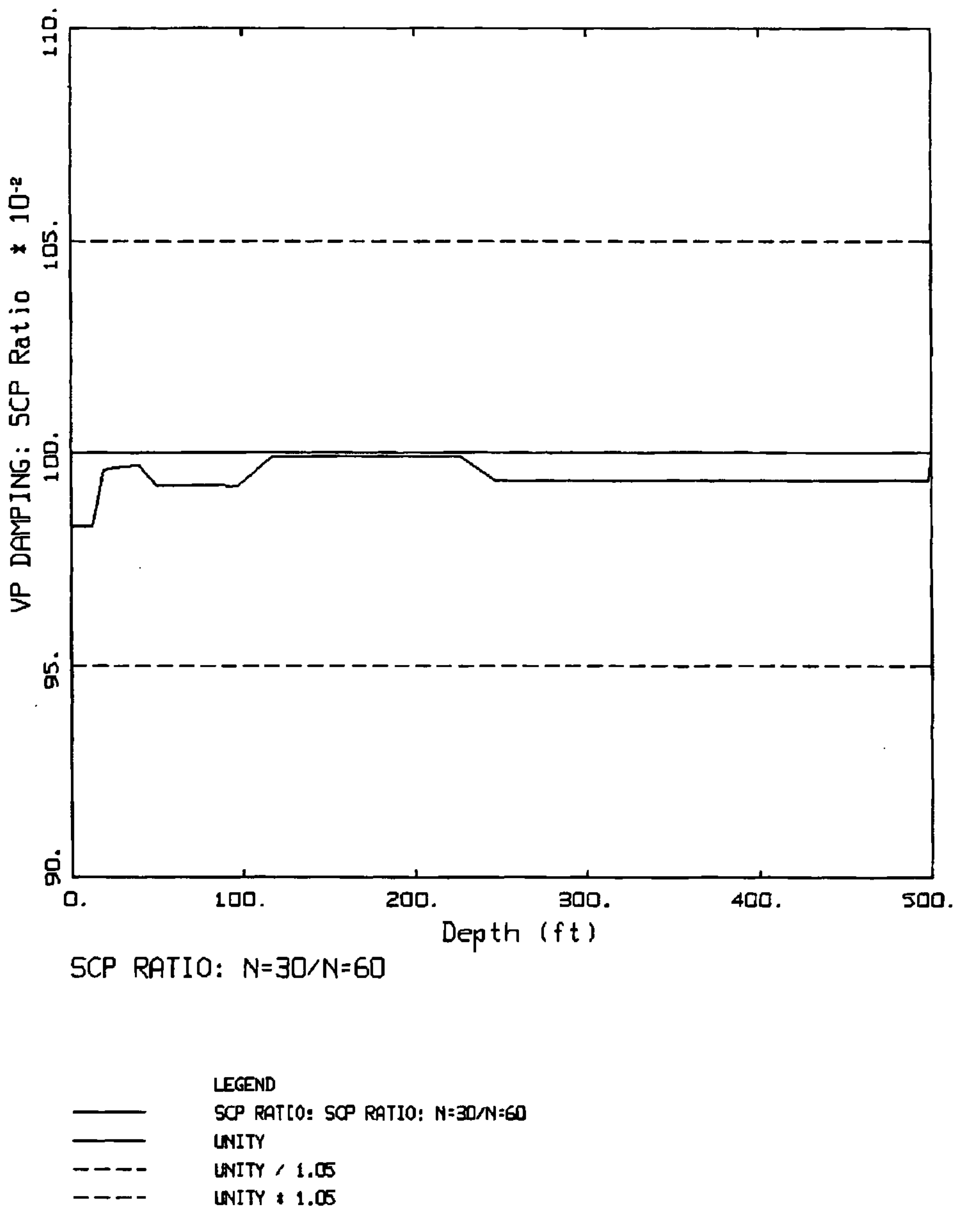


Figure 2 (continued), Ratios (30 realizations /60 realizations) of Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

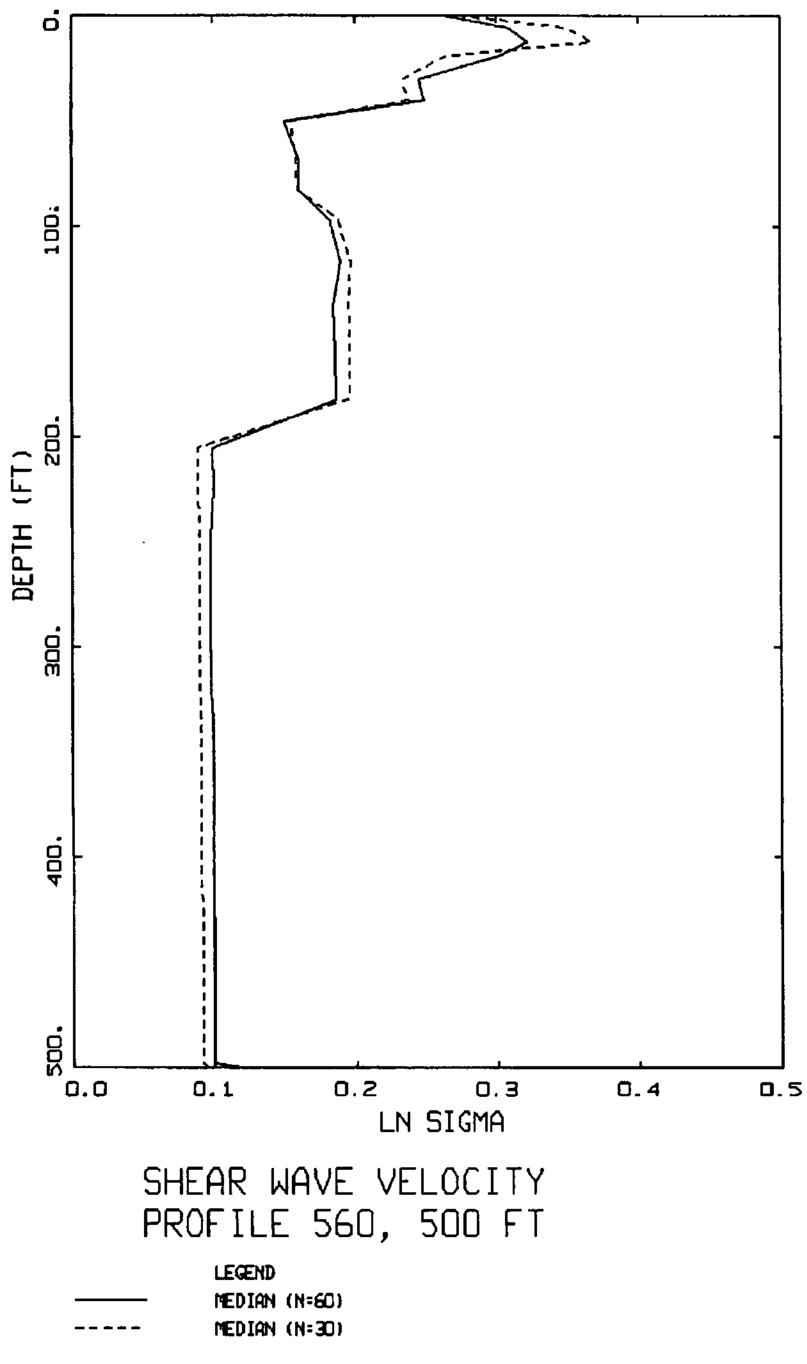


Figure 3, Comparison of Standard Deviation for Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

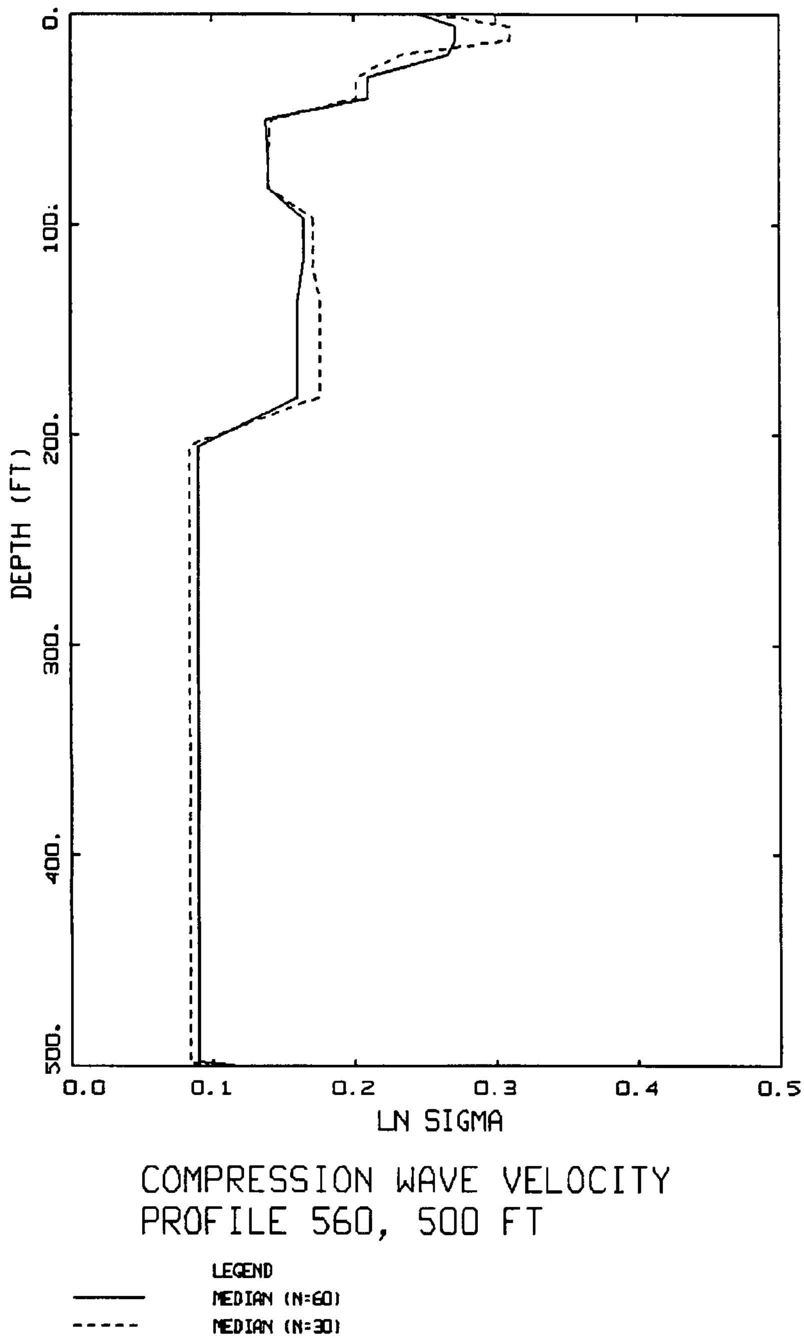


Figure 3 (continued), Comparison of Standard Deviation for Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

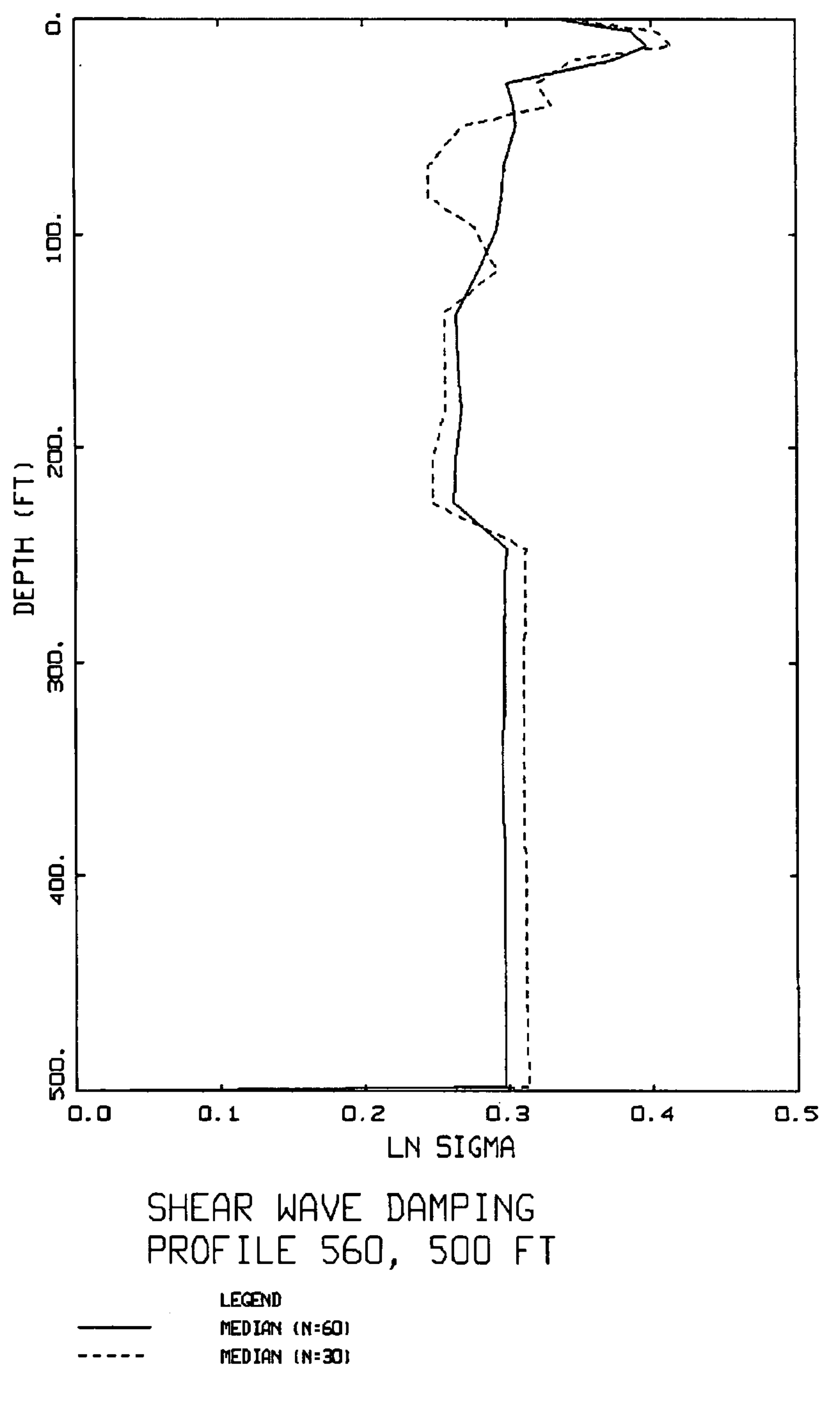


Figure 3 (continued), Comparison of Standard Deviation for Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

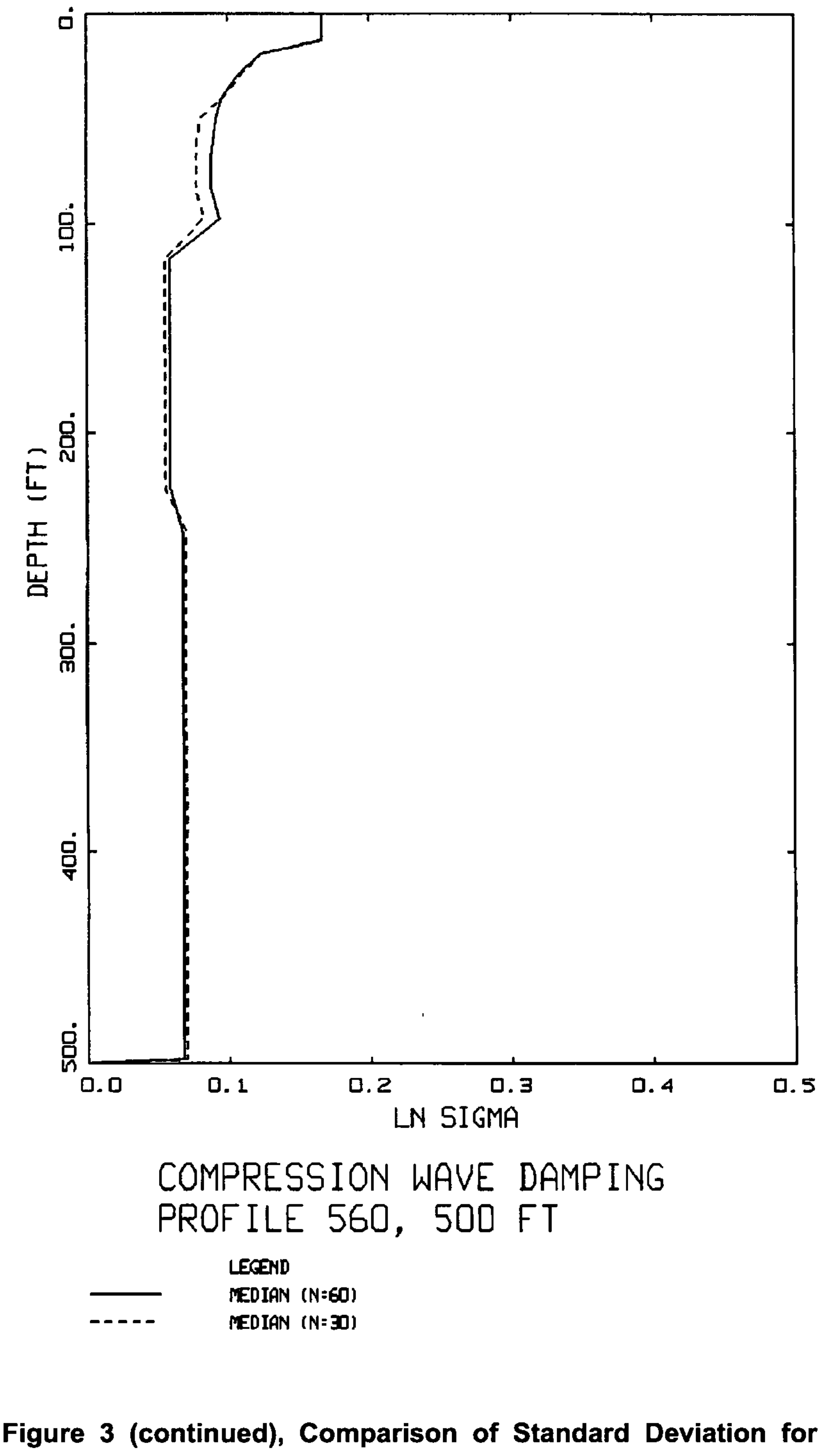


Figure 3 (continued), Comparison of Standard Deviation for Median Estimates for Strain Compatible Properties (shear-wave velocity, compressional-wave velocity, shear-wave damping, compressional-wave damping) Developed for 60 and 30 Realizations for 500 ft Deep Profile 560-500

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334, REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-36:

In its response to RAI 850-6002, Question 03.07.01-23, the applicant states that, "Although the most representative earthquake for the CSDRS is a M 7.5, the use of a seed time histories from a smaller event for use in the SSI analyses is not an issue. The key requirement as described in SRP 3.7.1 (Reference 1) is that the 5 - 75% duration requirement be met in generating the CSDRS compatible ground motion artificial time histories."

The values of the 5-75% duration for the CSDRS compatible ground motion time histories are listed in Table 5.1-3 of MUAP-10001 (R3) (Page 5-10) which are 7.52 seconds and 7.145 seconds for the two horizontal components and 8.77 seconds for the vertical component, respectively. Also listed in Table 5.1-3 is the minimum duration of seven (7) seconds taken from Table 2.3-1 of ASCE 4-98. The staff has not reviewed and endorsed Table 2.3-1 of ASCE 4-98. Therefore, the applicant is requested to delete any reference and values from the referenced ASCE Table 2.3-1.

ANSWER:

Technical Report MUAP-10006, Rev. 3 will not have a reference to ASCE 4-98 or include any values from ASCE Table 2.3-1. The minimum duration criteria presented in NUREG/CR-6728 (Reference 1) will be used. The details are presented below.

The duration criteria are provided for different magnitude and distance bins in NUREG/CR-6728, Table 3-2 (Page 3-9). Table 1 lists the duration criteria with magnitude bins of M6.5 and M7.5, which can vary from 3.1 seconds to 36.5 seconds for distance bins from 10 to 200 km. The strong motion durations of the design basis time histories, developed from Northridge Mt. Baldy seeds using SRP 3.7.1 (Reference 2) Option1, Approach 1, are 7.9 seconds and 9.5 seconds for the two horizontal components and 10.4 seconds for the vertical components. These values fall in the range of the duration criteria.

Table 1, Magnitude and Distance Bins and Duration Criteria (NUREG/CR-6728, Table 3-2)

M	*R* (km)	Durations (sec) *	
		Rock	Soil
6.5 (6 -7)	10 – 50	3.1 – 7.0	3.6 – 8.2
	50 – 100	5.1 – 11.6	5.7 – 12.8
	100 -200	8.1 – 18.3	8.7 – 19.5
7.5 (7+)	10 – 50	6.6 – 14.0	7.2 – 16.1
	50 – 100	8.7 – 19.5	12.2 – 27.5
	100 -200	11.7 – 26.3	16.2 – 36.5

*5% - 75% total cumulative Arias' Intensity

References:

1) "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines," NUREG/CR-6728, NRC, October 2001.
2) "Seismic Design Parameters," NUREG-0800, SRP 3.7.1, Rev. 3, NRC, March 2007.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-37

In its response to item (i) of RAI 850-6002, Question 03.07.01-27, the applicant states that the equivalent linear random vibration theory (RVT) approach was used to compute strain compatible properties as input to the SSI analyses. The staff noticed that the CSDRS compatible ground motion time histories generated in Section 5.1 of MUAP-10001 (R3) were not used in the site response analyses; instead, the equivalent RVT approach was used. The staff considers this approach to be inconsistent because the time histories generated in Section 5.1 which are used in the SSI analyses, pass through the soil columns that are not excited by these time histories. The applicant is requested to provide data to show that the nonlinearity of soil obtained by the RVT approach is comparable to that induced by the time histories generated in Section 5.1.

Also, the staff did not find any description of the power spectral density function used in the RVT approach described in the report. The applicant is requested to provide a description for the power spectral density function used. In addition, the applicant is requested to compare the computed power spectral density functions at the rock outcrop with those of the CSDRS response spectra for both the horizontal and vertical directions. The comparisons should be presented in graphical form.

In Section 5.2.1 of MUAP-10001(R3), the applicant states that, "Distances are adjusted such that the median spectrum computed for each profile approaches does not exceed the horizontal and vertical CSDRS." The applicant is requested to provide technical information explaining why "does not exceed" is imposed instead of "matching" when comparing the response spectra.

ANSWER:

MHI's position is that ground motion time histories compatible to US APWR certified seismic design response spectra (CSDRS) are inappropriate for use as control motions for the site response analyses that provide the generic profiles of strain dependent dynamic soil/rock properties. The CSDRS are smooth design spectra which reflect the contributions of multiple site conditions and/or earthquakes of varying sizes. The use of CSDRS defined control motion in the site response analyses will induce artificially high loads on an any individual soil column resulting in strains that exceed those from any of the single contributors (earthquakes) to the CSDRS. The broad band CSDRS defined control motion will overdrive the soil column yielding artificially high shear-strains and unrealistic strain compatible properties (e.g., Approach 1, NUREG/CR-6728). The high shear strains will result in higher soil material damping that will overestimate the dissipation of energy in the soil-structure interaction (SSI) model and reduce the seismic responses.

The US-APWR CSDRS are broad band design spectra that represent an envelope of the contributions of multiple site conditions and earthquakes. For example, UHRS developed for CENA locations typically reflect contributions from large magnitude ($M \geq 6.5$) sources at low structural frequency and small magnitude ($M \leq 6.5$) sources at high structural frequency, as numerous deaggregations have shown. Based on earthquake occurrence, the use of ground motion time histories compatible to US-APWR CSDRS acknowledges the possibility of both the low-frequency and high-frequency earthquakes occurring at the same time, which reflects a very rare event sequence with probabilities far below that of any design criteria. Additionally, even if the two controlling earthquakes did occur simultaneously, the time histories would not add coherently, resulting in a response spectrum significantly below any deterministic envelope.

In order to further explain, the concept embodied in RG 1.165 and NUREG/CR-6728 advocating multiple (two +) single earthquake spectra, each developed for a single earthquake reflecting reference (base-of-soil) site conditions and used to develop site-specific transfer functions, was put forward specifically to avoid overdriving a soil column with a broad uniform hazard response spectrum (UHRS), foundation input response spectra (FIRS) or ground motion response spectra (GMRS). The concept recommended was the development of transfer functions applicable to specific frequency ranges in the broad reference site design spectrum, such as UHRS or performance based surface response spectrum (PBSRS) that are represented by a set of multiple single earthquake spectra. The concept was further elaborated in NUREG/CR-6728 as Approach 2 (specifically Approaches 2a and 2b) for deterministic analyses and Approaches 3 and 4 for fully probabilistic soil analyses.

The RG 1.60 spectrum ($\geq$ 10 Hz), is a broadened spectrum based on a few predominately large magnitude recordings on a variety of site conditions and developed as a plus one sigma spectral shape. Consequently, at low-frequency, its spectral levels are more representative of a large magnitude earthquake on deep soil, while the high-frequency levels reflect shallow stiff soil amplification. It should be noted that the maximum spectral amplification for RG 1.60 is 2.9, far in excess of the empirical value of 2.1 to 2.3 based on abundant recordings on a variety of site conditions (EPRI, 2004; Power et al., 2008). Therefore, a RG 1.60 spectrum is inappropriate to serve as the basis for control motions for site response for conditions where dynamic material properties are expected to have strain dependencies. The CSDRS, which reflects a RG 1.60 spectrum further broadened at high frequency (> 10 Hz), is also considered inappropriate for use as control motions for site response in the context of nonlinear or equivalent-linear analyses.

In developing the strain compatible properties, the random vibration theory equivalent-linear approach, as referred to in RG 1.208, was used with hard rock control motions developed using the well validated point-source model (EPRI, 1993; Silva et al., 1996; NUREG/CR 6728, 6769). The point-source model was used to generate control motions for the site amplification in EPRI (1993) as well as development and illustration of recommended site response approaches in NUREG/CR-6728 and 6769. The point-source model also was the dominant contributor to the ground motion prediction equations (GMPEs) used in developing the hard rock design spectra for the recent COLA and ESP applications (EPRI, 2004; 2006) as well as the currently under way update of the GMRS at existing nuclear power plant sites.

In developing the strain compatible soil properties for each profile, since enveloping the CSDRS results in unrealistic demands within the soil, the single earthquake median soil spectrum with control motion defined by the point-source model was considered the most appropriate (and most likely) spectrum to occur at a given site that reflected realistic loading conditions. The distance to the earthquake was adjusted such that the median spectrum at its highest point was tangent to the CSDRS. This approach was not taken to infer spectral design levels, which are controlled by the CSDRS. The approach was considered to reflect the most appropriate and realistic loading levels at which to develop strain compatible properties. That is, this approach was designed to result in strain compatible properties that are CSDRS consistent, that is consistent with the both the CSDRS as well as realistic single earthquake loading for individual profiles. This approach avoids the undesirable condition of overdriving a soil column with a broad control motion such as a CSDRS that is inappropriate for any single earthquake.

The associated power spectral density of the control motions is defined by the point source model (EPRI, 1993; NUREG/CR-6728) and reflects a shape appropriate for a single earthquake with a control point located appropriately at the base of the soil or rock column. Because the location reflects hard rock site conditions (EPRI, 2004, 2006) as well as a single earthquake, the power spectral density is neither broad-band nor comparable to the power spectral density of the CSDRS.

References:

1. "CEUS Ground Motion Project Final Report," Electric Power Research Institute (EPRI) TR-1009684, 2004.
2. "Guidelines for Determining Design Basis Ground Motions," Vol. 1 5, EPRI TR-102293, 1993.
3. McGuire, R.K., W.J. Silva, and C.J. Costantino, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Development of Hazard- and Risk-consistent Seismic Spectra for Two Sites." NUREG/CR-6769, U.S. Nuclear Regulatory Commission, 2002.
4. McGuire, R.K., W.J. Silva, and C.J. Costantino, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motions Spectra Guidelines." NUREG/CR-6728, U.S. Nuclear Regulatory Commission, 2001.
5. Power, M., Chiou, B., Abrahamson, N., Bozorgnia, Y., Shantz, T., Roblee, C., "An Overview of the NGA Project," Earthquake Spectra, 24(1), 3-21, 2008.
6. Silva, W. J., Abrahamson N., Toro G., Costantino C., "Description and Validation of the Stochastic Ground Motion Model," Report Submitted to Brookhaven National Laboratory, Associated Universities, Inc., 1996.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-38:

In its response to RAI 850-6002, Question 03.07.01-28, the applicant states, in part, that "The vertical CSDRS (Figure 5.2-4) reflects extremely conservative levels of motion and is inconsistent with current observations as well as the community understanding of strong ground motions."

The staff finds that there is evidence that the influence of high water table level, as well as the degree of ground saturation, can have very significant influence on the seismic response, especially in the higher frequencies. For example, in Yang and Sato (2000 a,b), the authors point out that, in measurement in a borehole array during the 1995 Hyogo-ken Nanbu (Kyoto) earthquake, "the vertical motions were greatly amplified at the surface, with peak value of 556 cm/sec^2, which was about 1.5 to 2.0 times larger than the horizontal components." Further, in that same paper, the authors state that "Vertical component motions may be significantly affected by the pore-water saturation of shallow soil layers, suggesting that we may need to carefully examine the condition of saturation in the study of vertical site amplification." These papers indicate that the water table at the grade level with the soil fully saturated may not be the critical case concerning the vertical motions.

The applicant is requested to clarify and confirm that for the soil profiles considered in the US-APWR standard design, the effects on the vertical seismic response component resulting from varying levels of the groundwater, including the degree of groundwater saturation, have been explicitly considered in the design basis seismic analysis. In particular, the applicant is requested to confirm that these effects will not result in significant increase of the vertical component of ground shaking, and that the US-APWR design remains conservative.

References:
Yang, J. and T. Sato (2000a),"Interpretation of Seismic Vertical Amplification Observed at an Array Site," Bulletin of the Seismological Society of America, 90, 2, p. 275-286.

Yang, J. and T. Sato (2000b), "Effects of Pore-water Saturation on Seismic Reflection and Transmission from a Boundary of Porous Soils," Bulletin of the Seismological Society of America, 90, 5, p. 1313-1317.

ANSWER:

The cited statement from MHI response to RAI 850-6002, Question 03.07.01-28 was concluded based on the condition that "The horizontal CSDRS in spectral shape represents a Magnitude M of about 7.5 and, in terms of absolute levels, reflects (source) distances exceeding 50 km". For these conditions vertical motions are expected to be much lower than the horizontal motions at all frequencies and the vertical certified seismic design response spectra (CSDRS) using RG 1.60 V/H ratios is conservative.

It has been observed that vertical motions can exceed horizontal motions at short period and near-source distance, and this was verified by 1995 Hyogo-ken Nanbu (Kyoto) earthquake data shown in the papers referenced. At very close distances (≤ 15 km) for large magnitude (M ≥ 5) earthquakes, high-frequency (≥ 10 Hz) 5% damped response spectra of the vertical motions are expected to exceed horizontal motions, at soft rock and soil sites with V/H ratios (vertical over horizontal component ratio) exceeding unity (References 1, 2, 3 and 4). The exceedence is due to the dominance of compressional-waves over shear-waves for vertical components at high-frequencies, resulting from converted shear-waves (≥ 10 Hz) (Reference 1 and 3). The exceedence of the vertical component over the horizontal component is larger for soils due to the nonlinear site response of the horizontal, decreasing the high-frequency spectral levels (Reference 2 and 5). For vertical components, any nonlinear effect at high-frequency in unsaturated soils would involve the constrained modulus with associated dilatational strains. The dilatational strains would be lower than any shear-strains at similar loading levels due to the much higher compressional-wave velocity, reducing the potential for non-linear effects to reduce high-frequency vertical motions. For saturated soils, the constrained modulus remains largely linear as the bulk modulus is controlled by the fluids. As a result, for both saturated and unsaturated soils, at close distances, vertical motions are expected to exceed horizontal motions at high-frequency. For distances exceeding about 15 km, high-frequency vertical motions are expected to be lower than corresponding motions by a significant amount that depends on frequency (Reference 1, 2 and 4). The CSDRS design spectra were not intended to reflect near-source conditions, being appropriate for a majority of site locations across the US and not sited adjacent to large magnitude active sources.

The US-APWR Standard Plant design considers the ground water table as being one foot below plant finished grade. Accordingly, the six generic soil profiles are developed to represent fully saturated soil conditions and site independent design basis soil-structure interaction (SSI) analyses are performed for the standard plant structures. In order to assess the effects of water table fluctuations, a set of SSI sensitivity analyses are performed on the reactor building (R/B) complex structure for soil profiles that are developed to represent unsaturated soil conditions. The water table effects on seismic response of the Standard Plant structures are determined by comparing the structural responses for two set of bounding subgrade soil cases (i.e., fully saturated soils, which serves as design-basis vs. unsaturated soils) on which SSI sensitivity analyses are performed. Technical Report MUAP-10006, Rev. 3 is being revised to include updated site independent design basis SSI analyses for standard plant structures, and Technical Report MUAP-11007, Rev. 1 to update the sensitivity study of water table fluctuation effect. The revised reports provide detailed information regarding development of saturated and unsaturated soil profiles and corresponding SSI analysis.

This RAI response will be supplemented subsequent to the completion of Technical Report MUAP-10006, Rev. 3 and MUAP 11007 Rev. 1.

References:

1) Silva, W. J., "Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design," Proc. of the FHWA/NCEER Workshop on the Nat'l Rep. of Seismic Ground Motion for New and Existing Highway Facilities, Technical Report NCEER 97 0010, 1997.
2) Abrahamson, N. A and Shedlock, K. M., "Overview." Seismic Research Lett., 68(1), 9 23, 1997.
3) Beresnev, I. A,, Nightengale, A. M., and Silva, W. J., "Properties of Vertical Ground Motions." Bull. Seism. Soc. Am., 92(2), 3152-3164, 2002.
4) Campbell, K. W., and Bozorgnia, Y., "Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra," Bull. Seismic Soc. Am., 93(1), 314-331, 2003.
5) Power, M., Chiou, B., Abrahamson, N., Bozorgnia, Y., Shantz, T., and Roblee, C., "An Overview of the NGA Project," Earthquake Spectra, 24(1), 3-21, 2008.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Reports MUAP-10006 and MUAP-11007 are being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-39:

1. In the response to item 1 of RAI 850-6002, Question 03.07.01-30, the applicant refers to the response to RAI 850-6002, Question 03.07.01-22. In its evaluation for RAI 850-6002, Question 03.07.01-22, the staff considers the applicant's response to be not satisfactory. Therefore, the corresponding response to Part 1 of this question is also not acceptable.

2. In the response to item 2 of RAI 850-6002, Question 03.07.01-30, the applicant states that the RASCAL computer code was used in the study and cites a report for RASCAL code (Reference 4 in the response). The referenced report is: "Silva, W., and Lee, K. 1987, "State-of-the-art for Assessing Earthquake Hazards in the United States; Report 24, WES RASCAL Code for Synthesizing Earthquake Ground Motions," Miscellaneous Paper S-73-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS."

   According to the above cited report, the RASCAL computer code accepts only single layered soil above the half space. For soil profiles considered in US-APWR a single layered soil model is not adequate. The applicant is requested to provide description and appropriate references to the software (or current version of RASCAL code) that are used to calculate multilayered media site response for both the horizontal and vertical component of seismic motion.

3. In the response to item 3 of RAI 850-6002, Question 03.07.01-30, the applicant states that, "The horizontal SSI response analyses are performed assuming vertically propagating plane shear (SV or SH) wave-field excitations with the shear-strain-compatible damping values limited to no more than 15%, as required by SRP 3.7.1 Acceptance Criteria Item 2 (Reference 2). The vertical SSI response analysis is performed assuming vertically propagating plane compression wave-field excitation, the shear-strain-compatible damping values derived from the horizontal site response analyses are used but with their values limited to no more than 10%, as recommended by the correlation studies reported in Reference 1." The above quoted sentences are not clear to the staff. Since the shear-strain-compatible damping limits are different for the horizontal component analysis (15%) than that for the vertical component analysis (10%), are there two strain compatible soil profiles, one for horizontal component analysis and the other for the vertical component analysis?

The applicant is requested to clarify this statement.

ANSWER:

1. MHI has evaluated the use of 60 realizations vs. 30 and provided the details in response to this RAI (939-6334), Question 03.07.01-35.

2. There is a typo in the response to item 2 of RAI 850-6002, Question 03.07.01-30. The reference for the RASCAL code should be Reference 1, not Reference 4 in the response. Reference 1 is: Guidelines for Determining Design Basis Ground Motion, Volume 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.

3. The same strain compatible soil profile is used for the horizontal and vertical soil structure interaction (SSI) analyses. Since the damping values are always less than 10%, the horizontal and vertical damping values used are both set equal to the shear wave strain compatible damping value (see Reference 1).

   This will be documented in Technical Report MUAP-10006, Rev. 3 that is being revised and submitted in accordance with the Seismic Closure Plan.

References:

1) Mok, Chin Man, Chang, C.-Y., and Lagapsi, Dante E., "Site Response Analyses of Vertical Excitation", Proceedings of the Third Specialty Conference on Geotechnical Earthquake Engineering and Soil Dynamics, Seattle, Washington, Geotechnical Special Publication No. 75, ASCE, August 3 – 6, 1998.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

Enclosure 3

UAP-HF-12265
Docket No. 52-021

Amended Response to Request for Additional Information No. 940-6532 Revision 3

September 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 940-6532 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-40:

In its response to RAI No.886-6202 Revision 3, Question No. RAI 03.07.01-33, MHI provided digitized acceleration verses time traces for the current design-basis Northridge Earthquake seed records and for the synthetic acceleration time histories developed from the seed records to match the CSDRS. The staff has conducted independent numerical analysis using this information, to evaluate whether the developed synthetic time histories provide an acceptable match to the CSDRS, in accordance with the assessment procedures detailed in SRP 3.7.1.

The applicant has specified that SRP 3.7.1, Option 1, Approach 2, criteria are satisfied. However, the staff has determined that Option 1, Approach 2, is not specifically applicable to site-independent CSDRS based on the RG 1.60 spectra. The acceptance criteria in Option 1, Approach 2, are not appropriate for site-independent CSDRS; rather it is applicable for developing synthetic time histories to match a site-specific uniform hazard response spectrum (UHRS).

When a single time history method is used, the SRP 3.7.1 specifies two approaches to generate synthetic time history. In Revision 2 (1989) of the SRP 3.7.1, for single time history, Option 1 had only one approach i.e., Approach 1. Approach 1 applies to RG. 1.60 types of site-independent broad band spectra. In Revision 3 (2007), the guidance was enhanced to address site-specific uniform hazard type of spectra that are continuous curves and different in shape from RG 1.60 spectra. The technical basis for Revision 3 to SRP 3.7.1 is provided in NUREG/CR-6728. NUREG/CR-6728 was developed to provide guidance on generating time histories for site-specific hazard- and risk-consistent ground motion spectra. NUREG/CR-6728 is cited as reference 9 in SRP 3.7.1.

The staff performed an independent evaluation of the US APWR synthetic acceleration time histories to check whether the synthetic time histories satisfy the SRP 3.7.1 Option 1, Approach 1 criteria. The staff finds that for all three directions (2-horizontal, and 1 vertical) of the CSDRS, SRP 3.7.1 Option 1, Approach 1 criteria are not satisfied. The staff's evaluation also showed that for the case of 5% damping, which satisfied the Option 1, Approach 2 criteria, the criteria in Option 1, Approach 1 is not satisfied. Therefore, the staff requests the applicant to develop the design basis synthetic time histories for all three directions of the

CSDRS in the DCD (R3), that satisfy the spectral matching criteria and PSD matching criteria of the SRP 3.7.1, Option 1, Approach 1.

(1) In performing the spectral matching, demonstrate that for all three directions of the CSDRS, the Option 1, Approach 1, criteria are met for 2%, 3%, 5%, 7%, and 10% damping, or justify an alternate damping range based on the values used in the design basis seismic response analysis of SSCs.

(2) In performing the PSD match,

(a) develop target PSDs representative of each of the three directions the CSDRS, which are the stretched RG 1.60 spectra;

(b) provide the details of the method employed to develop the target PSDs; and

(c) describe the method and assumptions used to generate the PSDs for the synthetic time histories.

ANSWER:

MHI has revised the time history methodology used to develop the time history for structural design and in-structure response spectra (ISRS) development to satisfy the SRP 3.7.1 Option 1, Approach 1 criteria. (The terminology used here for time history refers to all three components, i.e., North South, East West and vertical.) The design basis time history in Technical Report MUAP-10006, Rev. 3 is being developed to satisfy the spectral matching criteria and power spectral density (PSD) matching criteria of the SRP 3.7.1, Option 1, Approach 1. The details of how the SRP guidance criteria are satisfied and the resulting time history data are presented below:

Question 1: Performing Spectra Match in Accordance with the SRP 3.7.1 Option 1, Approach 1

The Modified Northridge time histories were redeveloped according to the provisions of SRP 3.7.1 Option 1, Approach 1 (Reference 1), at 2%, 3%, 5%, 7%, and 10% damping. As requested in our June 21, 2012 meeting, Figures 1 through 6 compare the current modified Northridge time histories with the previous modified Northridge time histories, which were developed using Option 1, Approach 2 criteria. Figures 7 through 12 depict the response spectra of the modified Northridge time histories developed in accordance with SRP 3.7.1 Option 1, Approach 1.

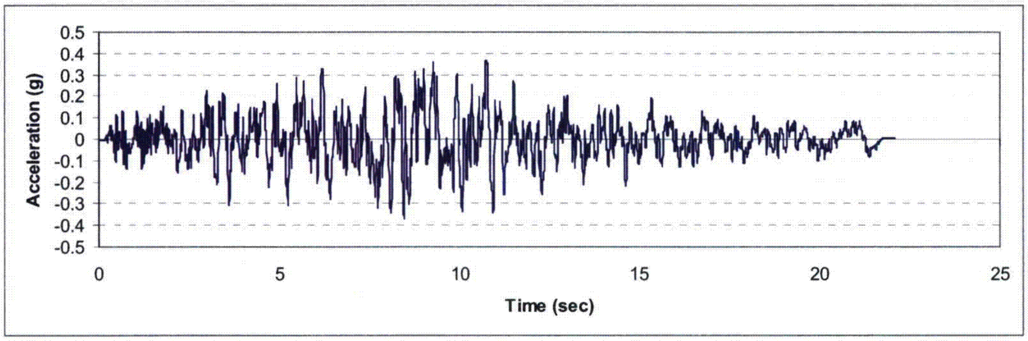


Figure 1, Design Acceleration Time History (Northridge) – X Component (H1, North-South) Developed using SRP 3.7.1, Option 1, Approach 1

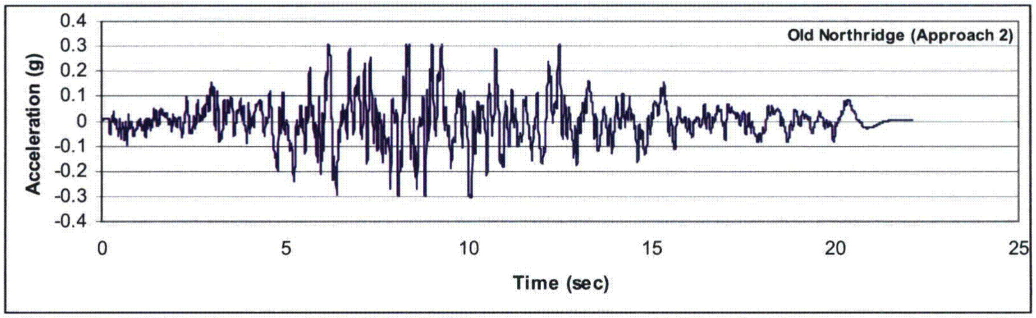


Figure 2, Previous Northridge Time History Developed using Option 1, Approach 2 – X Component (H1, North-South)

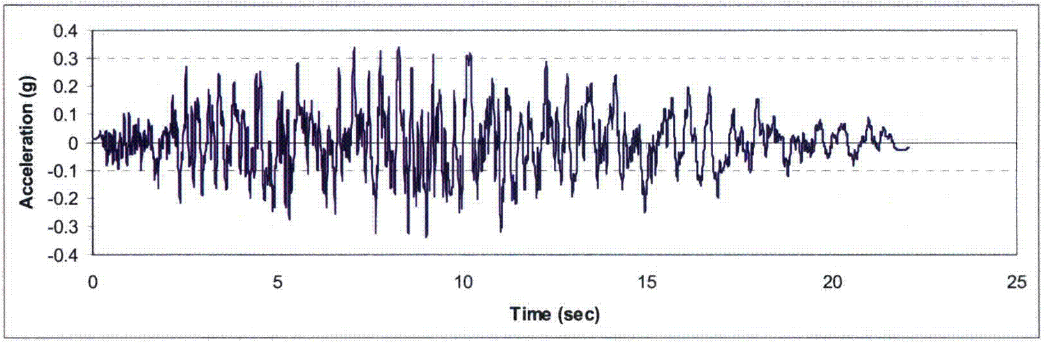


Figure 3, Design Acceleration Time History (Northridge) – Y Component (H2, East-West) Developed using SRP 3.7.1, Option 1, Approach 1

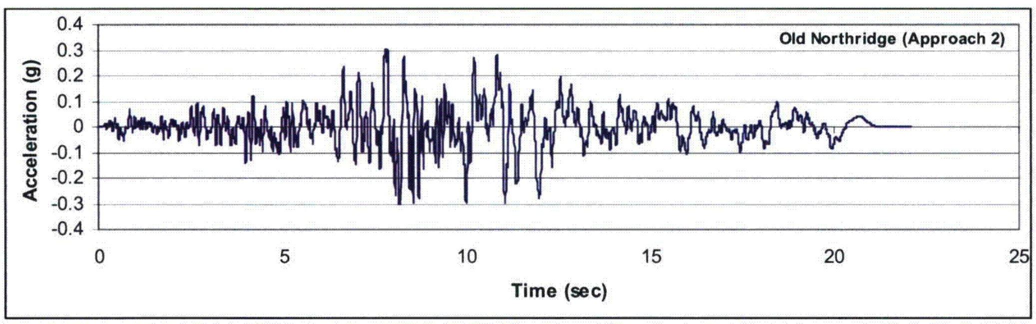


Figure 4, Previous Northridge Time History Developed using Option 1, Approach 2 – Y Component (H2, East-West)

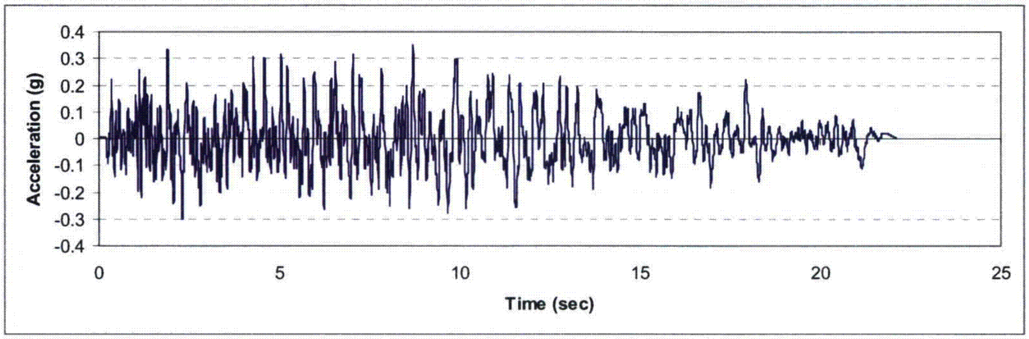


Figure 5, Design Acceleration Time History (Northridge) – Vertical Component (Up) Developed using SRP 3.7.1, Option 1, Approach 1

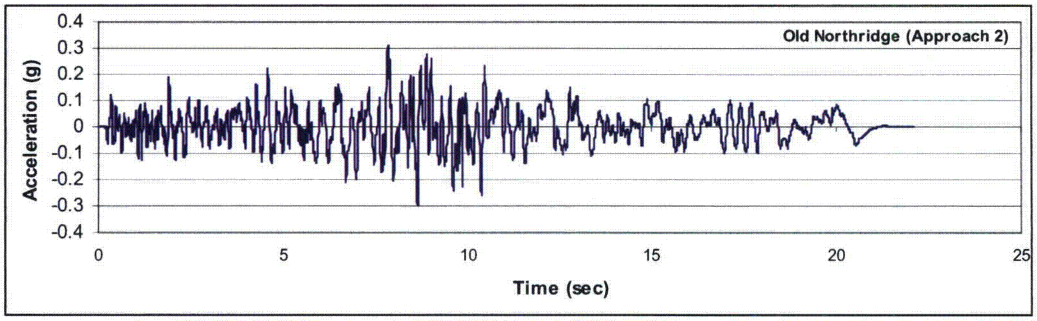


Figure 6, Previous Northridge Time History Developed using Option 1, Approach 2 – Vertical Component (Up)

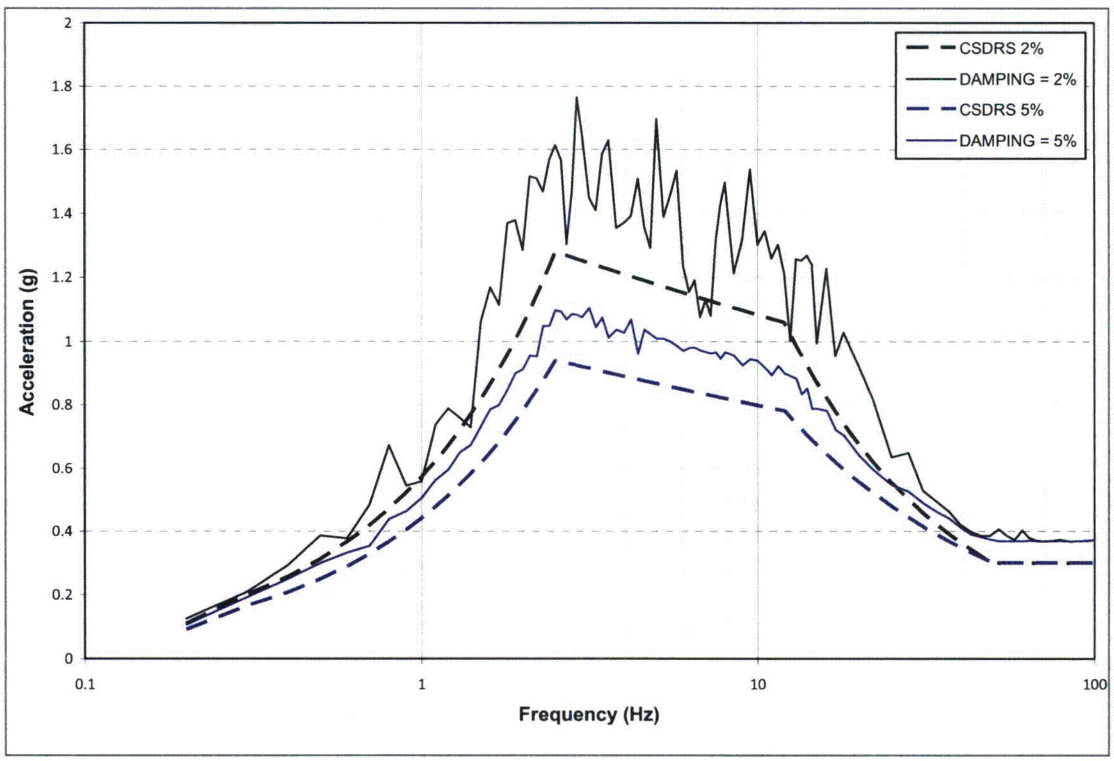


Figure 7, Response Spectra at 2% and 5% Damping – X Component (H1, North-South)

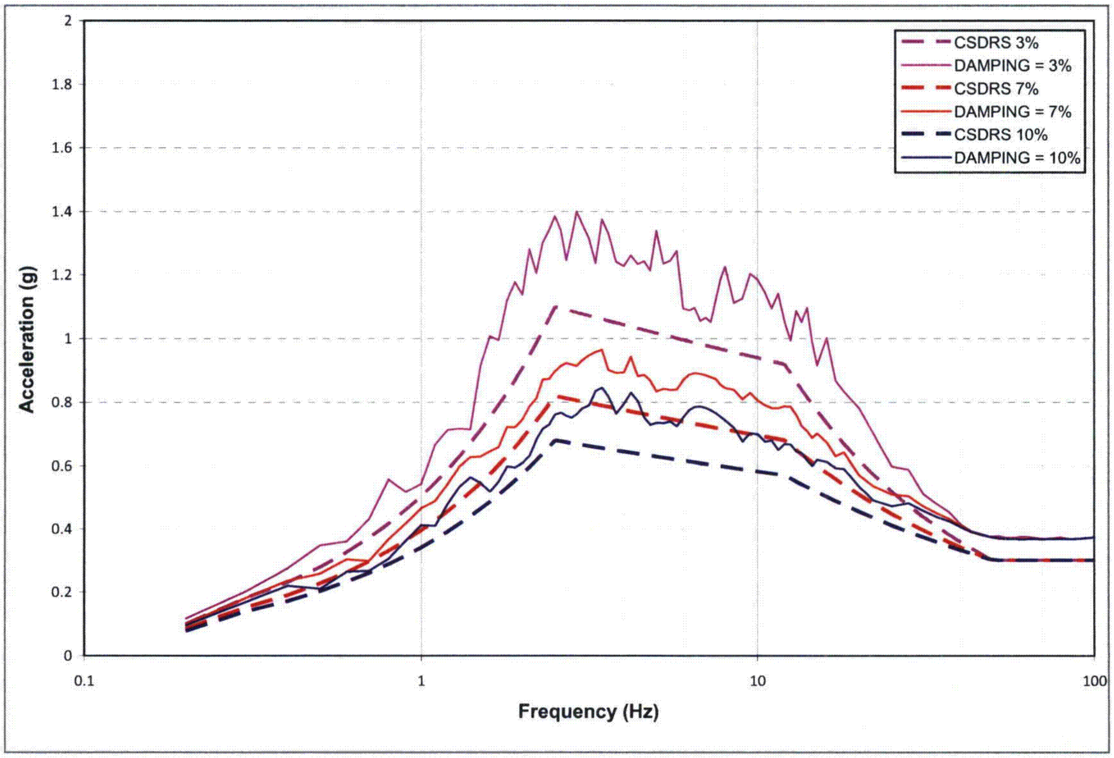


Figure 8, Response Spectra at 3%, 7% and 10% Damping – X Component (H1, North-South)

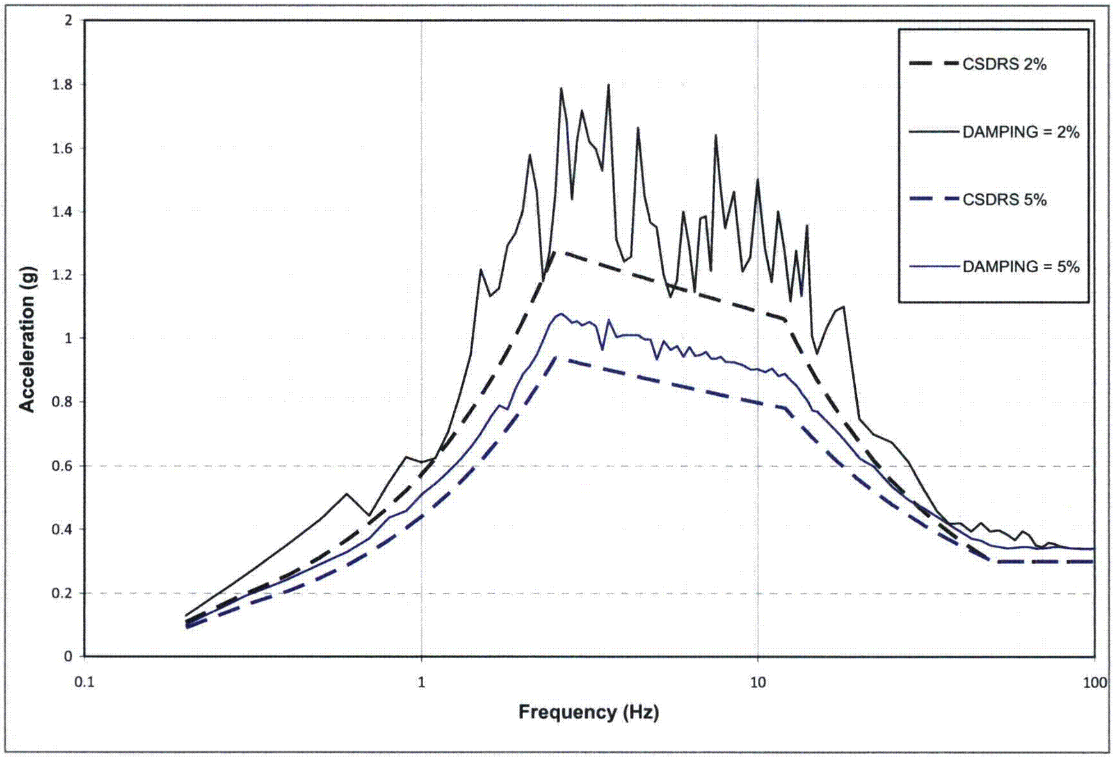


Figure 9, Response Spectra at 2% and 5% Damping – Y Component (H2, East-West)

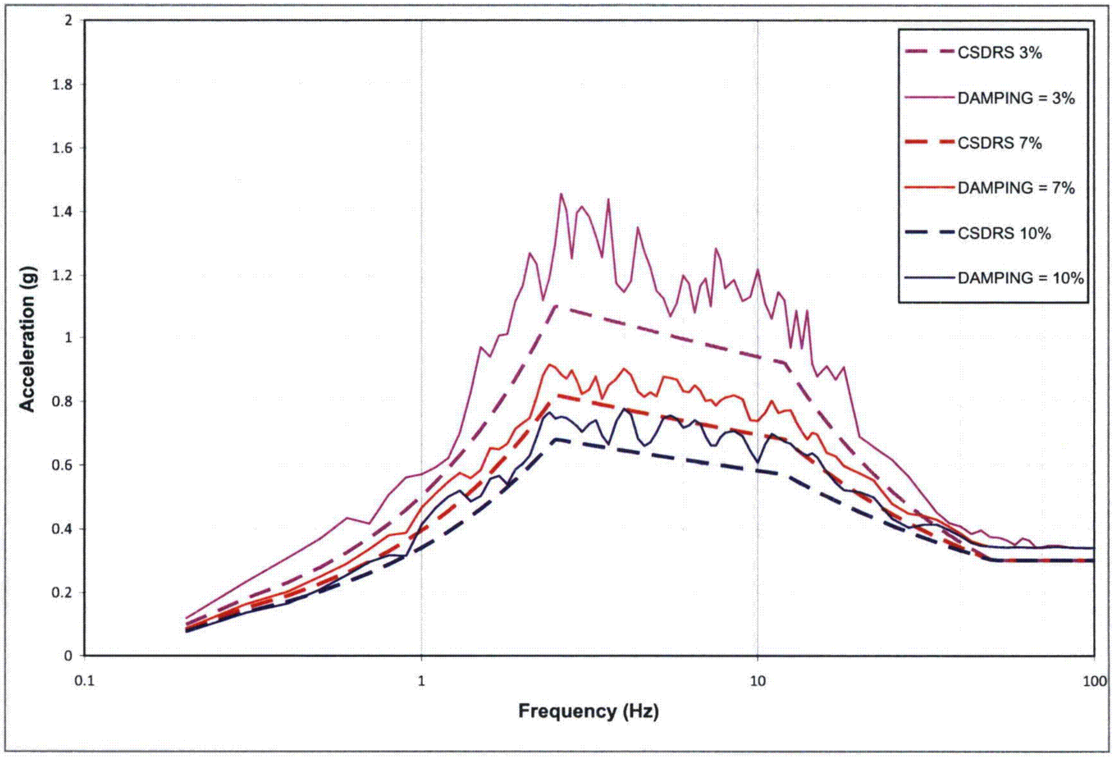


Figure 10, Response Spectra at 3%, 7% and 10% Damping – Y Component (H2, East-West)

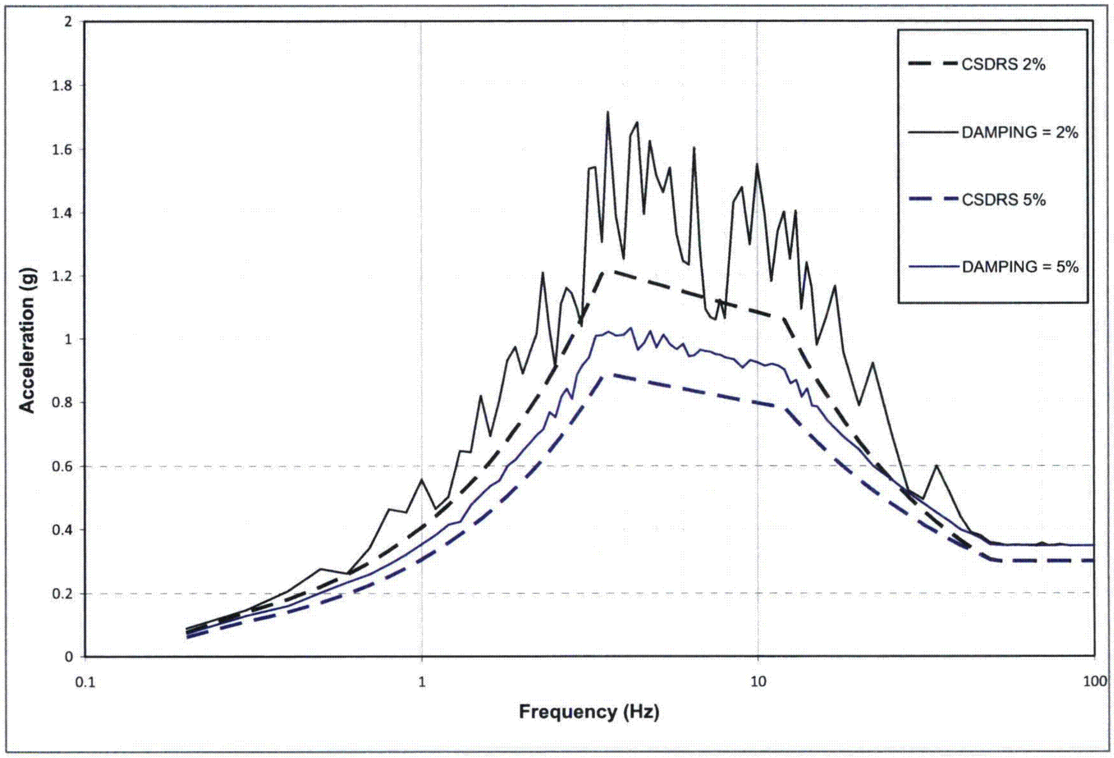


Figure 11, Response Spectra at 2% and 5% Damping – Vertical Component (Up)

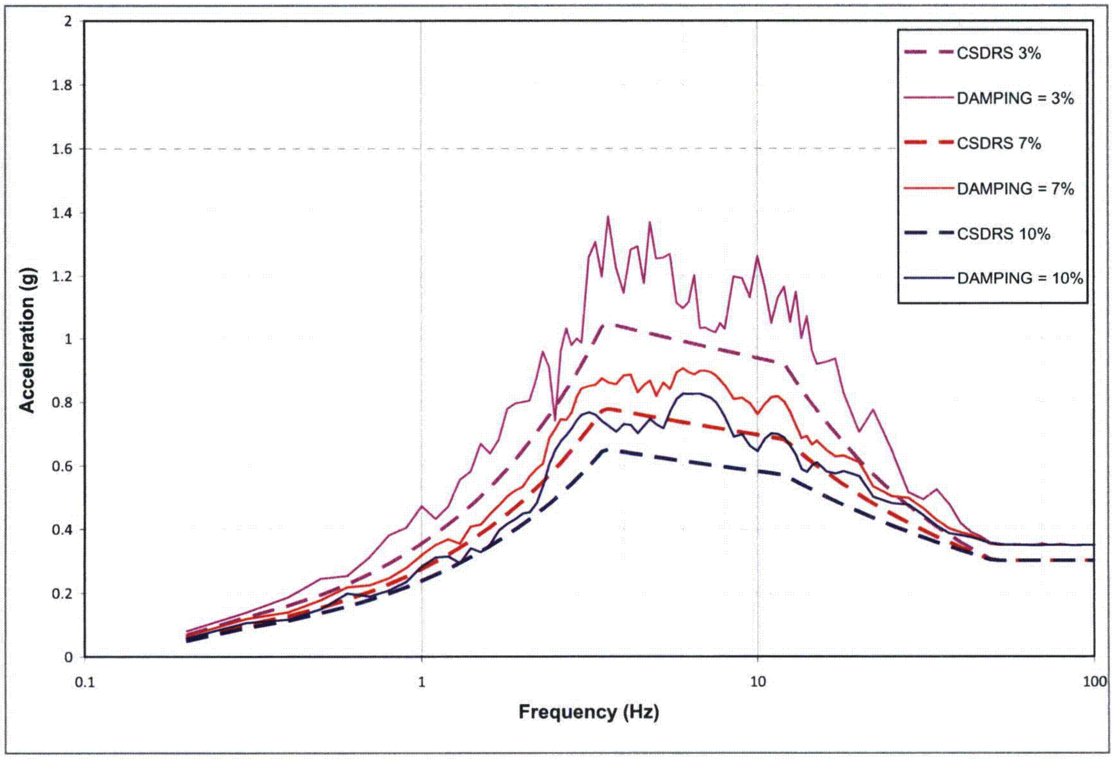


Figure 12, Response Spectra at 3%, 7% and 10% Damping – Vertical Component (Up)

Table 1 provides numerical data that demonstrates compliance to the SRP 3.7.1 Option 1, Approach 1 criteria. It shows that the maximum number of points below the target certified seismic design response spectra (CSDRS) in each direction is equal to or less than five, which is acceptable. Further, it shows that the minimum acceleration ratio is 0.945, which meets the SRP guidance criteria of a minimum of 0.90.

Table 1, Summary of Compliance to SRP Option 1, Approach 1 Spectral Match Requirements

Requirement		Damping Value				
		2%	3%	5%	7%	10%
X Component (H1, North-South)	Number of points with acceleration ratios < 1.0 (if 5 or less OK)	5	0	0	0	0
	Minimum acceleration ratio (if greater than 0.90 OK)	0.947	1.065	1.074	1.006	1.024
Y Component (H2, East-West)	Number of points with acceleration ratios < 1.0 (if at most 5 OK)	2	0	0	0	4
	Minimum acceleration ratio (if greater than 0.90 OK)	0.970	1.056	1.064	1.024	0.962
Vertical Component (Up)	Number of points with acceleration ratios < 1.0 (if at most 5 OK)	5	1	0	0	2
	Minimum acceleration ratio (if greater than 0.90 OK)	0.947	0.945	1.099	1.038	0.990

Table 2 provides the total duration and statistical independence values of the three components of the modified time histories, which satisfies the SRP guidance criteria of at least 20 seconds and an absolute value of 0.16 respectively. The table also shows the values of V/A, and AD/V^2 for the modified Northridge time histories for comparison with the values for V/A and AD/V^2 shown in Table 3.

Table 2, Summary of Compliance to Other SRP Requirements

Requirement	X Component (North-South)	Y Component (East-West)	Vertical Component
Total duration (if at least 20 seconds OK)	22.08	22.08	22.08
Strong motion duration (sec): Arias' intensity between 5% and 75% (1)	7.9	9.5	10.4
Statistical Independence (if abs value < .16 OK)	-0.018	-0.018	
		-0.055	-0.055
	-0.070		-0.070
PGA (g)	0.372	0.340	0.349
PGV (in/sec)	24.676	18.073	14.867
PGD (in)	12.702	10.711	9.464
V/A (in/sec/g)	66.333	53.156	42.599
AD/V^2	2.996	4.305	5.770

(1) Refer to response to RAI 939-6334, Rev. 3, Question 03.07.01-36 for the acceptance criteria.

Table 3 calculates the V/D and AD/V^2 values for mean ratios ± one standard deviation for the earthquakes of magnitude bins of M6.5+ with distance bins from 10 to 100 km, using data provided in NUREG/CR-6728, Table 3-6.

Table 3, CEUS V/A & AD/V2 Mean Ratios ± One Standard Deviation (NUREG/CR-6728, Table 3-6)

Distance Bin	M	V / A (cm/sec/g), σ_{ln}	AD / V^2, σ_{ln}	V/A / $e^{(\sigma_{ln})}$ (in/sec/g)	V/A * $e^{(\sigma_{ln})}$ (in/sec/g)	AD/V^2 / $e^{(\sigma_{ln})}$	AD/V^2 * $e^{(\sigma_{ln})}$
10 - 50, Rock	6.32	31.75, 0.51	6.58, 0.70	7.51	20.82	3.27	13.25
10 - 50 Soil	6.41	51.74, 0.35	3.49, 0.47	14.35	28.91	2.18	5.58
50 - 100, Rock	6.38	32.59, 0.33	4.66, 0.52	9.22	17.85	2.77	7.84
50 - 100, Soil	6.57	56.04, 0.36	3.01, 0.48	15.39	31.62	1.86	4.86
10 - 50, Rock	7.38	58.24, 0.72	7.78, 0.63	11.16	47.11	4.14	14.61
10 - 50 Soil	7.47	128.74, 0.27	3.57, 0.35	38.69	66.40	2.52	5.07
50 - 100, Rock	7.49	50.29, 0.56	10.60,0.46	11.31	34.66	6.69	16.79

The CSDRS are broad band spectra and do not represent any single earthquake or soil profile. The values of V/A and AD/V^2 for the CSDRS matched time histories are within the mean ratios ± one standard deviation for the earthquakes of magnitudes M6.5 with distance bins from 10 to 100 km, using data provided in NUREG/CR-6728, Table 3-6.

The target response spectra are matched down to 0.2 Hz, which is less than the lowest frequency of interest.

Question 2: Performing the PSD Match in Accordance with the SRP 3.7.1 Option 1, Approach 1

(a) Development of Horizontal and Vertical Target PSDs

The target PSDs are developed to be compatible with US-APWR CSDRS, in accordance with the guidance provided in NUREG/CR-5347 Appendix B (Reference 2).

The final horizontal target PSD anchored to 1.0g for US-APWR is:

$$S_{0H}(f) = \begin{cases} 650(f/2.5)^{0.2} \text{ for } f < 2.5\text{Hz} \\ 650(2.5/f)^{1.6} \text{ for } 2.5\text{Hz} \le f < 12\text{Hz} \\ 52.9(12.0/f)^{3} \text{ for } 12\text{Hz} \le f < 18\text{Hz} \\ 15.7(18/f)^{7} \text{ for } 18\text{Hz} \le f \end{cases} \quad (\text{in}^2/\text{sec}^3) \qquad \textbf{Equation (1)}$$

The final vertical target PSD anchored to 1.0g for US-APWR is:

$$S_{0V}(f) = \begin{cases} 380(f/3.5)^{0.2} \text{ for } f < 3.5\text{Hz} \\ 380(3.5/f)^{1.6} \text{ for } 3.5\text{Hz} \le f < 12\text{Hz} \\ 52.9(12.0/f)^{3} \text{ for } 12\text{Hz} \le f < 18\text{Hz} \\ 15.7(18/f)^{7} \text{ for } 18\text{Hz} \le f \end{cases} \quad (\text{in}^2/\text{sec}^3) \qquad \textbf{Equation}$$

(2)

As shown in Equations (1) and (2), and Figure 13, the slope of the second leg is modified to 1.6 from 1.8, which makes this leg of the PSD "flatter" than the PSD for RG 1.60 spectra. Further, the slope of the fourth leg is modified to 7 from 8, which makes this leg flatter. The control point at 9 Hz is extended to 12 Hz, and the control point at 16 Hz is extended to 18 Hz from the SRP 3.7.1 target PSD. All of these changes increase the power requirement at frequencies above 2.5 Hz.

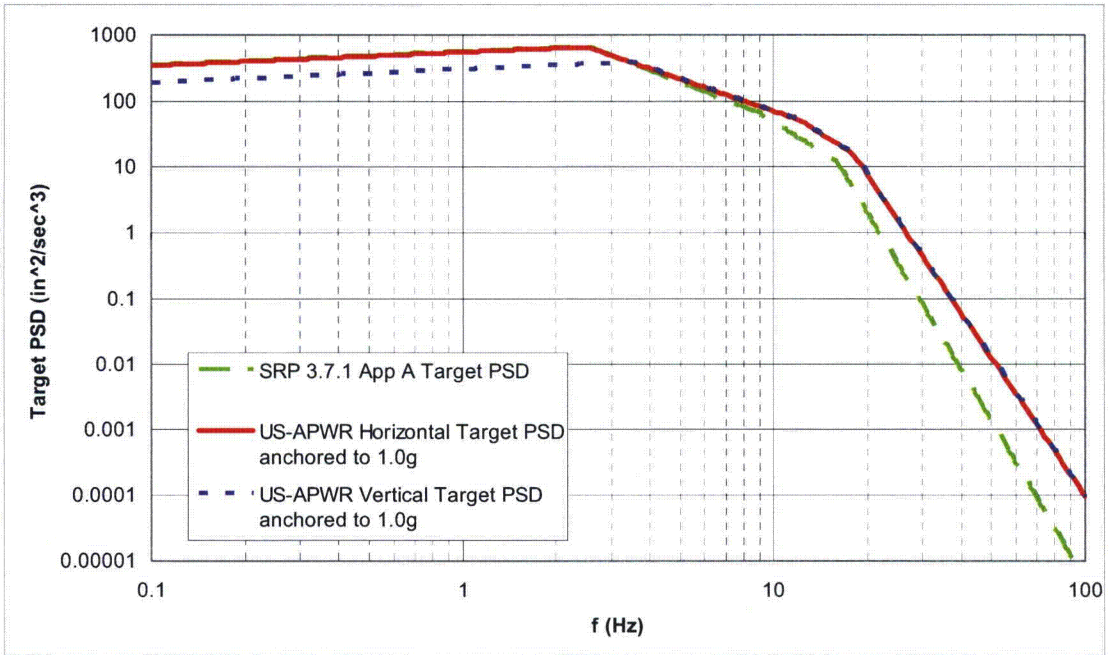


Figure 13, US-APWR Horizontal and Vertical Target PSDs vs. SRP Target PSD

(b) Methodology to Develop US-APWR Horizontal And Vertical Target PSDs

<u>The Procedure to Develop The Target PSDs</u>

I. Select a reasonable horizontal initial target PSD

II. Generate 30 artificial time histories from a deterministic time envelope function and 30 sets of randomly selected phase relationships, using the initial target PSD and Equations (7), (8) and (9) in NUREG/CR-5347, Appendix B. The time envelope function, as shown in Figure 14 and Table 4, similar to "Function B" in NUREG/CR-5347 Appendix B, is selected to simulate real earthquake time histories. Total duration of the time histories is set to be 20.24 seconds to satisfy the SRP 3.7.1 guidance requirement of minimum time history duration (20 seconds).

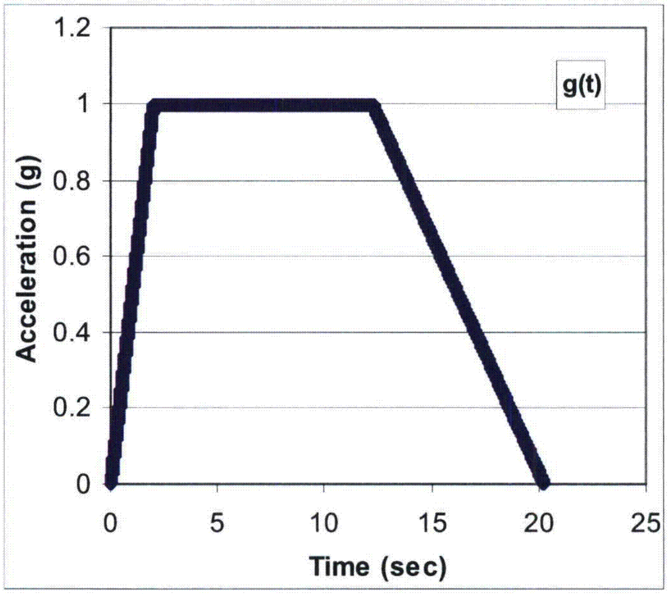


Figure 14, Time-Envelope Function to Generate US-APWR Artificial Time Histories

Table 4, Time-Envelope Function

Time	Envelope Function (sec)
t_r	2.0
t_m	10.24
t_d	8.0

III. Calculate the 2% damped pseudo-velocity response spectra from the acceleration CSDRS and compare the average velocity response spectra of the 30 time histories with the 2% damped CSDRS.

IV. The average response spectra of the 30 artificial time histories, generated from the target PSD compatible with the CSDRS, shall lie "*close to, but generally below*" the CSDRS (Reference 2). If not, adjust the target PSD and repeat the process from steps "II" and "III" until the average response spectra lies "close to, but generally below" the CSDRS.

V. The same process is used to generate the vertical target PSD compatible with the vertical US-APWR CSDRS.

Selection of Horizontal Initial Target PSD

By comparing RG 1.60 Spectra and US-APWR CSDRS, an initial horizontal target PSD is selected to envelop the "Modified SRP Target PSD" using straight line for each PSD frequency segment. The "Modified SRP Target PSD" is defined as:

$$\text{(Modified SRP Target PSD)} = \text{(SRP Target PSD)} * [\text{(APWR CSDRS)}/\text{(RG 1.60 Spectra)}]^2$$

This Modified SRP Target PSD is a series of curved lines. The initial target PSD is developed using equations of the same form as those presented in SRP 3.7.1 Appendix A. These equations are developed so that straight line segments (on a log-log plot) bound the curved lines of the Modified SRP Target PSD computed above. The two response spectra, i.e., CSDRS and RG 1.60 are shown in Figure 15 for the horizontal direction and in Figure 16 for the vertical direction.

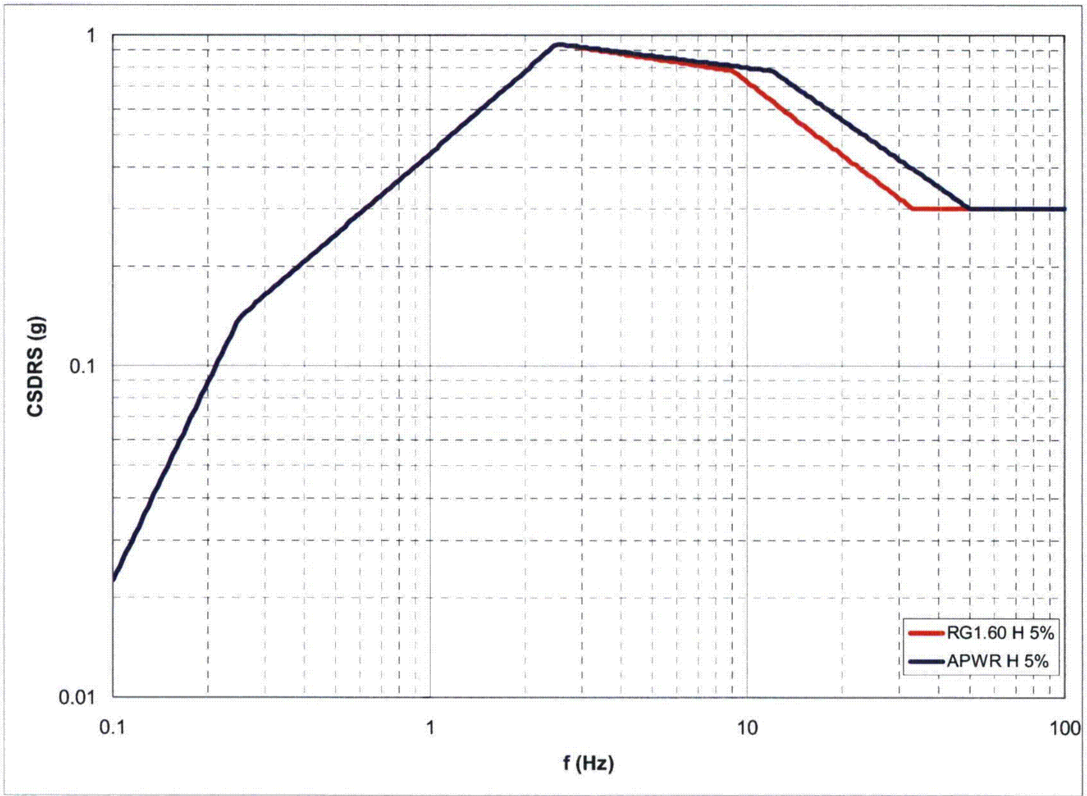


Figure 15 Horizontal RG 1.60 Spectra and US-APWR CSDRS at 5% Damping

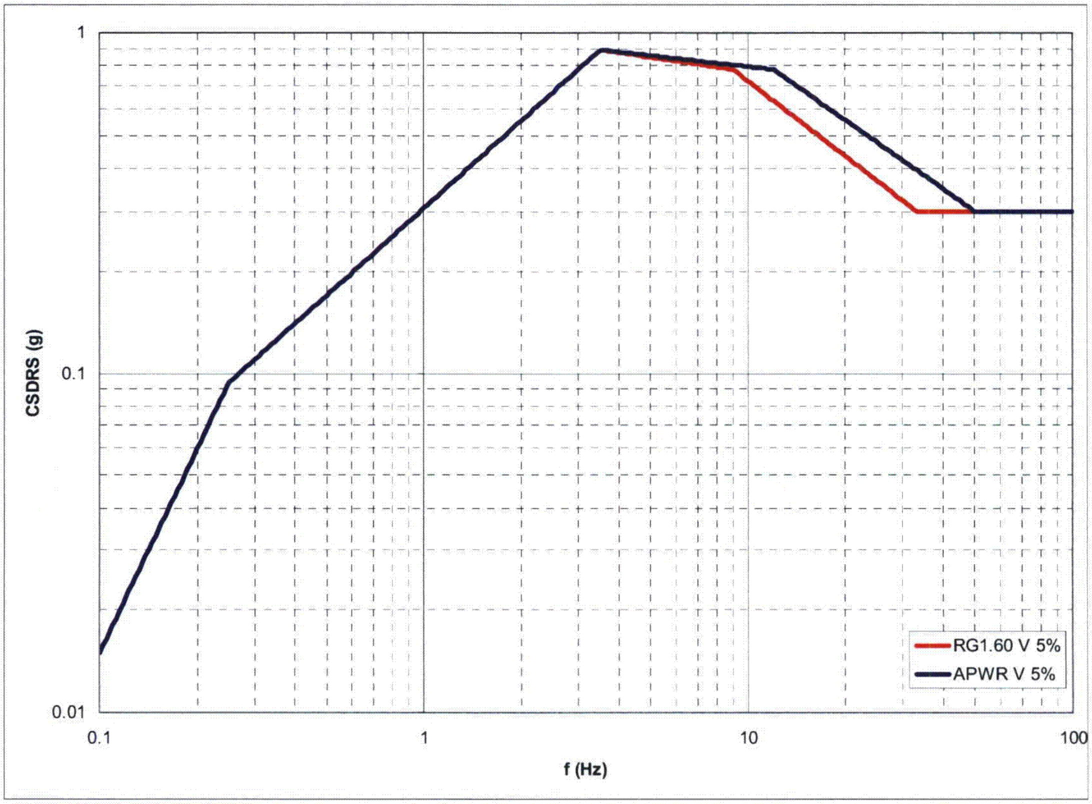
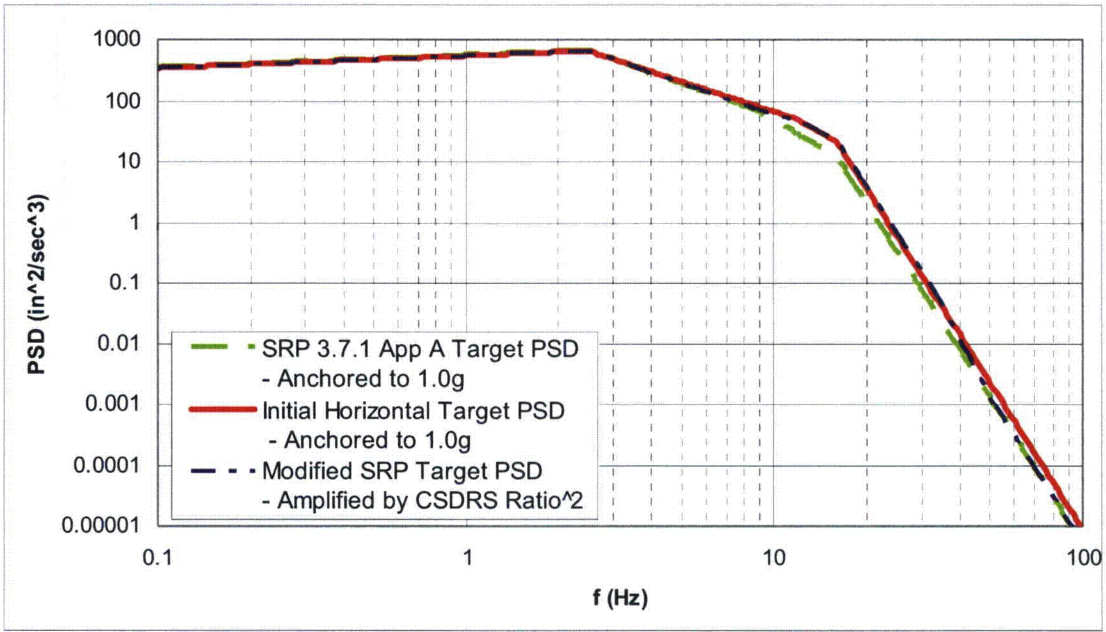


Figure 16 Vertical RG 1.60 Spectra and US-APWR CSDRS at 5% Damping

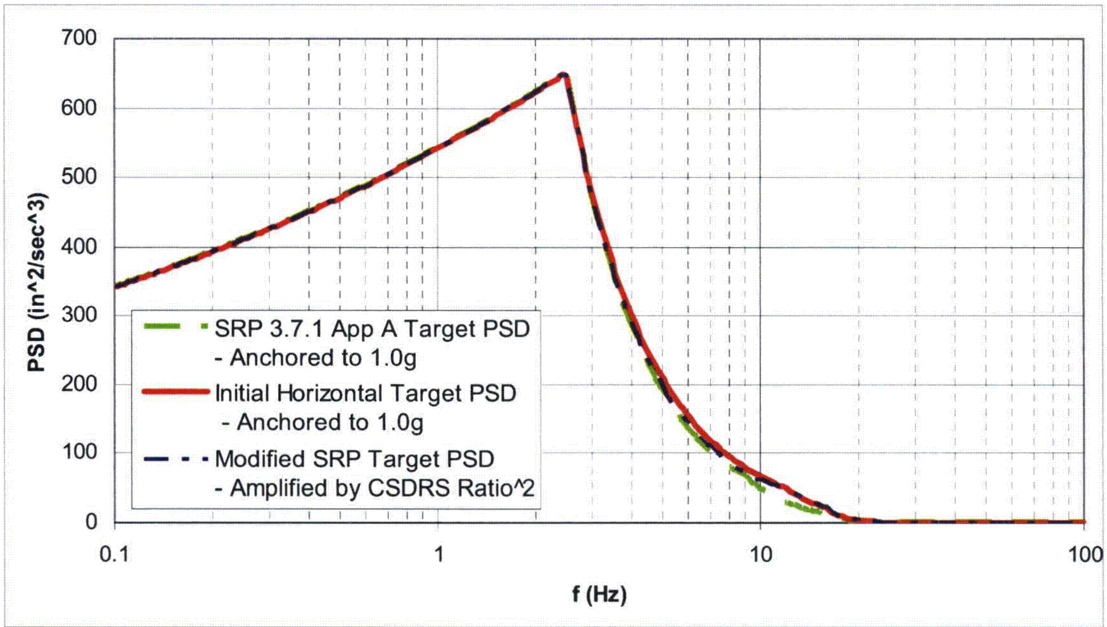
The equations that define the initial horizontal target PSD is developed as shown below:

$$S_{0H1}(f) = \begin{cases} 650(f/2.5)^{0.2} & \text{for } f < 2.5\text{Hz} \\ 650(2.5/f)^{1.65} & \text{for } 2.5\text{Hz} \le f < 12\text{Hz} \\ 48.85(12.0/f)^{3} & \text{for } 12\text{Hz} \le f < 16\text{Hz} \\ 20.61(16/f)^{8} & \text{for } 16\text{Hz} \le f \end{cases} \quad (\text{in}^2/\text{sec}^3) \qquad \textbf{Equation (3)}$$

These equations are plotted in Figure 17 (a) log-log plot and Figure 17 (b) semi-log, as requested.



(a)



(b)

Figure 17, US-APWR Initial Horizontal Target PSD
(a) log-log scale; (b) semi-log scale

Response Spectral Match Using Final Target PSDs

After several iterations, the pseudo-velocity response spectra (PSV) of the artificial time histories, generated using the final target PSDs, match the CSDRS very well, which demonstrates that the target PSDs (shown in Equations (1) and (2)) are compatible with the CSDRS. The horizontal response spectra are shown in Figure 18 and the vertical spectra are shown in Figure 19.

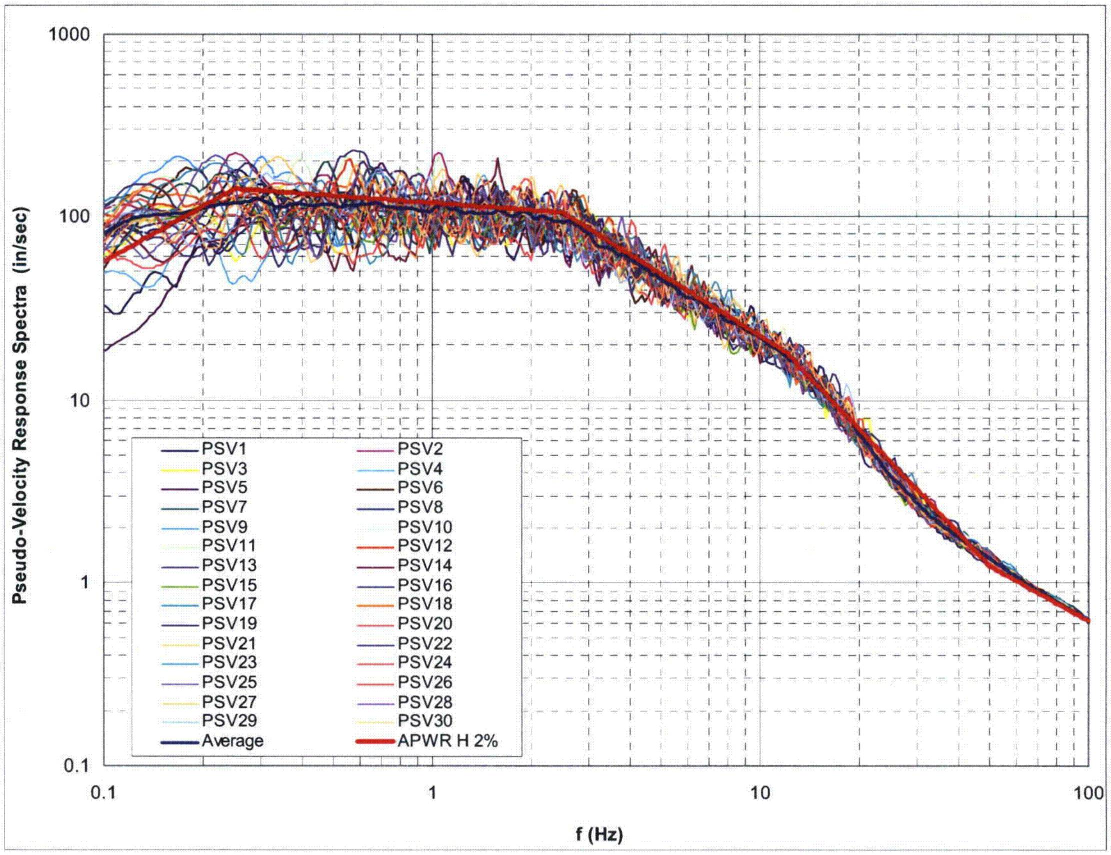


Figure 18, Horizontal Pseudo-Velocity Response Spectra (PSV) at 2% Damping of 30 Artificial Horizontal Time Histories

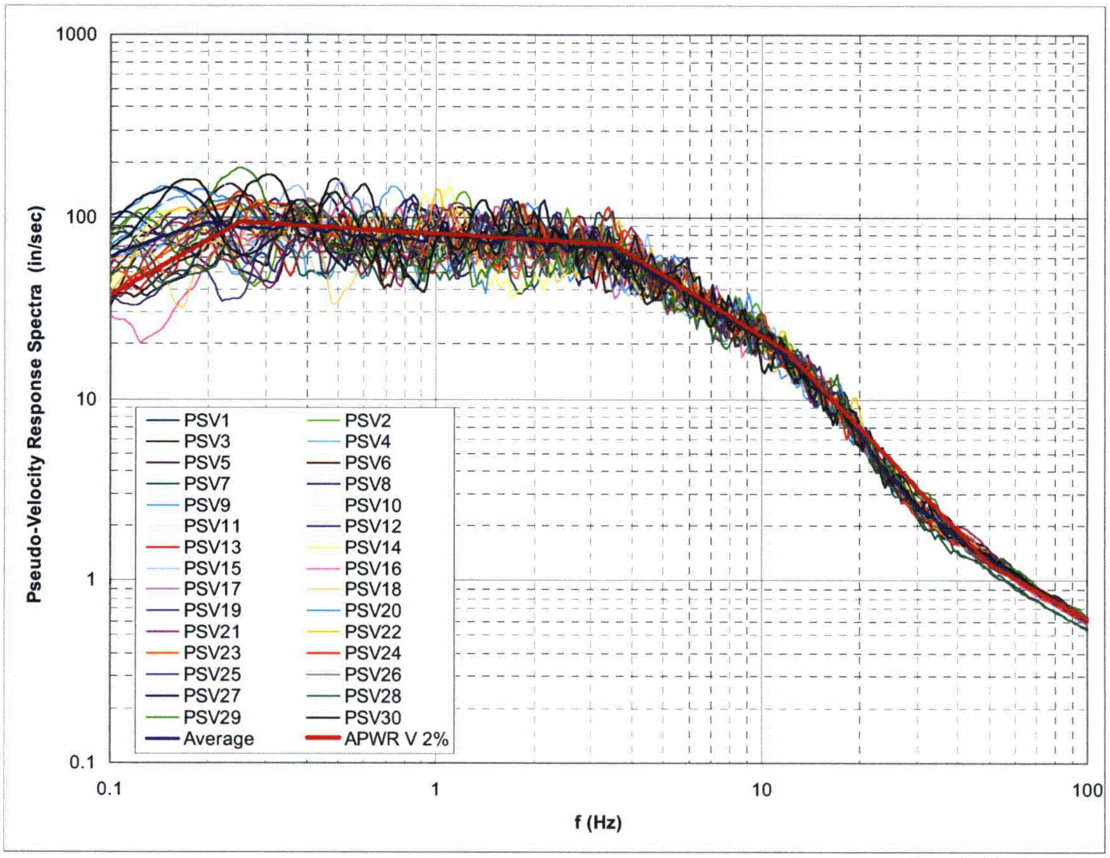


Figure 19, Vertical Pseudo-Velocity Response Spectra (PSV) at 2% Damping of 30 Artificial Vertical Time Histories

(c) Methodology to Compute PSD According to Standard Review Plan

<u>Equivalent Stationary Phase Strong Motion Duration</u>

The PSDs of the modified time histories are calculated using SRP 3.7.1 Appendix A, Equation (1). The PSD calculation procedure is confirmed by reproducing the SRP 3.7.1, Appendix A target PSD, using the methodology described in NUREG/CR-5347, Appendix B.

First, similar to the development of the target PSDs, 30 artificial time histories were generated using the SRP 3.7.1, Appendix A target PSD, 30 sets of random phase angles uniformly distributed between 0 to 2π, and a envelope function shown in Figure 20 and Table 5, which is the same function as used in the NUREG/CR-5347.

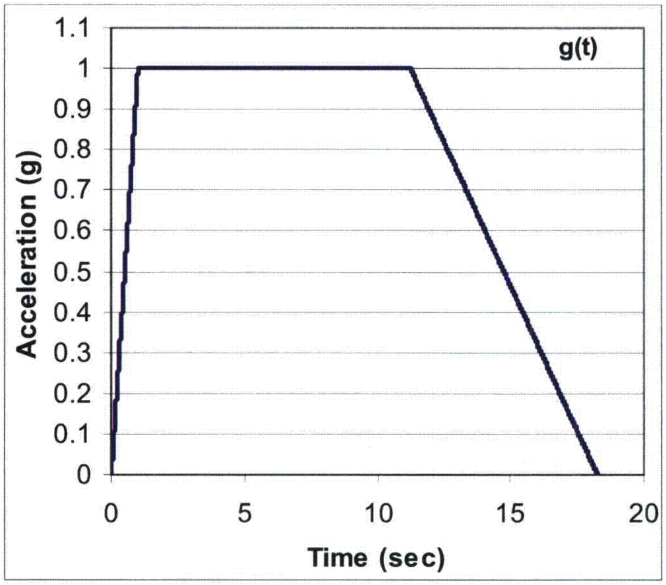


Figure 20, Time-Envelope Function to Generate US-APWR Artificial Time Histories

Table 5, Time-Envelope Function Used in NUREG/CR-5347

Time	Envelope Function (sec)
t_r	1.4
t_m	10.24
t_d	7.0

Second, calculate the PSDs of the 30 time histories using Equation (4),

$$S_0(f) = \frac{2|F(f)|^2}{2\pi T_D} \qquad \textbf{Equation (4)}$$

for the following three scenarios:

I. Compute Fourier amplitudes over the total time history duration with T_D equal to the total duration.

II. Compute Fourier amplitudes over the strong motion duration with T_D equal to the strong motion duration, calculated as shown in Equation (5):

$$T_D = T_{I=75\%} - T_{I=5\%} \qquad \textbf{Equation (5)}$$

Where $T_{I=5\%}$ and $T_{I=75\%}$ is time at which the Arias' Intensity is equal to 5% and 75%, respectively.

III. Compute Fourier amplitudes over the total time history duration with T_D equal to an "equivalent stationary phase strong motion duration", computed as shown in Equation (6):

$$T_D = \frac{T_{I=75\%} - T_{I=5\%}}{75\% - 5\%} = \frac{T_{I=75\%} - T_{I=5\%}}{0.7} \qquad \textbf{Equation (6)}$$

Finally, smooth the PSD within ±20% frequency range at the frequencies of interest. Compare the average PSD of the 30 time histories with the SRP 3.7.1, Appendix A target PSD.

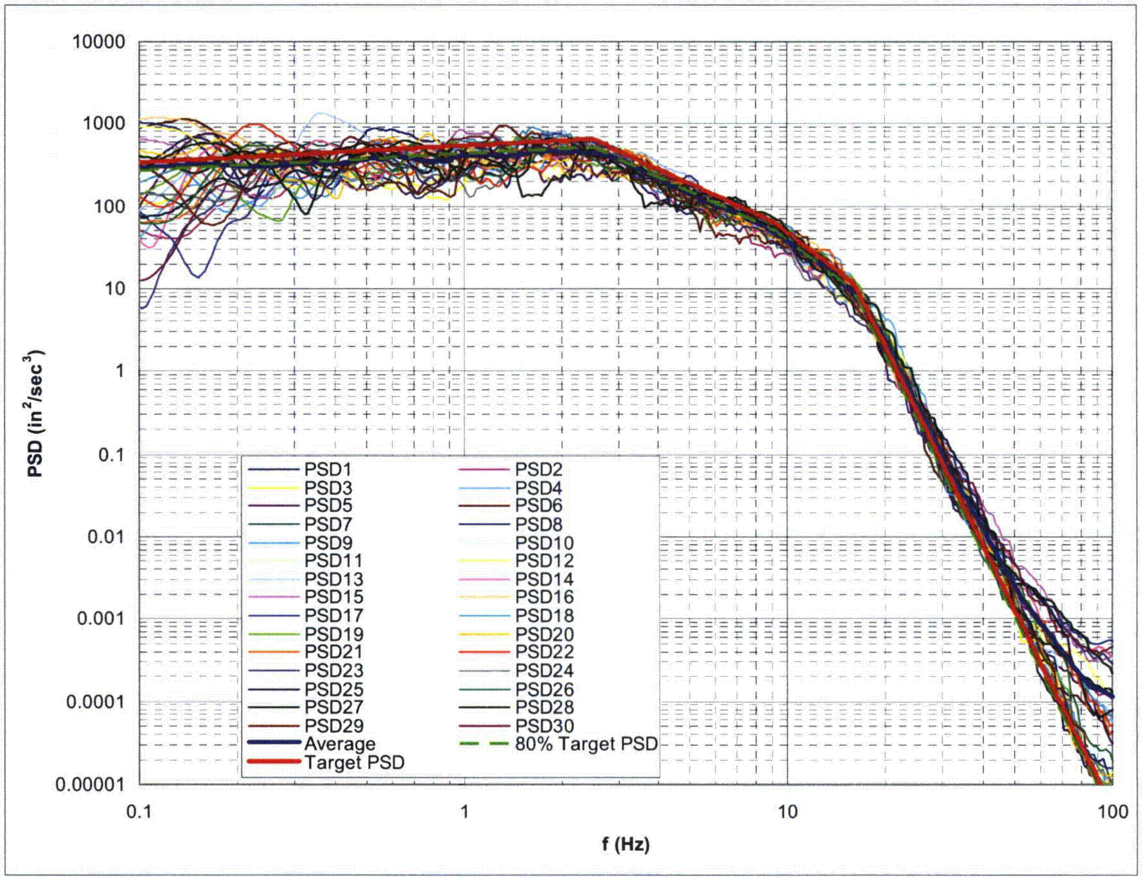


Figure 21, Scenario I PSDs vs. SRP 3.7.1 Target PSD

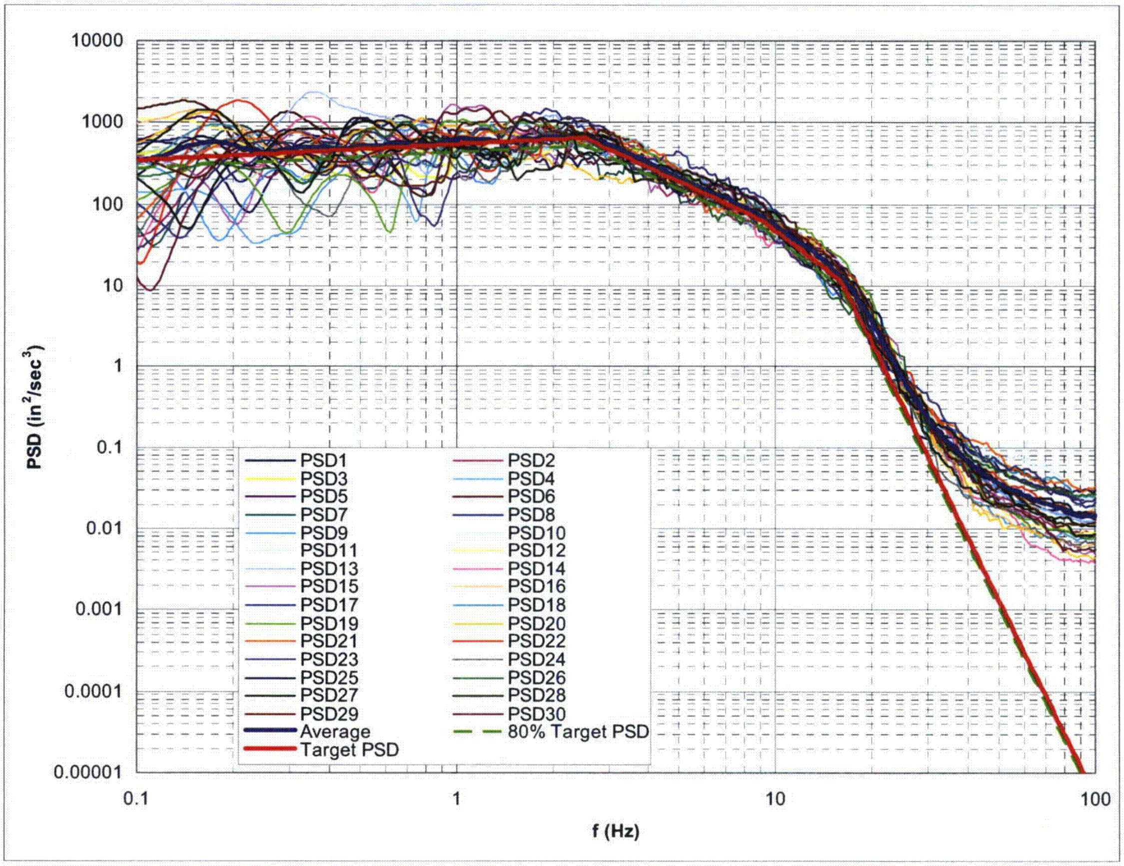


Figure 22, Scenario II PSDs vs. SRP 3.7.1 Target PSD

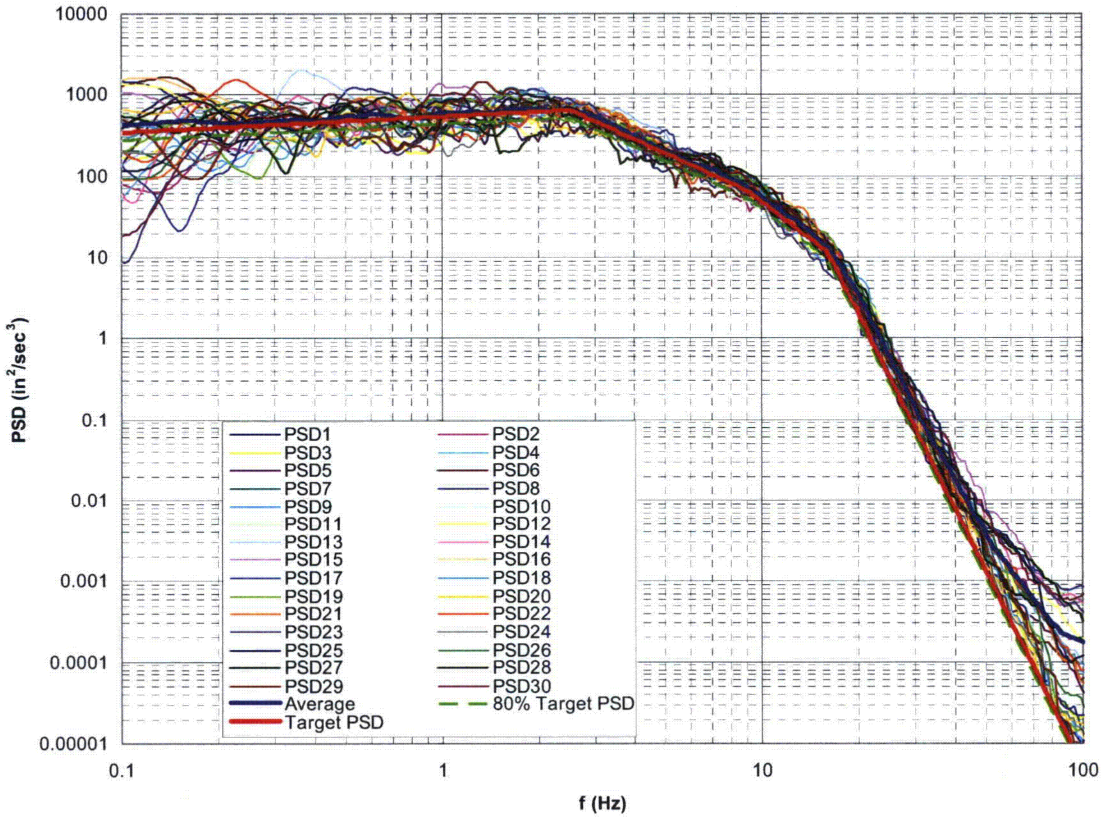


Figure 23, Scenario III PSDs vs. SRP 3.7.1 Target PSD

As shown in Figure 21 the average PSDs produced in "Scenario I" lie below the target PSD for most of the frequencies below 20 Hz, while average PSDs shown in Figure 22, computed in "Scenario II", are much higher than the target PSD beyond 20 Hz. "Scenario III" has the best PSD match as shown in Figure 23.

<u>Required Frequency Range for US-APWR PSD Bound Evaluation</u>

The SRP Appendix A stipulates that the PSD evaluation is unnecessary for frequencies beyond 24 Hz, since the power beyond 24 Hz for the target PSD is so low as to be inconsequential. At 24 Hz, the SRP 3.7.1, Appendix A target PSD has a value of:

$$11.5*(16.0/24.0)^8 = 0.4487 \text{ in}^2/\text{sec}^3$$

Applying the same criteria to the US-APWR target PSDs, the frequency for the upper limit can be obtained from:

$$15.7*(18.0/f_{cutoff})^7 = 0.4487 \text{ in}^2/\text{sec}^3$$

$$f_{cutoff} = 30 \text{ Hz}$$

However, SRP 3.7.1 Appendix B stipulates that "for Central and Eastern US Rock Sites checks above 50 Hz are unnecessary". Therefore, the upper bound frequency for the PSD evaluation is conservatively selected as 50 Hz.

The lower bound frequency limit is the same as specified in SRP 3.7.1 Appendix A, which is 0.3 Hz.

In summary, the PSD calculation follows the procedure below:

- The Fourier amplitudes are computed over the total time history duration.
- The "equivalent stationary phase strong motion duration" is used to calculate the PSD.
- At any frequency the smoothed PSD is computed within ±20% of the frequencies of interest.
- Frequency range required for PSD evaluation is:

  The lower frequency limit: 0.3 Hz

  The upper frequency limit: 50 Hz

Smoothed PSDs of the modified Northridge time histories are shown in Figures 24 to 26. These are compared to 80% of the target PSDs anchored to 0.3g.

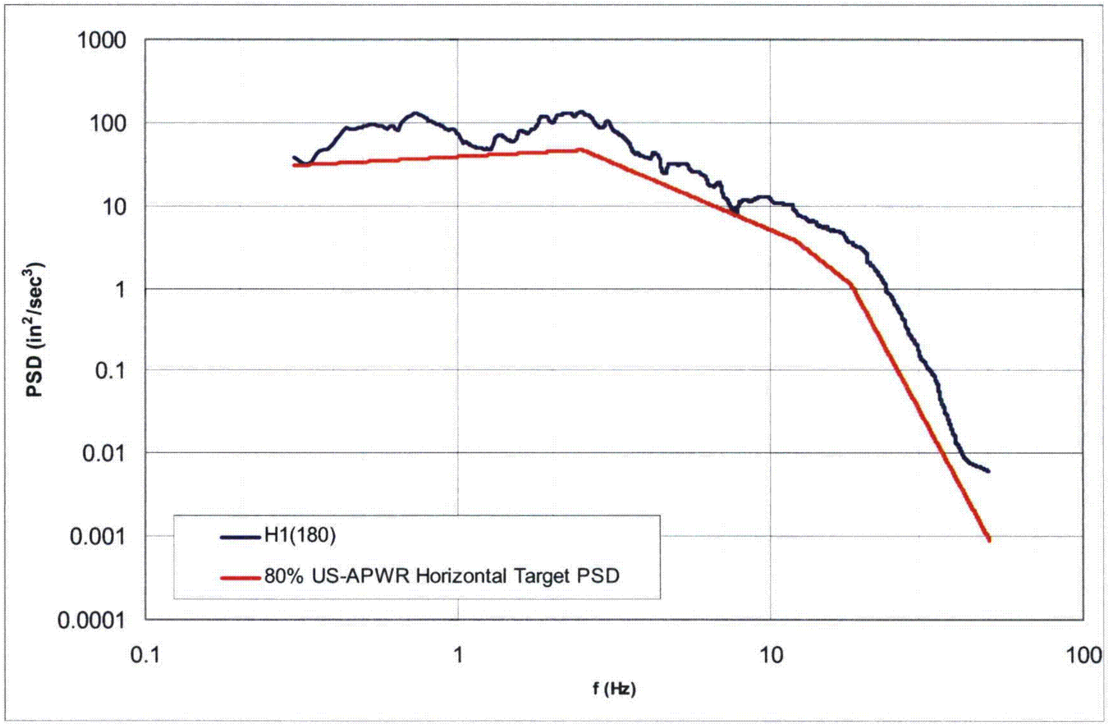


Figure 24, X Component PSD of Modified Northridge Time History vs. US-APWR Target PSD

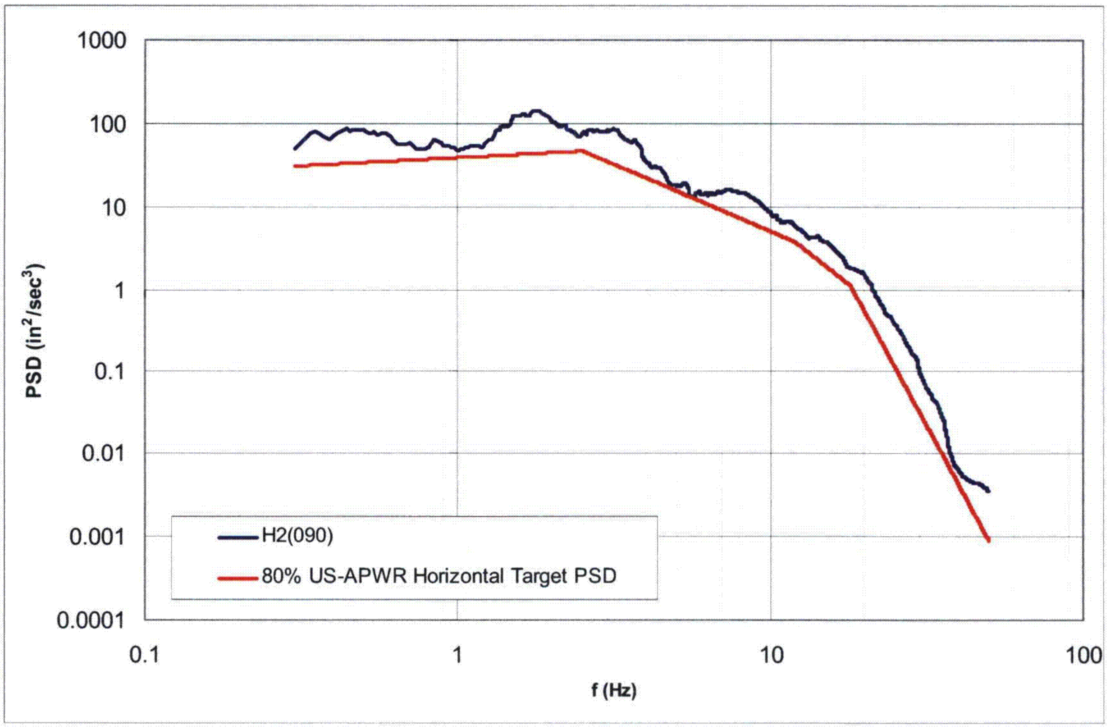


Figure 25, Y Component PSD of Modified Northridge Time History vs. US-APWR Target PSD

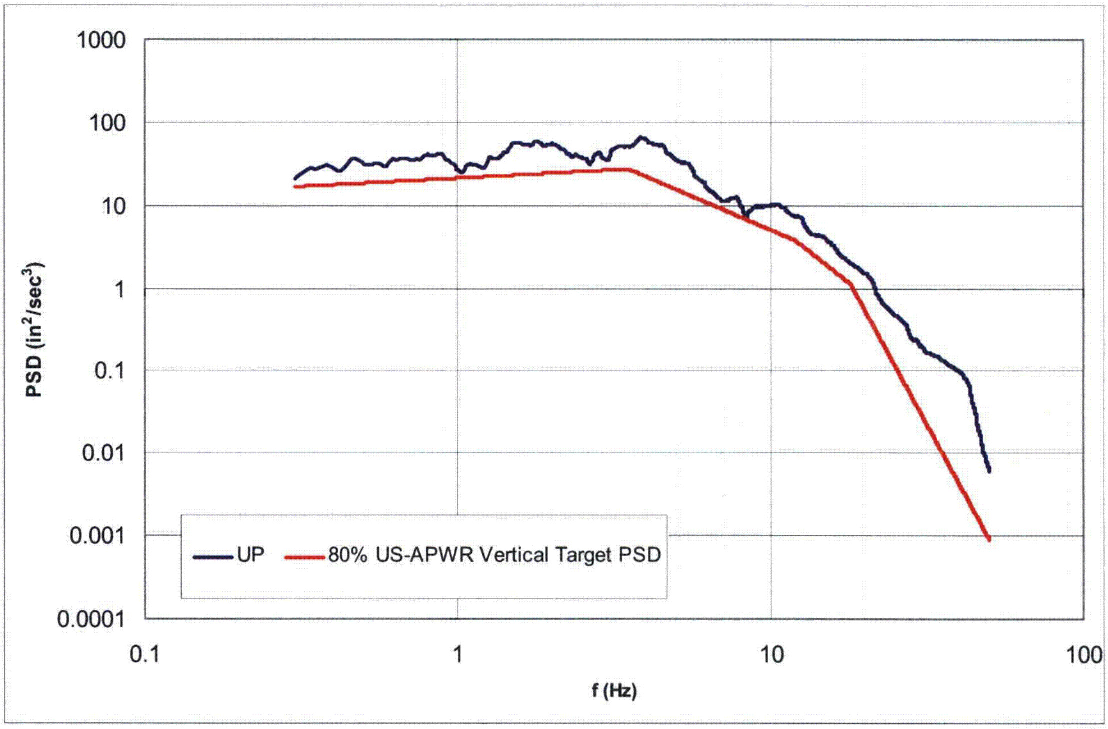


Figure 26, Vertical Component PSD of Modified Northridge Time History vs. US-APWR Target PSD

Figures 24 to 26 demonstrate that the PSDs of the modified time histories, developed from the Northridge seeds, satisfy the SRP 3.7.1 PSD requirements.

Time Histories for the Calculation of Sliding Displacements

Five time histories will be developed for the calculation of the sliding displacements. This will be the only use for these five time histories. The segment of the Northridge Mount Baldy recorded time history (this is the same seed as was used for the development of the CSDRS compliant time history as described in the response to Question1 above), and the Nahanni Site 3 recorded time history and three additional recorded time histories will comprise the five seed time histories for the development of the five time histories.

Using the guidance specified in the SRP Option 2 for Multiple Sets of Time Histories, these seeds will then be developed to be compatible with the CSDRS using the criteria specified in SRP, Section 3.7.1, Option 1, Approach 1. Specifically, the seeds will be developed to be compatible with the CSDRS at 5% damping using the frequency list in Table 3.7.1-1 from the SRP. The seeds will be developed so that the average value of the response spectra from the five time histories will match the CSDRS. In order to provide more detail, the response spectrum from each of the five time histories will be computed at 5% damping using the frequency list in Table 3.7.1-1. Then at every frequency in the list, the average value of five response spectra will be computed. This average value will be used to match the CSDRS where only 5 average value points will be allowed to fall below the target response spectrum and no more than 10% below.

Further, the time histories will be developed so that the average of the five smoothed one sided PSDs of the five time histories will be above 80% of the target PSD in the frequency range of 0.30 to 50.00 Hz. At any frequency *f*, the smoothed one sided PSD will be computed over a frequency band width of ± 20 percent centered in the frequency *f*, e.g., 4 Hz to 6 Hz band width for *f* = 5 Hz. Specifically, the smoothed one sided PSD of the each of the five time histories will be computed. Then at the each of the frequencies the average of the five PSDs will be computed. This average PSD will be required to be above 80% of the target PSD in the frequency range of 0.30 to 50.00 Hz. The raw PSDs will be computed for the frequency range of 0.10 to 60 Hz (minimum) in increments of 0.025 Hz.

These five time histories will then be used in non-linear time history analyses to compute sliding displacements of the facility. The envelopes of these values will then be used as the basis for the design displacements.

References:

(1) "Seismic Design Parameters," NUREG-0800, SRP 3.7.1, Rev. 3, NRC, March 2007.

(2) Recommendations for Resolution of Public Comments on USI A-40, "Seismic Design Criteria" NUREG/CR-5347, NRC.

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

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 940-6532 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-41:

In its response to RAI No.886-6202 Revision 3, Question No. RAI 03.07.01-33, MHI provided digitized acceleration verses time traces for the current design-basis Northridge Earthquake seed records and for the synthetic acceleration time histories developed from the seed records to match the CSDRS. The staff has conducted independent numerical analysis using this information, to evaluate whether the developed synthetic time histories provide an acceptable match to the CSDRS, in accordance with the assessment procedures detailed in SRP 3.7.1.

The staff's independent calculations showed an unexpected significant difference in the value of the parameter, AD/V^2 between the two horizontal components for both the seed records and the synthetic time histories. The applicant is requested to explain the difference in the values of AD/V^2 between the two horizontal directions for both the seed records (15.4 vs. 3.8) and the generated synthetic times histories (7.22 vs. 2.80). The applicant is also requested to provide a detailed technical basis for the acceptability of such a large difference in the value of AD/V^2 within a single set of synthetic time histories developed to match the same target spectra.

ANSWER:

The differences between the values for the seeds and the values for the certified seismic design response spectra (CSDRS) matched time histories are due to the fact that the initial seeds were not baseline corrected. The initial seeds were truncated from the Northridge Mt Baldy records between 11 seconds and 33.08 seconds. Therefore, baseline correction needs to be applied to the segmented seeds in order to compute appropriate AD/V^2 ratios. The Northridge records are a magnitude M6.69 earthquake with the epicentral distance of 82.2 km and the average shear-wave velocity in the top 30m of 339 m/s. Table 6 presents the mean ratios of $AD/V^2 \pm$ one standard deviation for the WUS time history statistics with M6.5 and 50 to 100 km distance bins. Table 7 shows AD/V^2 ratios of the initial Northridge seed time histories without baseline correction. The high AD/V^2 ratios are mainly due to the drift effect of the un-baseline corrected displacements. After baseline correction, the AD/V^2

values of the seed time histories are within the normal range, as shown in Table 8. All the values are computed using integration method documented in Reference 2, Appendix III.

Table 6, AD/V^2 Mean Ratio $\pm$ One Standard Deviation (Data from Table 3-6 of NUREG/CR-6728)

Distance Bin	*M*	$A*D / V^2$, σ_{ln}	$A*D/V^2 / e^{(\sigma_{ln})}$	$A*D/V^2 * e^{(\sigma_{ln})}$
50 - 100, Rock	6.38	2.64, 0.51	1.59	4.40
50 - 100, Soil	6.57	2.44, 0.62	1.31	4.54

Table 7, Properties of Northridge Seed Time Histories before Baseline Correction

Requirement	X Component (North-South)	Y Component (East-West)	Vertical Component
PGA (g)	0.0698	0.0795	0.0369
PGV (in/sec)	1.769	1.526	0.971
PGD (in)	1.795	0.924	2.613
A*D/V^2	15.46	12.18	39.48

Table 8, Properties of Northridge Seed Time Histories after Baseline Correction

Requirement	X Component (North-South)	Y Component (East-West)	Vertical Component
PGA (g)	0.0698	0.0795	0.0369
PGV (in/sec)	1.700	1.487	0.857
PGD (in)	0.153	0.210	0.170
A*D/V^2	1.43	2.92	3.30

Refer to responses to RAI 940-6532, Rev. 3, Question 03.07.01-40, Table 2 for the AD/V^2 values for the modified Northridge time histories. As shown there, the AD/V^2 values are consistent with the values of the baseline corrected seeds.

References:

1) "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines," NUREG/CR-6728, NRC, October 2001.

2) Nigam, N., Jennings, P., "Digital Calculation of Response Spectra from Strong-Motion Earthquake Records", California Institute of Technology, June 1968.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 940-6532 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-42:

In its response to RAI No.886-6202 Revision 3, Question No. RAI 03.07.01-33, MHI provided digitized acceleration verses time traces for the current design-basis Northridge Earthquake seed records and for the synthetic acceleration time histories developed from the seed records to match the CSDRS. The staff noted that the selected seed records have 2210 points and a time increment of 0.01 seconds, while the synthetic acceleration time histories have 4417 points and a time increment of 0.005 seconds. The staff requests the applicant to:

(1) explain in detail how the intermediate points were interpolated from the seed records; and

(2) identify what database was used to select the starting Northridge seed records.

ANSWER:

(1) The intermediate points of the time histories are computed using linear interpolation in the time domain. Therefore, by definition, to cut the time step in half from 0.01s to 0.005s, the midpoint of a straight line connecting the recorded accelerations at the ends of each interval is used.

(2) The database used to select the Northridge seed time history is the Pacific Earthquake Engineering Research (PEER) Center Ground Motion Database.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/21/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 940-6532 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/12**

QUESTION NO. RAI 03.07.01-43:

The applicant stated that results presented in its response to RAI No.886-6202 Revision 3, Question No. RAI 03.07.01-33, reflect the old general arrangement of structures on separate basemat. Staff understands that a redesign to increase the size of the common basemat and to include additional buildings on the common basemat is currently underway. The Applicant committed to revise the current RAI response after completing the evaluation of new structural configuration that combines the Reactor Building, Containment Internal Structure, Pre-stressed Concrete Containment Vessel, Auxiliary Building and the two Power Source Buildings on a common basemat. The applicant is requested to submit a revised RAI response according to its commitment.

ANSWER:

On March 31, 2012, MHI submitted the details of the Seismic Closure Plan (MHI Letter UAP-HF-12082). The Seismic Closure Plan includes updating past RAI responses to address the latest methodology and analyses results, which are presented in the Technical Reports.

Impact on DCD

There is no current impact on the DCD. However, the DCD will be updated in accordance with the Seismic Closure Plan.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on a Technical/Topical Report

Technical Report MUAP-10006 is being revised in accordance with the Seismic Closure Plan.

Docket No. 52-021
MHI Ref: UAP-HF-12265

Attachment 1

Files Contained in CD 1

CD 1: Northridge Time Histories (09/12/2012)
-Version containing proprietary information

File Name	Size	Sensitivity Level
Northridge_MtBaldy_TH_Op1_App1_APA_New2.xls	420 KB	Proprietary