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TOKYO, JAPAN

December 1, 2011

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-11417

Subject: MHI's Responses to US-APWR DCD RAI No. 850-6002 Revision 3 (SRP 03.07.01)

Reference: 1) "Request for Additional Information No. 850-6002 Revision 3, SRP Section: 03.07.01 – Seismic Design Parameters," dated 10/21/2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 850-6002, Revision 3."

Enclosed are the responses to 14 RAIs contained within Reference 1. This transmittal completes the response to this RAI.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

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

Enclosure:

1. Responses to Request for Additional Information No. 850-6002, Revision 3

D081
NRO

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

Contact Information

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Enclosure 1

UAP-HF-11417
Docket No. 52-021

Responses to Request for Additional Information No. 850-6002, Revision 3

December, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

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

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-19:

Section 4.2 of MUAP-10001(R3), "Development of Soil Profiles and Strain Compatible Properties" (Page 4-5) states that a whole new suite of soil properties were developed for the new seismic analysis reported herein. The last two sentences in the first paragraph states, "The number of available profiles generally decreases rapidly with depth as noted in "Surface Geology Based Strong Motion Amplification Factors for the San Francisco Bay and Los Angeles Areas" (Reference 7). Therefore, judgment has to be used to extend the generic profiles at the deeper depths."

The staff believed that the US-APWR seismic analyses are to be applicable to a large number of sites in the Central and Eastern United States (CEUS), nonetheless, the reference cited (Reference 7) is meant for the Western US regions (specifically California). The Applicant is requested to explain: (1) how the material in Reference 7 in MUAP-10001(R3) is applied to the CEUS sites; and (2) describe the nature, extent, and the basis of the judgment that was necessary to determine the soil profiles that are applicable to and representative of the CEUS sites.

ANSWER:

The reference cited (Reference 7 of Technical Report MUAP-10001 (R3)) illustrates the process of developing a generic soil profile as an average of multiple measured profiles in this case within similar surficial geology. Reference 7 also clearly illustrates how the number of measured profiles decrease with increasing depth and the judgment process of extending the average to depths where only few profiles exist as well as deeper, where the shallow gradient is used to guide the extrapolation. An additional reference is Silva (1997) (Reference 3) where a similar process is illustrated to develop generic profiles based on Geomatrix site categories, a well-known recording site categorization scheme. The cited references were to describe the <u>process</u> only, not the development of the generic DCD profiles. The development of generic profiles in this manner has been validated by modeling recorded motions at over 500 sites from about 15 earthquakes using the generic profiles (EPRI, 1993, Reference 1; Silva et al., 1996, Reference 2; Silva, 1997, Reference 3) for sites worldwide. Because geologic processes do not change at 105° W longitude in the US and Canada, profiles and G/G_{max} and hysteretic damping curves are generally similar between western North America (WNA) and central and eastern North America (CENA). Sands, clays, and graves, Holocene soils, Pleistocene soils, soft, firm, and hard rock sites have similar dynamic material properties between WNA and CENA as well as worldwide. It is only the relative distributions that differ. For example, there are loess and till sites in both WNA and CENA but they cover a relatively larger area in CENA. There are glacially showered sites in WNA and CENA but again more widespread in the CENA. Hard rock sites as well as hard rock beneath soils exist in WNA but is much more common in CENA. Residual soils and saprolite exist across the U.S. but more common in CENA. As a result generic G/G_{max} and hysteretic damping curves are used worldwide and are not specific to any particular tectonic regime. The same tectonic independence applies to velocity profiles with the exception of the differences in the occurrence of hard basement rock between WNA and CENA. Hard basement rock beneath soils is more prevalent in the CENA than WNA which was the motivation for developing ground motion prediction equations (GMPEs) for hard rock outcrops (i.e., V_S = 2.83 km/sec) for the CENA (EPRI, 1993, Reference 1; 2004, Reference 4). However there are also large regions across the CENA with significantly lower velocity sedimentary rock beneath the soils. The area comprising the Gulf Coast (EPRI, 1993, Reference 1) as well as the large region of the gas bearing Marcellus and Devonian shales (Figure 1 below), with both regions comprising a significant portion of the CENA, have sedimentary rock comprised of siltstones, sandstones, mudstones, shales, and some limestones underlying the soils. Put another way, one cannot look at velocity profile and determine conclusively whether it is from WNA, CENA, Taiwan, Japan, Turkey, etc. If it is a soil profile and the underlying rock has a shear-wave velocity exceeding about 2.0 km/sec, it likely reflects a CENA location. If, on the other hand, there is a steep velocity gradient beneath the soil, the profile may be from WNA or CENA. For applications to a DCD the issue of significance is whether the distribution in profile stiffness and depth reflects an acceptable range in column frequencies as depicted in Technical Report MUAP-10001 (R4) Figure 5.2-15. This was the underlying motivation in profile development and final selection.

References:

1) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.
    - Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
    - Vol. 2: Appendices for Ground Motion Estimation
    - Vol. 3: Appendices for Field Investigations
    - Vol. 4: Appendices for Laboratory Investigations
    - Vol. 5: Quantification of Seismic Source Effects

2) Silva, W.J., N. Abrahamson, G. Toro and C. Costantino, (1996), "Description and validation of the stochastic ground motion model." Report Submitted to Brookhaven National Laboratory, Associated Universities, Inc. Upton, New York 11973, Contract No. 70573.

3) Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design, NCEER-97-0010, Proceedings of the FHWA/NCEER Workshop on the National Representation of Seismic Ground Motion for New and Existing Highway Facilities, I.M. Friedland, M.S Power and R. L. Mayes eds., Silva, W.J., 1997.

4) Electric Power Research Institute (2004). "CEUS Ground motion project" Palo Alto, Calif: Electric Power Research Institute, Final Report, EPRI Report 1009684.

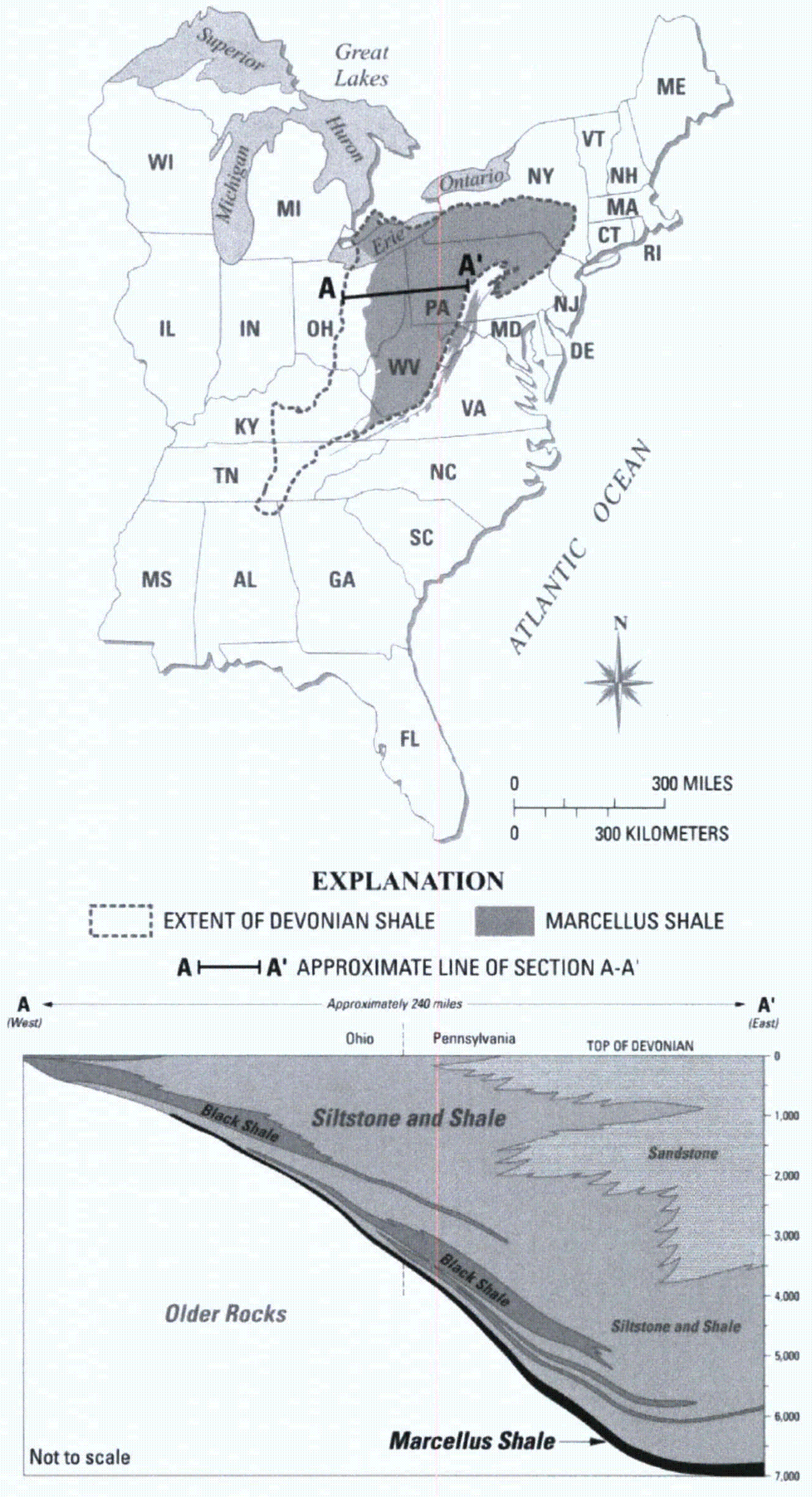

Figure 1 – Regions of Marcellus and Devonian Shales

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-20:

Section 4.2.1 of MUAP-10001(R3), states, "soft soil (270 m/s) with a depth of 100 feet was deemed not to be representative of conditions at candidate sites within the continental United States and therefore was not included in the SSI analysis."

At a number of current sites considered for placement of new plants (e.g. Vogtle, Calvert Cliffs and Levy sites), soft surficial soils are removed and replaced with well-compacted materials to form the basis of the plant foundation support. The measured velocities of these well-compacted soils still fall within this soft soil characterization. To ensure that the design for generic sites is adequate over a large range of site conditions, soft soil sites need to be considered in selecting the generic profiles. Thus, the applicant is requested to provide the technical basis for not considering soft soil conditions as illustrated above in the SSI analysis.

ANSWER:

Soft soil sites are considered in selecting the six generic profiles recently presented to the NRC by MHI on September 22, 2011. The definition used in the DCD considers soft soil to have a shear-wave velocity at the surface or foundation in the range of 1,000 ft/sec. Generic soil profile 270-500 is representative of a soft soil site, where "soft" is used in reference to sites competent for construction of nuclear power plants. Not all profiles are considered in the generic profiles selected for analyses of the Standard Plant structures and it is acknowledged that some conditions could produce high ISRS peaks that impose challenges to the design. For such site conditions consisting of shallow soils overlying soft to hard rock at depths less than 200 ft, site-specific SSI analyses will be performed to assess site suitability as required by COL action item 3.7(25).

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

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

RAI NO.:	**NO. 850-6002 REVISION 3**
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APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-21:

In Section 4.2.1 of MUAP-10001(R3), "Selection of Profiles," the second paragraph (page 4-6) states that "For compressional-waves, a water table depth at the plant surface of each profile was assumed. The US-APWR DCD specifies a water table depth of 1 foot below the plant grade which, for the development of vertical motions, is equivalent to the surface. Due to the absence of fluids over the top 1 foot, the lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles."

The applicant did not provide any data in the report to support the statement that the "lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles." The P-wave velocity for the saturated soil will be increased to a minimum of 5000 ft/s irrespective of the soil profile. It is expected that this increase in velocity will have an impact on the vertical motions in the high frequency range. The applicant is requested to provide technical basis and justification that supports the statement that the lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles. This information is required by the staff to evaluate the effects of the high water table on the seismic response of the SSCs and the results of the SSI analyses.

ANSWER:

The statement made in the DCD was strictly in reference to the location of the water table at a depth of 1 ft. In the analyses, a minimum compressional-wave velocity of 5,000 ft/sec was maintained to the surface. The statement was in the context of lowering the compressional-wave velocity over the top 1 ft would have "a very minor impact on vertical motions". For example if the compressional-wave velocity was lowered to 2,000 ft/sec, the lowest frequency of impact is about half the resonant frequency, or about 250 Hz.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
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DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-22:

In Subsection 4.2.2 of MUAP-10001(R3), "Development of US-APWR CSDRS Strain Compatible Properties Equivalent Dynamic Mass," the first paragraph (page 4-6) states, "To characterize the range in strain compatible properties for each profile and depth to hard or soft rock conditions in a fully probabilistic manner, each base-case profile is randomized in velocity as well as nonlinear dynamic material properties. Thirty realizations were generated for each profile category and depth to hard or soft rock."

Section 4.2 of Regulatory Guide 1.208 stipulates that 60 realizations should be performed for a Monte Carlo simulation. Thus, the applicant is requested to provide the technical basis for concluding that 30 realizations are sufficient, especially when SSI analyses must consider uncertainties in the procedures. In addition, the applicant needs to describe the criteria for making this determination.

ANSWER:

Thirty realizations are more than adequate to provide stable estimates of mean values as well as standard deviations. For example, from standard statistical tables only 9 realizations are required to provide a 95% confidence level that a mean velocity of 1,000 ft/sec is within ± 100 ft/sec of the population mean for a typical sigma of 300 ft/sec. Increasing the sigma to 500 ft/sec (half the mean) increases the number to only 24. For the standard deviation far less accuracy is required as SRP 3.7.2 places minimum and maximum constraints on the upper and lower bound strain compatible velocities, generally taken as ± 1 sigma estimates. For 30 realizations, standard statistical tables show estimates of the standard deviation are within 20% of the population sigma and within 25% of the population sigma at the 95% confidence limits. Increasing to 60 realizations has only a marginal improvement from 20% to 15% for the 90% confidence limit and from 25% to 17% at the 95% level. For a substantial improvement, from 20% to 10% at the 90% confidence level requires about 130 realizations and over 500 realizations for a 5% accuracy. Table 1 below, from standard statistical tables, summarizes the sample size requirements for standard deviations while population means naturally require far fewer realizations. As a result it is felt 30 realizations provide sufficiently stable estimates of means and standard deviations while increasing to 60 realizations reflects at best only an unnecessary and marginal improvement.

Table 1 Sample Size Required For Percent Error In The Standard Deviation For A Normal Distribution			
% Error	Confidence Levels (%)		
	90	95	99
	Sample Size		
50	5	7	13
30	15	21	35
20	30	46	80
10	130	200	300
5	550	700	>1000

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-23:

In Subsection 4.2.2 of MUAP-10001(R3), "Development of US-APWR CSDRS Strain Compatible Properties Equivalent Dynamic Mass," the second paragraph (page 4-7) states, "Control motions reflect a representative magnitude of M7.5 for CEUS hazard and are consistent with the overall spectral shape of the CSDRS."

The staff noticed that the criteria used in generating CSDRS compatible ground motion time histories are for a **M**6.5 earthquake (See footnote to Tables 5.1-2 and 5.1-3). The applicant is requested to provide an explanation as to why CSDRS represents a **M**7.5 earthquake; whereas, the CSDRS compatible motions only match a **M**6.5 earthquake.

ANSWER:

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 earlier CSDRS-compatible ground motion time histories based on the seed records of the Northridge earthquake have recently been re-generated considering different seed records, that of the Nahanni earthquake (also with magnitude of M6.7 as shown in Table 9.9 of TR-102293 Vol. 1, Reference 2), and is presented in Section 4.1 of Technical Report MUAP-10001 (R4). A M 6.5 is a reasonable mean magnitude for the central and eastern U.S. based on deaggregation of the probabilistic seismic hazard estimated by the USGS (Petersen et al., 2008, Reference 3). It should also be noted that the Nahanni earthquake is the largest earthquake recorded to date in the central and eastern U.S.

For the site response analysis, a RVT equivalent linear approach was used. This approach does not require time histories and the site response is only weakly dependent on magnitude (control motion spectral shape) conditional on control motion peak acceleration (see Bazzurro and Cornell, 2004, Reference 4).

The revised DCD discusses the motivation for use of a M 7.5 spectral shape to drive the soil column, setting the level such that the soil motions approach but do not exceed the CSDRS. This reflects the appropriate loading level for a single earthquake and a single soil profile while maintaining consistency with the CSDRS. A smaller magnitude would result in higher short period motions and higher strains. The M 6.5 is, of course, inconsistent with the CSDRS spectral shape as is any single earthquake as the CSDRS reflects a +1 sigma shape, but M 7.5 is the closest. The selection of seed recorded ground motion to be used as the basis of time history ground motion for the CSDRS of the US-APWR is being further considered at this time to develop a response to the recently received questions of SEB1 RAI 6202 Revision 3.

References:

1) NUREG-0800, SRP 3.7.1, Seismic Design Parameters, Revision 3, March 2007

2) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.

   - Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
   - Vol. 2: Appendices for Ground Motion Estimation
   - Vol. 3: Appendices for Field Investigations
   - Vol. 4: Appendices for Laboratory Investigations
   - Vol. 5: Quantification of Seismic Source Effects

3) Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Bod, O.S., Perkins, D.M., Luco, N., Field, E.H., Wills, C.J., and Rukstales, K.S., 2008, Documentation for the 208 update of the United State National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008-1128, 61 p.

4) Bazzurro, P. and Cornell, C.A., 2004, Nonlinear soil-site effects in probabilistic seismic-hazard analysis: Bulletin of the Seismological Society of America, v. 94, p. 2110-2123.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

Section 4.1 of Technical Report MUAP-10001 (R4) is currently revised to show that the artificial ground motion time history is based on the seed recorded Nahanni ground motion.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

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DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-24:

In Figure 4.2-2 of MUAP-10001 (R3), rock appears to have higher damping ratio than sand for comparable strain levels. To help the staff better understand the comparable damping ratios, the applicant is requested to provide the technical basis and identify the corresponding references leading to this result. Additionally, is this relationship considered appropriate for hard rock as well as firm or soft rock?; and discuss whether the high rock damping is conservative or unconservative from an SSI perspective and provide the appropriate technical justification.

ANSWER:

The unpublished suite of curves developed during the EPRI project (refer to TR-102293, Reference 1) labeled modulus reduction and damping curves for soft and firm rock shown after those for sand in Figure 4.2-2 of Technical Report MUAP-10001 (R3) that were actually provided for a gravel sands profile, are no longer used. The rock curves reflect relative high hysteretic damping ratios and were originally developed based on the reasonable assumption that soft and firm rock behaves in a manner similar to gravels at shallow depths prior to crack closure. Instead the EPRI soil degradation curves are used for soft and firm rock or gravel sands in Technical Report MUAP-10001 (R4) which are appropriate for generic soils comprised of gravels, sands, and low PI clays. These curves represent strain dependent properties of generic soils with more linear (less strain dependent) behavior than the previously used rock degradation curves. This change was among those identified in "Modifications to Standard Plant: generic soil profiles" that were proposed to eliminate excessive peaks in design ISRS and address staff concerns noted in RAIs 821-5984 and 659-5133 (ML110040136 & ML11178A071) as presented in a meeting with the NRC and MHI held on September 22, 2011. Soil degradation curves are not applied to hard rock profiles of the standard plant. This is because the sensitivity of the results of site response analyses to the selection of modulus reduction and damping curves for rock-like material is, in any case, limited by the fact that they generally have higher stiffnesses and thus develop lower shear strains than do soil-like materials for the same level of loading. At much greater depths, where weathering is absent and fractures are likely to remain closed, even under strong shaking, the behavior of rock-like materials can safely be assumed to remain largely elastic so that modulus reduction and damping curves are no longer considered to be applicable. As required by COL action 3.7(8), the COL Applicant is to evaluate the strain-dependent variation of the material dynamic properties for site materials.

Reference:

1) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.
   - Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
   - Vol. 2: Appendices for Ground Motion Estimation
   - Vol. 3: Appendices for Field Investigations
   - Vol. 4: Appendices for Laboratory Investigations
   - Vol. 5: Quantification of Seismic Source Effects

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

12/01/2011

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

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-25:

In Subsection 4.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," Item 2 of the first paragraph on Page 4-4 states:

"a. Run RSPMatch to simultaneously match the target for the five damping ratios defined in the target and multiple iterations.

b. Apply baseline correction to the matched time history motion.

c. Rerun RSPMatch to match only the 5% damped spectral target, only with a single iteration.

d. Apply baseline correction to that time history motion."

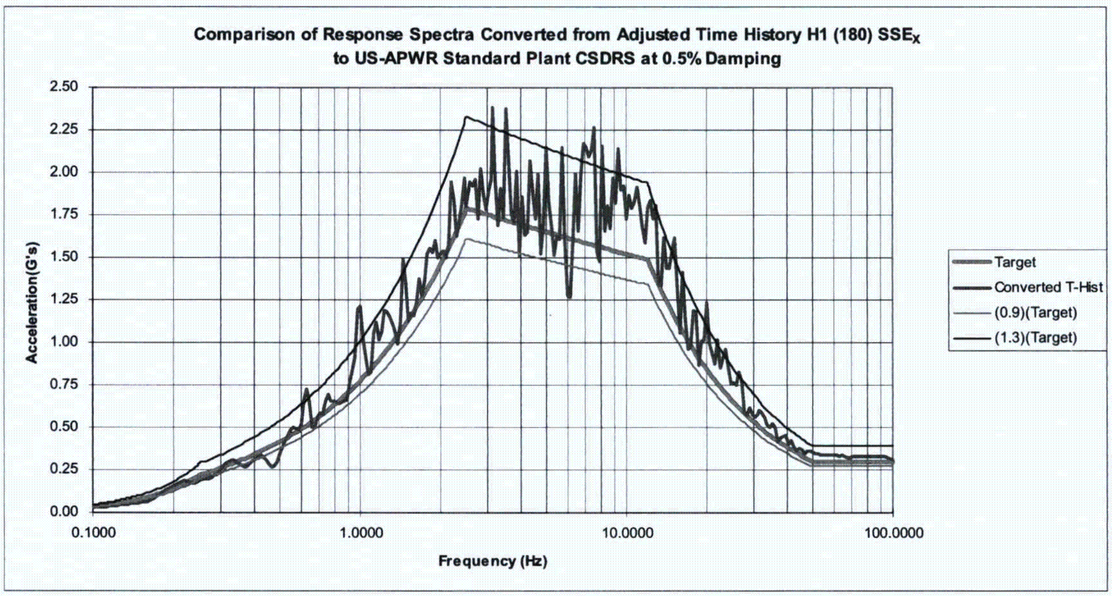
It is a general engineering practice that the spectrum from the artificial ground motion time history must envelop the free-field design response spectra for all damping values used in the seismic response analysis. The applicant is requested to clarify whether the time history obtained from step c stated above will simultaneously match the target spectra for the five damping ratios. The Applicant is also requested to provide graphical plots for the comparisons and to provide rationale for why step c is needed once step a is done.

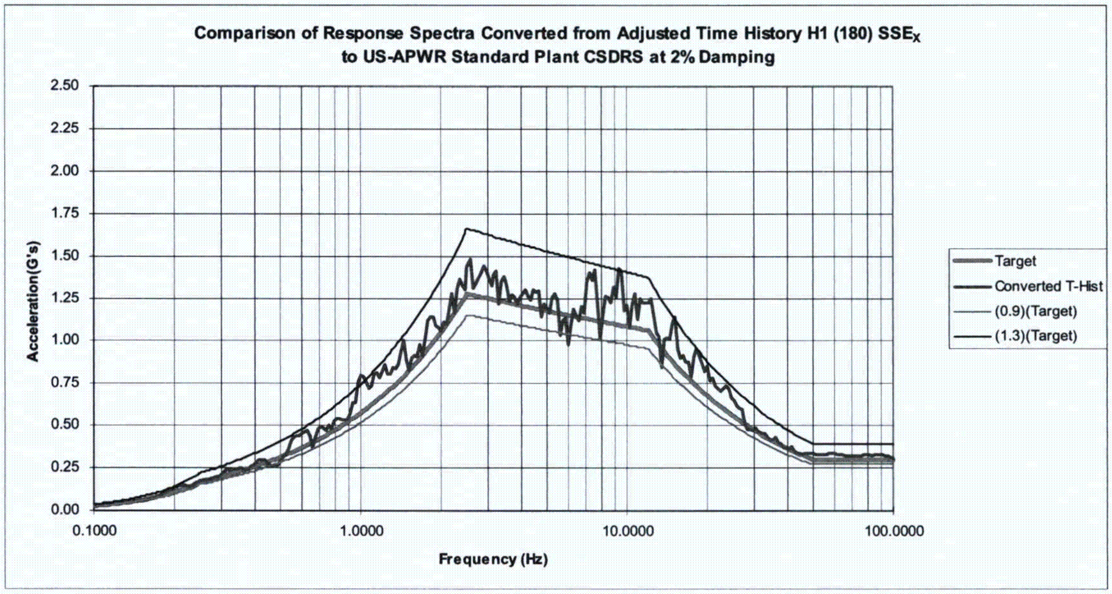
ANSWER:

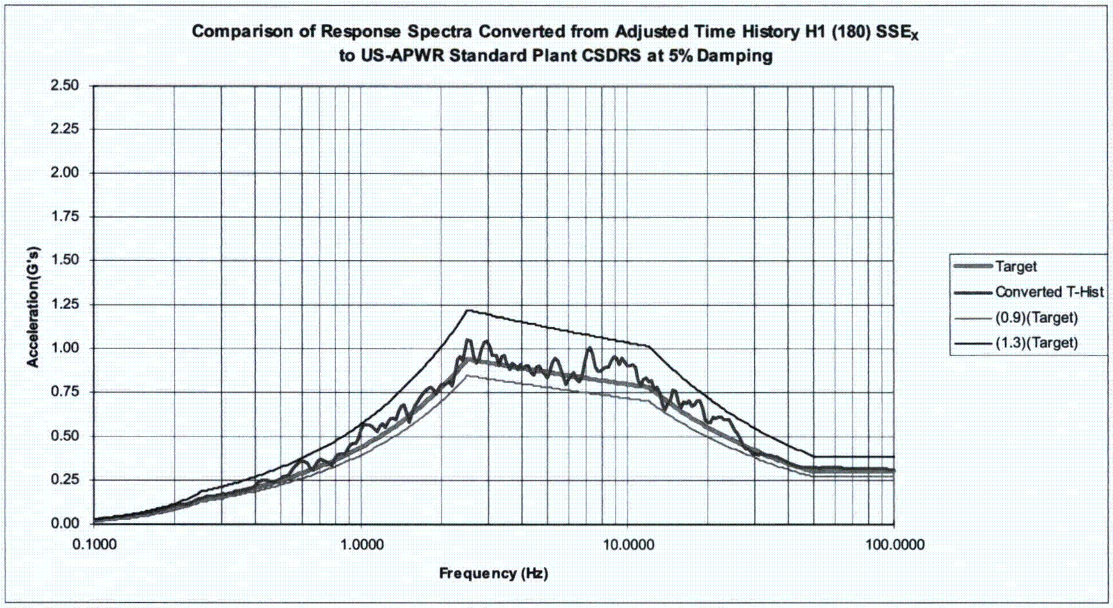
Please see the response to similar questions in RAI 852-6003 Question 03.07.02-112. The selection of seed recorded ground motion to be used as the basis of time history ground motion for the CSDRS of the US-APWR is being further considered at this time to develop a response to the recently received questions of SEB1 RAI 6202 Revision 3.

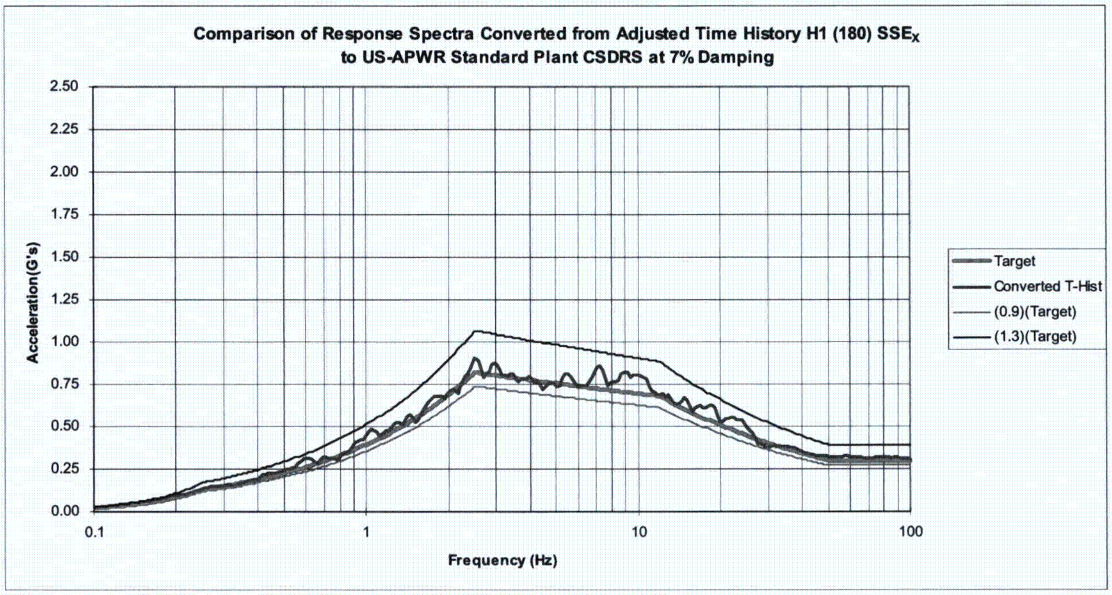
Neither ASCE 4-06 nor ASCE 43-05 contains a provision that the spectrum from the artificial ground motion time history must envelop the free-field design response spectra for all damping values used in the seismic response analysis. Also, this practice has generally not been applied when developing time histories to represent the site-specific input ground motion that is developed at each site in COL Applications. Therefore MHI understanding is that it has not been a general engineering practice that the spectrum from the artificial ground motion time history must always envelop the free-field design response spectra for all damping values used in the seismic response analysis. In fact, this issue is only recently being studied (see reference cited below). The re-generated time histories for the US-APWR are generated in accordance with the guidance of option 1 approach 2 of SRP 3.7.1 (R3). Unlike the guidance for option 1 approach 1, option 1 approach 2 only requires envelop of the computed 5% damping response spectrum of the accelerogram (see items ii.c and ii.d of the SRP). The time histories obtained from step c referred to in this RAI question do not simultaneously envelope the target spectrum for the other four of the five damping ratios to the criteria of the SRP. Baseline correction as part of the RSPMatch code process to achieve optimal convergence in a single iteration instead of multiple iterations to match the target damped response spectra alters the time history and its corresponding conversion to a response spectra such that step c is needed once step a is done to ensure matching of the final 5% damping.

(A) For "the BAL (Mt Baldy, CA) recording of the January 14, 1994, Northridge earthquake (magnitude M6.7), comparisons between the CSDRS spectra presented in Technical Report MUAP 10001 (R3) and the spectra generated from the artificial time histories are provided below for three component directions of each of the five damping ratios including 0.5%, 2%, 5%, 7%, and 10% damping:

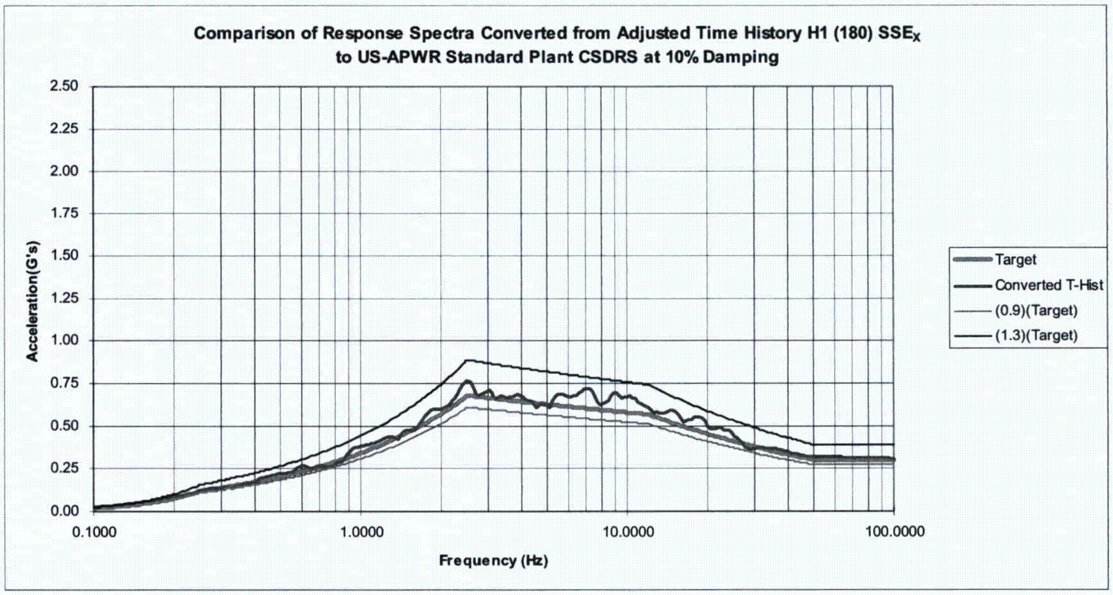



Comparison of Response Spectra Converted from Adjusted Time History H1 (180) SSE$_X$
to US-APWR Standard Plant CSDRS at 2% Damping
Acceleration(G's)
Frequency (Hz)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
0.1000
1.0000
10.0000
100.0000
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

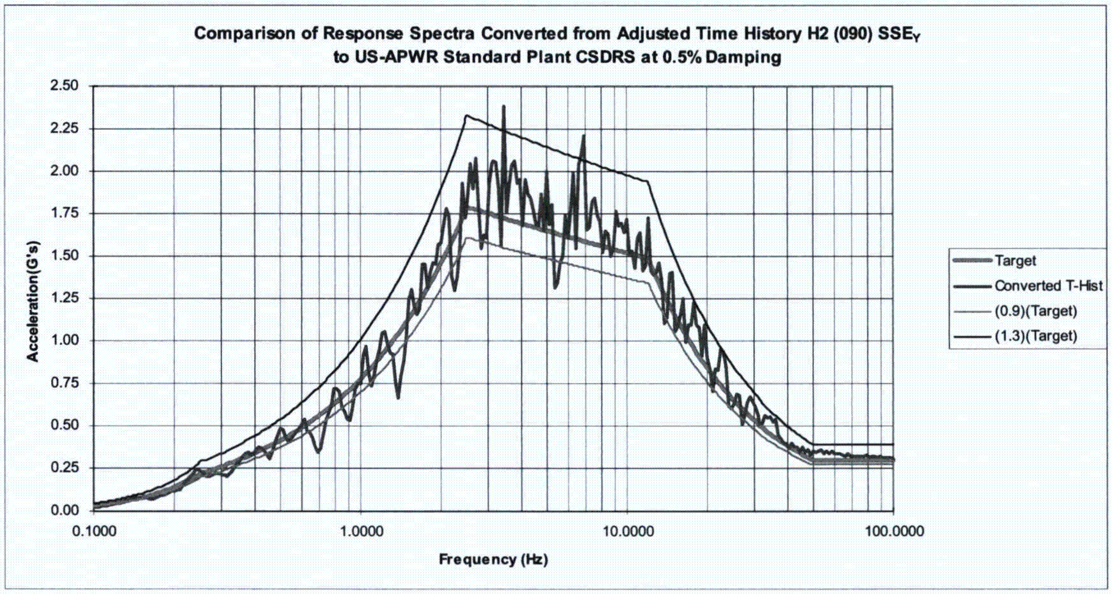

Comparison of Response Spectra Converted from Adjusted Time History H1 (180) SSE$_X$
to US-APWR Standard Plant CSDRS at 5% Damping
Acceleration(G's)
Frequency (Hz)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
0.1000
1.0000
10.0000
100.0000
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

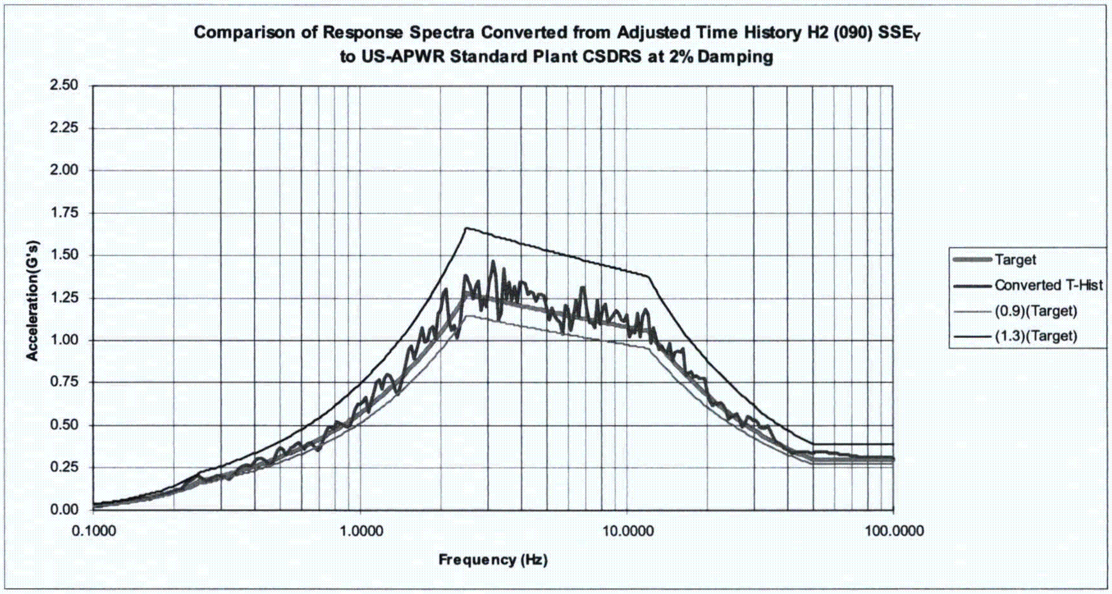


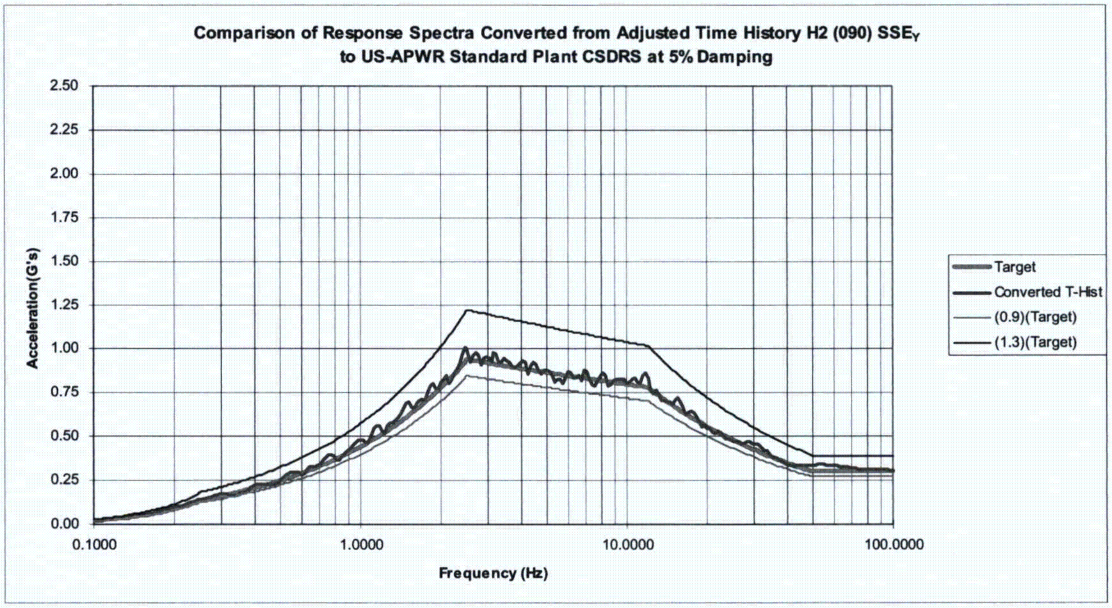
Comparison of Response Spectra Converted from Adjusted Time History H1 (180) SSE$_X$
to US-APWR Standard Plant CSDRS at 7% Damping
Acceleration(G's)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1
1
10
100
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

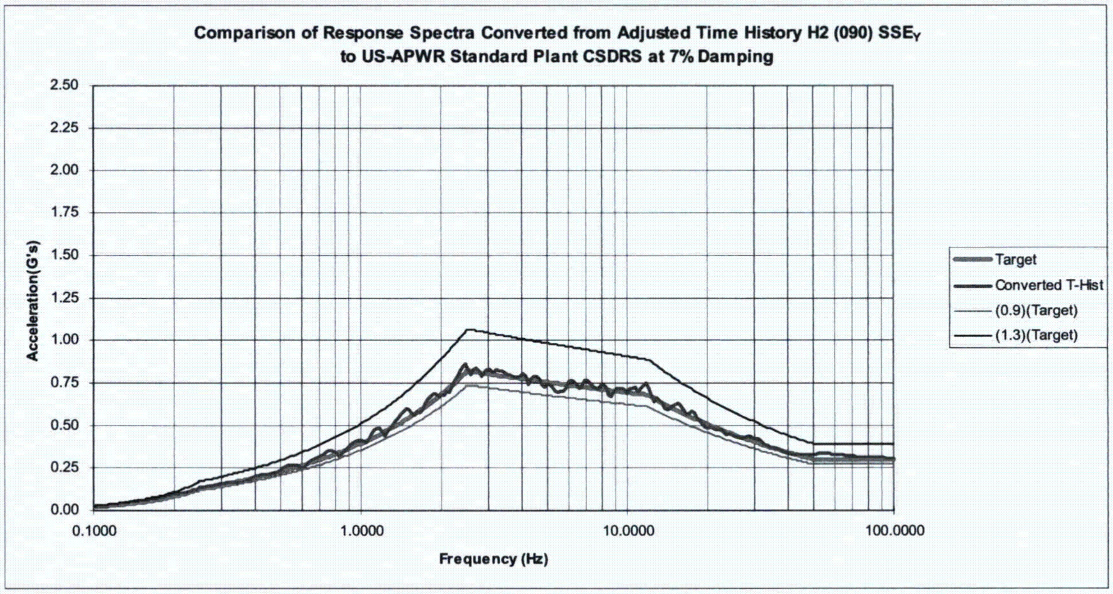


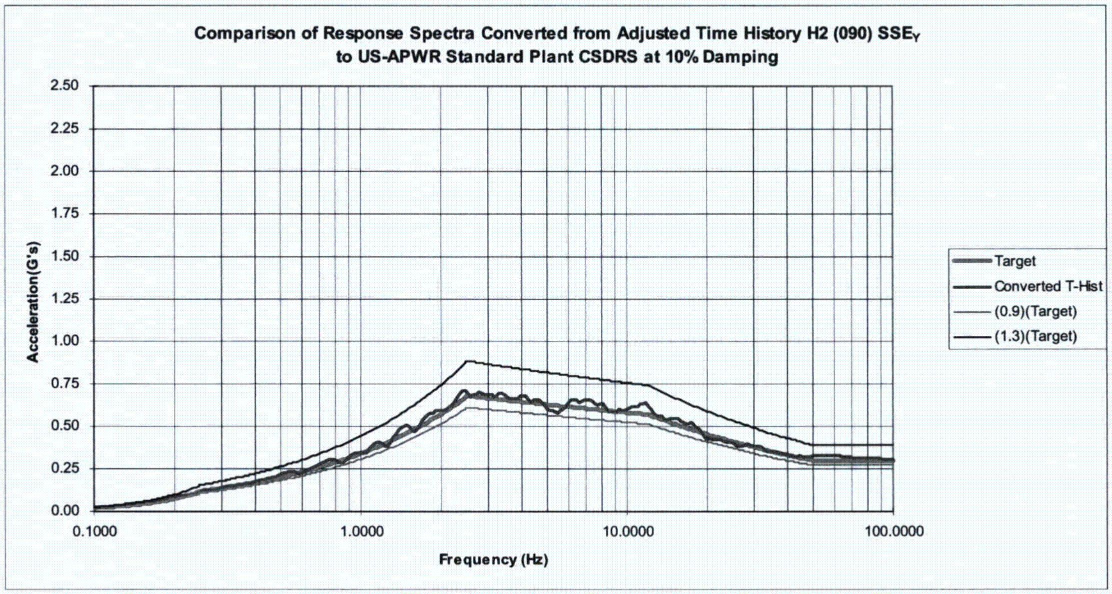
Comparison of Response Spectra Converted from Adjusted Time History H1 (180) SSE$_X$
to US-APWR Standard Plant CSDRS at 10% Damping
Acceleration(G's)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

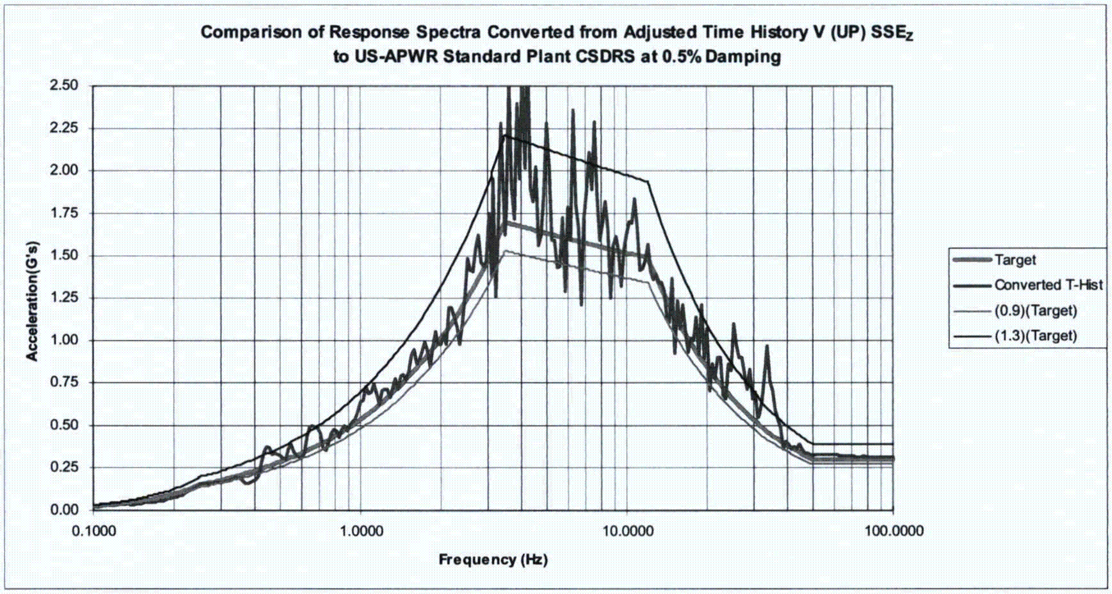

Comparison of Response Spectra Converted from Adjusted Time History H2 (090) SSE$_Y$
to US-APWR Standard Plant CSDRS at 0.5% Damping
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Acceleration(G's)
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

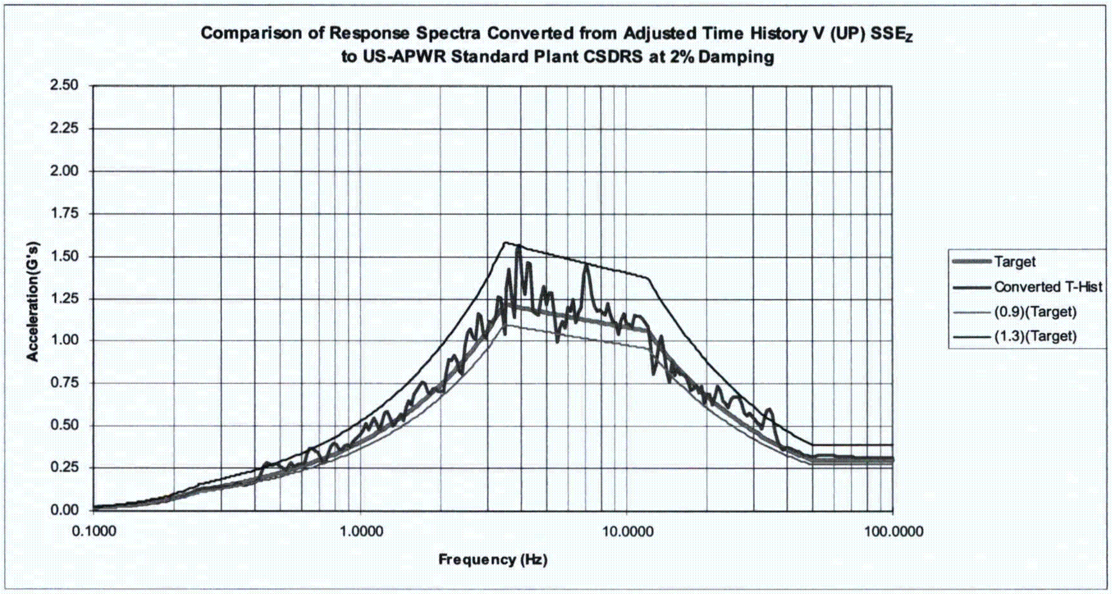

Comparison of Response Spectra Converted from Adjusted Time History H2 (090) SSE$_Y$
to US-APWR Standard Plant CSDRS at 2% Damping
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Acceleration(G's)
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)


Comparison of Response Spectra Converted from Adjusted Time History H2 (090) SSE$_Y$
to US-APWR Standard Plant CSDRS at 5% Damping
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Acceleration(G's)
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)

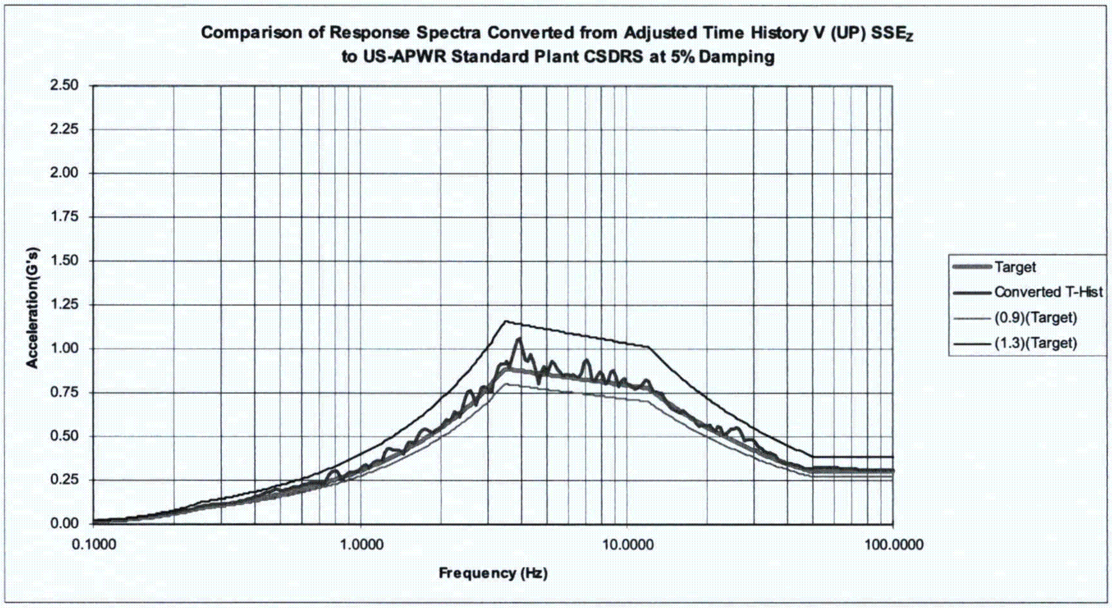

Comparison of Response Spectra Converted from Adjusted Time History H2 (090) SSE$_Y$
to US-APWR Standard Plant CSDRS at 7% Damping
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Acceleration(G's)
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)


Comparison of Response Spectra Converted from Adjusted Time History H2 (090) SSE$_Y$
to US-APWR Standard Plant CSDRS at 10% Damping
Acceleration(G's)
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1000
1.0000
10.0000
100.0000

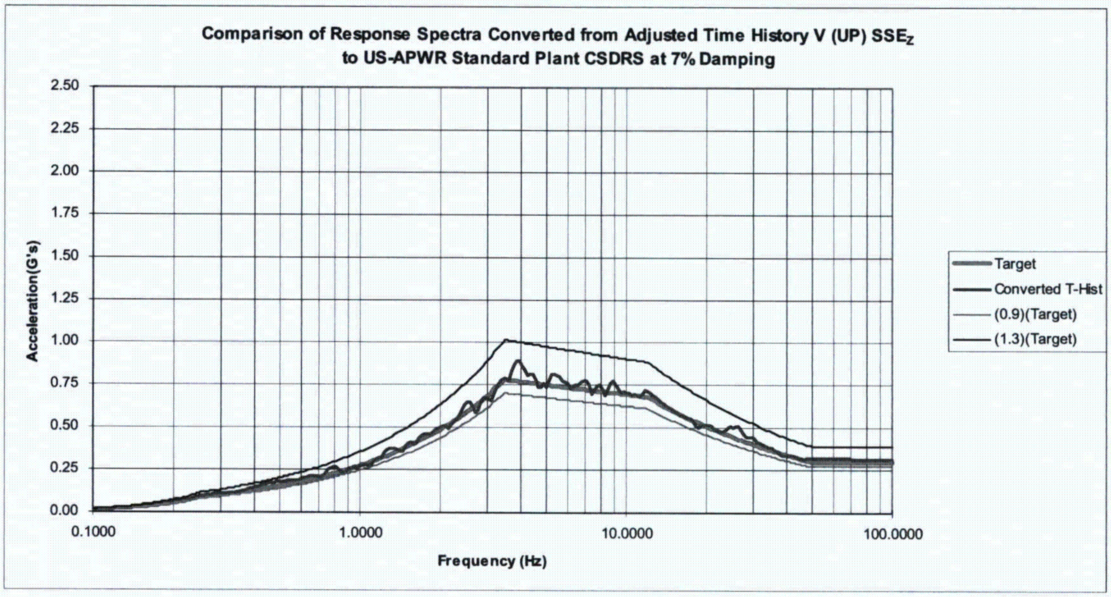

Comparison of Response Spectra Converted from Adjusted Time History V (UP) SSE$_Z$
to US-APWR Standard Plant CSDRS at 0.5% Damping
Acceleration(G's)
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1000
1.0000
10.0000
100.0000

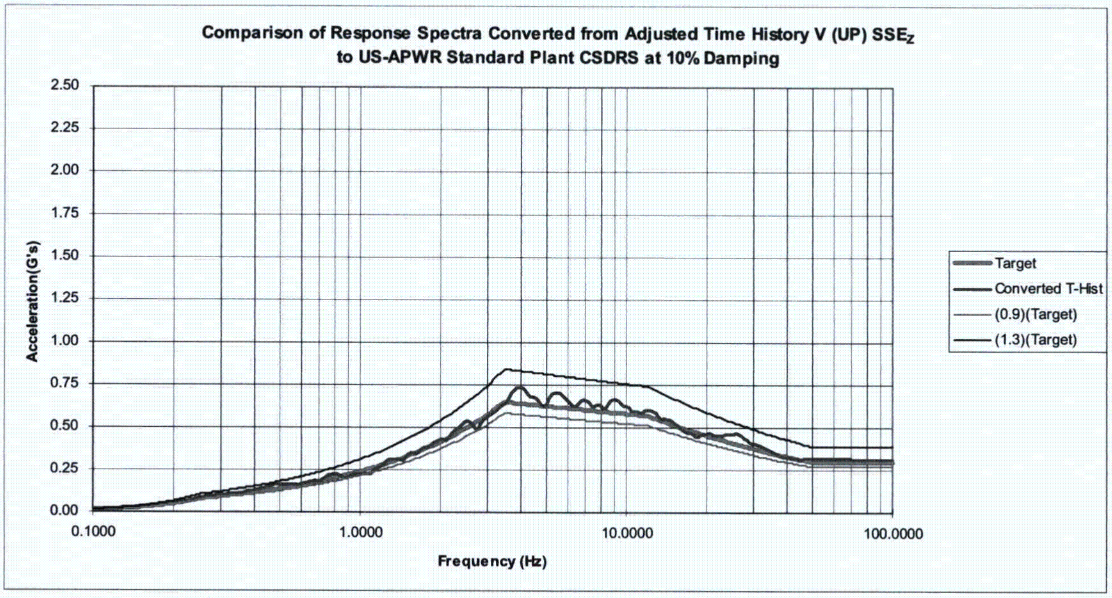


Comparison of Response Spectra Converted from Adjusted Time History V (UP) SSE$_Z$
to US-APWR Standard Plant CSDRS at 2% Damping
Acceleration(G's)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)



Comparison of Response Spectra Converted from Adjusted Time History V (UP) SSE$_Z$
to US-APWR Standard Plant CSDRS at 5% Damping
Acceleration(G's)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.1000
1.0000
10.0000
100.0000
Frequency (Hz)
Target
Converted T-Hist
(0.9)(Target)
(1.3)(Target)





Reference: "Draft: Investigation of the Impact of Seed Record Selection on Structural Response;" PVP2010-25919; Proceedings of the ASME 2010 Pressure Vessels & Piping Division / K-PVP Conference, July 18-22, 2010, Bellevue, Washington, USA. [www.osti.gov/servlets/purl/1019557-1rQA93/]

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

Section 4.1 of Technical Report MUAP-10001 (R4) has been revised to show that the artificial ground motion time history is based on the seed recorded Nahanni ground motion.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-26:

In Subsection 5.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," the last sentence of the first paragraph (Page 5-1) states, "The time history motion plots of the ground acceleration, velocity, and displacement are shown together to demonstrate their non-stationary process."

The applicant did not provide any explanation as to how the time history motion plots of the ground acceleration, velocity, and displacement demonstrate the non-stationary process. The Applicant is requested to provide the required explanation.

ANSWER:

The non-stationary process is demonstrated by compliance with SRP 3.7.1 Option 1, Approach 2 requirements as summarized in Tables 5.1-1 and 5.1-2 of Technical Report MUAP-10001(R3). The plots reflect this compliance in that variations associated with rise time duration, strong motion time duration, and decay time duration can be observed as well as any periodic or repeated patterns present with in the time history plots. The plots of acceleration, velocity and displacement in time also can be observed to reflect their integration relationships.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-27:

The purpose of Section 5.2.1 of MUAP-10001(R3), "Site Response Analysis," for Standard plant structures is not clear to the staff. The Applicant is requested to explain its purpose and how the results presented have been used in conducting the SSI analyses for the CSDRS.

(i) The first paragraph on Page 5-16 states, "The site response analyses are conducted using the equivalent linear RVT approach (Reference 8, Reference 10, and NUREG/CR-6729 (Reference 17)) with the point-source model used to generate both the horizontal and vertical motions (References 8, 10, and 11)." The staff did not find the relevance of the equivalent linear RVT approach in the SSI analyses.

(ii) The last sentence of the 1st paragraph (Page 5-16), states: "Figure 5.2-3 also suggests a simple manner to update the CSDRS to reflect the expected spectral shape for CEUS strong ground motions." The Applicant is requested to explain the relevance of Figure 5.2-3 and how Figure 5.2-3 will is used in the SSI analysis and design of the standard plant SSCs.

The applicant is also requested to explain the different base rock definitions in the footnote to Table 5.2-1 on page 5-12 that defines the base rock differently for different soil profiles.

ANSWER:

Related to item (i), the equivalent linear RVT approach was used to compute strain compatible properties as input to the SSI analyses of the standard plant similar to the methodology presented in EPRI Report TR-102993 Vol 2. See the related information in the response to Question RAI 03.07.01-23 of this RAI.

Related to item (ii), the statement is not relevant and is removed in Technical Report MUAP-10001 (R4).

As discussed in the revised text for profiles 270 and 560, sedimentary rock was placed above the crystalline basement to incorporate the presentence of sedimentary or weathered rock beneath the profiles.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

The above quoted sentence in Item (ii) has been removed in Technical Report MUAP-10001 (R4).

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-28:

In Section 5.2.1 of MUAP-10001(R3), "Site Response Analysis," the last sentence in the 2nd paragraph (Page 5-16) states, "For applications to sites with a water table at or very near the surface, linearity of the constrained modulus is also a realistic assumption as compressional waves control the high-frequencies in vertical motions (Refer to "Properties of Vertical Ground Motions," Reference 19), where nonlinearity has its largest effect."

The applicant is requested to explain whether the assumption of linearity of the constrained modulus is still realistic for applications to sites with a water table at or near the bottom of the R/B basemat (or even lower), and to provide the basis and technical justification for the assumption. If the assumption is not realistic then the applicant is requested to describe the anticipated behavior of the modulus for these water table conditions. Additionally, the applicant is requested to provide the details of the sensitivity of the water table location to demonstrate that the seismic SSI response of the standard plant SSCs is enveloped for all potential water table locations.

This information is required by the staff in order to assess the effects of the location of the water table on the seismic SSI response of the SSCs.

ANSWER:

At soil sites, where nonlinearity of the constrained modulus for dry conditions may be an issue due to low compressional-wave velocity, vertical motions are controlled by compressional-waves at high-frequency (≥ 10 Hz, Beresnev et al., 2002, Reference 1; Silva, 1997, Reference 3). However, as Technical Report MUAP-10001 (R4) Figures 5.2-3 & 5.2-4, and (Abrahamson and Silva (1997), Reference 2) illustrate, vertical motions are significantly below the corresponding horizontal motions at all frequencies when the source is beyond about 20 km. At close rupture distances and large magnitude, high-frequency vertical motions can exceed the horizontal motions by a significant degree (Silva, 1997, Reference 3).

However, even in these cases any nonlinearity of the constrained modulus would be dependent on the dilation due to inclined compressional-waves. Because the compressional-wave velocity is typically much greater than the shear-wave velocity, the resulting dilation would be small along with any change in constrained moduli.

As a result, the assumption of linearity (effective) for the constrained modulus in unsaturated soils reflects a realistic assumption for the levels of motion reflected in the horizontal CSDRS shown in Figure 5.2-3. That is, the horizontal CSDRS in spectral shape represents a magnitude **M** of about 7.5 and, in terms of absolute levels, reflects distances exceeding 50 km (Figure 5.2-3 and Table 5.2-2 of Technical Report MUAP-10001(R4)). For these conditions vertical motions are expected to be much lower (Figure 5.2-4) than horizontal motion at all frequencies and remain linear in constrained modulus. 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. As such it is also inconsistent with the magnitudes and distances implied by the horizontal CSDRS.

The response to RAI 660-5134, Revision 2 Question 03.07.02-60 (ML110040071) also concluded that the comparison of ARS results obtained considering dry and submerged soil conditions indicate that the presence of water within the top 40 ft below the nominal plant grade has a small influence on the SSI response of the buildings where the subgrade below 40 ft is saturated. Because this was confirmed in the response to RAI 660-5134, Revision 2 Question 03.07.02-60 and in the response to Question RAI 03.07.01-21 of this RAI, the assumption of linearity of the constrained modulus is realistic for applications to sites with a water table at or near the bottom of the R/B basemat. For site specific conditions where water table elevations are even lower than the bottom of the R/B basemat, per COL Action Item 3.7 (25) the COLA applicant will perform confirmation SSI analyses of the standard plant structures to consider the site specific profile conditions including the effects of the water table elevation.

References:

1) Properties of vertical ground motions, Bulletin of the Seismological Society of America, 92(2), pages 3152-3164, Beresnev, I.A, Nightengale, A.M. Silva, W.J., 2002.

2) Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes, Seismological Research Letter, 68(1), pages 94-127, Abrahamson, N.A. and Silva, W.J., 1997.

3) Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design, NCEER-97-0010, Proceedings of the FHWA/NCEER Workshop on the National Representation of Seismic Ground Motion for New and Existing Highway Facilities, I.M. Friedland, M.S Power and R. L. Mayes eds., Silva, W.J., 1997

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

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

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-29:

Figure 5.2.1 of MUAP-10001(R3), shows that two soil sites with depth to hard rock of greater than 500' and two rock sites with depth to hard rock of 350' and 100' have been selected. Considering that the depth of the plant foundation is about 50', the distance from bottom of foundation to hard rock is greater than 450', 300' and 50'. These depths to hard rock would correspond approximately to frequencies of 2 Hz, 3 Hz and 20 Hz, respectively, assuming Vs is 1000 ft/sec. Considering the typical frequency range of interest for SSI effects, the applicant is requested to explain why an additional profile with an intermediate depth to hard rock (e.g., 150') was not selected.

ANSWER:

"Modifications to Standard Plant: generic soil profiles" have been proposed to eliminate excessive peaks in design ISRS and address staff concerns noted in RAIs 821-5984 and 659-5133 (ML110040136 & ML11178A071) as presented in a meeting with the NRC and MHI held on September 22, 2011. Two of the profiles have been removed to now consist of six profiles. The presentation of these six profiles is included in Subsection 4.2.1 of Technical Report MUAP-10001 (R4). Only 100 ft, 200 ft and 500 ft depths are included without selection of a 150 ft depth. Variations such as a 150 ft depth or other site specific attribute would be covered by US-APWR DCD COL Item 3.7(25) which requires site-specific SSI evaluation for every COL application to ensure safety of the plant for any site-specific condition. COL applicants with similar site conditions can alternatively undertake remediation measures of top soil if necessary to mitigate any impact on design from SSI response amplifications should it result from a 150 ft depth.

In addition, the selection of a 150 ft depth of profile is not considered necessary because a broad SSI frequency range is covered by the site-independent SSI analyses for these six profiles as discussed in Section 5.2.2 of Technical Report MUAP-10001 (R4) and Section 4.1 of Technical Report MUAP-10006 (R2).

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

Subsection 4.2.1 of Technical Report MUAP-10001 (R4) includes the six generic soil profiles discussed above for use in the SSI analysis.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

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

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-30:

In Subsection 5.2.2 of MUAP-10001(R3), "Strain Compatible Properties," the paragraph (Page 5-21) states, "For the eight combinations of profile categories and depths to hard or soft rock material (Table 5.2-1) strain compatible properties are developed reflecting median (best estimate) and $\pm 1\sigma$ (upper and lower range) estimates over the thirty (30) realizations of profiles and G/Gmax and hysteretic damping curves (Section 4.2.2). The strain compatible properties are summarized in Tables 5.2-4 to 5.2-11, with Figures 5.2-6 to 5.2-14 showing the median and $\pm 1\sigma$_ estimates for the shear and compressional wave velocities and associated damping."

The applicant is requested to provide information that addresses the following:

1. Per Regulatory Guide 1.208, subsection 4.2 of Part C. Regulatory Position (Page 17 of RG 1.208), at least 60 convolution analyses should be performed to define the mean and the standard deviation of the site response. However, in the above quoted paragraph from the Report, only 30 were used. The applicant is requested to provide numerical data to justify that the mean and the standard deviation of the site response are stabilized after 30 simulations.

2. The applicant is requested to provide information for the computer code used in this study. Since the damping curves presented in Figure 4.2-2 are for shear strains, the applicant is requested to provide information on how the hysteretic damping for compression waves is calculated.

3. In Tables 5.2-4 through 5.2-11 of MUAP-10001 (R3), separate damping values are provided for shear waves and compression waves. However, in Tables 3-3A through 3-3H of MUAP-10006 (R1), the same damping is used for both compression waves and shear waves, which appear to be the damping ratios associated with shear waves in Tables 5.2-4 through 5.2-11 of MUAP-10001 (R3). The applicant is requested to provide the basis and justification for assuming that the compression wave damping is the same as shear wave damping, especially when applied to the saturated soil that is assumed to be at the elevation of plant grade according to Subsection 4.2.1 of MUAP-10001 (R3).

4. Normally shear wave and compression wave speeds in elastic media are related by and are consistent with the Poisson's ratios for the media. In the case of saturated soil, the applicant has used the approach of enforcing a minimum compression wave speed of approximately 5,000

feet/second as evidenced by Tables 5.2-4 through 5.2-11 of MUAP-10001 (R3) and the note to Figure 5.2-1 of MUAP-10001 (R3). The applicant is requested to discuss whether this enforcement of the compression wave speed in saturated soil leads to inconsistencies in the relationships between the shear wave speeds, the compression wave speeds, and the Poisson's ratios. If it does result in inconsistencies, the applicant is requested to provide the basis and technical justification for the validity of the approach.

ANSWER:

1. See the response to Question RAI 03.07.01-22 of this RAI.

2. The RASCAL computer code used in this study is described in Section 6.B.3.2 of EPRI Report TR-102293, Vol 2 (Reference 1). The RASCAL code represents an implementation of the equivalent-linear formulation (Seed and Idriss, Reference 2) applied to one-dimensional site response analysis. The RASCAL code is an RVT-(random vibration theory) based equivalent-linear approach which propagates the point-source outcrop power spectral density through a one-dimensional soil column. RVT is used to predict peak time domain values of shear strain based upon the shear-strain power spectrum. In this sense, the procedure is analogous to the program SHAKE (Reference 3) except that peak shear strains in SHAKE are measured in the time domain. In the frequency-domain approach, the estimates of peak shear strain as well as oscillator response are, as a result of the RVT, fundamentally probabilistic in nature. The RVT equivalent-linear methodology was validated in References 1 and 7.

The damping curves presented in Figure 4.2-2 of Technical Report MUAP-10001 (R3) are no longer used. See the response to Question RAI 03.07.01-24 of this RAI and Technical Report MUAP-10001 (R4).

The horizontal component and vertical component analyses are assumed to be independent. The median values of hysteretic damping for shear waves are calculated during the site response analysis using the RASCAL Code (Reference 4) using EPRI soil degradation curves with the shear-strain-compatible damping values limited to no more than 15%, as required by the SRP 3.7.1 Acceptance Criteria Item 2 (Reference 5). 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 (Mok, et al, Reference 6). The site response analyses use very low values for the material damping of hard baserock in order to model the low dissipation of energy in the deep hard rock strata. In order to improve the numerical stability of SSI results, the damping of the baserock material when included in the site profile is set to a low nominal value of 0.1%.

The vertical motions (Figure 5.2-4 of Technical Report MUAP-10001 (R4)) were computed as incident inclined P-Sv waves (Section 5.2.1 of Technical Report MUAP-10001 (R4)) in linear analyses with hysteretic damping for compressional-waves taken as equal to the shear-wave low-strain damping (Johnson and Silva, 1981, Reference 7).

References:

1) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.
   - Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
   - Vol. 2: Appendices for Ground Motion Estimation

- Vol. 3: Appendices for Field Investigations
- Vol. 4: Appendices for Laboratory Investigations
- Vol. 5: Quantification of Seismic Source Effects

2) Seed, H. B., and Idriss, I., M., "Influence of Soil Conditions on Ground Motions During Earthquakes," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 95, No. SM1, 1969, pp. 99-138.

3) Schnabel B., Lysmer, J., and Seed, H. B., SHAKE, "A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," Report No. EERC 72-12, College of Engineering University of California, Berkeley, CA, 1972

4) 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.

5) NUREG-0800, SRP 3.7.1, Seismic Design Parameters, Revision 3, March 2007

6) 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.

7) Johnson, L.R., and Silva, W., "The effects of unconsolidated sediments upon the ground motion during local earthquakes." Bull. Seism. Soc. Am., 71, pp. 127-142, 1981.

3. The site profiles used for the site-specific soil-structure interaction (SSI) analyses use the median values of shear wave damping for both shear and compression-wave damping in order to account in a more realistic manner for the dissipation of energy in the soil under the wave propagation pattern present in the SSI model. Due to the simplified assumption in wave propagation in SSI analyses as vertically propagating compression-waves, strain iterated shear-wave damping is typically assumed for compression-wave damping to avoid unrealistic vertical motions at high-frequencies. Also, seismic SSI analysis is usually performed separately for horizontal and vertical seismic input motions. In these analyses, the horizontal and vertical input motions are assumed caused by different horizontal and vertical seismic wave field excitations even though the seismic input environment is always 3-D consisting of simultaneous 3-component seismic input motions.

Correlation studies of the vertical site response motions recorded in actual earthquakes with the vertical motions predicted from vertical 1-D wave propagation site response analyses have been made (Reference 1). These studies conclude that, using the strain-compatible soil damping values derived from the horizontal site response analyses as the damping values for vertical site response analysis, but limiting their values to no more than 10%, produces reasonably good correlation between the predicted and recorded vertical site response motions. Consistent with this conclusion, the soil damping values used for the horizontal and vertical SSI analyses are the shear-strain-compatible soil damping values derived from the horizontal free-field site response analyses. 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.

See the discussion of Section 7.A.1.2 of EPRI Report TR-102293, Vol 2 (Reference 3) and discussion of Section 5.2.2 of Technical Report MUAP-10001 (R4).

It should be noted that the empirical analyses referred to in Reference 1 considered profiles saturated nearly to the surface. Due to the long wavelengths of compressional-waves (compared to shear-waves at the same frequency), any change in damping in the shallow part of a profile would have little effect on vertical motions at frequencies of interest.

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.

2) NUREG-0800, SRP 3.7.1, Seismic Design Parameters, Revision 3, March 2007

3) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.

- Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
- Vol. 2: Appendices for Ground Motion Estimation
- Vol. 3: Appendices for Field Investigations
- Vol. 4: Appendices for Laboratory Investigations
- Vol. 5: Quantification of Seismic Source Effects

4. The enforcement of the compression wave speed in saturated soil of 5,000 ft/sec does not lead to inconsistencies in the relationships between the shear wave speeds, the compression wave speeds, and the Poisson's ratios. For a compressional-wave velocity of about 1.5 km/sec, a wide range in Poisson ratios is observed from about 0.20 to 0.49, depending on the shear-wave velocity.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

The modulus reduction and damping value curves for soft and firm rock profiles have been deleted from Figure 4.2-2 of Technical Report MUAP-10001 (R4) as discussed in Part 2 above.

The first paragraph of Subsection 5.2.2 of Technical Report MUAP-10001 (R4) has been revised to reflect that six instead of eight generic soil profiles are used in the SSI analysis as discussed in Part 3 above.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-31:

The site response analyses used to develop the subgrade properties use degradation curves for damping and shear modulus that are appropriate for the media considered. The applicant is requested to discuss whether the subgrade properties were developed using dry soils, saturated soils, or both. If both dry and saturated soils were used to develop the subgrade properties, the applicant is requested to discuss if different sets of degradation curves were used for dry and saturated soils, and if not, the applicant is requested to discuss the applicability of using the same degradation curves in each case.

This information is required by the staff in order to assess the effects of the water table on the seismic response of the SSCs and the results of the SSI analyses.

ANSWER:

The same degradation curves were used for dry and saturated soils in the site response analyses of the suit of soil properties developed for the standard plant. The sensitivity of the modulus reduction and damping curves for dry and moist sands to the initial confining pressure is shown in Figures 7.A-12 through 7.A-15 of EPRI Report TR-102293 Vol. 2 (Reference 1). The third and fourth paragraphs of Section 7.A-6 of the report explains that for sands there is only minor differences in the modulus reduction factors and that damping at high strains is markedly reduced for saturated sands, consistent with the experimental data of Matasovic and Vucetic (Reference 2). Thus, the use of the same degradation curves of Figures 7.A-18 and 7.A-19 for dry and saturated soils is conservative and applicable to both dry and saturated soils.

References:

1) Guidelines for Determining Design Basis Ground Motions, Volumes 1-5, TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.
   - Vol.1: Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America
   - Vol. 2: Appendices for Ground Motion Estimation
   - Vol. 3: Appendices for Field Investigations

- Vol. 4: Appendices for Laboratory Investigations
- Vol. 5: Quantification of Seismic Source Effects

2) Matasovic, N. and Vucetic, M., "Modeling of the Cyclic Stress-Strain Behavior of Liquefiable Sands," Research Report, University of California, Los Angeles, 1992.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

There is no impact on the Technical/Topical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/01/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 850-6002 REVISION 3**
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DATE OF RAI ISSUE:	**10/21/2011**

QUESTION NO. RAI 03.07.01-32:

In Subsection 5.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," the paragraph under the subtitle of "Duration of Motion" (Page 5-10) states, "The set of three statistically independent components of the artificial time history earthquake which are developed for design of the US-APWR seismic Category I buildings are characterized by the strong duration of motion times, listed in Table 5.1-2 and total duration of motion time of 22.085 seconds."

The staff noticed that the duration of 22.005 seconds is given in item (a) of the paragraph on Page 5-7 of MUAP-10001(R3); whereas it is 22.085 seconds in the above quoted sentence. Also, the US-APWR DCD (R3) states the duration as 22.005 seconds. The applicant is requested to clarify this discrepancy.

ANSWER:

Please refer to the response to RAI 810-5874 Question 03.07.02-18 item 6 which clarifies this discrepancy. The artificial ground motion time history also has recently been re-generated considering a different seed recorded ground motion, and is presented in Section 4.1 of Technical Report MUAP-10001 (R4) with key data such as duration of motion.

Impact on DCD

There is no impact on the DCD.

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 Technical/Topical Report

Subsection 4.2.1 of Technical Report MUAP-10001 (R4) includes the six generic soil profiles discussed above for use in the SSI analysis.

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