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Your ref: Docket No. 52-006
Our ref: DCP/NRC2477

May 14, 2009

Subject: AP1000 Response to Request for Additional Information (SRP 6)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 6. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP6.2.2-SPCV-15

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Request for Additional Information on SRP Section 6

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 6

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-16
Revision: 2

Question (Revision 1: December 17, 2008):

(a) Identify the values of structural material damping that were used in the HRHF-based seismic analyses, and demonstrate consistency with the guidance in RG 1.61, Rev. 1, on the use of response-compatible damping values.

DCD Rev 15, Section 3.7.2, describes the design-basis seismic analyses performed for the SSE (i.e., modified RG 1.60 spectra at 0.3 g PGA) applied to a hard rock site. DCD Rev. 16 added Appendix 3G to describe the revised seismic design-basis, for the SSE applied to a range of layered soil sites, in addition to the original hard rock site. The description in Rev. 15, Section 3.7.2 was deleted. DCD Rev 16 also added Appendix 3I to describe the seismic analysis results for CEUS hard rock high frequency (HRHF) site spectra. The results for the HRHF site spectra, presented in Appendix 3I, indicate a lower seismic response of the structures than for the SSE. RG 1.61, Rev. 1, presents guidance on the use of response-compatible structural damping values. As the response level of a structure decreases, the effective damping also decreases.

(b) The staff requests Westinghouse: (1) specifically define the types of cable tray supports/configurations for which DCD Figure 3.7.1-13 is judged to be applicable; (2) identify whether any of these types of supports/configurations are candidates for use in AP1000; and (3) if not candidates, delete DCD Figure 3.7.1-13.

The staff notes that the damping values shown in DCD Figure 3.7.1-13 were developed from tests conducted in the 1980s during the Systematic Evaluation Program (SEP), to seismically qualify as-built cable tray systems that had not been seismically analyzed at the plant design stage. It is unclear to the staff whether the support types/configurations that produced 20% damping values will be implemented for new design applications.

DCD Revisions 15 and 16, Section 3.7.1.3, both state: "The damping values for conduits, cable trays and their related supports are shown in Table 3.7.1-1 and Figure 3.7.1-13. The damping value of conduit, empty cable trays, and their related supports is similar to that of a bolted structure, namely 7 percent of critical. The damping value of filled cable trays and supports increases with increased cable fill and level of seismic excitation. For cable trays and supports demonstrated to be similar to those tested, damping values of Figure 3.7.1-13 may be used. These are based on test results (Reference 19)." In RG 1.61, Rev. 1, (March 2007), the staff currently accepts a maximum of 10% damping for cable tray systems, independent of the support type/configuration.

(c) The staff requests Westinghouse: (1) identify whether it plans to implement the RG 1.61, Rev. 1, damping values for electrical cabinets and cable trays; and (2) if damping values different from RG 1.61, Rev. 1, are used, provide the technical basis for concluding that the selected damping values will provide sufficient conservatism, including reference to recognized, readily available, and well documented test results that support the use of the selected damping values, and also addresses the uncertainty associated with scatter of the measured data.

DCD Revisions 15 and 16, Section 3.7.1.3, Table 3.7.1-1, lists damping values for use in seismic analysis of seismic Category I structures, systems, and components. The staff notes that the listed damping values for electrical cabinets and cable trays are not consistent with the damping values currently acceptable to the staff, as identified in RG 1.61, Rev. 1, (March 2007).

(d) The staff requests Westinghouse: (1) identify whether it is implementing the RG 1.61, Revision 1 damping values for design-basis piping analyses; (2) identify the piping damping values used in the HRHF sample piping analyses; and (3) if damping values different from RG 1.61, Rev. 1, are used, provide the technical basis for concluding that the selected damping values will provide sufficient conservatism, including reference to recognized, readily available, and well documented test results that support the use of the selected damping values, and also addresses the uncertainty associated with scatter of the measured data.

Westinghouse states in DCD Section 3.7.3.15, Revision 15 and Revision 16: "Piping systems analyzed by the uniform envelope response spectra method with rigid valves can be evaluated with 5 percent damping. Five percent damping is not used in piping systems that are susceptible to stress corrosion cracking." The staff previously accepted this in the FSER for DCD Revision 15. The complete list of restrictions that the staff placed on the use of 5% piping damping is in FSER Section 3.12. Although not specifically identified in DCD Section 3.7.3.15, the staff placed a restriction on the ground response spectra; the PGA frequency of the ground spectra cannot exceed 33 Hz. Therefore, 5% piping damping is not applicable to piping analyses for CEUS HRHF sites.

RG 1.61, Revision 1 (March 2007) identifies either 4% damping without restrictions or former Code Case N-411 damping with restrictions, as being acceptable to the staff, based on a re-assessment of available piping damping data. Therefore, use of 5% damping for the uniform envelope response spectra method with rigid valves is not consistent with the latest staff guidance.

Additional Request (Revision 2):

(a) DCD Rev 15, Section 3.7.2, describes the design-basis seismic analyses performed for the SSE (i.e., modified RG 1.60 spectra at 0.3 g PGA) applied to a hard rock site.

DCD Rev. 16 added Appendix 3G to describe the revised seismic design-basis, for the SSE applied to a range of layered soil sites, in addition to the original hard rock site. The description in Rev. 15, Section 3.7.2 was deleted.

DCD Rev 16 also added Appendix 3I to describe the seismic analysis results for CEUS hard rock high frequency (HRHF) site spectra. The results for the HRHF site spectra, presented in Appendix 3I, indicate a lower seismic response of the structures than for the SSE.

RG 1.61, Rev. 1, presents guidance on the use of response-compatible structural damping values. As the response level of a structure decreases, the effective damping also decreases.

Identify the values of structural material damping that were used in the HRHF-based seismic analyses, and demonstrate consistency with the guidance in RG 1.61, Rev. 1, on the use of response-compatible damping values.

(b) DCD Revisions 15 and 16, Section 3.7.1.3, both state: "The damping values for conduits, cable trays and their related supports are shown in Table 3.7.1-1 and Figure 3.7.1-13. The damping value of conduit, empty cable trays, and their related supports is similar to that of a bolted structure, namely 7 percent of critical. The damping value of filled cable trays and supports increases with increased cable fill and level of seismic excitation. For cable trays and supports demonstrated to be similar to those tested, damping values of Figure 3.7.1-13 may be used. These are based on test results (Reference 19)."

The staff notes that the damping values shown in DCD Figure 3.7.1-13 were developed from tests conducted in the 1980s during the Systematic Evaluation Program (SEP), to seismically qualify as-built cable tray systems that had not been seismically analyzed at the plant design stage. It is unclear to the staff whether the support types/configurations that produced 20% damping values will be implemented for new design applications.

In RG 1.61, Rev. 1, (March 2007), the staff currently accepts a maximum of 10% damping for cable tray systems, independent of the support type/configuration

The staff requests Westinghouse to (1) specifically define the types of cable tray supports/configurations for which DCD Figure 3.7.1-13 is judged to be applicable; (2) identify whether any of these types of supports/configurations are candidates for use in AP1000; and (3) if not candidates, delete DCD Figure 3.7.1-13.

(c) DCD Revisions 15 and 16, Section 3.7.1.3, Table 3.7.1-1, lists damping values for use in seismic analysis of seismic Category I structures, systems, and components.

The staff notes that the listed damping values for electrical cabinets and cable trays are not consistent with the damping values currently acceptable to the staff, as identified in RG 1.61, Rev. 1, (March 2007).

The staff requests Westinghouse to (1) identify whether it plans to implement the RG 1.61, Rev. 1, damping values for electrical cabinets and cable trays; and (2) if damping values different from RG 1.61, Rev. 1, are used, provide the technical basis for concluding that the selected damping values will provide sufficient conservatism, including reference to recognized, readily available, and well documented test results that support the use of the selected damping values, and also addresses the uncertainty associated with scatter of the measured data.

(d) Westinghouse states in DCD Section 3.7.3.15, Revision 15 and Revision 16: "Piping systems analyzed by the uniform envelope response spectra method with rigid valves can be evaluated with 5 percent damping. Five percent damping is not used in piping systems that are susceptible to stress corrosion cracking."

The staff previously accepted this in the FSER for DCD Revision 15. The complete list of restrictions that the staff placed on the use of 5% piping damping is in FSER Section 3.12.

RG 1.61, Revision 1 (March 2007) identifies either 4% damping without restrictions or former Code Case N-411 damping with restrictions, as being acceptable to the staff, based on a re-assessment of available piping damping data. Therefore, use of 5% damping for the uniform envelope response spectra method with rigid valves is not consistent with the latest staff guidance.

Although not specifically identified in DCD Section 3.7.3.15, the staff placed a restriction on the ground response spectra; the PGA frequency of the ground spectra cannot exceed 33 Hz. Therefore, 5% piping damping is NOT applicable to piping analyses for CEUS HRHF sites.

The staff requests Westinghouse to (1) identify whether it is implementing the RG 1.61, Revision 1 damping values for design-basis piping analyses; (2) identify the piping damping values used in the HRHF sample piping analyses; and (3) if damping values different from RG 1.61, Rev. 1, are used, provide the technical basis for concluding that the selected damping values will provide sufficient conservatism, including reference to recognized, readily available, and well documented test results that support the use of the selected damping values, and also addresses the uncertainty associated with scatter of the measured data.

02/25/09 UPDATE: Response submitted 02/06/2009. The responses to (a), (b), (c), and (d) are unacceptable. For (a), only the structural loads are addressed. The more important consideration is the effect on the HRHF in-structure response spectra needed for analysis of systems and components potentially susceptible to high frequency excitation. For (b), W needs to define a technical basis for demonstrating similarity. Otherwise, it is subject to interpretation by each COL applicant. For (c), the impact of complying with RG 1.61 Rev.1 for electrical cabinets is negligible, since seismic qualification analyses have not been performed yet. If seismic qualification is by test, the specified damping for analysis has no importance. For (d), W needs to justify using 5% damping for piping analyses using HRHF in-structure response spectra. This is a violation of the Rev. 15 FSER. Complying with RG 1.61 Rev.1 damping for piping analyses would require minimal re-work, if any. The design-basis piping seismic analyses for most, if not all, systems that will utilize uniform support motion RSA methodology and 5% damping, have not been performed yet.

Westinghouse Response (Revision 1):

a. The damping values used in the HRHF-based seismic analyses are those listed in DCD, Revision 17, Table 3.7.1-1. No attempt was made to reduce damping levels based on stress levels since it was Westinghouse's intent to have a comparable basis for comparison (i.e., same damping values). It is recognized that the lower damping values will increase the load and stress levels, and the HRHF calculated values will approach or possibly even exceed the CSDRS (Certified Seismic Design Response Spectra) calculated values. If the HRHF comparison values with the lower damping are equal to or below the CSDRS values, then the CSDRS analyses control design. If the HRHF values exceed the CSDRS values, this does not imply that the HRHF calculated values will control design. This is because the stress levels have reached stress levels where the higher damping is applicable. Therefore, the conclusions reached from the HRHF evaluations that the CSDRS controls the AP1000 design remains unchanged.

b. Westinghouse recognizes that the DCD Figure 3.7.1-13 is only applicable if the cable trays and supports are similar to those tested. For this reason note 1, applicable to cable trays and supports, was added to DCD Table 3.7.1-1 that states "Cable tray systems similar to those tested in Reference 19 may use the damping values given in Figure 3.7.1-13." Therefore, for cable trays and supports demonstrated to be similar to those tested, damping values up to 20% may be used. Otherwise, a maximum value of 10% shall be used.

c. Westinghouse is using the damping ratios listed in DCD, Revision 17, Table 3.7.1-1. These damping values were approved by the NRC in their FSER document NUREG-1793, September 2004. In Section 3.7.1.3 it is stated: "The use of the damping ratios documented in DCD Tier 2, Table 3.7.1-1, meets the guidelines prescribed in RG 1.61 *[Revision 0]* and/or common industry practice. On this basis, the staff concludes that the damping ratios proposed by the applicant are acceptable." Westinghouse is not changing the damping values from those used to support the certified design documented in DCD Revision 15. The damping value criteria included in the regulatory guide is based on the type of construction of the structure and is not dependent on the spectra used for the seismic analysis. Therefore including six soil cases in the design ground response spectra does not subject the damping values to review as part of the design certification amendment review.

The AP1000 design uses the regulatory guidance effective six months prior to the submittal of the design certification application in March, 2002. Regulatory Guide 1.61, Revision 1 was published in March 2007. This is well after the application for AP1000 design certification. The application for the design certification amendment was submitted in May 2007. Even if the application did reset the regulatory guidance cut off, a regulatory guide published in March 2007 is effective less than six months prior to the amendment application and is not applicable to the design certification amendment.

d. Westinghouse is not assessing the AP1000 design to Regulatory Guide 1.61 Revision 1. The AP1000 design uses the regulatory guidance effective six months prior to the submittal of the design certification application in March, 2002. Regulatory Guide 1.61, Revision 1 was published in March 2007. This is well after the application for AP1000 design certification. The AP1000 design was assessed for conformance with regulatory guidance in effect at the time that the application design certification was filed. The AP1000 is not required to assess conformance with guidance developed later.

The damping values used for piping are those that were included in DCD Revision 15 and approved as part of the Design Certification. Westinghouse has not altered the values of damping for piping analysis which remain the same in DCD Revision 17. This information is covered by the design finality of the Design Certification. The damping value criteria included in the regulatory guide for piping are not dependent on the spectra used for the seismic analysis. Therefore including six soil cases in the design ground response spectra does not subject the damping values to review as part of the design certification amendment review. See item c above.

Westinghouse Response (Revision 2)

a. Structural damping of 7% is used in the development of Hard Rock High Frequency (HRHF) in-structure response spectra (ISRS) consistent with guidance provided in U.S. NRC R.G. 1.61, Rev. 0, "Damping Values for Seismic Design of Nuclear Power Plants" (dated October 1973), as well as common industry practice. U.S. NRC R.G. 1.61, Rev. 0 states that if the maximum combined stresses due to static, SSE seismic and other dynamic loading are significantly lower than the yield stress in any structure or component, damping values lower than those specified in the table should be used for that structure or component to avoid underestimating the amplitude of vibrations or dynamic response of structures. The seismic analyses that developed the HRHF safe shutdown earthquake (SSE) ISRS did not compare the combined stresses to yield. Evaluation of the HRHF results consisted of comparison of the HRHF seismic responses to the CSDRS seismic responses. These comparisons showed that the HRHF ISRS exceeded the CSDRS ISRS for some locations, mostly above 15 Hertz and no reduction of damping was employed in the analysis.

The HRHF SSE ISRS generated from the analysis are used in evaluating the acceptability of safety-related equipment and components which are potentially susceptible to HRHF seismic excitation. Acceptability of the equipment is demonstrated by performing a HRHF SSE seismic test run after seismic testing to the AP1000 CSDRS ISRS.

To address the potential that the seismic response for the HRHF SSE ISRS may have been underestimated, additional seismic test margin will be introduced into the HRHF seismic screening evaluation of safety-related equipment vulnerable to HRHF excitation. U.S. NRC R.G. 1.61, Rev. 0 identifies a critical damping value of 4% for ½ SSE analysis of reinforced concrete structures. The margin between 4% critical damping and the 7% critical damping used for the building structural analysis is approximately 30%. This margin will be realized in seismic testing by using the 3% damping HRHF SSE ISRS as though it were a 5% damping HRHF SSE ISRS. Figures RAI-SRP3.7.1-SEB1-16-1 and RAI-SRP3.7.1-SEB1-16-2 provide a comparison of the 3% and 5% HRHF SSE ISRS for the Main Control Room (horizontal and vertical direction) which shows a margin of approximately 30% for frequencies below the ZPA.

b. It is noted that the COL applicant will not be designing conduits and cable trays. The test program (conducted by ANCO Engineers Inc.) considered rigid supports, various tray hanger systems, effects of tray types, effects of strut connections, and effects of bracing spacing, unbraced and braced tray systems. Cable ties were also used during the test program. Based on observations during the tests, the high damping values within the cable tray system are provided mainly by the movement, sliding or bouncing of the cables within the tray. The AP1000 design for cable tray support configurations are of similar construction (unistrut with bolted connections) as referenced in the test reports. The limiting condition for design of the AP1000 Standard cable tray supports is for full cable tray weight. The damping value being used for the design of this condition is 10%. This value is consistent with the value listed in DCD Table 3.7.1-1 for Full Cable Trays and Related Supports.

c. Westinghouse employs electrical cabinets and panels in safety-related applications. These electrical cabinets and panels are an assembly of structures, subassemblies and individual components. Westinghouse electrical cabinets and panels are generally constructed of carbon steel framing members, angle support channels and panels with a combination of bolted and welded connections designed to support subassemblies and components mounted within. Westinghouse electrical cabinets and panels normally employ a bolting interface to secure the cabinets and panels to an interface mounting support base and directly to the embedment floor whenever possible.

The structural damping of cabinets and panels will vary as a function of the materials of design construction, the mass distribution and method of interconnection (bolted / welded). NRC R.G. 1.61, Rev. 0, "Damping Values for Seismic Design of Nuclear Power Plants" (dated October 1973) defines the following criteria for safe shutdown earthquake (SSE) level damping values for structure or components:

Welded Steel Structures	4%
Bolted Steel Structures	7%

This is also the same criteria identified in the AP1000 Design Control Document (DCD) Rev. 17.

It should be noted that the structural damping will also increase as a function of stress level. It is reasonable to perform the analysis of combined bolted and welded structures using an average of the structural damping associated with the bolted or welded steel structures as defined in R.G. 1.61, Rev. 0. This is consistent with the criteria defined in Section 3.7, Table 3.7.1-1 of the AP1000 DCD Rev. 17.

Westinghouse does not intend to use the SSE level damping value of 3% for electrical cabinets and panels identified in Table 6 of NRC R.G. 1.61, Rev. 1.

Westinghouse has employed a structural damping value of 5% damping in performance of static coefficient analyses demonstrating structural integrity of electrical cabinets and panels. Static coefficient analysis of bolting for component or sub-assembly supports, cabinet to floor mounting, cabinet to base, base to floor and component to cabinet mounting using 5% critical damping is reasonable and conservative in relation to what is defined in R.G. 1.61 Rev. 0.

Dynamic structural finite element analyses performed by Westinghouse employ models validated through the use of qualification test program results. The response of the finite element model is developed and validated against test data and used as the basis for any modifications that are needed.

The results of seismic testing are used in the correlation of dynamic in-equipment response, and the modal and structural damping results from the resonant search test data are used to determine the natural frequency of vibration and associated structural damping used in model correlation process. In most instances, this leads to the use of 4% and 5% critical damping in the finite element analysis.

Example of Use of Damping Values in Seismic Qualification Analyses

Seismic qualification test programs are performed in compliance with the requirements of IEEE Std 344-1987 to demonstrate functionality and structural integrity of cabinet assemblies. In most seismic test programs, Test Response Spectra (TRS) generated at 5% critical damping are compared to the Required Response Spectra (RRS) to demonstrate acceptability of the test run. Cabinet in-equipment response spectra (IERS) are generated at 5% critical damping from cabinet mounted accelerometers and may also be used as the RRS for supplemental qualification testing of components not included in the test program.

While the seismic qualification of safety-related component's functionality is demonstrated by seismic testing, frequently modifications to the component mounting are evaluated analytically. Static coefficient analysis of the mounting is employed using a static coefficient of 1.5 along with the spectral peak acceleration of the 5% damping IERS to determine the seismic loads on the bolted mounting connections. Lower values of damping may be used for the evaluations if required by the customer specification.

Analyses of cabinet structures are frequently performed using a finite element model (FEM) of the cabinet assembly. The FEM may be used to determine structural integrity of the various cabinet configurations and cabinet line-ups, and/or to develop IERS for qualification of safety-related devices by seismic testing. The FEM is validated based on seismic test data regarding the modal responses. The structural damping value used in the analysis is also validated against the seismic test data.

Experience from past test programs has shown that most cabinets and panels with a combined bolted and welded configuration have higher than 3% structural damping. In most cases the damping in the side-side direction is higher than in the front-back direction. The majority of FEM analyses use 4% or 5% structural damping. There are very few instances where combined bolted and welded cabinets will have as low as 3% critical damping. Where lower damping values are seen, they are generally found to be a false indication of the actual structural damping resulting from inconstant mass distribution within the cabinet assembly, chatter or noise caused by door rattling, or some other non-structural aspect.

Conclusion

The Westinghouse use of structural damping is consistent with the requirements in NRC R.G. 1.61, Rev. 0 when performing SSE level analysis of electrical cabinets and panels. Structural damping of 4% or 5% is used as appropriate for finite element analysis based on the structural damping determined during testing. Structural damping of 5% is typically used for the static coefficient evaluation of bolting mounting interfaces.

Westinghouse does not intend to use the SSE level damping value of 3% for electrical cabinets and panels identified in Table 6 of NRC R.G. 1.61, Rev. 1.

d. The NRC staff requested a one-to-one comparison between AP1000 design basis analysis and the HRHF analysis. They had no objection from using 5% damping for this comparison when using uniform envelope response spectra analysis. This value is consistent with damping for design basis piping analyses given in DCD Revision 17 (Table 3.7.1-1). The NRC staff did not make any requirements to use RG 1.61, Revision 1, damping values.

Reference(s): None

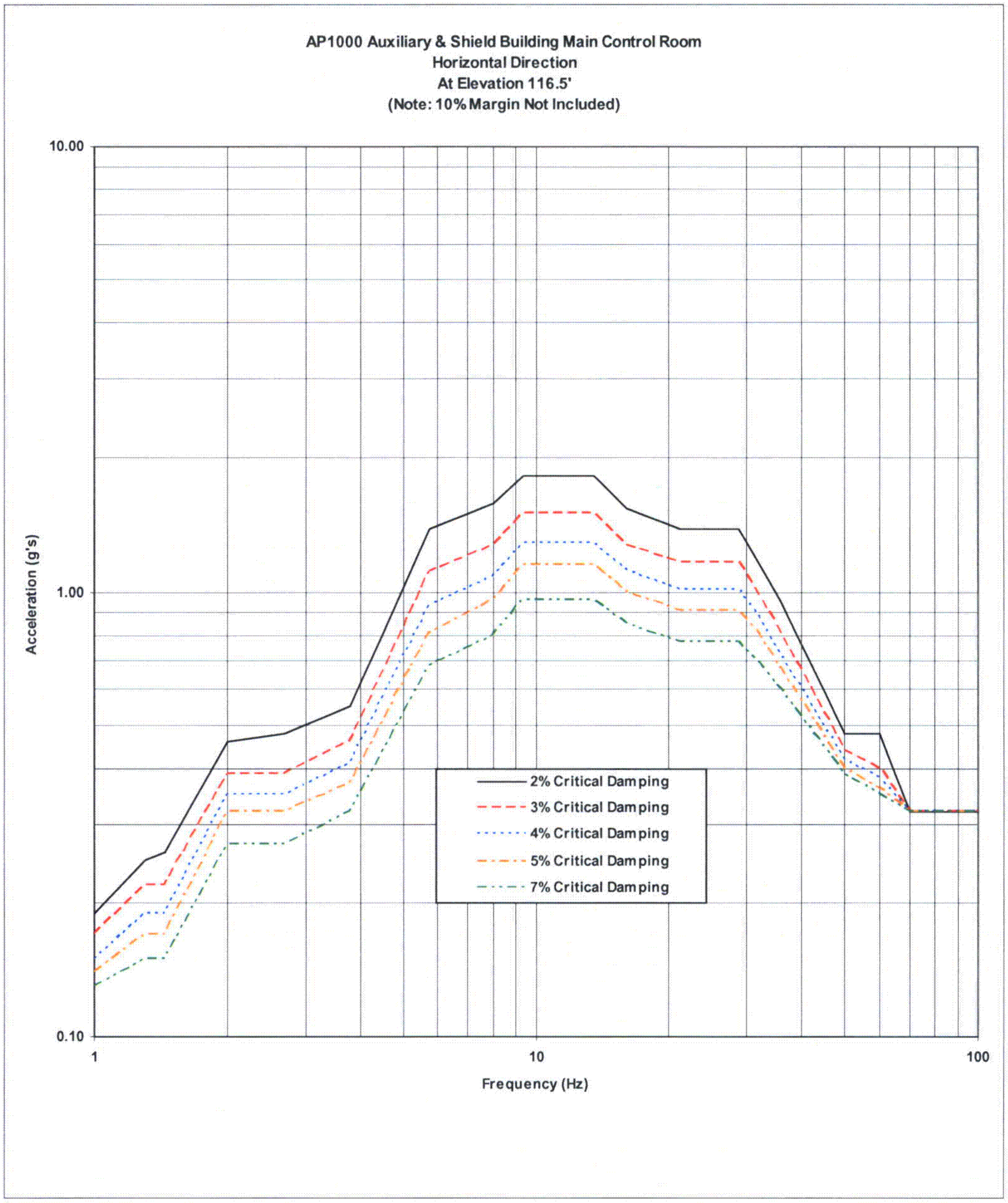

Figure RAI-SRP3.7.1-SEB1-16-1: AP1000 Auxiliary & Shield Building Main Control Room - Hard Rock High Frequency Safe Shutdown Earthquake Floor Response Spectra Horizontal Direction, At Elevation 116.5'

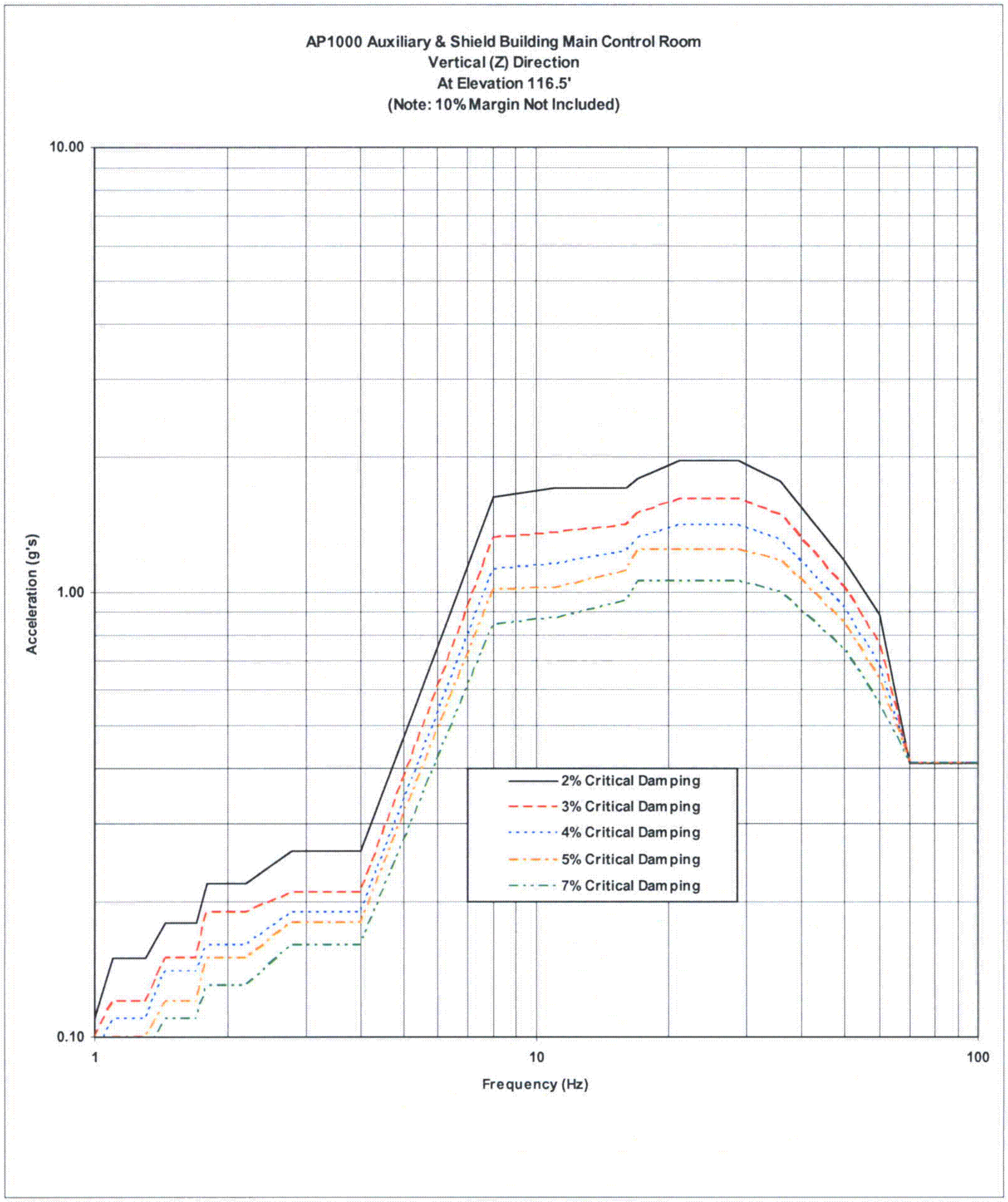

Figure RAI-SRP3.7.1-SEB1-16-2: AP1000 Auxiliary & Shield Building Main Control Room - Hard Rock High Frequency Safe Shutdown Earthquake Floor Response Spectra Vertical Direction, At Elevation 116.5'

Design Control Document (DCD) Revision:

In DCD Revision 18 add the following to Section 3I.6.4, Page 3I-8, after "The first and third evaluation methods are part of the AP1000 HRHF screening program and are further detailed below."~~None~~

The first and third evaluation methods are part of the AP1000 HRHF screening program and are further detailed below. The AP1000 HRHF seismic screening evaluation will employ the AP1000 HRHF SSE response spectra as input in verifying potential HF sensitive safety-related equipment is not vulnerable to HRHF seismic excitation. Additional seismic test margin will be introduced into the HRHF seismic screening evaluation as needed.

Method 1: Review of Seismic Test Data

PRA Revision:

None

Technical Report (TR) Revision:

None