ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-02
Revision: 4

Question:

Quoting the first paragraph of the TR-115 Introduction:

> "The purpose of this report is two fold: (1) to confirm that high frequency seismic input is not damaging to equipment and structures qualified by analysis for the AP 1000 Certified Seismic Design Response Spectra (CSDRS); and (2) to demonstrate that normal design practices result in an AP 1000 design that is safer and more conservative than that which would result if designed for the high frequency input."

The purpose of the report is incorrectly stated, and may lead a reader to an incorrect conclusion. (1) and (2) above apply at best to the HRHFRS that Westinghouse has defined in this report (as further revised in TR-144), which supposedly envelope the 3 currently proposed CEUS hard rock sites. As stated above, a reader may reach the conclusion that Westinghouse's two-fold purpose applies generically to "high frequency seismic input". The staff requests that Westinghouse accurately state the purpose of TR-115.

Quoting the last paragraph of the Introduction:

> "This report describes the methodology and criteria used in the evaluation to confirm that high frequency input is not damaging to equipment and structures qualified by analysis for the AP1000 CSDRS. This report also demonstrates that the AP1000 envelopes any requirements that HF would impose. Thus, HF does not need to be considered explicitly in the design. It provides supplemental criteria for selection and testing of equipment whose function might be sensitive to high frequency. This report provides a summary of the analysis and applicable test results."

This paragraph is also misleading, and may lead a reader to an incorrect conclusion. The staff requests that Westinghouse accurately state what has been specifically demonstrated in TR-115.

On August 21, 2008 the NRC has requested the following additional information be provided.

The staff requested Westinghouse to revise the TR-115 introduction and conclusion, to more accurately describe the scope of applicability of the TR-115 results. In its response, Westinghouse proposed revised wording that is generally acceptable to the staff. However, the staff noted that Westinghouse has not defined the site parameter requirements (i.e., minimum shear wave velocity of underlying medium) that must be satisfied in order to reference the results in TR-115. The staff notes that the definition of a hard rock site in the DCD is a minimum shear wave velocity equal to 8000 fps.

Therefore, the staff requests that Westinghouse specifically identify in TR-115 the site parameter requirements (i.e., minimum shear wave velocity of underlying medium) that must be satisfied in order to reference the results in TR-115, and provide the technical basis for this determination. The staff also requests Westinghouse to identify the 3 COL applicants that are currently covered by TR-115, and the minimum shear wave velocity of the underlying medium at each site.

Additional Request (Revision 2):

The staff determined that Westinghouse's response to RAI-SRP3.7.1-SEB1-02 (Revision 1) did not sufficiently address the staff's questions. Therefore, the staff is repeating its request in a more specific manner:

(a) Describe in detail the modeling of underlying media and any side media in the special SASSI analyses of the HRHF GMRS. How many cases were analyzed? Describe each case and the purpose for each case.
(b) What is the shear wave velocity associated with each of the media included in the SASSI analyses?
(c) How was the seismic motion at the surface developed, for input to the SASSI analyses? Was the HRHF GMRS applied directly as surface motion, or was the surface motion developed from the HRHF GMRS applied at the NI foundation level? If the latter, describe in detail the method used to calculate the surface motion.
(d) Define numerically, the range of shear wave velocity of the underlying media for which the special SASSI analyses are valid. Provide a detailed technical basis for this determination (e.g., results from parametric studies, previous documented studies, documented test results, "expert" judgment, etc.)
(e) For all COL applications that reference DCD Appendix 3I and/or TR 115, are the site characteristics enveloped by the range of shear wave velocities defined in (d) above?

Additional Request (Revision 3):

Responses to d and e should be expanded per telecom with the NRC on March 5, 2009.

Additional Request (Revision 4):

A statement should be added to Technical Report 115 (TR115) to indicate that a comparison of the site-specific shear wave velocity profile to the generic HRHF shear wave velocity profile is needed in addition to the comparison of the site-specific spectra to the generic HRHF spectra.

Westinghouse Response (Revision 0 & 1):

Westinghouse does not believe that the purpose as defined in the first paragraph of TR-115 could be misleading applying to all high frequency input. Westinghouse will however clarify TR-115 to provide more clarity regarding its purpose. The conclusions reached in TR-115 apply

only to those sites whose site GMRS are enveloped by the HRHF seismic response that was used for the evaluation as clarified in TR-144. In TR-144 under Section III, DCD Mark-UP, Tier 1, Table 5.0-1 Site Parameters, Seismic SSE it is stated: "The HRHF GMRS provide an alternate set of spectra for evaluation of site specific GMRS. A site is acceptable if its site specific GMRS fall within the AP1000 HRHF GMRS." Therefore, a site cannot be considered acceptable if it does not fall within Figures 5.0-3 and 5.0-4 as given in TR-144.

The last paragraph of the introduction is also not misleading. The high frequency input that is referred to is the one that is used in the evaluation. This high frequency input seismic response spectra envelopes the AP1000 HRHF GMRS given in TR-144 shown in Figures 5.0-3 and 5.0-4.

The only requirement that the COL applicants must demonstrate so that they are currently covered by TR-115 is to demonstrate that their site ground motion response spectra is enveloped by the HRHF spectra as defined in TR-144, and provided below under Technical Report (TR) Revisions. Sites with high shear wave velocities have higher loads due to high frequency than those with lower shear wave velocity. Sites that are enveloped by the HRHF input spectra, but have lower shear wave velocities, will have lower HRHF seismic loads than those used in the evaluation reported in TR-115 and are acceptable for AP1000.

It is not appropriate for Westinghouse to identify the COL applicants that are currently covered by TR-115 along with the minimum shear wave velocity of the underlying medium at each site. This is considered to be part of the COL application.

Westinghouse Response (Revision 2):

a) One Hard Rock Soil Profile was analyzed with ACS SASSI incoherent SSI analysis. Table RAI-SRP3.7.1-SEB1-02-1 shows the hard rock underlying media. There is no side media considered in the analysis. Only one case was considered since it is sufficient to demonstrate that the high frequency seismic input is non-damaging to equipment and structures qualified by analysis for the AP1000 Certified Seismic Design Response Spectra (CSDRS).

b) HRHF shear wave velocity profile is shown in Table RAI-SRP3.7.1-SEB1-02-1.

c) Two horizontal and one vertical synthesized time history was generated which enveloped the HRHF GMRS shown below in Figure 1.0-1 and Figure 1.0-2 under the section titled "Technical Report (TR) Revision". The HRHF GMRS time histories are applied at NI foundation level of 60.5 ft. HRHF GMRS and FIRS are identical for the HRHF sites.

d) There is no specific range of shear wave velocity of the underlying media for which the special SASSI analyses are valid. The only requirement is stated in Westinghouse Response (Revision 0 & 1): "The site ground motion response spectra is enveloped by the

HRHF spectra as defined in TR-144." Further it is stated in DCD Revision 17, Tier 1.0, Section 5.0:

> "Structures, systems, and components for the AP1000 are evaluated for generic ground motion response spectra (GMRS) with high frequency seismic input. The spectra shown in Figure 5.0-3 and Figure 5.0-4 provide hard rock high frequency (HRHF) GMRS at the foundation level for both the horizontal and vertical directions for 5% damping. An actual site is acceptable if its site-specific GMRS falls within the AP1000 HRHF parameters in Figures 5.0-3 and 5.0-4. No additional design or analyses are required for the structures, systems, and components for sites that fall within the AP1000 HRHF parameters."

e) The COL applicants that reference DCD Appendix 3I and/or TR115 need only consider that their site specific GMRS is enveloped by the HRHF GMRS (see item d response).

There are no shear wave requirements or limits given in the Interim Staff Guidance (ISG). The only place that mentions the shear wave velocity is in ISG Section 5, "The staff also expects COL applicants to address quantitatively in terms of soil dynamic properties (e.g., shear wave velocity and/or shear wave velocity gradient) to make it clear what kind of soil/rock needs to have RC/TS testing."

According to the ISG, the shear wave velocity is not a requirement for the high frequency SSC evaluation.

Table RAI-SRP3.7.1-SEB1-02-1 - HRHF Soil Properties

Layer width (ft)	Soil Wt (kcf)	Vs (ft/s)	Vp (ft/s)	Damping
5.5	0.16	7847	13591	0.005
5	0.16	9777	16934	0.005
10	0.16	9777	16934	0.005
20	0.16	9777	16934	0.006
20	0.16	9769	16920	0.006
20	0.16	9759	16904	0.007
20	0.16	9754	16895	0.007
20	0.16	9751	16889	0.007
10	0.16	9194	15924	0.007
15	0.16	9191	15920	0.007
Half Space	0.16	9625	16671	0.01

Westinghouse Response (Revision 3)

In response to a telecom with the NRC on March 5, 2009, responses to d and e are expanded.

d) The shear wave velocities for a site where TR115 is applicable are those that are associated with the hard rock site. The shear wave velocity at the bottom of the basemat can drop to 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths.

e) A COL applicant that has site GMRS that exhibits HRHF characteristics, but is not enveloped by the AP1000 HRHF GMRS or the AP1000 CSDRS, or has shear wave velocities that are not associated with hard rock (see item d) may perform site specific studies to demonstrate that the high frequency is not damaging for their site. This may be accomplished by:

   1. Demonstrating that the site floor response spectra, developed at the locations of the spectra given in TR115 (Sections 5.2 and 6.3) using the seismic input defined by the site GMRS, are enveloped by the AP1000 HRHF or CSDRS spectra.

   2. If it is shown in step one that the spectra are not enveloped, evaluations similar to those performed for TR115, would be made to demonstrate that the high frequency input is non-damaging.

Westinghouse Response (Revision 4)

In response to an NRC request, a statement will be added to Technical Report 115 (TR115) to indicate that a comparison of the site-specific shear wave velocity profile to the generic HRHF shear wave velocity profile is needed in addition to the comparison of the site-specific spectra to the generic HRHF spectra. The language to be added in TR115 (end of Section 1.0) is shown below.

"The evaluation documented in this report is for a site application having HRHF envelope response spectra that is in conformance with the following limitation on shear wave velocity. This shear wave velocity limitation is defined at the bottom of the basemat equal to or higher than 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths."

Reference(s): None

Design Control Document (DCD) Revision: (Post Revision 17 given below)

Modify bullet 4 given in DCD Section 2.5.2.1 as shown below.

4. In lieu of (1) and (2) above, for a site where the nuclear island is founded on hard rock ~~with~~ defined by a shear wave velocity at the bottom of the basemat equal to or higher than 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths, ~~shear wave velocity greater than 8000 feet per second, the site-specific peak ground acceleration and~~ site specific spectra may be developed at the top of the competent rock and shown at the foundation level to be less than or equal to those given in Figures 3I.1-1 and 3I.1-2 over the entire frequency range. If a COL applicant has site GMRS exhibiting HRHF characteristics, but is not enveloped by the AP1000 HRHF GMRS or the AP1000 CSDRS, or has shear wave velocities that are not associated with hard rock may perform site specific studies to demonstrate that the high frequency is not damaging. This may be accomplished by:

    1. Demonstrating that the site floor response spectra, developed at the locations of the spectra given in TR115 (Sections 5.2 and 6.3) using the seismic input defined by the site GMRS, are enveloped by the AP1000 HRHF or CSDRS spectra.

    2. If it is shown in step one that the spectra are not enveloped, evaluations similar to those described in Appendix 3I (documented in TR115, Reference 3), would be made to demonstrate that the high frequency input is non-damaging.

Add reference to DCD section 2.6 as shown:

2.6 References

3. APP-GW-GLR-115, "Effect of High Frequency Seismic Content on SSCs," Westinghouse Electric Company LLC.

PRA Revision:

None

Technical Report (TR) Revision:

~~No more changes are being made beyond those given in Revision 1. When necessary, changes are made within the DCD as shown above.~~ The language to be added in TR115 Revision 3 (end of Section 1.0) is shown below.

"The evaluation documented in this report is for a site application having HRHF envelope response spectra that is in conformance with the following limitation on shear wave velocity. This shear wave velocity limitation is defined at the bottom of the basemat equal to or higher than 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths."

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-04
Revision: 4

Question:

In Section 4.0 of TR-115, Westinghouse lists the four (4) screening criteria used to select systems, structures, and components (SSC) for detailed evaluation:

- Select systems, structures, and components based on their importance to safety. This includes the review of component safety function for the Safe Shutdown Earthquake (SSE) event and its potential failure modes due to an SSE. Those components whose failure modes do not impact the ability to achieve safe shutdown are excluded.

- Select systems, structures, and components that are located in areas of the plant that are susceptible to large high frequency seismic inputs.

- Select systems, structures, and components that have significant modal response within the region of high frequency amplification. Significance is defined by such items as: modal mass, participation factor, stress and/or deflection.

- Select systems, structures, and components that have significant total stress as compared to allowable, when considering load combinations that include seismic.

Based on the Westinghouse screening criteria, it is not clear to the staff why the Containment Structure is not identified for detailed comparison of the CSDRS response and the HRHFRS response. The staff requests that Westinghouse either include a detailed comparison for the Containment Structure in Section 6.1, or describe in detail its technical basis for excluding the Containment Structure.

On August 21, 2008 the NRC has requested the following additional information be provided.

The staff requested Westinghouse to explain why the containment structure was not included in the HRHF evaluation sample, considering its importance in mitigating the consequences of an accident. Westinghouse responded that it was not included because it would not be significantly affected by high frequency seismic input, based on the low frequency of its fundamental response mode. The staff finds this response to be unacceptable, based on information included in DCD Rev. 16. In the discussion of the containment stick model response vs. the containment shell model response, Westinghouse identifies modes in the upper closure dome in the 20 to 30 Hz range. In addition, the modal properties of the attached water weirs and the air baffle attachments may be in the same frequency range. Westinghouse justified the adequacy of the containment stick model on the basis that these high frequency modes in the containment dome and attachments would NOT be excited by the CSDRS (modified RG 1.60 spectra), because the CSDRS has no energy in this frequency range. The staff notes that the HRHF

GMRS has significant energy in this frequency range and would be expected to excite these vibration modes.

Therefore, the staff requests that Westinghouse expand its HRHF evaluation sample to include the Containment Structure, and also to specifically evaluate these high frequency modes, which are not represented in the AP1000 containment stick model.

Additional Request (Revision 2):

The staff determined that Westinghouse's response to RAI-SRP3.7.1-SEB1-04 (Revision 1) did not sufficiently address the staff's questions. Therefore, the staff is making its request more specific.

Based on information in DCD Rev. 16, Section 3G.2.1.3, in the discussion of the containment stick model response vs. the containment shell model response, Westinghouse identifies modes in the upper closure dome in the 23 to 30 Hz range. In addition, the modal properties of the attached water weirs and the air baffle attachments are identified to be in the same frequency range. Westinghouse justified the adequacy of the containment stick model on the basis that these high frequency modes in the containment dome and attachments would NOT be excited by the CSDRS (modified RG 1.60 spectra), because the CSDRS has no energy in this frequency range. While this may be adequate justification for use of a stick model for analysis of the steel containment shell response to the CSDRS, the staff notes that the HRHF GMRS has significant energy in 20-30 Hz frequency range, and would be expected to excite the shell vibration modes in the upper closure dome.

Based in the information reviewed to date, the staff is concerned that Westinghouse did not select an adequate sample of structures locations, for demonstrating that the AP1000 structural responses due to the HRHF GMRS are enveloped by the structural responses due to the CSDRS. Since the upper closure dome of the steel containment shell will be excited by the HRHF GMRS, the staff requests that Westinghouse provide detailed results for the response of the steel containment shell, including the local flexible modes in the upper closure dome, due to seismic excitation by the HRHF GMRS, and compare it to the design-basis CSDRS response, for both a stick model representation and a shell model representation of the steel containment shell.

Additional Request (Revision 3):

The shell vibration modes of the steel containment shell, including the local modes of the upper head, which could potentially be excited by the HRHF input, need to be audited. The CSDRS spectra and the HRHF spectra at the base of the containment shell need to be audited, to assess why the CSDRS spectra envelope the HRHF spectra over the entire frequency range of interest, in conjunction with the assessment in (1) above. The results of response spectrum analysis of the containment shell model, for both the CSDRS spectra and the HRHF spectra,

needs to be audited, for possible impact on the containment shell stress evaluation to ASME Code Section III, Subsection NE requirements. Please document the results that were audited during the audit performed the week of April 12, 2009.

Additional Request (Revision 4)

In its latest response, the applicant stated that the NI20 ACS SASSI analysis for the HRHF ground motion input produced in-structure response spectra at the base of the SCV that are completely enveloped by the comparable in-structure response spectra produced by the CSDRS ground motion input, across the entire frequency range. The staff noted that, if this is the case, then the HRHF input would not excite the vibration modes in the SCV dome. The applicant's response can only be evaluated when the re-analysis of HRHF models is completed. Pending the staff's evaluation of the applicant's revised incoherency analysis results Westinghouse to provide a comparison of ISRS at the base of the containment incorporating corrected results of the seismic model.

Westinghouse Response (Revision 0 & 1):

The steel containment structure was not chosen for evaluation since it does not meet the 3rd bullet of the general screening criteria:

- Select systems, structures, and components that have significant modal response within the region of high frequency amplification. Significance is defined by such items as: modal mass, participation factor, stress and/or deflection.

Shown below are the dominant frequencies with modal mass associated with the steel containment vessel with polar crane. The dominant modes for horizontal response are below 10 hertz, and the dominant mode in the vertical direction is below 20 hertz. The dominant modes are not in the region where the HRHF exceeds the AP1000 CSDRS. Further, over 75 % of the mass is participating prior to the exceedance of the AP1000 CSDRS by the HRHF. Therefore, the Steel Containment Structure was excluded from the evaluation.

Direction	Frequency (hertz)	Effective Mass Participation (kip-sec^2/ft)	Percent of Mass Participation
X (North-South)	5.090	151.499	60.578
	8.109	32.009	75.306
	17.546	31.095	88.628
Y (East-West)	3.240	31.480	12.709
	6.095	156.933	76.062
	18.947	40.003	93.161
Z (Vertical)	6.692	22.140	9.057
	16.376	166.317	77.236
	27.318	18.628	90.367

In response to the NRC August 21, 2008 request, Westinghouse offers the following.

The seismic response spectra in the vicinity of the polar crane (~224' elevation) is representative of the seismic response that the upper closure dome and the attached water weirs and air baffle attachments will experience. These floor response spectra (5% damping) are shown in Figures RAI-SRP3.7.1-SEB1-04-1 to RAI-SRP3.7.1-SEB1-04-3. As seen from these spectra comparisons, the CSDRS floor response spectra identified as SSIENV envelop the HRHF floor response spectra. Therefore, it can be stated that the items identified (upper closure dome, water weirs and the air baffle attachments) will have lower response due to HRHF response than that obtained from the CSDRS excitation.

Westinghouse Response (Revision 2):

It is true that the upper closure dome is in the 23 to 30 Hz range. However, as seen in Figures RAI-SRP3.7.1-SEB1-04-1 to RAI-SRP3.7.1-SEB1-04-3 near the location of the polar crane the dominant frequency is below 10 hertz for the horizontal directions, and below 20 hertz in the vertical direction. The high frequency motion will be filtered, and there will be no significant energy to excite the higher modes in the 23 to 30 hertz range. The filtering of the high frequency motion is seen in the RAI figures. Westinghouse has selected an adequate sample of structural locations for demonstrating that the AP1000 structural responses due to the HRHF GMRS are enveloped by the structural responses due to the CSDRS.

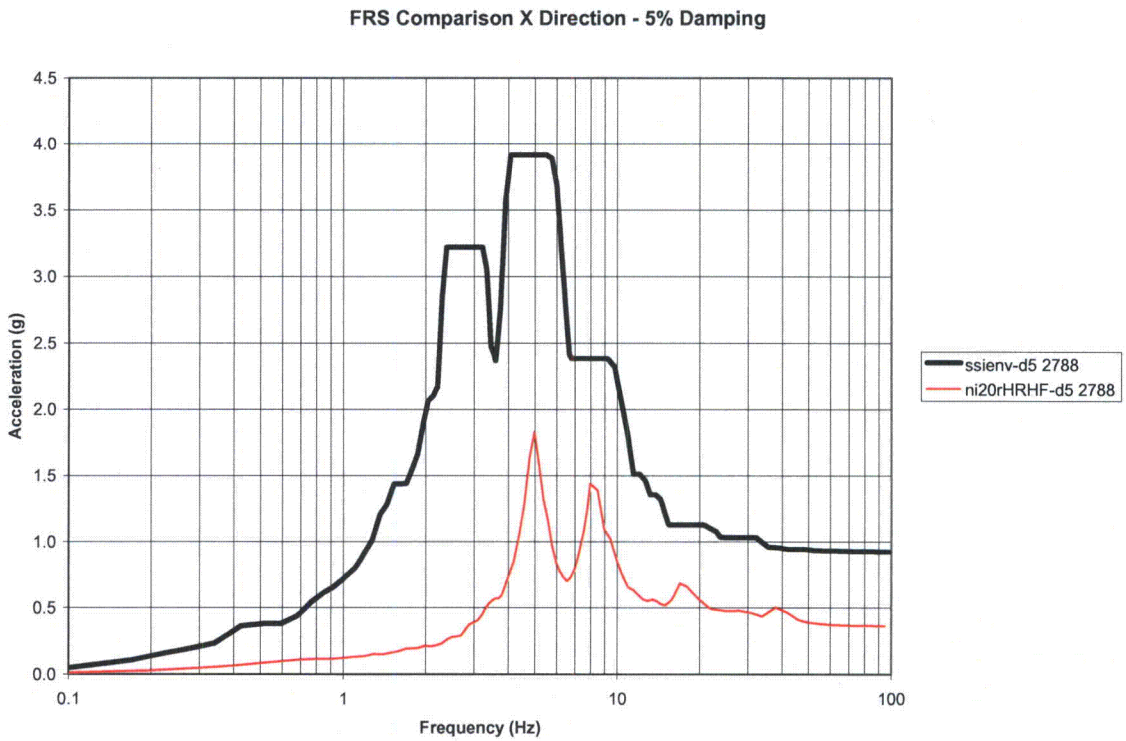


Figure RAI-SRP3.7.1-SEB1-04-1 – X Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

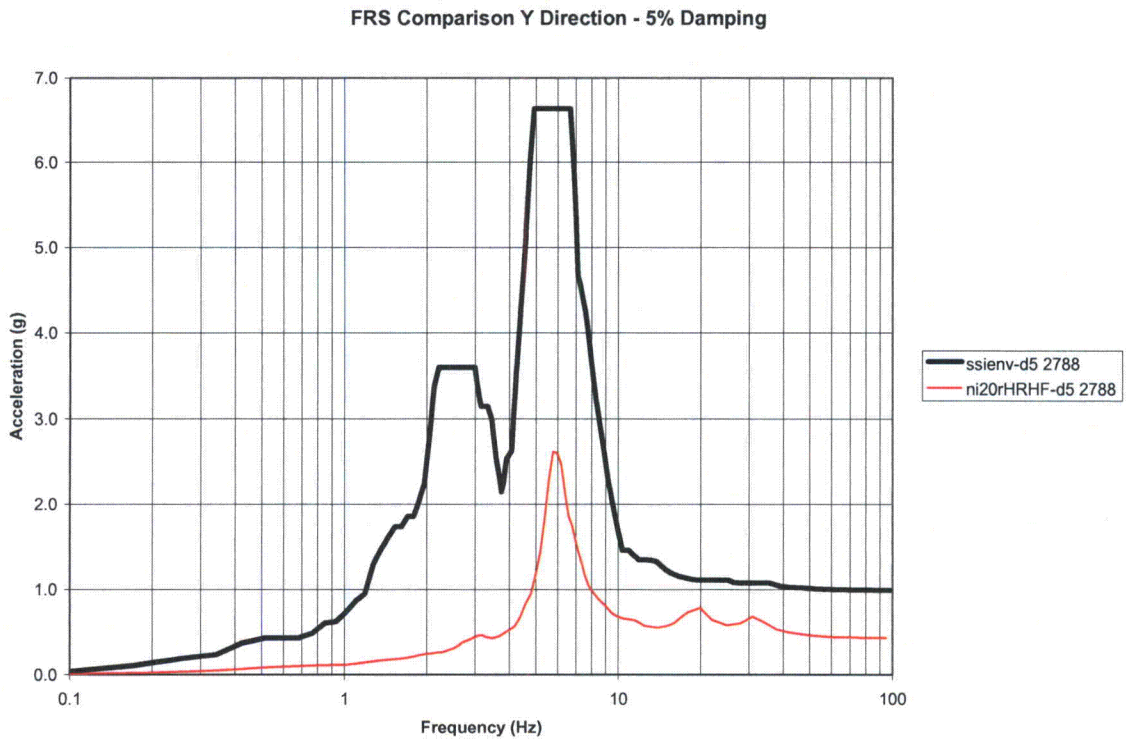


Figure RAI-SRP3.7.1-SEB1-04-2 – Y Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

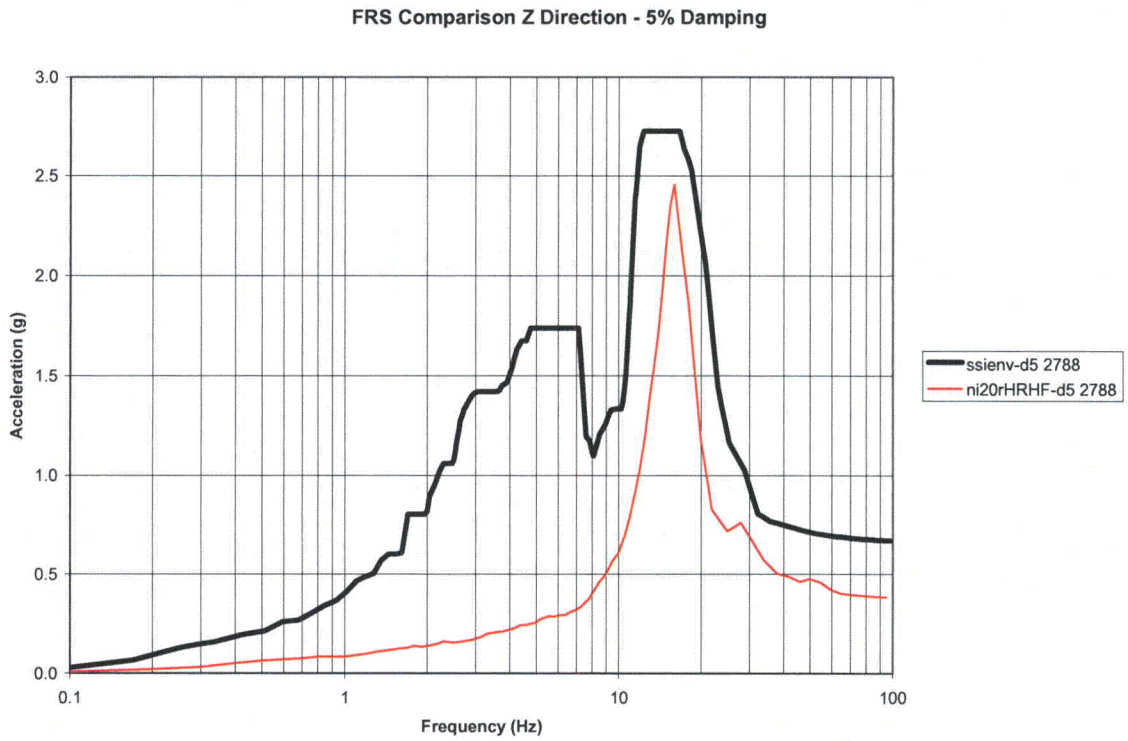


Figure RAI-SRP3.7.1-SEB1-04-3 – Z Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

Westinghouse Response (Revision 3):

Westinghouse was requested by the NRC to provide additional information to demonstrate that the Steel Containment Vessel (SCV) upper shell is not excited by the HRHF input.

An axisymmetric model is used to develop certain properties of the SCV stick model for use in the AP1000 nuclear island dynamic model. This approach was used for both the AP600 and AP1000 Hard Rock certifications. The steps used were:

- Create an axisymmetric model of the steel containment vessel
- Calculate vertical modal behavior from zero harmonic
- Calculate horizontal modal behavior from first harmonic
- Develop equivalent stick model with properties to match axisymmetric results
- Check out stick model by comparing results of stick against results of axisymmetric model

In Figure RAI-SRP3.7.1-SEB1-4 to RAI-SRP3.7.1-SEB1-04-9 are shown the vertical modes obtained from the axisymmetric model. A comparison of the frequencies and effective mass for the modes from the axisymmetric and stick model is given in Table RAI-SRP3.7.1-SEB1-1. As seen from this table the dynamic behavior of the stick and axisymmetric models are the same. The stick model can be used in the combined nuclear island seismic analyses.

The Steel Containment Vessel (SCV) did not meet the HRHF screening criteria since the SCV HRHF spectra are enveloped by the AP1000 CSDRS spectra. This is seen in Figure RAI-SRP3.7.1-SEB1-10 that compares the CSDRS and HRHF spectra at the base of the SCV. The AP1000 CSDRS spectra were used to evaluate the SCV upper shell susceptibility to high frequency motions. Two response spectra analyses (RSA) were performed:

- Modes from 0-24 Hz, about 80 modes were used
- Modes from 0-50 Hz, about 800 modes were used

The results were compared against an equivalent static analysis. The results are shown in Figures RAI-SRP3.7.1-SEB1-04-11 and RAI-SRP3.7.1-SEB1-04-12. It was found that the equivalent static analysis middle layer results were within 4% OF THE RSA 0-50 Hz analysis, and the equivalent static analysis top and bottom results within 3% of the RSA 0-50 Hz analysis. It is concluded that:

- Stresses at the SCV Upper Shell are small no matter what seismic methodology is used.
- The equivalent static analysis provides results that are very close to those from response spectra analysis.
- The stick model can be used in the combined nuclear island seismic analyses.

Westinghouse Response (Revision 4)

Figures RAI-SRP3.7.1-SEB1-04-1, RAI-SRP3.7.1-SEB1-04-2, RAI-SRP3.7.1-SEB1-04-3, and RAI-SRP3.7.1-SEB1-04-10 have been updated to reflect the corrected seismic model. The conclusions stated in previous revisions of this RAI are still valid due to the fact the CSDRS is still the enveloping response spectra with negligible exceedance in the y-direction.

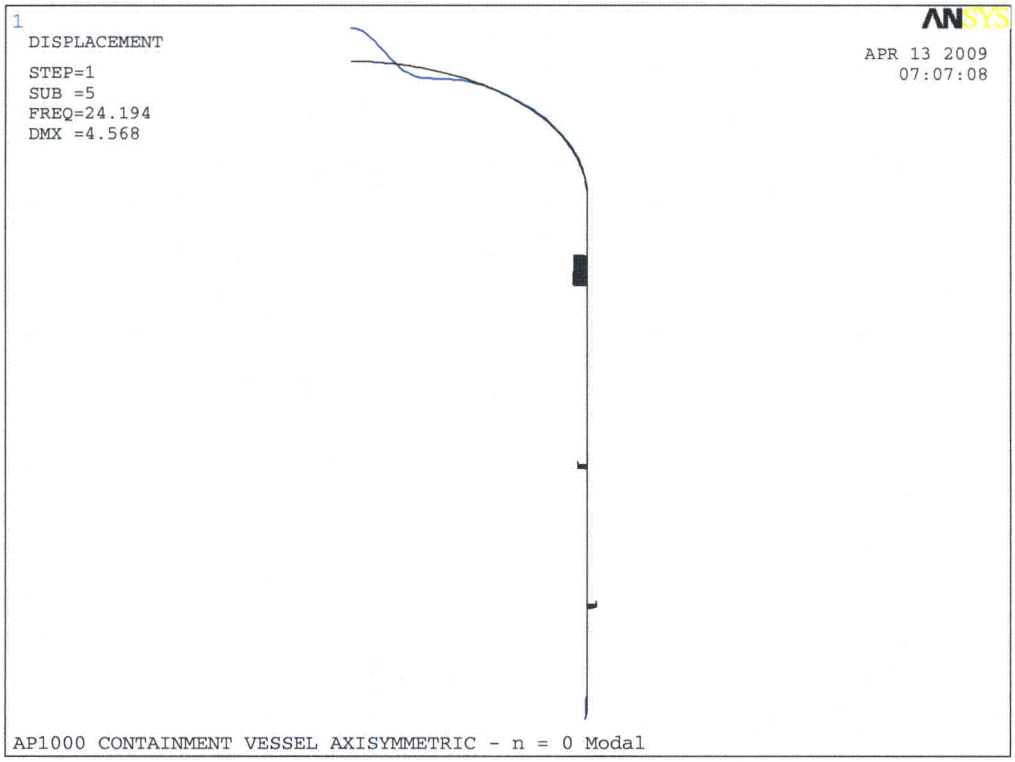


Figure RAI-SRP3.7.1-SEB1-04 - Vertical Mode No. 3 (mode 5 from the analysis, 24.2 Hz)

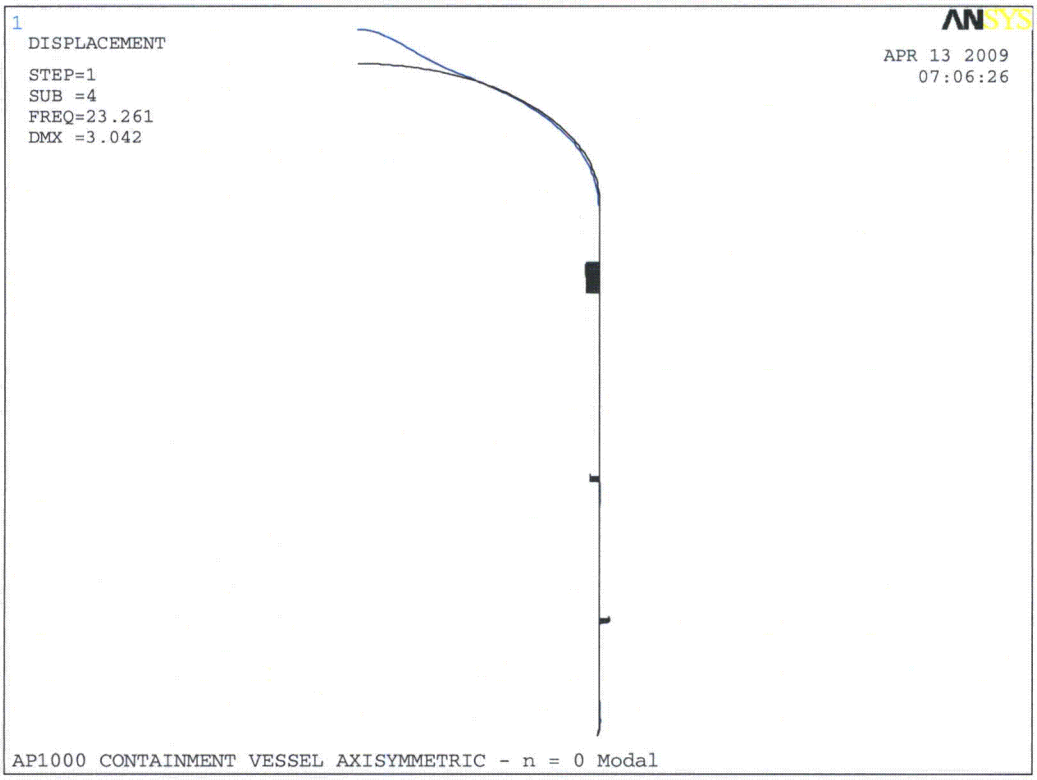


Figure RAI-SRP3.7.1-SEB1-05 - Vertical Mode No. 2 (mode 4 from the analysis, 23.3 Hz)

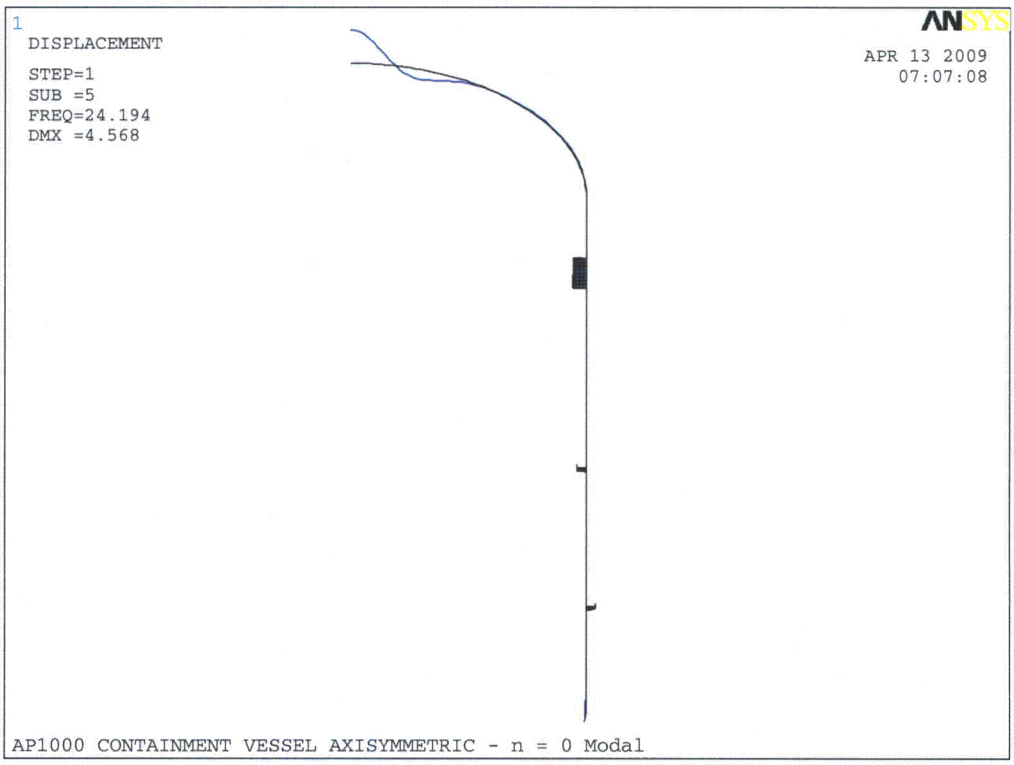


Figure RAI-SRP3.7.1-SEB1-06 - Vertical Mode No. 3 (mode 5 from the analysis, 24.2 Hz)

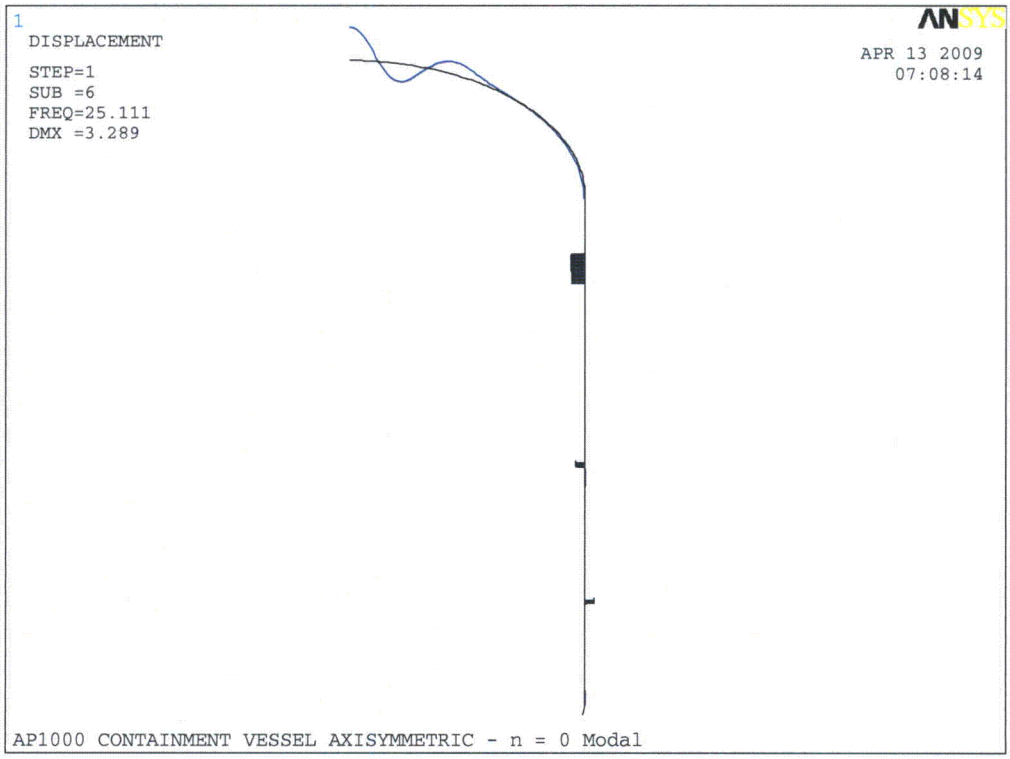


Figure RAI-SRP3.7.1-SEB1-07 - Vertical Mode No. 4 (mode 6 from the analysis, 25.1 Hz)

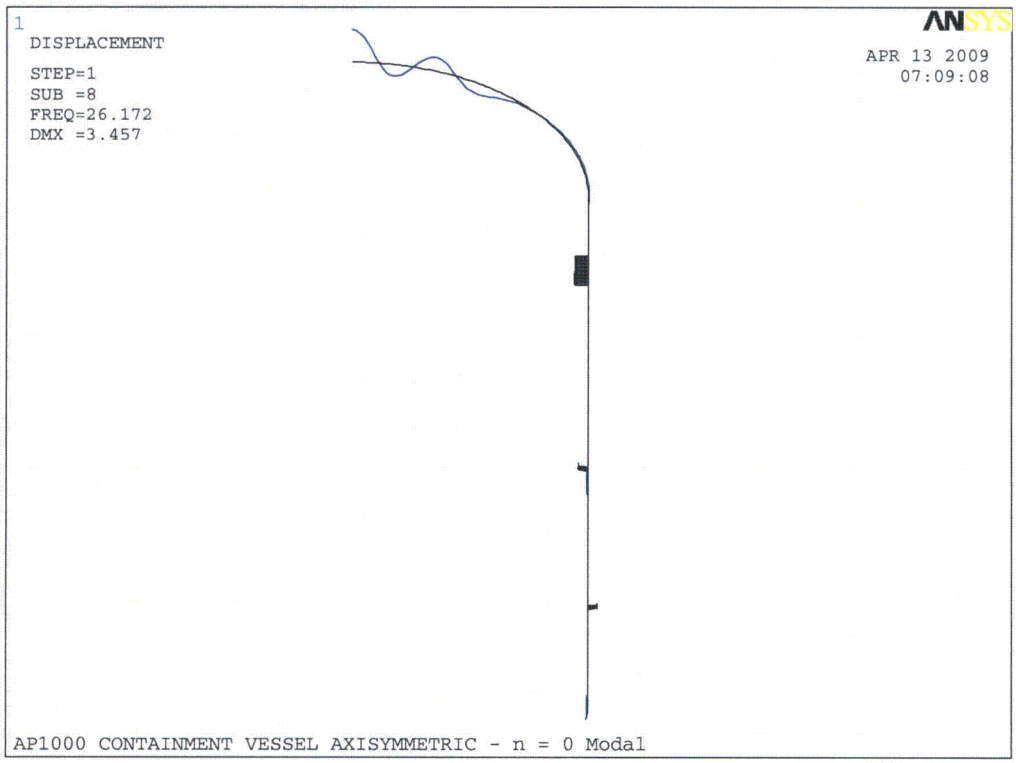


Figure RAI-SRP3.7.1-SEB1-08 - Vertical Mode No. 5 (mode 8 from the analysis, 26.2 Hz)

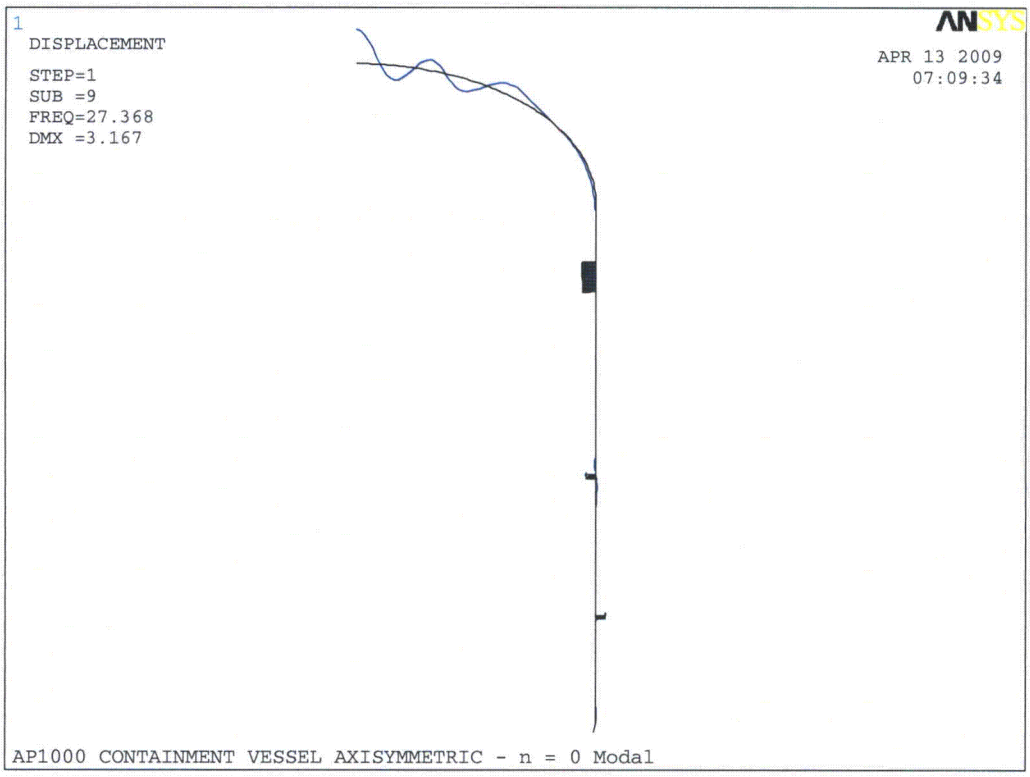
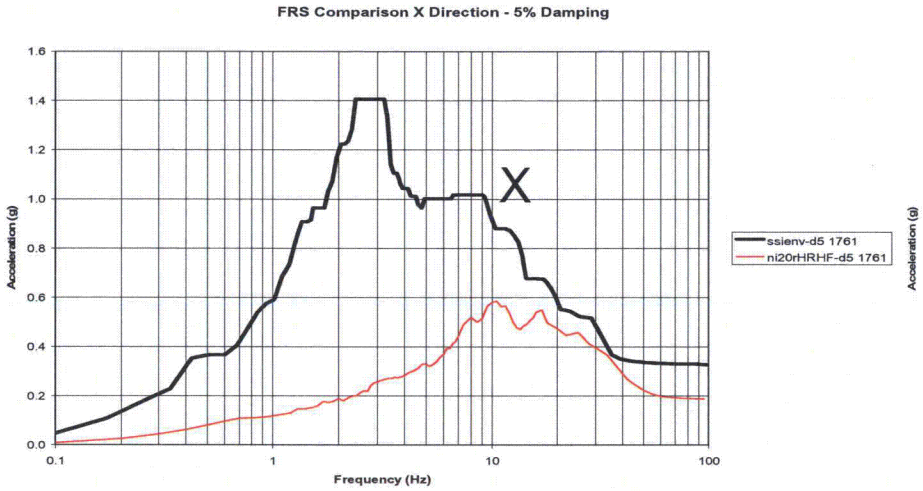
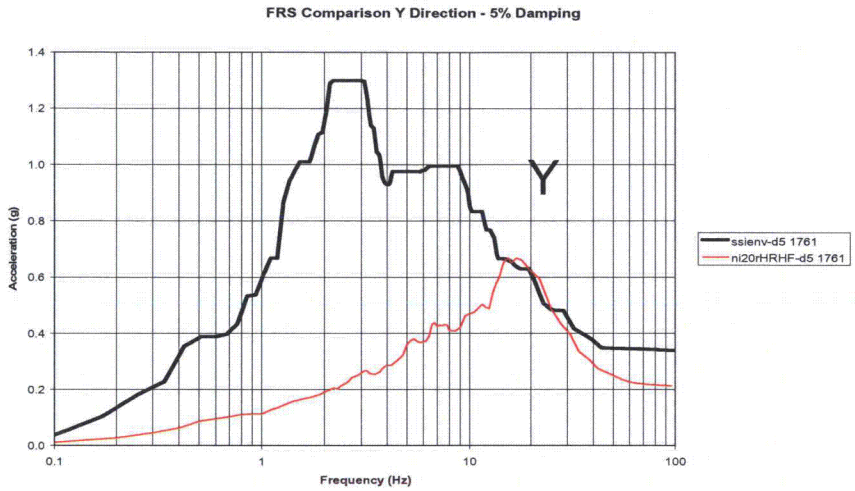
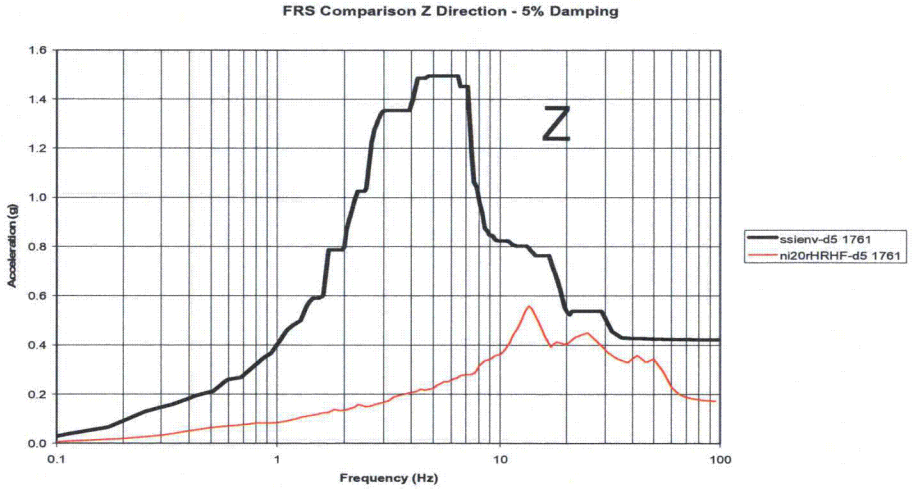


Figure RAI-SRP3.7.1-SEB1-09 - Vertical Mode No. 6 (mode 9 from the analysis, 27.4 Hz)

Response to Request For Additional Information (RAI)







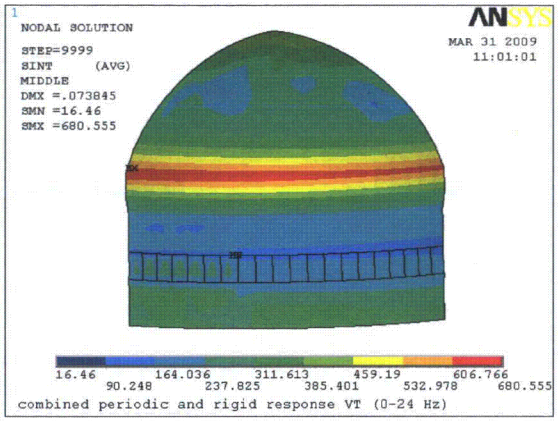
SCV HRHF Spectra is enveloped by AP1000 Spectra.

HRHF input has lower energy below 10 Hz and because it is above a region that has a very thick base (rigid) basemat the coherency function is very effective in reducing the response above 10 Hz

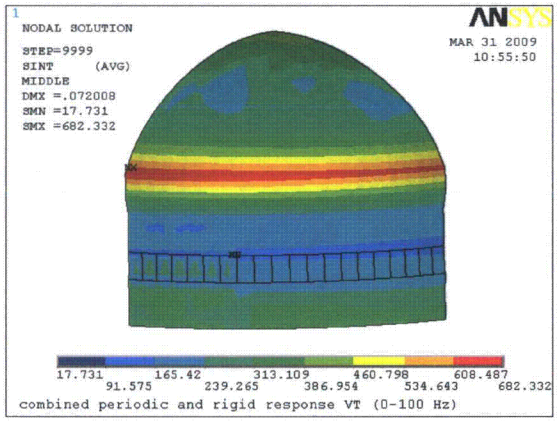
Figure RAI-SRP3.7.1-SEB1-10 – SCV CSDRS and HRHF Input Spectra

Response to Request For Additional Information (RAI)

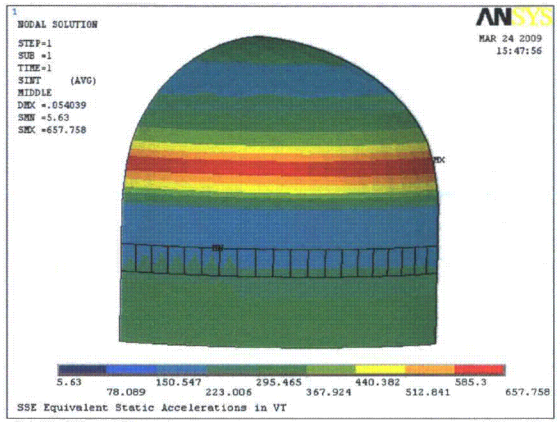
RSA 0-25 Hz



RSA 0-50 Hz



Equivalent Static

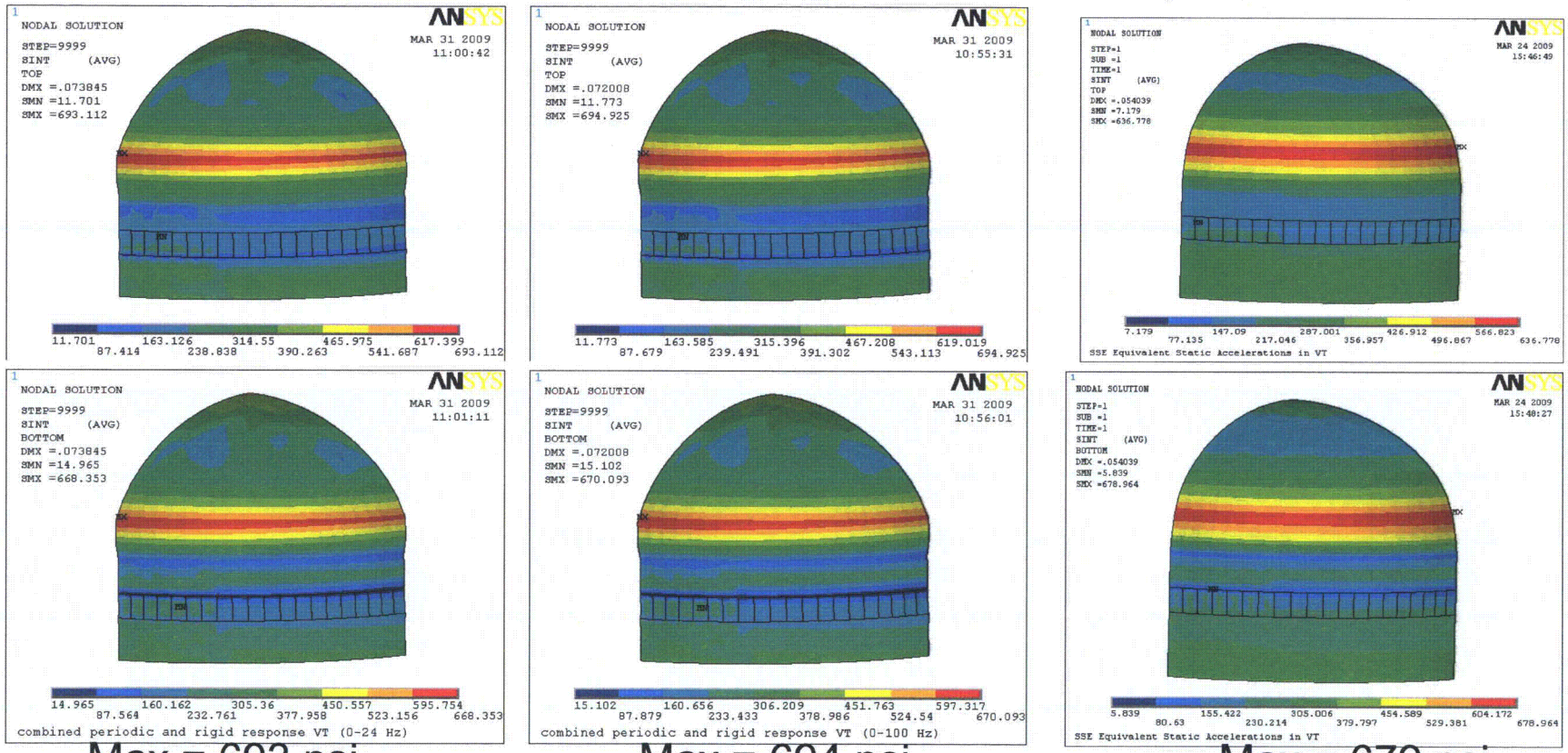


Stress Intensity, Middle Surface, Equivalent Static within 4% of RSA 0-50Hz

Figure RAI-SRP3.7.1-SEB1-11 – Stress Intensity comparisons, Middle Surface

Response to Request For Additional Information (RAI)

RSA 0-25 Hz | RSA 0-50 Hz | Equivalent Static



Max = 693 psi | Max = 694 psi | Max = 679 psi

Figure RAI-SRP3.7.1-SEB1-12 – Stress Intensity, Outer and Inner Surface (Top and Bottom Layer), Equivalent Static within 3% of RSA 0-50 Hz

Table RAI-SRP3.7.1-SEB1-1 – Comparison of Dynamic Response Characteristics between Axisymmetric and Stick Models

Axisymmetric Model					Stick Model		
Mode number	Frequency Hz	Effective Mass Kip-sec^2/ft			Mode number	Frequency Hz	Effective Mass
Vertical Modes							
		X(R)	Z(θ)	Y(vertical)			
0,2	16.51			160.8	4	16.97	171
0,4	23.261			14	7	28.201	28.1
0,5	24.194			4.6			
0,6	25.111			3.6			
Torsional mode (units for ROTY effective Mass: kip-sec^2-ft					Units for ROTZ effective Mass: Kip-sec^2-ft		
			Z(θ)	ROTY			ROTZ
0,1	12.905		188.4	732,351	3	12.942	735,208
Horizontal modes in X direction							
		X(R)	Z(θ)	X + Z			
1,1	6.203	89.9	78.1	168	1	6.309	159.2
1,2	18.585	17	18.8	35.8	5	18.96	40.3

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-08
Revision: 4

Question:

The staff also noted that there are an insufficient number of comparisons presented in TR-115 Section 5.1. The NI10 results presented show no significant amplification in the higher frequency range on any of the figures. The staff requests that Westinghouse include in Section 5.1, NI10 vs. NI20 comparisons at locations/directions where there is significant amplification at higher frequency.

Additional Request (Revision 2):

The staff reviewed Westinghouse's supplemental response to RAI-SRP3.7.1-SEB1-08, which provided NI10 vs. NI20 ANSYS vs. NI20 SASSI comparisons for 2 additional locations. These 2 locations exhibit more significant response at higher frequency than the 3 locations included in TR-115, Rev. 0, Section 5.1. Significant spectral amplification in x and y occurs in the 10-20 Hz range at Node NI20 2247, and in the 20-30 Hz range at Node NI20 2078. Significant spectral amplification in z occurs at about 23 Hz for both locations.

The staff noted that the comparisons presented do not exhibit a consistent pattern of correlation among the 3 models. In the x direction at Node NI20 2247, there are significant differences in the 7-8 Hz range, where excellent correlation would be expected. The greatest concern is with the z direction responses.

For the Auxiliary Building Southeast Corner, Elevation 135', Figure RAI-SRP3.7.1-SEB1-08-4 (Node NI20 2247 Direction Z) the spectral peak occurs at 23 Hz. The approximate magnitudes are:

NI10	NI20 ANSYS	NI20 SASSI
1.5g	3.2g	2.3g

For the Auxiliary Building Northeast Corner, Elevation 116.5', Figure RAI-SRP3.7.1-SEB1-08-8 (Node NI20 2078 Direction Z) the spectral peak occurs at 21-23 Hz. The approximate magnitudes are:

NI10	NI20 ANSYS	NI20 SASSI
1.5g	1.2g	2.4g

From the data presented above, there is consistency between the 2 locations for the NI10 and NI20 SASSI results, but a very significant discrepancy for the NI20 ANSYS results. This is indicative to the staff that there is either a modeling error or a reporting error.

Consequently, the staff requests Westinghouse to evaluate the results presented in its supplemental RAI response, and either (1) confirm the accuracy of the data presented and provide a technical explanation, or (2) explain the discrepancies and provide the correct data. In its evaluation, Westinghouse should consider, at a minimum, the scatter of data in the 7-8 Hz

range in the x direction at Auxiliary Building Southeast Corner, Elevation 135', and the discrepancy in the z-direction results.

Additional Request (Revision 3)

Please provide more detail.

Additional Request (Revision 4)

In a letter dated June 3, 2009, Westinghouse submitted a third supplemental response to this RAI, trying to specifically explain the inconsistent results reported in the Z direction between nodes 2247 and 2078. The staff reviewed the additional information, and concluded that while the explanation is plausible, it may also be indicative of errors in the SASSI NI20 model and/or the ANSYS NI20 model. The staff determined that resolution of the issues raised in this RAI would need to be deferred until the staff had completed its independent confirmatory analysis program. It is requested that Westinghouse address the differences in Figure 5.1-7 and 5.1-8 in Technical Report 115 (TR115).

Westinghouse Response (Revision 0 & 1):

As stated in RAI-SRP3.7.1-SEB1-06, demonstration of the adequacy of the model used to develop HRHF response is to be based on a maximum analysis frequency of 50 hertz. It was shown in the response to this RAI that the NI20 model has sufficient accuracy in the building structure model. Therefore, further comparison than that given in Section 5.1 is not necessary.

In the meeting on May 19-23, 2008, it was requested by the NRC to provide additional spectra focused on the amplification at higher frequencies in the NI10 results when compared to the NI20 model results. Figures RAI-SRP3.7.1-SEB1-08-1 to RAI-SRP3.7.1-SEB1-08-8 show the locations and response spectra of the additional nodes for which floor response spectra comparisons are provided.

Note: In the Revision 3 response the FRS have been renumbered.

Westinghouse Response (Revision 2):

Westinghouse provided the NRC the additional spectra at locations that exhibit amplification in the higher frequency regions. The results presented were obtained from different models (NI10 and NI20) and different technologies (ANSYS – time domain solution & SASSI – frequency domain solution). This can result in the differences identified. What the response spectra show is that:

- In general the shape of the response spectra are similar
- The NI20 model has higher response than the NI10 model

- SASSI analyses are conservative.

Westinghouse Response (Revision 3):

Westinghouse provided the NRC additional spectra at locations that exhibit amplification in the higher frequency regions. These additional spectra locations showed what at first glance seemed apparent inconsistencies and/or errors. The results presented were obtained from different models (NI10 and NI20) and different technologies (ANSYS – time domain solution & SASSI – frequency domain solution). The NI20 model uses less nodes and elements to represent the nuclear island. As a result there are regions of the NI20 model that can not be represented with as much detail as in the NI10. The size of the opening in southeast corner differs between the NI10 and NI20 models as seen in Figure RAI-SRP3.7.1-SEB1-08-1 while the opening at the northeast corner is the same in both models. This opening differences results in different response due to the HRHF input between the two models for the southeast corner location (node 2247, see Figure RAI-SRP3.7.1-SEB1-08-6).

Westinghouse Response (Revision 4)

In response to an NRC request, a statement will be added to Technical Report 115 (TR115) to address the differences in Figure 5.1-7 and 5.1-8. The language to be added in TR115 (Section 5.1) is shown below.

"The differences in Figure 5.1-7 and 5.1-8 are due to the differences in geometry between the NI10 and NI20 models at the Southeast and Northeast Corners."

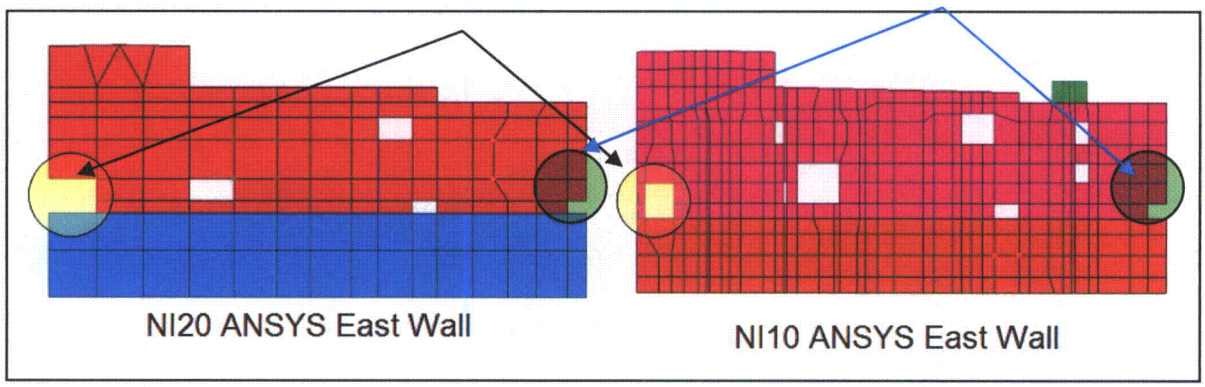


Figure RAI-SRP3.7.1-SEB1-08-1: Modeling difference in the Southeast Corner

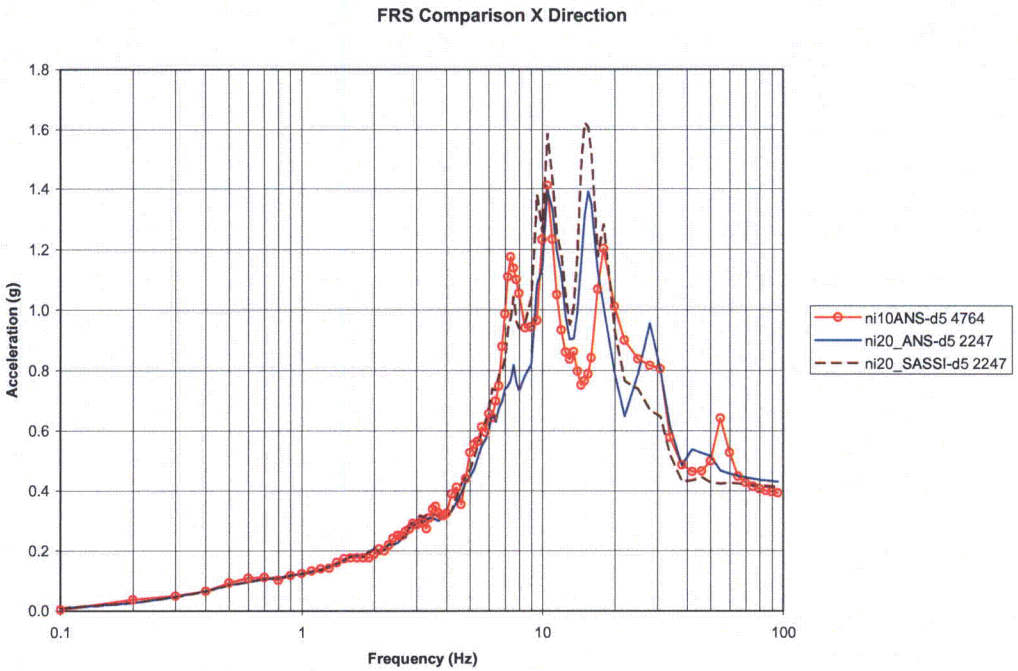


Figure RAI-SRP3.7.1-SEB1-08-2: Node NI20 2247 Direction X Elevation 135'

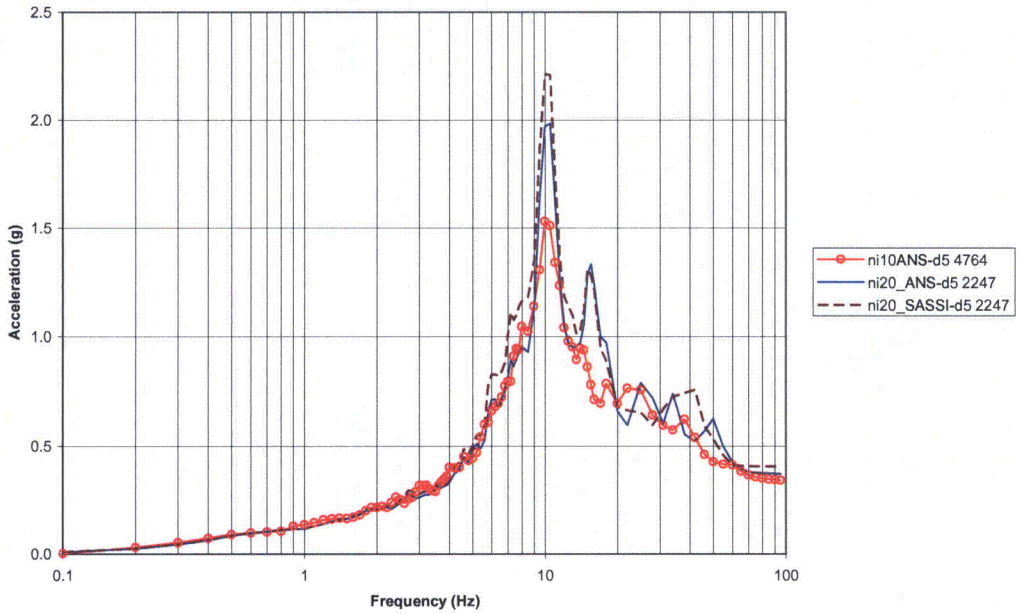


Figure RAI-SRP3.7.1-SEB1-08-3: Node NI20 2247 Direction Y Elevation 135'

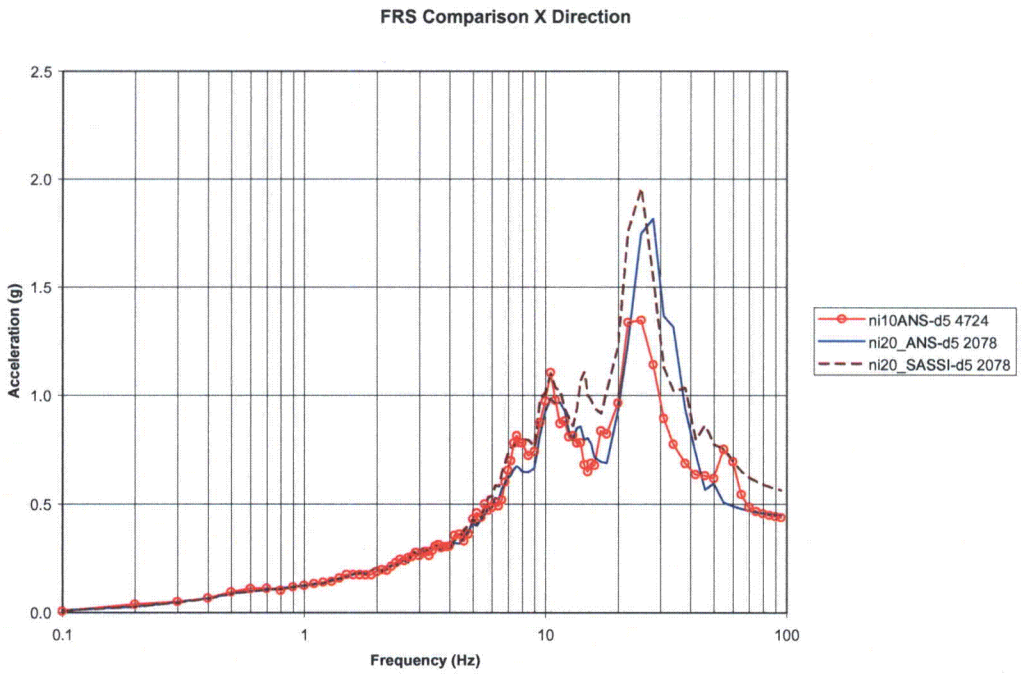


Figure RAI-SRP3.7.1-SEB1-08-4: Node NI20 2078 Direction X Elevation 116.5'

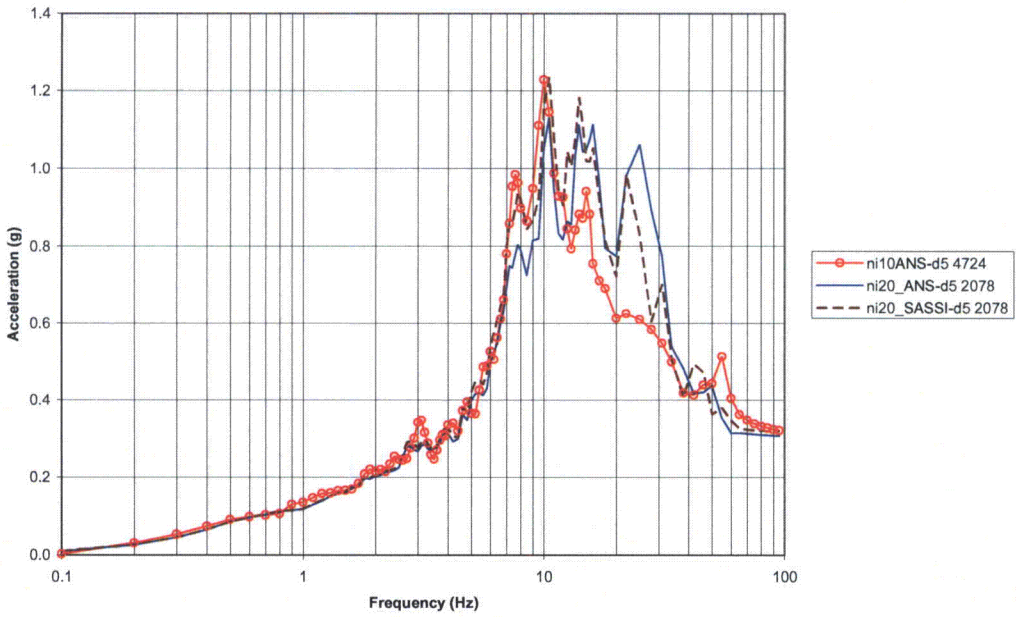


Figure RAI-SRP3.7.1-SEB1-08-5: Node NI20 2078 Direction Y Elevation 116.5'

Although in general the SASSI results are higher than the ANSYS results at frequencies higher than 10 Hz, the results presented in the supplemental RAI response show some different behavior. The apparent inconsistency in FRS results in the vertical direction (see Figure RAI-SRP3.7.1-SEB1-08-6 through Figure RAI-SRP3.7.1-SEB1-08-8) between the NI20 ANSYS and the NI20 SASSI is the due to the fact that the nuclear island base motion differs between the two methodologies. In ANSYS the base motion of all nodes is the same. In SASSI the motion of the base nodes differs.

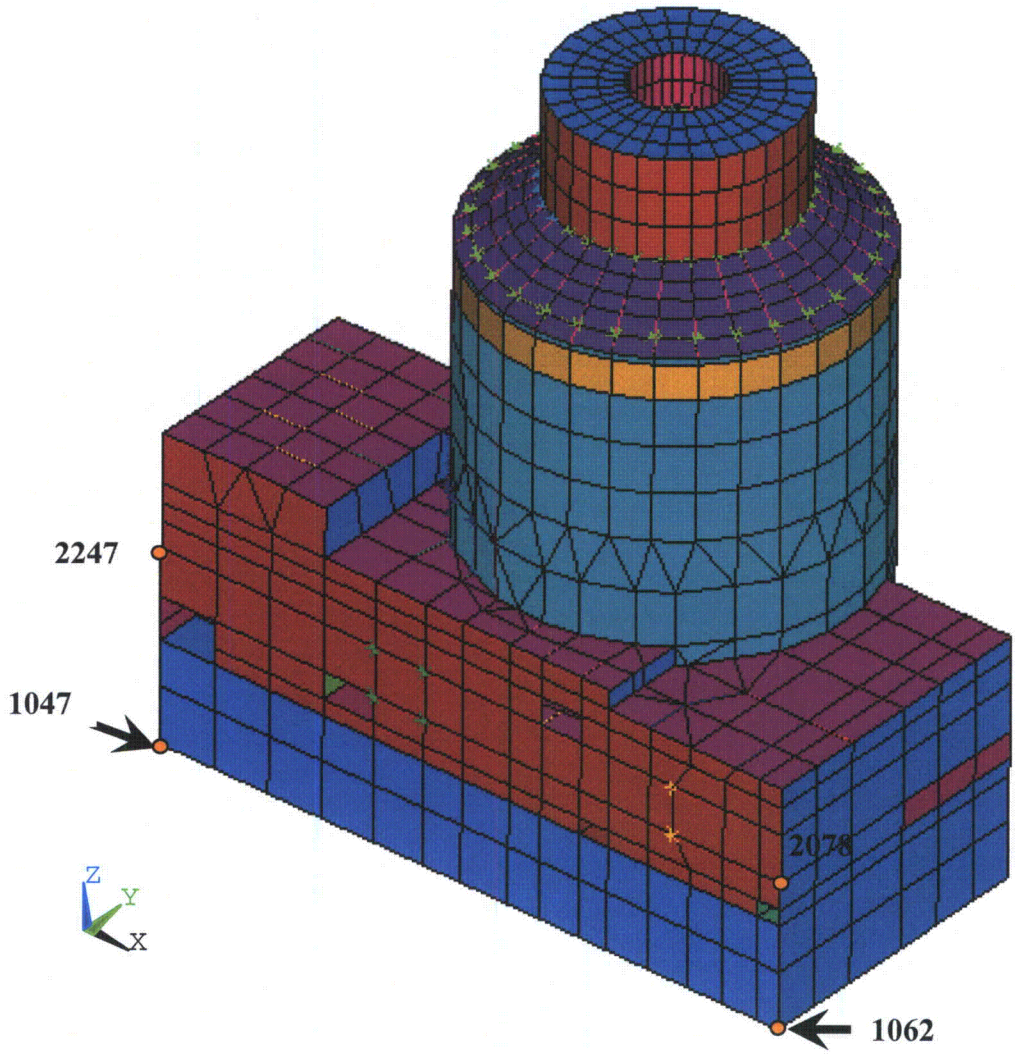


Figure RAI-SRP3.7.1-SEB1-08-6: Auxiliary building S.E. Corner Elevation 135'

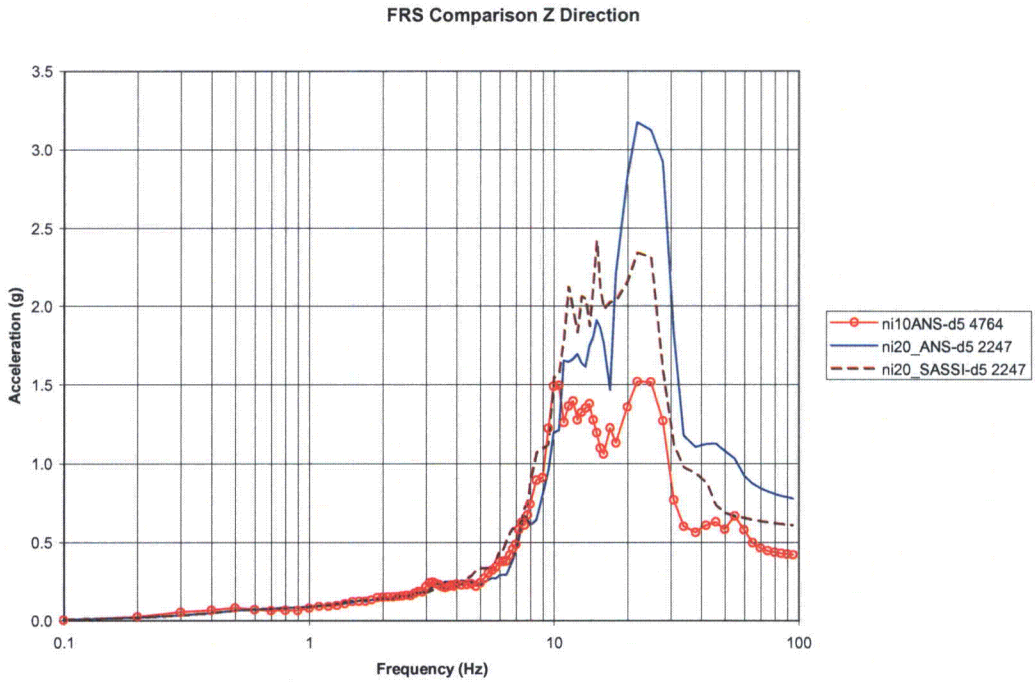


Figure RAI-SRP3.7.1-SEB1-08-7: Node NI20 2247 Direction Z Elevation 135

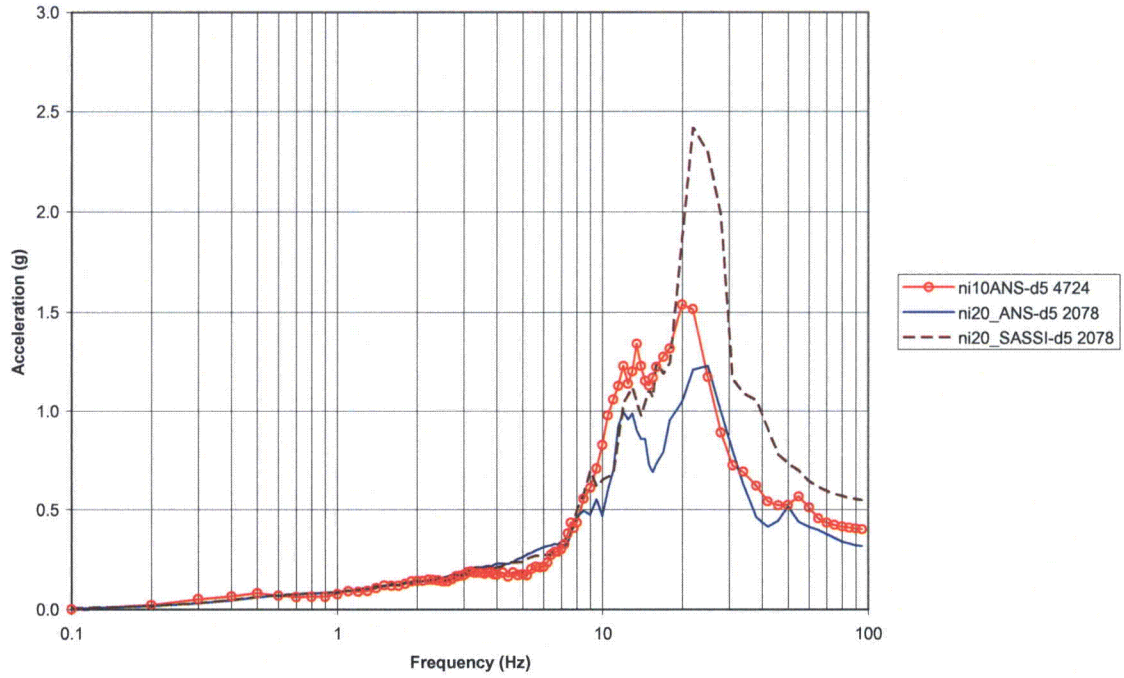


Figure RAI-SRP3.7.1-SEB1-08-8: Node NI20 2078 Direction Z Elevation 116.5'

The base nodes that affect the building nodes 2078 and 2247 are shown in Figure RAI-SRP3.7.1-SEB1-08-9. The difference in response between the Northeast and Southeast corners and how it affects the nodes above the base is shown in Figures RAI-SRP3.7.1-SEB1-08-10 and RAI-SRP3.7.1-SEB1-08-11.

When comparing the Z-direction response in the base of the Southeast corner (node 1047), Figures RAI-SRP3.7.1-SEB1-08-10, the ANSYS base motion exceeds the SASSI model beginning at about 19 Hz and through about 30 Hz. The figure also shows that in this range, not only do all the SASSI base nodes fall below the ANSYS base motion; the SASSI nodes have different responses. The FRS comparison of node 2247 shows that the ANSYS NI20 response is higher than the SASSI NI20 after 18 Hz.

In contrast, the Z-direction response in the base of the Northeast corner (node 1062), Figures RAI-SRP3.7.1-SEB1-08-11, the SASSI base response exceeds the ANSYS base response for practically the entire frequency range. The FRS comparison of node 2078 shows that the SASSI NI20 response is higher than the ANSYS NI20 for the whole frequency range.

Thus, the building corner response is shown to be consistent with the input base motion at the corners. The accuracy of the information presented is confirmed, and neither a modeling error nor a reporting error is noted.

Finally, in response to the original RAI request to show more points with high frequency response, an analysis using input motion with frequency content up to 50 Hz is described in the response to RAI-SRP3.7.1-SEB1-06.

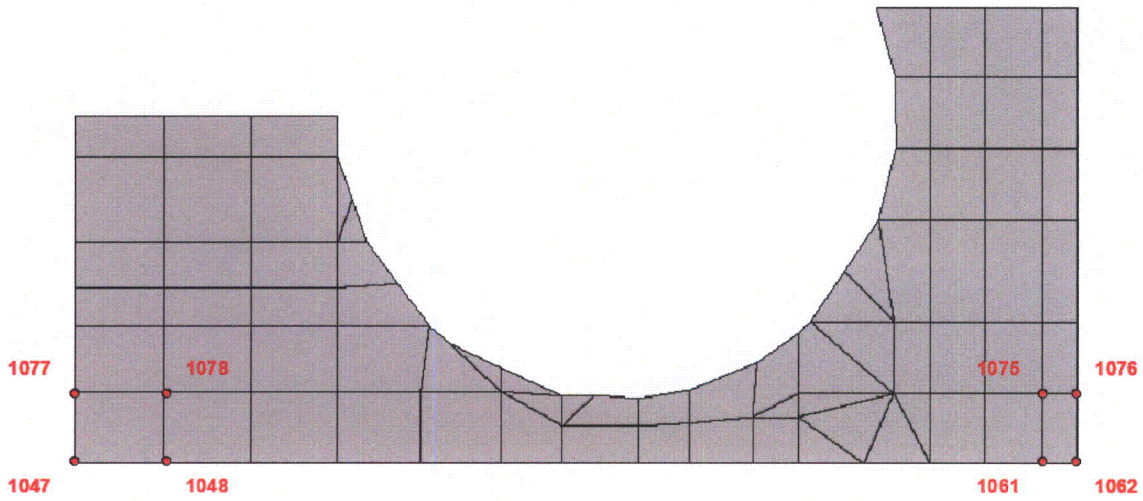
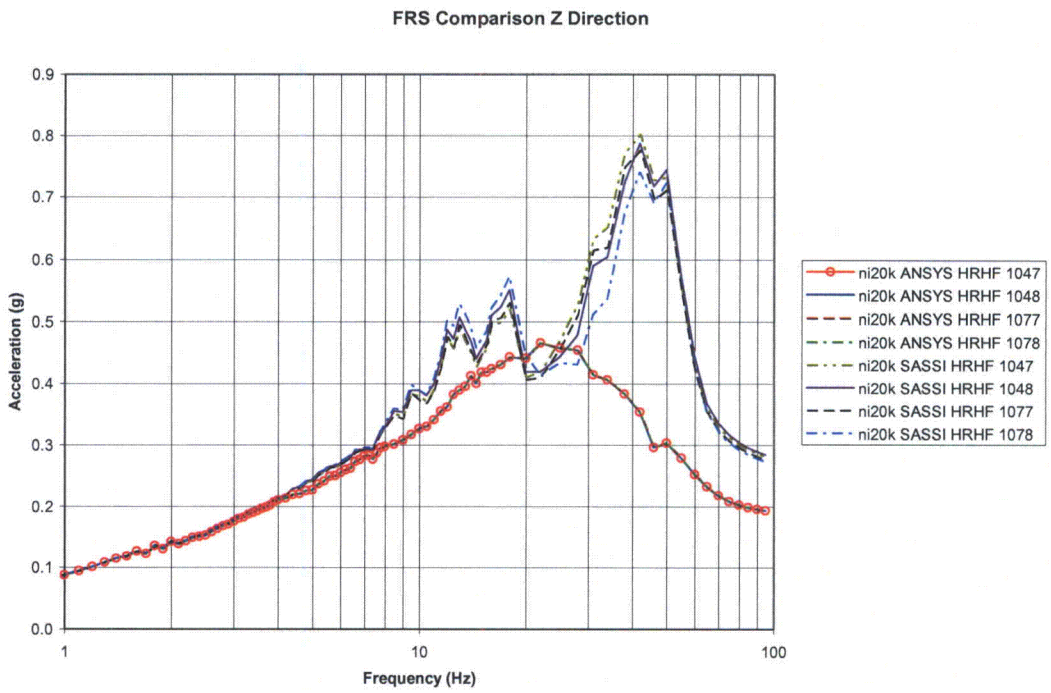


Figure RAI-SRP3.7.1-SEB1-08-9: Basemat nodes and Southeast and Northeast corners



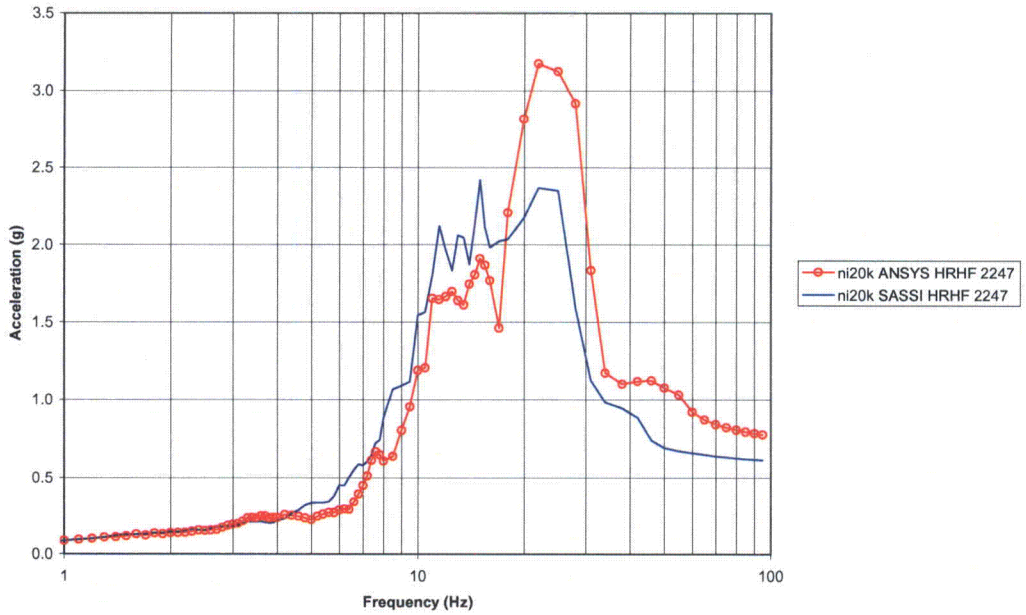


Figure RAI-SRP3.7.1-SEB1-08-10: Southeast Node NI20 2247 Direction-Z at elevation 135'

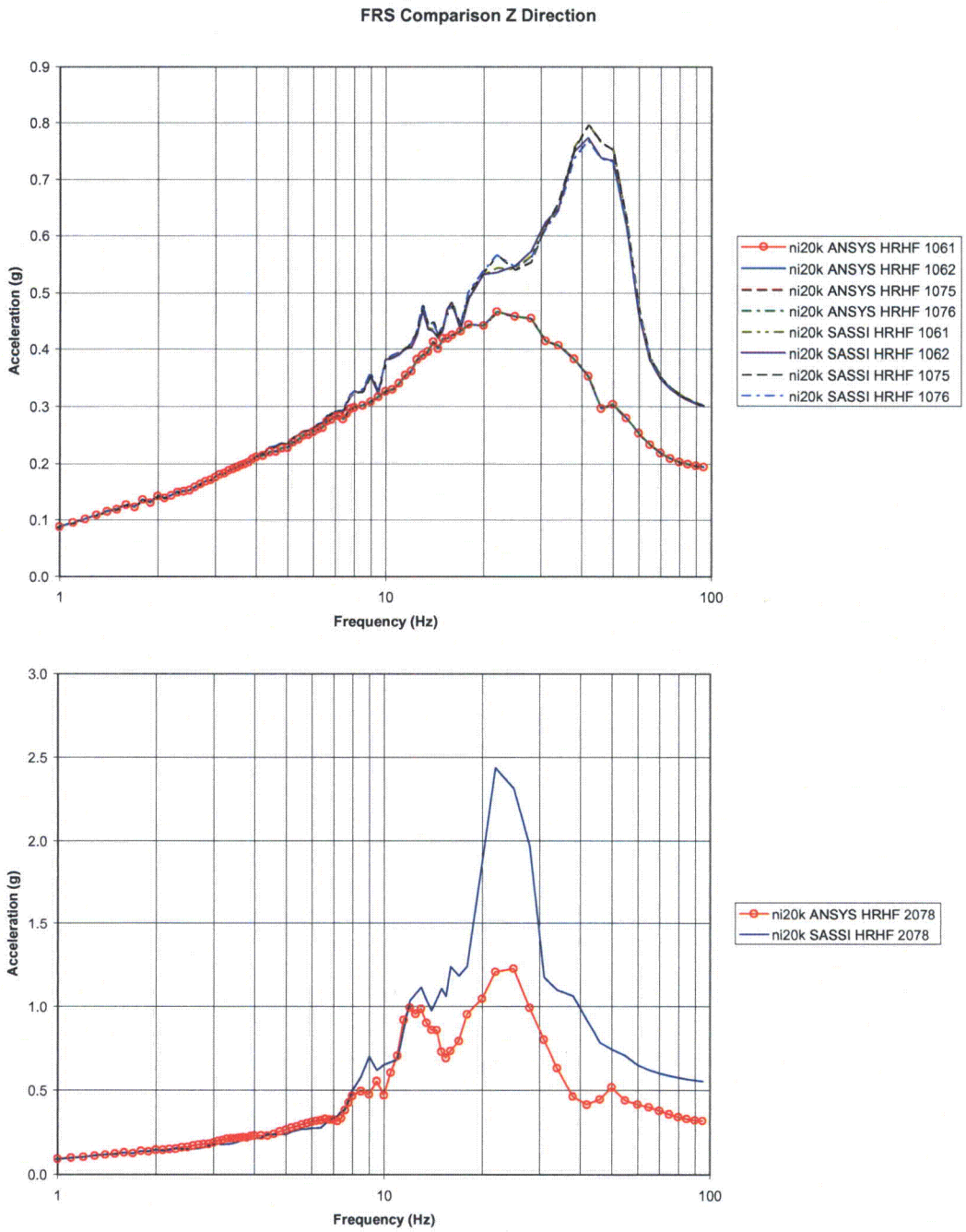


Figure RAI-SRP3.7.1-SEB1-08-11: Northeast Node NI20 2078 Direction-Z at elevation 116'

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revisions:

~~None~~The figures provided, RAI-SRP3.7.1-SEB1-08-1 to RAI-SRP3.7.1-SEB1-08-8, will be added to Section 5.1 of the TR-115 as Figures 5.1-4 and 5.1-5. Note that each figure will show the node location and the floor response spectra for the X, Y and Z locations.

(TR-115 Section 5.1 Last Paragraph)

A comparison between the fine mesh (NI10) model used for design and the NI20 model shows the adequacy of the NI20 model to represent building responses. This comparison is shown in Figures 5.1-1 to 5.1-~~3~~5 (5% damping). The response spectra from the two models compare closely, with the response spectra from the NI20~~,~~ being slightly more conservative in most cases. Figures 5.1-1 to 5.1-3 compare results from ANSYS. Figures 5.1-4 and 5.1-5 compare results from ANSYS and SASSI.

Add the following text to Section 5.1 at the end of the second to the last paragraph.

"The differences in Figure 5.1-7 and 5.1-8 are due to the differences in geometry between the NI10 and NI20 models at the Southeast and Northeast Corners."

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-09
Revision: 4

Question:

The staff noted that improved, more readable Figures 5.2-1 through 5.2-6 in TR-115 are needed. The ordinate scale and the legend cannot be read even by zooming in the electronic file. High resolution printing makes them barely readable. The staff requests that Westinghouse submit larger, readable copies of Figures 5.2-1 through 5.2-6, to facilitate the staff's evaluation of the information.

Additional Request (Revision 2):

The staff reviewed Westinghouse's responses to RAI-SRP3.7.1-SEB1-09 Rev.1, RAI-SRP3.7.1-SEB1-10 Rev.1, and RAI-SRP3.7.1-SEB1-11 Rev.1. The staff noted that the -10 figures add the coherent results to the incoherent results presented in the -09 response. The -11 response presents coherent, incoherent, and CSDRS comparisons for 2 additional locations (Nodes 2675 and 3067), and also repeats the -09 and -10 results for Node 2711. The staff noted that there is consistency of common information among the -09, -10, and -11 responses.

After review of the three (3) RAI responses and the information contained in the figures, the staff requests the following clarifications and additional information, to facilitate its further evaluation of the calculated reductions in FRS, obtained by considering the effects of incoherency:

(a) Explain why Node 2711 is included in the -11 response, considering that Node 2711 is also included in the -09 and -10 responses. Specifically identify any differences between the -11 results and the -09 and -10 results for Node 2711.

(b) Based on the data presented in Figures RAI-SRP3.7.1-SEB1-10-1 thru -21, the spectral acceleration ratio for coherent motion to incoherent motion is as high as 3. See Figure RAI-SRP3.7.1-SEB1-10-4 at 50 Hz, and Figure RAI-SRP3.7.1-SEB1-10 -6 at 40-50 Hz. A ratio of 2 is fairly common in other figures. Please provide the detailed technical basis for concluding that the calculated reductions are reasonable, and consistent with the expectations of the industry and staff experts that negotiated the ISG on this subject. Describe any independent peer review of Westinghouse's results.

(c) Based on the data presented in Figures RAI-SRP3.7.1-SEB1-10-1 thru -21, spectral acceleration reductions are calculated for frequencies as low as 6-10 Hz. See Figures RAI-SRP3.7.1-SEB1-10 -1, -2, -3, -17, -19, -20, -21. Please provide the detailed technical basis for concluding that the calculated reductions at low frequency are reasonable, and consistent with the expectations of the industry and staff experts that negotiated the ISG on this subject. Describe any independent peer review of Westinghouse's results.

(d) Even when the beneficial effects of incoherency are included, there are high-frequency exceedances at a number of the sample locations evaluated. See Figures RAI-SRP3.7.1-SEB1-10-4, -5, -6, -7, -8, -9, -12, -15, and Figure RAI-SRP3.7.1-SEB1-11-7. However, Westinghouse apparently has concluded that the worst-case exceedances have been determined, without expanding the sample size and evaluating additional locations. Please provide a detailed technical basis for concluding that the seismic response of AP1000 structures, systems, and components to the HRHF GMRS is enveloped by the response at the selected sample locations.

(e) Considering that the fundamental vertical vibration mode at the top of the shield building (El. 327') is around 6 Hz, it would be expected that the HRHF GMRS may excite a second vertical vibration mode. Figure RAI-SRP3.7.1-SEB1-09-01c: ASB at Elevation 327.4' Z Direction (Node 3345), and Figure RAI-SRP3.7.1-SEB1-10-3: ASB at Elevation 327.4' Z-Direction (Node 3329) do not show this behavior. Figure RAI-SRP3.7.1-SEB1-11-3: Seismic Response Spectra on Roof of Shield Building Z-Direction (Node 3067) does show a second amplified response for the HRHF GMRS at around 14 Hz. Provide a picture depicting the location of Nodes 3345, 3329, and 3067, and provide the technical explanation for the difference in results at these nodes.

(f) Based on the data presented in Figures RAI-SRP3.7.1-SEB1-10-1 thru -21, two (2) of the sample locations that Westinghouse selected for evaluation of the effects of the HRHF GMRS appear to be poor choices. In Figures RAI-SRP3.7.1-SEB1-10-1, -2, -3 [ASB at Elevation 327.4' (Node 3329)], and Figures RAI-SRP3.7.1-SEB1-10-19, -20, -21 [RCP at elevation 99' (Node 1757)], there is no evidence of high frequency excitation. This is inconsistent with a major criterion for selection of sample locations. Provide a detailed technical explanation for selection of these two (2) sample locations, especially in light of Westinghouse's argument for not including any sample locations in the steel containment shell (i.e., no high frequency excitation).

(g) The staff reviewed the spectral plots in Figures RAI-SRP3.7.1-SEB1-10-4, -5, -6 [Containment Operating Floor, East Side, Elevation 134.25' (Node 2136)], and Figures RAI-SRP3.7.1-SEB1-7, -8, -9 [Containment Operating Floor, West Side, Elevation 134.25' (Node 2170)]. The staff notes that these plots are also contained in TR 115 Rev. 1, Figure 5.2-2. The staff observed that the East Side and West Side y-direction spectra are very similar. However, the East Side and West Side x-direction spectra and the East Side and West Side z-direction spectra are very different, for the HRHF-coherent and HRHF-incoherent cases. The peak spectral accelerations are as follows for the HRHF-coherent and HRHF-incoherent cases:

Location	Direction	HRHF-coherent	HRHF-incoherent
East Side	X	1.6g (20 Hz)	1.05g (20 Hz)
West Side	X	3.5g (13 Hz)	2.8g (13 Hz)
East Side	Y	3.5g (16 Hz)	1.95g (16 Hz)

West Side	Y	3.7g (16 Hz)	2.05g (16 Hz)
East Side	Z	1.9g (40-50 Hz)	0.65g (40-50 Hz)
West Side	Z	3.2g (30 Hz)	1.7g (30 Hz)

The staff cannot determine the reason for this behavior. Provide a detailed technical explanation for these apparently inconsistent results.

Additional Request (Revision 3):

It is requested that Westinghouse revise the response to parts d and f addressing Screening & Selection of Key Locations reported in TR115.

Additional Request (Revision 4):

It is requested that Westinghouse indicates how exceedances of CSDRS-based ISRS by HRHF-based ISRS will be addressed in the Technical Report 115 (TR115) Section 5.2 and provide a comparison of ISRS for CSDRS and HRHF input motion in Figures 5.2-1 through 5.2-6 in TR115.

Westinghouse Response (Revision 0 & 1):

The requested figures are found in Figures RAI-SRP3.7.1-SEB1-09-01a to RAI-SRP3.7.1-SEB1-09-06c. These figures will replace the Figures 5.2-1 through 5.2-6 in the next revision to TR-115. See also RAI-SRP-3.7.1-SEB1-10 and RAI-SRP-3.7.1-SEB1-11.

Westinghouse Response (Revision 2):

a) There are no differences in Node 2711 results given in -11 from those given in -09 and -10. The node was included responding to the various requests made by the NRC as noted below:

- The figures included in RAI-SRP3.7.1-SEB1-09, Rev.1 are in response to "The staff requests that Westinghouse submit larger, readable copies of Figures 5.2-1 through 5.2-6, to facilitate the staff's evaluation of the information."

- The figures included in RAI-SRP3.7.1-SEB1-10 Rev. 1 are in response to "The staff requests that Westinghouse augment Figures 5.2-1 through 5.2-6 in TR-115, by adding the HRHF broadened spectra from the NI20 fixed base analysis, without any

reduction for incoherency or other considerations." The coherent curves are added for all the nodes 2136, 2170, 2341, 2669, 2711 and 1757. Node 3345 is replaced by node 3329 because coherent data were not available for node 3345. Node 3345 is at west corner and node 3329 is at the south corner of the ASB at elevation 327.4' as shown in Figure RAI-SRP3.7.1-09-A in item (e) below.

- The figures included in RAI-SRP3.7.1-SEB1-11, Rev. 1 are in response to the request to provide additional incoherent and coherent comparison response spectra.

b) SASSI-Simulation incoherency approach used to generate the seismic response spectra is in accordance with Section 4, subsection 1.0 of "Interim Staff Guidance (ISG) on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combine License Applications" supplements to Section 3.7.1, "Seismic Design Parameters," of NUREG-0800. In generating the seismic response spectra Westinghouse made no changes to the accepted industry methodology. The technical basis for incoherence is discussed in EPRI report 1012966, "Effect of Seismic Wave Incoherence on Foundation and Building Response," Dec. 2005. Similar results were shown in Figure 6-1 to 6-11 of EPRI report 1012966. Figure 6-12 showed 5 times reduction at 50 Hz.

c) See b) above. Figure 6-6 of EPRI report 1012966 showed the similar reduction at 10 Hz.

d) Westinghouse had agreed to evaluate a representative sample of SSCs located in areas that are subject to high frequency response, and have frequency content in the high frequency region, to confirm that high frequency seismic input is not damaging, and to demonstrate that normal design practices using the Certified Seismic Design Response (CSDRS) result in an AP1000 design that is safer and more conservative. This evaluation is reported in TR 115. The SSCs selected based on the screening criteria are sufficient to demonstrate that high frequency seismic events are not damaging. There may be spectra that have higher exceedances; however safety related equipment may not be located in these locations, SSCs located in these areas may not have high frequency response, and further the evaluation performed demonstrate that the HRHF seismic event is not damaging and there is margin between the CSDRS and HRHF response. Westinghouse evaluation approach is in compliance with Section 4, subsection 3.0 and 4.0 of the "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," ML081400293.

   i. 3.1 Structure Modeling:
   Section 5.1 is used to demonstrate the SASSI NI20 Model is adequate for ISG 3.1.1 "The range of HF to be transmitted should cover a model refinement frequency of at least equal to 50 Hz." RAI-SRP3.7.1-SEB1-6, Rev.2 further

demonstrates the adequacy of the SASSI NI20 model. Two additional figures are added in TR115 (figure 5.1-7 and 5.1-8) to demonstrate the responses up to 50 Hz as requested in the NRC review meeting.

ii. 3.2 Evaluation of SSCs other than HF Sensitive Mechanical and Electrical Equipment and Components
Section 5.2 is used to demonstrate the HRHF responses do exceed the CSDRS in several locations; this is under ISG 3.2.2 "For those cases where the GMRS/FIRS-based ISRS exceed the CSDRS-based ISRS below 50 Hz, further structure structural integrity and functionality evaluations are required." Section 6.0 of TR115 is in compliance with ISG 3.2.2 for further structural integrity and functionality evaluations.

iii. 3.2.3 If a screening approach is used, the following information will be provided.

3.2.3.1 The selection criteria "safety significance, location in the vicinity of the HF response, potential for significant effects of rotational components, and significant increase in forces on supports and anchorage of rigid equipment."

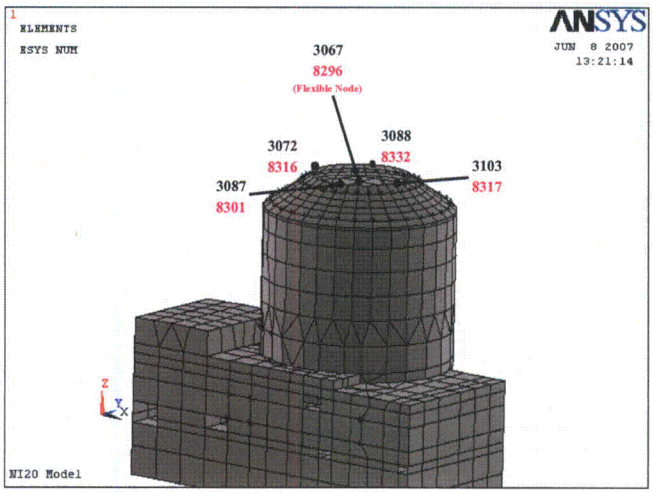
Section 6.0 is based on the screening criteria. Three groups of SSCs are selected: Building Structure, Primary Equipment, and Piping systems.

iv. 3.2.3.2 For selected SSCs, describe the evaluation methodologies (including selection of failure modes) used for the assessment and their basis.

1. Section 6.1 Building Structures are analyzed according to the parameters provided in 3.2.3.2. Based on the analysis result and additional analysis for SCV provided in RAI-SRP3.7.1-SEB1-04, Rev. 2, the following conclusion is reached as stated in the RAI. "Westinghouse has selected an adequate sample of structure locations for demonstrating that the AP1000 structure responses due to the HRHF GMRS are enveloped by the structure responses due to the CSDRS."
2. Section 6.2 Primary Coolant Loop is analyzed according to the parameters provided in 3.2.3.2. The analysis result showed that CSDRS cases are bounding at all Primary Coolant Loop system.
3. Section 6.3 Piping Systems are analyzed according to the parameters provided in 3.2.3.2. The conclusion is in Section 6.3.4.

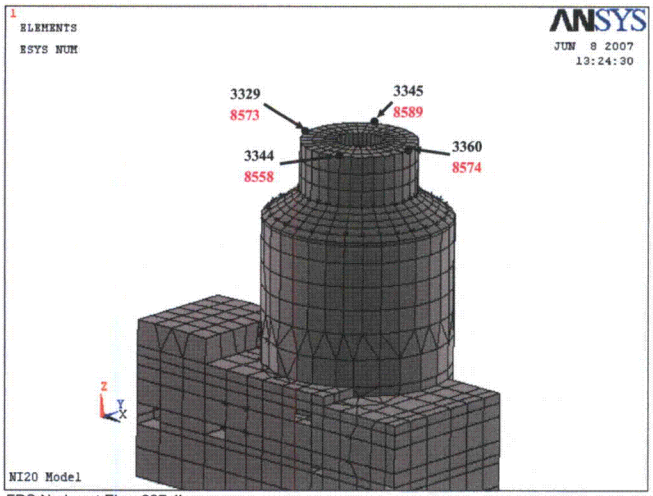
v. 4.0 Identification and Evaluation of HF Sensitive Mechanical and Electrical Equipment/Components.
Section 6.4 Safety-Related Electrical Equipment is in complying with ISG section 4.0.

e) Figures RAI-SRP3.7.1-09-A and RAI-SRP3.7.1-09-B show the location of the three nodes 3067, 3329, and 3345. Node 3067 shown in Figure RAI-SRP3.7.1-09-A is at flexible area (response in 14 Hz region) that is not influenced by rocking motion as much as nodes 3329 and 3345.



FRS Nodes at Elev. 289.2'

Figure RAI-SRP3.7.1-09-A: FRS nodes at Elevation 289.2'



FRS Nodes at Elev. 327.4'

Figure RAI-SRP3.7.1-09-B: FRS nodes at Elevation 327.4'

f) The seismic response spectra were provided to respond to the NRC request to show HRHF broadened spectra with coherent and incoherent considerations. Westinghouse provided response spectra where these comparisons were available. Some of these locations show that the high frequency response does not transmit to these areas. In some of the Figures in RAI-SRP3.7.1-SEB1-10-1 thru -21 shows that some structures

will transmit the high frequency vibration and some structures will not transmit the high frequency vibration because the major frequency content is below 10 Hz. For example, Figures RAI-SRP3.7.1-SEB1-10-1, 2 and 3 (Node 3329 located on top of the shield building) show that the HRHF GMRS does not excite the shield building. Westinghouse followed the screening criteria given in TR115 and DCD 3I.5, Revision 17. The SSCs evaluated must be in an area of high frequency response which exceeds the CSDRS floor response spectra. The spectra associated with RCP demonstrate that the HRHF seismic response has been filtered and the CSDRS does envelope. The RCP was not chosen for evaluation, the reactor internals and primary coolant loop supports and nozzles were evaluated (TR 115, Section 6.2). These areas are subject to high frequency response that exceeds the CSDRS as seen in Figure 5.2-2 in TR 115. See RAI-SRP3.7.1-SEB1-04, Rev. 2, for a discussion of the SCV.

g) Figure RAI-SRP3.7.1-09-C show the location of nodes 2136 and 2170. Node 2170 is surrounded by a large semi-circle IRWST water tank while node 2136 is surrounded by concrete structure floor and steam generator compartment wall. Node 2136 showed more interaction in X and Z direction between the containment internal structures. The responses of both nodes in Y direction are similar because of less structure interaction between the steam generator compartment wall and other concrete structure. The differences between coherent and incoherent responses are justified in b) and c) above.

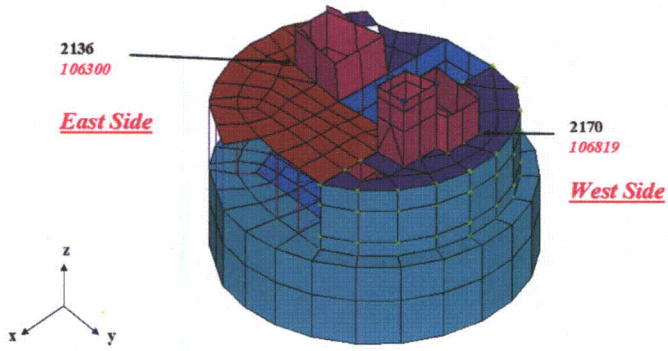


Figure RAI-SRP3.7.1-09-C: Containment Operating Floor (Elevation 134.25')

Westinghouse Response (Revision 3):

d) In the hard rock high frequency evaluation documented in Technical Report 115, it was not the intent of Westinghouse to ensure that the worst-case exceedances be determined. The evaluation of the AP1000 nuclear island for high frequency input is based on the analysis of a representative sample of structures, components, supports, and piping to demonstrate that the high frequency seismic response is non-damaging. This evaluation included:

- Since the integrity of the reactor coolant system is of primary safety concern, portions of the primary coolant loop are evaluated. The reactor internals, primary component supports, and nozzles were evaluated.

- Two piping systems were considered in the evaluation. The selection of the piping systems required that: the HRHF input spectra have exceedances relative to the AP1000 CSDRS spectra; have modes with significant participating mass in the frequency range of spectra exceedances; and include valve or other concentrated masses that would require closely spaced supports and therefore, cause high local natural frequencies. A presentation was given to the NRC during the April 13-17, 2009 audit that detailed the selection process. This presentation has been provided to the NRC.

- From the assessment of the safety related electrical equipment it was concluded that Electro-Mechanical Equipment sensitive to high frequency seismic input must be qualified by test to the HRHF seismic response spectra. This equipment is identified in Appendix 3I of the AP1000 DCD (Revision 17). A presentation was given to the NRC during the April 13-17, 2009 audit that provided additional details related to the seismic testing qualification process. This presentation has been provided to the NRC.

- Representative areas related to the Nuclear Island building structures were evaluated. In item f below is provided the process used to select these locations.

f) Specific areas of the Nuclear Island Building structures were chosen for evaluation that are subject to high frequency response. The process used is given below:

- The representative portions of the building structures evaluated must be excited by the seismic excitation resulting in relatively high seismic loads.

- The locations selected for evaluation are representative of other regions within the building structures so that the selected evaluation sample represents the Nuclear Island building complex.

- The areas of the building structures are selected that are subject to high frequency response. These areas are bottom of walls, in the vicinity of floors that are influenced by high frequency response, and corner intersections of walls.

- The portions of the building structures evaluated must have HRHF seismic response spectra that are higher than the spectra associated with the CSDRS. This is judged from the seismic response spectra in the vicinity of the area evaluated.

- The largest HRHF response with exceedances above the CSDRS for the Auxiliary Building is in the lower elevations. Higher up in the Auxiliary Building the HRHF response is not that significant, with small exceedances.

- The HRHF response in the Shield Building has some CSDRS exceedances at elevation 135' that decreases to very small to none in the higher elevations.

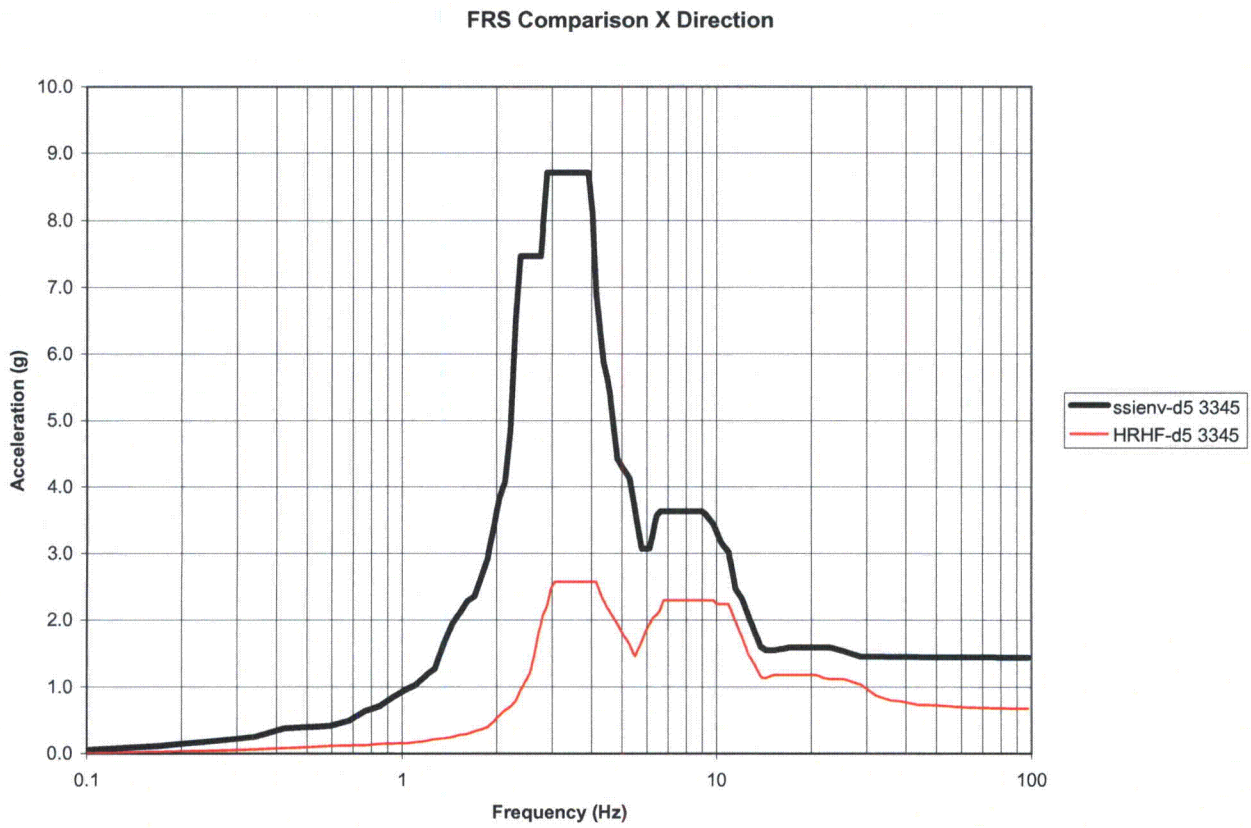
- The Containment Internal Structure has significant HRHF response whose spectra exceed the CSDRS spectra.

- In all cases evaluated for the Nuclear Island Building Structures the HRHF seismic loads were one-third to one-half of the CSDRS response. This is consistent with the industry position expressed in Reference 1 that the high frequency seismic excitation is not damaging to structures.

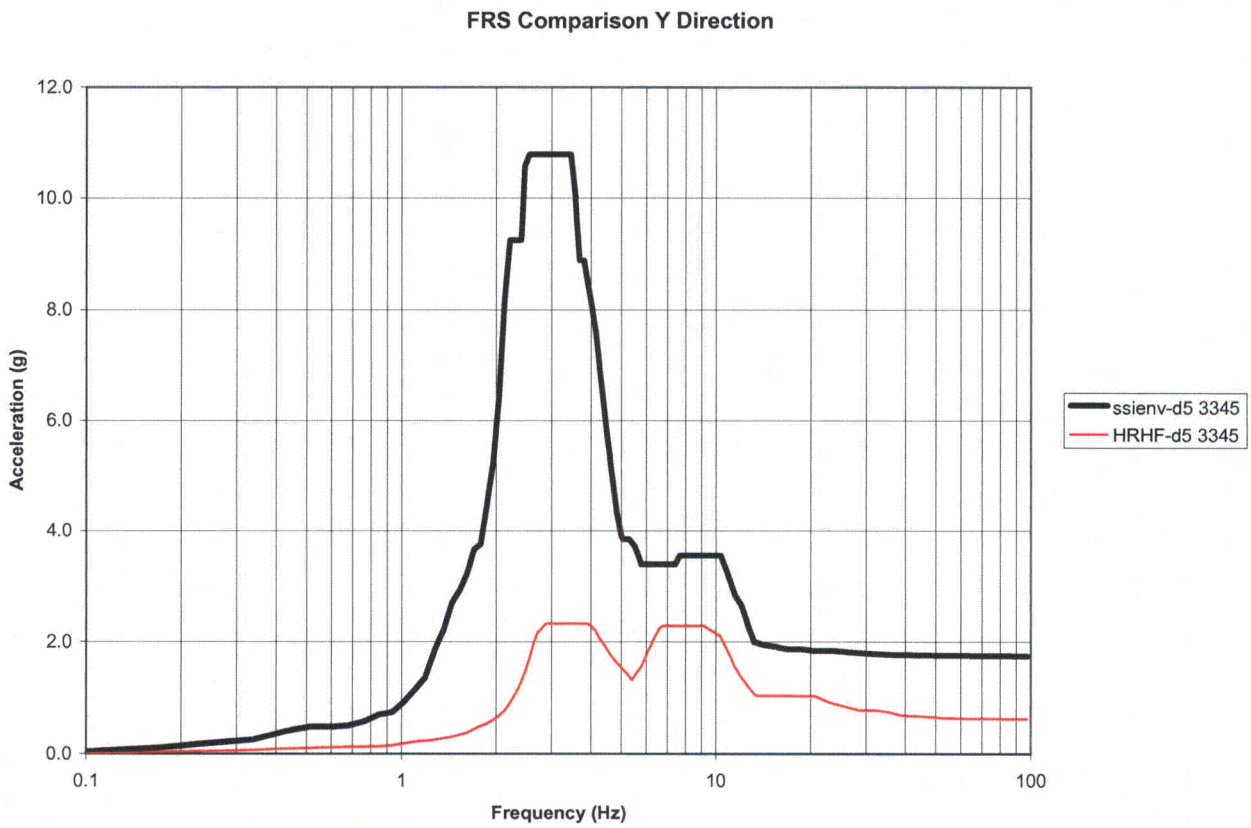
Westinghouse Response (Revision 4)

In response to an NRC request, a statement will be added to Technical Report 115 (TR115) to indicate how exceedances of CSDRS-based ISRS by HRHF-based ISRS are addressed and provide a comparison of ISRS for CSDRS and HRHF input motion in Figures 5.2-1 through 5.2-6 in TR115. The language to be added in TR115 (end of Section 5.2) is shown below.

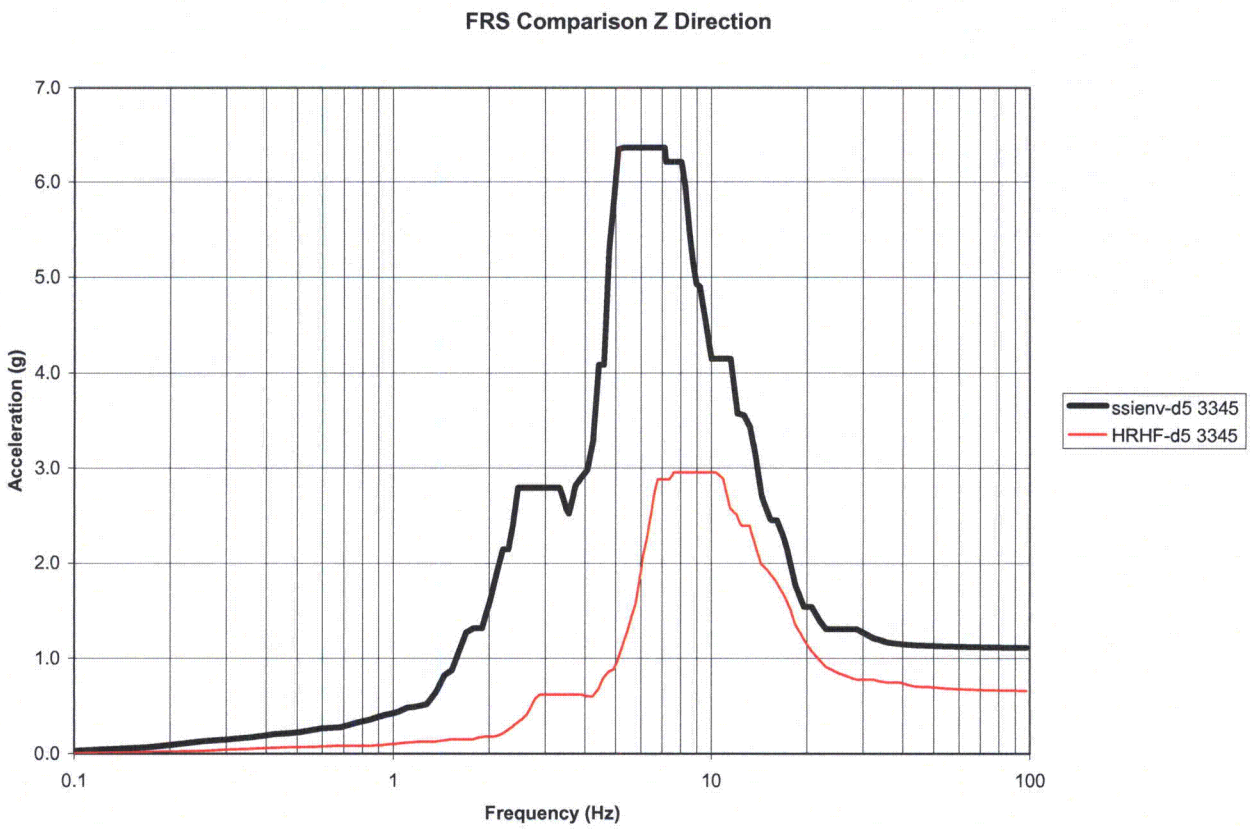
"The exceedances of CSDRS-based ISRS by HRHF-based ISRS are addressed as part of the sampling evaluation documented in this report to confirm that high frequency input has marginal effect on equivalent piping, and structures qualified by analysis for the AP1000 CSDRS."



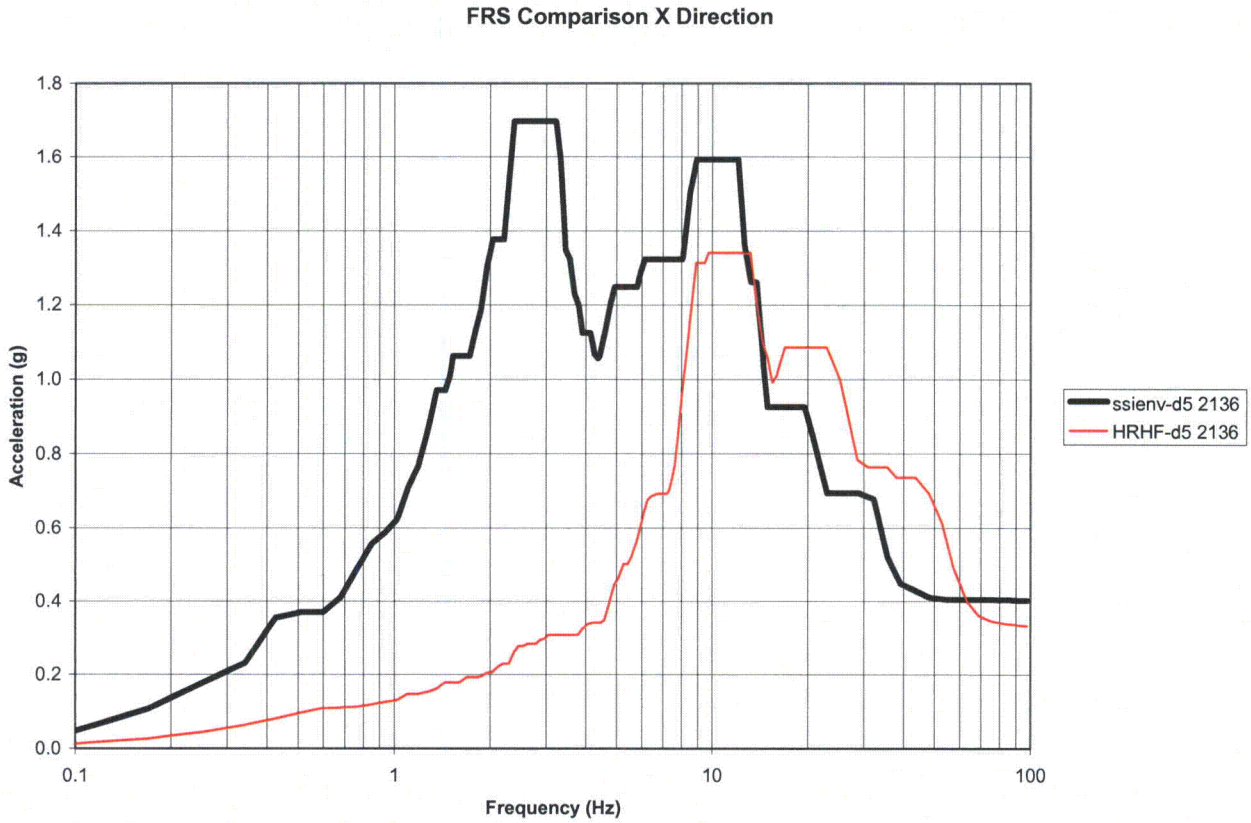
RAI-SRP3.7.1-SEB1-09-01a: ASB at Elevation 327.4' X Direction



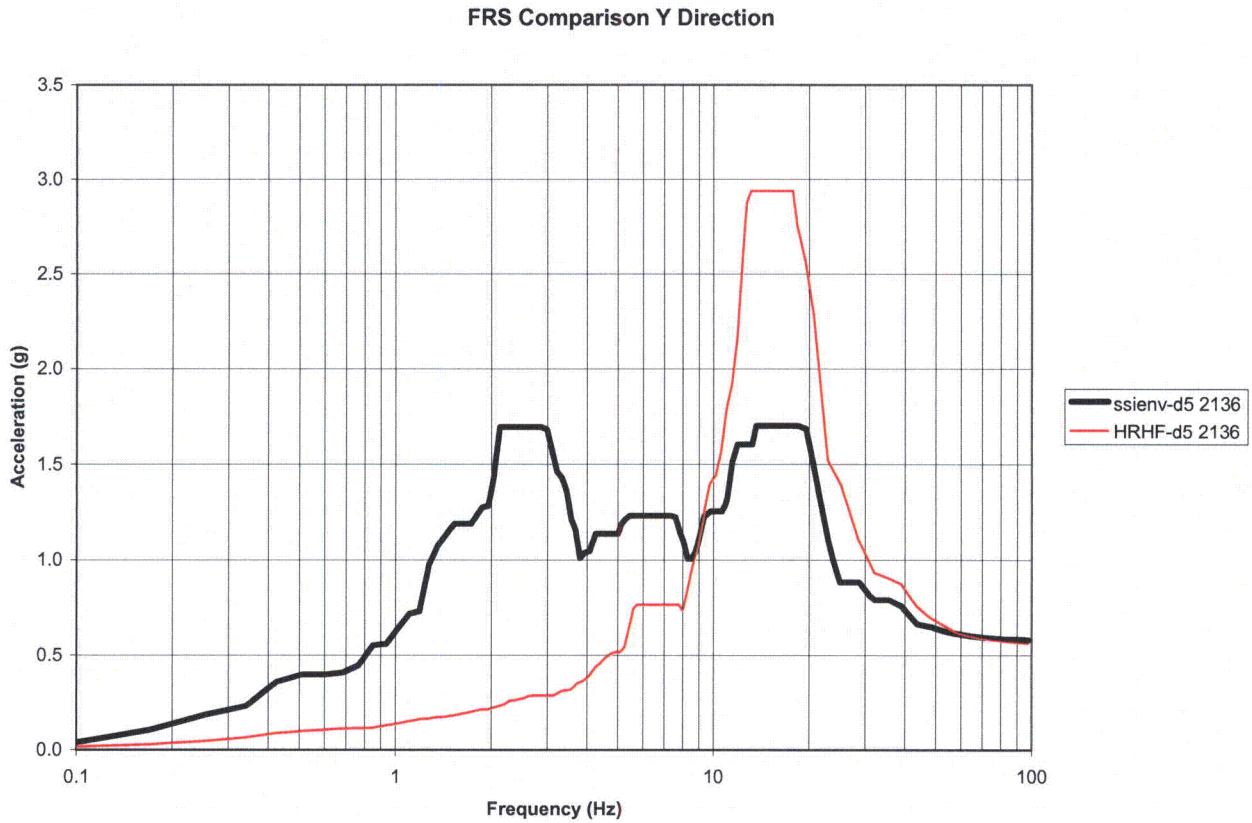
RAI-SRP3.7.1-SEB1-09-01b: ASB at Elevation 327.4' Y Direction



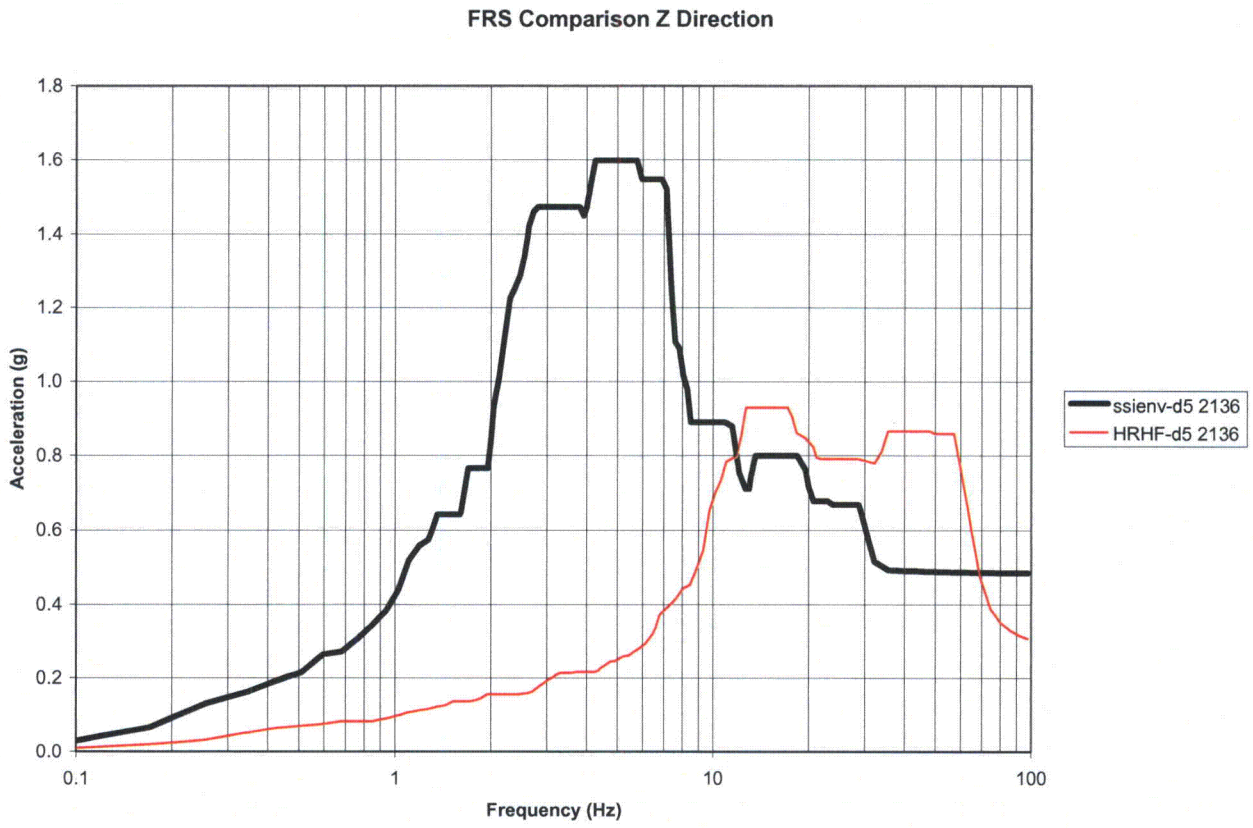
RAI-SRP3.7.1-SEB1-09-01c: ASB at Elevation 327.4' Z Direction



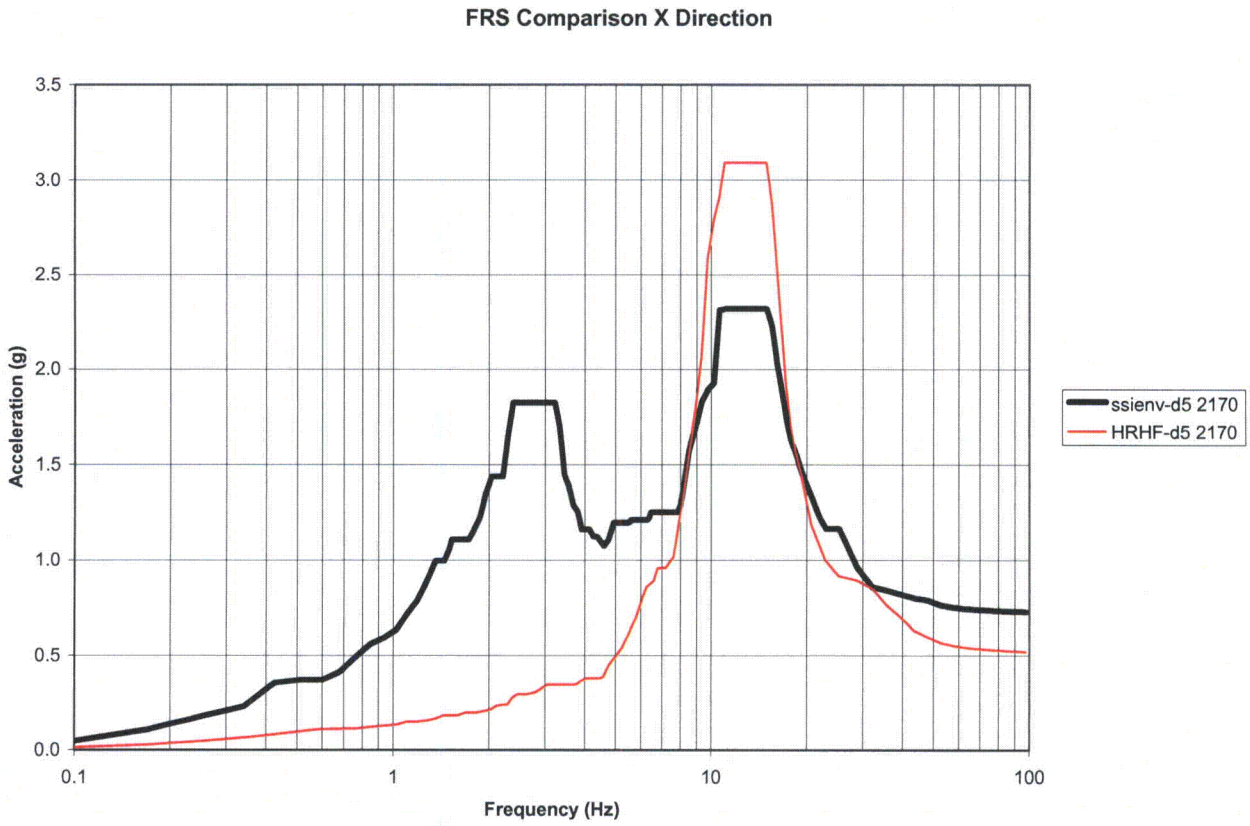
RAI-SRP3.7.1-SEB1-09-02 Ea: Containment Operating Floor (Elevation 134.25')
East Side X Direction



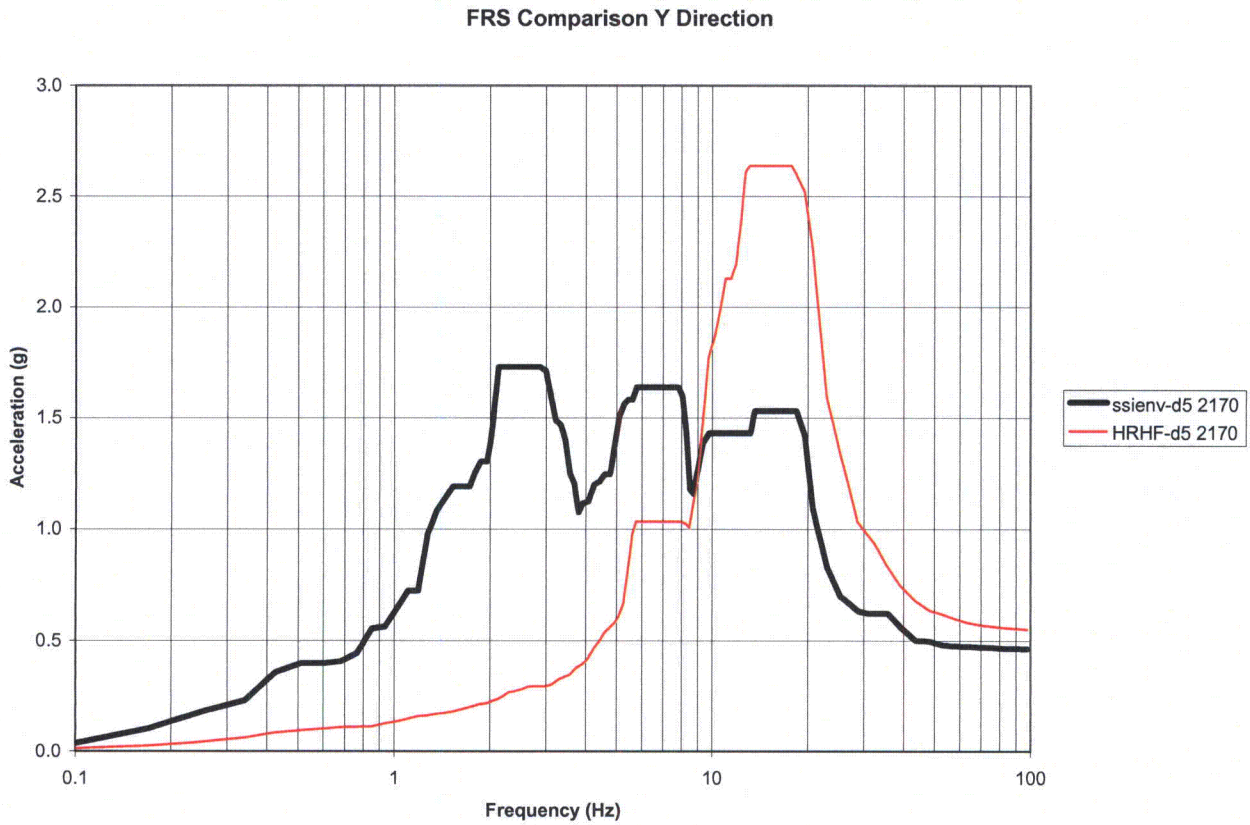
RAI-SRP3.7.1-SEB1-09-02 Eb: Containment Operating Floor (Elevation 134.25')
East Side Y Direction



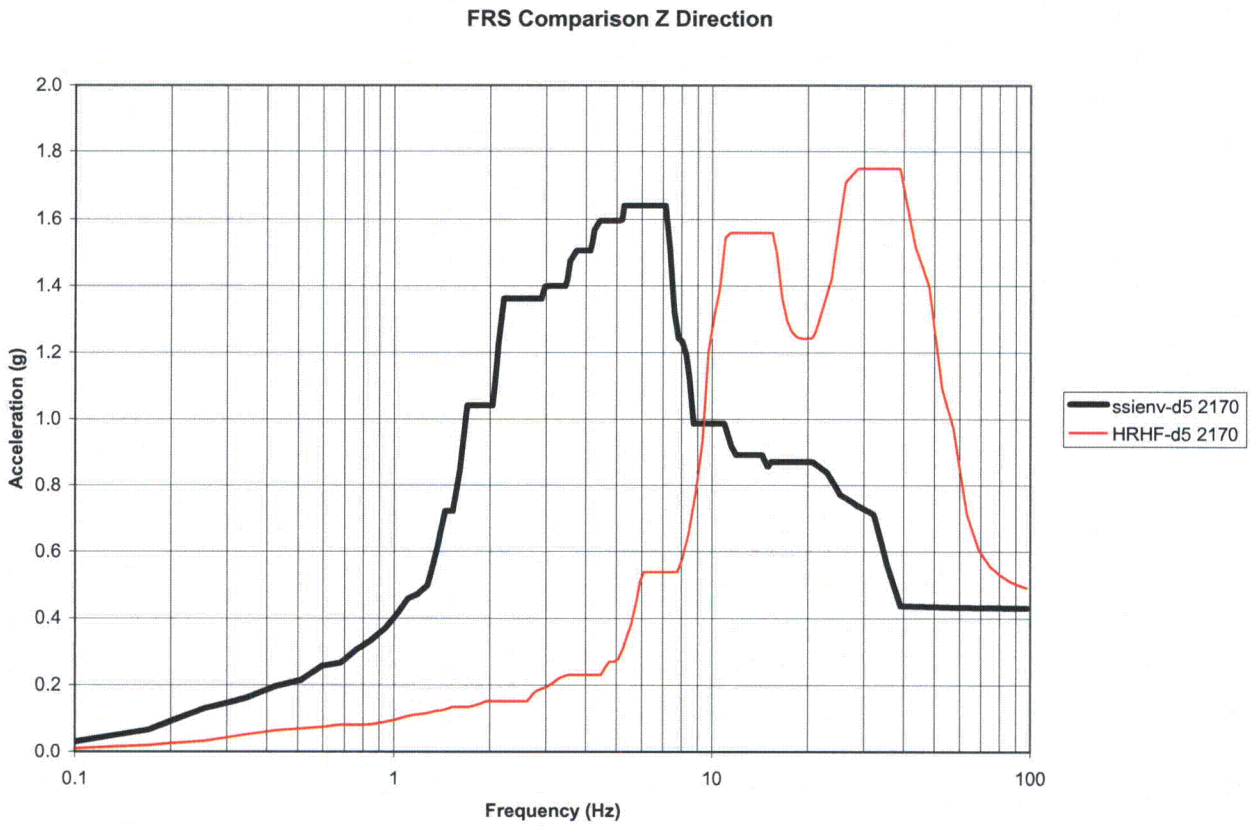
RAI-SRP3.7.1-SEB1-09-02 Ec: Containment Operating Floor (Elevation 134.25')
East Side Z Direction



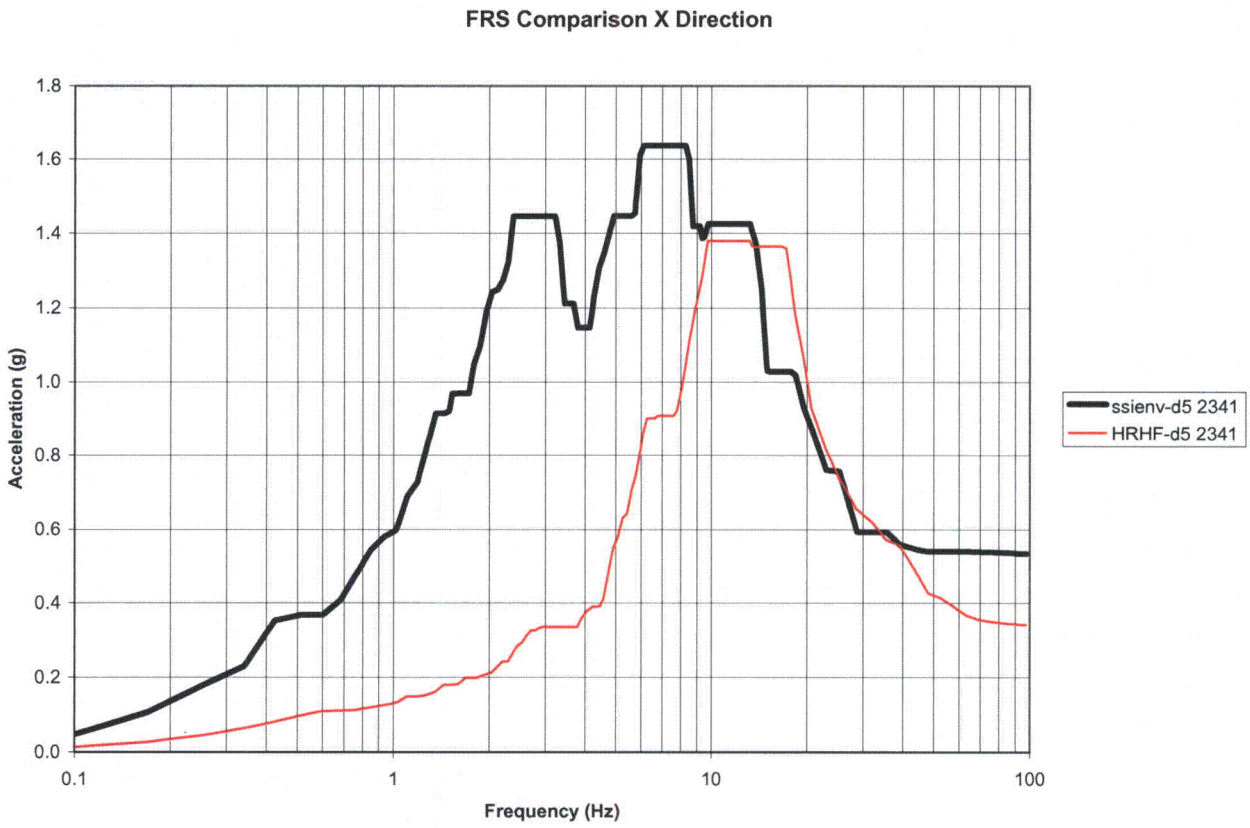
RAI-SRP3.7.1-SEB1-09-02 Wa: Containment Operating Floor (Elevation 134.25')
West Side X Direction



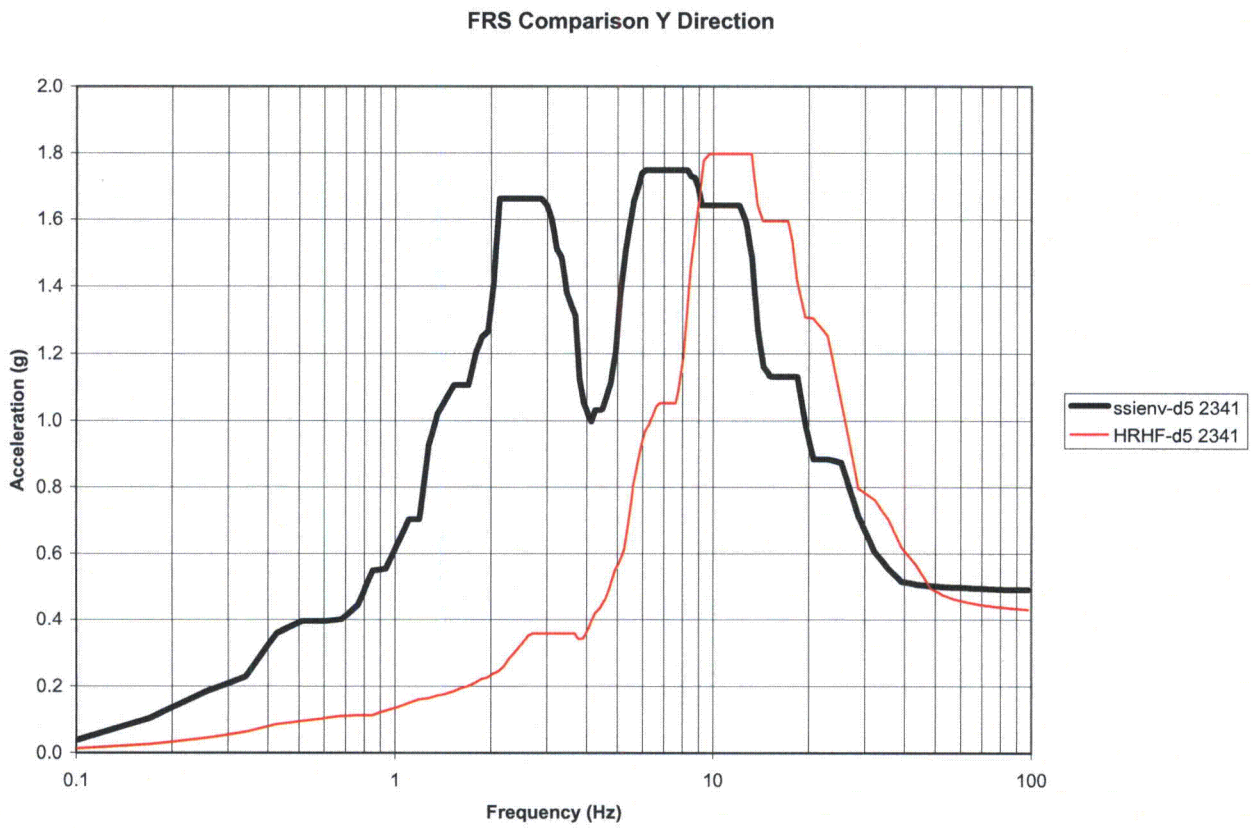
RAI-SRP3.7.1-SEB1-09-02 Wb: Containment Operating Floor (Elevation 134.25')
West Side Y Direction



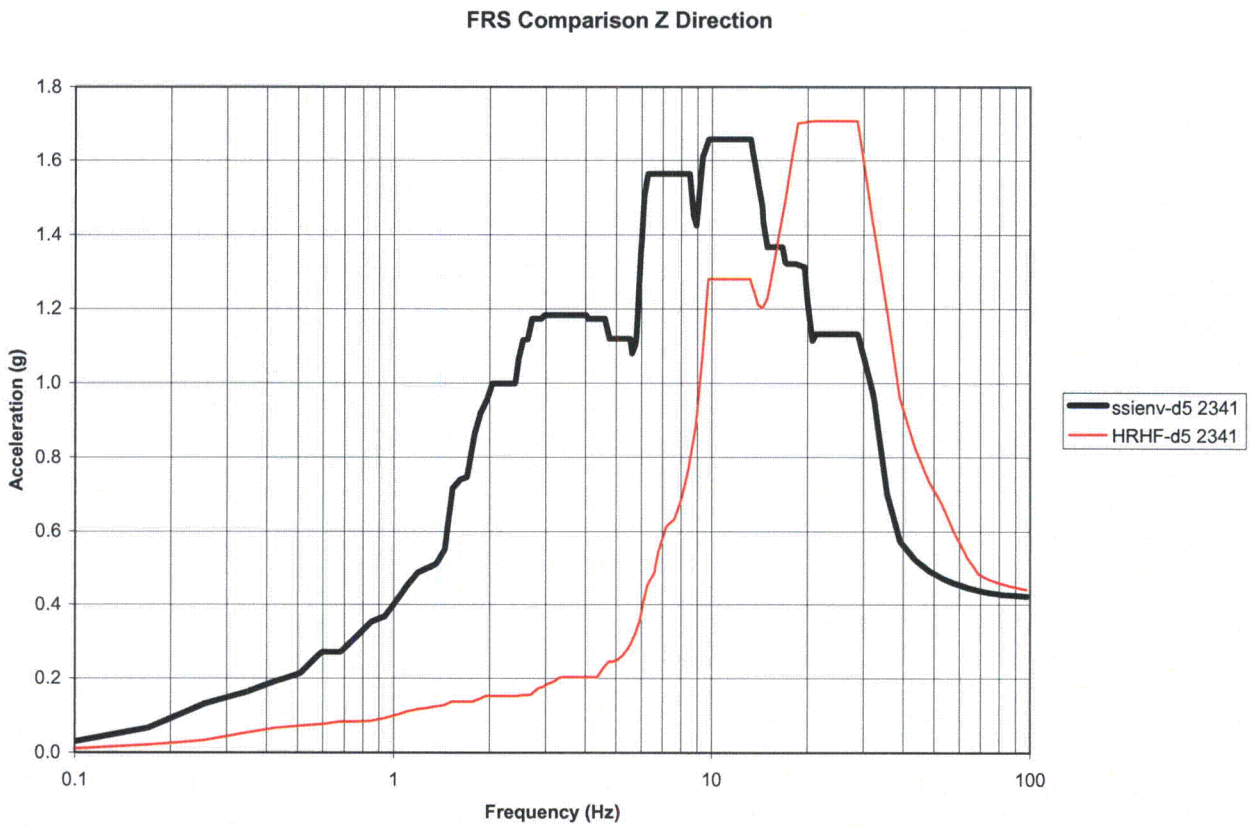
RAI-SRP3.7.1-SEB1-09-02 Wc: Containment Operating Floor (Elevation 134.25')
West Side Z Direction



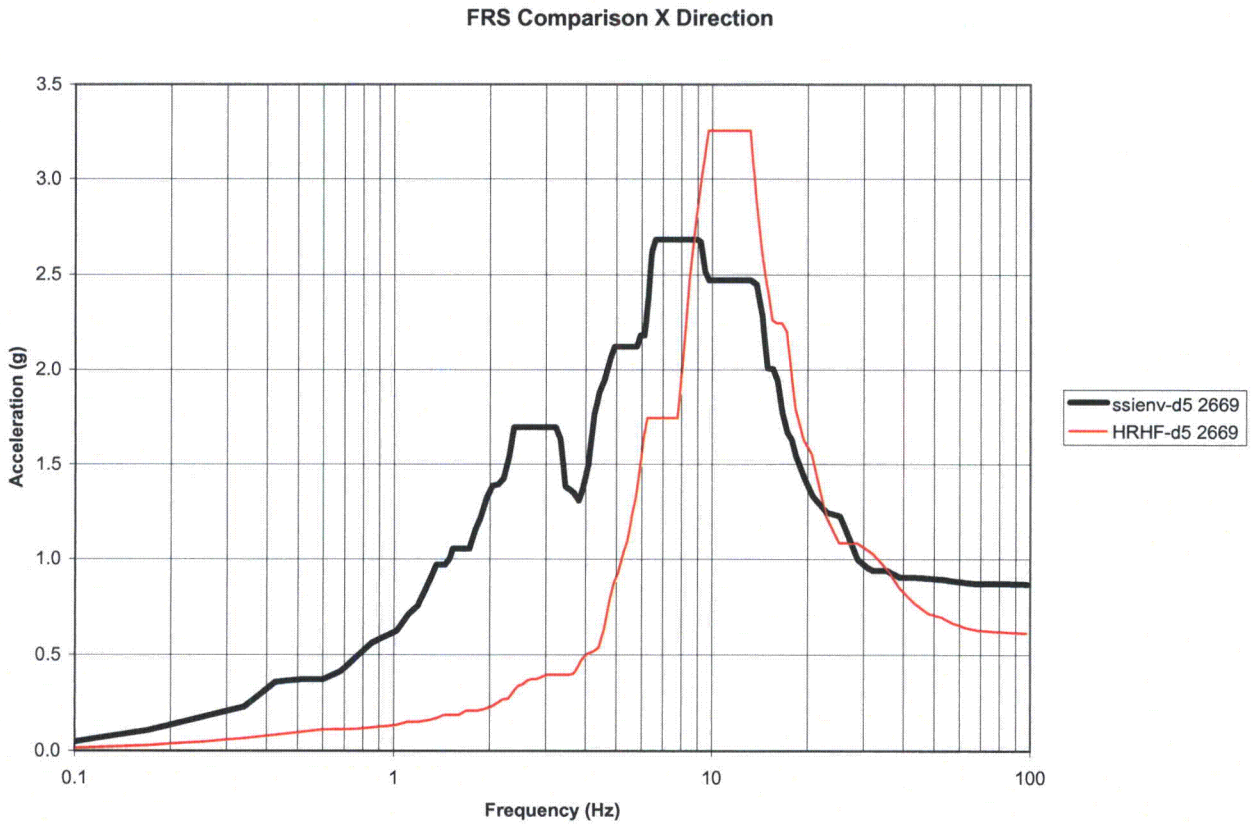
RAI-SRP3.7.1-SEB1-09-03a: ASB at Northeast Corner (Elevation 134.5') X Direction



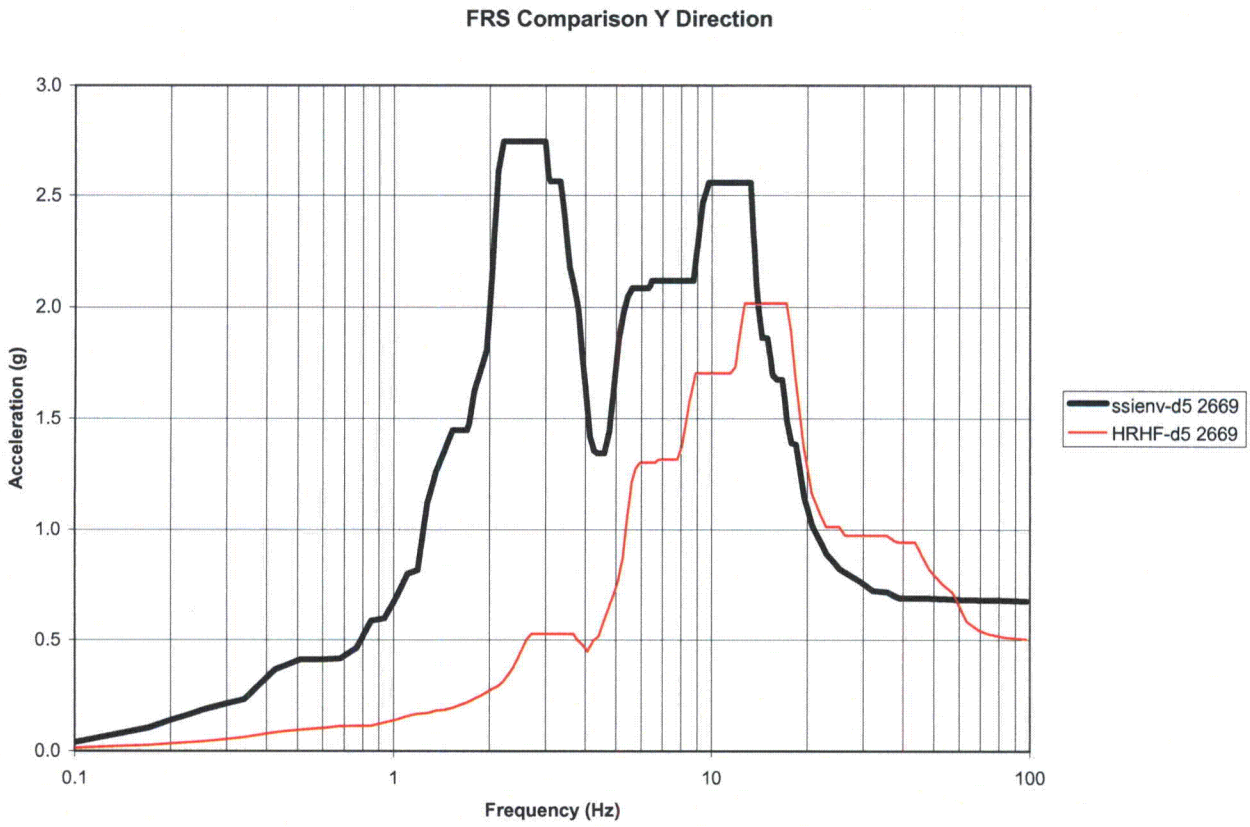
RAI-SRP3.7.1-SEB1-09-03b: ASB at Northeast Corner (Elevation 134.5') Y Direction



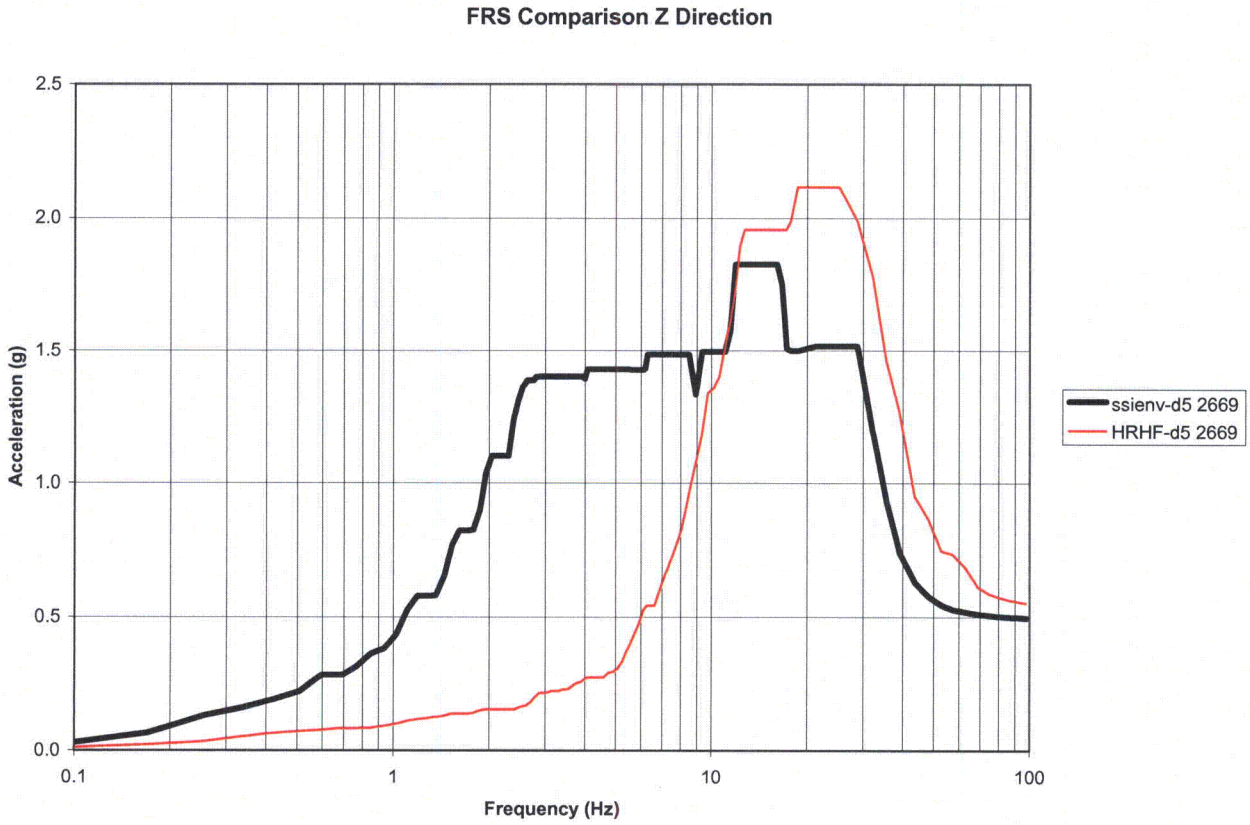
RAI-SRP3.7.1-SEB1-09-03c: ASB at Northeast Corner (Elevation 134.5') Z Direction



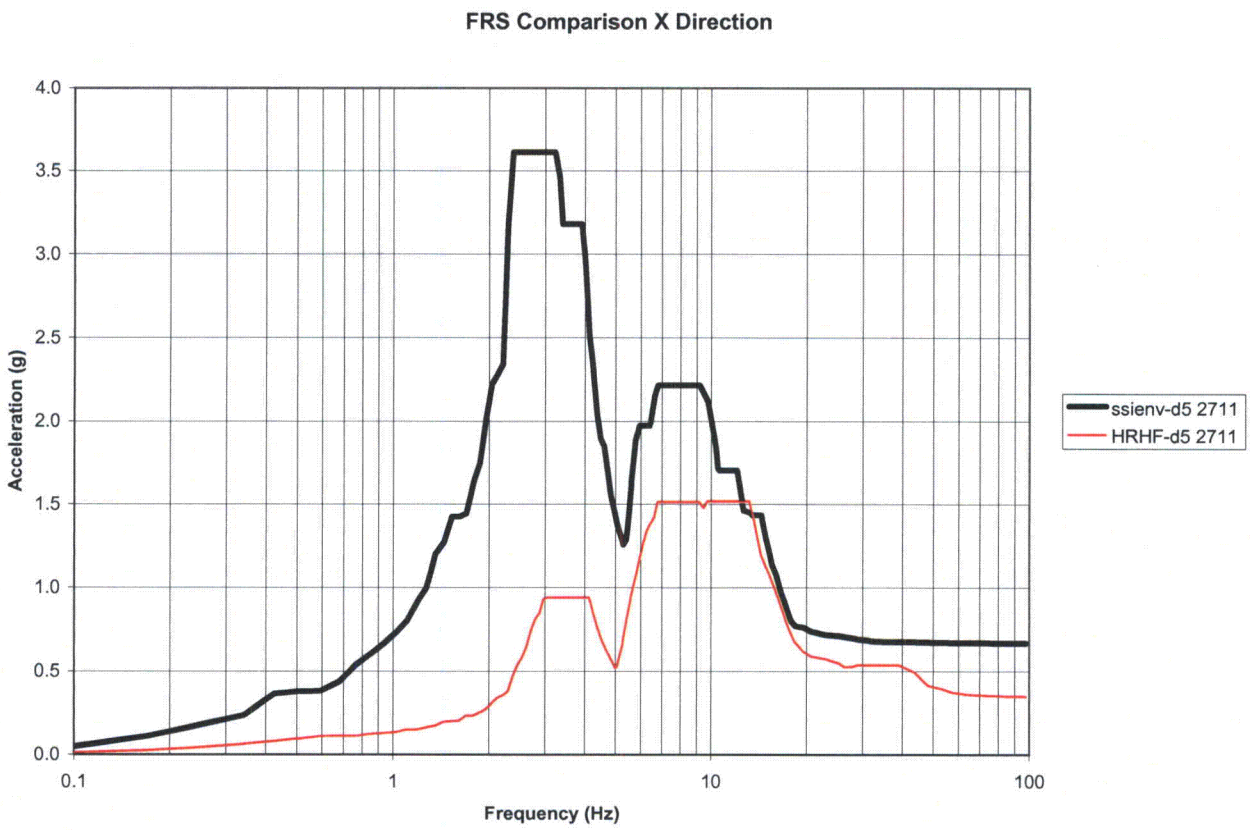
RAI-SRP3.7.1-SEB1-09-04a: ASB at Fuel Building Roof (Elevation 179.56') X Direction



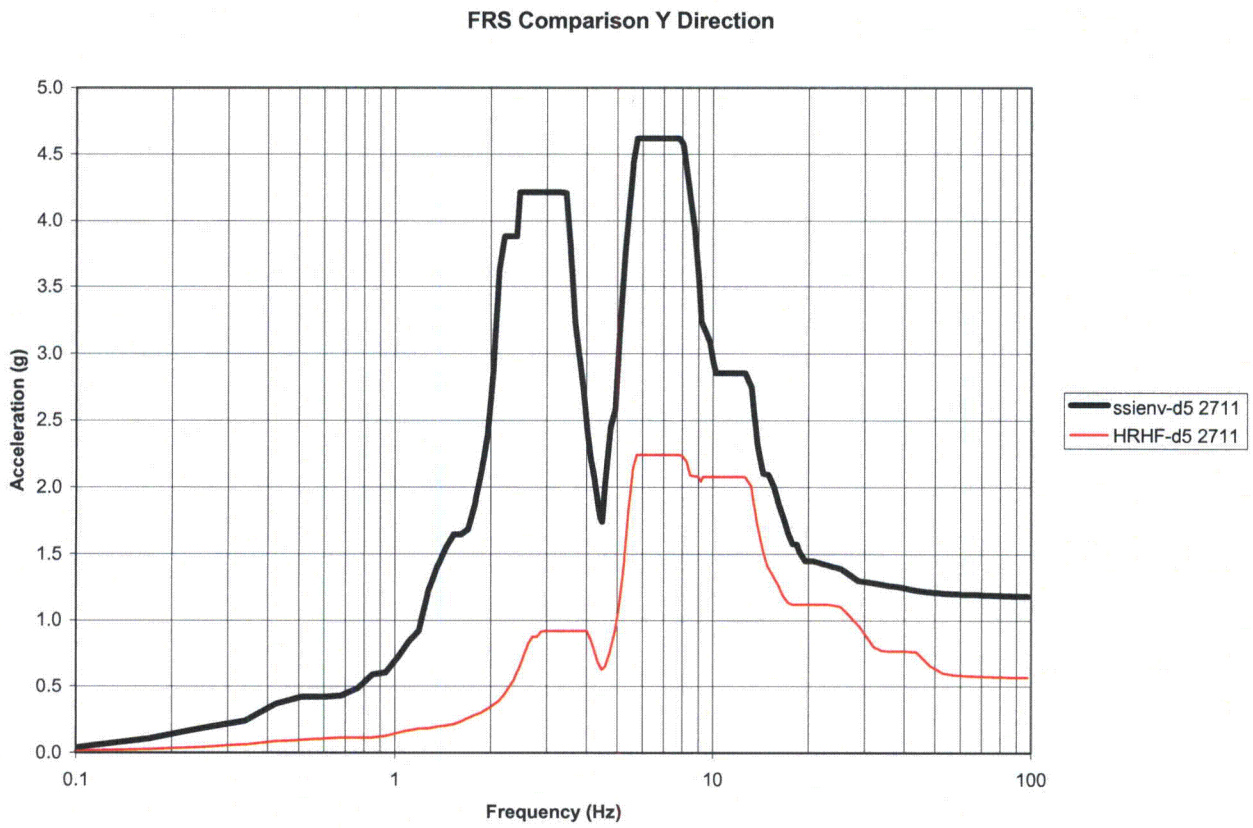
RAI-SRP3.7.1-SEB1-09-04b: ASB at Fuel Building Roof (Elevation 179.56') Y Direction



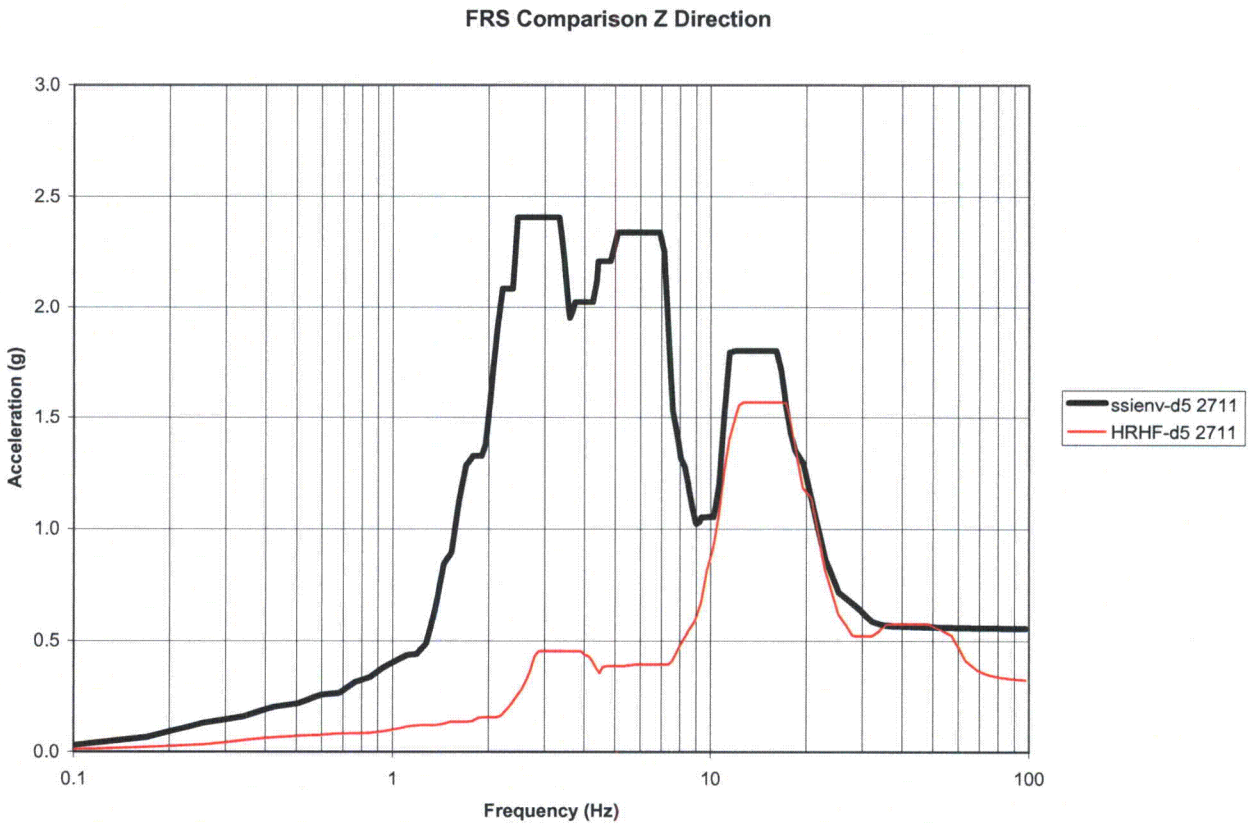
RAI-SRP3.7.1-SEB1-09-04c: ASB at Fuel Building Roof (Elevation 179.56') Z Direction



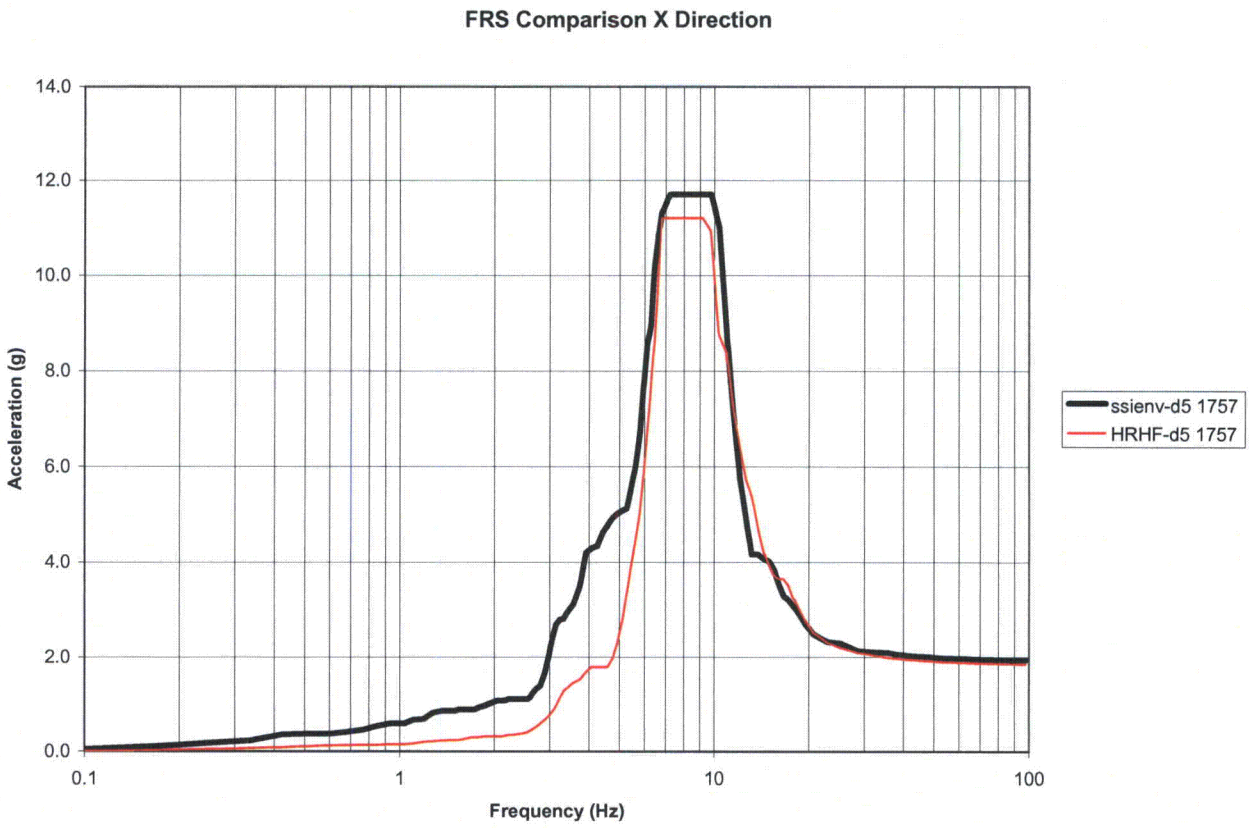
RAI-SRP3.7.1-SEB1-09-05a: ASB Shield Building (Elevation 180') X Direction



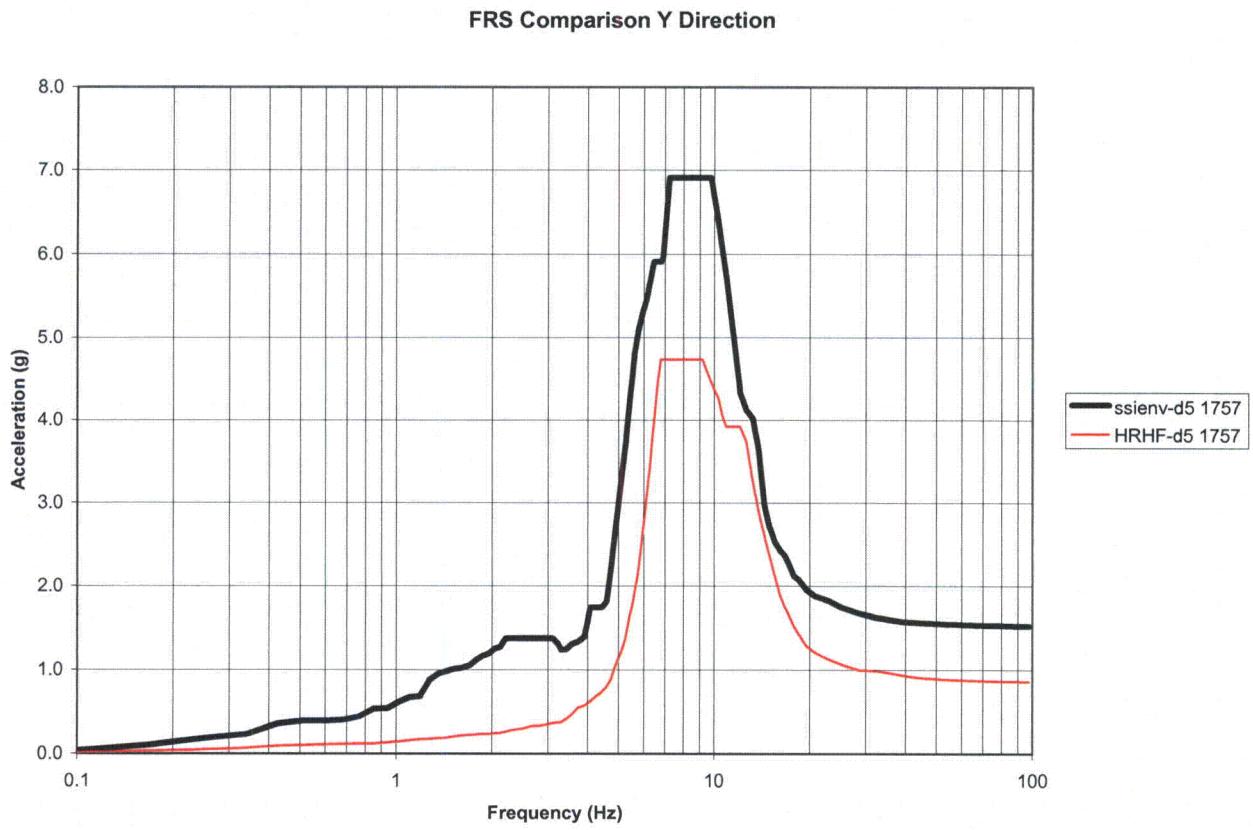
RAI-SRP3.7.1-SEB1-09-05b: ASB Shield Building (Elevation 180') Y Direction



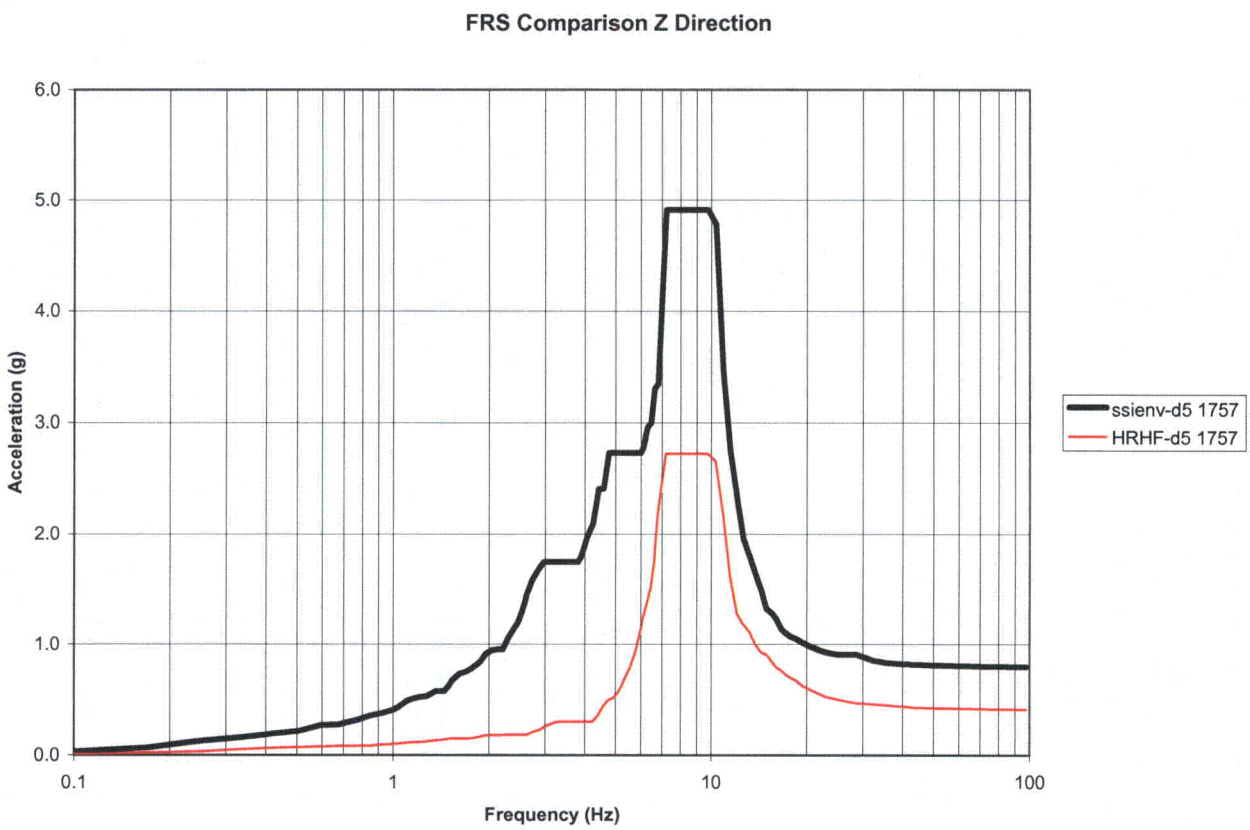
RAI-SRP3.7.1-SEB1-09-05c: ASB Shield Building (Elevation 180') Z Direction



RAI-SRP3.7.1-SEB1-09-06a: Reactor Coolant Pump X Direction



RAI-SRP3.7.1-SEB1-09-06b: Reactor Coolant Pump Y Direction



RAI-SRP3.7.1-SEB1-09-06c: Reactor Coolant Pump Z Direction

Reference(s):

~~None~~

1. EPRI Draft White Paper, "Considerations for NPP Equipment and Structures Subjected to Response Levels Caused by High Frequency Ground Motions," 03/19/2007, NRC Accession Number ML071010497.

Design Control Document (DCD) Revision: none

PRA Revision: none

Technical Report (TR) Revisions:

The updated ~~Figures RAI-SRP3.7.1-SEB1-09-01a to RAI-SRP3.7.1-SEB1-09-06c will replace~~ Figures 5.2-1 through 5.2-6 are provided in RAI-SRP3.7.1-SEB1-10~~in the next revision to TR-115~~.

The language to be added in TR115 (end of Section 5.2) is shown below.

"The exceedances of CSDRS-based ISRS by HRHF-based ISRS are addressed as part of the sampling evaluation documented in this report to confirm that high frequency input has marginal effect on equivalent piping, and structures qualified by analysis for the AP1000 CSDRS."

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-10
Revision: 4

Question:

The staff requests that Westinghouse augment Figures 5.2-1 through 5.2-6 in TR-115, by adding the HRHF broadened spectra from the NI20 fixed base analysis, without any reduction for incoherency or other considerations. This will provide the staff with results needed to conduct an evaluation of the effect of incoherency.

Additional Request by NRC Audit during April 13th to 17th (Revision 2):

Perform additional calculations using EPRI model and rectangular foundation and AP1000 on hard rock foundation.

Additional Request (Revision 3)

A. Westinghouse will provide explanation why the incoherent response has a significant reduction when compared to coherent response in low frequencies (below 10Hz)
B. Review interpolation function for NI20 SASSI model.
C. Reanalysis of seismic response will correct/clarify values and results will be re-issued as a new revision to RAI-SRP3.7.1-SEB1-10.

Additional Request (Revision 4)

Westinghouse is requested to update figures provided as part of previous revisions that are changed as a result of the revised responses.

Westinghouse Response (Revision 0 and 1):

It is noted that Westinghouse uses the NEI recommended coherency function that reduces high frequency ground motions by accounting for special seismic wave incoherency. The rock-based coherency function that is being used was developed by Dr. Norman A. Abrahamson. This function is consistent with the requirements of the "Common Understanding" developed by the NRC staff and industry representatives during the December 20-21, 2006 public meeting. Since Westinghouse is using the coherency function that is consistent with the "Common Understanding" between the NRC and industry, it is not considered necessary to provide this information. There is nothing unique in the Westinghouse application of the coherency function.

In response to the question raised by the NRC during May 19-23, 2008, Westinghouse has provided the response spectra for the HRHF broadened NI20 model with coherent and incoherent considerations in Figure RAI-SRP3.7.1-SEB1-10-1 to RAI-SRP3.7.1-SEB1-10-21 (5% damping).

Westinghouse Response (Revision 2):

In Figures RAI-SRP3.7.1-SEB1-10-1 to RAI-SRP3.7.1-SEB1-10-21 some of the reductions ratios (defined as Incoherent response / coherent response) are shown to be less than 0.5 in some cases. Analyses have been performed using the EPRI model to provide the staff with additional results needed to conduct an evaluation of the effect of incoherency. The results show that the size and shape of the basemat has a significant effect on the reductions obtained from incoherence.

The following three cases using the EPRI Stick model have been analyzed:

1. EPRI AP1000 stick model with EPRI soil profile (Shear wave velocity, Vs, from 3300 fps to 8500 fps at depth of 130 ft) and EPRI input time history.
2. EPRI AP1000 stick model with EPRI soil profile and HRHF input time history.
3. EPRI AP1000 stick model (basemat size 158' by 254') with HRHF soil profile (Average Vs=8000 fps below grade) and HRHF input time history.

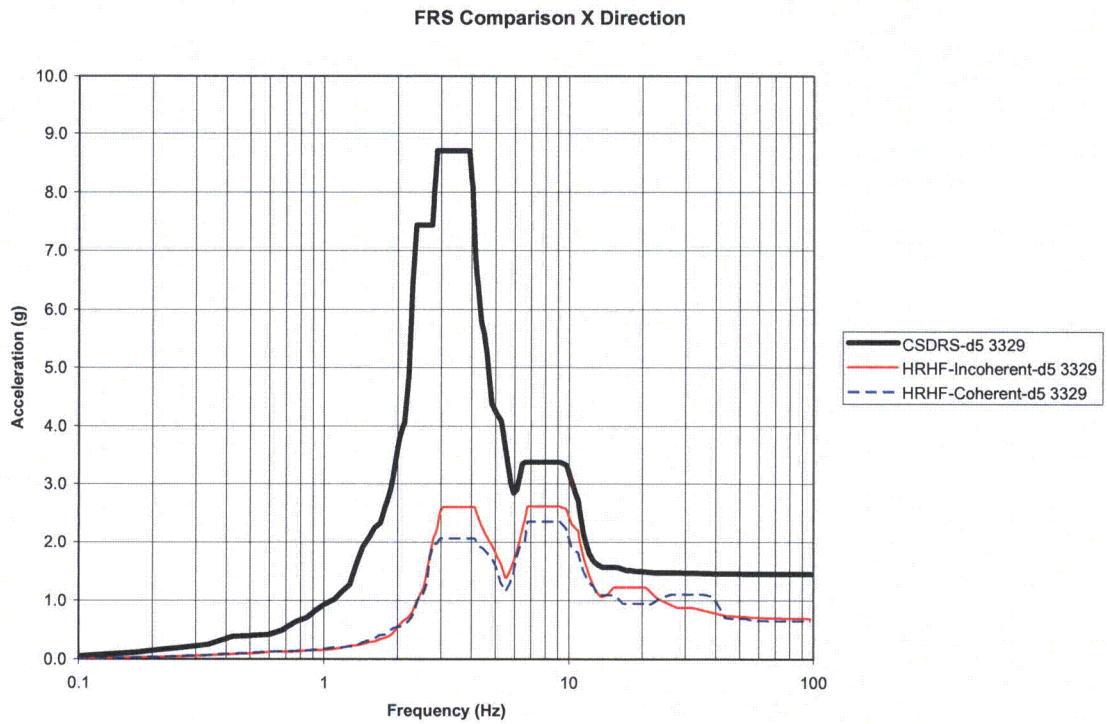
Four Locations are selected for comparison:

A. Nuclear Island foundation at elevation 60.5' (Node 1).
B. Top of Containment Internal Structure Mass Center at elevation 169' (Node 129).
C. Top of Steel Containment Vessel at elevation 281.9' (Node 45).
D. Top of Shield Building at elevation 333.3' (node 18).

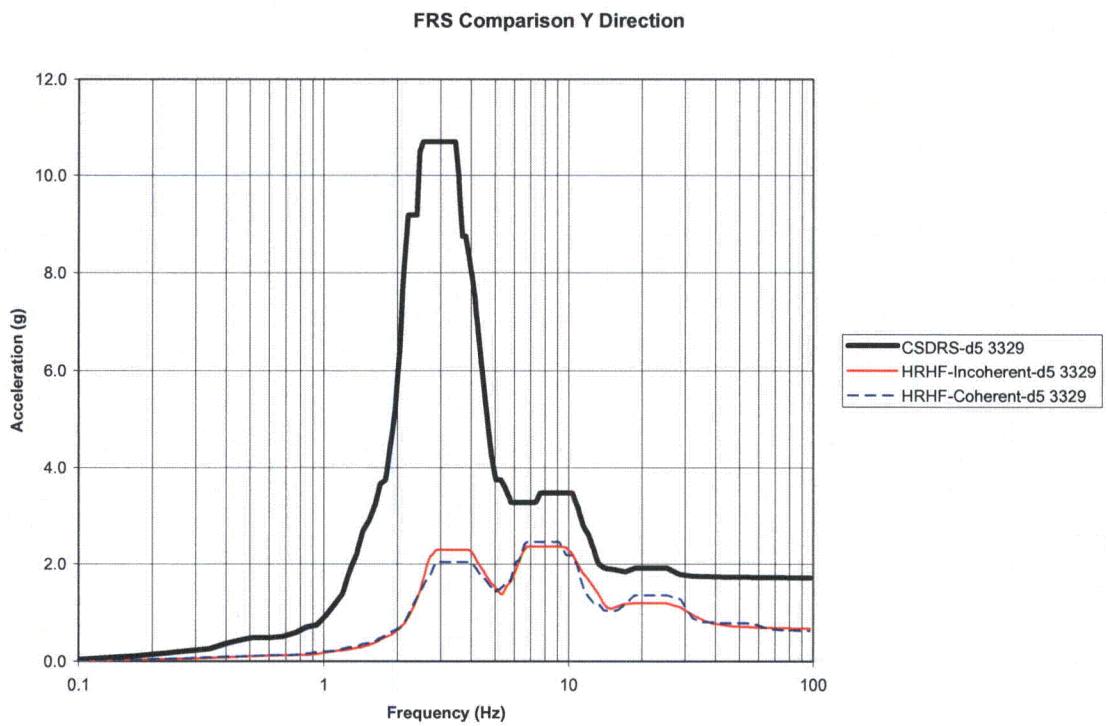
The 5% damping floor response spectra of four nodes and the reduction factors (Coh/Incoh) are shown in Figures RAI-SRP3.7.1-SEB1-10-22 to RAI-SRP3.7.1-SEB1-10-33. The Nuclear Island foundation results at elevation 60.5' (Node 1) show that the larger foundation will have larger reduction in response due to incoherency effects. The results for Top of Containment Internal Structure Mass Center at elevation 169' (Node 129), show reductions of the magnitude seen in the NI20 results. The top of the steel containment vessel and the top of the shield building also show similar results.

Finally, Figures RAI-SRP3.7.1-SEB1-10-34 to RAI-SRP3.7.1-SEB1-10-36 show a comparison of basemat response at the center (node 1 and 1153) and edges (node 230 and 1047) of the basemat of the EPRI and NI20 models. As can be seen the reductions are similar.

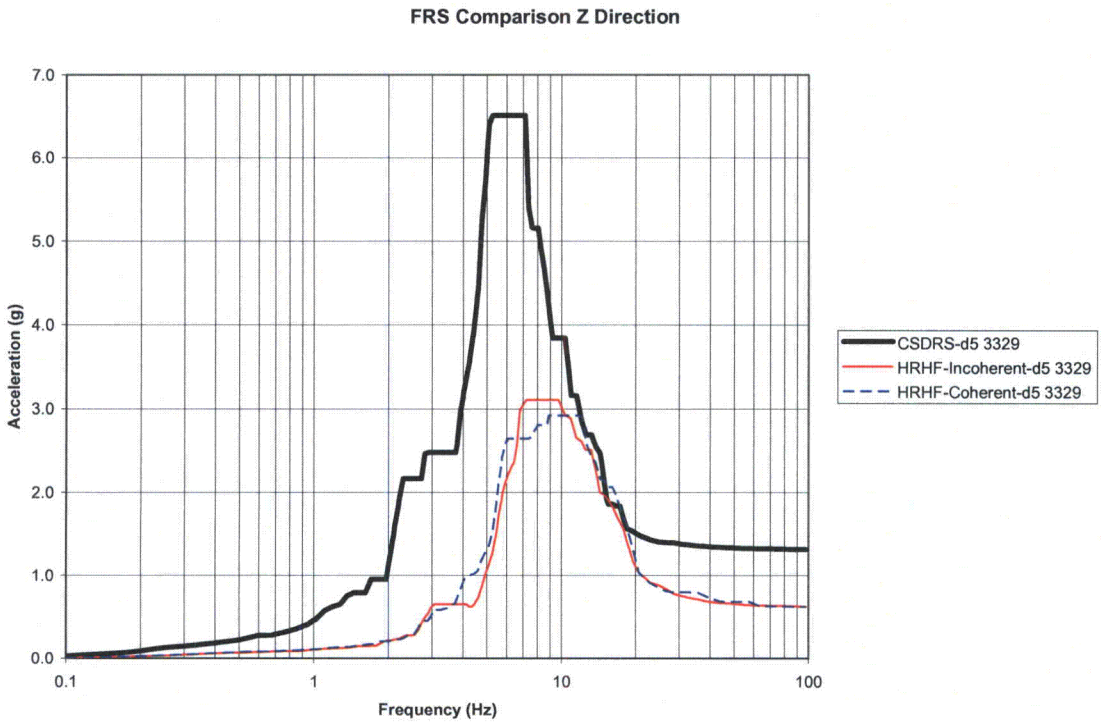
Thus, in conclusion the NI20 achieves similar reductions as the EPRI model for the same size foundation. The good comparisons show that the validated EPRI incoherent SSI methodology (Abrahamson, 2007 Hard-Rock Coherency Functions, Reference 1) was implemented correctly to the NI20 model ACS SASSI analyses.



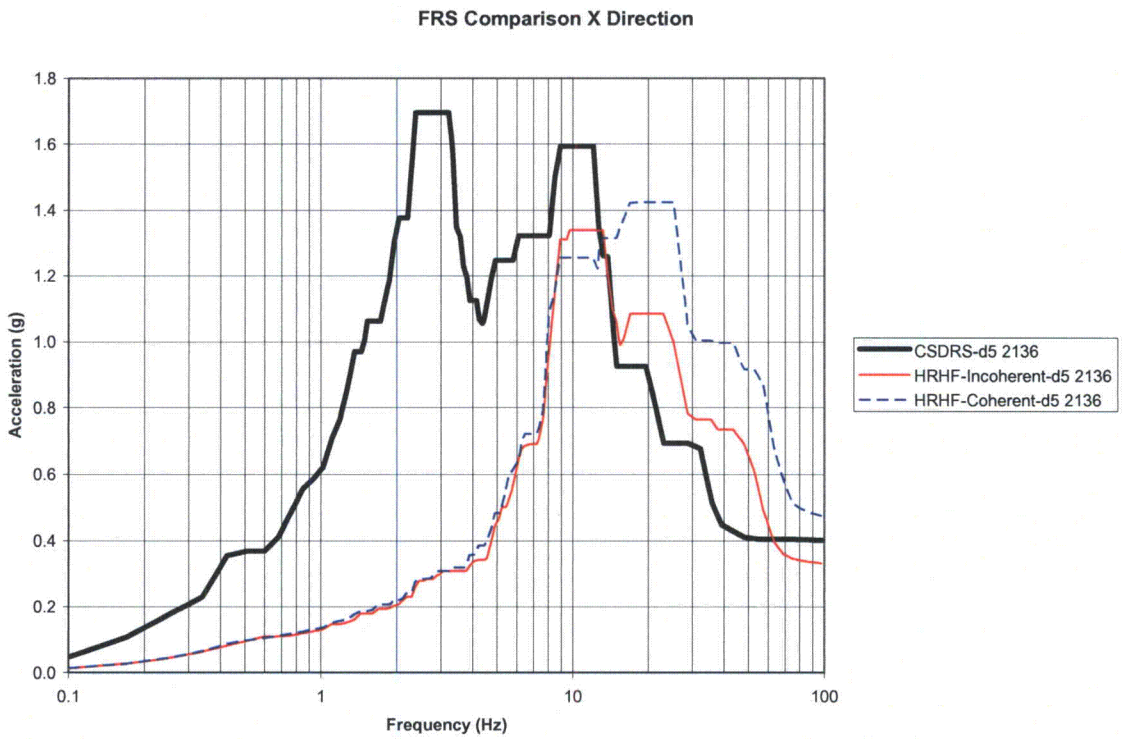
RAI-SRP3.7.1-SEB1-10-1: ASB at Elevation 327.4' X-Direction



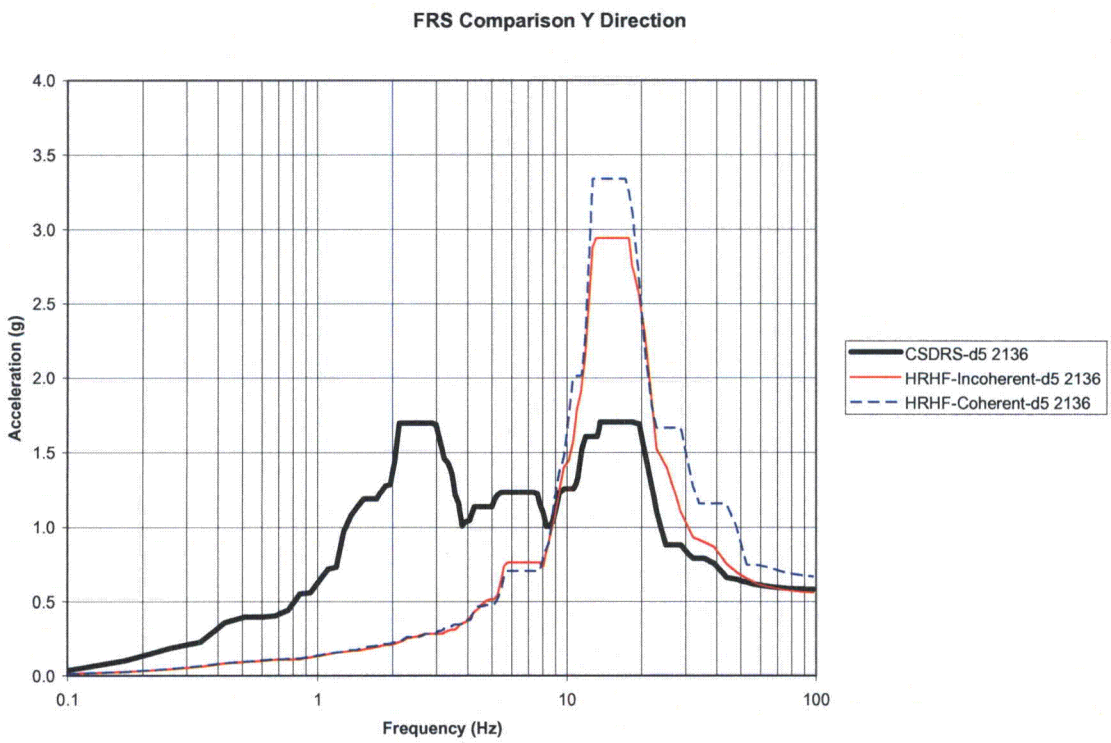
RAI-SRP3.7.1-SEB1-10-2: ASB at Elevation 327.4' Y-Direction



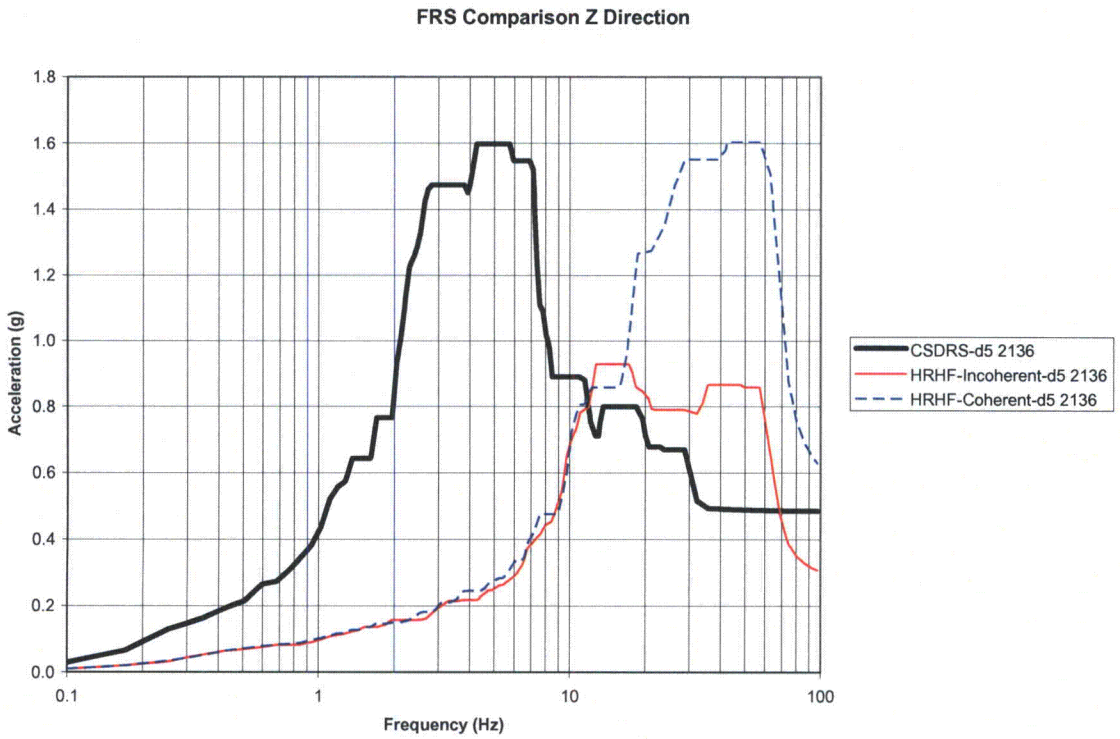
RAI-SRP3.7.1-SEB1-10-3: ASB at Elevation 327.4' Z-Directions



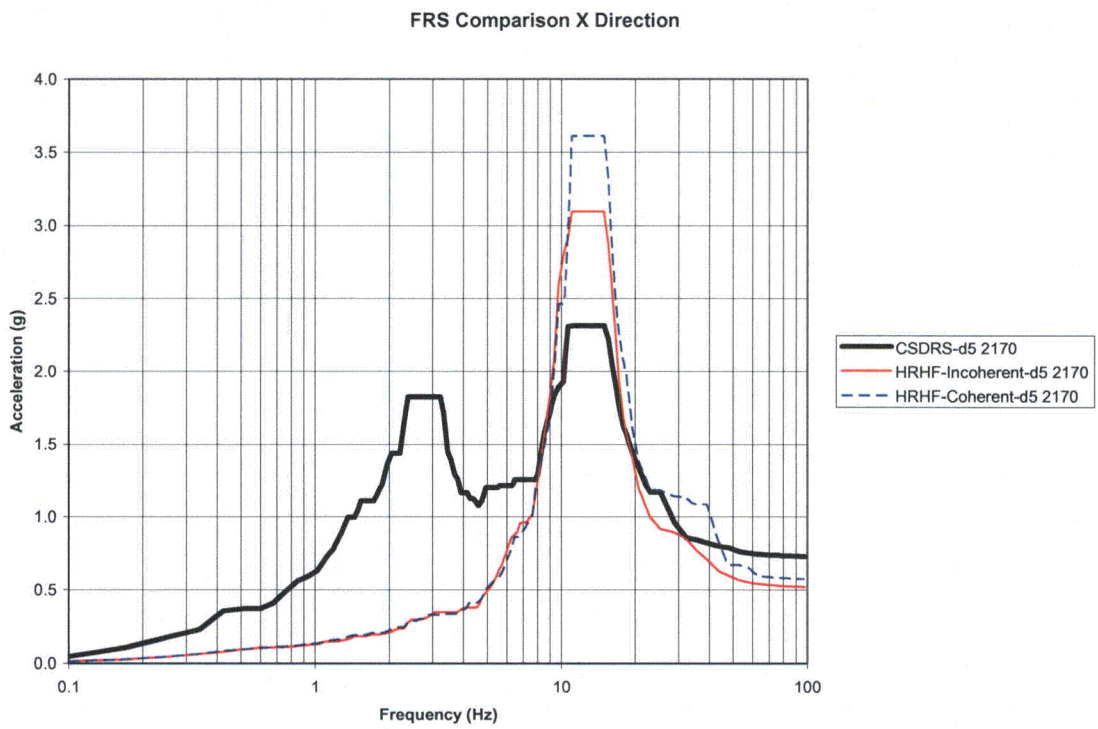
RAI-SRP3.7.1-SEB1-10-4: East Side Containment Operating Floor (Elevation 134.25') X-Direction



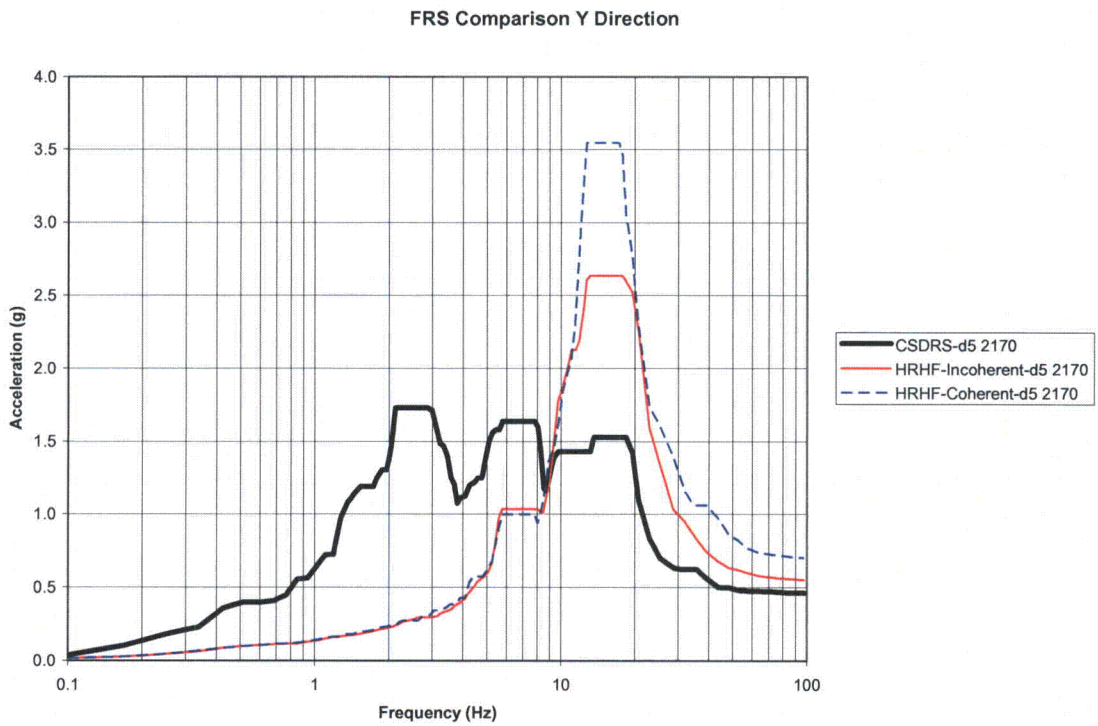
RAI-SRP3.7.1-SEB1-10-5: East Side Containment Operating Floor (Elevation 134.25') Y-Direction



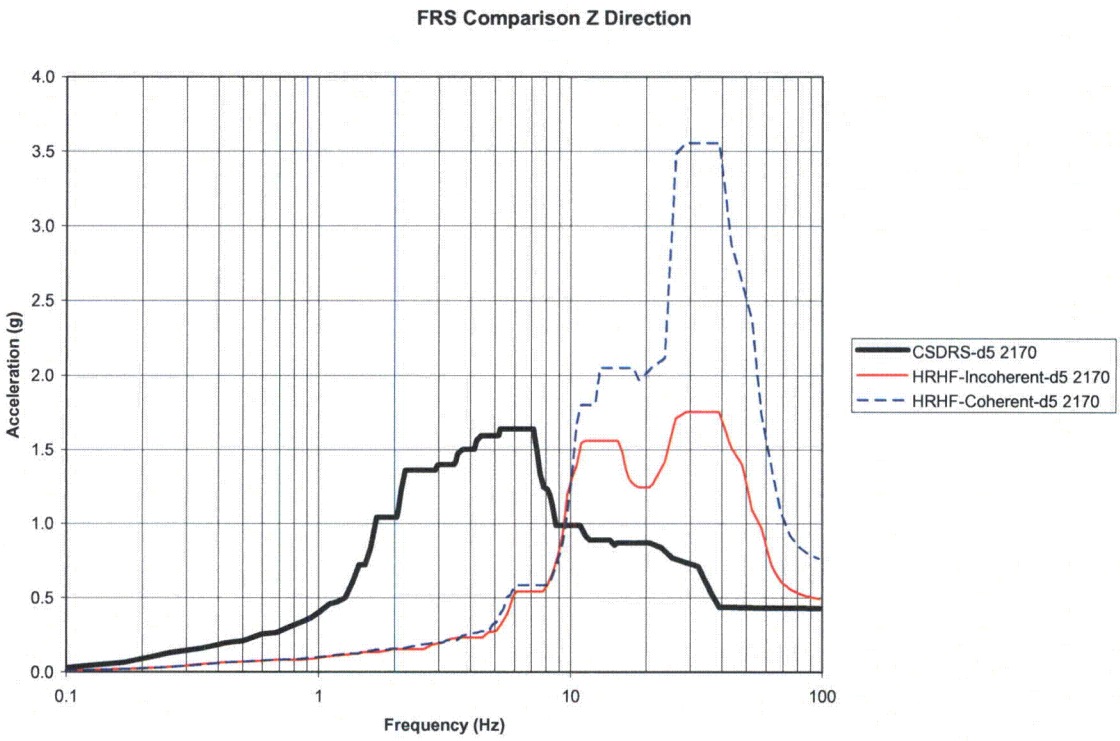
RAI-SRP3.7.1-SEB1-10-6: East Side Containment Operating Floor (Elevation 134.25') Z-Direction



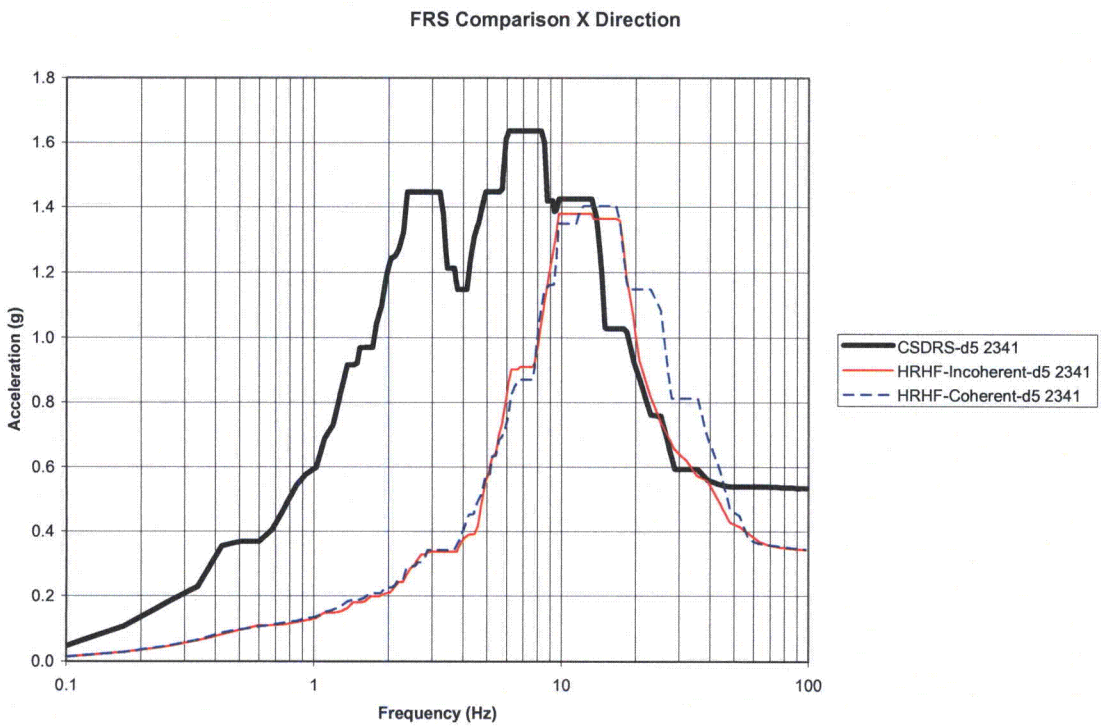
RAI-SRP3.7.1-SEB1-10-7: West Side Containment Operating Floor (Elevation 134.25') X-Direction



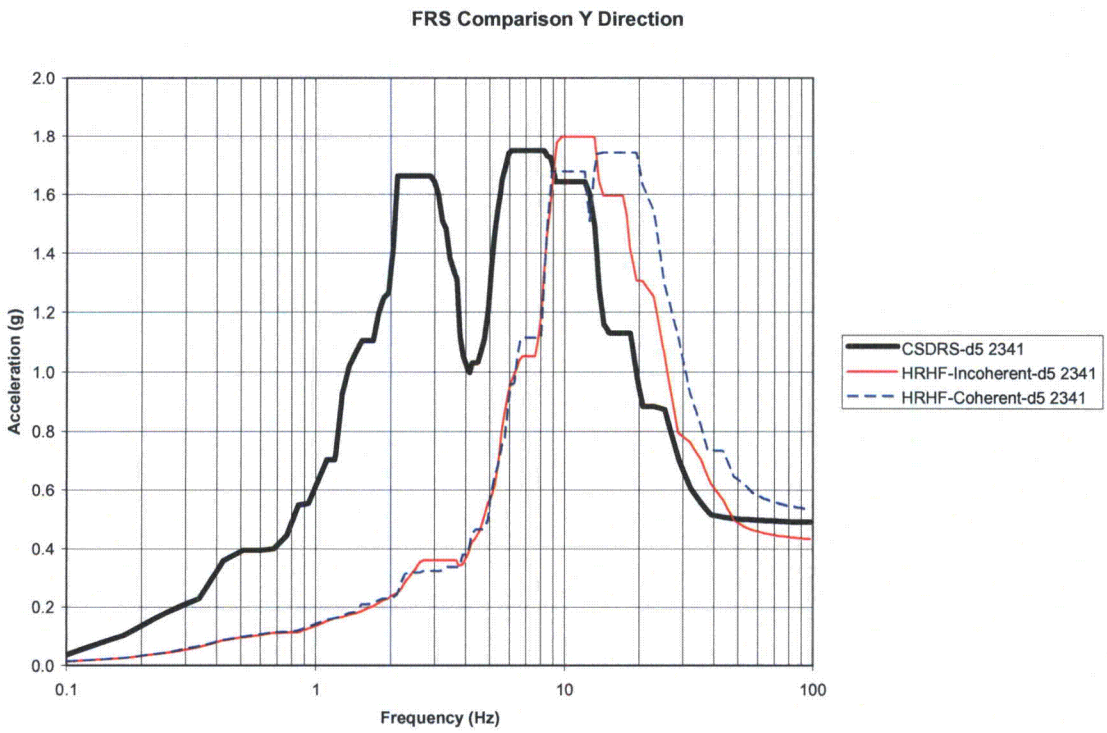
RAI-SRP3.7.1-SEB1-10-8: West Side Containment Operating Floor (Elevation 134.25') Y-Direction



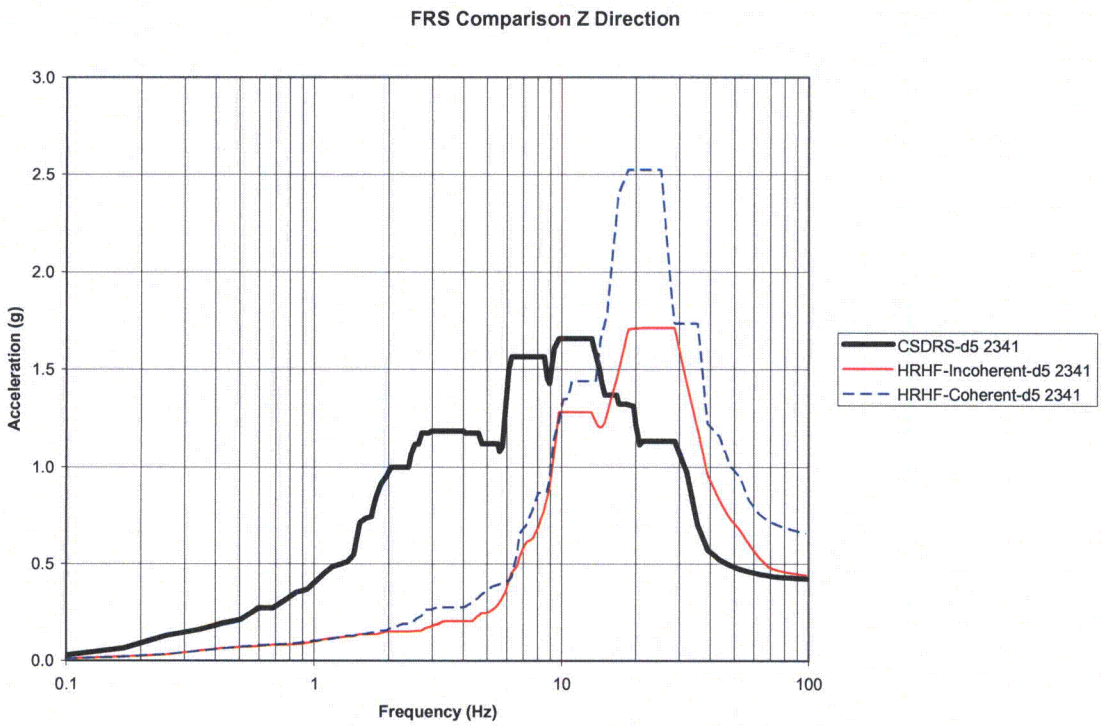
RAI-SRP3.7.1-SEB1-10-9: West Side Containment Operating Floor (Elevation 134.25') Z-Direction



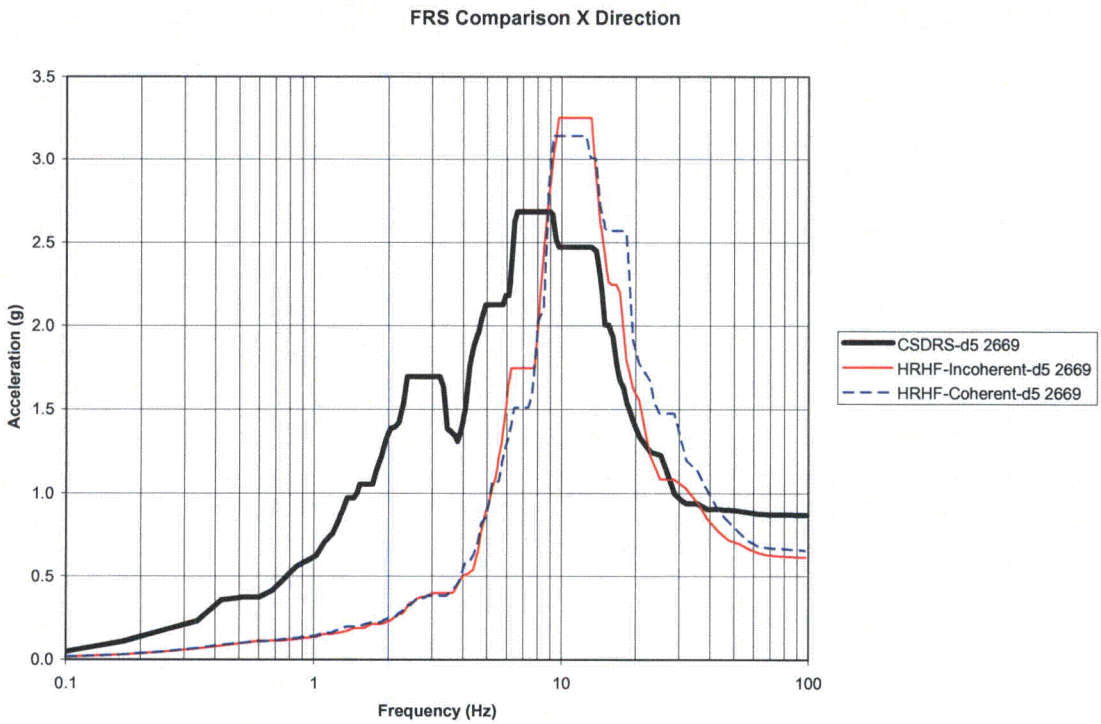
RAI-SRP3.7.1-SEB1-10-10: ASB at Northeast Corner (Elevation 134.5') X-Direction



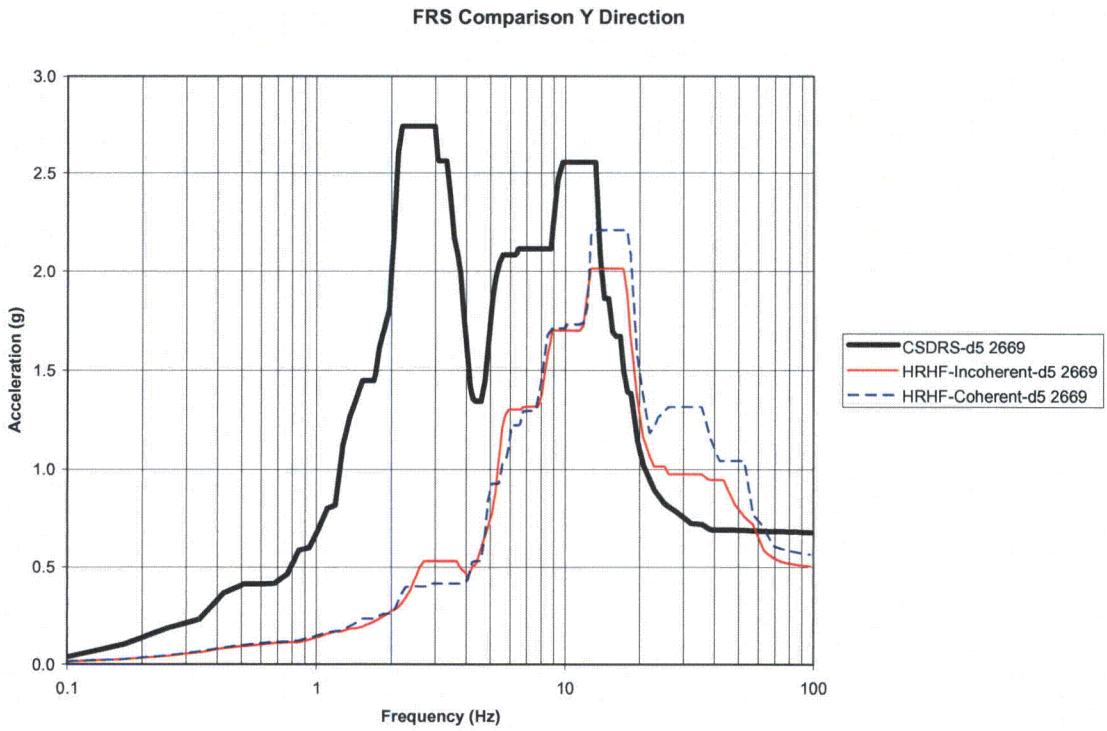
RAI-SRP3.7.1-SEB1-10-11: ASB at Northeast Corner (Elevation 134.5') Y-Direction



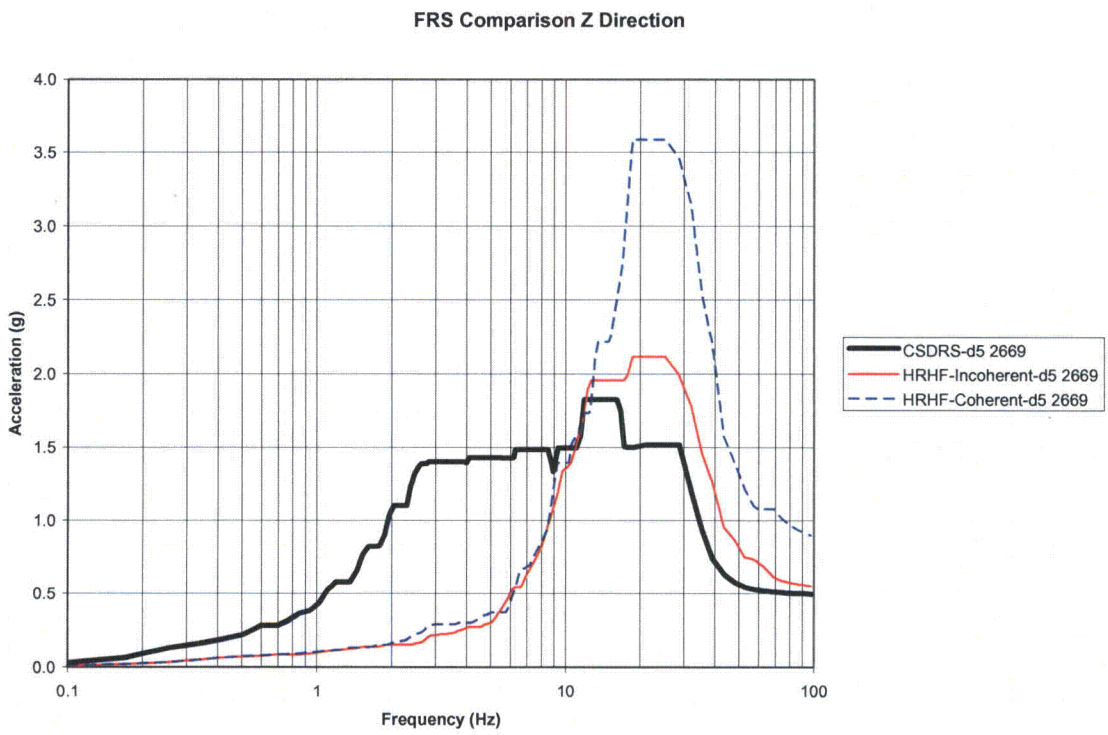
RAI-SRP3.7.1-SEB1-10-12: ASB at Northeast Corner (Elevation 134.5') Z-Direction



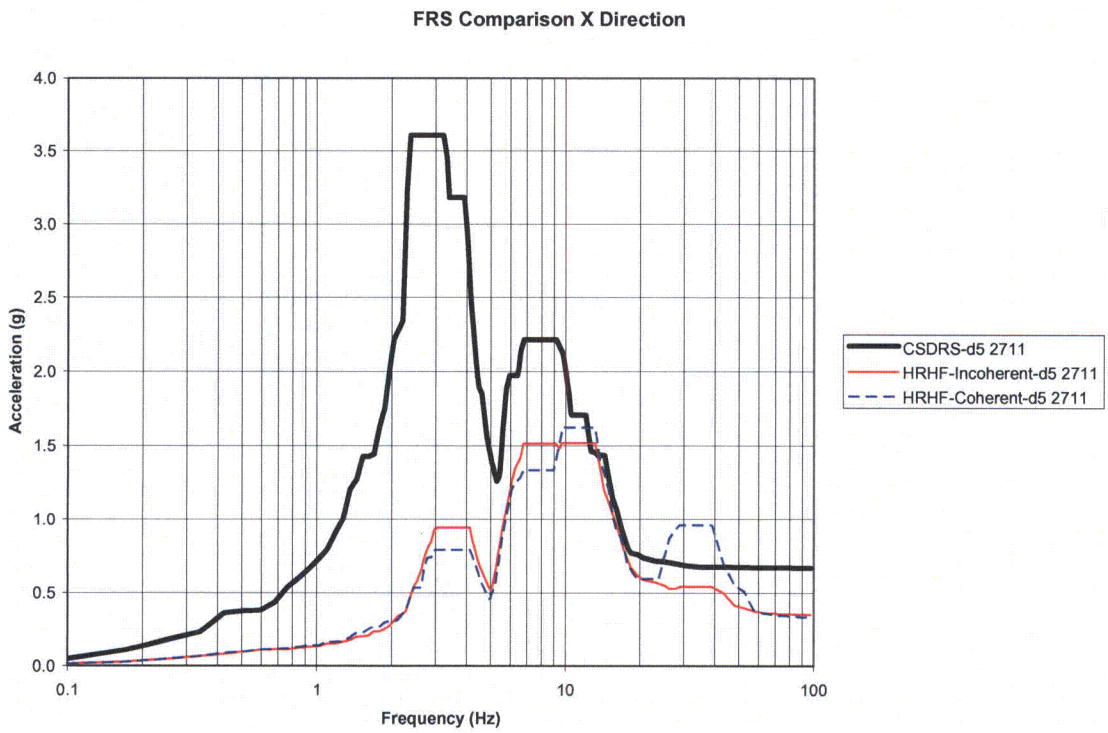
RAI-SRP3.7.1-SEB1-10-13: ASB at Fuel Building Roof (Elevation 179.56') X-Direction



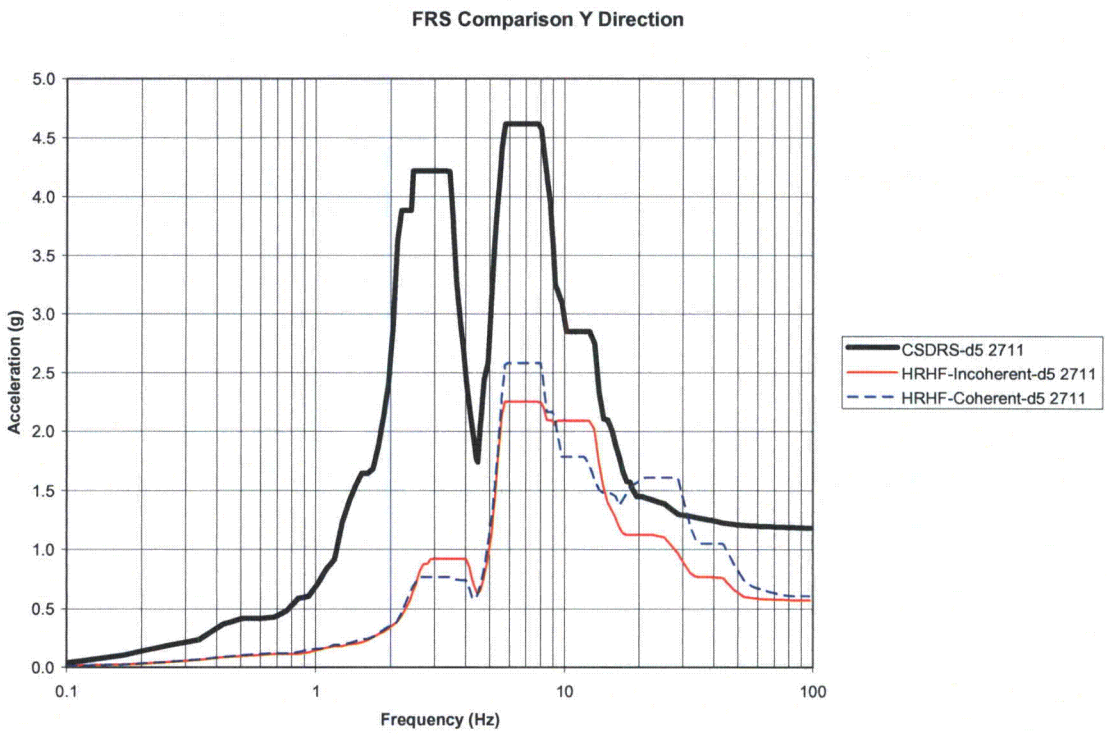
RAI-SRP3.7.1-SEB1-10-14: ASB at Fuel Building Roof (Elevation 179.56') Y-Direction



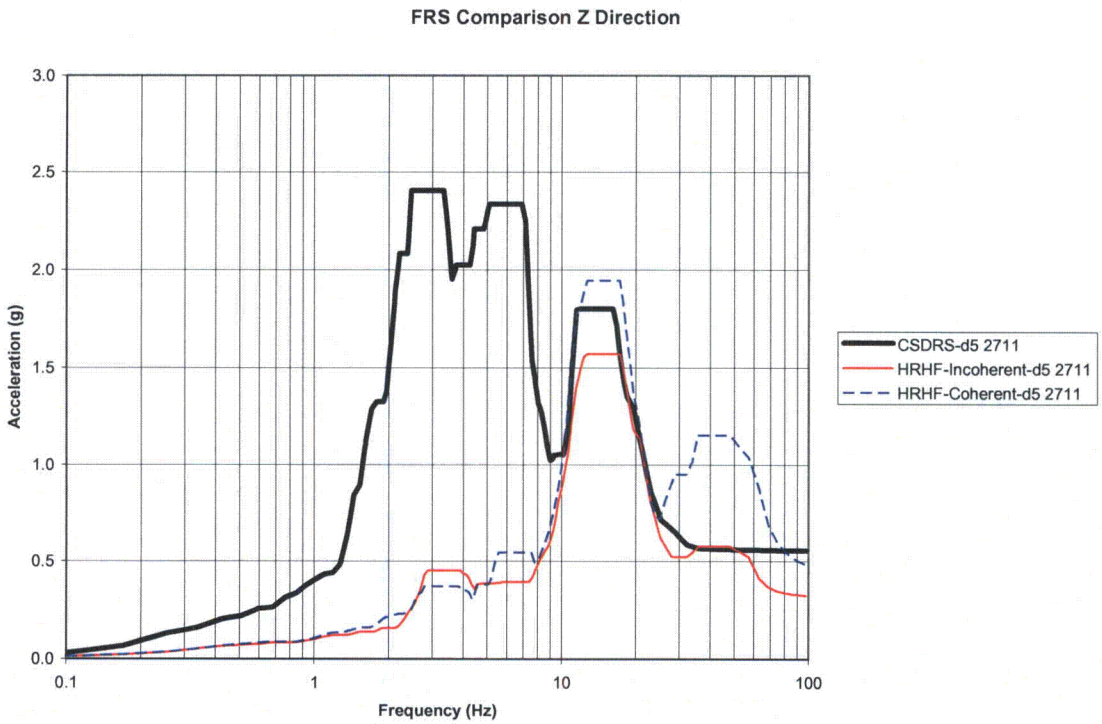
RAI-SRP3.7.1-SEB1-10-15: ASB at Fuel Building Roof (Elevation 179.56') Z-Direction



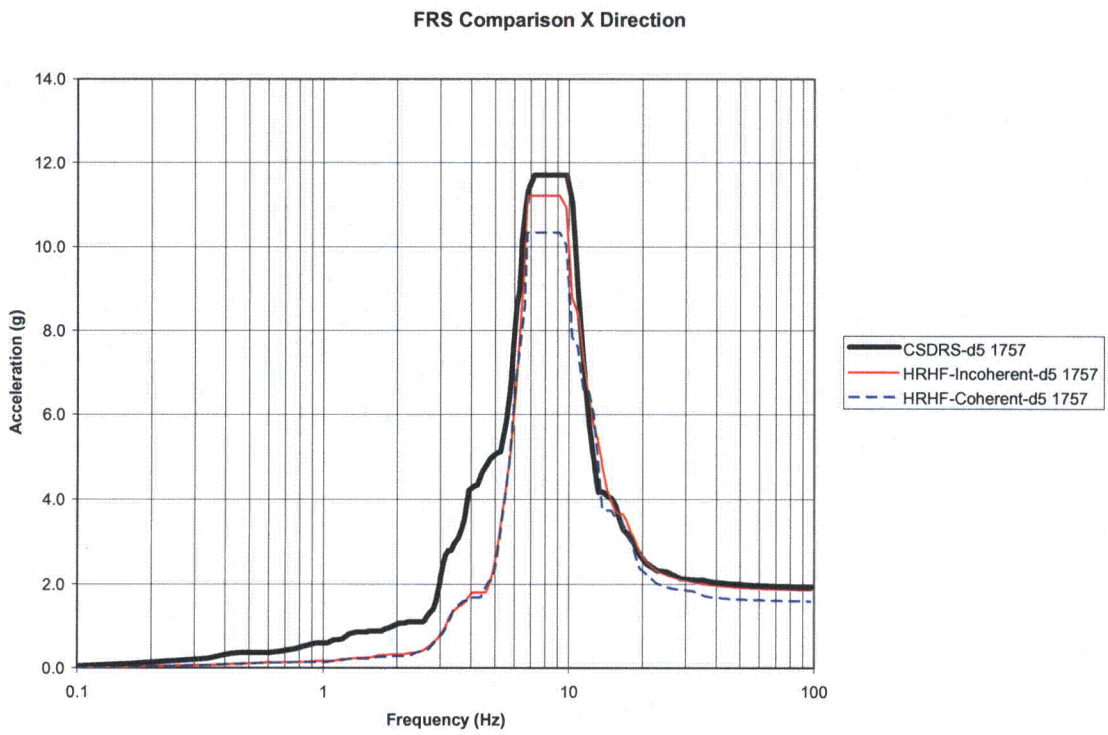
RAI-SRP3.7.1-SEB1-10-16: FRS Nodes – Elevation 180' X-Direction



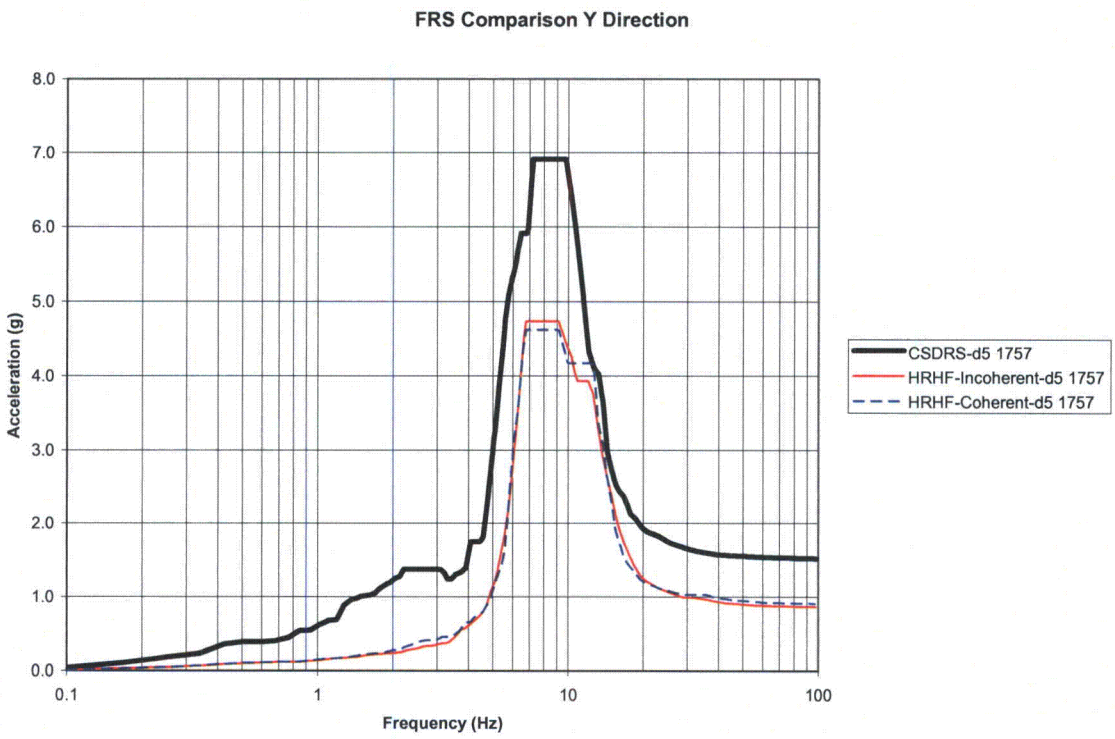
RAI-SRP3.7.1-SEB1-10-17: FRS Nodes – Elevation 180' Y-Direction



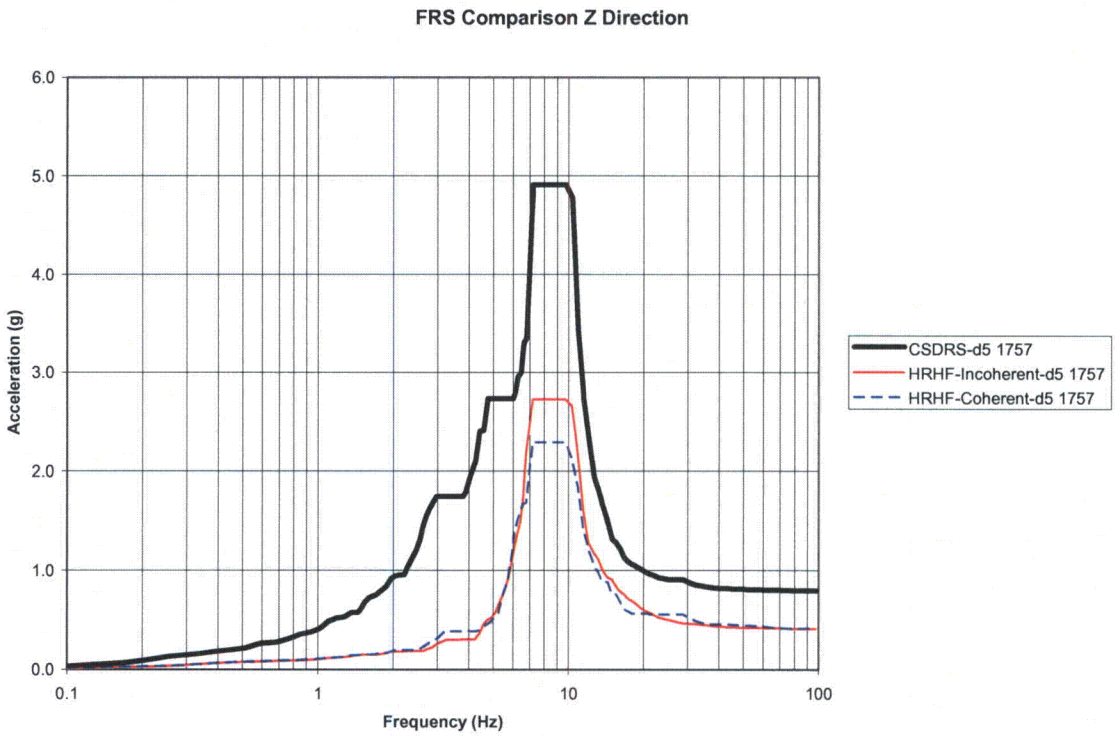
RAI-SRP3.7.1-SEB1-10-18: FRS Nodes – Elevation 180' Z-Direction



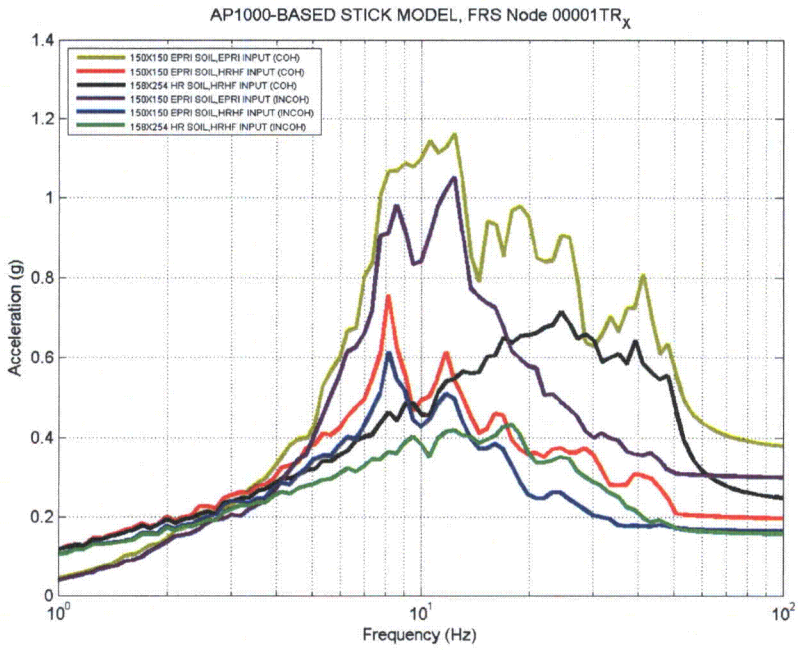
RAI-SRP3.7.1-SEB1-10-19: Reactor Coolant Pump – Elevation 99' X-Direction

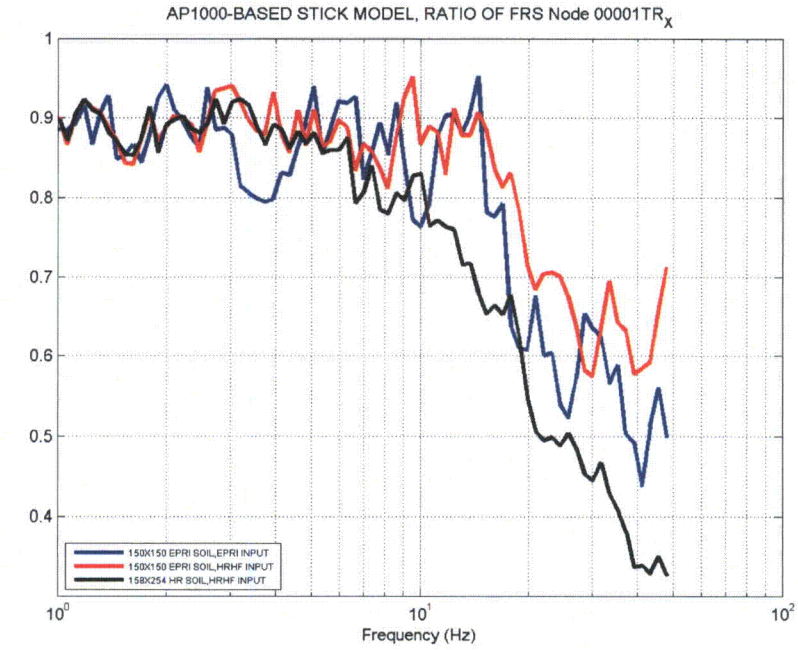


RAI-SRP3.7.1-SEB1-10-20: Reactor Coolant Pump – Elevation 99' Y-Direction

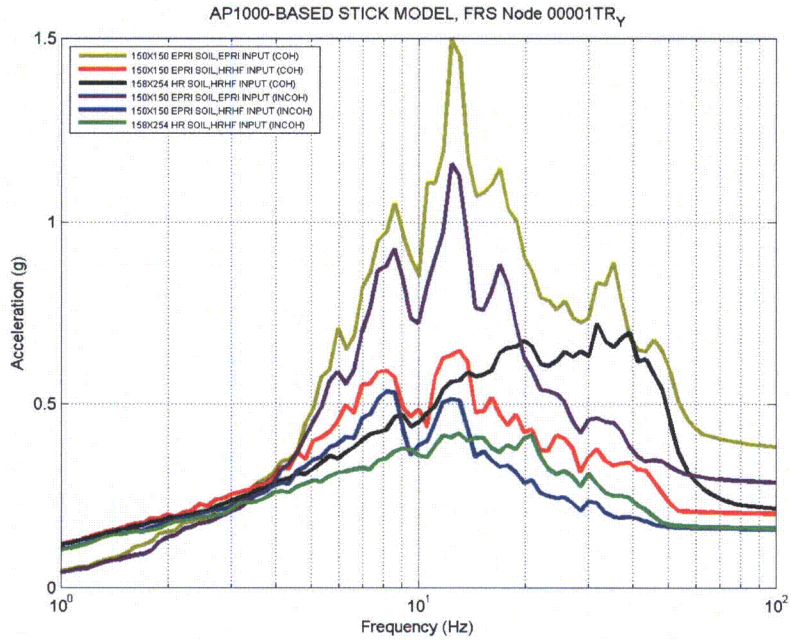


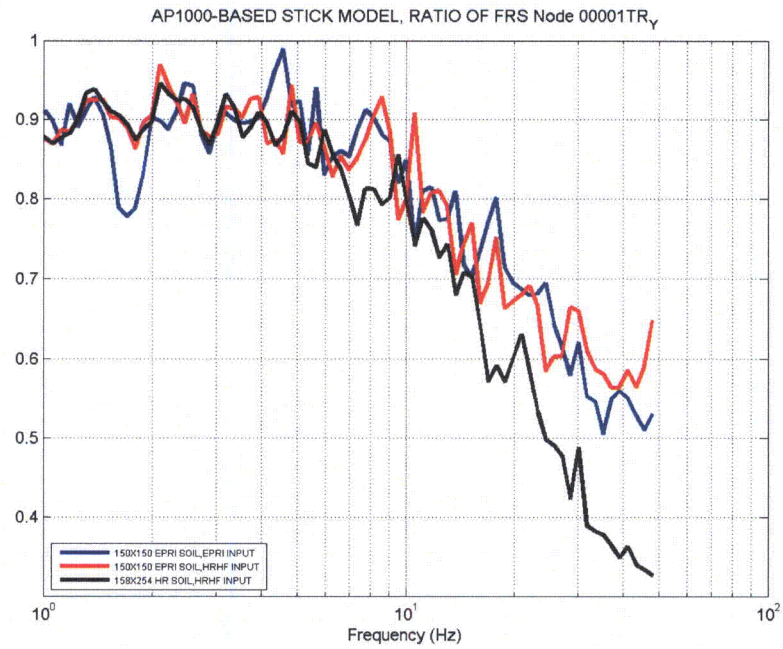
RAI-SRP3.7.1-SEB1-10-21: Reactor Coolant Pump – Elevation 99' Z-Direction



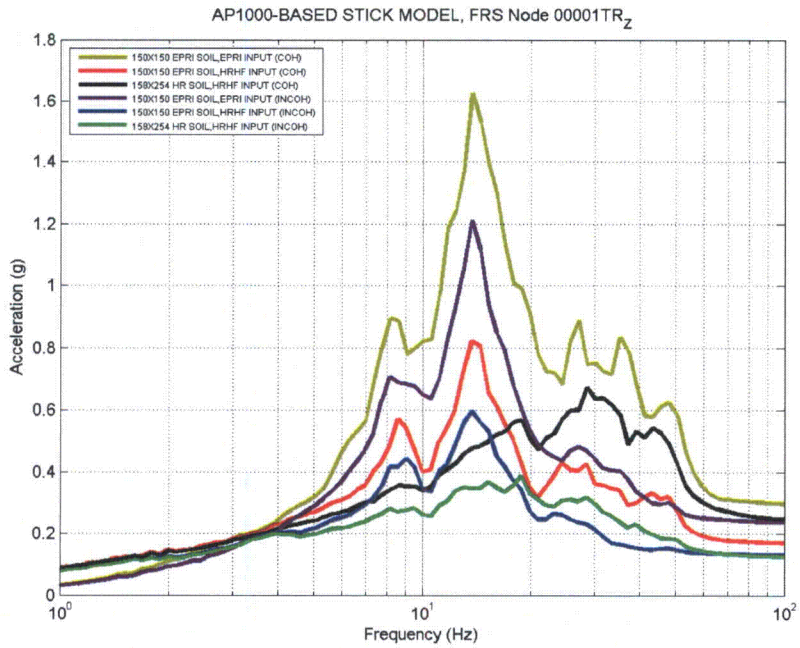


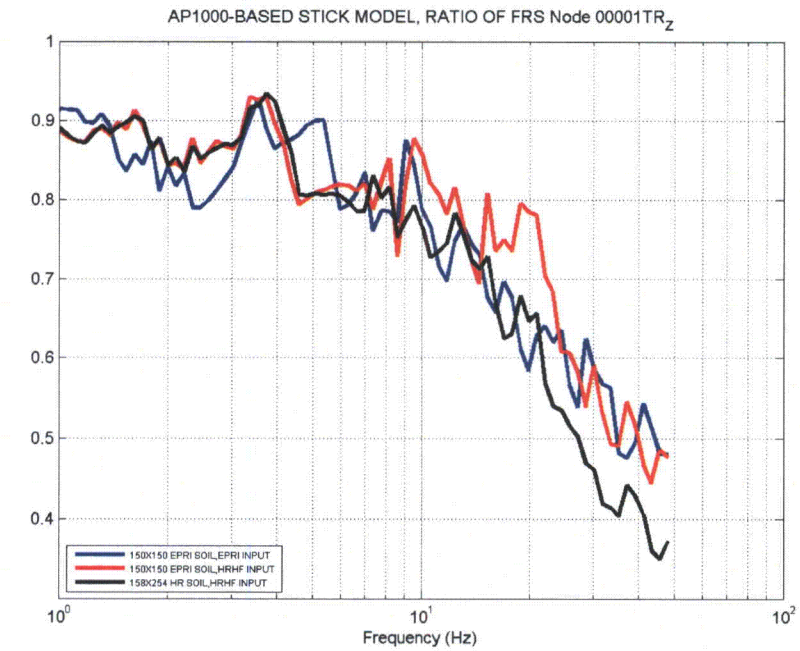
RAI-SRP3.7.1-SEB1-10-22: Foundation of Auxiliary Shield Building – Elevation 60.5' X-Direction



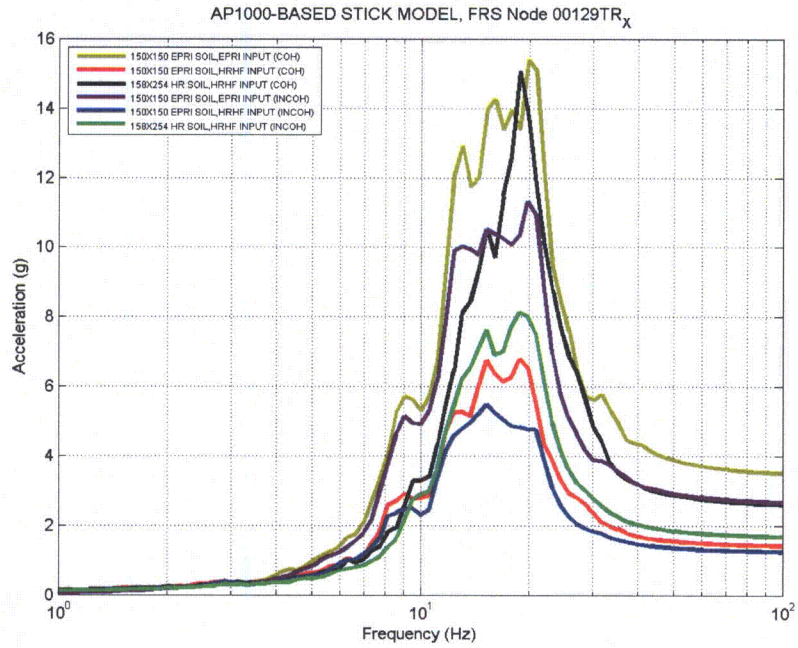


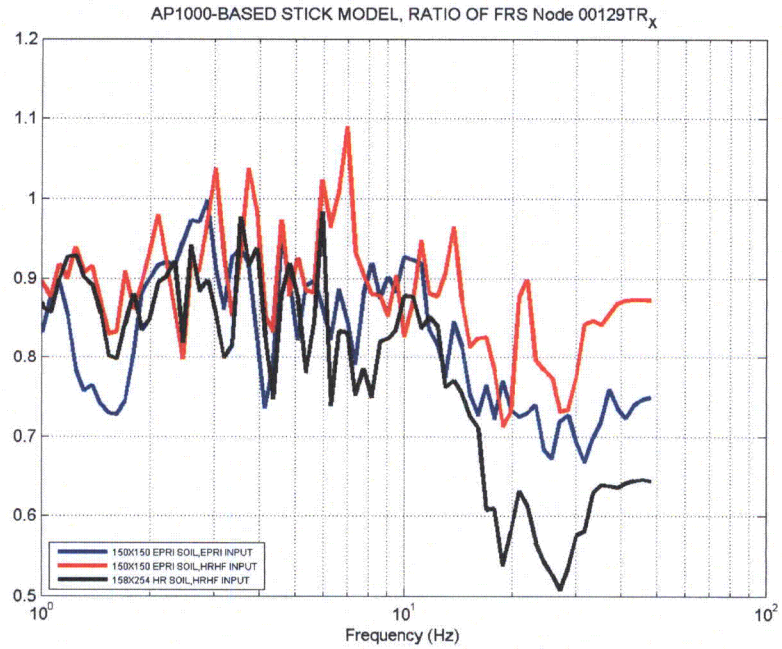
RAI-SRP3.7.1-SEB1-10-23: Foundation of Auxiliary Shield Building – Elevation 60.5' Y-Direction



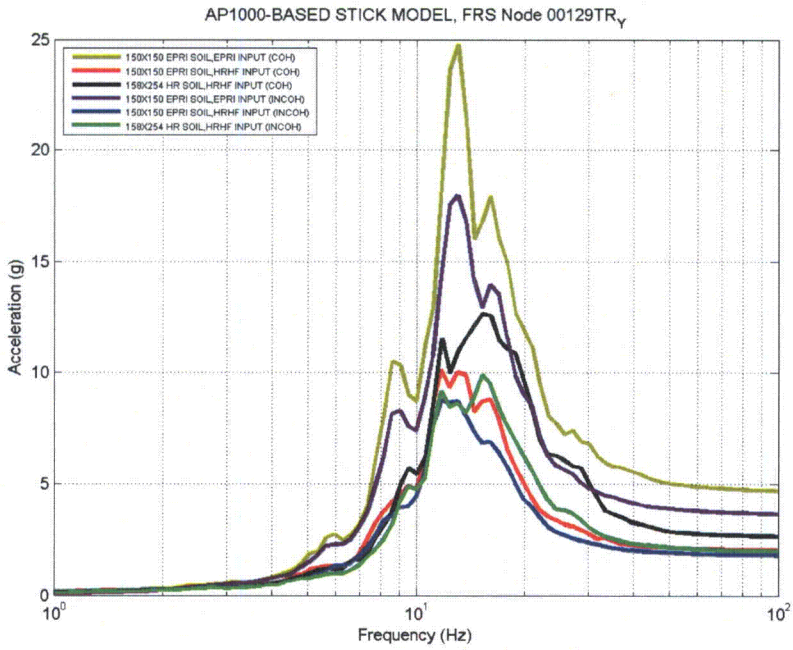


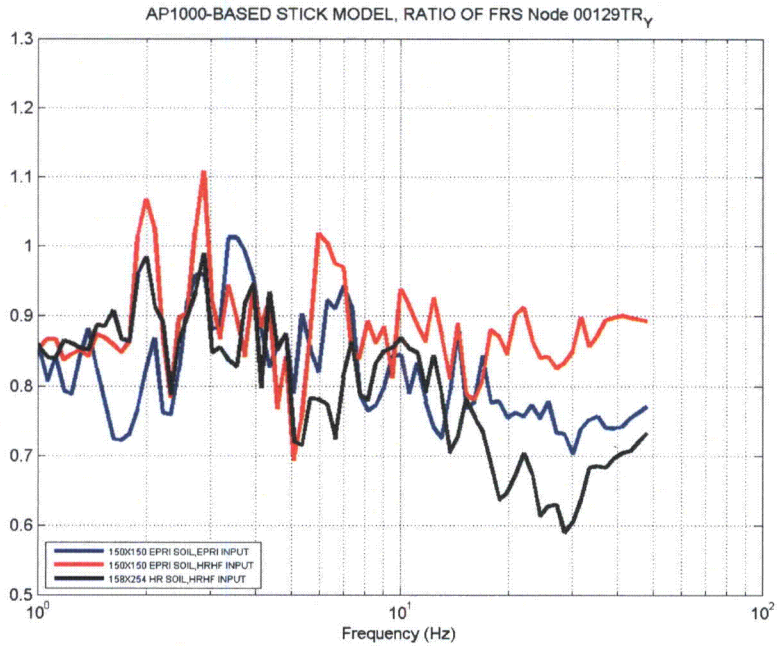
RAI-SRP3.7.1-SEB1-10-24: Foundation of Auxiliary Shield Building – Elevation 60.5' Z-Direction



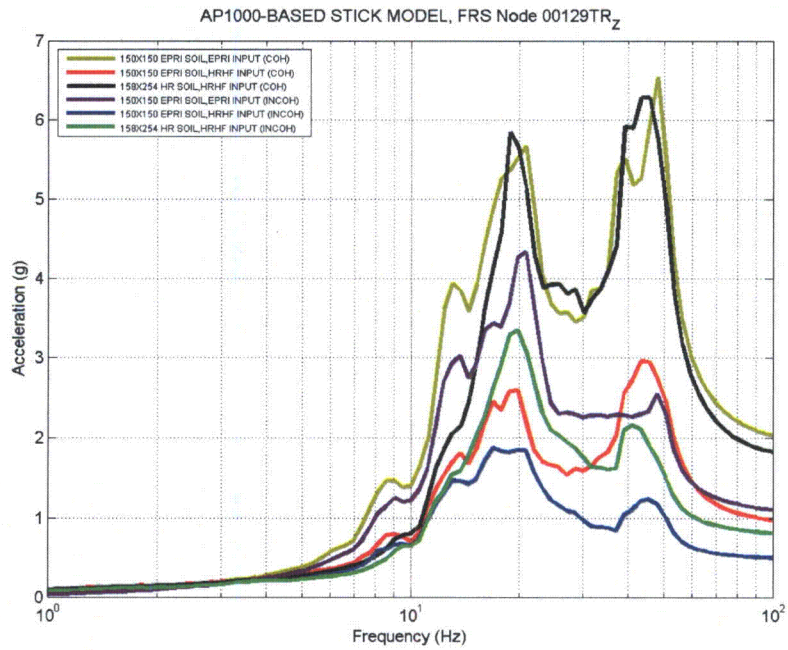


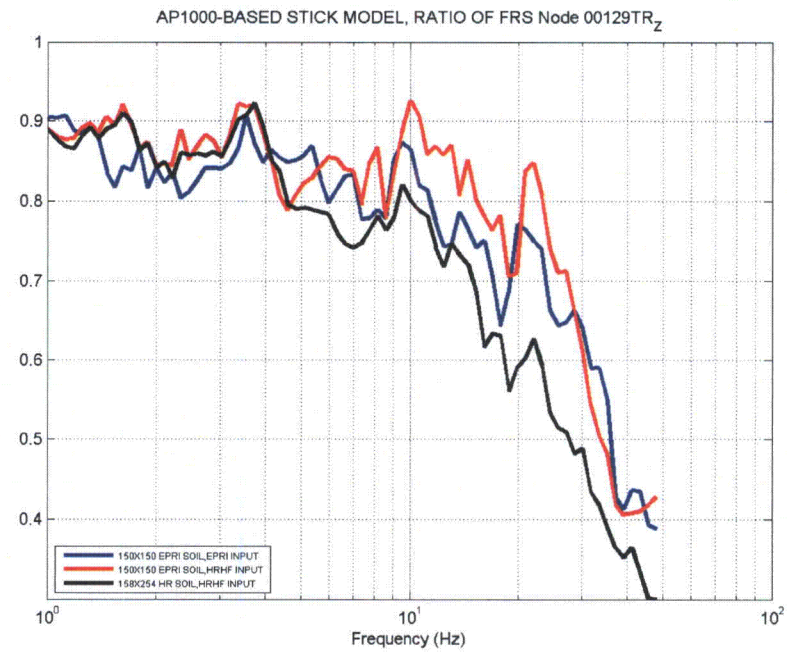
RAI-SRP3.7.1-SEB1-10-25: Top of CIS Mass Center– Elevation 169' X-Direction



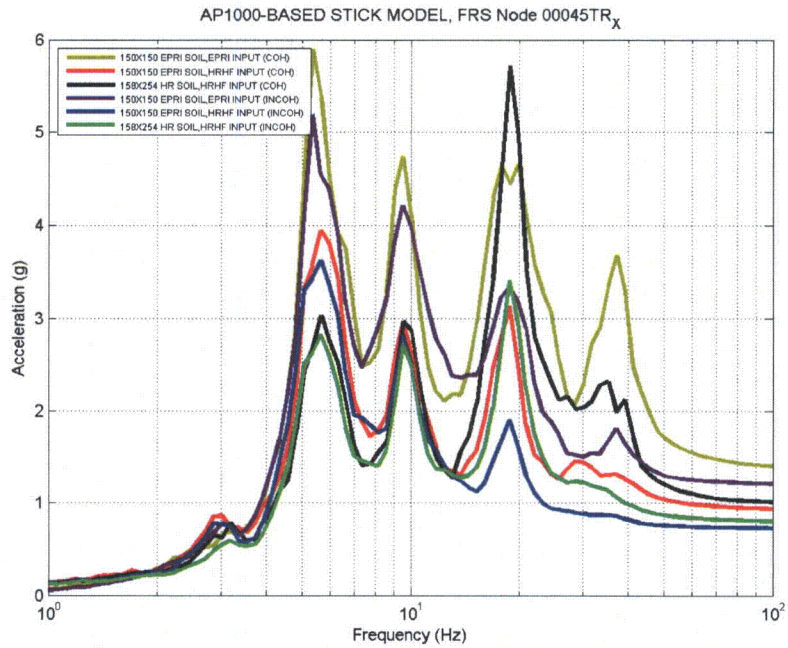


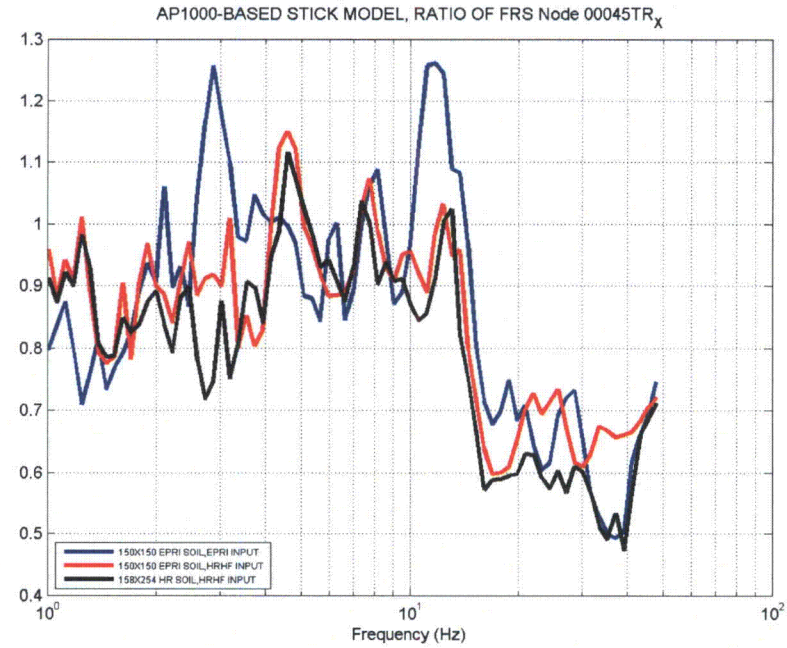
RAI-SRP3.7.1-SEB1-10-26: Top of CIS Mass Center– Elevation 169' Y-Direction



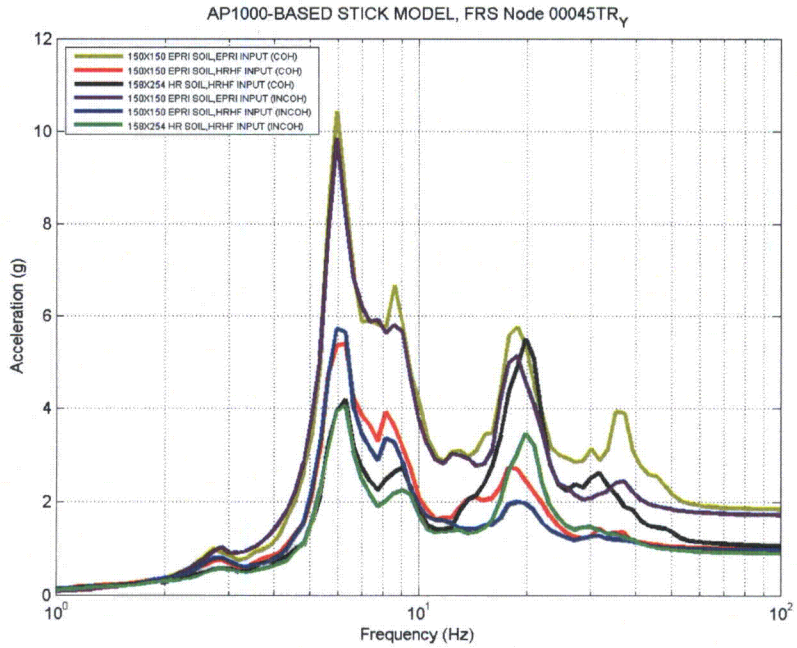


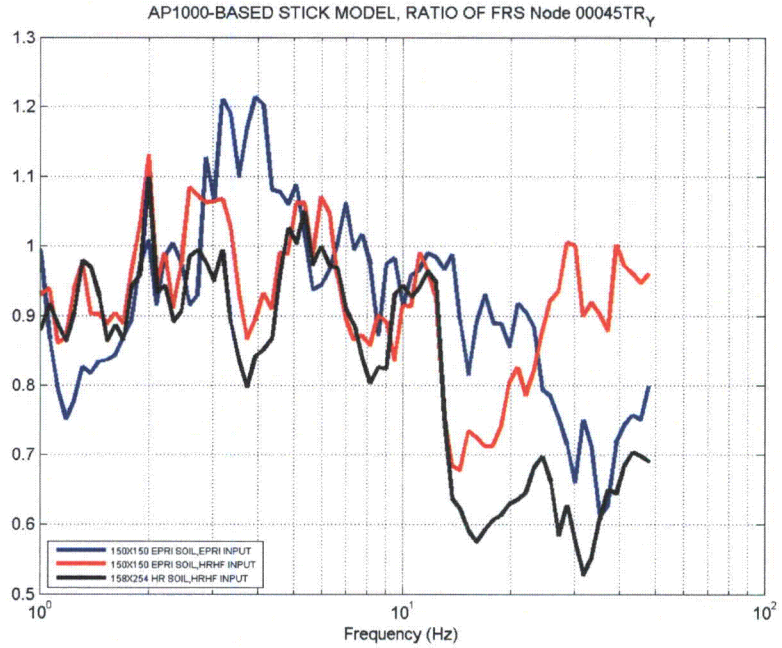
RAI-SRP3.7.1-SEB1-10-27: Top of CIS Mass Center– Elevation 169' Z-Direction



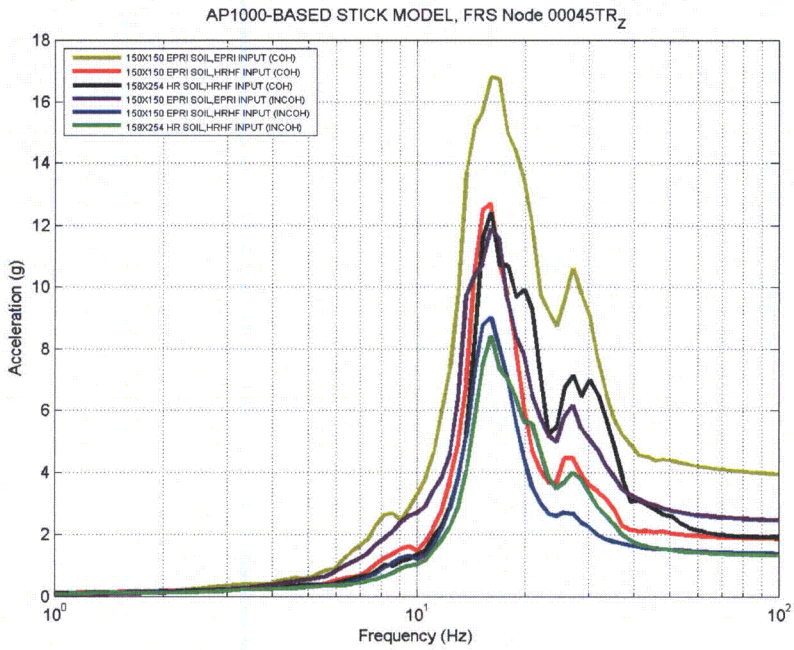


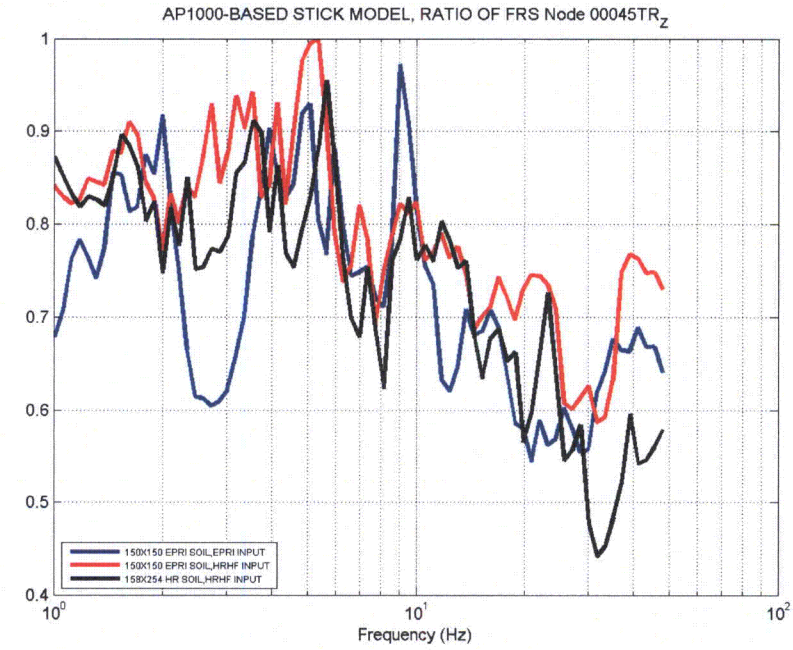
RAI-SRP3.7.1-SEB1-10-28: Top of Steel Containment Vessel – Elevation 281.9' X-Direction



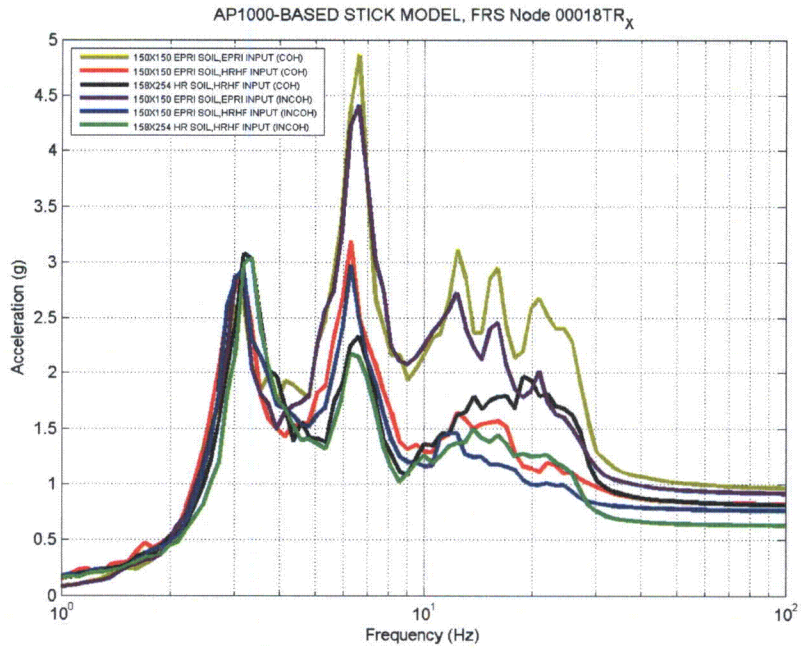


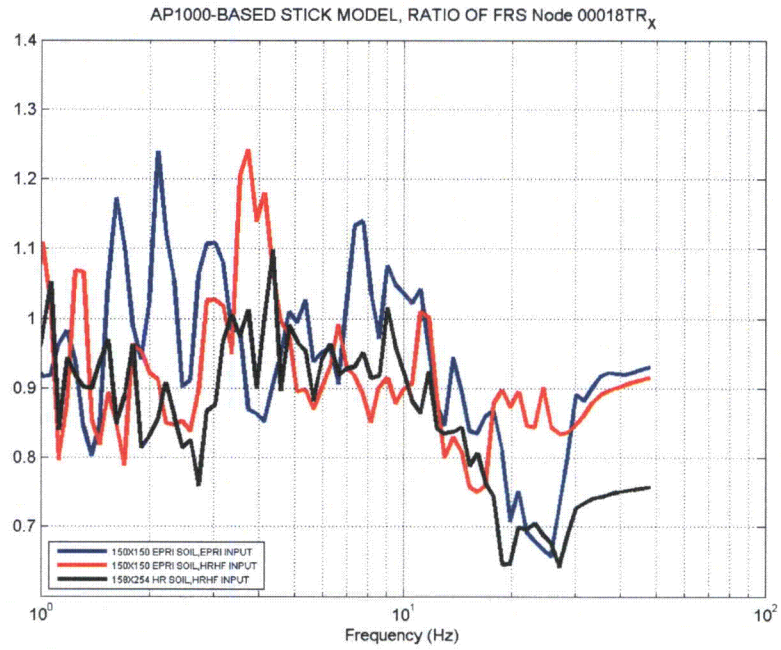
RAI-SRP3.7.1-SEB1-10-29: Top of Steel Containment Vessel – Elevation 281.9' Y-Direction



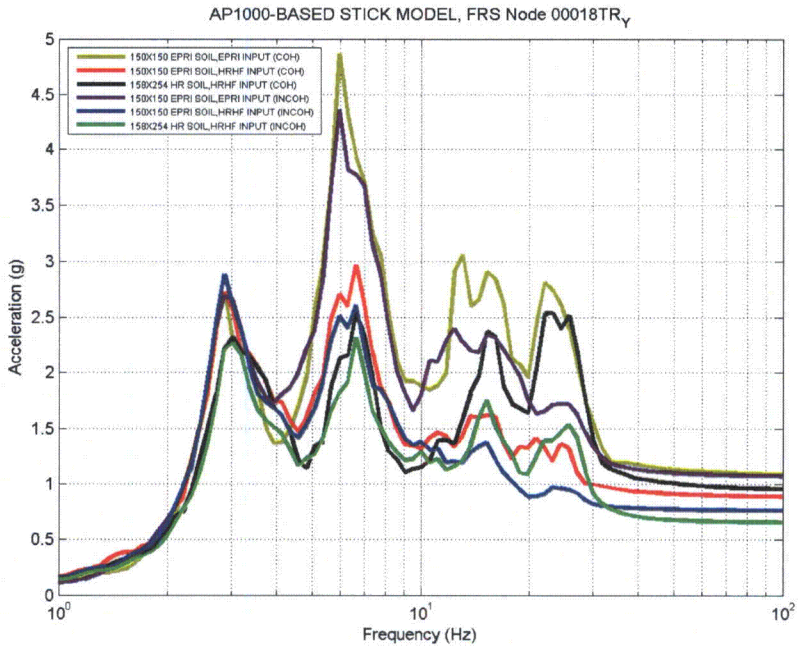


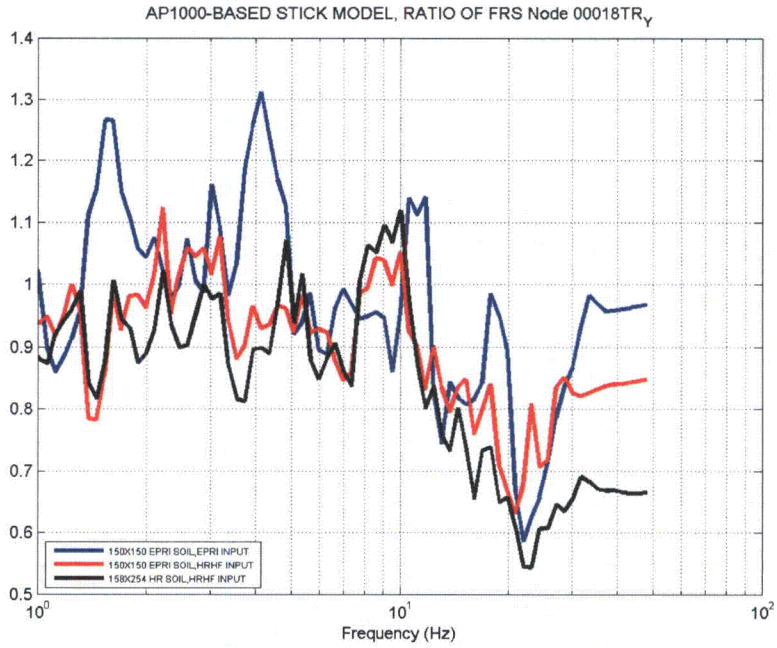
RAI-SRP3.7.1-SEB1-10-30: Top of Steel Containment Vessel – Elevation 281.9' Z-Direction



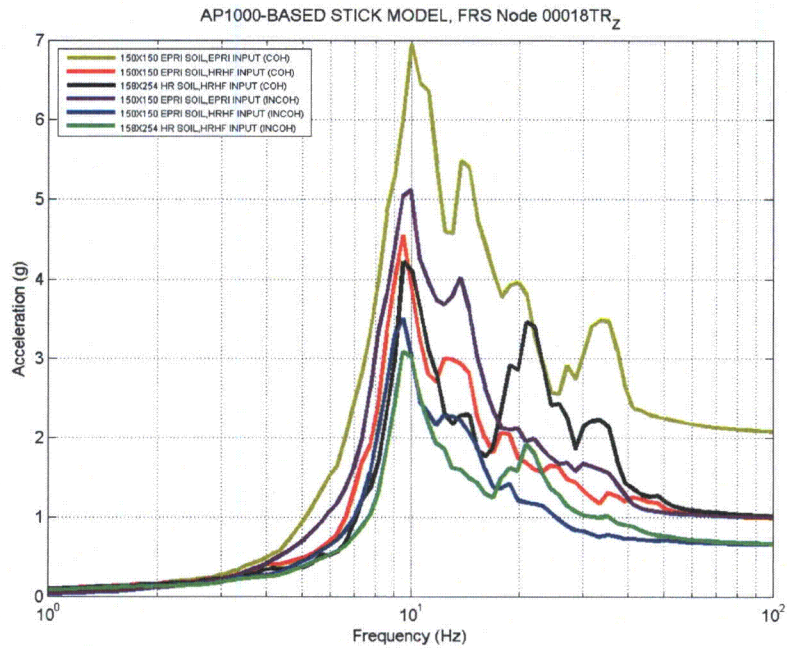


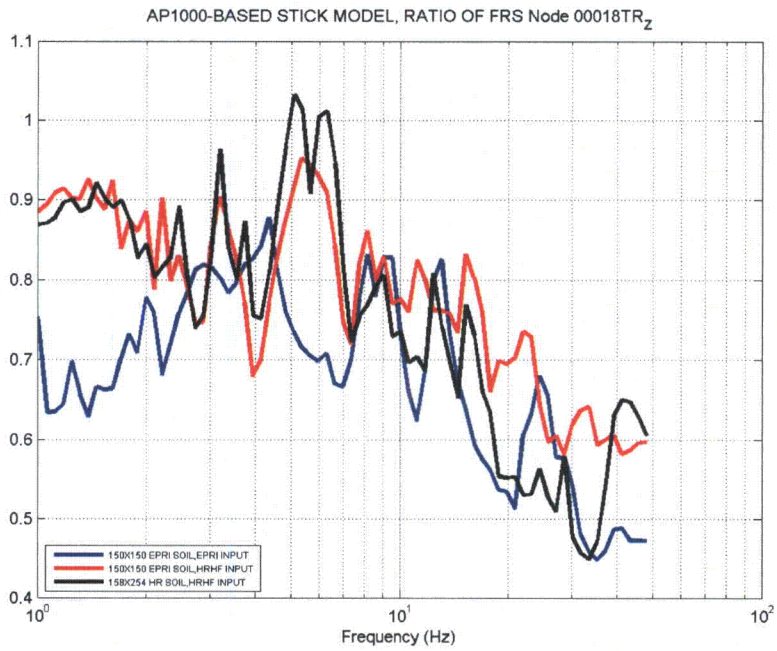
RAI-SRP3.7.1-SEB1-10-31: Top of Shield Building – Elevation 333.3' X-Direction



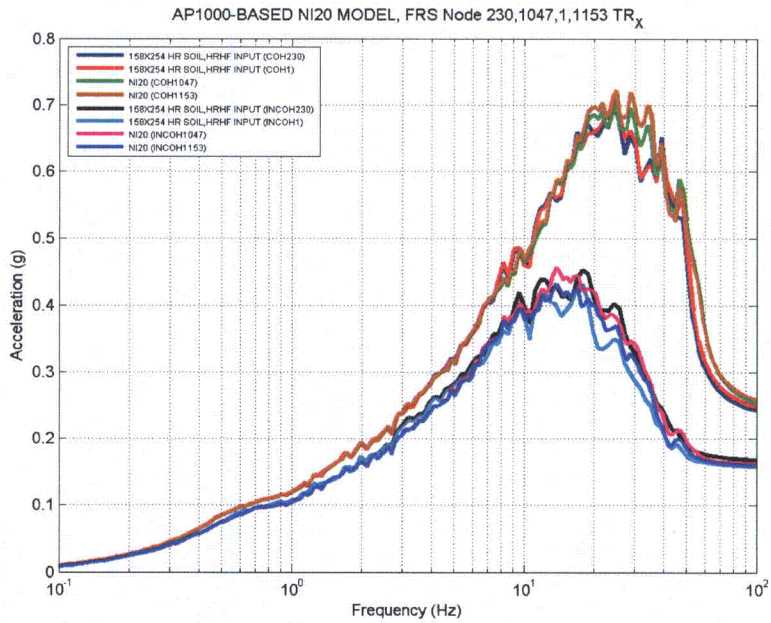


RAI-SRP3.7.1-SEB1-10-32: Top of Shield Building – Elevation 333.3' Y-Direction

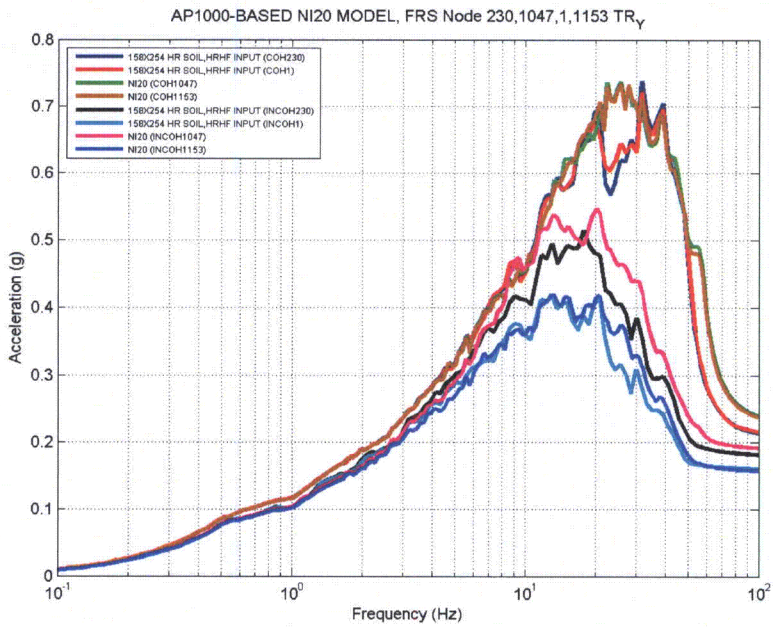




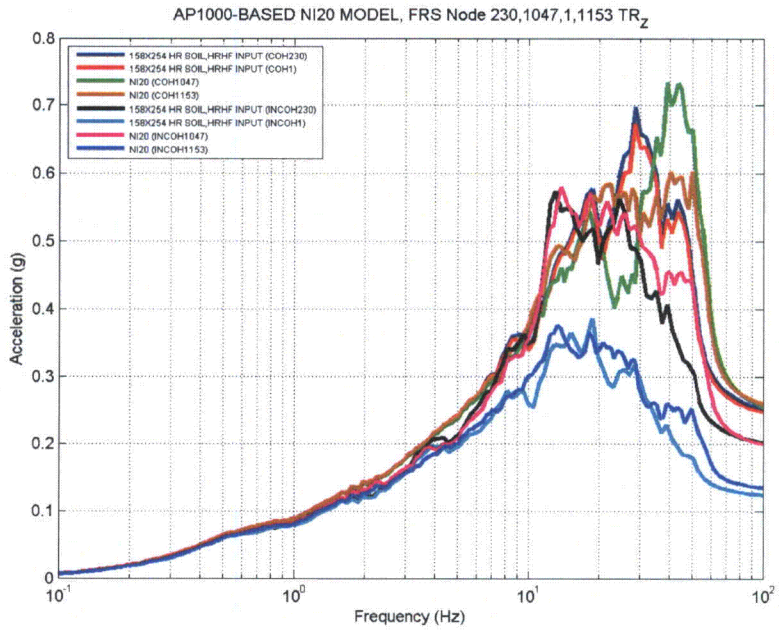
RAI-SRP3.7.1-SEB1-10-33: Top of Shield Building – Elevation 333.3' Z-Direction



RAI-SRP3.7.1-SEB1-10-34: NI20 Basemat – Elevation 60.5' X-Direction



RAI-SRP3.7.1-SEB1-10-35: NI20 Basemat – Elevation 60.5' Y-Direction



RAI-SRP3.7.1-SEB1-10-36: NI20 Basemat – Elevation 60.5' Z-Direction

Reference:

1. Draft EPRI Report, "Hard-Rock Coherency Functions Based on the Pinyon Flat Array Data," July 5, 2007, (ADAMS Accession NO. ML071980104).

Westinghouse Response (Revision 3):

a. The following is an explanation as to why the incoherent response has a significant reduction when compared to the coherent response at low frequencies (below 10 Hz). The incoherent response below 10 Hz as shown in Figures RAI-SRP3.7.1-SEB1-10-1 to 3, 10-16 to 17, and 10-19 to 21 show significant reduction compared to the coherent response. Node 3329 shows a 26%, 36% and 33% reduction in X, Y and Z direction, respectively. Node 2711 shows a 31% and 30% reduction in X and Y direction, respectively. Node 1757 shows a 12%, 19% and 28% reduction in X, Y and Z direction, respectively. The incoherent runs are based on the 2007 Abrahamson coherency function shown in Figure RAI-SRP3.7.1-SEB1-10-37. The average reduction between 6 to 9 Hz is up to 20% for horizontal and up to 30% for vertical direction.

   This reduction of incoherent Floor Response Spectra (FRS) in the 6 to 9 Hz range is a cumulative effect of two reductions due to the incoherency effects and the sharp peak clipping from statistical averaging. The sharp peaks are smoothed by averaging the 25 incoherent FRS curves. The reduction due to incoherency is expected based on the 2007 Abrahamson coherency function for hard-rock. It is noted that the 2007 Abrahamson coherency function shows a smaller reduction when compared to the 2005 coherency function which the EPRI report is based on. The HRHF incoherent analysis shows a consistent reduction as shown in the approved EPRI technical report (Reference 1).

   The EPRI report TR-1015111 "Program on Technical Innovation: Validation of CLASSI and SASSI Code to treat Seismic Wave Incoherence in Soil-Structure Interaction (SSI) Analysis of Nuclear Power Plant (NPP) Structure" (Reference 2) shows the similar reduction. Figure RAI-SRP3.7.1-SEB1-10-38 from the EPRI report shows the incoherent response reduction of node 118 in the horizontal direction. Node 118 in the X Direction shows coherent 5.2g versus incoherent 4.4g between 6-7 Hz, a 15% reduction. Node 118 in the Y Direction shows coherent 5.7g versus incoherent 4.1g between 6-7 Hz, a 28% reduction. Figure RAI-SRP3.7.1-SEB1-10-39 and 40 from the EPRI report show the incoherent response reduction of node 1 and Node 129 in the vertical direction. Node 1 in the Z Direction shows coherent at 0.9g versus incoherent at 0.63g between 8-9 Hz, a 30% reduction and Node 129 in the Z Direction shows coherent at 2.0g versus incoherent at 1.1g between 8-9 Hz, a 45% reduction.

b. The interpolation function for the NI20 SASSI model was reviewed. In ACS SASSI for the numerical simulations of incoherent motions, an arbitrary set of random phase angles are used in conjunction with the spectral factorization of the coherency matrix at each frequency, from the first frequency to the highest frequency selected. Due to the simulation of the set of random phases at each frequency, each simulation has a different transfer function phase angle that is the same at all interaction nodes. At the first frequency, there is no difference between coherent and incoherent motions since the transfer function amplitudes are constant and equal to 1.00 at all nodes. The ground motion is a static translation with the same amplitude in space in the given input direction (e.g., no phase angle variations occur). The arbitrary values of the random phase angles at first frequency does not affect the Fourier transform calculations or any physics of the seismic incoherent SSI analysis, as long as these phase angle values are the same at all interaction nodes, so that there is no relative phase angle variations between different nodal motions.

   The HRHF tape 8 submitted has been verified and the transfer function amplitude of 1.0 is for all nodes.

The reanalysis of the seismic response to correct or clarify the values is not required. The reanalysis is not required based on the EPRI technical report and the Abrahamson coherency function. The EPRI report TR-1015111 "Program on Technical Innovation: Validation of CLASSI and SASSI Code to treat Seismic Wave Incoherence in Soil-Structure Interaction (SSI) Analysis of Nuclear Power Plant (NPP) Structure" is referenced in the Office of New Reactors "Transmittal of Final Interim Staff Guidance – Notice of Availability of the Final Interim Staff Guidance DC/COL-ISG-01 on Seismic Issues Associated with High Frequency Ground Motion" document. The guidance indicates that the use of the SASSI incoherency approach is considered acceptable for treatment of random phasing effects. This EPRI report shows the similar incoherent response reduction. In addition, the reduction due to incoherency is expected based on the 2007 Abrahamson coherency function for hard-rock. It is noted that the 2007 Abrahamson coherency function shows a smaller reduction when compared to the 2005 coherency function which the EPRI report is based on.

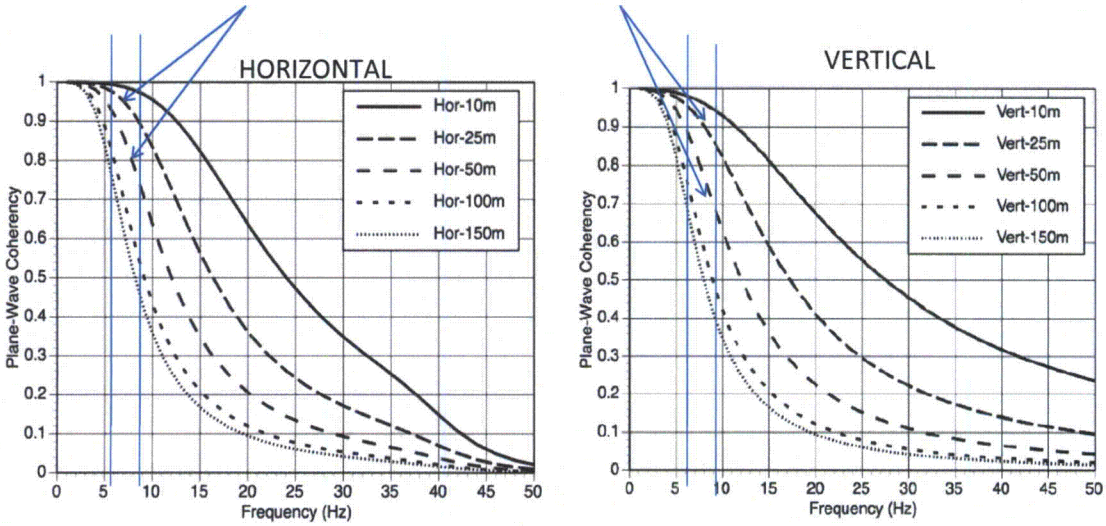
Reference:

2. "Program on Technical Innovation: Validation of CLASSI and SASSI Code to treat Seismic Wave Incoherence in Soil-Structure Interaction (SSI) Analysis of Nuclear Power Plant Structure", EPRI report TR-1015111, Final Report, November 2007.

Westinghouse Response (Revision 4)

In response to an NRC request, Figures RAI-SRP3.7.1-SEB1-10-1 through RAI-SRP3.7.1-SEB1-10-21 have been updated.

2007 ABRAHAMSON COHERENCY



RAI-SRP3.7.1-SEB1-10-37: The 2007 Abrahamson coherency function

CLASSI and SASSI In-Structure Response Spectra Comparisons

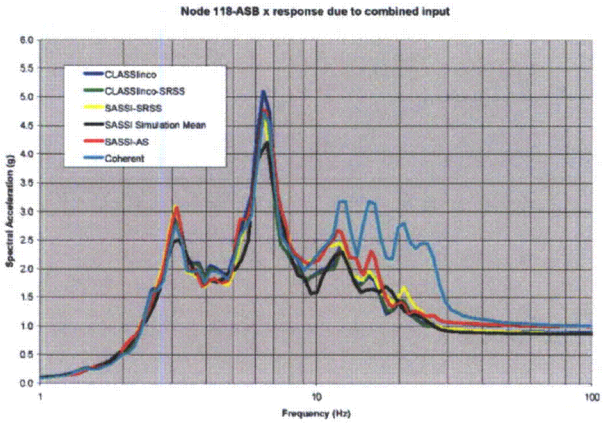


Figure 5-11
ASB Outrigger Response Spectra – X Direction – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 118)

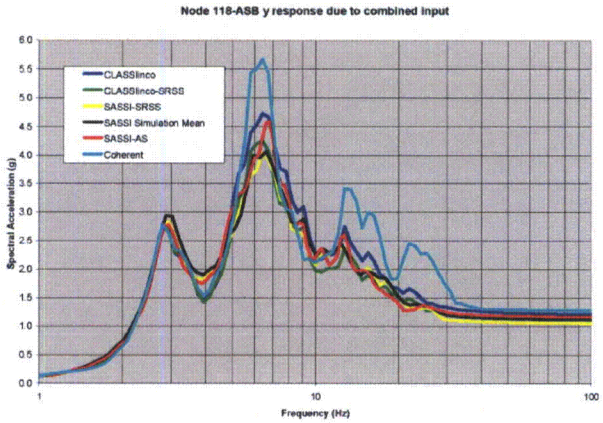


Figure 5-12
ASB Outrigger Response Spectra – Y Direction Due – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 118)

5-10

RAI-SRP3.7.1-SEB1-10-38: EPRI TR- 1015111 Node 118

CLASSI and SASSI In-Structure Response Spectra Comparisons

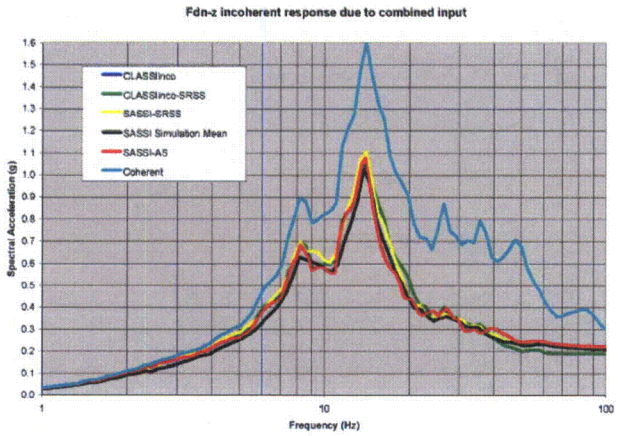


Figure 5-4
Center of Foundation Response Spectra – Z Direction – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 1)

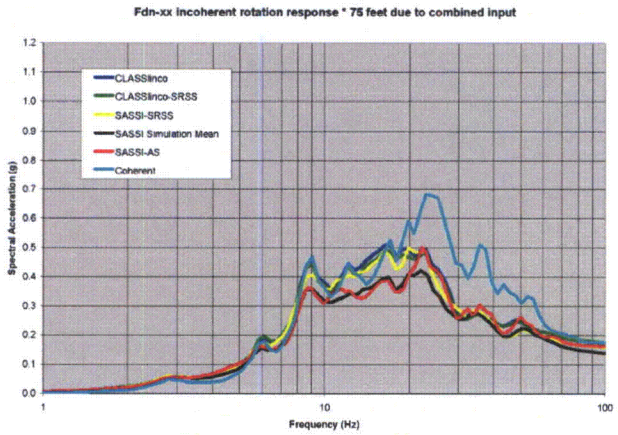


Figure 5-5
Edge of Foundation Response Spectra –XX Rotation – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 1)

CLASSI and SASSI In-Structure Response Spectra Comparisons

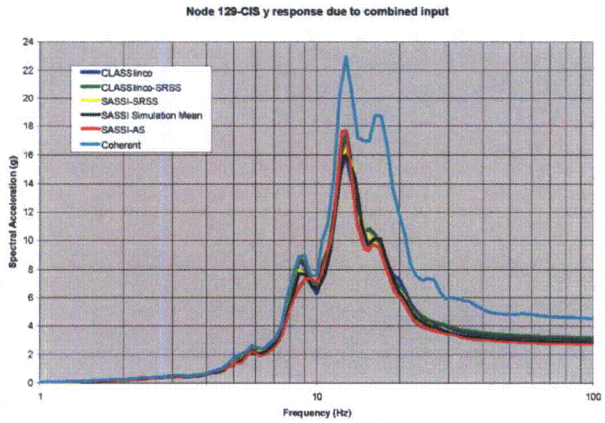


Figure 5-18
Top of CIS Horizontal Mass Center Response Spectra – Y Direction – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 129)

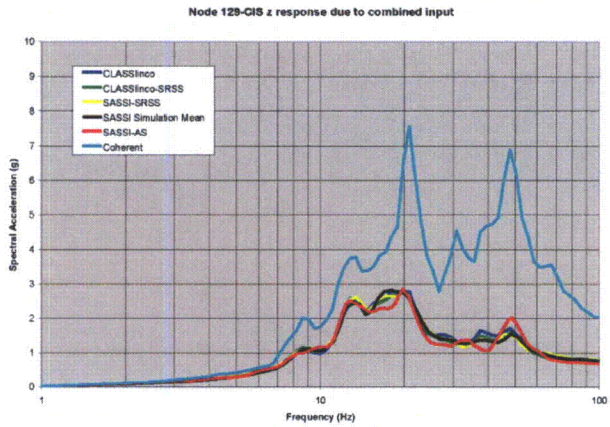


Figure 5-19
Top of CIS Horizontal Mass Center Response Spectra – Z Direction – CLASSIinco, CLASSIinco-SRSS, SASSI-SRSS, SASSI Simulation Mean, SASSI-AS (Node 129)

5-14

RAI-SRP3.7.1-SEB1-10-40: EPRI TR- 1015111 Node 129

Design Control Document (DCD) Revision: None

PRA Revision: None

Technical Report (TR) Revision: The Figure RAI-SRP3.7.1-SEB1-10-1 to RAI-SRP3.7.1-SEB1-10-21 will replace Figure 5.2-1 through 5.2-6 in TR-115. See also RAI-SRP3.7.1-SEB1-11 for changes to Section 5.2.

5.2 Comparison of CSDRS and HRHF Response Spectra

To show the significance of the HRHF response spectra, the CSDRS and HRHF seismic responses are compared. Figures 5.2-1 through 5.2-6 (5% damping) compare the response spectra with coherent and incoherent considerations at a number of locations in the nuclear island. There are some exceedances, mostly above the 15 Hz region. These curves are typical of the plant comparative responses found throughout the plant.