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Your ref: Docket No. 52-006
Our ref: DCP/NRC2478

May 14, 2009

Subject: AP1000 Response to Request for Additional Information (SRP 3)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

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

RAI-SRP3.7.1-SEB1-04 R3

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

Very truly yours,

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

/Enclosure

1. Response to Request for Additional Information on SRP Section 3

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NRO

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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-SEB1-04
Revision: 3

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.

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 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.

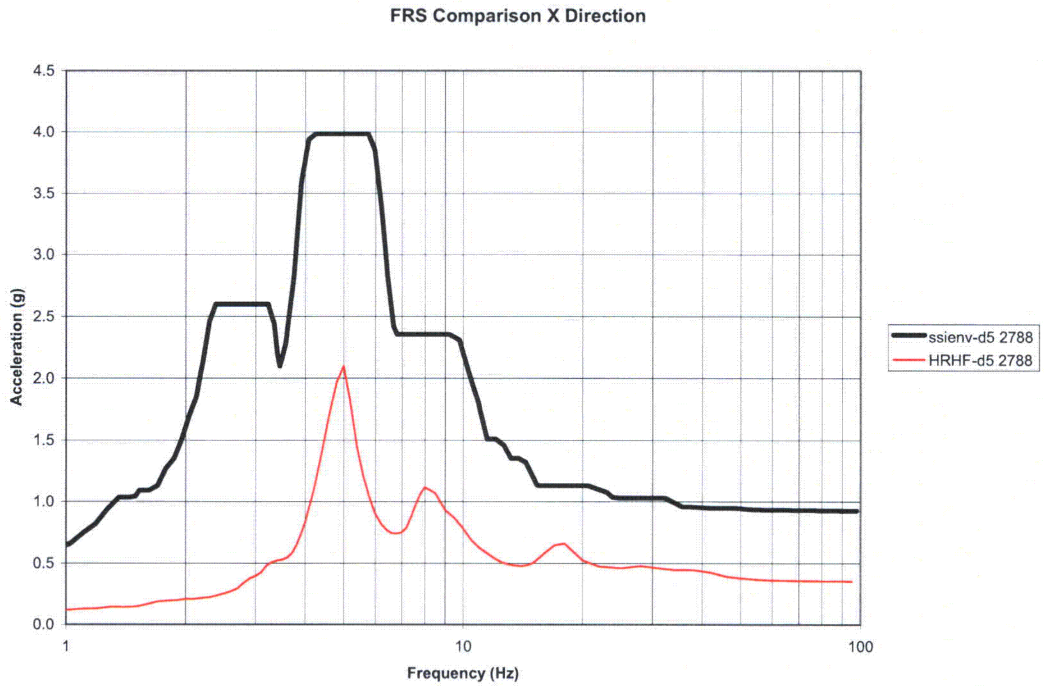


Figure RAI-SRP3.7.1-SEB1-04-1 – X Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

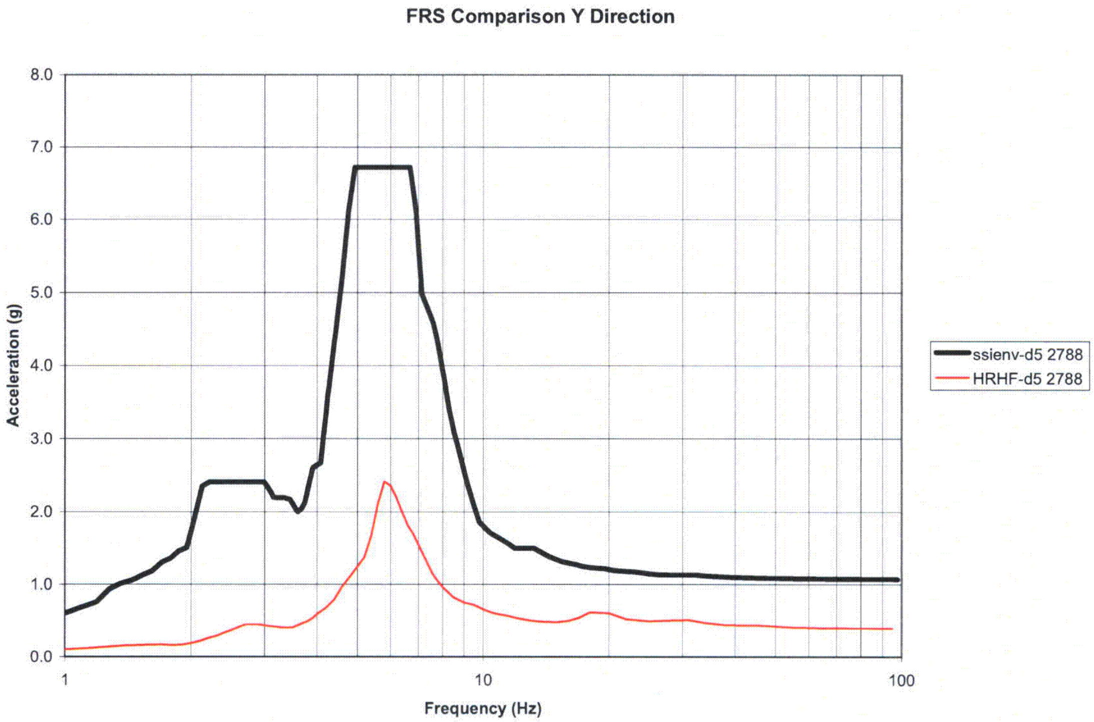


Figure RAI-SRP3.7.1-SEB1-04-2 – Y Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

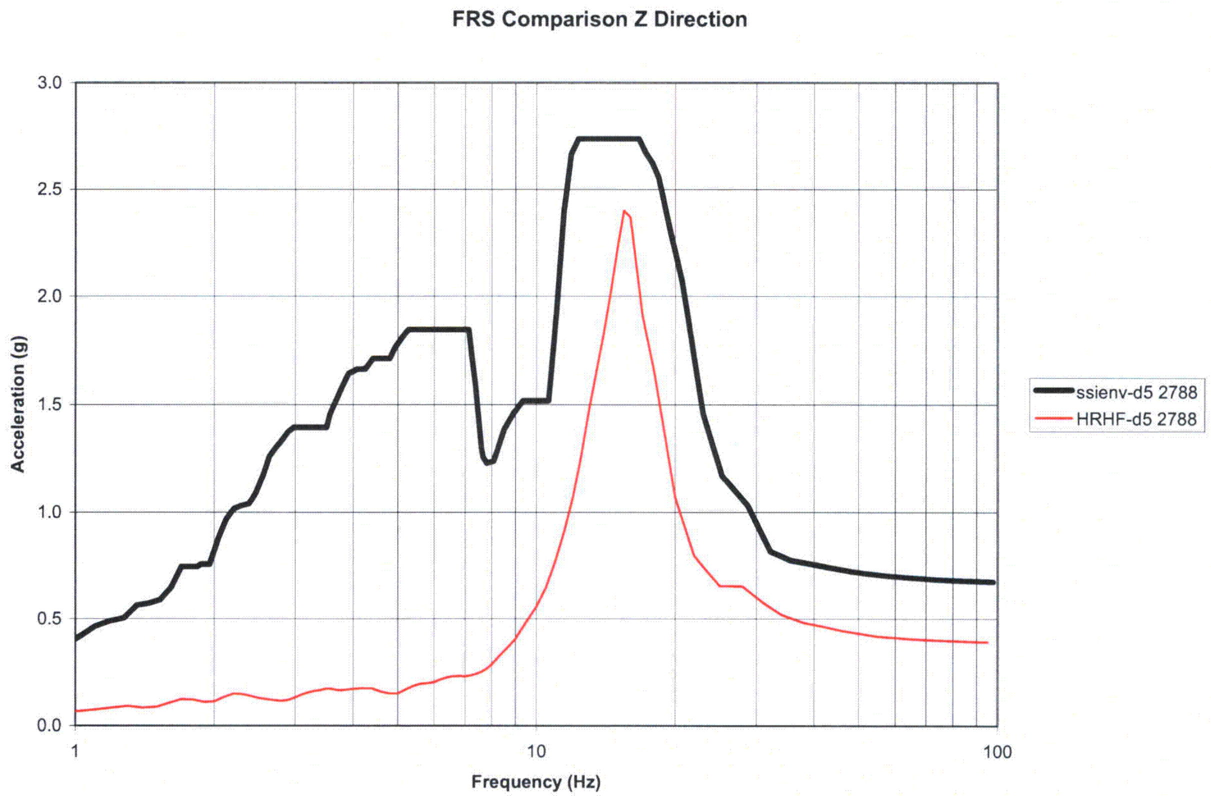


Figure RAI-SRP3.7.1-SEB1-04-3 – Z Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

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 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. 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.

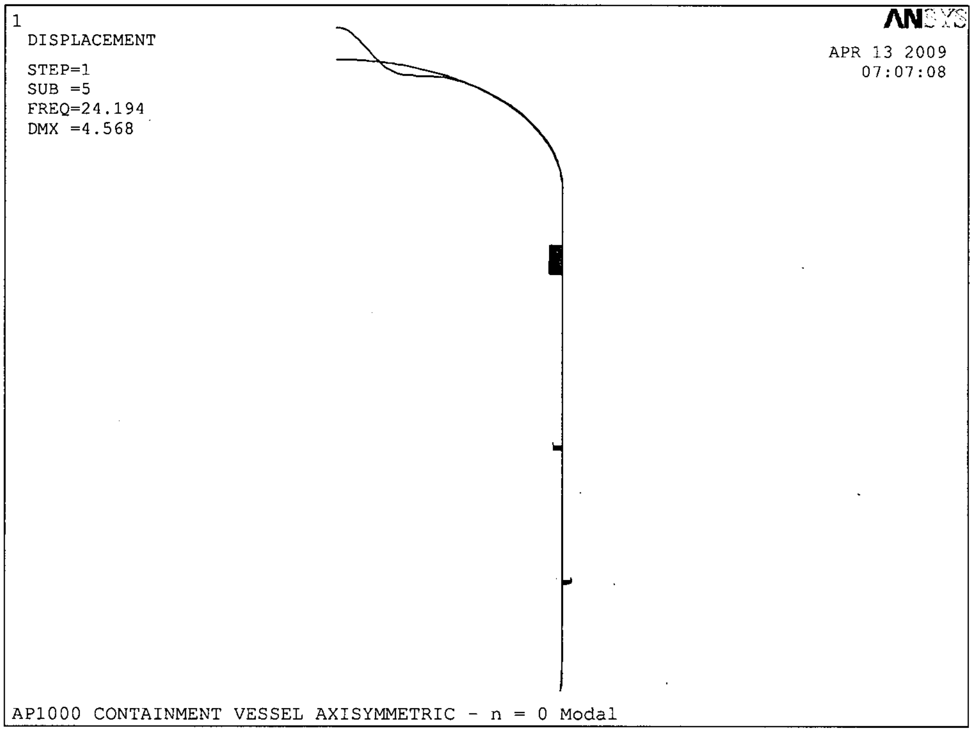


Figure RAI-SRP3.7.1-SEB1-04 - Vertical Mode No. 3 (mode 5 from the analysis, 24.2 Hz)

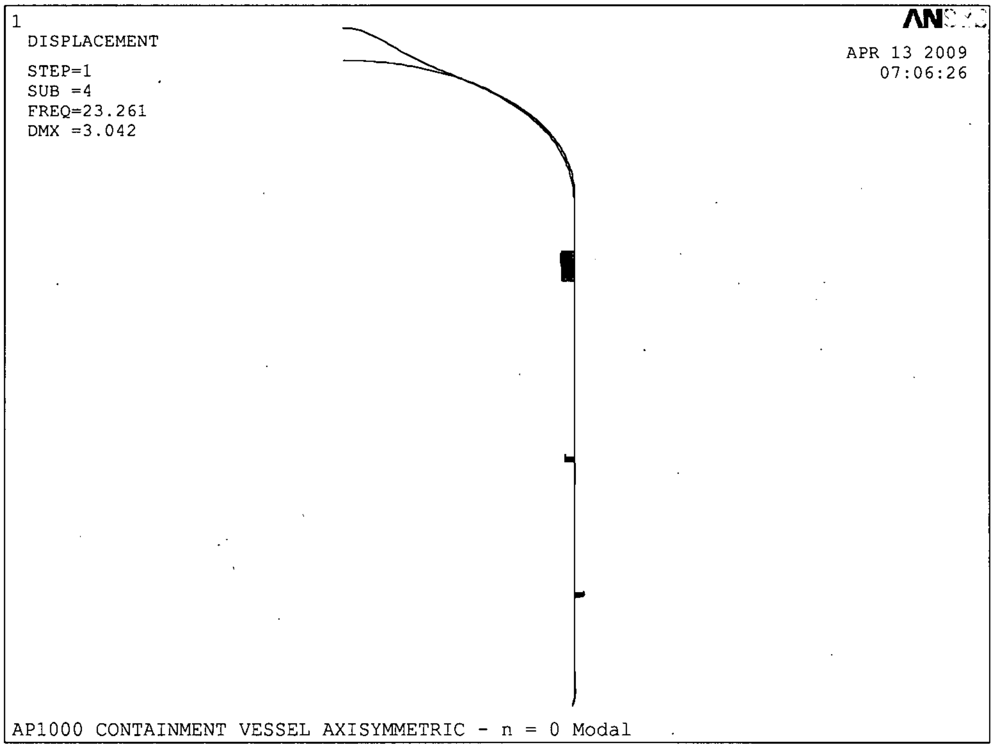


Figure RAI-SRP3.7.1-SEB1-05 - Vertical Mode No. 2 (mode 4 from the analysis, 23.3 Hz)

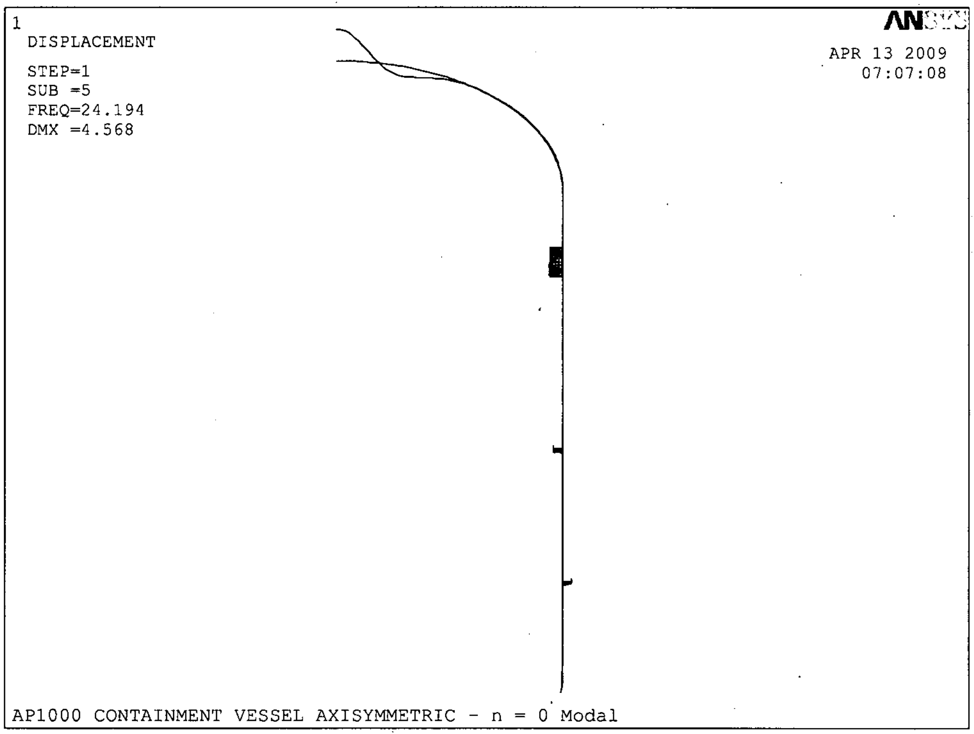


Figure RAI-SRP3.7.1-SEB1-06 - Vertical Mode No. 3 (mode 5 from the analysis, 24.2 Hz)

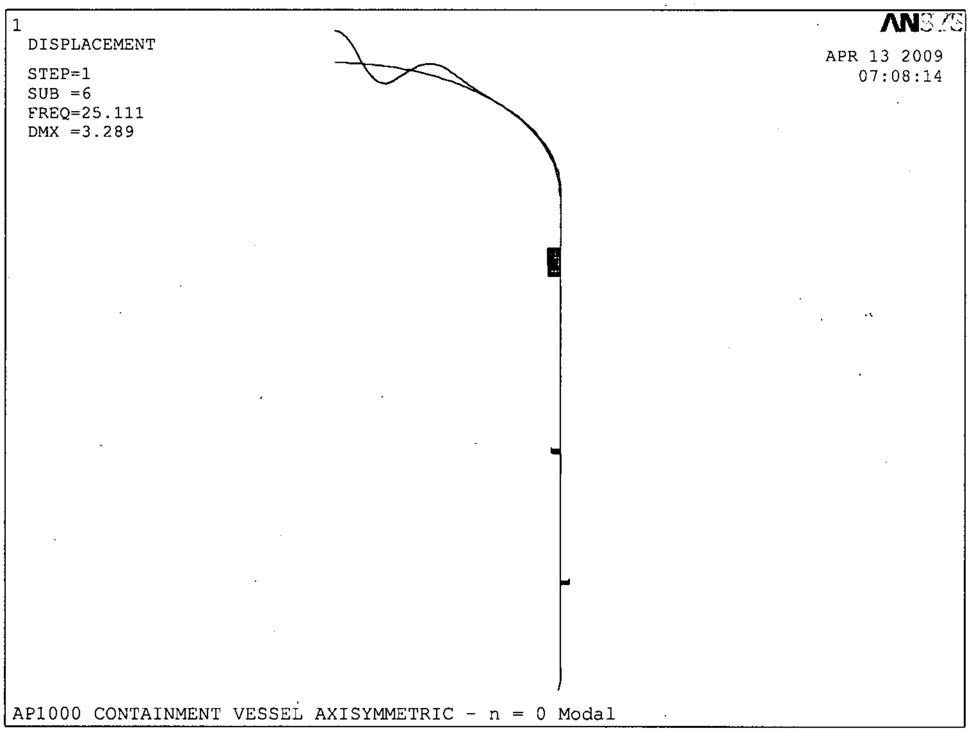


Figure RAI-SRP3.7.1-SEB1-07 - Vertical Mode No. 4 (mode 6 from the analysis, 25.1 Hz)

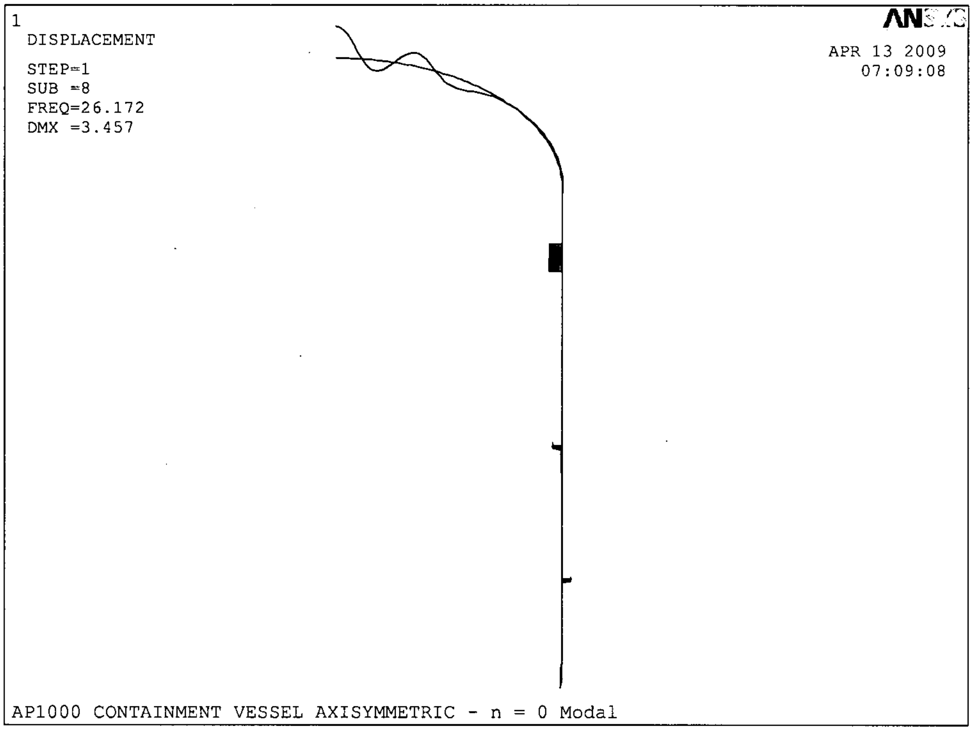


Figure RAI-SRP3.7.1-SEB1-08 - Vertical Mode No. 5 (mode 8 from the analysis, 26.2 Hz)

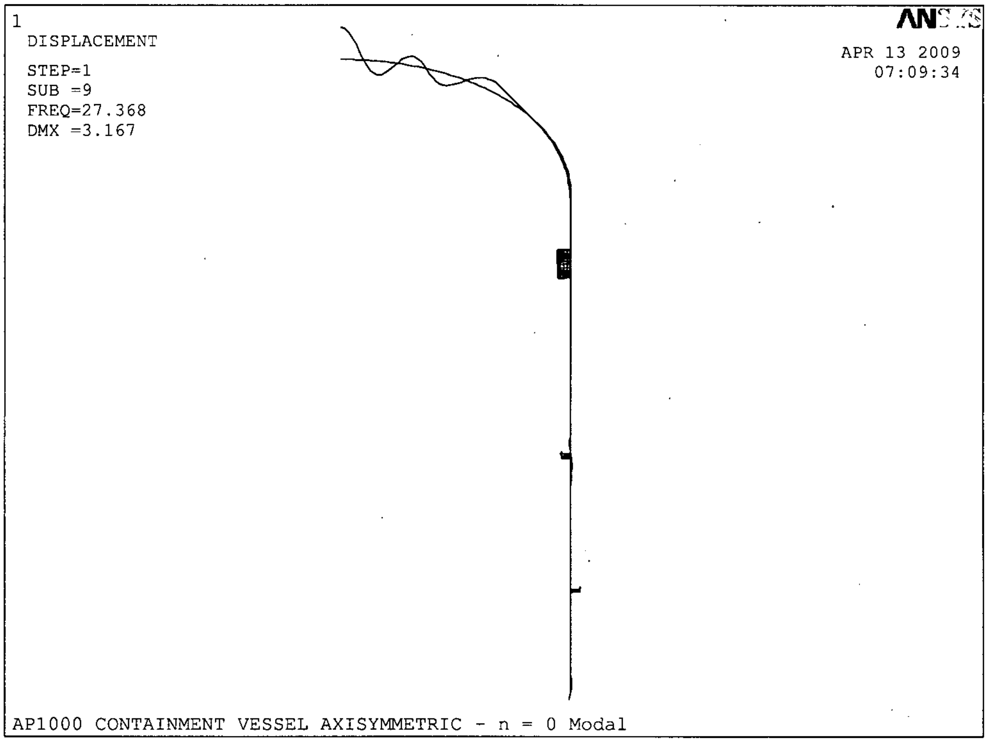
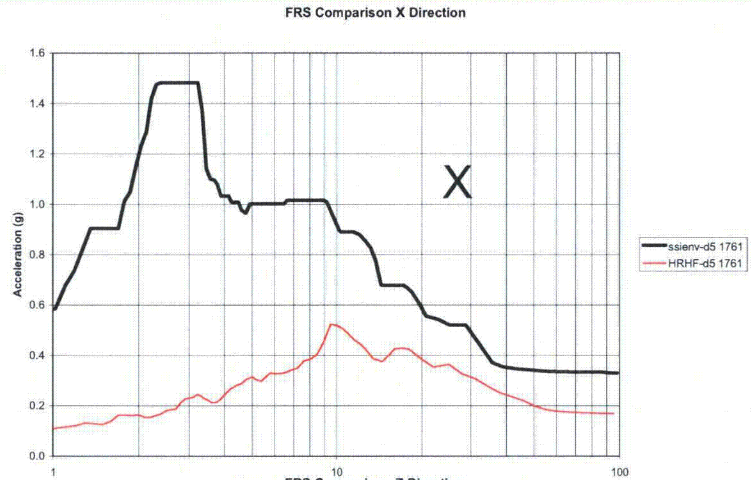
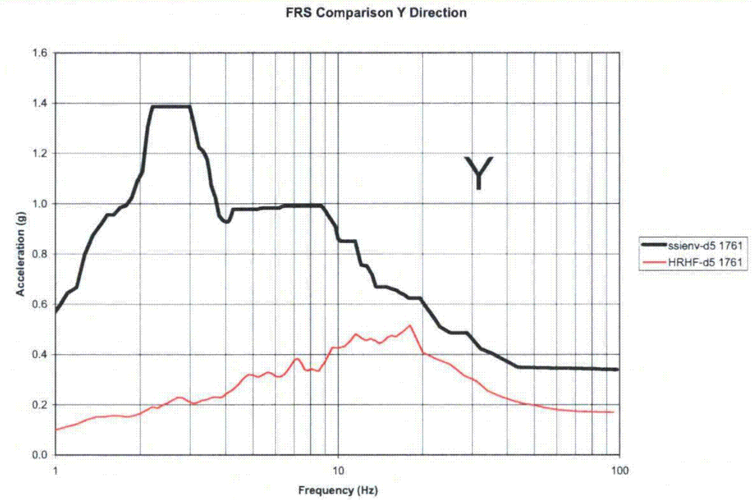
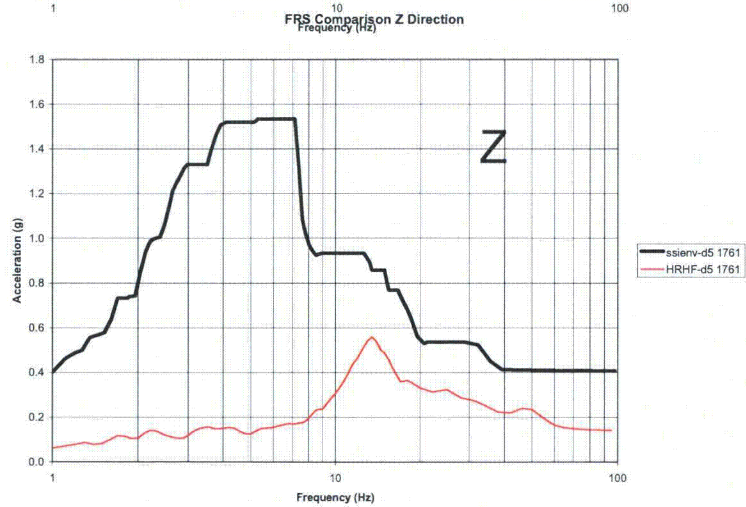


Figure RAI-SRP3.7.1-SEB1-09 - Vertical Mode No. 6 (mode 9 from the analysis, 27.4 Hz)





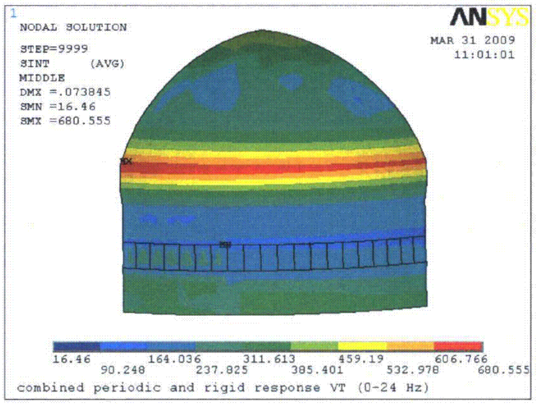


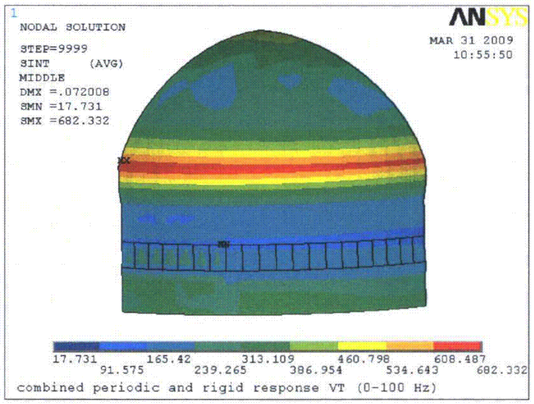
SCV HRHF Spectra is enveloped by AP1000 Spectra.

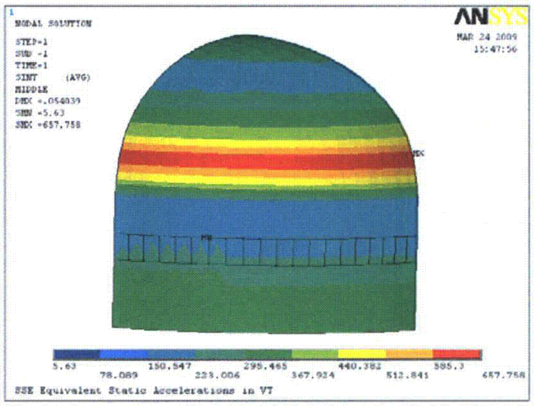
HRHF input has lower energy below 10 Hz and because it is above a region that has a very thick base (rigid) basemat the coherency function is very effective in reducing the response above 10 Hz

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

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



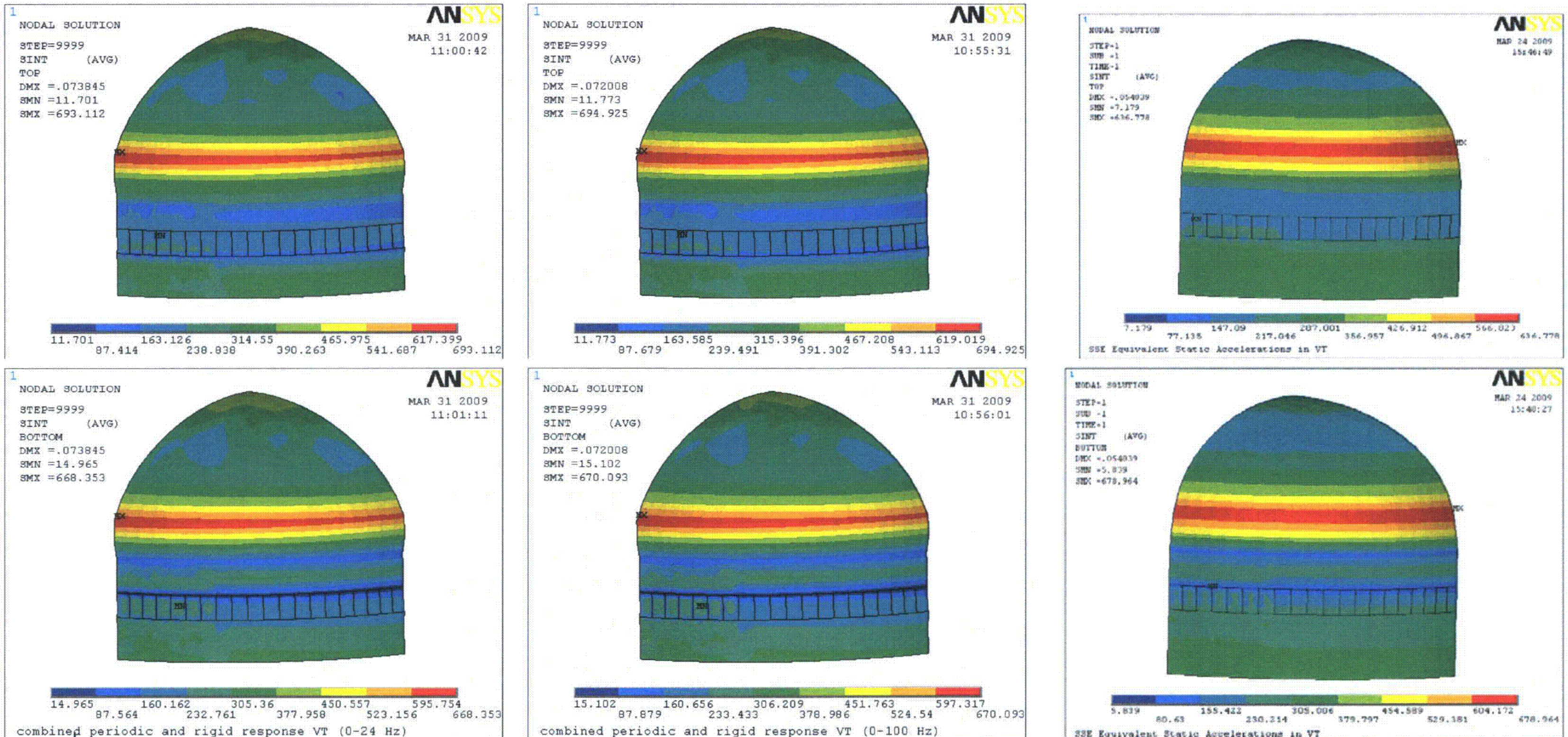




Stress Intensity, Middle Layer, Equivalent Static within 4% of RSA 0-50Hz

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

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, 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