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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002977

July 27, 2010

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-SEB1-06 R5
RAI-SRP3.7.1-SEB1-17 R2

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

Very truly yours,

Robert Sisk

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

/Enclosure

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

DO63
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-SEB1-06
Revision: 5

Question:

Westinghouse's calculation in TR-115 indicates 4 points per wavelength for 80 Hz. This is the bare minimum to represent a full cycle of sinusoidal displacement variation. The staff requests that Westinghouse include in Section 5.1 a comparison of frequencies and mode shapes between the NI10 and NI20 models, as an alternate way to demonstrate the adequacy of the NI20 model to accurately predict high frequency modes (up to 80 Hz).

Additional Request (Revision 2):

The staff initially requested that Westinghouse include in Section 5.1 of TR 115, a comparison of frequencies and mode shapes between the NI10 and NI20 models, as an alternate way to demonstrate the adequacy of the NI20 model to accurately predict high frequency modes (up to 80 Hz). In its initial response, Westinghouse pointed out that the final ISG for addressing HRHF GMRS only requires modeling refinement to accurately predict up to 50 Hz. Instead of providing a comparison of frequencies and mode shapes between the NI10 and NI20 models up to 50 Hz, Westinghouse indicated that there are 7 nodes per wavelength in the NI20 model for a 50 Hz. frequency. In a supplement to its initial response, as a result of discussions at the May 2008 onsite audit, Westinghouse presented additional information about the frequency distributions in the NI10 and NI20 models, and claimed that this information demonstrated adequacy of the NI20 model up to 50 Hz.

The staff reviewed this information and concluded (1) it does not demonstrate adequacy of the NI20 model up to 50 Hz; and (2) the information raises additional concern about the possibility of modeling and/or analysis errors.

The staff noted the following, for which Westinghouse needs to provide a detailed technical explanation:

(a) In the 0-10 Hz range, there are 58 modes for NI20 and 69 modes for NI10. In the low frequency range, the correlation would be expected to be near 100%.

(b) In the 10-40 Hz range, the difference in number of modes is very large: 658 for NI20; 1234 for NI10.

(c) In the 40-55 Hz range, the difference in number of modes is relatively small: 484 for NI20; 545 for NI10.

The staff notes that acceptable criteria to demonstrate adequate model refinement is delineated in SRP 3.7.2, Revision 3 (March 2007), Paragraph II.1.A.iv(1). The staff requests that Westinghouse review the SRP criteria, and provide sufficient information on NI20 frequencies and mode shapes so that the staff can independently assess whether NI20 satisfies the SRP criteria, up to 50 Hz.

Additional Request (Revision 3)

Please provide more detail.

Additional Request (Revision 4)

Westinghouse will provide justification on how flexible regions (walls, floors, and roof panels) are addressed in the Hard Rock High Frequency evaluation. Review and identify responses to less that 50 Hz for HRHF. Evaluate the screening locations for HRHF. Reanalysis of seismic response will correct/clarify values and results will be re-issued as a new revision to RAI-SRP3.7.1-SEB1-06).

Additional Request (Revision 5):

Staff comments on RAI-SEB1-06, July 2010

In general, the draft response is consistent with the information presented at the 3.7 audit. In the formal submittal, the following items need to be incorporated for completeness and consistency with the response to RAI-TR03-032:

(a) A list of flexible regions (<50 Hz) identified in the NI05 model that are not represented in the NI20 model.
(b) A representative sample of ISRS comparisons, at locations where the NI05 results exceed the NI20 results.
(c) A summary discussion of the effect of the additional local amplification on the structures, piping, and equipment sampling assessments.

Westinghouse Response (Revision 0 & 1):

At the December 20, 2007 meeting between the U.S. NRC staff and industry related to the high frequency seismic events, it was agreed that a maximum analysis frequency of 50 hertz would be sufficient to transmit the high frequency response through the model. Using this frequency and the formulas given in Section 5.1 the acceptable mesh size is determined.

Shortest wavelength = $\lambda = Vs / f_{max}$

Vs = 6900 ft/sec (given in Section 5.1)
f_{max} = 50 hertz

λ = 6900 / 50 = 138'

Using the NI20 model (mesh size of 20'), and the shortest wavelength of 138', then close to 7 nodes per wavelength are obtained to transmit the high frequency through the finite elements. This is sufficient accuracy in the building structure model to transmit the high frequency through the finite elements in the NI20 model. Therefore, it is not necessary to include in Section 5.1 a comparison of frequencies and mode shapes between the NI10 and NI20 models.

In addition to the above, a modal response comparison is made between the NI10 and NI20 models to demonstrate the adequacy of the NI20 model to predict high frequency response up to 50 hertz.

Table RAI-SRP3.7.1-SEB1-06-1 shows the comparison of the frequency for each model at certain modes. Due to the increased refinement of the NI10 model, the NI20 reaches higher frequencies at lower modes. This is also shown in Tables RAI-SRP3.7.1-SEB1-06-2 and RAI-SRP3.7.1-SEB1-06-3. Tables RAI-SRP3.7.1-SEB1-06-2 and RAI-SRP3.7.1-SEB1-06-3 show the highest numbered mode found in each 10 Hz frequency range and also shows how many modes are in each of the aforementioned ranges.

Figures RAI-SRP3.7.1-SEB1-06-1 to RAI-SRP3.7.1-SEB1-06-3 show a summation of the of the effective mass verses frequency for the X, Y and Z directions. The effective masses associated with the NI20 and NI10 models compare closely over the frequency range of 1 to 80 Hz.

From this comparison it can be concluded that the modal response of the NI20 model is very similar to the NI10 model, and therefore, is adequate to predict the high frequency response up to 50 hertz.

Westinghouse Response (Revision 2):

The difference in the number of modes between theNI10 and NI20 models is due to the increased number of degrees of freedom in the NI10 model. Therefore, it is expected that the NI10 model will have more modes within given frequency ranges. It is not possible to easily provide direct comparisons of the mode shapes between the two shell models because of their complexities and size. The best demonstration that the models are responding in a similar manner is by the comparison of modal mass over the frequency range of interest. This comparison has been provided in Figures RAI-SRP3.7.1-SEB1-06-1 to RAI-SRP3.7.1-SEB1-06-3. As seen from the comparison plots the modal response is the same in both models demonstrating the modal response will be similar.

Table **RAI-SRP3.7.1-SEB1-06-1**: Mode Number vs. Frequency

Mode	Ni20	Ni10
50	9.29	8.29
100	14.05	12.47
150	16.81	14.83
200	20.27	16.73
250	22.61	18.69
300	24.82	21.00
350	26.97	22.37
400	28.72	23.48
450	30.59	24.49
500	32.39	25.37
550	34.23	26.13
600	35.84	26.71
650	37.52	27.48
700	39.38	28.59
750	41.15	29.87
800	42.81	30.96
850	44.34	32.19
900	45.85	33.48
950	47.41	34.48
1000	48.86	35.44
1050	50.10	36.18
1100	51.72	36.99
1150	53.10	37.78
1200	54.55	38.37
2000	N/A	58.8127

Table RAI-SRP3.7.1-SEB1-06-2: Modes Per Range (NI10)

NI10		
Frequency Range	**Max Mode in Range**	**Modes Per Range**
0-10	69	69
10-20	277	208
20-30	755	478
30-40	1303	548
40-55	1848	545

Table RAI-SRP3.7.1-SEB1-06-3: Modes Per Range (NI20)

NI20		
Frequency Range	**Max Mode in Range**	**Modes Per Range**
0-10	58	58
10-20	193	135
20-30	434	241
30-40	716	282
40-55	1200	484

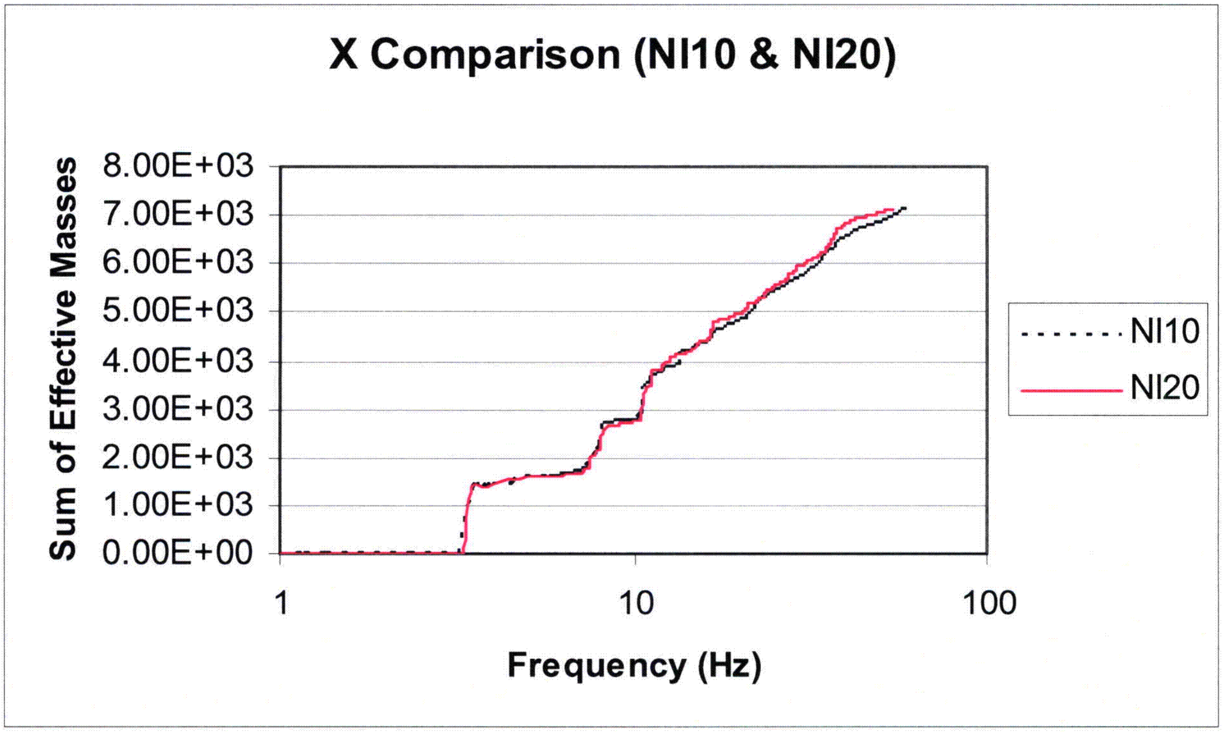

Figure RAI-SRP3.7.1-SEB1-06-1: X-Direction Comparison

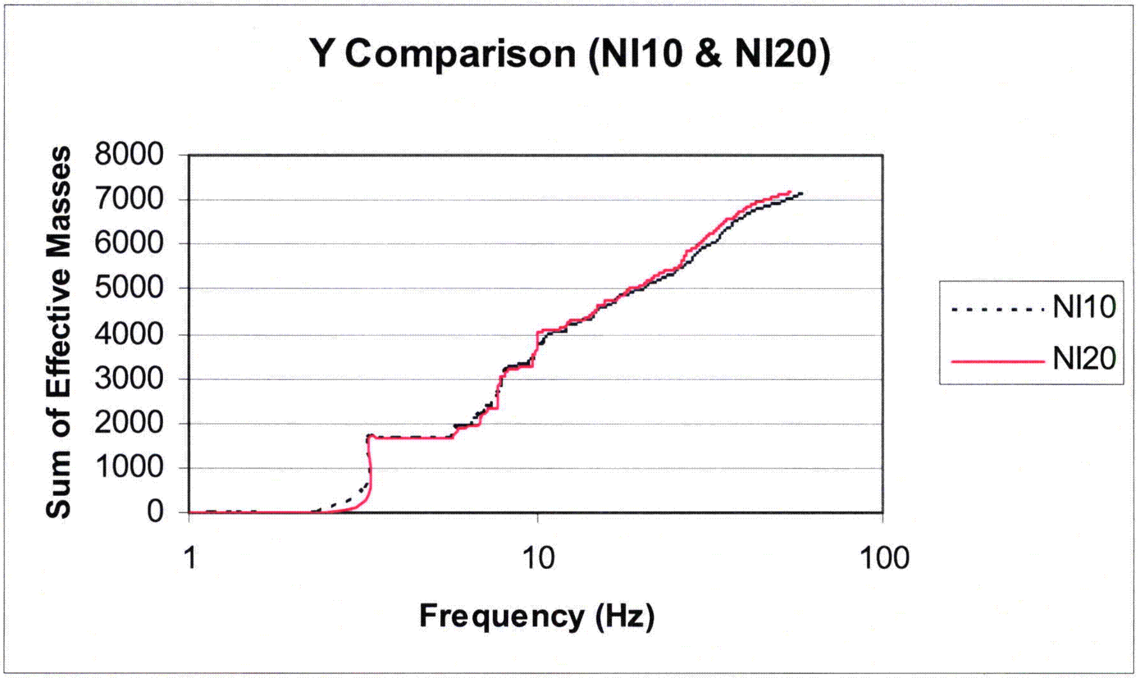

Figure RAI-SRP3.7.1-SEB1-06-2: Y-Direction Comparison

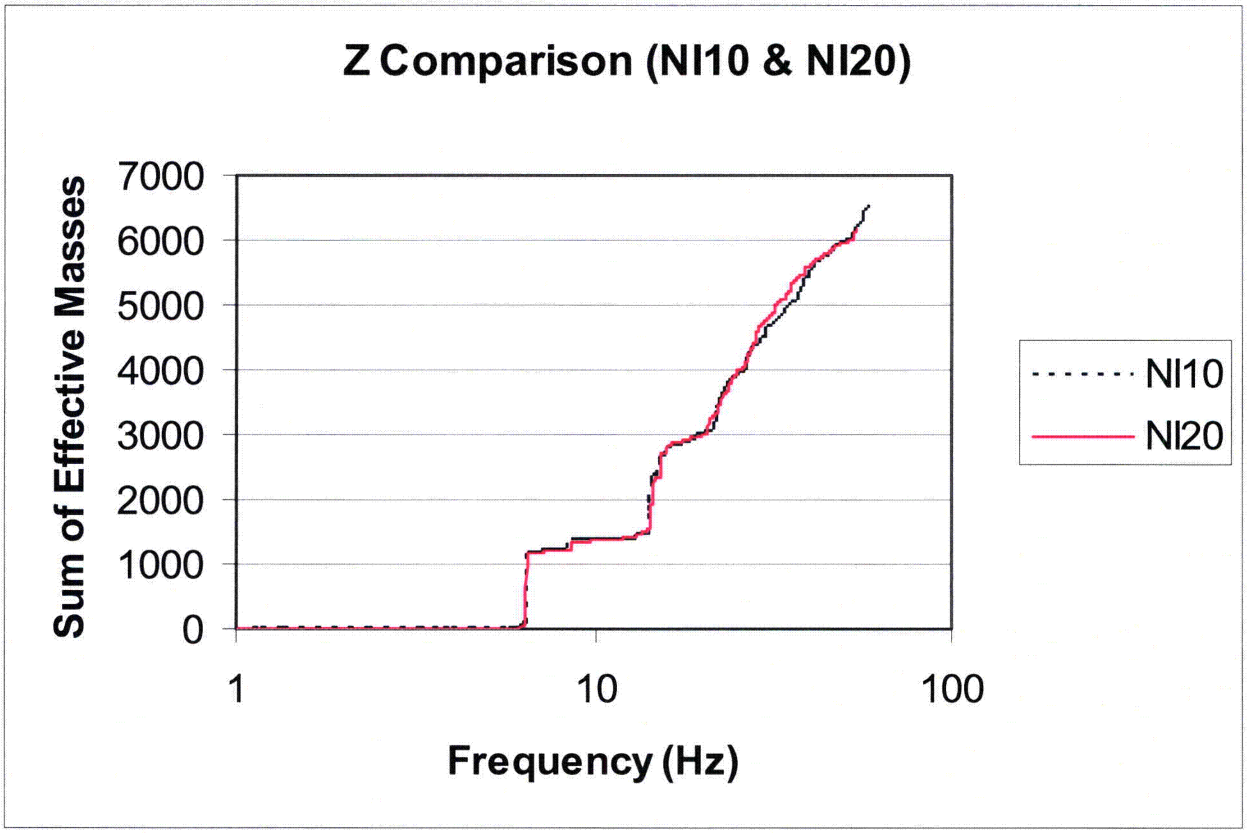

Figure RAI-SRP3.7.1-SEB1-06-3: Z-Direction Comparison

Westinghouse Response (Revision 3):

The Revision 3 response is provided to acknowledge the NRC request to provide more detail.

In addition, to demonstrate that the NI20 model satisfies the SRP criteria up to 50 Hz, the staff has been shown, during two previous audits, mode shapes of both the NI10 and NI20 models. Both models showed similar "breathing" type modes up to 50 Hz.

The HRHF spectra peaks at about 25 Hz. In order to confirm the NI20 model's adequacy for frequencies up to 50 Hz, a time history analysis was performed in ANSYS using the NI20 and NI10 models with the Westinghouse defined Hard Rock High Frequency (HRHF) input time history. The time step for the HRHF time history was changed from 0.005 to 0.003 seconds. This shifts the peak of the input time history to 50 Hz while maintaining the statistically

indeterminate properties of the original HRHF spectra defined in TR115. We shall refer to this as the Hard Rock Super High Frequency (HRSHF) analysis in subsequent discussions.
The HRHF and HRSHF acceleration response spectra have been provided in Figures RAI-SRP3.7.1-SEB1-06-04 and RAI-SRP3.7.1-SEB1-06-05 to show the acceleration peak shift due to the time step change.

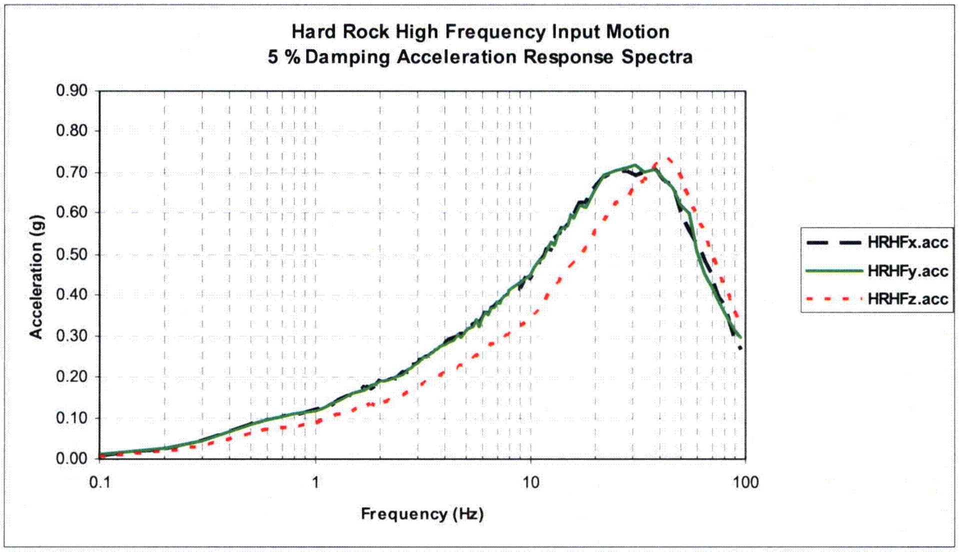

Figure RAI-SRP3.7.1-SEB1-06-04: HRHF Acceleration Response Spectra

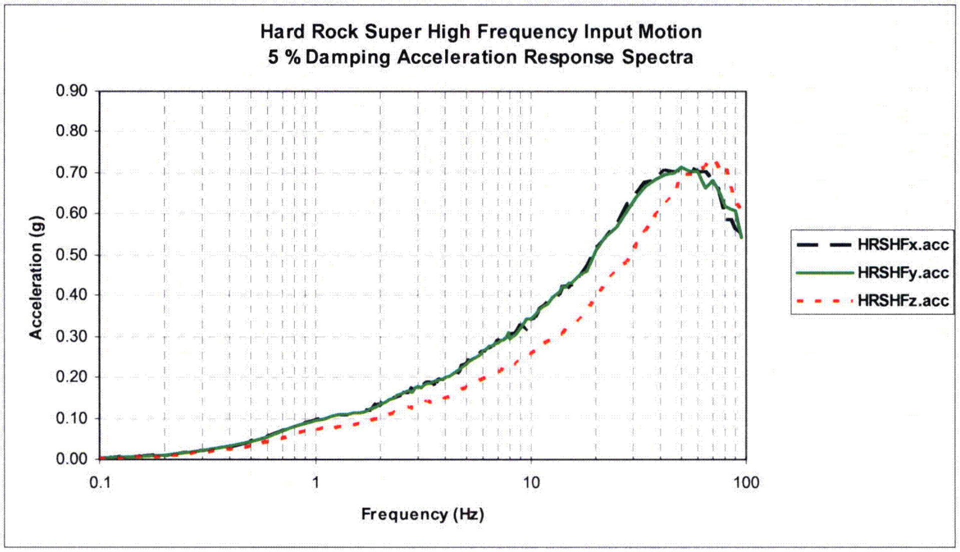

Figure RAI-SRP3.7.1-SEB1-06-05: HRSHF Acceleration Response Spectra

~~The nodes selected for comparison are presented in Figure RAI-SRP3.7.1-SEB1-06-06.~~

~~Figure RAI-SRP3.7.1-SEB1-06-06: NI20 ANSYS Auxiliary building locations~~

The floor response spectra (FRS) of these nodes have been provided in Figures RAI-SRP3.7.1-SEB1-06-07 through RAI-SRP3.7.1-SEB1-06-21. The HRSHF analysis shows that the NI20 ANSYS FRS results are either similar or conservative to the NI10 ANSYS FRS results. The results also show that the NI20 model will respond up to a frequency of 50 Hz.

In conclusion, Westinghouse has shown that the NI20 structural model behaves consistently with the much more refined NI10 model. The NI20 model is adequately refined to sufficiently capture the high frequency content of the HRHF spectra given in Figure RAI-SRP3.7.1-SEB1-06-04. Using the input from the HRSHF which peaks at about 50 Hz, Figure RAI-SRP3.7.1-SEB1-06-05, the NI20 model is shown to have sufficient model refinement to transmit a frequency up to 50 Hz.

The information previously provided for the model in Figure RAI-SRP3.7.1-SEB1-06-06 and for the floor response spectra in Figures RAI-SRP3.7.1-SEB1-06-07 through RAI-SRP3.7.1-SEB1-06-21 are based on an earlier model and have been deleted in Revision 5 of the response.

Westinghouse Response (Revision 4):

In order to identify flexible regions considered to have frequencies of significant modal response between 33 hertz and 50 hertz, the NI05 model is used. Based on the dynamic response information, flexible areas are identified that may amplify the high frequency seismic input. The mode shapes from the NI05 model are compared to those from the NI20 model. This is to ensure that there is a node in the NI20 model that is within the area of amplification that reflects the floor flexibility and corresponding additional amplification. Response spectra are then developed for each of these additional flexible areas (frequencies above 33 hertz and below 50 hertz) and included in the design in-structure response spectra for evaluation of the HRHF seismic event. This allows the identification of additional flexible regions at frequencies above 33 hertz and below 50 hertz to be addressed in Technical Report APP-GW-GLR-115, Revision 2 (TR115).

Westinghouse Response (Revision 5):

(a)

Table RAI-SRP3.7.1-06-4 lists the flexible regions already captured in the coupled building analysis using the NI10 (for Hard Rock) and NI20 (for the soil sites). See the response given in Revision 5 of RAI-TR03-32 for a discussion of flexible regions added based on the NI05 analysis for the envelope of all soil site conditions. Table RAI-SRP3.7.1-06-5 lists the additional nodes representing flexible regions summarized in that response. Additionally, for the analysis of building structures for HRHF input, Table RAI-SRP3.7.1-06-6 lists the regions identified in NI05 model that could amplify HRHF input (have fundamental modes less than 50Hz) but are not identified in either Table RAI-SRP3.7.1-06-4 or RAI-SRP3.7.1-06-5. Tables RAI-SRP3.7.1-06-7 and RAI-SRP3.7.1-06-8 list all Ni05 nodes reviewed for flexible response for building walls and floors, respectively.

(b)

The response spectra comparisons for the 7 additional NI05 flexible nodes against the design "groups" at the same elevation are shown in Figures RAI-SRP3.7.1-06-6 to Figures RAI-SRP3.7.1-06-12 (out-of-plane direction only). Each of the spectra in Figures RAI-SRP3.7.1-06-4 through RAI-SRP3.7.1-06-10 shows amplification beyond the "group" spectra for the NI20 HRHF time history analysis.

(c)

The resulting 7 areas with amplified spectra (for regions with frequencies less than 50Hz) as well as the 7 already identified (for regions with frequencies less than 50 Hz – see RAI-TR03-32, Rev. 5) are included with the 13 original flexible areas identified in TR-03 (for NI10 and NI20 analysis) as shown in Table RAI-SRP3.7.1-06-4 through RAI-SRP3.71.-06-6 (labeled NI05) and in the "Technical Report (TR) Revision" section of this response. The resulting FRS for all "flexible nodes" will also be included in the HRHF spectra document.

The information previously provided for the model and for the floor response spectra in Revision 3 of the response are based on an earlier model and have been deleted in Revision 5 of the response.

Table RAI-SRP3.7.1-06-4: List of Auxiliary Building Walls and Floors and Corresponding Flexible Node Incorporated in Ni10 and Ni20 Models

Flexible Area	Soil Site Node	Hard Rock Site Node
Flexible floor area East of Shield Building to column line I and between column lines 7 to 7.3, EL. 116.5'	2030 2034 2038	4548 4556 4570
Fuel pool wall L2 between Column Lines 2 to 4, EL. 92.71' to 135'	2266	7397
Wall Q between Column lines 9.1 to 11, EL. 117.5' to 135'	2333	6823
Flexible floor East of Shield Building between column lines 4 to 5, EL. 135'	2281 2287	4925 4939
Flexible floor on North of Shield Building between column lines I to L and 5 to 7.3, EL. 135'	2295 2299 2303	4959 4967 4981
Flexible floor on North of Shield Building between column lines I to L and 7.3 to 11, EL. 135'	2331	5080
Wall I between column lines 1 & 4,above EL. 160'	2596	6948
Wall N between column lines 1 & 4,above EL 160'	2597	6897
Wall 1 between column line I & N, above EL.160'	2591	6939
Floor between column lines 7.3 &11 and I to L, EL. 160'	2515	5314
Roof East of Shield Building to Column line I and between column lines 7 to 7.3, EL. 160'	2626 2630 2634	5485 5494 5507
Roof South side of Aux Bldg between column lines I & N and column lines 1 to 4. , EL. 180'	2695 2697	5628 5633
Center of shield Bldg , EL. 289.2'	3067	8296

Table RAI-SRP3.7.1-06-5: List of Auxiliary Building Walls and Floors and Corresponding Flexible Node Based on Ni05 Analysis for CSDRS (Less than 33 Hz)

Flexible Area	Building Node
Wall 4 at midspan near elevation 170'	12188 (NI05)
Wall 7.3 at midspan near elevation 145'	21870 (NI05)
Wall 11 at midspan near elevation 110'	16996 (NI05)
Wall J-2 at midspan near elevation 120'	21285 (NI05)
Wall K-2 at midspan near elevation 113'	20911 (NI05)
ASB Floor between column lines 7.3 & 9.1 at elevation 81'	6244 (NI05)
SE ASB Floor between column lines 2 & 4 at elevation 106'	12009 (NI05)

Table RAI-SRP3.7.1-06-6: List of Additional Auxiliary and Shield Building Areas Based on Ni05 Analysis Considered for the Effects offor HRHF Input (Less than 50 Hz)

Flexible Area	Building Node
Wall 2 at midspan near elevation 103'	20426 (NI05)
Wall 5 at midspan near elevation 126'	21349 (NI05)
Wall 9.3 at midspan near elevation 75'	19523 (NI05)
ASB Floor at Elevation 81'	6188 (NI05)
SE ASB Floor at Elevation 106'	7899 (NI05)
Northwest Control Room Floor 116'	8005 (NI05)
ASB Flexible Floor Elevation 135'	9091 (NI05)

Table RAI-SRP3.7.1-06-7: List of Auxiliary Building Walls Additional NI05 Nodes Reviewed for Flexible Response

Wall Name		NI05_Node	X	Y	Z
W_1		18259	862.50	957.00	158.44
		18249	862.50	978.32	158.44
		16800	862.50	947.50	116.50
		16819	862.50	926.56	116.50
W_11		16996	1116.50	963.06	109.61
W_2		20426	885.00	961.25	102.58
W_3		7977	907.00	947.50	116.50
W_4		12188	929.00	954.06	170.69
		22010	929.00	957.00	150.03
W_5		21349	986.00	922.25	125.75
W_7.3		21870	1045.75	924.50	145.38
		21361	1045.75	938.40	125.75
W_9.3		19523	1079.25	955.56	74.83
W_I		10877	1069.74	913.00	165.13

		16855	912.42	913.00	109.61
W_J		19935	1095.13	930.50	88.17
		19908	1055.66	930.50	84.83
W_J1		20787	907.00	931.00	113.06
W_J2		21285	939.50	947.50	121.13
		23575	1027.17	1065.60	121.13
W_K		10338	1087.54	1027.50	152.19
		6062	1075.88	927.22	81.50
W_K2		20911	892.25	968.50	113.00
		20928	919.47	968.50	109.61
W_L		21726	1092.51	974.00	131.73
W_L2		20951	900.38	989.50	116.50
		11336	921.67	917.17	179.35
W_M		21458	1091.33	992.00	125.75
W_N		18214	896.00	1000.00	158.44
		18222	879.00	1000.00	162.19
W_P		21483	1091.33	1010.00	121.13
W_Q		17538	1091.33	1027.50	134.88
		17528	1107.50	1027.50	134.88

Table RAI-SRP3.7.1-06-8: List of Auxiliary Building Floors Additional NI05 Nodes Reviewed for Flexible Response

Floor Name	Room Number	NI05_Node	X	Y	Z
F_81	R_12201	6168	1098.92	920.06	81.50
	R_12202	6188	1098.92	937.56	81.50
	R_12203	6212	1098.92	955.56	81.50
	R_12204	6244	1098.92	983.94	81.50
	R_12205	6264	1098.92	1002.94	81.50
	R_12207	6225	1095.13	966.94	81.50
	R_12211	6160	1083.75	1017.83	81.50
	R_12212	5954	1060.28	937.56	81.50
	R_12213	5998	1063.63	955.56	81.50
	R_12251	5788	972.26	921.33	81.50
	R_12252	5727	943.00	939.25	81.50
	R_12255	5852	1009.70	921.79	81.50
	R_12261	5838	1005.25	913.00	81.50
	R_12262	5582	903.25	939.25	81.50
	R_12271	5328	872.88	921.33	81.50
	R_12272	5361	872.88	944.89	81.50
	R_12273	5380	872.88	961.25	81.50

	R_12274	5469	875.94	978.32	81.50
	R_12275	5478	875.94	993.00	81.50
F_106	R_12351	7803	947.33	927.75	106.17
	R_12352	7899	978.00	921.33	106.17
	R_12354	7865	959.72	941.53	106.17
	R_12363	12009	919.47	939.25	106.17
F_116	R_12400	8237	1063.63	938.40	116.50
	R_12401	8468	1095.41	944.91	116.50
	R_12404	8501	1091.33	983.94	116.50
	R_12405	8521	1091.33	1002.94	116.50
	R_12406	8534	1091.33	1017.83	116.50
	R_12411	8189	1056.00	925.92	116.50
	R_12412	8252	1063.63	958.71	116.50
	R_12421	8104	1014.14	921.33	116.50
	R_12422	8079	1000.00	922.25	116.50
	R_12423	8169	1041.92	917.17	116.50
	R_12452	8061	975.59	927.76	116.50
	R_12461	7955	896.00	921.27	116.50
	R_12462	8005	919.47	957.00	116.50
	R_12472	7930	879.00	993.00	116.50
F_134	R_12501	9489	1079.25	941.44	134.88
	R_12505	9633	1095.13	999.06	134.88
	R_12551	9091	934.70	921.33	134.88
	R_12552	9489	1079.25	941.44	134.88
	R_12553	9220	978.00	921.33	134.88
	R_12554	9169	954.11	916.28	134.88
	R_12555	9265	1002.63	922.25	134.88
	R_12556	9320	1034.25	924.50	134.88
	R_12561	9091	934.70	921.33	134.88
	R_12562	8935	896.00	921.33	134.88
F_145	R_12651	9796	934.70	951.13	145.38
		9905	972.26	924.50	145.38
F_161	R_12692	10708	968.50	924.50	161.34
		10665	950.00	924.50	161.74

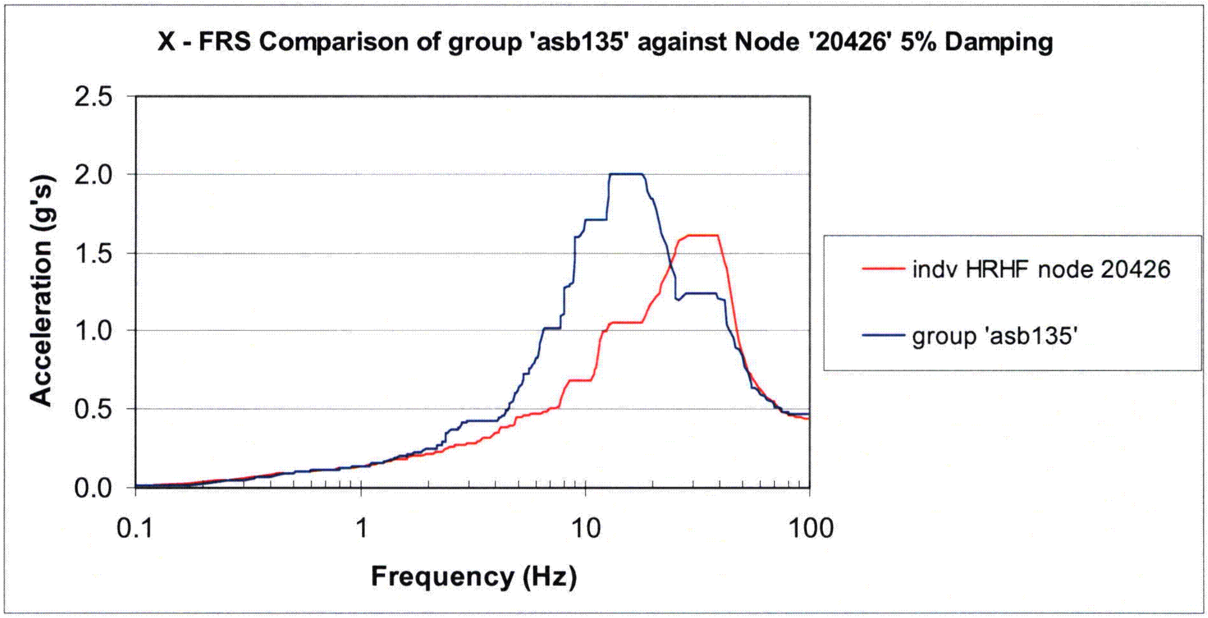

Figure RAI-SRP3.7.1-06-6: Wall 2 Response Spectra at Node 20426 Compared to Group Design FRS at Elevation 135 ft

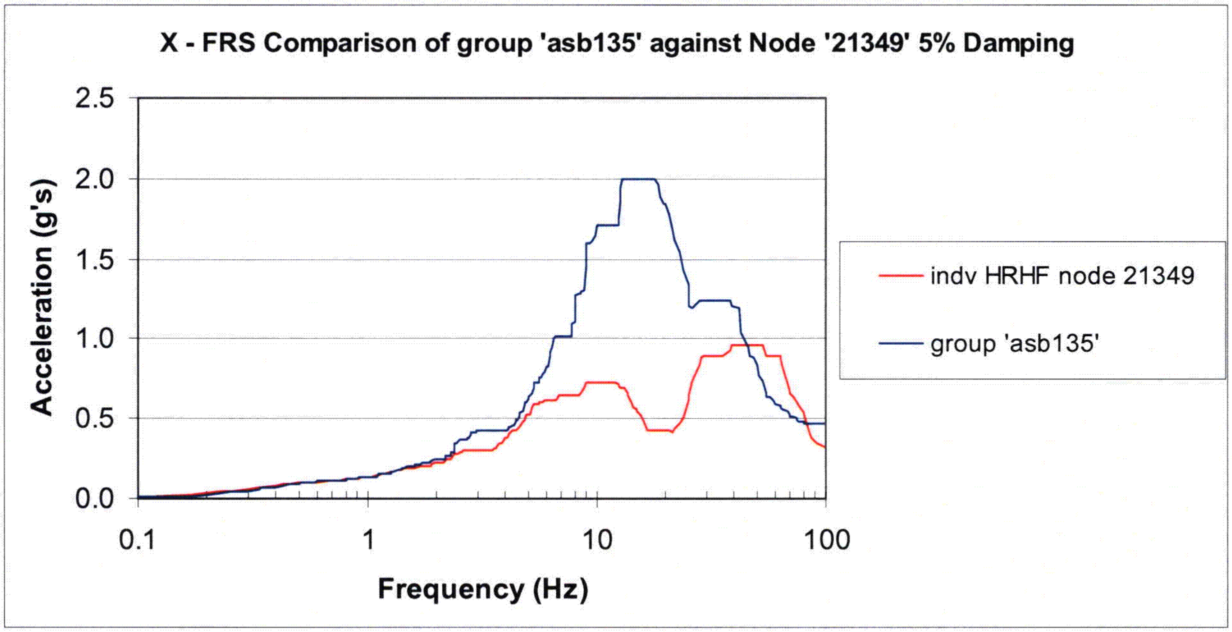

Figure RAI-SRP3.7.1-06-7: Wall 5 Response Spectra at Node 21349 Compared to Group Design FRS at Elevation 135 ft

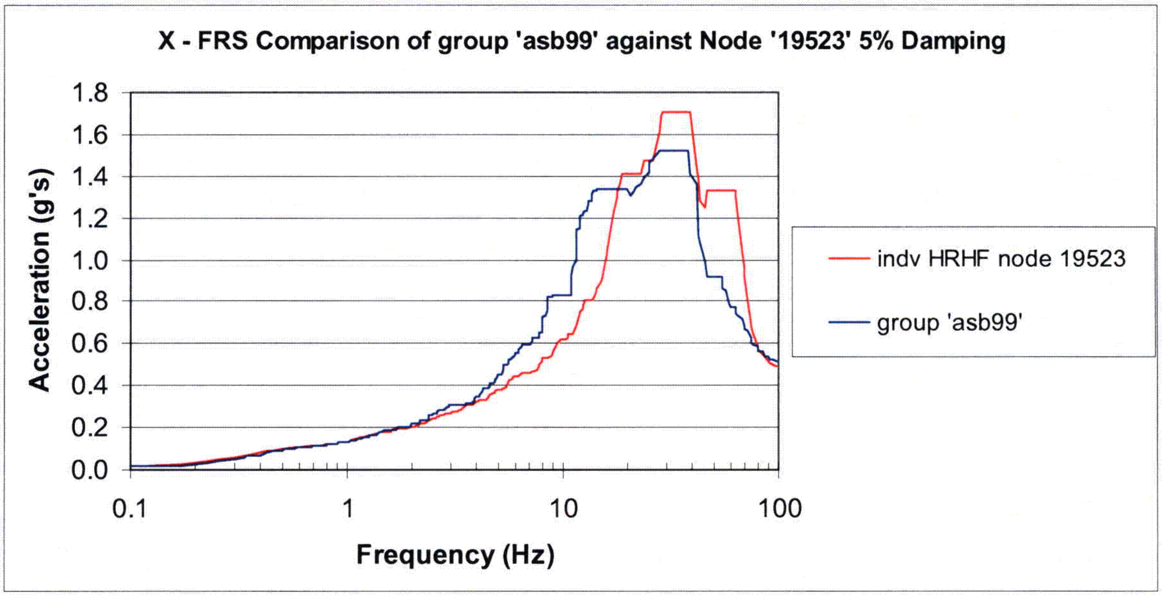

Figure RAI-SRP3.7.1-06-8: Wall 9.3 Response Spectra at Node 19523 Compared to Group Design FRS at Elevation 100 ft

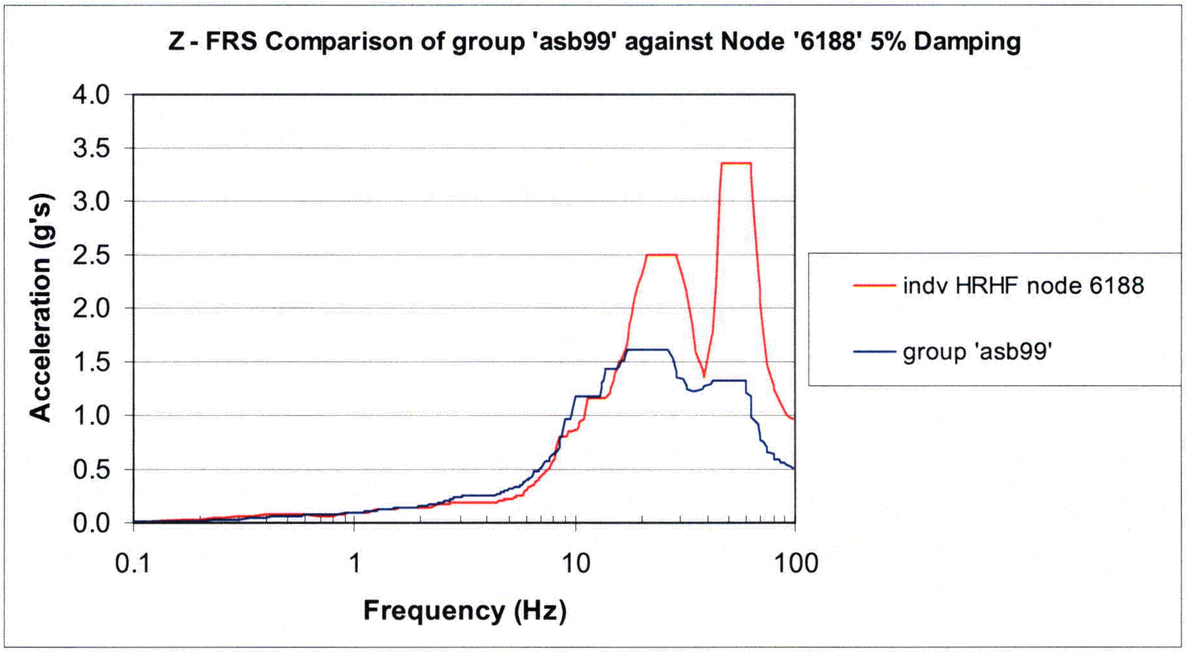

Figure RAI-SRP3.7.1-06-9: ASB Floor Elevation 81 ft Response Spectra at Node 6188 Compared to Group Design FRS at Elevation 100 ft

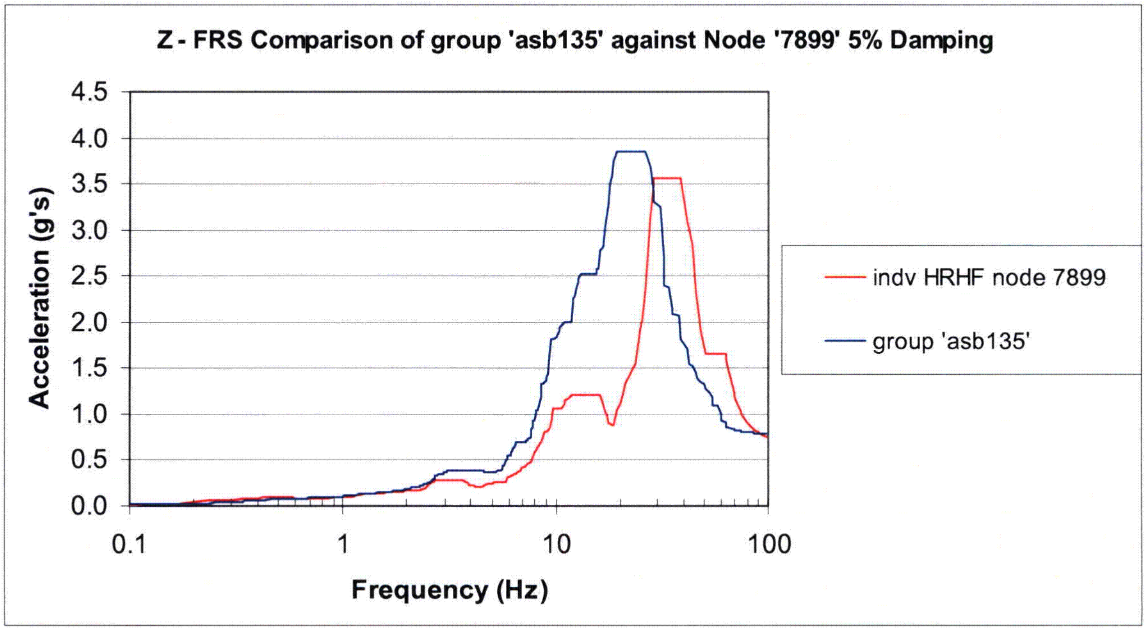

Figure RAI-SRP3.7.1-06-10: Southeast Auxiliary Building Floor at Elevation 1016 ft Response Spectra at Node 7899 Compared to Group Design FRS at Elevation 135 ft

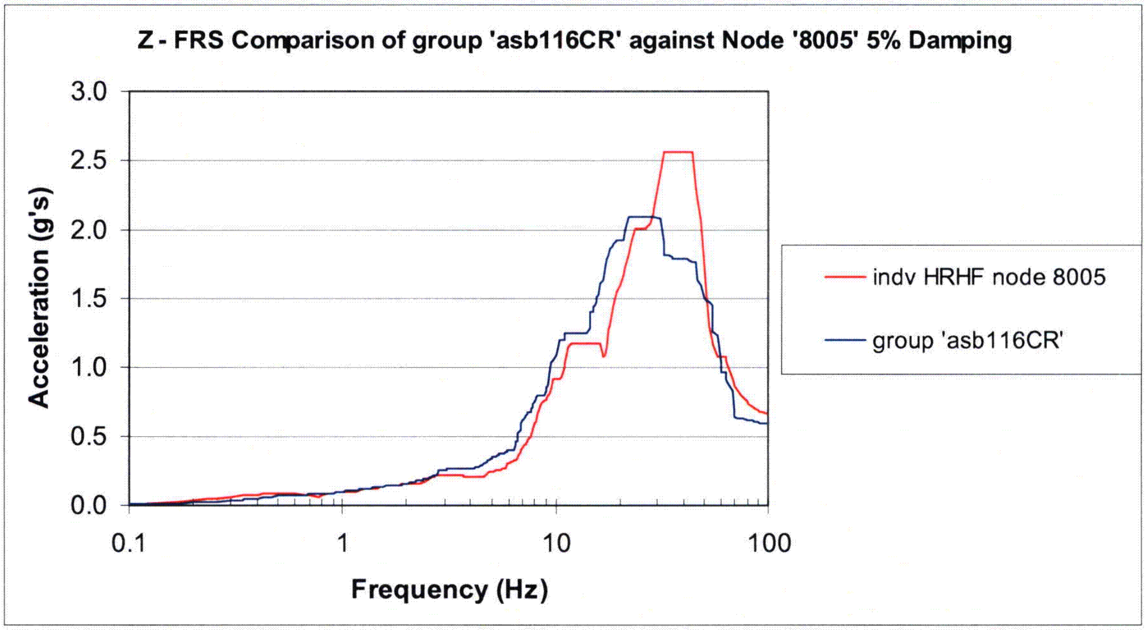

Figure RAI-SRP3.7.1-06-11: Northwest Control Room Floor Elevation 116 ft Response Spectra at Node 8005 Compared to Group Design FRS at Elevation 11600 ft

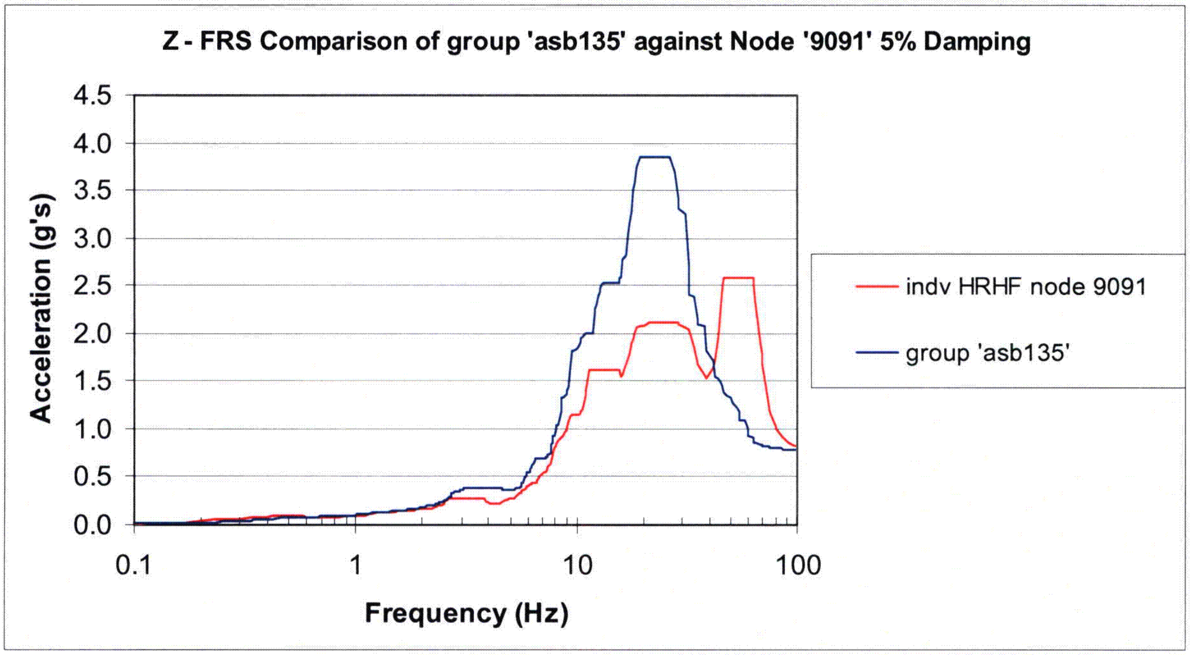

Figure RAI-SRP3.7.1-06-12: Auxiliary Building Flexible Floor Elevation 135 ft Response Spectra at Node 9091 Compared to Group Design FRS at Elevation 135 ft

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision (The changes given below are in Revision 1): (Revision 0 to 2)

Section 5.1 is revised to reflect the 50 hertz requirement on the dynamic models.

5.1 Adequacy of CSDRS and HRHF Response Spectra

The adequacy of the NI20 model is demonstrated by:

1. Mesh size is adequate to transmit the high frequency through the finite elements
2. Close comparison to NI10 results

The NI20 (~20' finite element mesh size) model is used to develop the HRHF response spectra using the finite element program SASSI. For a concrete of 4000 psi with a Poisson's ratio (υ) of approximately 0.17, the shear modulus of elasticity (G) is 221,846 ksf.

$$G = \frac{57400\sqrt{fc'}}{2(1+\nu)}$$ Where *fc'* is Concrete stress in psi

The shear wave velocity (V_s) is 6900 ft/sec for the concrete density of 0.15 ksf.

$$V_s = \sqrt{\frac{G}{\rho}}$$ ρ is mass density

For a maximum analysis frequency (f_{max}) of 50 Hz which must transmit through the finite elements, the shortest wavelength (λ) is 138 ft.

$$\lambda = \frac{V_s}{f_{\max}}$$

Approximately 7 (6.9) nodes per wavelength are available for a mesh size of 20', and this is adequate to transmit the high frequency through the finite elements in the NI20 model. A portion of the NI20 model has an element mesh size of ~ 10' for the Containment and Internal Structure (CIS).

The discussion of the modal response as presented in the Westinghouse response is added at the end of Section 5.1.

Technical Report (TR) Revision (these changes will be incorporated into Revision 3): ~~(Revision 3)~~

Revise Section 5.3 (complete replacement) as follow~~s~~s:

5.3 ~~Supplemental Analysis for Flexible Building Walls and Floors~~

~~The NI05 model has been reviewed for flexible (less than 33 Hz) regions which may produce amplified response spectra. Each of these areas is listed in Table 5.3-1.~~

~~In addition to the flexible areas already identified, each of the principal walls and floors in the Auxiliary and Shield Buildings as well as CIS has been reviewed as listed in Tables 5.3-2 and 5.3-3. A modal analysis of the NI05 model for both the Auxiliary and Shield Buildings and CIS has been performed for each of these regions. Specific areas within each wall or floor where out-of-plane modes,, which may respond to either CSDRS or HRHF input (including structures with modes less than 33 Hz and between 33 Hz to 50 Hz), have been identified. The survey reveals that some regions, typically in the middle of a floor or wall, exhibit amplified behavior compared to the critical nodes at the corner and edge building locations. The amplified FRS for these regions is generated in addition to the typical set of critical nodes for building analysis by a single time history analysis of the NI05 building model subject to the HRHF time history input. Seismic response spectra for each of the "flexible" nodes are considered when selecting the pre-existing "group" spectra, which is the envelope of the entire floor in that area.~~

~~If equipment or a structure is supported at more than one elevation, then the seismic input as an envelope of multiple groups, based on the support locations, will be defined. Therefore, if the equipment or structure is supported on a combination of both rigid and flexible floor areas, the response spectra (horizontal and vertical directions) used by the analyst will be the envelope of the rigid and flexible areas that include inside and outside nodes.~~

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If equipment or a structure is supported at more than one elevation, then the seismic input as an envelope of multiple groups, based on the support locations, will be defined. Therefore, if the equipment or structure is supported on a combination of both rigid and flexible floor areas, the response spectra (horizontal and vertical directions) used by the analyst will be the envelope of the rigid and flexible areas that include inside and outside nodes.

Table 5.3-1: List of Flexible Nodes

~~F~~Flexible Area	Soil Site Node	Hard Rock Site Node
F~~F~~lexible floor area East of Shield Building to column line I and between column lines 7 to 7.3, EL. 116.5'	2030 2034 2038	4548 4556 4570
F~~F~~uel pool wall L2 between Column Lines 2 to 4, EL. 92.71' to 135'	2266	7397
W~~W~~all Q between Column lines 9.1 to 11, EL. 117.5' to 135'	2333	6823
F~~F~~lexible floor East of Shield Building between column lines 4 to 5, EL. 135'	2281 2287	4925 4939
F~~F~~lexible floor on North of Shield Building between column lines I to L and 5 to 7.3, EL. 135'	2295 2299 2303	4959 4967 4981
F~~F~~lexible floor on North of Shield Building between column lines I to L and 7.3 to 11, EL. 135'	2331	5080
W~~W~~all I between column lines 1 & 4, above EL. 160'	2596	6948
W~~W~~all N between column lines 1 & 4, above EL 160'	2597	6897
W~~W~~all 1 between column line I & N, above EL.160'	2591	6939
F~~F~~loor between column lines 7.3 &11 and I to L, EL. 160'	2515	5314
R~~R~~oof East of Shield Building to Column line I and between column lines 7 to 7.3, EL. 160'	2626 2630 2634	5485 5494 5507
R~~R~~oof South side of Aux Bldg between column lines I & N and column lines 1 to 4~~.~~, EL. 180'	2695 2697	5628 5633
Center of shield Bldg , EL. 289.2'	3067	8296
CSDRS Flexible (Less than 33 Hz) Nodes	**Building Node**	
Wall 4 at midspan near elevation 170'	12188 (NI05)	
Wall 7.3 at midspan near elevation 145'	21870 (NI05)	
Wall 11 at midspan near elevation 110'	16996 (NI05)	
Wall J-2 at midspan near elevation 120'	21285 (NI05)	
Wall K-2 at midspan near elevation 113'	20911 (NI05)	
ASB Floor between column lines 7.3 & 9.1 at elevation 81'	6244 (NI05)	
SE ASB Floor between column lines 2 & 4 at elevation 106'	12009 (NI05)	
HRHF Flexible (Less than 50 Hz) Nodes	**Building Node**	
Wall 2 at midspan near elevation 103'	20426 (NI05)	
Wall 5 at midspan near elevation 126'	21349 (NI05)	
Wall 9.3 at midspan near elevation 75'	19523 (NI05)	
ASB Floor at Elevation 81'	6188 (NI05)	
SE ASB Floor at Elevation 106'	7899 (NI05)	
Northwest Control Room Floor 116'	8005 (NI05)	
ASB Flexible Floor Elevation 135'	9091 (NI05)	

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-17
Revision: 2

Question (December 17, 2008):

(a) The staff requests that Westinghouse specifically describe its compliance with or deviations from SRP 3.7.2, Rev. 3, and RG 1.92, Rev.2; and provide the technical basis for the adequacy of all seismic analysis methods and acceptance criteria that deviate from the current staff guidance.

In DCD Revision 15, Section 3.7.2.1, Westinghouse stated "Seismic analyses of the nuclear island are performed in conformance with the criteria within SRP 3.7.2." The staff confirmed in its detailed review of DCD Revision 15, Section 3.7.2, that Westinghouse had committed to the provisions of SRP 3.7.2, Rev. 2, (and supporting RGs), in existence at the time of the staff's review. Subsequent to the issuance of the staff's FSER on DCD Revision 15 in September 2004, the staff issued SRP Section 3.7.2, Rev. 3, in March 2007 and supporting RG 1.92, Rev. 2, in July 2006. The staff notes that DCD Revision 16 still states "Seismic analyses of the nuclear island are performed in conformance with the criteria within SRP 3.7.2." However, the staff's detailed review of Revision 16, Section 3.7.2, determined that Westinghouse has not committed to the latest staff guidance. The methods and acceptance criteria cited are the same as in Revision 15.

(b) The staff requests Westinghouse to (1) identify whether it is implementing the RG 1.92, Rev. 2 and SRP 3.7.2, Rev. 3, guidelines for conducting response spectrum analysis; and (2) if not, provide the technical basis for concluding that the response spectrum analysis methods Westinghouse has applied provide comparable accuracy.

RG 1.92, Rev. 2, (July 2006) and SRP 3.7.2, Rev. 3, (March 2007) updated the staff guidelines to improve the accuracy of results obtained when implementing the response spectrum analysis method for SC-I systems and subsystems. DCD Revision 16, Section 3.7.3.7, "Combination of Modal Responses", describes Westinghouse's procedures for response spectrum analysis. These are unchanged from DCD Revision 15, which pre-dates the latest staff guidance.

(c) The staff requests Westinghouse (1) identify whether it satisfies the latest SRP Section 3.7.2.II.1.a.iv acceptance criteria for confirming adequate model refinement; and (2) if not, to provide the technical basis for concluding that the method Westinghouse applied provides sufficient solution accuracy.

In March 2007, the staff issued Revision 3 to SRP 3.7.2. The acceptance criteria formerly provided in SRP Section 3.7.2.II.3, to confirm the adequacy of the model refinement, has been deleted. It has been replaced by a new criterion based on review of modal responses up to the maximum frequency of interest. This is described in SRP Section 3.7.2.II.1.a.iv.

(d) The staff requests Westinghouse to identify whether it is implementing the RG 1.92, Revision 2 approach, and if not, to provide the technical basis for concluding that the method Westinghouse is applying provides a comparable level of solution accuracy.

An acceptable method to account for the modes corresponding to frequencies higher than the PGA frequency in a mode superposition time history analysis is described in RG 1.92, Revision 2, Regulatory Position C.1.4.1 (July 2006), and is referenced in SRP 3.7.2 (March 2007).

Westinghouse Response:

a. The technical basis for the adequacy of seismic analysis methods is conformance with the regulatory guidance in effect six months prior to the submittal of the AP1000 Design Certification application in March, 2002. This is consistent with the requirements of 10 CFR 52.47(a)(9). The statement given in the DCD that the "Seismic analyses of the nuclear island are performed in conformance with the criteria within SRP 3.7.2," is consistent with the applicable guidance (e.g., SRP 3.7.2, Revision 2) applying to the AP1000 plant at the time of filing.

Westinghouse is not changing the seismic analysis methods from those used to support the certified design documented in Design Control Document (DCD) Revision 15. The seismic analysis methods are not dependent on the spectra used for the seismic analysis. Therefore including six soil cases in the design ground response spectra does not subject the seismic analysis methods to review as part of the design certification amendment review.

Westinghouse is not assessing the AP1000 design to SRP 3.7.2, Revision 3. The AP1000 design uses the regulatory guidance effective six months prior to the submittal of the design certification application in March, 2002. In Westinghouse letter DCP/NRC1751, dated June 15, 2006, Westinghouse submitted APP-GW-SRP-010, "Extension of Nuclear Island Seismic Analysis to Soil Sites". This document provided information to support the expansion of the AP1000 design response spectra to include additional soil conditions. This submittal was well before the publishing of Revision 3 of SRP 3.7.2. The application for the design certification amendment which was supported by Revision 16 of the AP1000 Design Control Document was submitted in May 2007. Revision 16 of the DCD incorporated changes consistent with the information included in APP-GW-S2R-010. Even if the application did reset the regulatory guidance cut off, a Standard Review Plan Section published in March 2007 is effective less than six months prior to the amendment application and is not applicable to the design certification amendment.

See Item b below for discussion of RG 1.92.

b. Westinghouse identifies both Revision 1 and 2 of RG 1.92, DCD Section 1.9, Revision 17, Table 1.9-1 (Sheet 8) for the AP1000 plant. RG 1.92, Revision 2, has been used for building structures as noted in DCD Appendix 3G, Section 3G.4.3.1, Revision 17. Both Revision 1 and 2 of RG 1.92 is acceptable for use in seismic analysis by Westinghouse since Revision 1 combination methods are more conservative as stated in RG 1.92, Revision 2 (Background). It is stated: "This guide (Revision 2) describes methods that the NRC staff considers acceptable in view of those improvements. The more conservative methods of combining modal responses (as described in Revision 1) remain acceptable." Westinghouse does address the residual rigid response of missing massing (see DCD Section 3.7.3.7, Revision 17).

   As explained in item a. above Westinghouse is not assessing the AP1000 design to SRP 3.7.2, Revision 3. The AP1000 design uses the regulatory guidance effective six months prior to the submittal of the design certification application in March, 2002. SRP 3.7.2, Revision 3 was published in March 2007. This is well after the application for AP1000 design certification.

c. Westinghouse follows SRP 3.7.2, Revision 2 for defining the solution accuracy of the methods used. As explained in item a. above Westinghouse is not assessing the AP1000 design to SRP 3.7.2, Revision 3.

d. See item b above.

Staff comments on RAI-SEB1-17(d), July 2010

In general, the draft response is consistent with the information presented at the 3.7 audit. In the formal submittal, the following items need to be incorporated for completeness:

(a) Top of page 10, specify figures -10 through -18, NOT -4 through -6.
(b) Explain how the red and blue lines were plotted. There is no red on many of the figures.
(c) Specify the seismic loading inputs for the NI10 analyses and for the NI05 analyses. They are different, and differences in response at the same location, between NI10 and NI05, are expected. This should be discussed to avoid confusion.
(d) Discuss the difference in results in Figure -19.
(e) Include the following information, discussed at the 3.7 audit:
   (1) the method used to specify damping in the mode superposition time history analyses.
   (2) the mode extraction method used in the mode superposition time history analyses.

Westinghouse Response (Revision 2):

d. Westinghouse fixed base modal superposition time history analysis provides sufficient solution accuracy, because the modes which respond beyond cutoff frequency have no significant contribution to the in-structure amplified response spectra.

To verify the accuracy of the analysis, Westinghouse performed a time history analysis at cutoff frequency (identified as 44Hz for the NI10 model) and an identical time history analysis with significantly more modes (up to 64Hz for ASB, up to 100Hz for CIS). The resulting amplified response spectra are compared in Figures SRP 3.7.1-SEB1-17d-1 through SRP 3.7.1-SEB1-17d-9 for the CIS critical locations in the nuclear island and Figures SRP 3.7.1-SEB1-17d-10 through SRP 3.7.1-SEB1-17d-18 for the ASB critical locations. Additionally, a similar analysis was performed with Ni05 fine mesh model at cutoff frequency (identified as 40 Hz) and with significantly more modes (up to 85 Hz). The resulting amplified response spectra are compared in Figures SRP 3.7.1-SEB1-17d-19 through SRP 3.7.1-SEB1-17d-27 for the same three ASB critical locations in the nuclear island. Each of the nodes selected are described in Tables SRP 3.7.1-SEB1-17d-1 for CIS and SRP 3.7.1-SEB1-17d-2 for ASB.

For the NI10 analyses presented in the RAI, the time history input is the standard hard rock time history input for a fixed base analysis. The two analyses presented for the NI10 model represent the same time history input, but with a different number of modes extracted (one for design basis, one performed at another frequency cutoff). The six critical locations selected for comparison in TR-03 (See Table SRP 3.7.1-SEB1-17d-1) are selected as an adequate sample to show the parity in the response of model with modes up to cutoff frequency and then to a much higher frequency limit.

For the NI05 analyses presented, the time history input is a synthesized time history motion generated to bound the envelope of the AP1000 CSDRS curve and each of the soil site conditions at nodes along the edges, sidewalls, and center of the nuclear island basemat at elevation 60.5'. For the comparison of FRS at cutoff frequency and at high frequency, 3 nodes at critical locations (See Table SRP 3.7.1-SEB1-17d-2) in the Auxiliary and Shield Building structures were identified and compared.

As discussed in the June 2010 Chapter 3.7 audit, the material dependent damping is used in mode superposition time history analyses.

Damping is assigned as a material dependent property in the finite element model. Structures such as concrete have 7% of critical damping, steel has 4%, and composite sections such as the exposed shield wall reinforced concrete with steel liner plates have a composite property at 5% of critical damping. As part of the modal analysis, each mode is assigned a composite damping which is the average of the effective damping for the materials which were excited at a particular frequency. For example, a flexural mode of the shield building wall will have a composite modal damping value near 5% whereas a mode from one the steam generators would have a composite damping value near 4% of critical damping. Modes are extracted using the ANSYS Block Lanczos subroutine.

Table SRP 3.7.1-SEB1-17d-1: Critical Nodes for CIS

Location	NI10 Node	NI20 Node	General Area	Elevation (feet)
CIS at Reactor Vessel Support Elevation	130401	1761	SCV Center	100.00
CIS at Operating Deck	105772	2199	SG West compartment, NE	134.25
SCV Near Polar Crane	130412	2788	SCV Stick Model	224.00

Table SRP 3.7.1-SEB1-17d-2: Critical Nodes for ASB

Location	NI10 Node	NI20 Node	NI05 Node	General Area	Elevation (feet)
ASB NE Corner at Control Room Floor	4724	2078	8629	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	5754	2675	11568	NW Corner of Fuel Bldg	179.19
ASB Shield Building Roof Area	8573	3329	1023786	South side of Shield Bldg	327.41

In Figures SRP 3.7.1-SEB1-17d-1 through SRP 3.7.1-SEB1-17d-9 **ni10r6-cis (design basis)** represents the 45Hz time history analysis and **CIS-100Hz** represent the expanded mode analysis. In each figure, the design basis curve is plotted in red and the confirmatory analysis is plotted in blue. In curves where no red shows up, the confirmatory analysis matches the design basis exactly.

FRS Comparison X Direction - 5% Damping

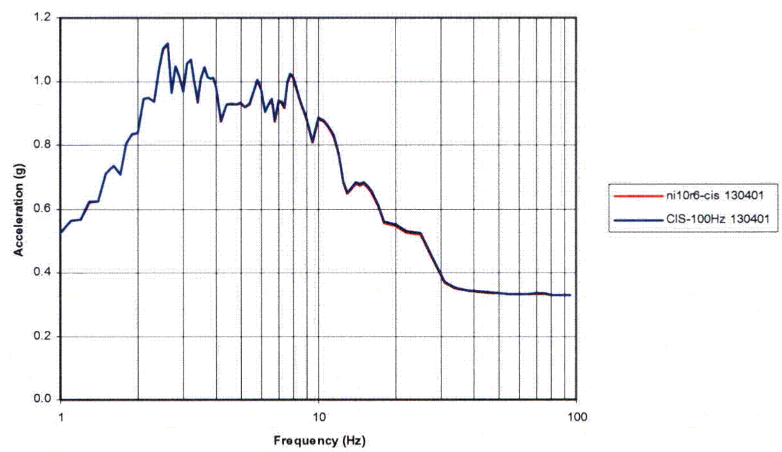

Figure SRP 3.7.1-SEB1-17d-1 – Ni10 CIS FRS Comparison – CIS at RPV Support Elevation North/South Direction

FRS Comparison Y Direction - 5% Damping

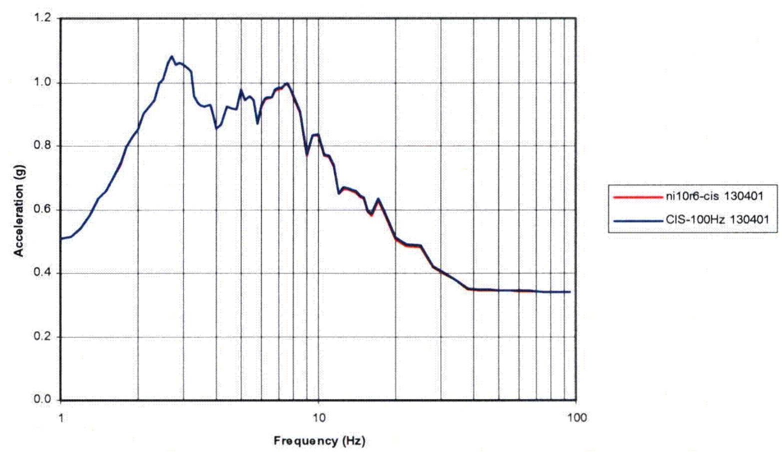

Figure SRP 3.7.1-SEB1-17d-2 – Ni10 CIS FRS Comparison – CIS at RPV Support Elevation East/West Direction

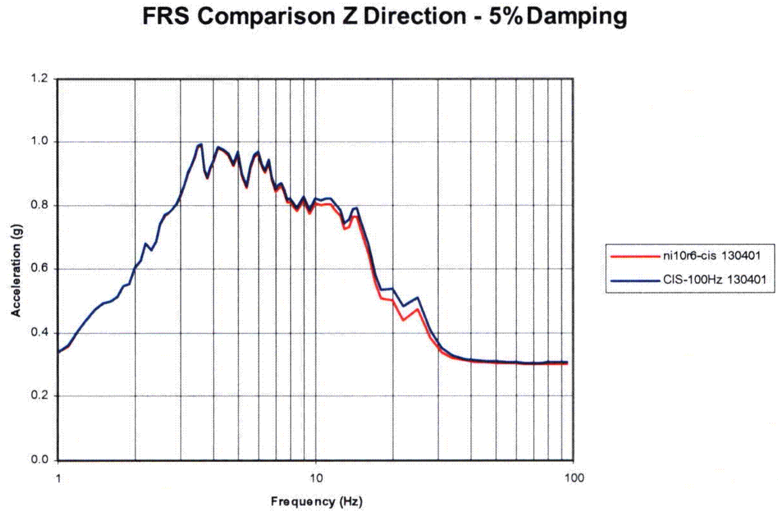

Figure SRP 3.7.1-SEB1-17d-3 – Ni10 CIS FRS Comparison – CIS at RPV Support Elevation Vertical Direction

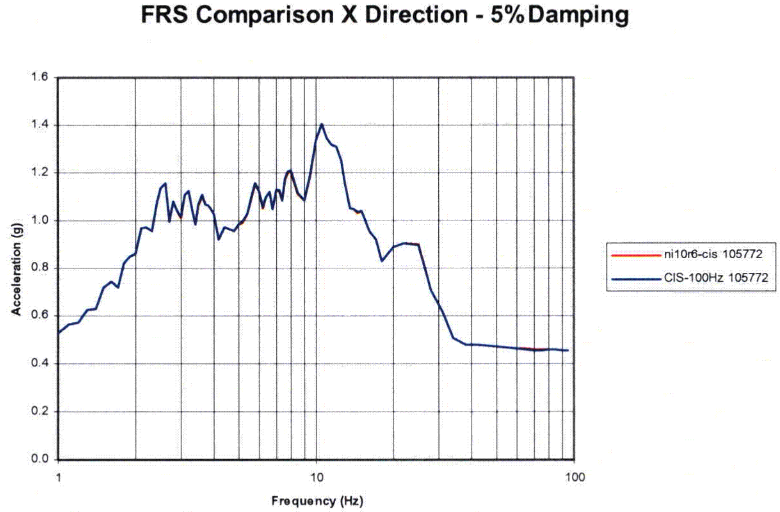

Figure SRP 3.7.1-SEB1-17d-4 – Ni10 CIS FRS Comparison – CIS at Operating Deck North/South Direction

FRS Comparison Y Direction - 5% Damping

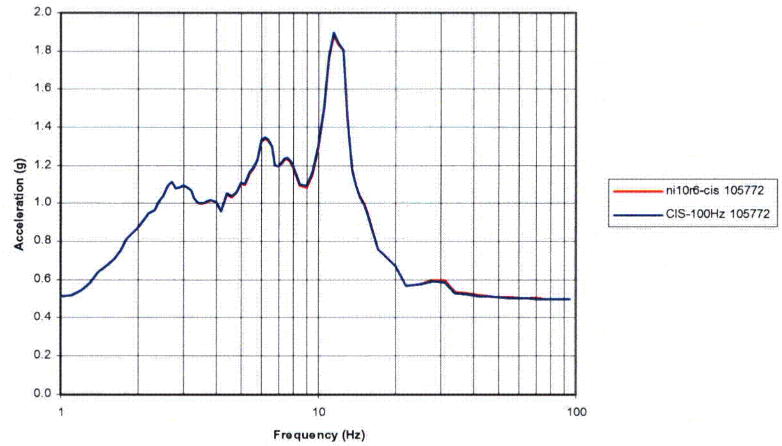

Figure SRP 3.7.1-SEB1-17d-5 – Ni10 CIS FRS Comparison – CIS at Operating Deck East/West Direction

FRS Comparison Z Direction - 5% Damping

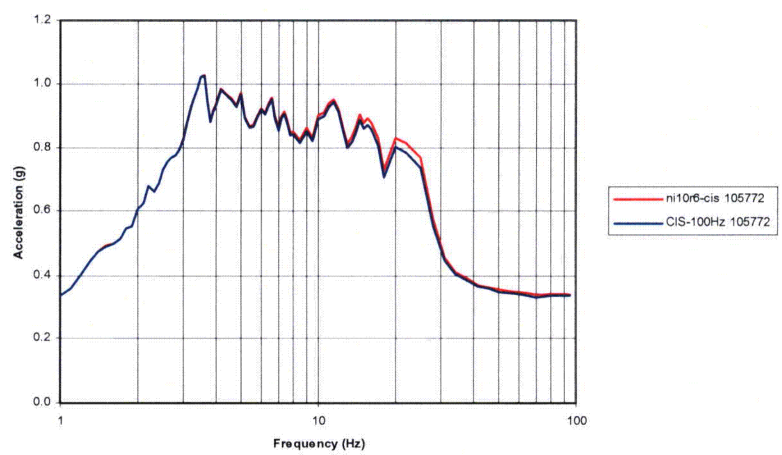

Figure SRP 3.7.1-SEB1-17d-6 – Ni10 CIS FRS Comparison – CIS at Operating Deck Vertical Direction

FRS Comparison X Direction - 5% Damping

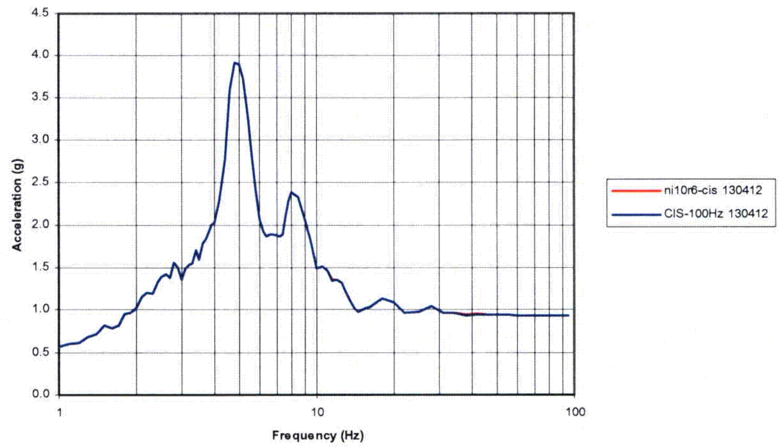

Figure SRP 3.7.1-SEB1-17d-7 – Ni10 CIS FRS Comparison – SCV near Polar Crane North/South Direction

FRS Comparison Y Direction - 5% Damping

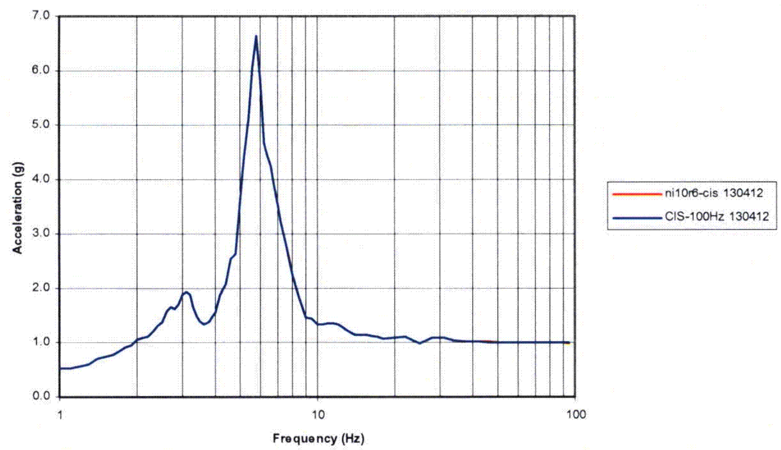

Figure SRP 3.7.1-SEB1-17d-8 – Ni10 CIS FRS Comparison – SCV near Polar Crane East/West Direction

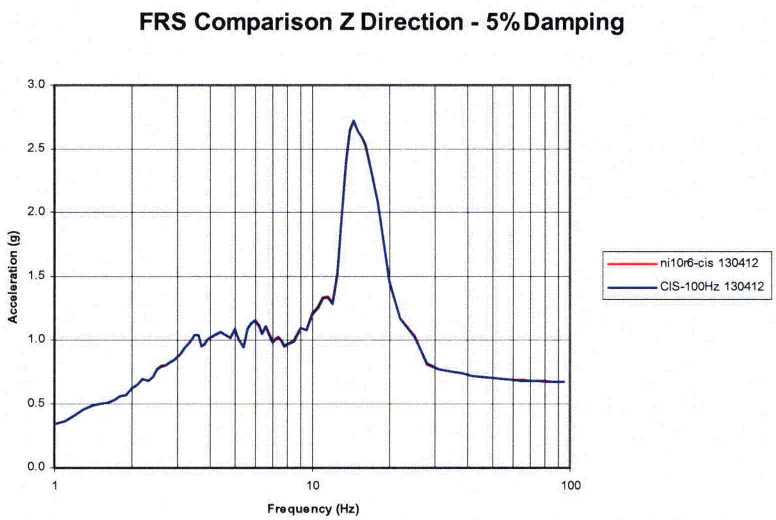

Figure SRP 3.7.1-SEB1-17d-9 – Ni10 CIS FRS Comparison – SCV Near Polar Crane Vertical Direction

In Figures SRP 3.7.1-SEB1-17d-10 through SRP 3.7.1-SEB1-17d-18 **ni10r6-asb (design basis)** represents the 64Hz time history analysis and **ni10-44Hz** represent the cutoff frequency (44Hz) analysis. In each figure, the design basis curve is plotted in red and the confirmatory analysis is plotted in blue. In curves where no red shows up, the confirmatory analysis matches the design basis exactly.

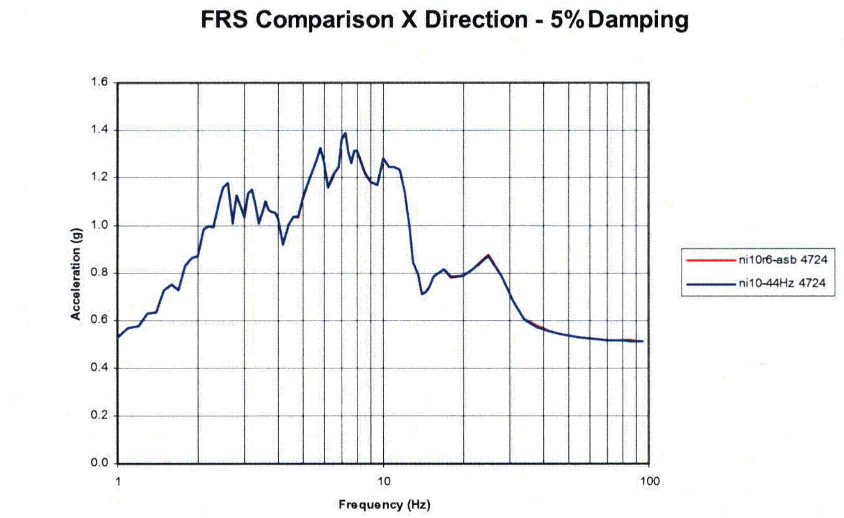

Figure SRP 3.7.1-SEB1-17d-10 – Ni10 ASB FRS Comparison – NE Corner of Control Room Floor North/South Direction

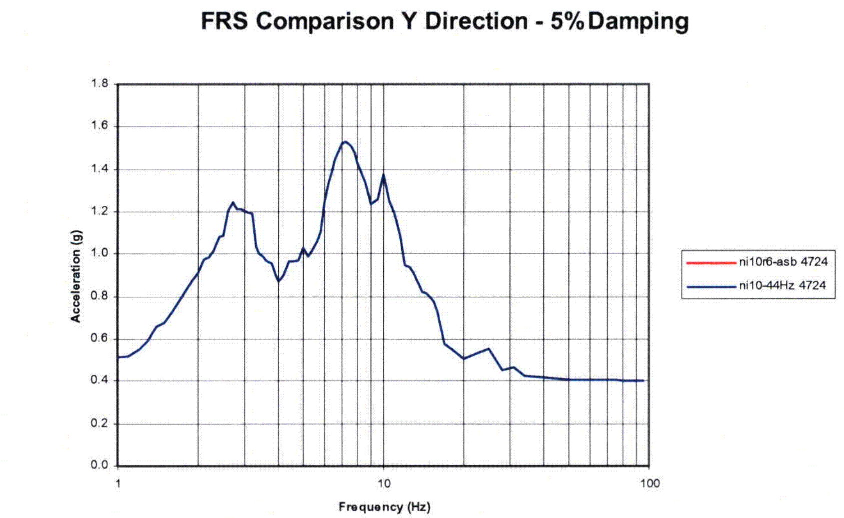

Figure SRP 3.7.1-SEB1-17d-11 – Ni10 ASB FRS Comparison – NE Corner of Control Room Floor East/West Direction

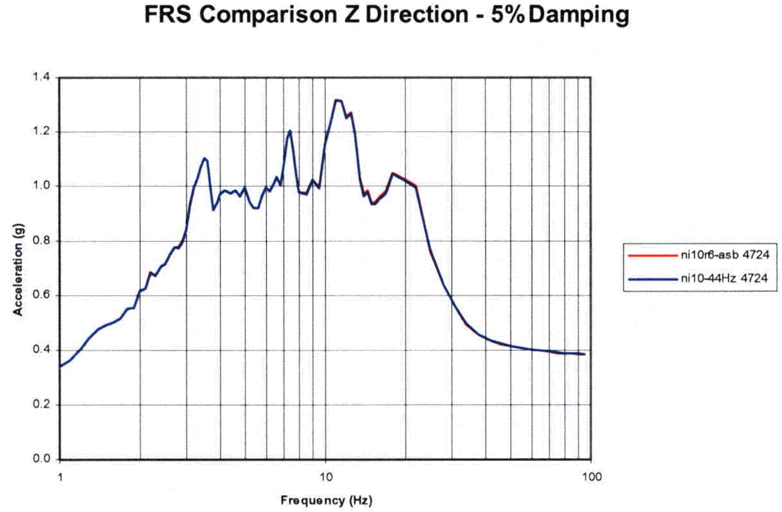

Figure SRP 3.7.1-SEB1-17d-12 – Ni10 ASB FRS Comparison – NE Corner of Control Room Floor Vertical Direction

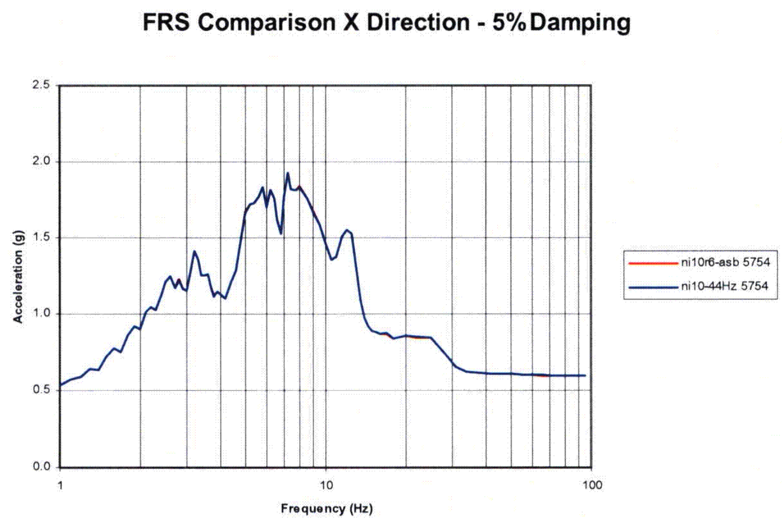

Figure SRP 3.7.1-SEB1-17d-13 – Ni10 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building North/South Direction

FRS Comparison Y Direction - 5% Damping

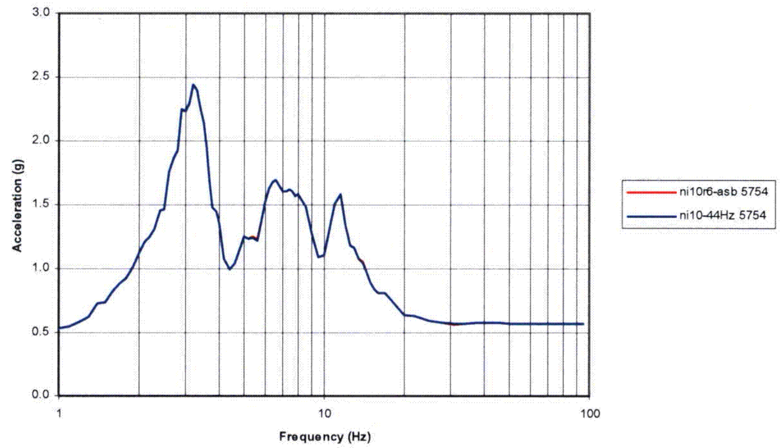

Figure SRP 3.7.1-SEB1-17d-14 – Ni10 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building East/West Direction

FRS Comparison Z Direction - 5% Damping

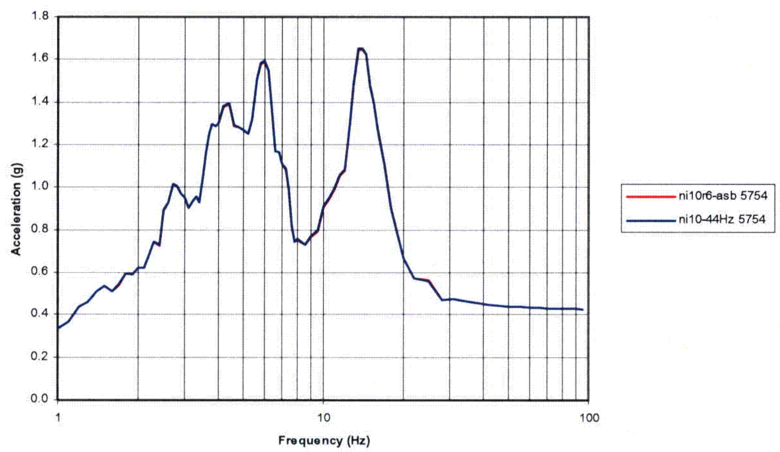

Figure SRP 3.7.1-SEB1-17d-15 – Ni10 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building Vertical Direction

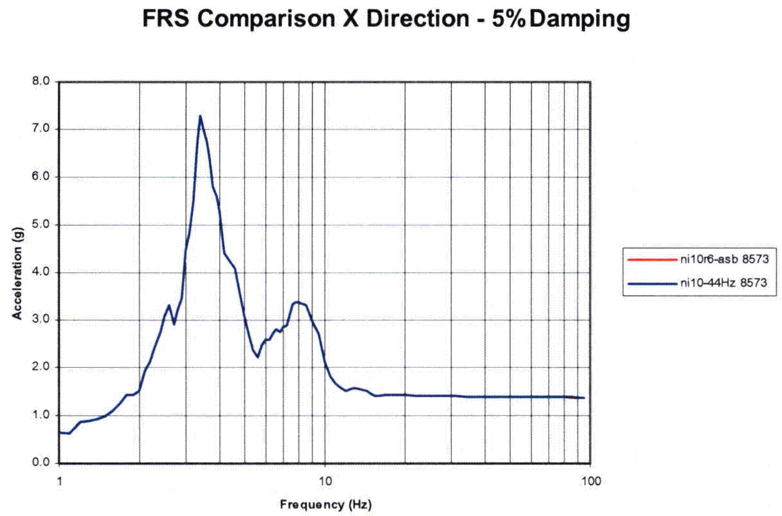

Figure SRP 3.7.1-SEB1-17d-16 – Ni10 ASB FRS Comparison – South Side ASB Roof at 327.4' North/South Direction

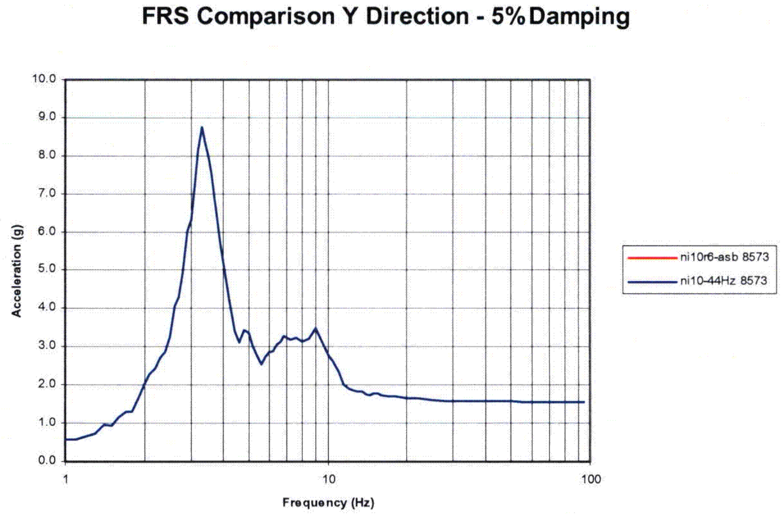

Figure SRP 3.7.1-SEB1-17d-17 – Ni10 ASB FRS Comparison – South Side ASB Roof at 327.4' East/West Direction

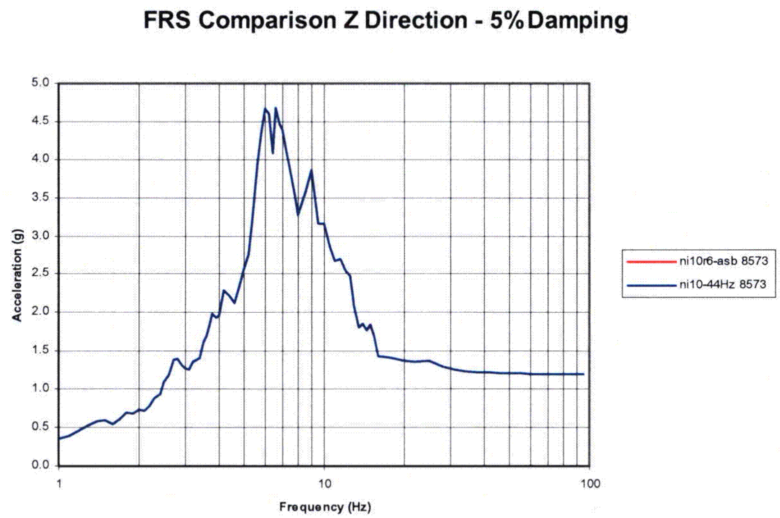

Figure SRP 3.7.1-SEB1-17d-18 – Ni10 ASB FRS Comparison – South Side ASB Roof at 327.4' Vertical Direction

In Figures SRP 3.7.1-SEB1-17d-19 through SRP 3.7.1-SEB1-17d-27 **ni05-40Hz** represents the 40Hz cutoff frequency time history analysis and **ni05-85Hz (design basis)** represents the expanded mode analysis (up to 85Hz). In each figure, the design basis curve is plotted ~~i~~in red and the confirmatory analysis is plotted in blue. In curves where no red shows up, the confirmatory analysis matches the design basis exactly. In Figures SRP 3.7.1-SEB1-17d-19, 22, and 24 the design basis (at 85 Hz) shows small exceedances near cutoff frequency (33 Hz). These minor differences are due to higher mode effects that have no significance to the design spectra.

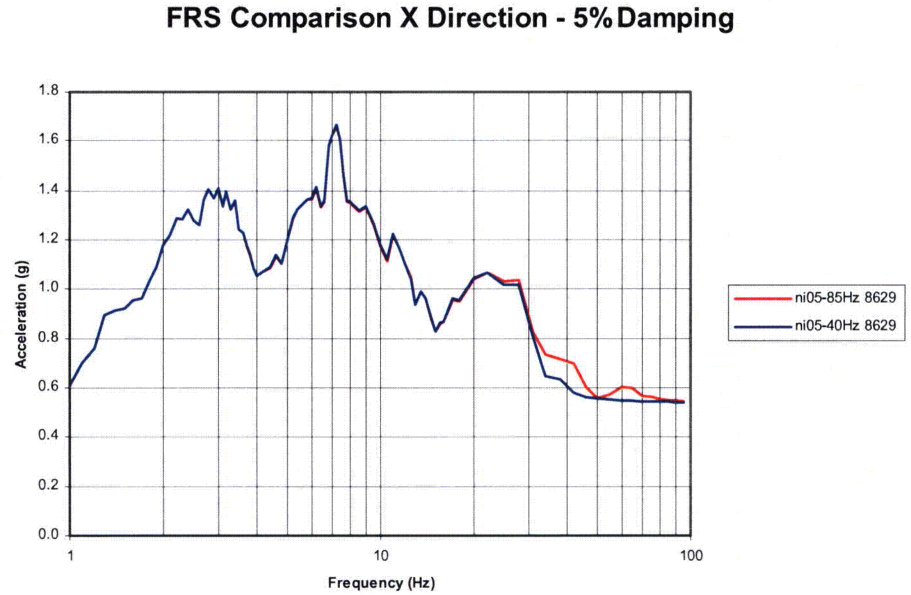

Figure SRP 3.7.1-SEB1-17d-19 – NI05 ASB FRS Comparison – NE Corner of Control Room Floor North/South Direction

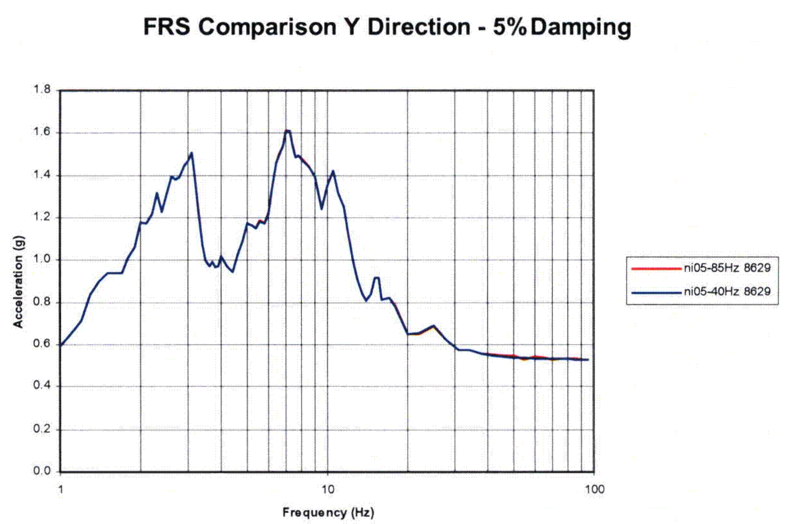

Figure SRP 3.7.1-SEB1-17d-20 – NI05 ASB FRS Comparison – NE Corner of Control Room Floor East/West Direction

FRS Comparison Z Direction - 5% Damping

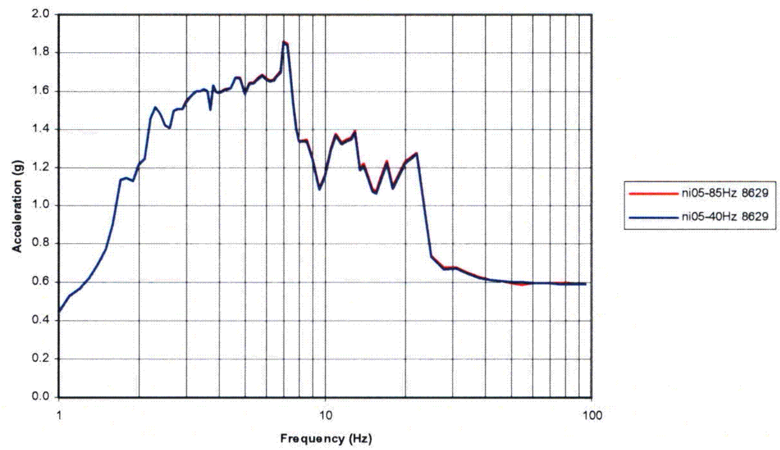

Figure SRP 3.7.1-SEB1-17d-21 – NI05 ASB FRS Comparison – NE Corner of Control Room Floor Vertical Direction

FRS Comparison X Direction - 5% Damping

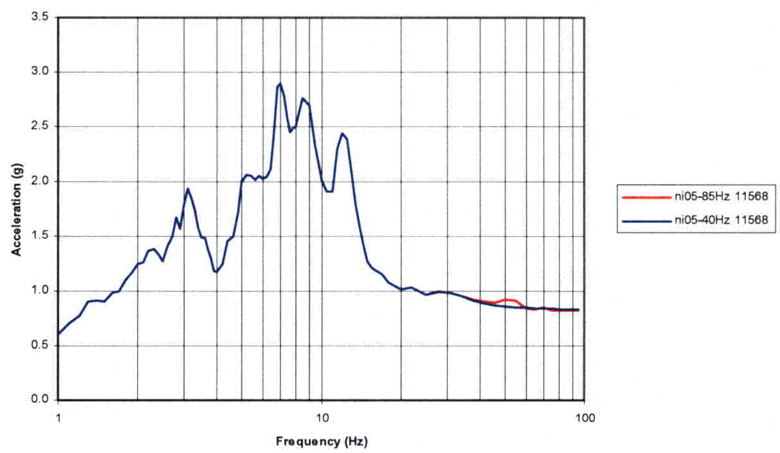

Figure SRP 3.7.1-SEB1-17d-22 – NI05 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building North/South Direction

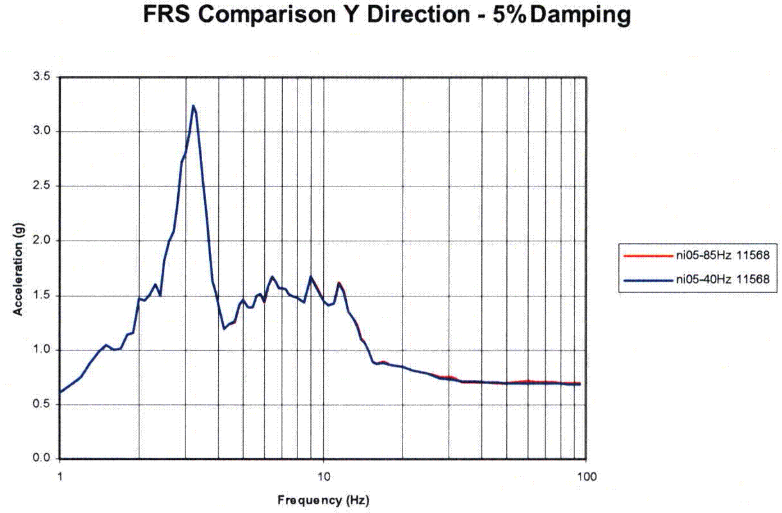

Figure SRP 3.7.1-SEB1-17d-23 – NI05 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building East/West Direction

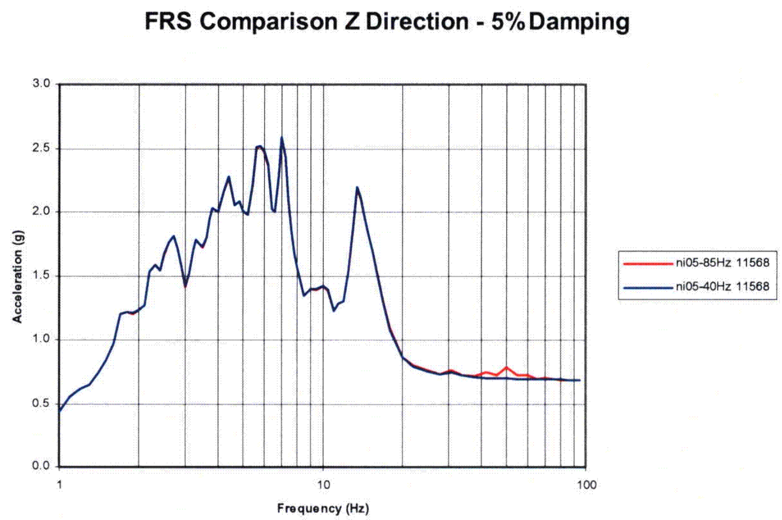

Figure SRP 3.7.1-SEB1-17d-24 – NI05 ASB FRS Comparison – NW Corner of Fuel Roof at Shield Building Vertical Direction

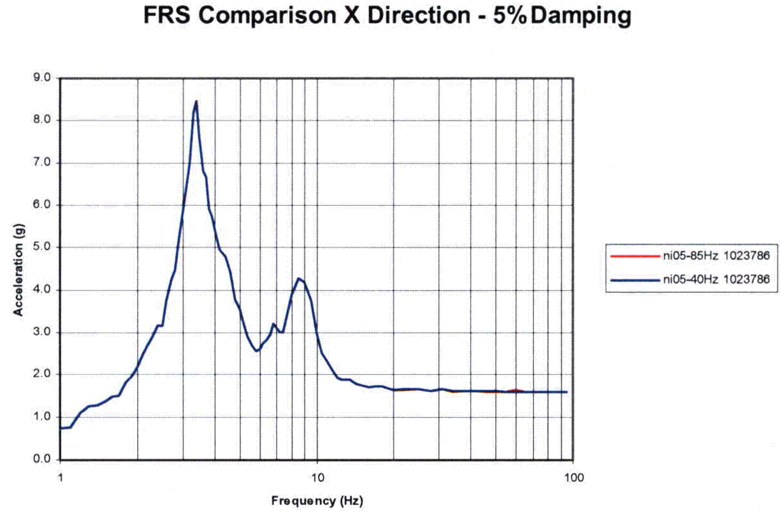

Figure SRP 3.7.1-SEB1-17d-25 – NI05 ASB FRS Comparison – South Side ASB Roof at 327.4' North/South Direction

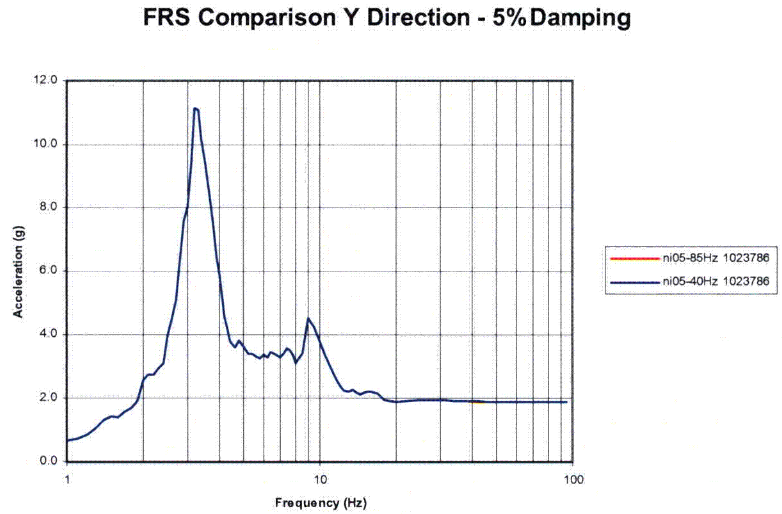

Figure SRP 3.7.1-SEB1-17d-26 – NI05 ASB FRS Comparison – South Side ASB Roof at 327.4' East/West Direction

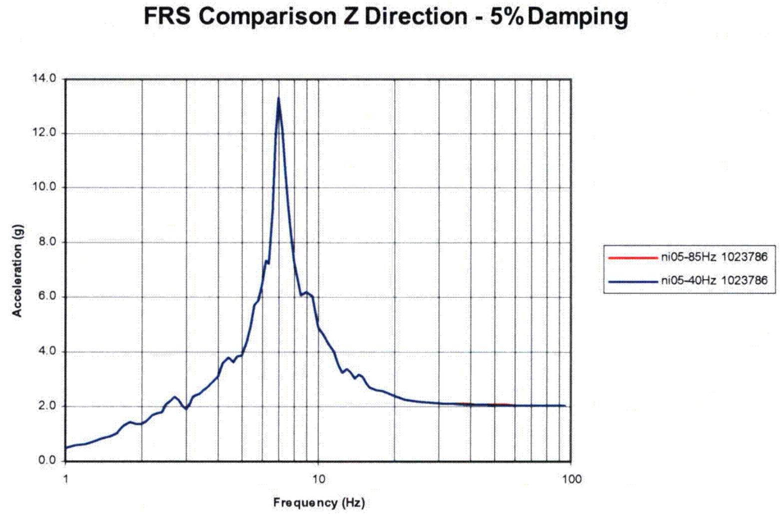

Figure SRP 3.7.1-SEB1-17d-27 – NI05 ASB FRS Comparison – South Side ASB Roof at 327.4' Vertical Direction

Reference(s): None

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None