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Your ref: Docket No. 52-006
Our ref: DCP/NRC2367

January 30, 2009

Subject: AP1000 Responses to Requests for Additional Information (SRP 3)

Westinghouse is submitting responses to the NRC request for additional information (RAI) on SRP Section 3. These RAI responses are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the responses 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 RAIs:

RAI-SRP3.7.1-SEB1-04 R2
RAI-SRP3.7.1-SEB1-06 R2
RAI-SRP3.7.1-SEB1-15

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

Very truly yours,

D.A. Lindgren /for

Robert Sisk, Manager
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/Enclosure

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

D063
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: 2

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.

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.

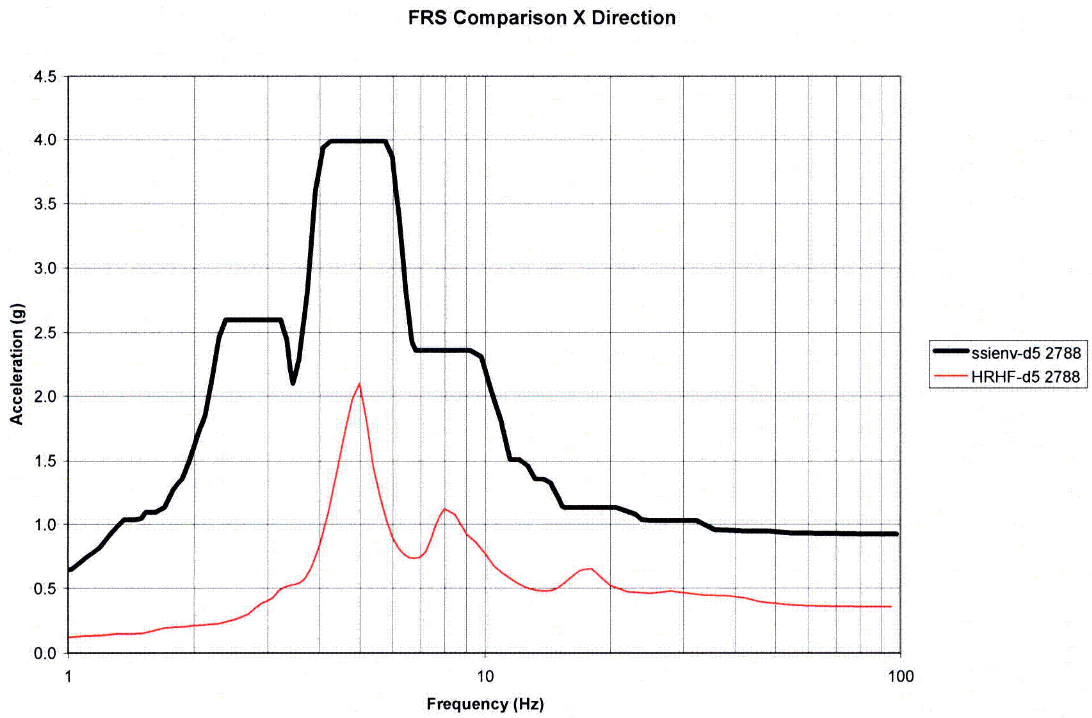

Figure RAI-SRP3.7.1-SEB1-04-1 – X Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

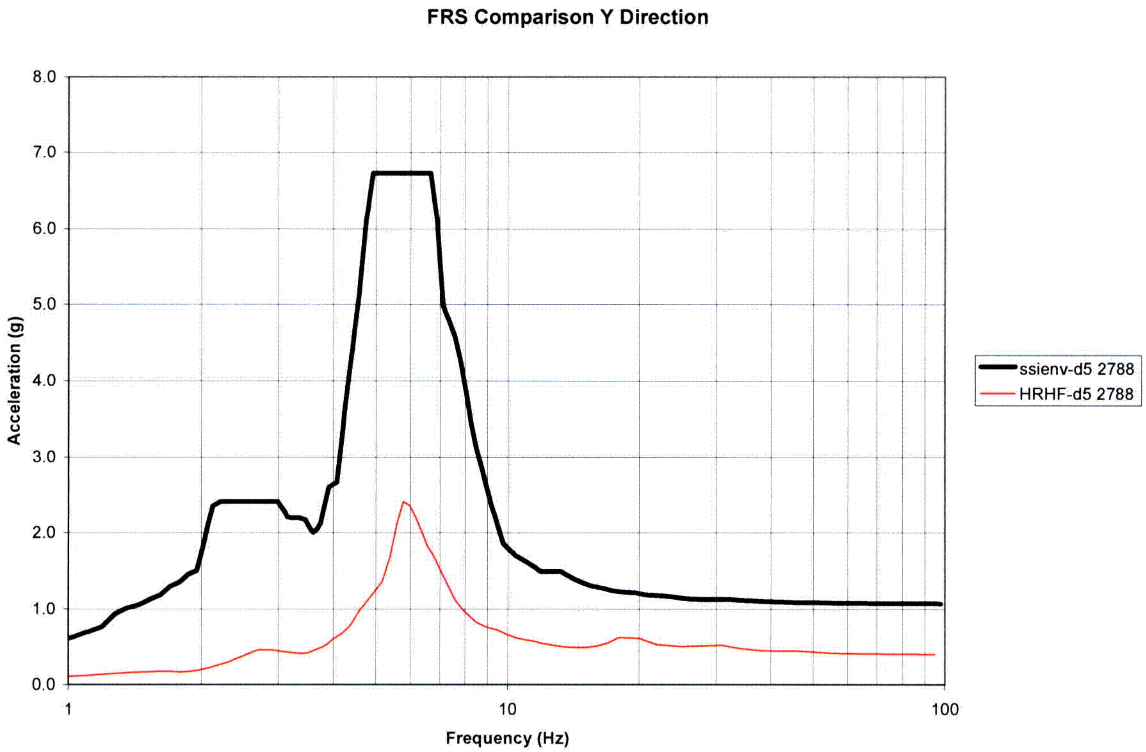

Figure RAI-SRP3.7.1-SEB1-04-2 – Y Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

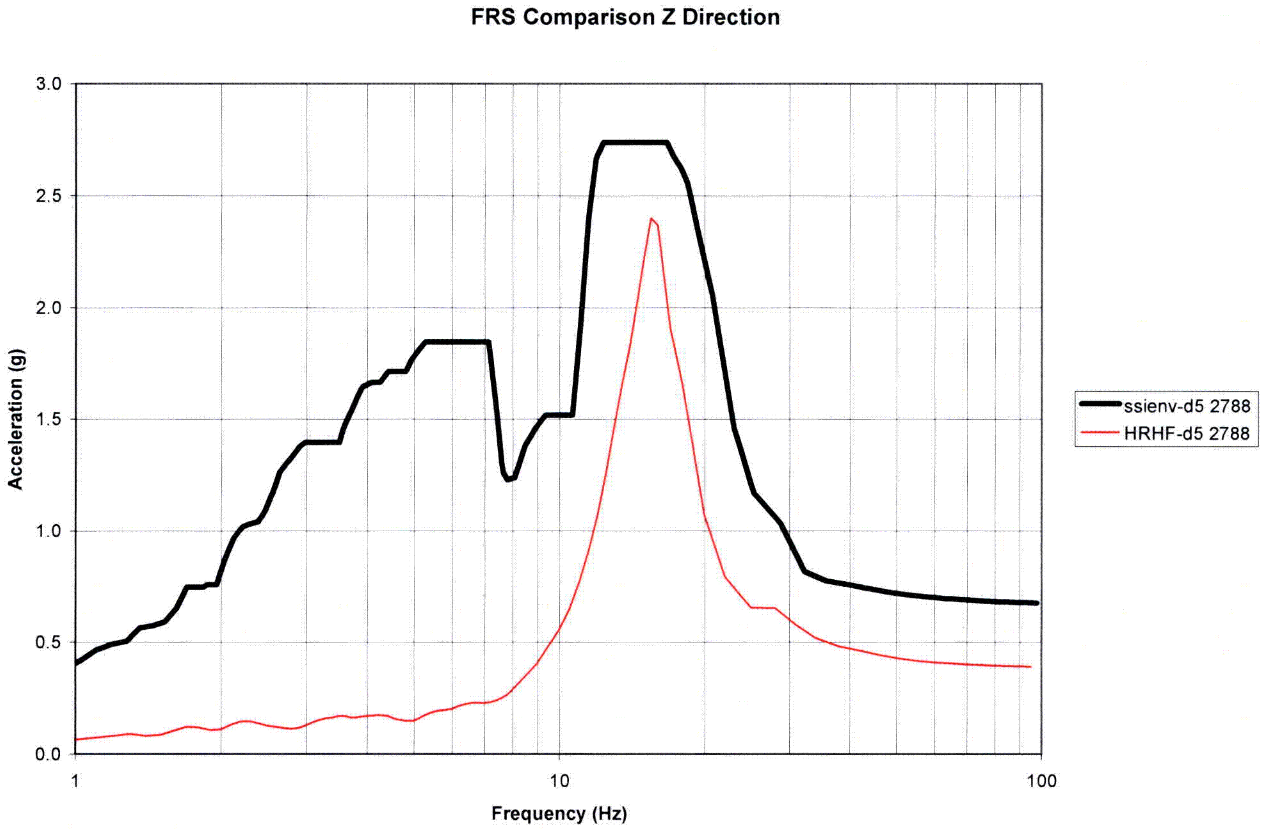

Figure RAI-SRP3.7.1-SEB1-04-3 – Z Seismic Response Spectra on Steel Containment Vessel at Elevation 224'

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-SEB1-06
Revision: 2

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.

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

$\lambda = 6900 / 50 = 138'$

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

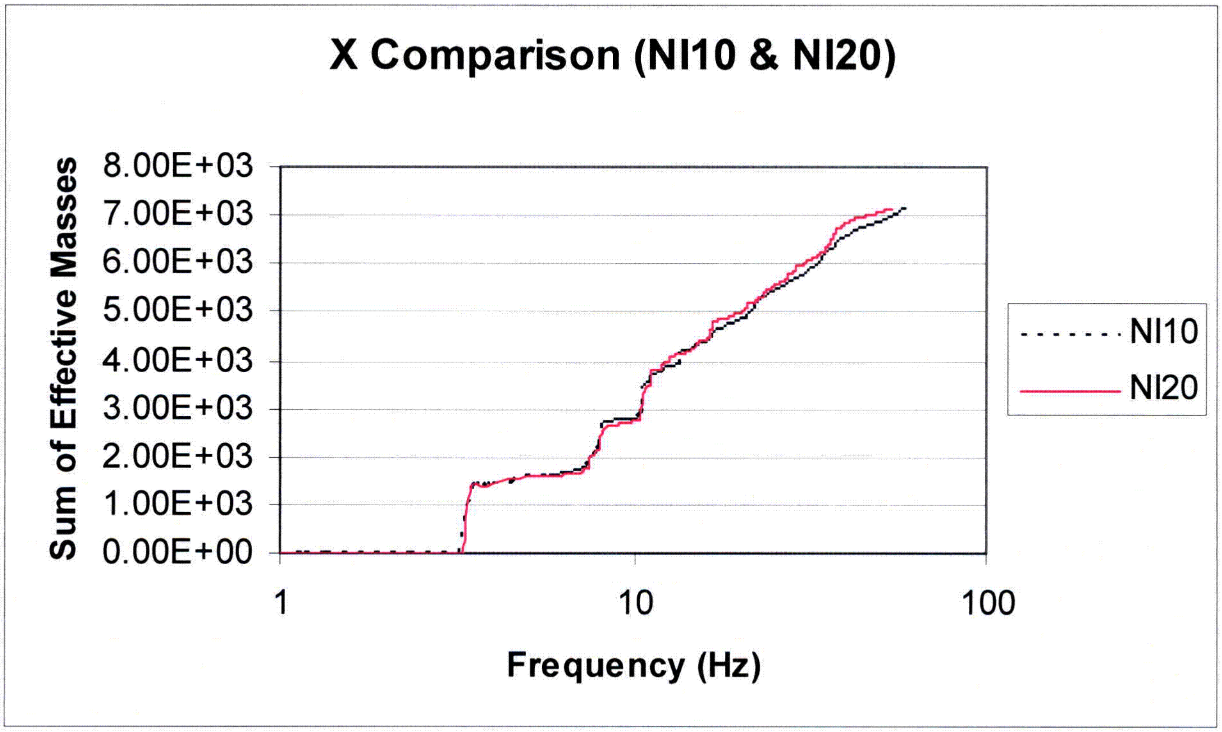

Figure RAI-SRP3.7.1-SEB1-06-1: X-Direction Comparison

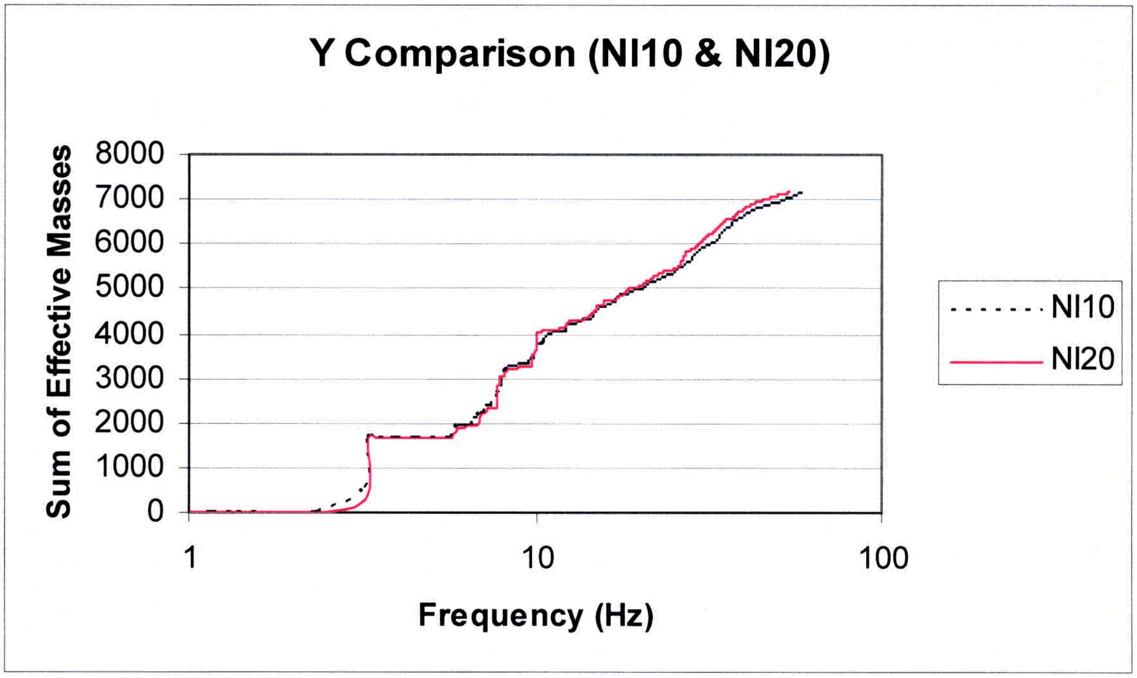

Figure RAI-SRP3.7.1-SEB1-06-2: Y-Direction Comparison

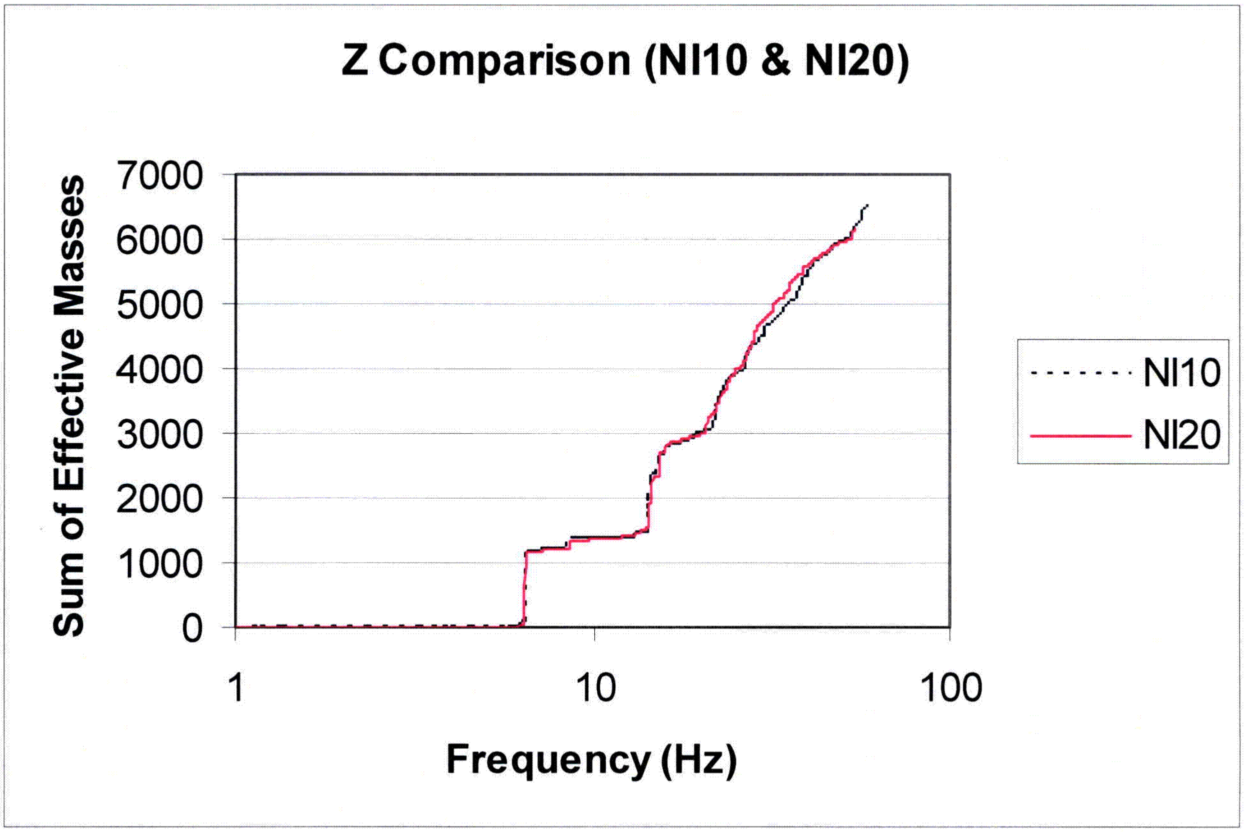

Figure RAI-SRP3.7.1-SEB1-06-3: Z-Direction Comparison

Design Control Document (DCD) Revision:

None

PRA Revision:

None

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

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.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-15
Revision: 0

Question:

Based on the information in DCD Rev. 16, Sections 3.7.2, 3.7.2.8, 3.7.2.8.1, and 3.7.2.8.3, the staff requires clarification of Westinghouse's treatment of structures adjacent to the nuclear island. The staff requests Westinghouse address the following:

(a) Confirm that the commitment made in Section 3.7.2, namely that "Seismic Category II building structures are designed for the safe shutdown earthquake using the same methods and design allowables as are used for Seismic Category I structures. The acceptance criteria are based on ACI 349 for concrete structures and on AISC N690 for steel structures including the supplemental requirements described in subsections 3.8.4.4.1 and 3.8.4.5," has been implemented.

(b) Clarify the seismic classification and method of seismic analysis applied to the entire annex building. For analysis purposes, has the entire annex building been treated has SC-II? If not provide the technical basis for not treating it as such.

(c) Provide the technical basis for the turbine building not being classified as SC-II, considering its proximity to the nuclear island and the infeasibility of demonstrating the acceptability of a collapse.

(d) If any changes were made in DCD Rev. 17 that relates to these requests, provide the reference.

Westinghouse Response:

(a) It is confirmed that the statement made in DCD Section 3.7.2 that "Seismic Category II building structures are designed for the safe shutdown earthquake using the same methods and design allowables as are used for seismic Category I structures. The acceptance criteria are based on ACI 349 for concrete structures and on AISC N690 for steel structures including the supplemental requirements described in subsections 3.8.4.4.1 and 3.8.4.5," has been implemented.

(b) As stated in DCD Section 3.7.2.8.1, Annex Building, "The portion of the annex building adjacent to the nuclear island is classified as seismic Category II." As shown in DCD Table 3.2-2 the annex building area outlined by columns E-I.1 and 2-13 is classified as seismic Category II. The annex building area outlined by columns A-D and 8-13, as well as column A-G and 13-16 are classified as non-seismic. For design purposes, only the portion identified as seismic Category II are designed following the Seismic Category I structures acceptance criteria. This is acceptable since criteria listed in DCD Section 3.7.2.8 are satisfied. Specifically the portions of the annex building classified as nonseismic are not adjacent to the nuclear island, and their collapse will not cause the nonseismic structure to strike a seismic Category I structure, system or component, nor will their collapse impair the integrity of seismic Category I structures, systems or components. Further, the nonseismic portion of the annex building is only one story with roof elevations below 120'. If this portion of the annex building would fail it would not cause any failure to the seismic Category II portion that would impair the integrity of the seismic Category I structures.

(c) During the hard rock certification of the AP1000 the NRC reviewed the classification of the turbine building as a non-seismic structure. The NRC concluded from this review (AP1000 FSER) "that the method and criteria used for the design of the turbine building will prevent, during a SSE event, the turbine building to jeopardize the safety function of the NI structure, and are therefore acceptable." This conclusion was reached after Westinghouse agreed to modify the analysis and design requirements to:

- Upgrade the Uniform Building Code (UBC) seismic design from Zone 2A, importance Factor of 1.25, to Zone 3 with an Importance Factor of 1.0 in order to provide margin against collapse during the safe shutdown earthquake, and

- To use eccentrically braced steel frame structures meeting the requirements given in DCD Section 3.7.2.8.3.

The turbine building is designed as an eccentrically braced frame structure under the guidance of the UBC and is, by the principal of the code, therefore designed to deform during the design seismic event rather than collapse.

The methods and criteria that were agreed to with the NRC have not changed and are given in DCD Section 3.7.2.8.3, Revision 17.

(d) No changes were made in DCD Revision 17 that relates to these requests.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None