ENCLOSURE 3

APP-GW-GLR-115 Rev. 3 (TR115) "Effect of High Frequency Seismic Content on SSCs"

APP-GW-GLR-115
Revision 3

AP1000 Standard Combined License Technical Report Effect of High Frequency Seismic Content on SSCs

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AP1000 RECORD OF CHANGES

Rev	Date	Revision Description
0	10/07	Original Issue
1	See EDMS	See Revision 1 Road Map that follows
2	05/10	See Revision 2 Road Map that follows
3	1/11	See Revision 3 Road Map that follows

ROAD MAP OF CHANGES FROM REV. 0 TO REV. 1 FOR TR115 (APP-GW-GLR-115)

Item	Rev. 0 Section Number	Change in Rev. 1	Reason for Change
1	Introduction	1st, 5th, and last paragraphs modified; Tables 1.0-1 and 1.0-2 replaced	RAI-SRP3.7.1-SEB1-02
2	5.1 Adequacy of CSDRS and HRHF Response Spectra	Entire section modified; Table 5.1-1 through 5.1-3 inserted; Figures 5.1-1 to 5.1-3 inserted.	RAI-SRP3.7.1-SEB1-06
3	5.1 Adequacy of CSDRS and HRHF Response Spectra	Last paragraph modified; Figures 5.1-7 and 5.1-8 inserted.	RAI-SRP3.7.1-SEB1-08 Rev. 1
4	5.2 Comparison of CSDRS and HRHF Response Spectra	First paragraph modified; Figure 5.2-1 through 5.2-6 replaced.	RAI-SRP3.7.1-SEB1-10 Rev. 1
3	Table 6.1-1	Table replaced	RAI-SRP3.7.1-SEB1-14
4	Table 6.1-2	Table replaced	RAI-SRP3.7.1-SEB1-14
5	Table 6.1-3	Table replaced	RAI-SRP3.7.1-SEB1-14
6	Table 6.1-4	Table replaced	RAI-SRP3.7.1-SEB1-14
7	Table 6.1-5	Table replaced	RAI-SRP3.7.1-SEB1-14
8	Table 6.1-6	Table replaced	RAI-SRP3.7.1-SEB1-14
9	6.3 Piping Systems	1st sentence of 1st paragraph, "seismic response spectra" is replaced with "envelope response spectra"	RAI-SRP3.12-EMB-03 Rev. 1
10	6.3 Piping Systems	2nd sentence of 1st paragraph, "seismic" replaced with "envelope response spectra," AP1000 inserted before "CSDRS," "basis" removed	RAI-SRP3.12-EMB-03 Rev. 1
11	6.3 Piping Systems	2nd paragraph, 1st bullet, "floor response spectra" replaced with "envelope response spectra" and "design spectra" replaced with "CSDRS"	RAI-SRP3.12-EMB-03 Rev. 1
12	6.3.1 Package Consideration	Last sentence of first paragraph replaced	RAI-SRP3.12-EMB-03 Rev. 1
13	6.3.1.1 Layout	"Packages without valves or concentrated…" added to end of paragraph	RAI-SRP3.12-EMB-03 Rev. 1

Item	Rev. 0 Section Number	Change in Rev. 1	Reason for Change
14	6.3.1.2 Review of Spectra	1st paragraph, "AP1000 CSDRS seismic…" removed, "in structure design" replaced with "the AP1000 CSDRS" , last sentence replaced with "The elevations with…"	RAI-SRP3.12-EMB-03 Rev. 1
15	6.3.1.2 Review of Spectra	3rd paragraph replaced with "Packages below elevation…"	RAI-SRP3.12-EMB-03 Rev. 1
16	6.3.1.3 Modal Analysis	"system" removed from 1st paragraph, "Likewise" replaced with "Inversely" in 2nd paragraph	RAI-SRP3.12-EMB-03 Rev. 1
17	Table 6.3.1-1: Reviewed Lines	Reasons replaced for Direct Vessel Injection Line A, Direct Vessel Injection Line B, CMT 2B Supply Line, ADS 4th Stage East, Normal RHR Suction Line, Spent Resin from Cont. Pen., From SCV Pen. To CVS-12A0007, Hydrogen Supply from CVS-12A0022, Main Steam Line B, and From Cont. Pen. To past Valve V024	RAI-SRP3.12-EMB-03 Rev. 1
18	6.3.2.1 Automatic Depressurization System 4th Stage West and Passive RHR Supply (APP-PXS-PLA-030)	1st paragraph, Figures 6.3.2.1-1, 6.3.2.1-2, and 6.3.2.1-3, and last sentence of 2nd paragraph replaced.	RAI-SRP3.12-EMB-03 Rev. 1
19	6.3.2.2 Normal RHR Heat Exchanger Inlet and Outlet (APP-RNS-PLA-170)	1st and 2nd paragraphs replaced with "Figures 6.3.2.2-1 to 6.3.2.2-3 are plots of local…"; Figures 6.3.2.2-1, 6.3.2.2-2, and 6.3.2.2-3 replaced; last sentence of last paragraph replaced.	RAI-SRP3.12-EMB-03 Rev. 1
20	6.3.2.3 Analysis Method	Section replaced.	RAI-SRP3.12-EMB-03 Rev. 1
21	6.3.3 Results	Section removed.	RAI-SRP3.12-EMB-03 Rev. 1
22	6.3.3.1 Automatic Depressurization System Stage 4 West (APP-PXS-PLA-030)	1st paragraph modified, 2nd paragraph removed, 3rd and 4th paragraphs modified. Tables 6.3.3.1-1 and 6.3.3.1-2 replaced, new table inserted for 6.3.3.1-3, Tables 6.3.3.1-4, 6.3.3.1-5, 6.3.3.1-6, 6.3.3.1-7, and 6.3.3.1-8 replaced. Results summary at end of section replaced.	RAI-SRP3.12-EMB-03 Rev. 1

Item	Rev. 0 Section Number	Change in Rev. 1	Reason for Change
23	6.3.3.2 Normal RHR Heat Exchanger Inlet and Outlet between P19 and P20 (APP-RNS-PLA-170)	1st paragraph modified 2nd paragraph removed 3rd and 4th paragraphs modified. Tables 6.3.3.2-1 and 6.3.3.2-2 replaced, new table inserted for 6.3.3.2-3, Tables 6.3.3.2-4, 6.3.3.2-5, 6.3.3.2-6, 6.3.3.2-7, and 6.3.3.2-8 replaced. Results summary at end of section replaced.	RAI-SRP3.12-EMB-03 Rev. 1
24	6.3.4 Summary and Conclusions	Section replaced.	RAI-SRP3.12-EMB-03 Rev. 1

ROAD MAP OF CHANGES FROM REV. 1 TO REV. 2 FOR TR115 (APP-GW-GLR-115)

Item	Rev. 1 Section Number	Change in Rev. 2	Reason for Change
1	Front matter	Addition of List of Acronyms	Editorial
2	Section 5.1 Adequacy of CSDRS and HRHF Response Spectra	Table 5.1-1 to 5.1-3 updated, Figures 5.1-1 to 5.1-3 updated	Changes made to reflect changes to model addressing new shield building and corrections to boundary conditions as discussed in RAI-SRP 3 7 1-SEB1-11, R3. Spectra also reflect latest CSDRS results that have the current shield building design modeled.
3	Section 5.2 Comparison of CSDRS and HRHF Response Spectra	Figures 5.2-1 through Figures 5.2-6 updated	Revised figures new reflect latest CSDRS and HRHF analysis results.
4	Section 5.3 is new to Rev. 2	Section 5.3 and Tables 5.3-1 through 5.3-3 added	New section added addressing walls and floors that may have amplified response in the frequency range from 33 Hz to 50 Hz. This section is related to RAI-SRP 3 7 1-SEB1-06, R4.
3	Section 6.1 Building Structures	Figure 6.1-1 through 6.1-6 updated; and Tables 6.1-1 through 6.1-6 updated	Changes made to reflect changes to model addressing new shield building and corrections to boundary conditions as discussed in RAI-SRP 3 7 1-SEB1-11, R3. Member forces also reflect latest CSDRS results that have the current shield building design model.
4	Section 6.2.1	Updated section to reflect analysis with revised seismic input associated with HRHF and CSDRS	Revised seismic results as discussed above for HRHF and CSDRS
5	Section 6.2.2	Updated section to reflect analysis with revised seismic input associated with HRHF and CSDRS; Tables 6.2.2-2, 6.2.2-3, and 6.2.2-5 updated.	Revised seismic results as discussed above for HRHF and CSDRS
6	Section 6.3 Piping Systems	1st paragraph updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
7	Section 6.3.1 Package Consideration	1st and 2nd paragraphs updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
8	Section 6.3.1.2 Review of Spectra	2nd and 3rd paragraphs updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS

Item	Rev. 1 Section Number	Change in Rev. 2	Reason for Change
9	Section 6.3.1.3 Modal Analysis	3rd and 4th paragraphs updated; Table 6.3.1-1 updated to reflect new package designators	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
10	Section 6.3.2.1 Automatic Depressurization System 4th Stage West and Passive RHR Supply (APP-PXS-PLA-030)	Updated package designator to Pressurizer Spray, Auxiliary Spray, CVS Letdown, CVS Charging (APP-RCS-PLR-020); 1st and 2nd paragraphs updated; added Figures 6.3.2.1-1 through 6.3.2.1-4	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
11	Section 6.3.2.2 Normal RHR Heat Exchanger Inlet and Outlet(APP-RNS-PLR-170)	Updated package designator to Normal RHR Suction Line (APP-RNS- PLR-010); 1st, 2nd, and 3rd paragraphs updated; added Figures 6.3.2.2-1 through 6.3.2.2-4	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
12	Section 6.3.2.3 Analysis Method	2nd paragraph updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
13	6.3.3.1 West (APP-PXS-PLA-030)	Updated package designator to Pressurizer Spray, Auxiliary Spray, CVS Letdown, CVS Charging (APP-RCS-PLR-020); 1st and 3rd paragraphs updated; Table 6.3.3.1-1 through 6.3.3.1-3 updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
14	6.3.3.2 RHR Exchanger Inlet and Outlet between P19 and P20 (APP-RNS-PLA-170)	Updated package designator to RHR Suction Line (APP-RNS-PLR-010); Tables 6.3.3.2-1 through 6.3.3.2-3 updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
15	6.3.4 Summary and Conclusion	2nd and 3rd paragraphs updated	Section 6.3 revised using new seismic response results as discussed above for HRHF and CSDRS
16	6.4.2 Evaluation Process	Updates provided based on new seismic analysis input	Section 6.4 revised using new seismic response results as discussed above for HRHF and CSDRS
17	6.4.3.3.3 Analysis of A01-A05 Console Line-up Model	Updated Table 6.4.3.3.3-1	Section 6.4 revised using new seismic response results as discussed above for HRHF and CSDRS
18	6.4.3.3.4 Analysis of APC Finite Element Model	Updated to; updated Table 6.3.3.4-1	Section 6.4 revised using new seismic response results as discussed above for HRHF and CSDRS
19	Appendix A	Changes to Rev. 17 Appendix 3I given	Changes to for Rev 18 from RAIs

ROAD MAP OF CHANGES FROM REV. 2 TO REV. 3 FOR TR115 (APP-GW-GLR-115)

Item	Rev. 2 Section Number	Change in Rev. 3	Reason for Change
1	1	Addition of text	Text added to incorporate comments from RAI-SRP3.7.1-SEB1-02 Rev 4
2	5.1	Update/addition of paragraphs at end of section	Text updated/added to incorporate comments from RAI-SRP3.7.1-SEB1-08 Rev 4; NRC TR115 action item 6
3	Figures 5.1-4, 5.1-5, 5.1-7, and 5.1-8	Updated figure titles for Figures 5.1-7 and 5.1-8. Restored figures 5.1-4 and 5.1-5 to Revision 2 versions.	Figure updated to incorporate comments from RAI-SRP 3.7.1-SEB1-08 Rev 4; NRC TR115 action item 6. Figures 5.1-4 and 5.1-5 incorrectly submitted in RAI response, WEC has restored them, and now figures 5.1-4 and 5.1-5 appear unchanged from Revision 2 to Revision 3.
4	5.2	Addition of text	Text updated to incorporate comments from RAI-SRP3.7.1-SEB1-09 Rev 4
5	Figures 5.2-1 through 5.2-6	Updated figures; Figures 5.2-1 title correction and correction to Figure title in TOC	Figures update to incorporate comments from RAI-SRP3.7.1-SEB1-10 Rev 4; NRC TR115 action item 4
6	Figures 5.2-7 and 5.2-8	Added figures; Updated TOC	NRC TR115 action item 2
7	5.3	Text updated	Text updated/added to incorporate comments from RAI-SRP3.7.1-SEB1-06 Rev 5; NRC TR115 item 3 part 1 and following NRC TR03 action item 9
8	Table 5.3-1	Rows added to table; Tables 5.3-2 and 5.3-3 deleted.	Table updated to incorporate comments from RAI-SRP3.7.1-SEB1-06 Rev 5; NRC TR115 action item 3.
9	6.0	Revised Text	Text added to incorporate comments from RAI-SRP3.12-EMB1-09 Rev 0
10	6.3	Section deleted	Text added to incorporate comments from RAI-SRP3.12-EMB1-09 Rev 0
11	7.0	Revised Text	NRC TR115 action item 1
12	Appendix A	Deleted	NRC TR115 action item 5. This Appendix has been deleted from TR 115, now that DCD Rev 18 has been formally submitted.

- **NRC TR115 action items are documented in letter WEC_WEC_000067.**

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LIST OF ACRONYMS

ACS	auxiliary control system
ADS	automatic depressurization system
APC	auxiliary protection cabinet
AS	algebraic sum
ASB	Auxiliary and Shield Building
ASME	American Society of Mechanical Engineers
CIS	containment internal structures
CMT	core makeup tank
CSDRS	certified seismic design response spectra
CVS	chemical and volume control system
DBE	design basis event
EPRI	Electric Power Research Institute
ERS	enveloping response spectra
FFT	fast Fourier transfer
FRS	floor response spectra
HF	high frequency
HRHF	hard rock high frequency
Hz	Hertz
HX	heat exchanger
IEEE	Institute of Electrical and Electronics Engineers
IERS	in-equipment response spectra
IRWST	in-containment refueling water storage tank
ISM	independent support motion
ISRS	in-structure response spectra
LOCA	loss-of-coolant accident
MCR	main control room
NRC	U.S. Nuclear Regulatory Commission
OBE	operating base earthquake
PCS	passive core coolant system
PI	process instrumentation
PRHR	passive residual heat removal
psi	pounds per square inch
RCL	reactor coolant loop
RHR	residual heat removal
ROP	remote operator shutdown panel
RPV	reactor pressure vessel
RRS	required response spectra
SSE	safe shutdown earthquake
SSI	soil structure interaction
SRSS	square root of the square of the sums
TF	transfer function
TRS	test response spectra
UBC	uniform building code
USM	uniform support motion methodology

LIST OF ACRONYMS cont.

VFS	containment air filtration system
ZPA	zero-period acceleration

1 INTRODUCTION

The seismic analysis and design of the AP1000 plant is based on the Certified Seismic Design Response Spectra (CSDRS) shown in Figures 1.0-1 and 1.0-2. These spectra are based on Regulatory Guide 1.60 with an increase in the 25 Hz region. The CSDRS has its dominant energy content in the frequency range of 2 to10 Hz. For new sites, the ground motion response spectra (GMRS) are obtained from site-specific probabilistic hazard-based ground motion. Many of the envelope response spectra of the Central and Eastern United States rock sites show higher amplitude at higher frequency than the CSDRS. However, these seismic response spectra are associated with significantly less displacement and lower response spectra values in the low frequency (less than 10 Hz) range, and therefore are expected to be less damaging for plant structures and housed equipment than events with input motions having spectra similar to the Regulatory Guide 1.60-based design spectra. The Electric Power Research Institute (EPRI) report Program on Technology Innovation: The Effects of High-Frequency Ground Motion on Structures, Components, and Equipment in Nuclear Power Plants (Reference 1.0-1) summarizes a significant amount of empirical and theoretical evidence, as well as regulatory precedents, which support the conclusion that such high frequency (HF) motions have marginal affect to the safety function of structures, systems, piping and equipment.

The industry position on HF seismic vibrations is that they do not pose a danger to the function and integrity of equipment, piping, and structures. This can be extended to AP1000 equipment, piping, and structures that are qualified by analysis for the AP1000 CSDRS. This report will confirm that position and demonstrate that normal design practices, when considering HF input, result in an AP1000 design that is both safer and more conservative than that which would result if designed for the HF input evaluated.

Westinghouse agrees with the industry position and offers in this report an evaluation of the AP1000 Nuclear Island for HF input based on the analysis of a representative sample of structures, components, supports, and piping to further demonstrate that the HF seismic response has marginal effect on the safety functions of structures, systems, piping, and is non-damaging. The evaluation includes building structures, reactor pressure vessel internals, primary component supports, primary loop nozzles, piping, and electro-mechanical equipment.

A hard rock high frequency (HRHF) spectrum has been developed that envelopes three hard rock sites for which Combined License applications using the AP1000 as the vendor design are being prepared. Figures 1.0-1 and 1.0-2 compare the HRHF at foundation level against the AP1000 CSDRS for both the horizontal and vertical directions for 5 percent damping. The HRHF exceeds the CSDRS for frequencies above about 15 Hz. Evaluations in this report are for envelope response spectra with high frequency input.

This revision of the technical report reflects the HRHF analysis revising the seismic response to reflect:

- Revised Shield Building design
- Correction to the incoherent runs
- Correction to the boundary conditions of rigid beams to solid elements in the NI20 SASSI model

- Modification of the transition shell to brick interface.

This report describes the methodology and criteria used in the evaluation to confirm that HF input has marginal affect on equipment, piping, and structures qualified by analysis for the AP1000 CSDRS. This report also demonstrates that the AP1000 envelopes any requirements that HF would impose. Thus, HF does not need to be considered explicitly in the design. This report provides supplemental criteria for selection and testing of equipment whose function might be sensitive to high frequency. The HRHF envelope response spectra provide an alternate set of spectra for evaluation of site-specific GMRS. A site is acceptable if its site specific GMRS falls within the AP1000 HRHF envelope response spectra. Therefore, a site is not considered acceptable without additional analyses if it does not fall within Figures 1.0-1 and 1.0-2. This report provides a summary of the analysis and applicable test results.

The analysis results documented in this technical report are in conformance with ISG-01 (Reference 1.0-2).

This shear wave velocity limitation is defined at the bottom of the basemat equal to or higher than 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths.

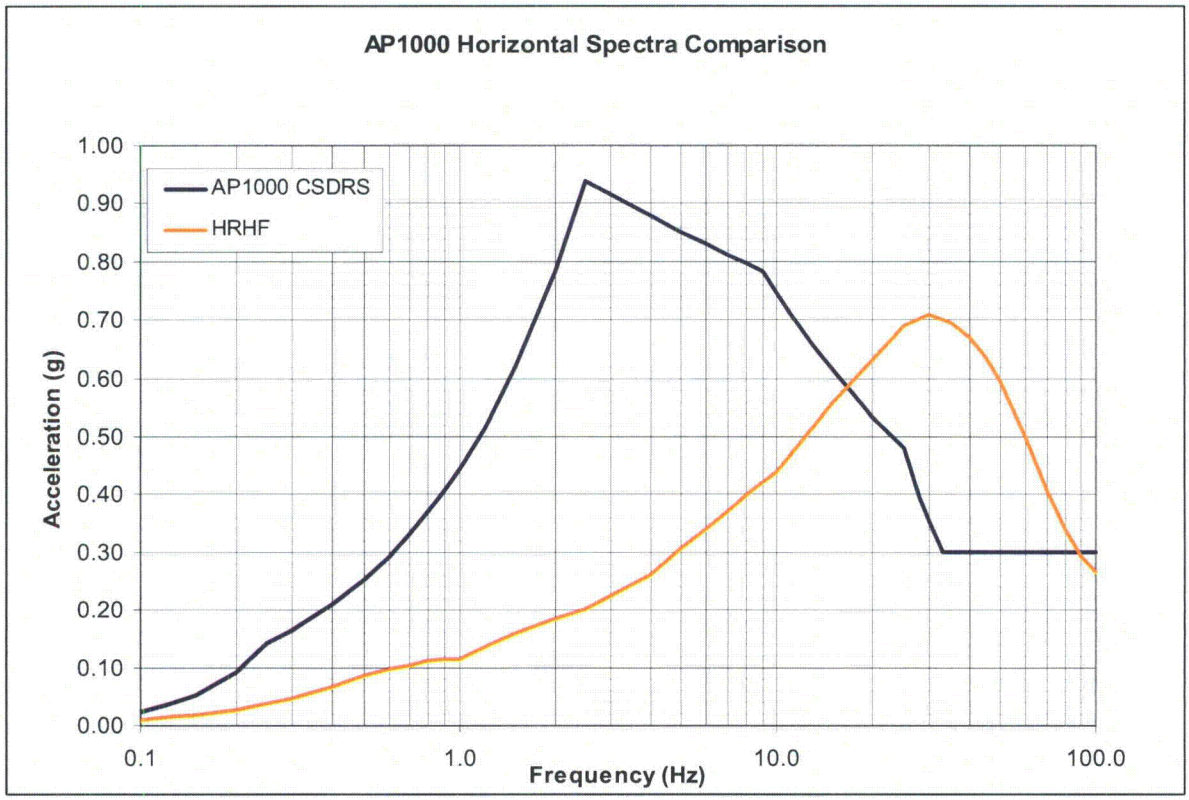


Figure 1.0-1 Comparison of the HRHF Horizontal Input Spectra to the CSDRS

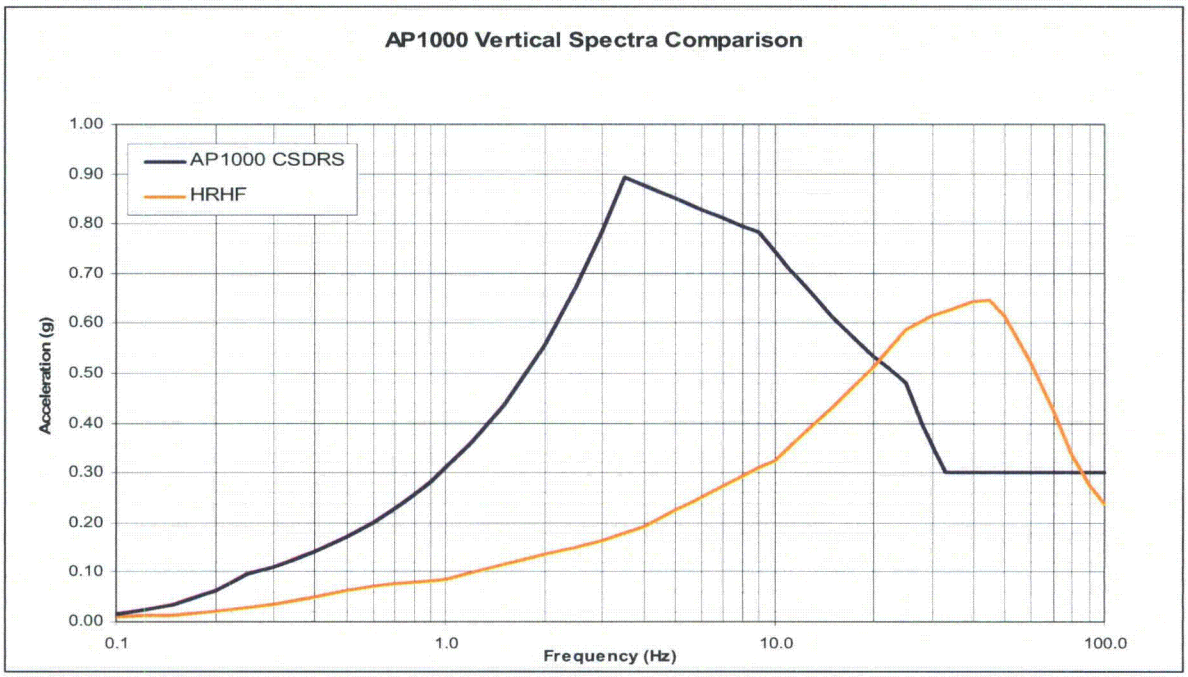


Figure 1.0-2 Comparison of the HRHF Vertical Input Spectra to the CSDRS

2 HIGH FREQUENCY SEISMIC INPUT

Presented in Figures 1.0-1 and 1.0-2 is a comparison of the horizontal and vertical HRHF envelope response spectra and the AP1000 CSDRS. The HRHF envelope response spectra presented is calculated at foundation level (39.5 feet below grade) at the upper most competent material and treated as an outcrop for calculation purposes.

For each direction, the HRHF envelope response spectra exceeds the design spectra in higher frequencies (greater than 15 Hz horizontal and 20 Hz vertical).

3 EVALUATION METHODOLOGY

Demonstration that the AP1000 nuclear power plant design is not controlled by the HF seismic response does not require analysis of the total plant. The evaluations are made of representative systems, structures, and components that have been selected by screening as potentially sensitive to HF input in locations where there were exceedances in the high frequency region. Acceptability of this sample is considered sufficient to demonstrate that the AP1000 design is controlled by the CSDRS.

The high frequency seismic analyses used the soil structure interaction code ACS SASSI (Reference 3.0-1). The results presented in this report are based on the stochastic (multiple, statistical analyses) seismic incoherent soil structure interaction (SSI) analysis approach referred herein as the simulation approach. The ACS SASSI incoherent SSI analysis includes the following computational steps:

1. Compute the free-field coherency matrix at interaction nodes

2. Perform spectral factorization of the coherency matrix (also checking its accuracy)

3. Use linear superposition of scaled spatial modes at each selected frequency (zero phases for algebraic sum (AS), and a set of simulated random phases for simulation)

4. Compute transfer functions (TF), including interpolation error smoothing to avoid spurious peaks (smoothing parameter was selected as SP=50 after a parametric SSI study)

5. Adjust TF phases to avoid canceling wave phase effects (default option)

6. Perform convolution of complex TF with input control motion fast Fourier transform (FFT)

7. Compute acceleration time histories at selected structural nodes by inverse FFT

8. Compute in-structure response spectra (ISRS) from acceleration time histories at selected structural nodes

9. If simulation is used, the mean SSI response is computed by statistical averaging of the individual SSI responses computed for the simulated random phase samples

10. The evaluations performed assess the ability of the system, structure, or component to maintain its safety function.

Supplementary analyses could have been performed as needed to show that high frequency floor response spectra exceedances are not damaging. These analyses include: gap nonlinearities and material inelastic behavior. These supplementary analyses were not necessary for the analyses reported herein. Tests on equipment are specified as needed where function cannot be demonstrated by analysis, or where analysis is not appropriate.

4 GENERAL SELECTION SCREENING CRITERIA

The following general screening criteria are used to identify representative AP1000 systems, structures, piping, and components for selected samples to be evaluated to demonstrate acceptability of the AP1000 nuclear power plant for the HF motion:

- Based on their importance to safety, including 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.
- According to location in areas of the plant that are susceptible to large HF seismic inputs.
- Have exhibited significant modal response within the region of high frequency amplification, as defined by such items as modal mass, participation factor, stress, and/or deflection.
- Possession of significant total stress as compared to allowable, when considering load combinations that include seismic.

5 COMPARISON OF HRHF FLOOR RESPONSE SPECTRA

5.1 ADEQUACY OF NI20 MODEL TO REPRESENT IN STRUCTURE HRHF RESPONSE SPECTRA

The NI20 (approximately 20 feet finite element mesh size) model is used to develop the HRHF response spectra using the finite element program ACS SASSI. A portion of the NI20 model has an element mesh size of approximately 10 feet for the containment internal structures (CIS).

A modal response comparison is made between the NI10 and NI20 models. Table 5.1-1 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 5.1-2 and 5.1-3. Tables 5.1-2 and 5.1-3 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 5.1-1 to 5.1-3 show a summation 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 similar to the NI10 model.

A comparison of in-structure response spectra for the ANSYS fine mesh (NI10) and coarse mesh (NI20) models is shown in Figures 5.1-4 to 5.1-6 (5 percent damping). The response spectra from the NI20 are more conservative in most cases.

Additionally, Figures 5.1-7 and 5.1-8 compare in-structure response spectra results from ANSYS (both NI10 and NI20 models) and SASSI (NI20). The differences shown in Figures 5.1-7 and 5.1-8 are attributed to the differences in geometric details between the NI10 and NI20 models at the Southeast and Northeast Corners of the Auxiliary Bldg.

Table 5.1-1 Mode Number vs. Frequency

Mode	NI20	NI10
50	8.66	8.30
100	13.69	12.47
150	16.68	14.78
200	20.29	16.76
250	22.65	18.75
300	25.02	21.06
350	27.29	22.42
400	28.99	23.56
450	30.78	24.60
500	32.65	25.37
550	34.46	26.13
600	36.06	26.71
650	37.78	27.53
700	39.73	28.73
750	41.51	29.93
800	43.03	31.10
850	44.63	32.29
900	46.18	33.55
950	47.78	34.54
1000	49.15	35.49
1050	50.54	36.26
1100	52.12	37.06
1150	53.45	37.81
1200	54.82	38.40
2000	N/A	59.08

Table 5.1-2 Modes Per Range (NI10)		
NI10		
Frequency Range	**Max Mode in Range**	**Modes Per Range**
0-10	67	67
10-20	276	209
20-30	751	475
30-40	1296	545
40-55	1839	543

Table 5.1-3 Modes Per Range (NI20)		
NI20		
Frequency Range	**Max Mode in Range**	**Modes Per Range**
0-10	64	64
10-20	194	130
20-30	426	232
30-40	707	281
40-55	1200	493

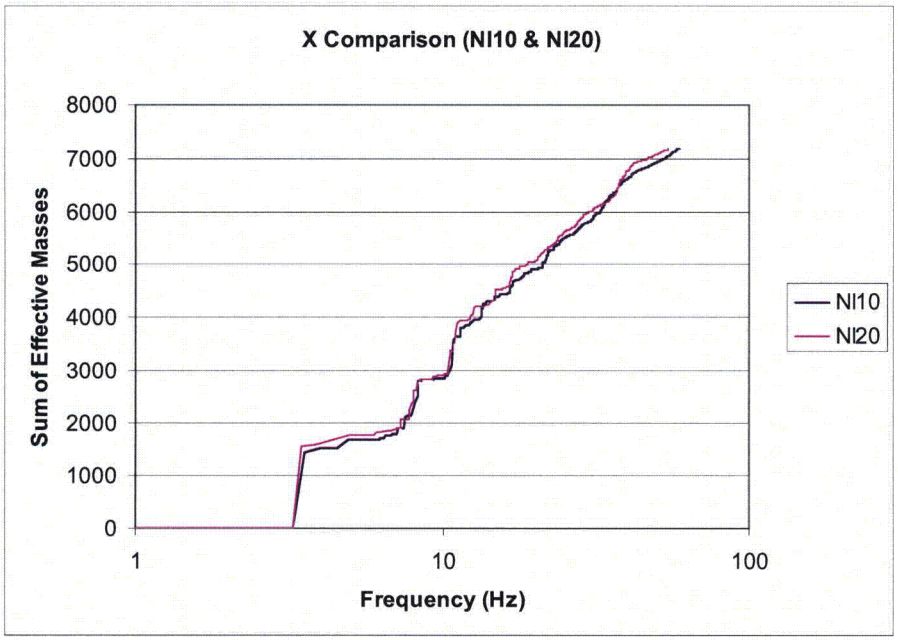


Figure 5.1-1 X Direction Comparison

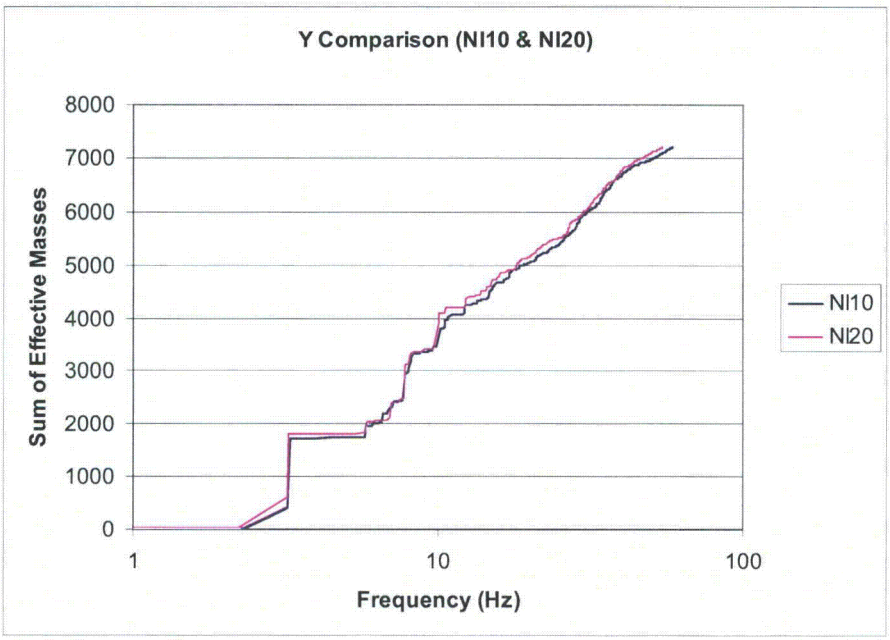


Figure 5.1-2 Y Direction Comparison

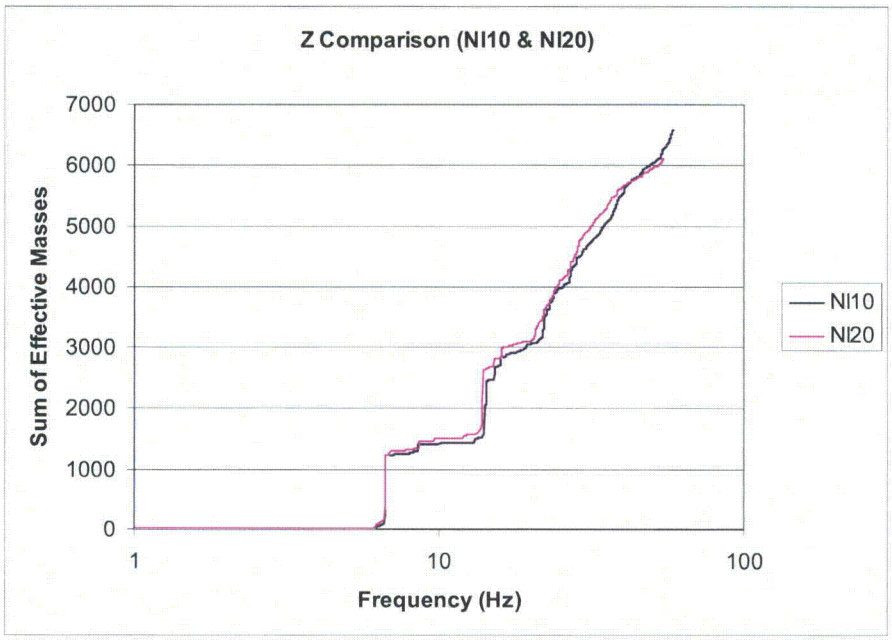
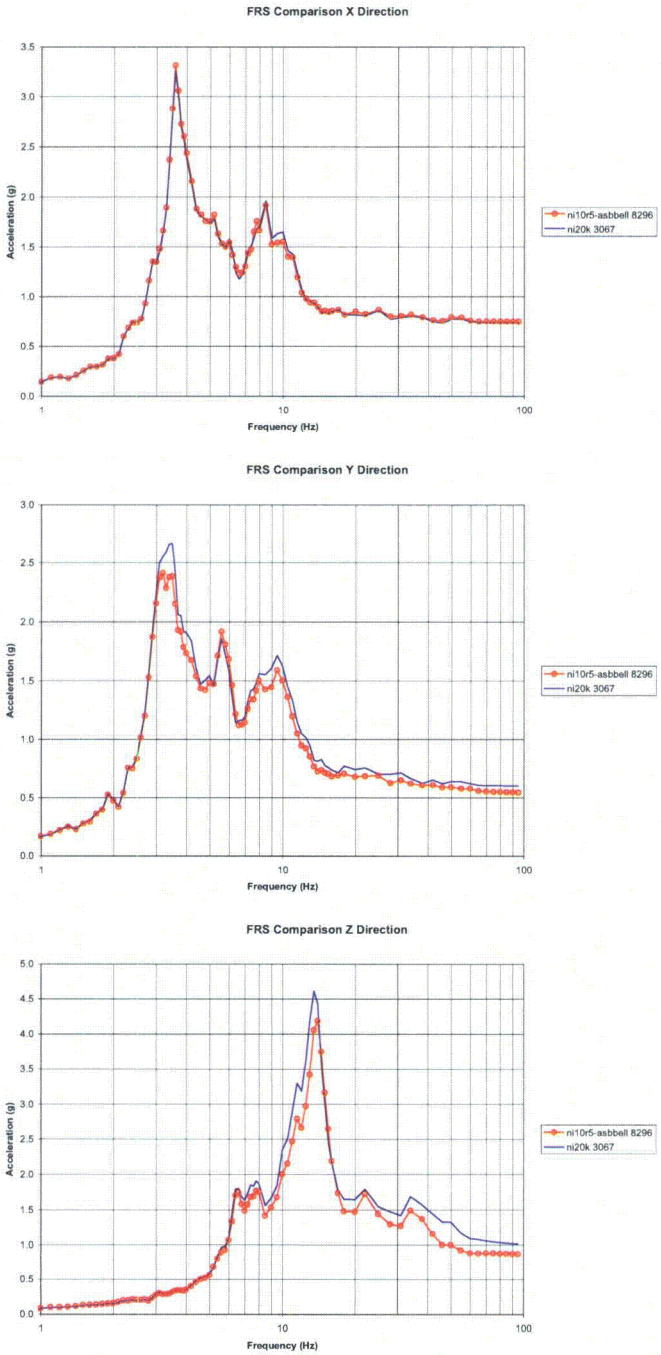


Figure 5.1-3 Z Direction Comparison



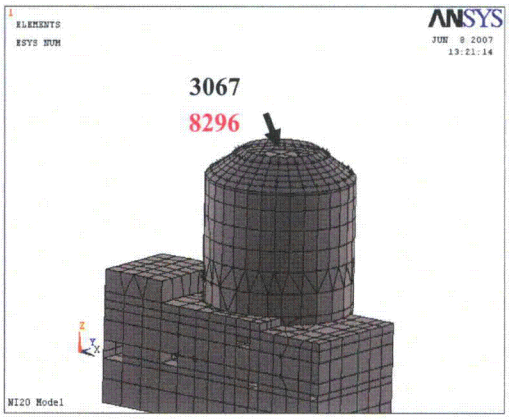
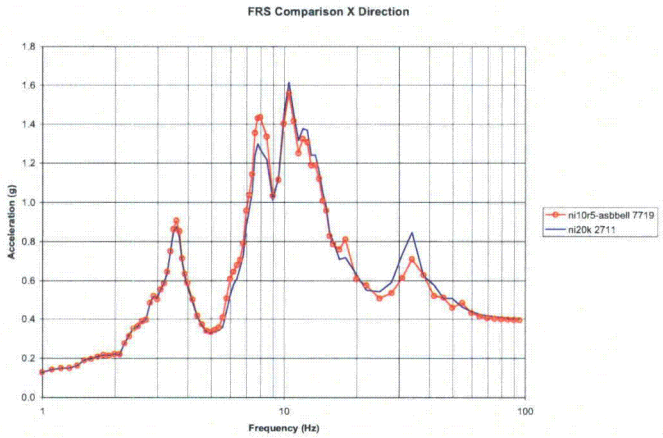
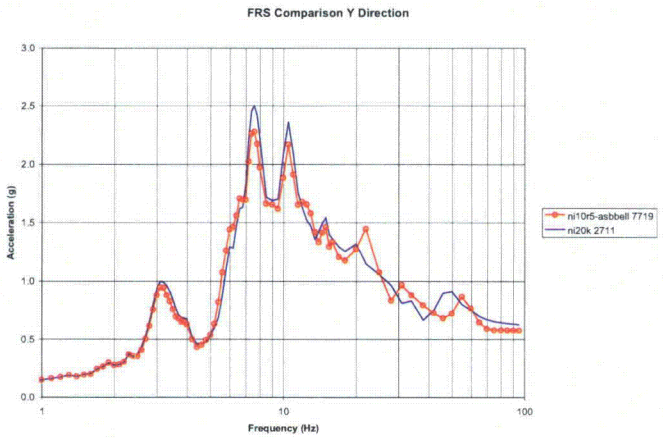
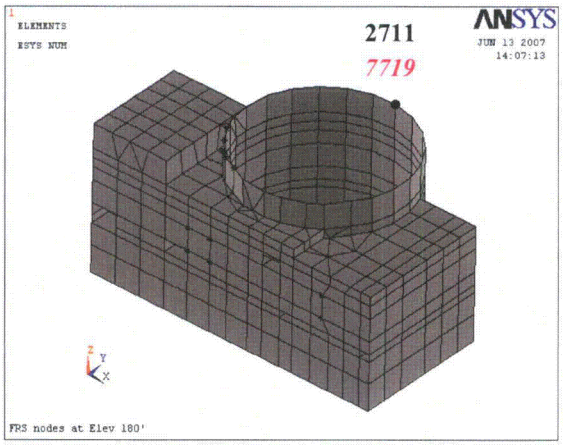


Figure 5.1-4 Comparison of NI20 and NI10 Seismic Response Spectra on Roof of Shield Building







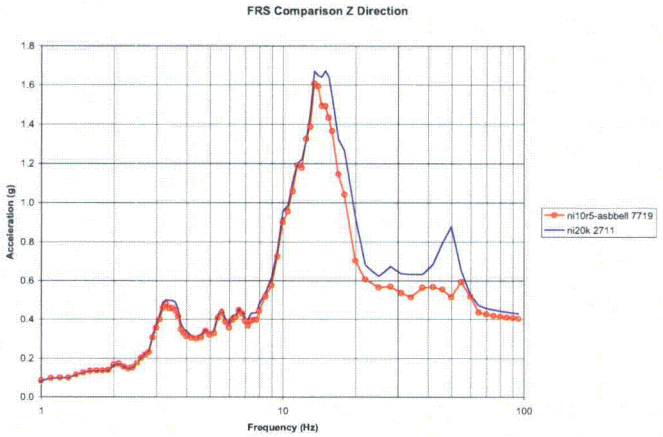
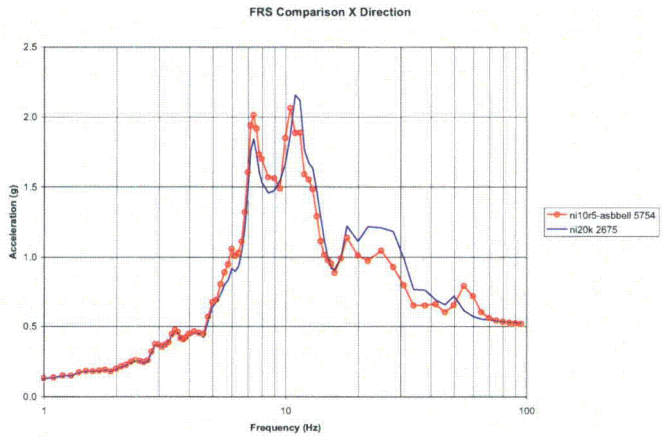
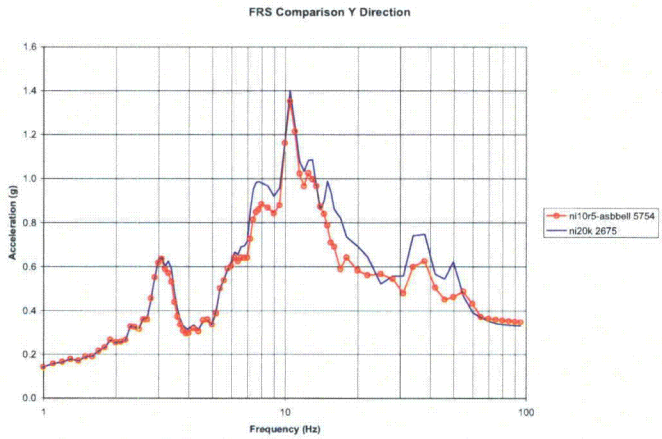
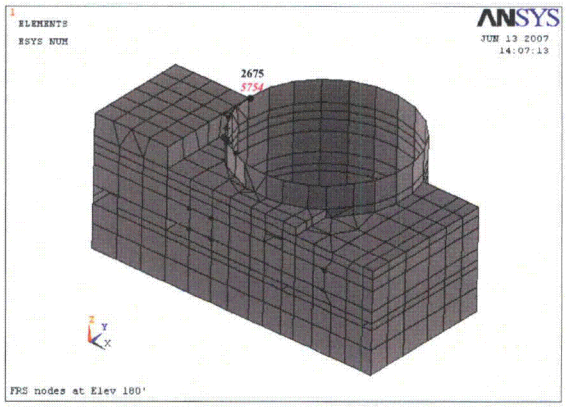


Figure 5.1-5 Comparison of NI20 and NI10 Seismic Response Spectra for West Side of Shield Building







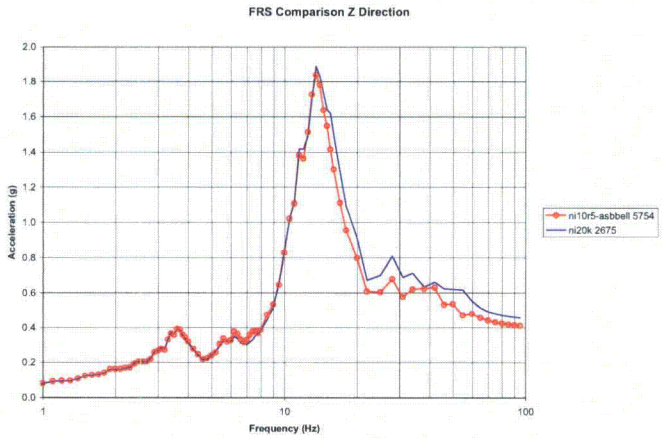


Figure 5.1-6 Comparison of NI20 and NI10 Seismic Response Spectra of South Side of Shield Building

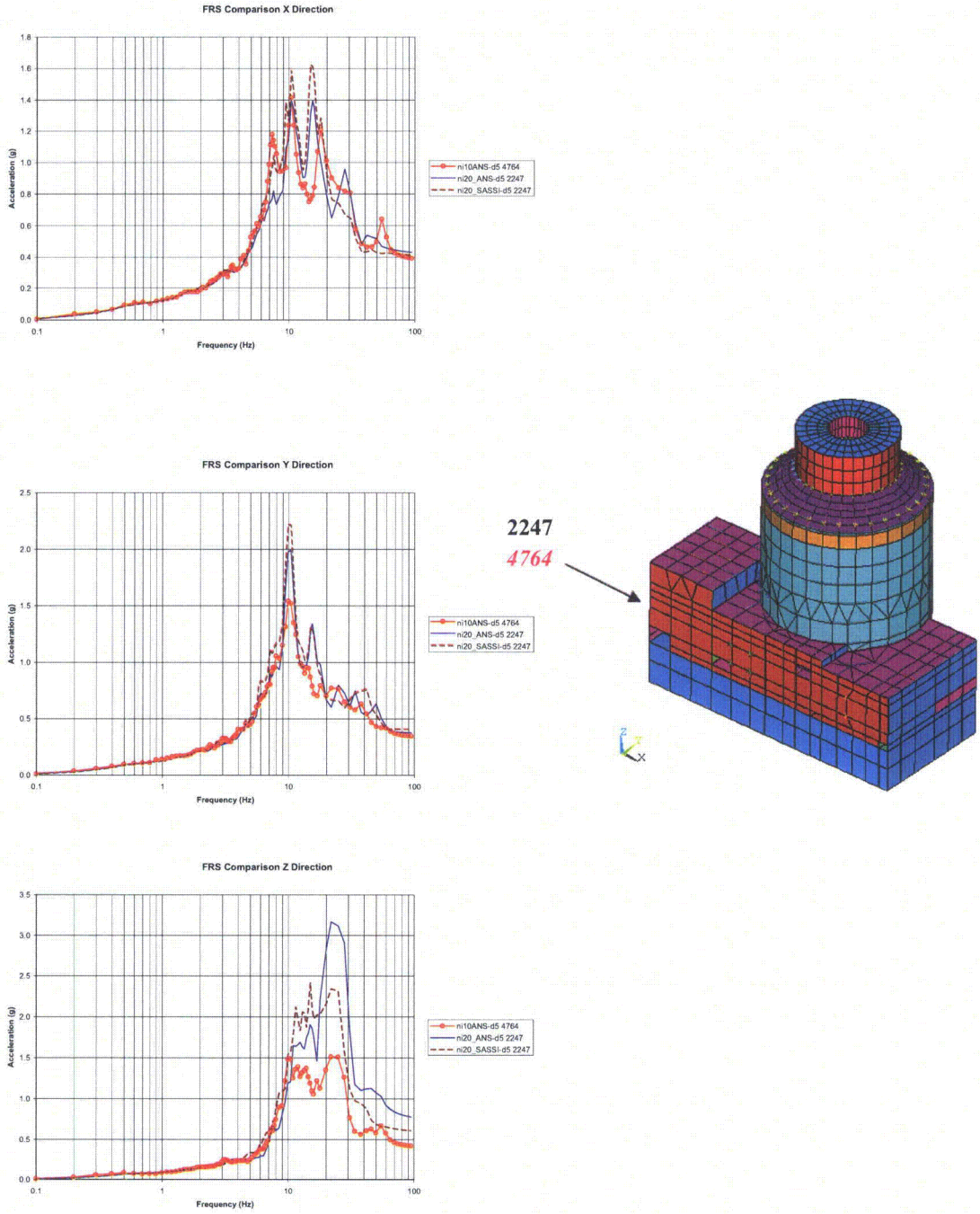
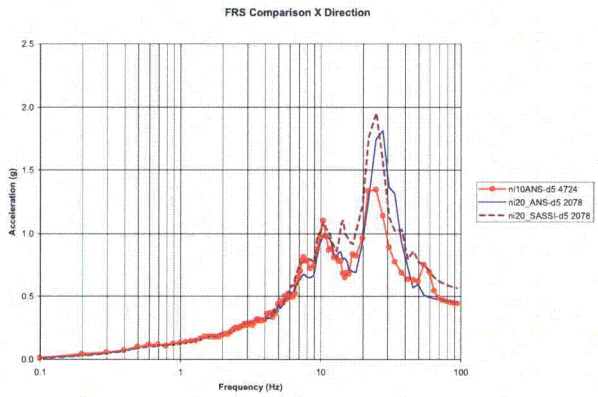
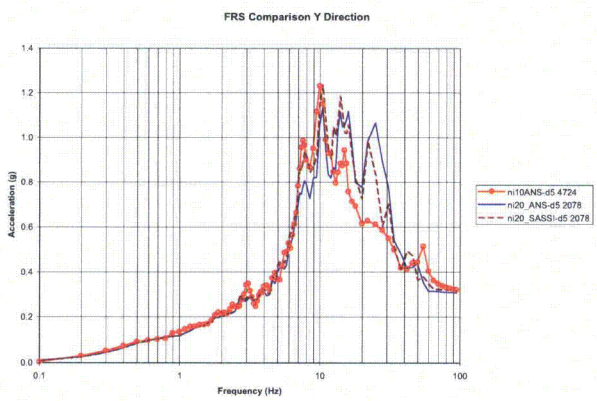
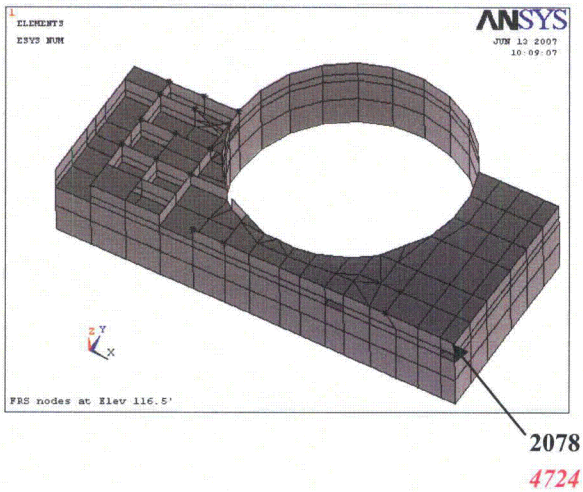


Figure 5.1-7 Comparison of NI20 ANSYS (ni20_ANS), NI20 SASSI (ni20_SASSI) and NI10 ANSYS (ni10ANS) Seismic Response Spectra at Southeast Corner of Auxiliary Building at Elevation 135'







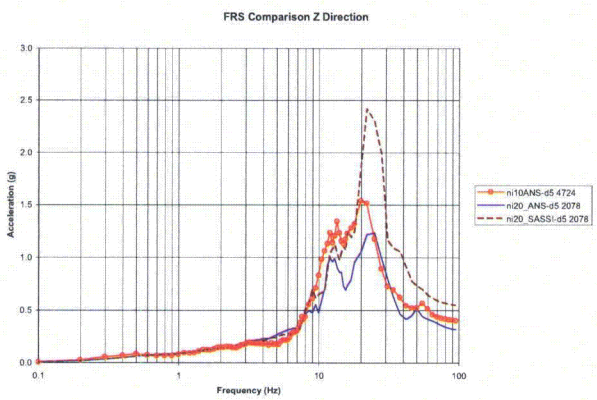
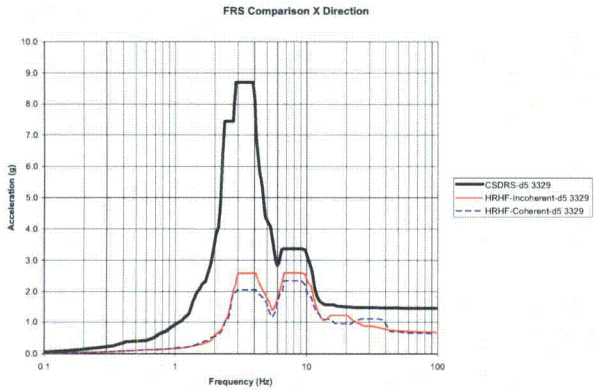


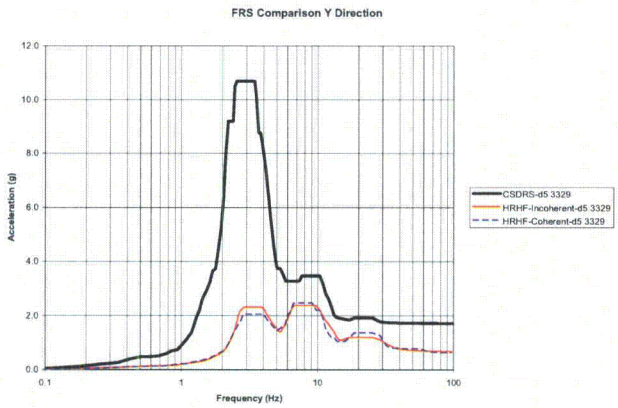
Figure 5.1-8 Comparison of NI20 ANSYS (ni20_ANS), NI20 SASSI (ni20_SASSI) and NI10 ANSYS (ni10ANS) Seismic Response Spectra at Northeast Corner of Auxiliary Building at Elevation 116.5'

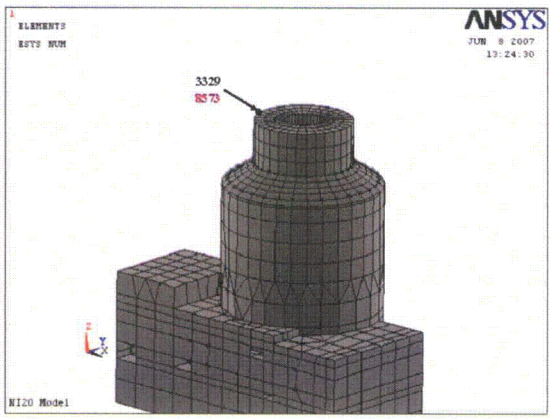
5.2 COMPARISON OF CSDRS AND HRHF RESPONSE SPECTRA

To show the significance of the HRHF response spectra, the CSDRS and HRHF seismic responses are compared. Figures 5.2-1 through 5.2-8 (5 percent damping) compare the in-structure response spectra with coherent and incoherent considerations at a number of locations in the Nuclear Island. There are some exceedances, mostly above the 15 Hz region. These curves are typical of the plant comparative responses found throughout the plant.

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







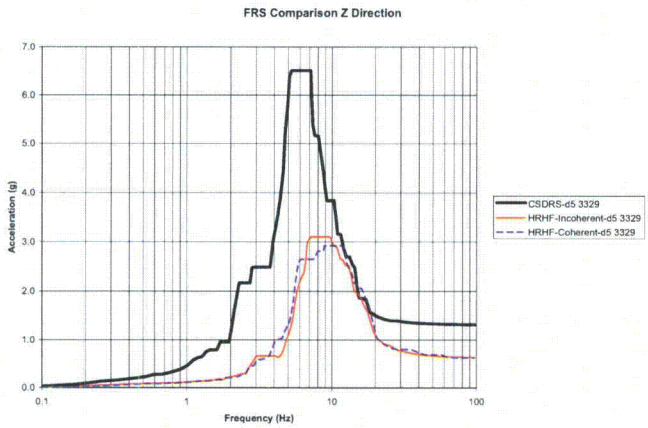
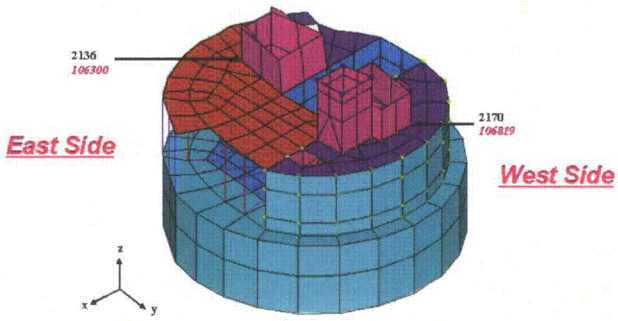


Figure 5.2-1 Auxiliary Shield Building (ASB) at Elevation 327.4'



East Side West Side

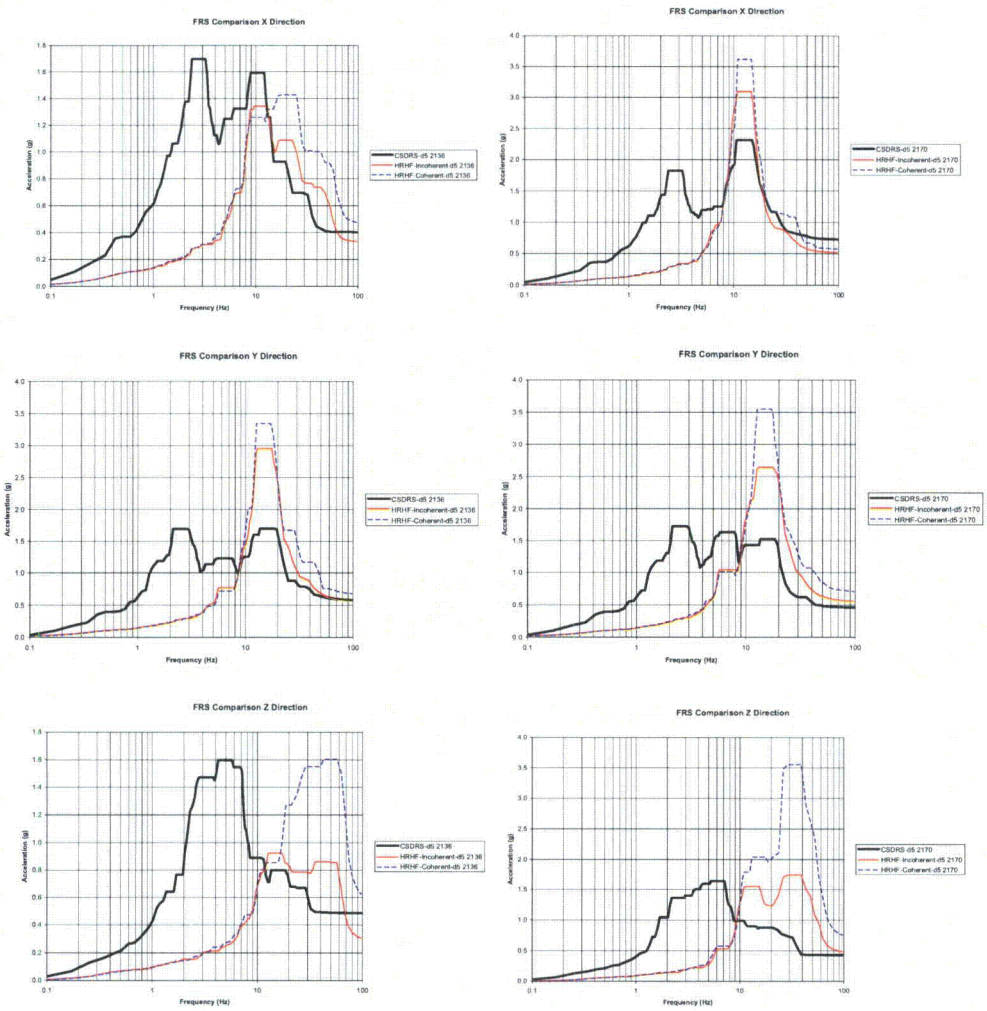
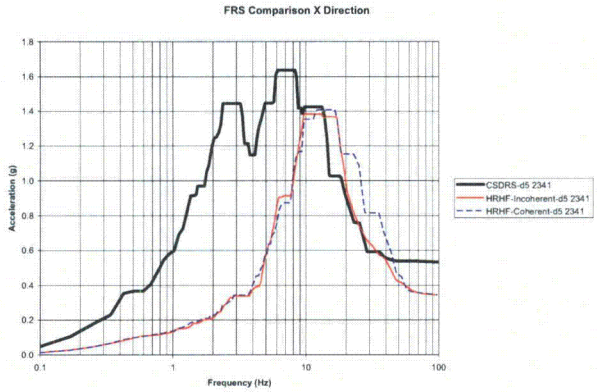
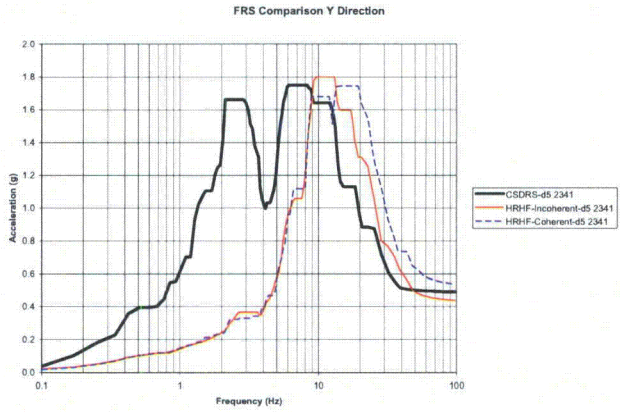
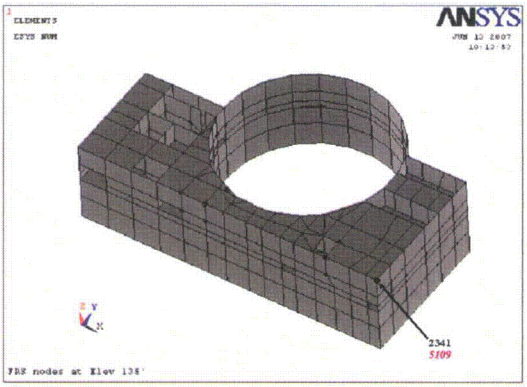


Figure 5.2-2 Containment Operating Floor (Elevation 134.25')







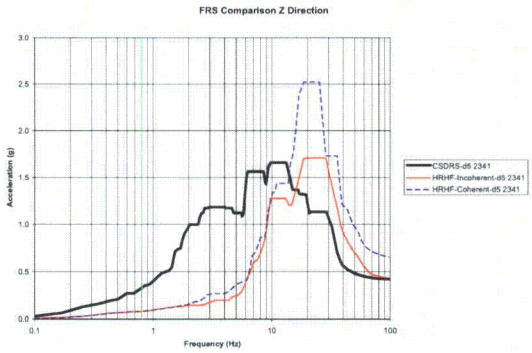


Figure 5.2-3 ASB at Northeast Corner (Elevation 134.5')

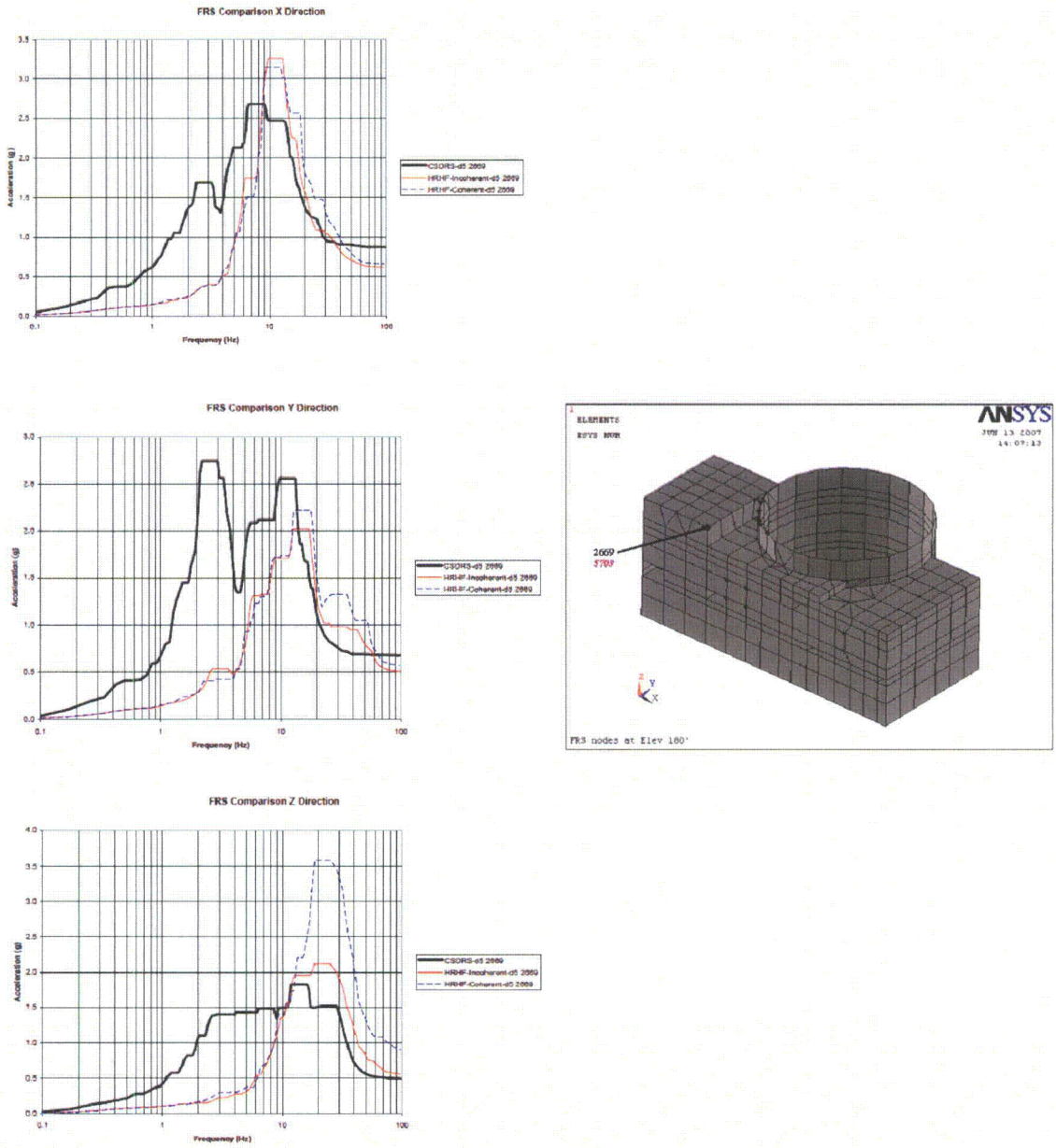
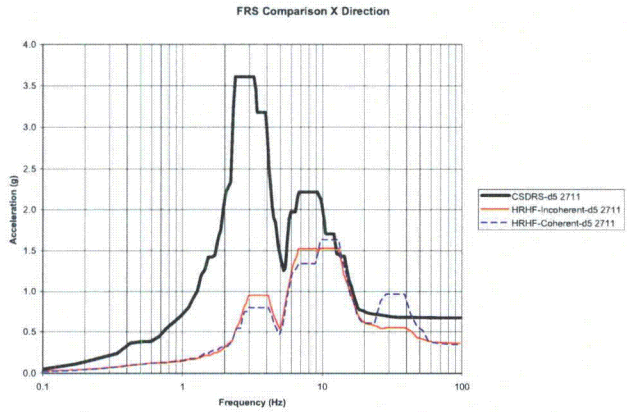
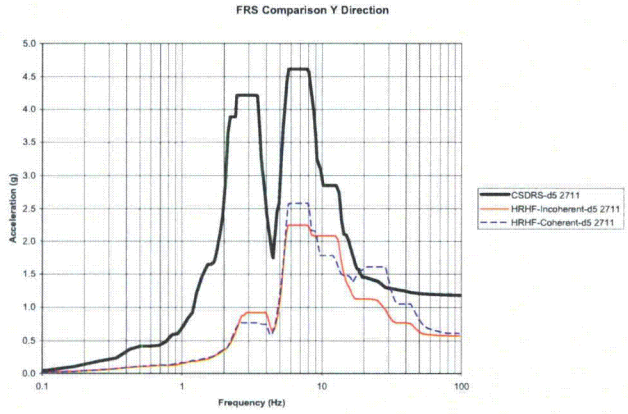
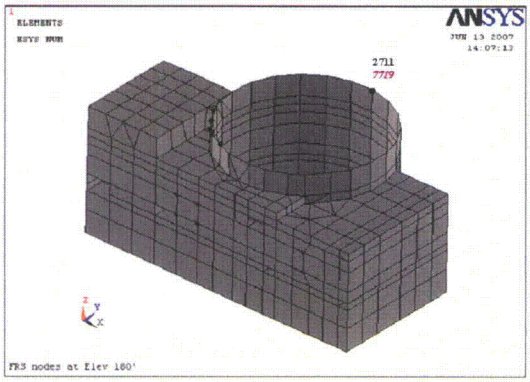


Figure 5.2-4 ASB at Fuel Building Roof (Elevation 179.56')







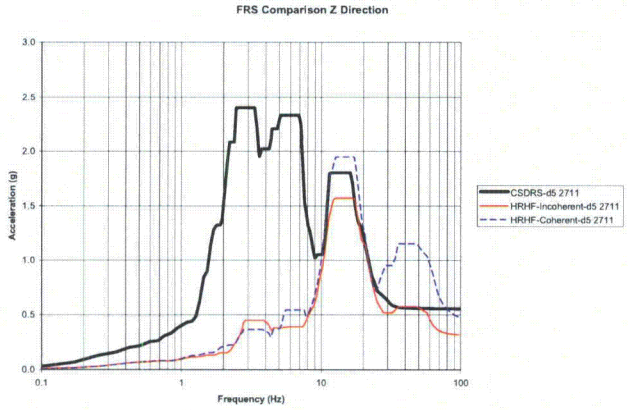


Figure 5.2-5 Floor Response Spectra (FRS) Nodes – West Wall at Elevation 180'

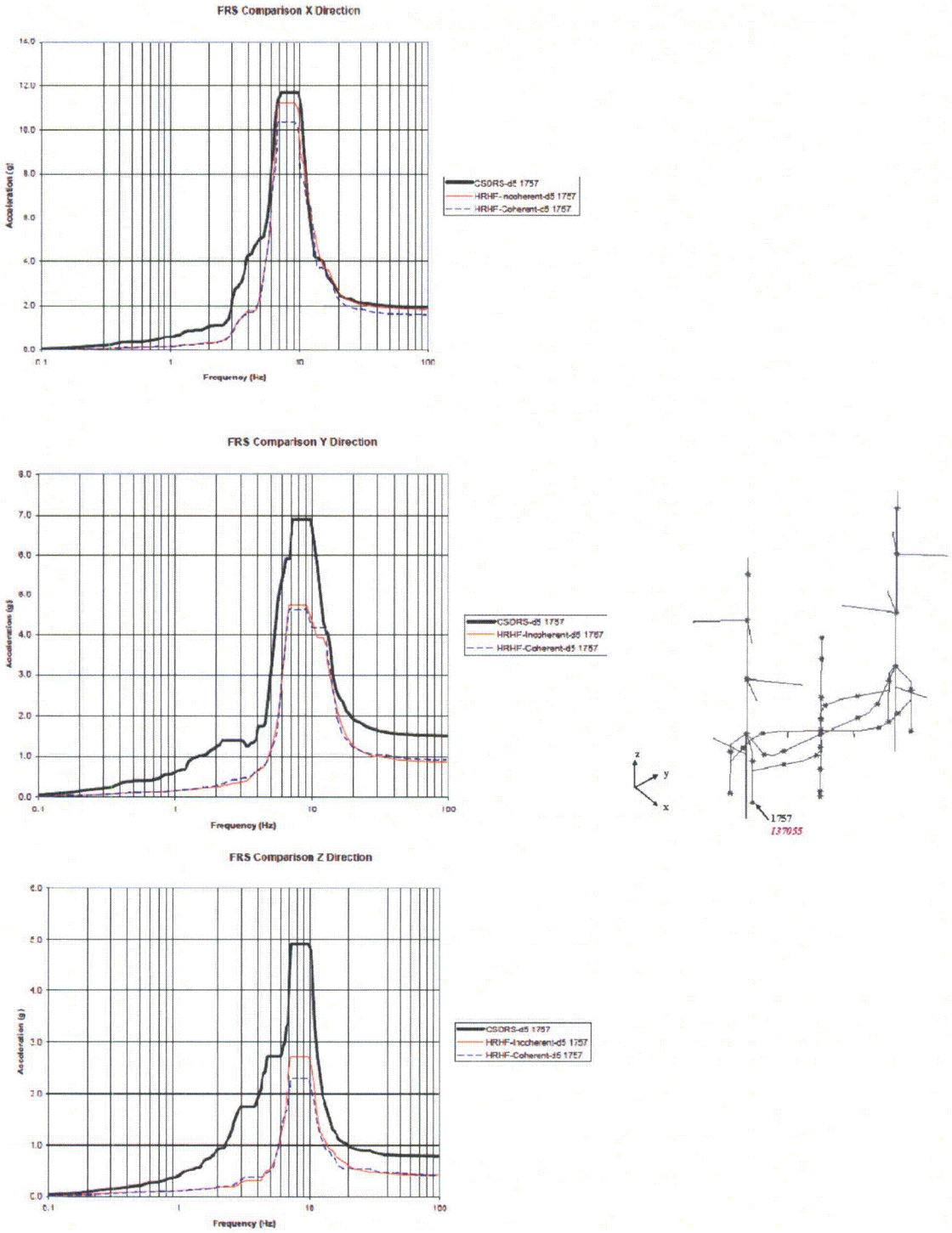
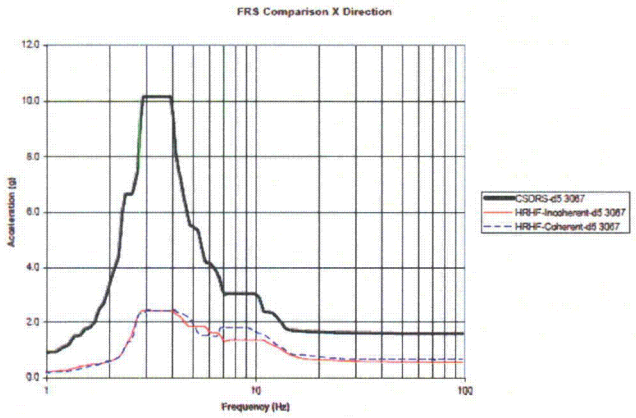
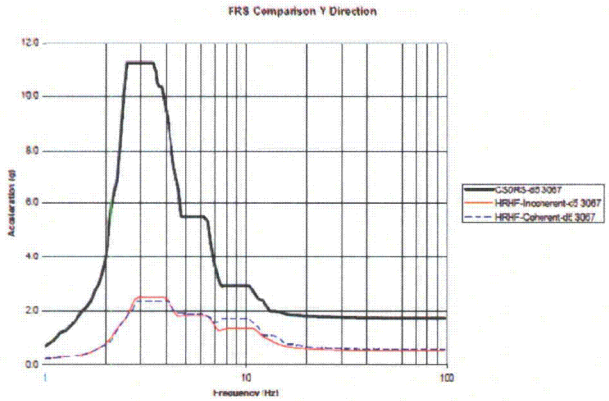
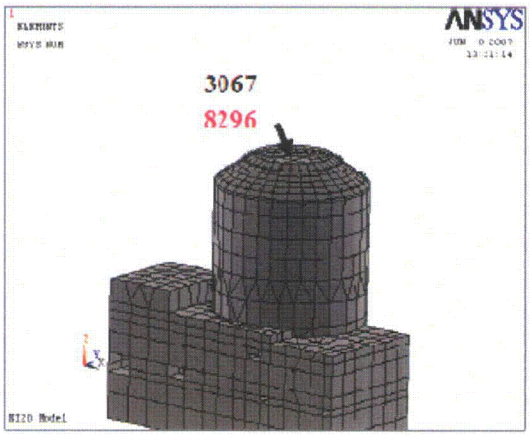


Figure 5.2-6 Reactor Coolant Pump







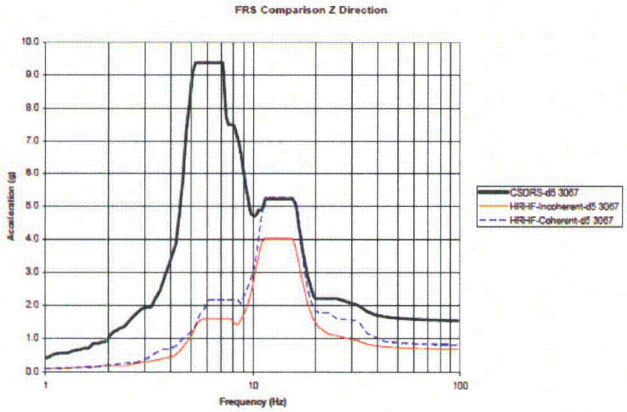
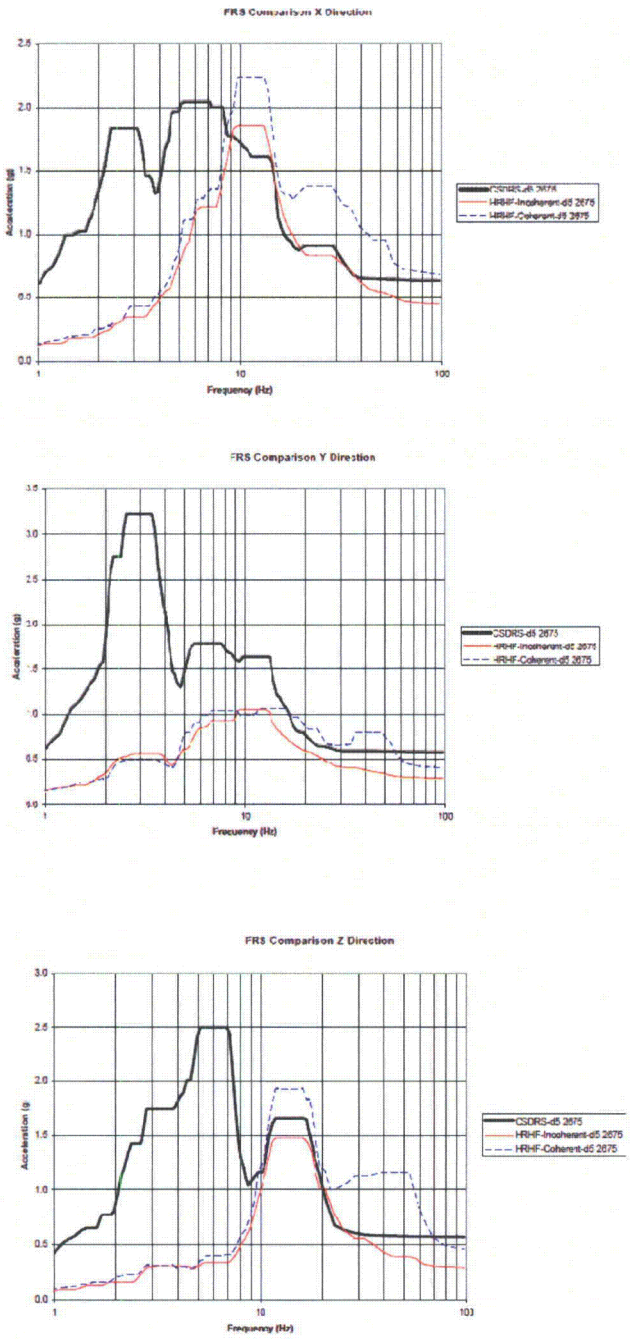


Figure 5.2-7 Seismic Response Spectra for Shield Building Roof Area



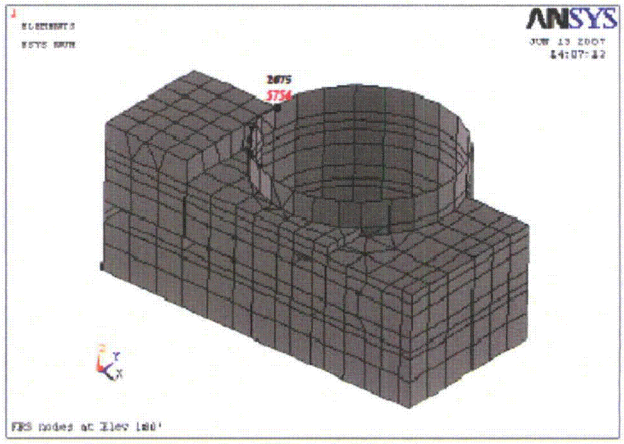


Figure 5.2-8 Seismic Response Spectra for South Side of Shield Building

5.3 SUPPLEMENTAL ANALYSIS FOR FLEXIBLE BUILDING WALLS AND FLOORS

The CSDRS design floor response spectra groups, identified in Section 4.2.4 in Reference 2.0-1, "APP-GW-S2R-010, Revision 5, "Extension of Nuclear Island Seismic Analysis to Soil Sites," are the same as those used in the evaluation of HRHF response (see Tables 4.2.4-1 through 4.2.4-7 in Reference 2.0-1). Additionally, Section 4.2.6 of Reference 2.0-1 identifies several "flexible" regions which are captured by the NI10 and NI20 models (see Table 4.2.6-1 in Reference 2.0-1, and reprinted here as Table 5.3-1) and an additional set of nodes which are only captured by the NI05 model (see Table 4.2.6-1 for additional 7 nodes marked NI05, and reprinted here as Table 5.3-1). These additional "flexible" regions are also used in the evaluation of HRHF response.

In addition to the flexible areas already identified (those less than 33Hz), each of the principal walls and floors in the Auxiliary and Shield Buildings as well as CIS has been reviewed. A modal analysis of the NI05 model for both the Auxiliary and Shield Buildings and CIS has been performed for each of these regions. Additional areas (7 of them) within each wall or floor where out-of-plane modes, which respond to HRHF input (structures with modes between 33 Hz to 50 Hz), have been identified and are listed in Table 5.3-1 (see subsection "HRHF Flexible Nodes"). 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 (as well as the original CSDRS "flexible" nodes) 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.

If an equipment or structure is supported exclusively by a floor or wall which is identified in Table 5.3-1 only that spectra will be used for design.

Table 5.3-1 List of Flexible Nodes

Flexible Area	Soil Site Node (NI20)	Hard Rock Site Node (NI10)
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 Building, EL. 289.2'	3067	8296
CSDRS Flexible (Less than 33 Hz) Nodes	**Building Node (NI05)**	
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 5.3-1 List of Flexible Nodes (cont.)	
HRHF Flexible (Less than 50 Hz) Nodes	**Building Node (NI05)**
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)

6 EVALUATION

Identified in this section are the portions of structures, components, and systems that are evaluated for high frequency seismic response. Based on the screening criteria applicable to the structures, systems, piping, and components, the sample to be evaluated consists of the following:

- Building structures
  - Auxiliary Building
  - Shield Building
  - CIS
- Primary Equipment
  - Reactor internals
  - Primary component supports
  - Reactor coolant loop primary equipment nozzles
- Piping Systems – See Section 6.3.
- Electro-Mechanical Equipment – Equipment that is potentially sensitive to HF input (see Table 6.4.6-1)

These structures, components, piping, and systems are discussed in more detail in the sections that follow.

6.1 BUILDING STRUCTURES

Maintaining the NI buildings' structural integrity is important to the safety of the plant. Representative portions of the buildings that were evaluated for the effect of high frequency input are selected based on the areas that can experience high seismic shear and moment loads due to the seismic event.

Three locations in the Auxiliary Building were selected for comparison and shown in Figure 6.1-1. These locations represent the bottom of a wall where the shear would be large (Element 1342), a wall in the vicinity of a floor that is influenced by HF response (Element 167), and a corner intersection of walls (Element 132).

Eight locations were evaluated on the Shield Building and are shown in Figures 6.1.-2 and 6.1-3. There are four at Elevation 107 feet and four at Elevation 211 feet. These locations are located on the east, west, north, and south sides.

Three areas within CIS were compared and shown in Figures 6.1-4 through 6.1-6. The southwest wall of the refueling canal (Figure 6.1-4) was evaluated since it is a representative wall on the refueling canal. The west wall of the steam generator (Figure 6.1-5) was evaluated because it receives contributions from both the steam generator lateral support and the refueling canal. The CA02 wall (Figure 6.1-6) was evaluated since it is a representative wall associated with the in-containment refueling water storage tank (IRWST).

The evaluation consisted of a comparison of the loads from high frequency input to those obtained from the AP1000 design spectra, shown in Figures 1.0-1 and 1.0-2, for the representative building structures. The Nuclear Island building structures are considered qualified for the high frequency input if the seismic loads from the CSDRS envelope those from the HF input. Tables 6.1-1 through 6.1-6 compare the member forces (TX, TY, and TXY) for elements shown in Figures 6.1-1 through 6.1-6. The element solutions for the upper portion of the southwest steam generator wall are grouped and the maximum member forces are reported in Table 6.1-5. The comparisons show that seismic loads from CSDRS enveloped those from the HF input.

The load comparisons for building structures shows that seismic loads resulting from the CSDRS input motion are greater than loads obtained from HRHF envelope response spectra input motion.

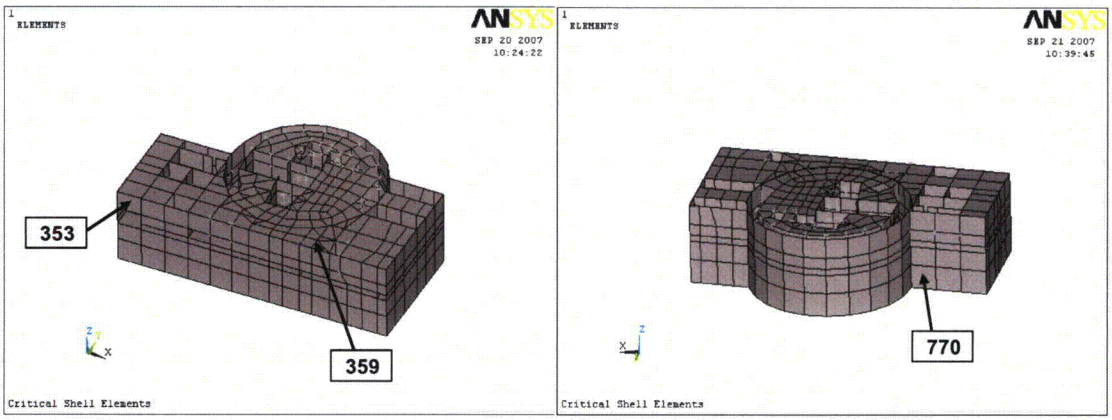


Figure 6.1-1 Auxiliary Building Critical Shell Elements

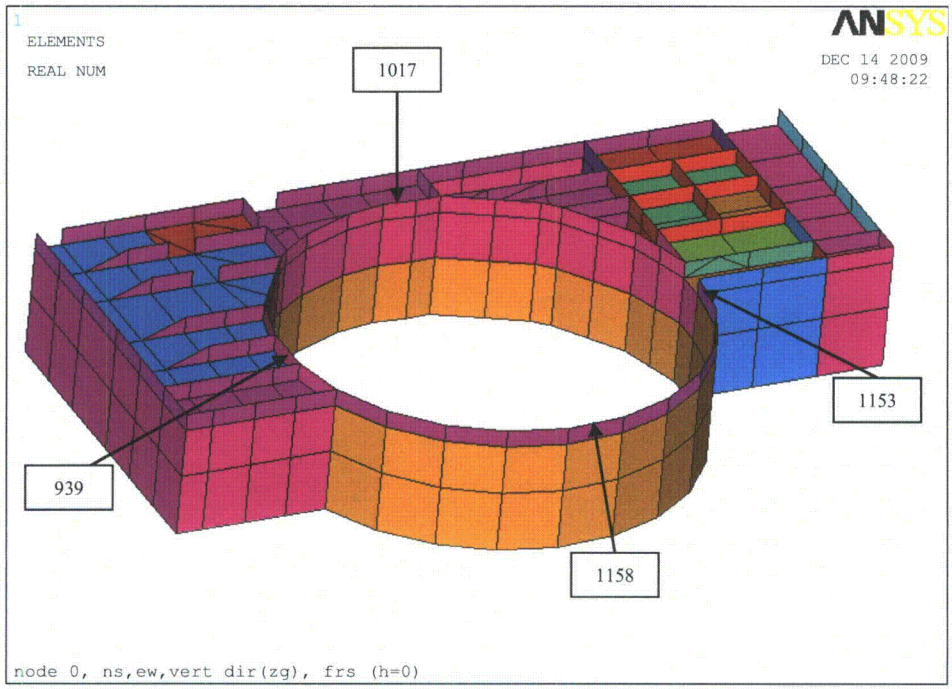


Figure 6.1-2 Shield Building Critical Shell Elements at Elevation 107'

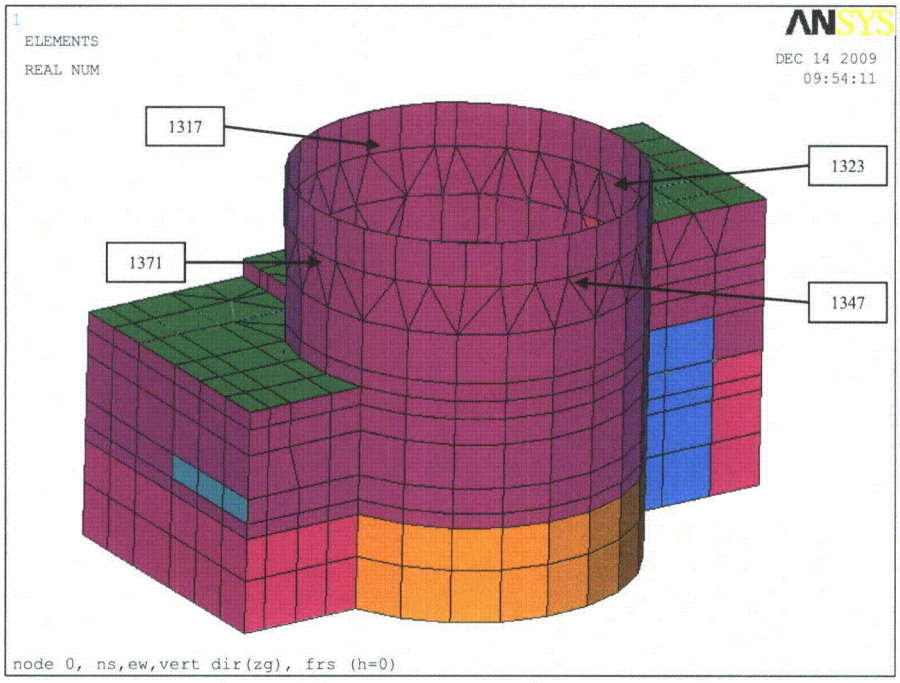


Figure 6.1-3 Shield Building Critical Shell Elements at Elevation 211'

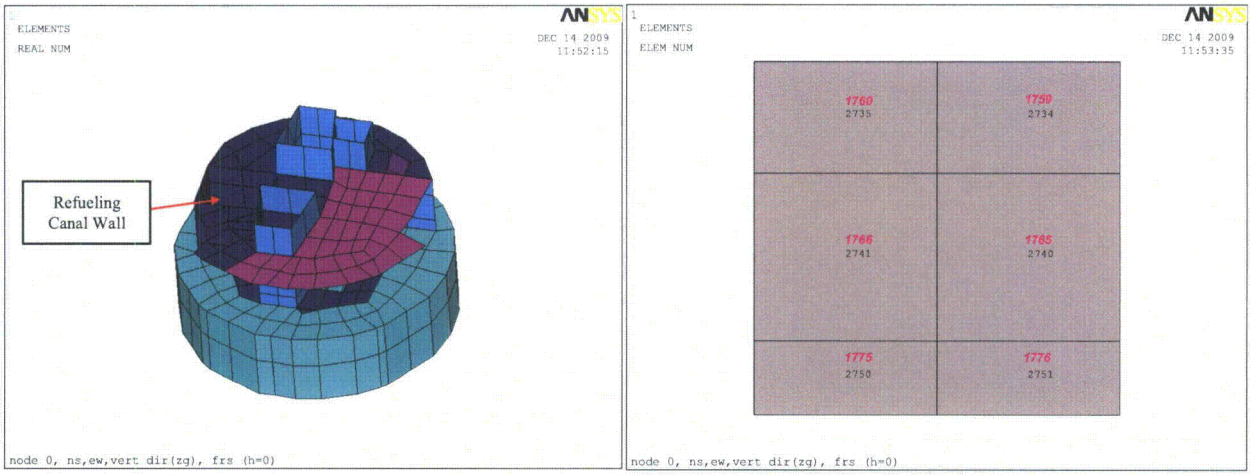


Figure 6.1-4 Southwest Refueling Canal Wall Shell Elements

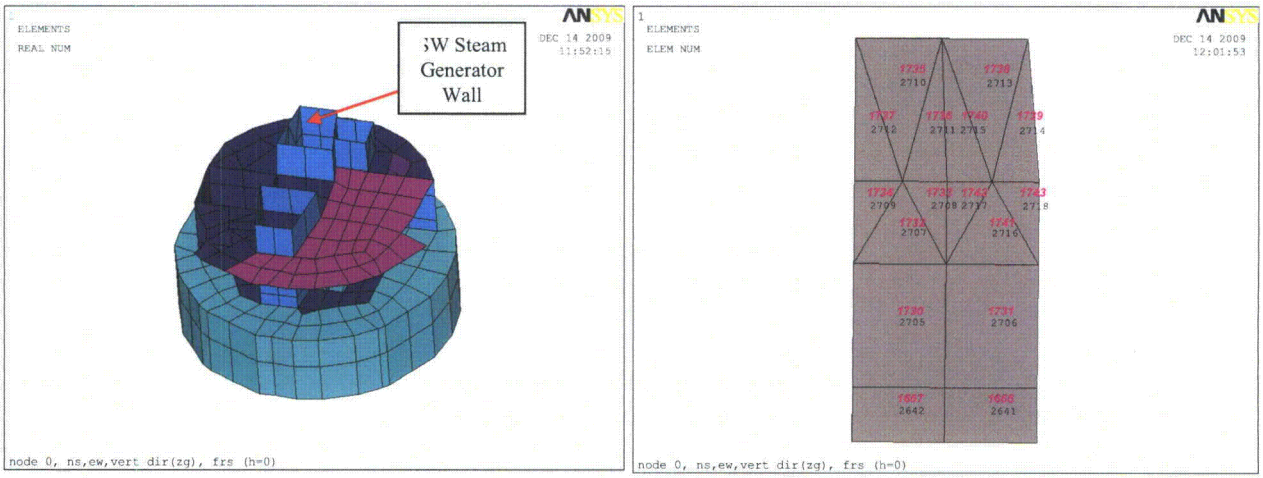


Figure 6.1-5 West Steam Generator Wall Shell Elements

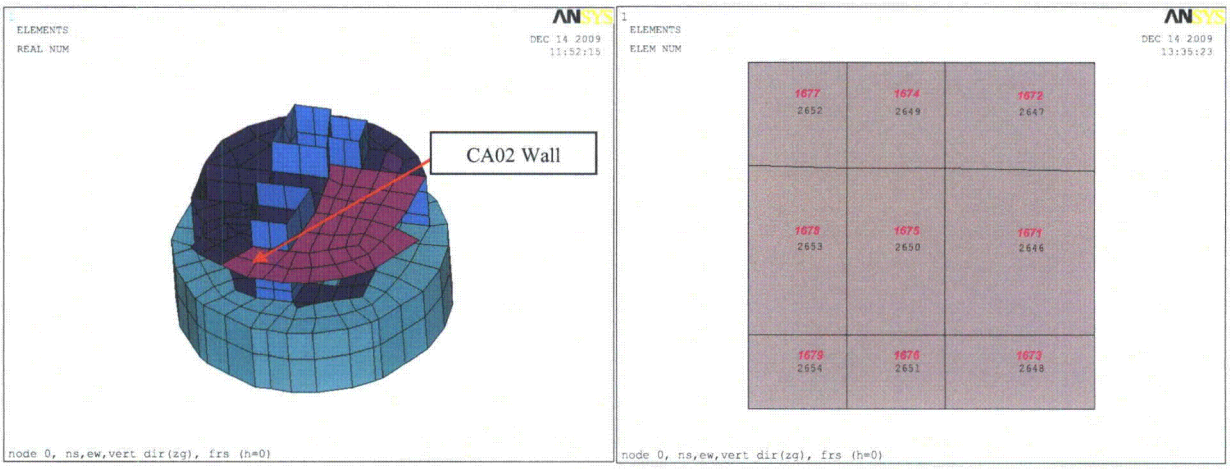


Figure 6.1-6 CA02 Wall Shell Elements

Table 6.1-1	Auxiliary Building Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
353	7.1	16.7	8.8	18.0	50.3	25.8
359	2.2	32.2	28.5	5.4	149.4	165.4
770	23.0	45.3	28.7	77.2	107.4	91.5

Table 6.1-2	Shield Building Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
939	7.0	47.1	42.3	22.3	156.5	125.1
1153	20.0	63.8	44.9	73.2	236.6	117.1
1158	16.3	102.4	53.9	72.6	456.1	196.9
1017	10.3	61.7	20.3	42.4	252.3	59.4

Table 6.1-3	Shield Building Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
1371	14.6	54.6	39.3	33.0	218.8	184.8
1317	12.4	45.8	40.2	36.7	193.6	152.5
1323	13.4	70.7	45.5	30.8	287.9	194.3
1347	13.3	51.0	33.5	31.4	184.9	125.2

Table 6.1-4	Refueling Wall Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
1759	4.1	6.6	18.3	8.9	12.0	39.6
1760	3.7	3.9	13.4	5.4	6.8	29.1
1765	5.7	8.7	20.5	13.4	16.5	41.6
1766	3.9	13.1	20.1	9.7	24.9	35.8
1775	8.0	22.7	20.0	21.8	42.3	38.5
1776	7.8	11.0	20.5	17.8	23.3	40.8

Table 6.1-5	Southwest Steam Generator Wall Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
1731	5.0	8.2	23.9	10.7	15.6	38.6
1730	4.0	29.7	18.7	9.6	48.3	27.6
1667	12.3	45.7	19.2	28.9	77.7	29.8
1666	9.3	9.9	15.0	22.1	20.8	25.9
1741-1743	21.6	20.2	14.7	35.0	38.2	24.2
1738-1740	11.5	24.8	17.5	25.6	57.6	40.1
1735-1737	7.0	14.8	17.4	12.5	29.5	39.6
1732-1734	14.3	24.8	13.1	21.8	38.0	24.6

Table 6.1-6	CA02 Wall Building Time History Member Force Comparison					
	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
1671	3.5	19.5	13.1	5.1	30.9	20.8
1672	2.9	6.0	7.4	4.5	7.4	11.1
1673	7.7	36.3	19.1	15.2	55.5	28.7
1674	5.6	4.5	15.3	6.9	5.2	24.4
1675	6.7	12.8	20.5	9.5	15.9	34.8
1676	6.5	15.1	20.4	11.5	23.1	38.8
1677	9.0	14.6	21.5	12.6	19.4	33.6
1678	6.1	11.4	21.5	10.2	13.6	38.1
1679	5.9	10.5	21.2	10.8	15.3	41.0

6.2 PRIMARY COOLANT LOOP

A failure within the reactor coolant loop could challenge the integrity of the reactor coolant pressure boundary. Therefore, it was chosen for evaluation. The components evaluated are as follows:

- Reactor internals
- Primary Component Supports and Nozzles

6.2.1 Reactor Vessel and Internals

The reactor vessel and internals were selected because they are important to safety and their analysis is representative of major primary components. The building structure below the reactor vessel supports is fairly stiff and there may be amplification at the supports of the reactor pressure vessel. Furthermore, reactor vessel internals have relatively complex structural systems including gap nonlinearities and sliding elements. Also, they may be sensitive to high frequency input as summarized below:

- Vertical and horizontal modes of the upper internals and the reactor vessel modes are in the relatively HF range.

- Additional high frequencies are associated with nonlinear impact.

The evaluation consisted of a comparison of the loads from the HRHF input to those obtained from the time history associated with the hard rock case input.

The reactor vessel and internals system model was utilized using the HRHF spectra time history and the resulting system loads were compared to the loads generated from the same reactor internals system model using time history associated with the CSDRS hard rock case.

An ANSYS model is shown in Figures 6.2.1-1 and 6.2.1-2. Figure 6.2.1-1 presents the entire system model, including the reactor coolant loops (RCLs). Figure 6.2.1-2 highlights the model of the core barrel, reactor pressure vessel (RPV), and the major components within the reactor internals.

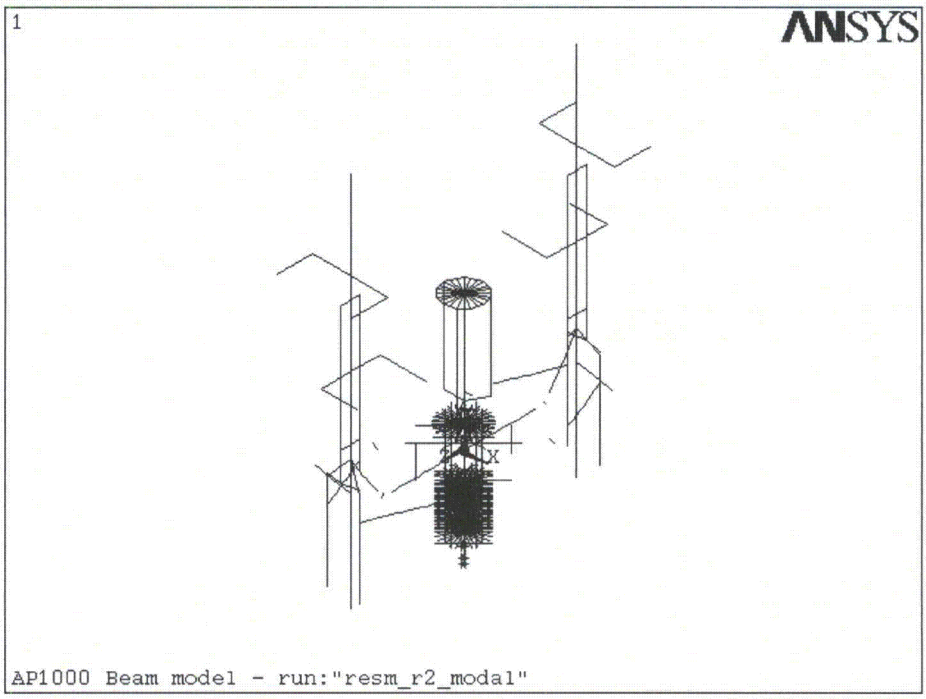


Figure 6.2.1-1 View of Entire System Model including RCL Super Elements

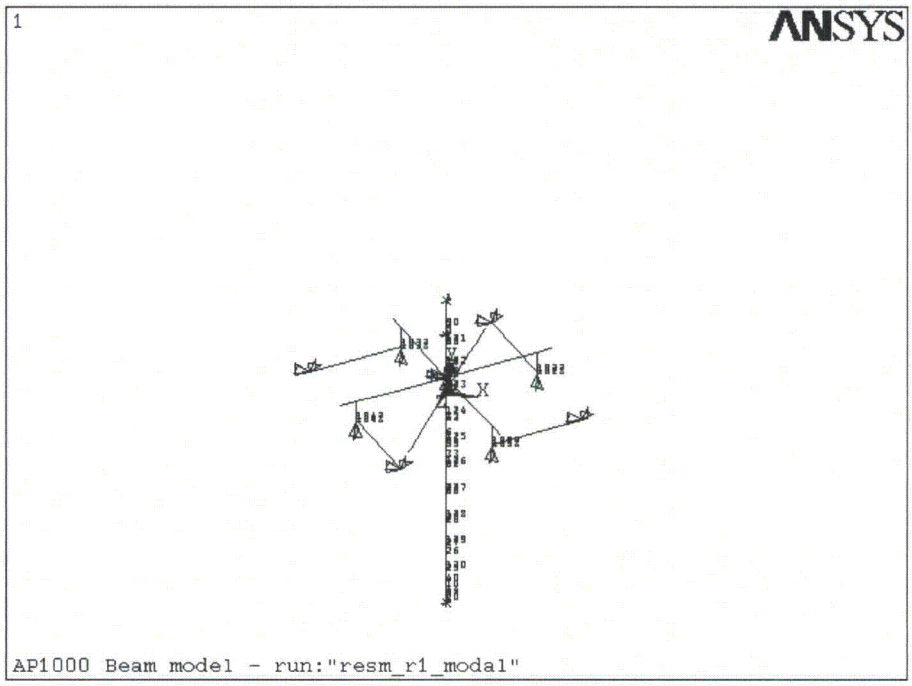


Figure 6.2.1-2 View of Model of Core Barrel, RPV, Inlet Nozzles, Outlet Nozzles, and Supports

The reactor equipment system model load generation analysis considered time history input at the vessel support elevation. Broadening was considered by frequency variation.

A comparison of the resulting interface loads for components such as the outlet nozzle, lower radial support, upper core plate pins, and the shroud pins; indicated a load reduction of approximately 71 to 37 percent for the HRHF time history compared to the previous interface loads generated from the CSDRS hard rock time history analysis.

In addition to the comparison of the interface loads above, equipment loads in a select list of major internal components were reviewed. The significant loads on the reactor internals, such as the transverse loads from use of HRHF excitation, were less than those of the CSDRS (hard rock only) excitation. There were some occurrences where seismic loads, due to the HRHF, were slightly increased from the CSDRS excitation, but these seismic loads are small and not sufficient to cause unacceptable stresses in the stress analysis because the loss-of-coolant accident (LOCA) loads dominate. This comparison is for hard rock. It is expected that evaluations of the CSDRS 'all-soil' case will bound the results of the HRHF as well as the hard soil CRDRS cases. The "all-soil" case includes the soft soil, soft-to-medium soil, upper-bound soft-to-medium soil, soft rock, firm rock, and hard rock cases. The all-soil case is higher than the hard rock case. The HRHF loads will not govern the design.

6.2.2 Primary Component Supports and Nozzles

Maintaining the integrity of the reactor vessel and steam generator supports is important to preserving the primary component safety function. The reactor vessel and steam generator supports are representative of supports on components and see high loads. The reactor coolant loop stick model is part of the Nuclear Island (NI20) model, with the primary support locations as shown in Figure 6.2.2-1. Included in Table 6.2.2-1 is a description of the support acronyms. A comparison of support loads on the RPV supports (both tangential and vertical) is provided in Table 6.2.2-2. A comparison of steam generator support loads (axial force in the supporting direction only) is provided in Table 6.2.2-3. The support loads for the CSDRS case are bounding at all locations.

The reactor coolant loop nozzles at the cold and hot leg interfaces of the RPV, reactor coolant pumps, and steam generators are important to include in the evaluation since these are critical areas of components. The evaluation of the primary component supports and RCL nozzles consisted of a comparison of the loads from the HRHF input to those obtained from the CSDRS input. These items are considered acceptable for the HRHF input if the seismic loads from the CSDRS enveloped those from the HF input.

The reactor coolant nozzles are identified in Figures 6.2.2-2 and 6.2.2-3. Included in Table 6.2.2-4 is a description of the nozzle acronyms. A comparison of nozzle loads (SRSS of the bending moments applied for the two non-axial directions) is provided in Table 6.2.2-5. The nozzle loads for the CSDRS case are bounding at all locations.

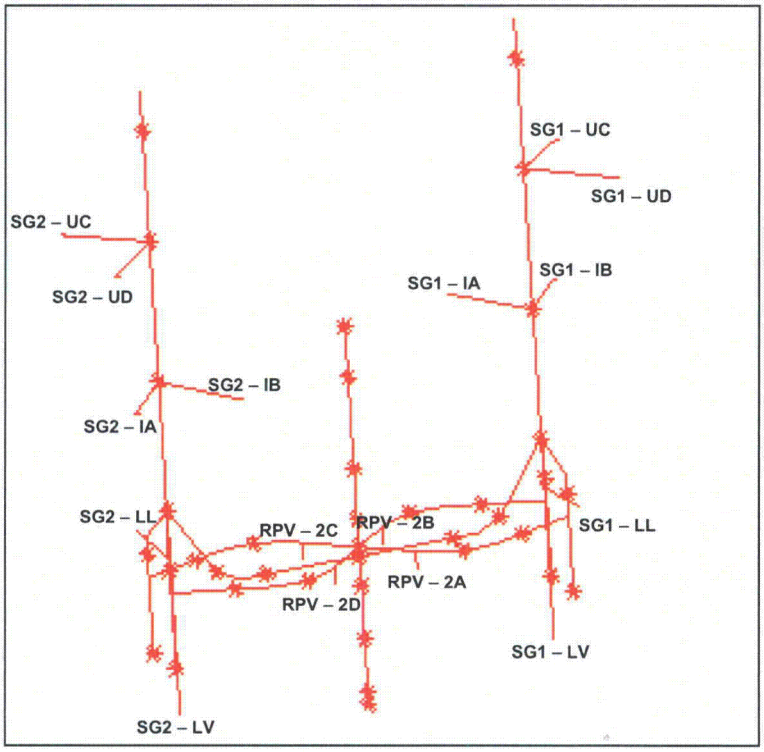


Figure 6.2.2-1 Reactor Coolant Loop Component Supports

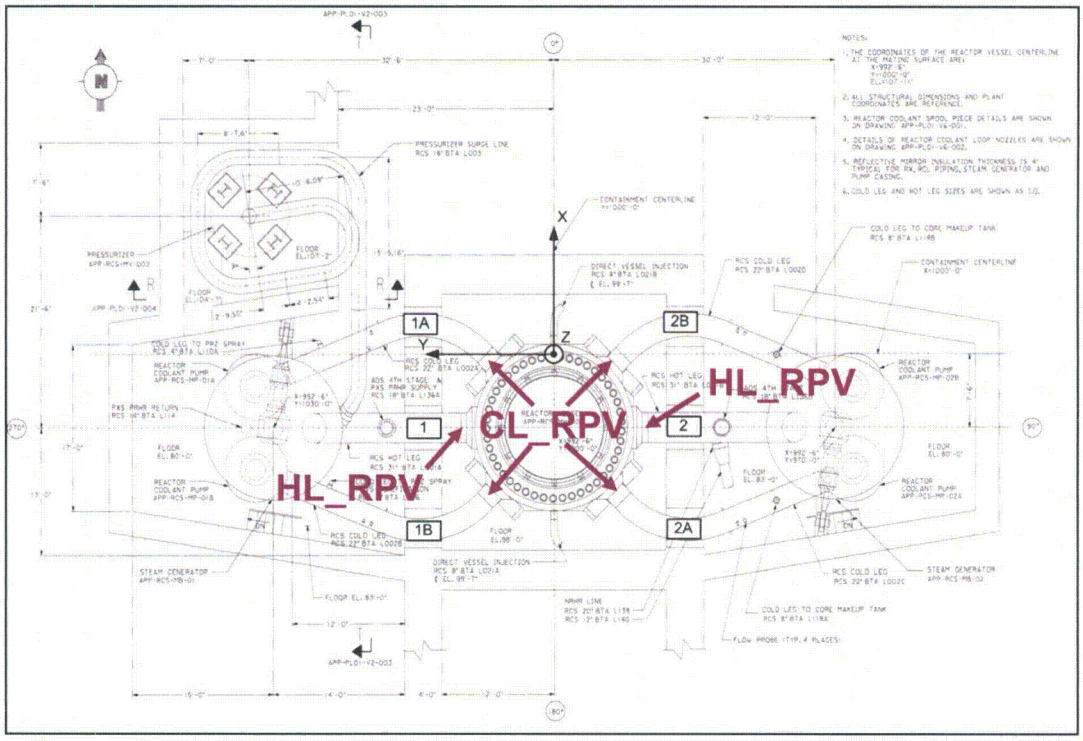


Figure 6.2.2-2 Reactor Coolant Loop Primary Equipment Nozzles

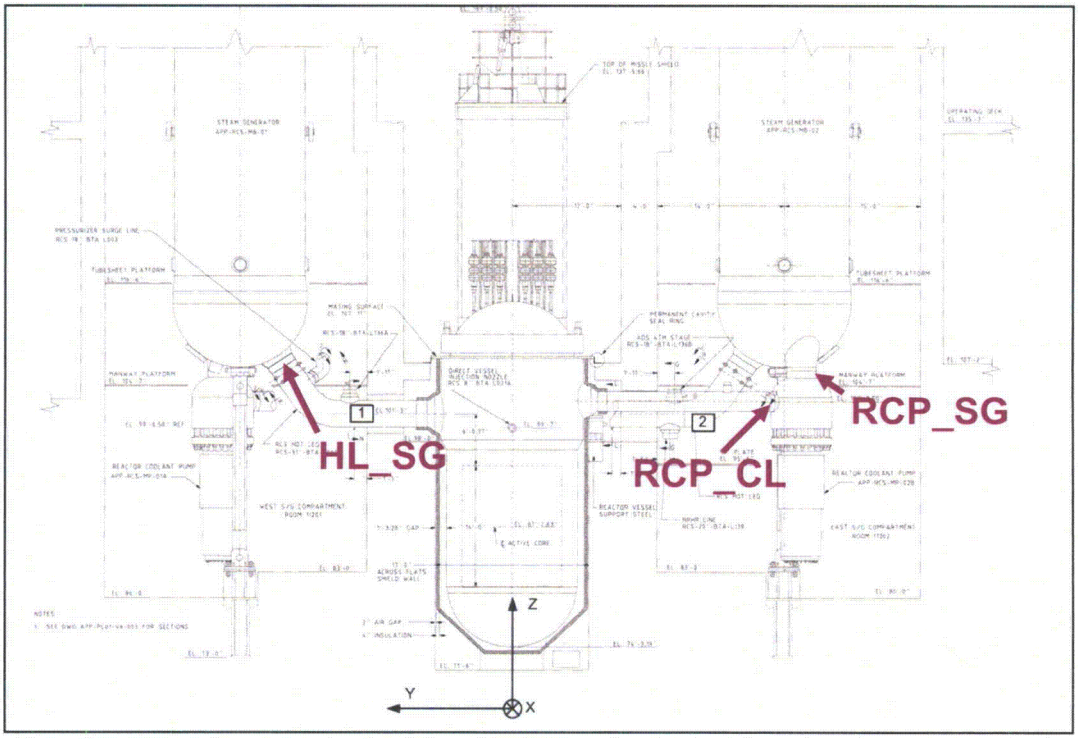


Figure 6.2.2-3 Reactor Coolant Loop Primary Equipment Nozzles

Table 6.2.2-1 Description of Reactor Coolant Loop Supports

Acronym	Support	Description
RPV- 2A	Cold Leg (L002A)	Reactor Pressure Vessel Supports, Connected at Cold Leg Indicated
RPV- 2B	Cold Leg (L002B)	
RPV- 2C	Cold Leg (L002C)	
RPV- 2D	Cold Leg (L002D)	
SG1-LV	SG1 Vertical Support	West Steam Generator Vertical Support Beam
SG1-LL	SG1 Lower Lateral	West Steam Generator Lower Lateral Support
SG1-IA	Int. Lateral 2A	West Steam Generator Intermediate Lateral Supports – Y Direction
SG1-IB	Int. Lateral 2B	
SG1-UC	Upper Lateral 3C	West Steam Generator Upper Lateral Supports – X Direction
SG1-UD	Upper Lateral 3D	
SG2-LV	SG2 Vertical Support	East Steam Generator Vertical Support Beam
SG2-LL	SG2 Lower Lateral	East Steam Generator Lower Lateral Support
SG2-IA	Int. Lateral 2A	East Steam Generator Intermediate Lateral Supports – Y Direction
SG2-IB	Int. Lateral 2B	
SG2-UC	Upper Lateral 3C	East Steam Generator Upper Lateral Supports – X Direction
SG2-UD	Upper Lateral 3D	

Table 6.2.2-2 Reactor Pressure Vessel Support Comparison

RPV Support Forces	HRHF Time History Forces (kips)	CSDRS Seismic Forces (kips)
Tangential	576	1203
Vertical	522	638

Table 6.2.2-3 Steam Generator Support Comparison		
RCL Support Forces	**HRHF Time History Forces (kips)**	**CSDRS Time History Forces (kips)**
Vertical	663	1574
Lower Lateral	497	1077
Intermediate Lateral	323	1107
Upper Lateral	440	959

Table 6.2.2-4 Description of Reactor Coolant Loop Nozzle Acronyms		
Acronym	**Component 1**	**Component 2**
RCP_SG	Reactor Coolant Pump	Steam Generator
RCP_CL	Reactor Coolant Pump	Cold Leg
CL_RPV	Cold Leg	Reactor Pressure Vessel
HL_RPV	Hot Leg	Reactor Pressure Vessel
HL_SG	Hot Leg	Steam Generator

Table 6.2.2-5 Reactor Coolant Loop Primary Equipment Nozzle Load Comparison		
	HRHF Time History	**CSDRS Time History**
RCL Nozzle	**Bending Moment (kip-ft)**	
RCP_SG	2446	3588
RCP_CL	2330	3728
CL_RPV	418	1012
HL_RPV	578	1344
HL_SG	435	736

6.3 PIPING SYSTEMS

This section has been removed to be consistent with DCD Tier 2, Chapter 3, Appendix 3I. ASME Class 1, 2 and 3 piping systems will be evaluated for the HRHF GMRS. This evaluation is within the scope of the Piping DAC (See COL Information Item 3.9-7).

6.4 SAFETY-RELATED ELECTRICAL EQUIPMENT

6.4.1 Introduction

The technical study performed on safety-related electrical equipment confirms that seismic qualification to the AP1000 CSDRS envelopes the seismic qualification to the HRHF seismic inputs for most applications.

The study also includes review of existing seismic test data of typical equipment supplied to nuclear power plants. The review concludes that low frequency seismic tests envelope HF input up to 2.0 g spectral acceleration (at 5 percent critical damping) and no additional seismic testing is required when the HRHF seismic inputs are below this level.

Susceptibility to excitation caused by HF input requires the following factors to be present:

- The local HRHF floor response spectra need to exceed the AP1000 CSDRS in the high frequency range.
- The safety-related equipment must have modes or natural frequencies in the high frequency range.
- The safety-related components must have potential failure modes involving change of state, chatter, signal change/drift, and/or connection problems.

It is expected that equipment with modes in the range of the high frequency response excitation will experience higher loads and amplifications than equipment with modes outside this range. To support this expectation and determine the effect of high frequency seismic motion on the AP1000 safety-related electrical equipment, a review of the equipment configuration, location, stress analysis methodology, and equipment qualification testing procedure was conducted. This review led to a selection of safety-related electrical equipment that is most susceptible to high frequency motion.

The conclusion of the study presented in this section is that the qualification methodology (analytical evaluations and testing procedures) currently employed generally leads to a more conservative design than that which would result from the HRHF spectra. This study also provides a process to determine and address equipment which may have sensitivity to the HRHF excitation.

6.4.2 Evaluation Process

The intent of the evaluation is to provide evidence that seismic qualification (testing and analysis) of safety-related equipment to the CSDRS produces seismic loads and accelerations that envelop the loads and accelerations generated by the high frequency seismic inputs. This is achieved by completion of the following steps:

1. Comparative Analyses

   Analysis is performed on finite element models of typical safety-related equipment structures to show that low frequency seismic input produces loads and accelerations that envelope most of the seismic loads and accelerations generated by the HF seismic input. The comparative seismic analyses are performed on finite element models associated with typical equipment used to house safety-related electrical equipment. The comparative seismic analyses (time history and response

spectra) are performed for both low frequency AP1000 CSDRS and HRHF seismic inputs generated for the AP1000 Auxiliary and Shield Building main control room (MCR) floor at Elevation of 116.5 feet. The analytical study compares results for AP1000 CSDRS low frequency seismic input against the AP1000 HRHF seismic input. The comparative seismic analyses are made using the ANSYS (Version 11.0) computer program.

The evaluation includes:

a. Selection of equipment samples and models

b. Comparison of the evaluation of analytical models to high and low frequency seismic inputs

c. Evaluation of the results

2. Review of Existing Test Data

Existing test data for multi-frequency (random) multi-axis seismic test programs are reviewed to determine if high frequency excitation was exhibited in the frequency range of 25 to 50 Hz. Test data for seismic test programs for safety-related electrical cabinets and electrical cabinets which were tested for compliance with the Uniform Building Code (UBC) were reviewed. Selection of test programs for this study was based on the following:

- Test program not fragility test program
- Equipment was required to maintain functional operability and structural integrity
- Seismic random test motion in each of the three orthogonal input axes was generated in compliance with Institute of Electrical and Electronics Engineers (IEEE) Standard 344-1987.

The evaluation includes:

a. Selection of existing seismic test programs
b. Review of seismic test data
c. Results and conclusions

3. Development of the Screening Process to Determine Sensitive Equipment

The end result of the evaluation is the development of a process to be followed for screening sensitive equipment. The evaluation includes:

a. Determination of structural response to high frequency
b. Identification of sensitive equipment and components
c. Establish criteria for screening equipment that may require incremental testing

6.4.3 Comparative Analyses

The purpose of the study is to gain intelligence and evaluate the effects of HF seismic input on typical safety-related equipment. These analyses are used to determine if qualification based upon low frequency seismic input generated in accordance with the CSDRS envelopes the qualification at sites with the HRHF high frequency input.

6.4.3.1 Seismic Inputs

The evaluation of the finite element models compares the seismic loads, stresses, displacements, and in equipment response spectra (IERS) produced by HF seismic input with those produced by low frequency seismic input. The high and low frequency response spectra and time histories provided for this study are based on the AP1000 MCR floor seismic requirements at Elevation of 116.5 feet. The high frequency response spectra and time histories are based on HRHF levels. Figure 6.4.3.1-1 shows the locations of the nodes from the finite element model of the AP1000 Auxiliary and Shield Building used to generate both the high and low frequency response spectra and time histories.

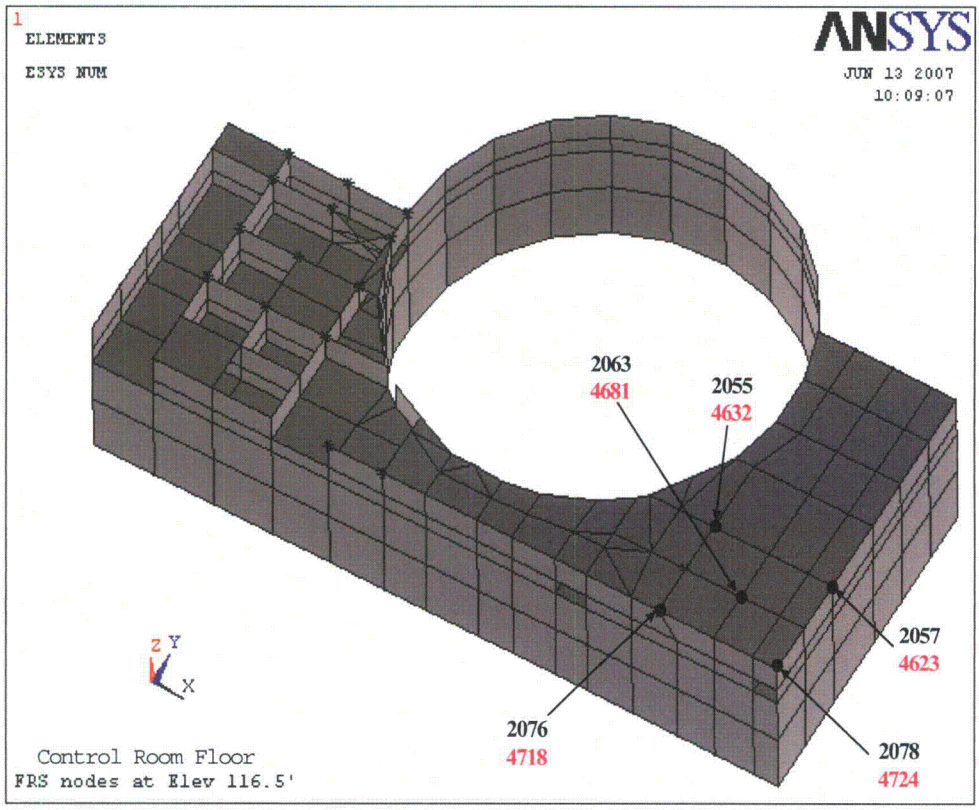


Figure 6.4.3.1-1 AP1000 Auxiliary and Shield Building Finite Element Model

6.4.3.2 Finite Element Model Samples

Equipment finite element models typical of safety-related equipment for nuclear power plant applications were used as representative samples for the comparative evaluation.

Five finite element cabinet and console models developed for seismic qualification of safety-related equipment in nuclear power plants were selected for this study. These models were chosen to provide a wide range of dynamic responses and dominant natural frequencies and include:

- MCR SafetyA01-A05 Console Line-up (Figure 6.4.3.2-1)
- Auxiliary Protection Cabinet (APC) (Figure 6.4.3.2-2)
- MCR Large Display (B13-B16) Panel Line-up (Figure 6.4.3.2-3)
- Process Instrumentation (PI) 4 Cabinet Suite (Figure 6.4.3.2-4)
- Remote Operator Shutdown Panel (ROP) Console (Figure 6.4.3.2-5)

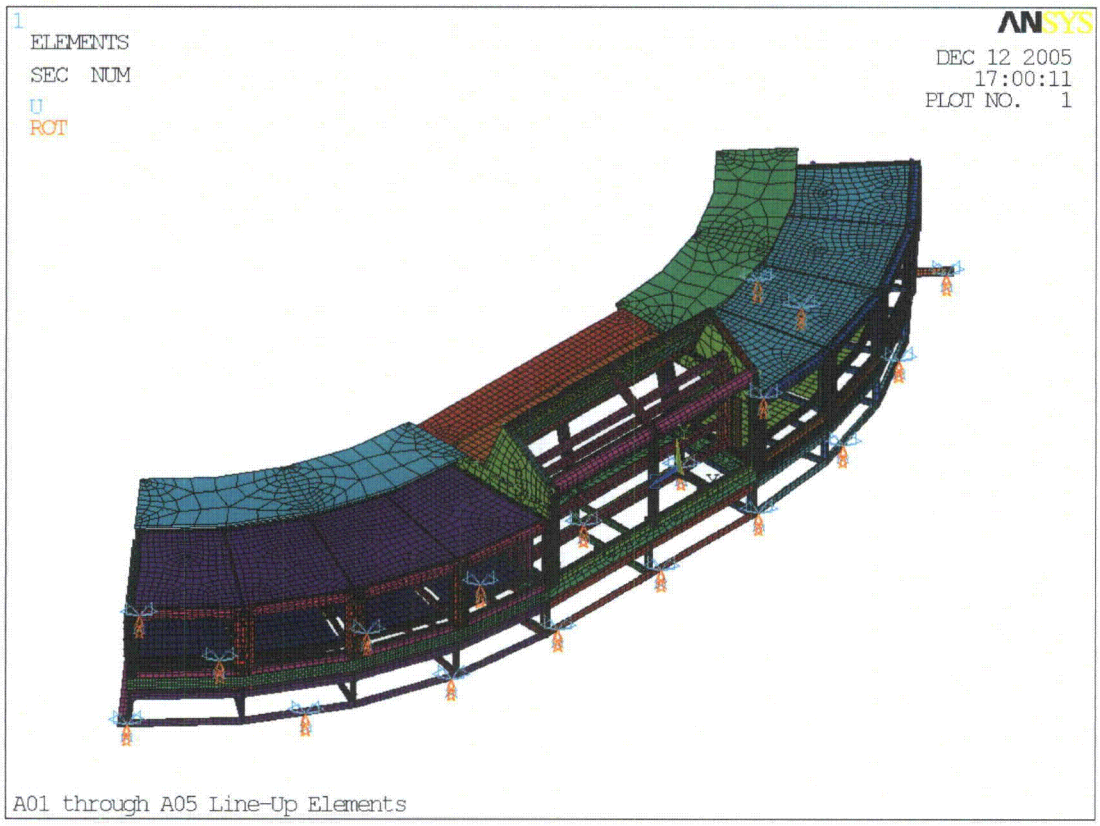


Figure 6.4.3.2-1 MCR (A01-A05) Safety Console Line-up Finite Element Model

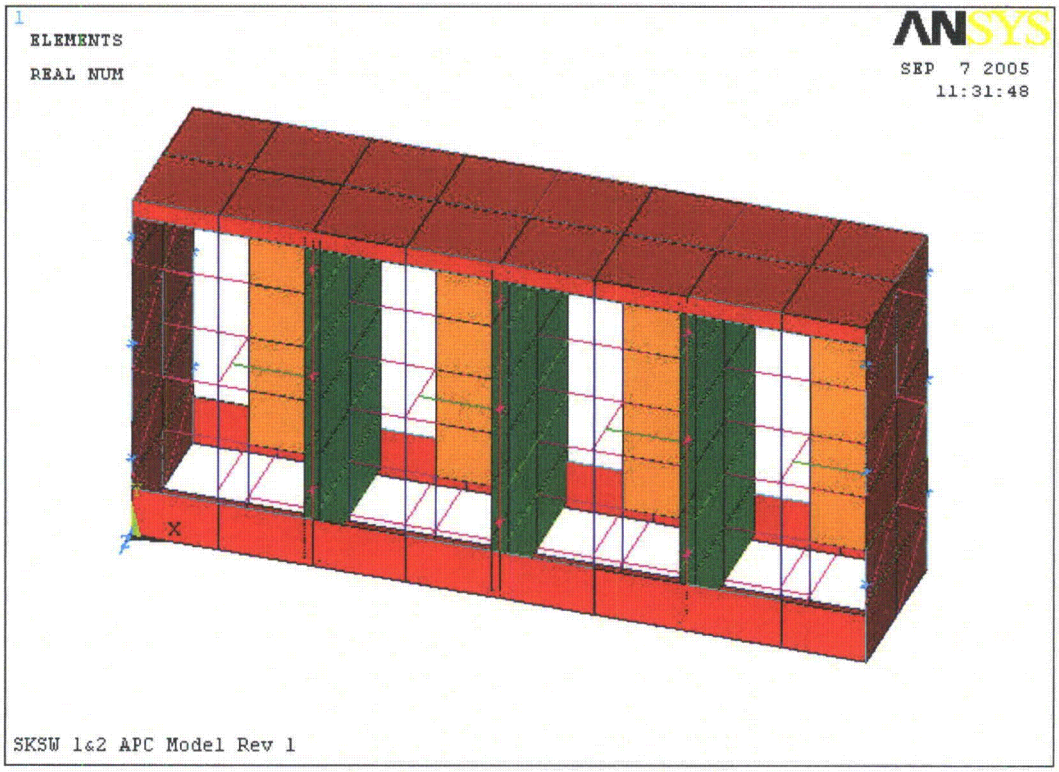


Figure 6.4.3.2-2 Finite Element Model of APC

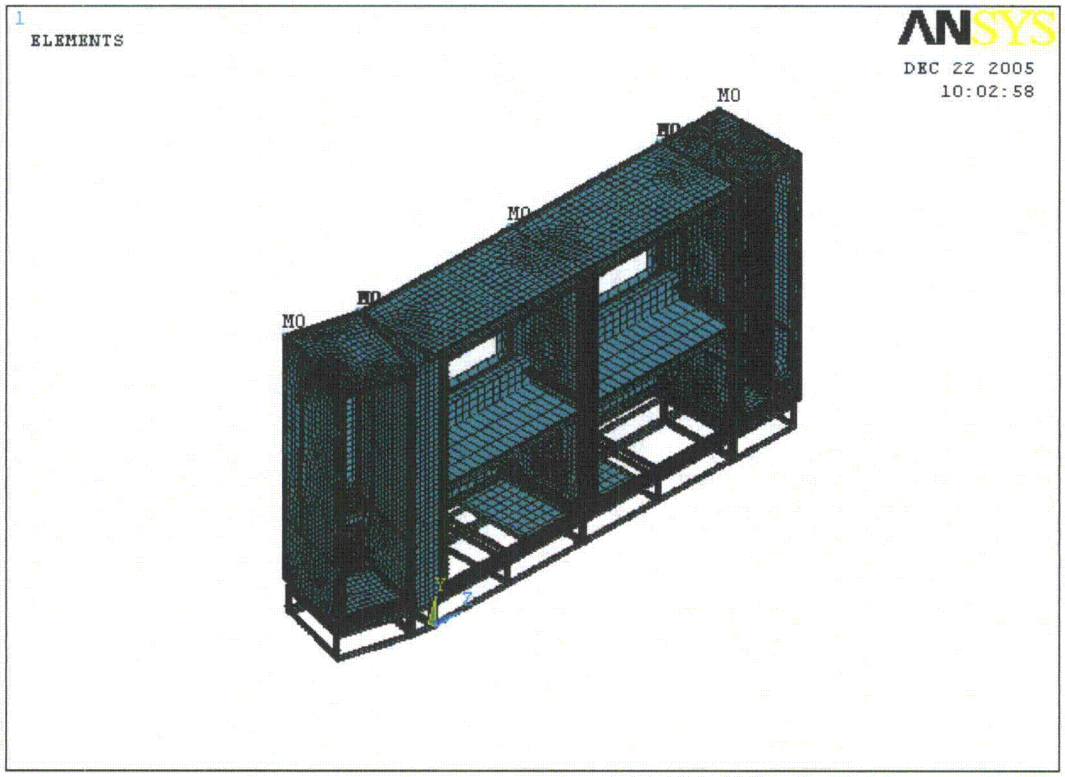


Figure 6.4.3.2-3 MCR Large Display (B13-B16) Panel Line-up Finite Element Model

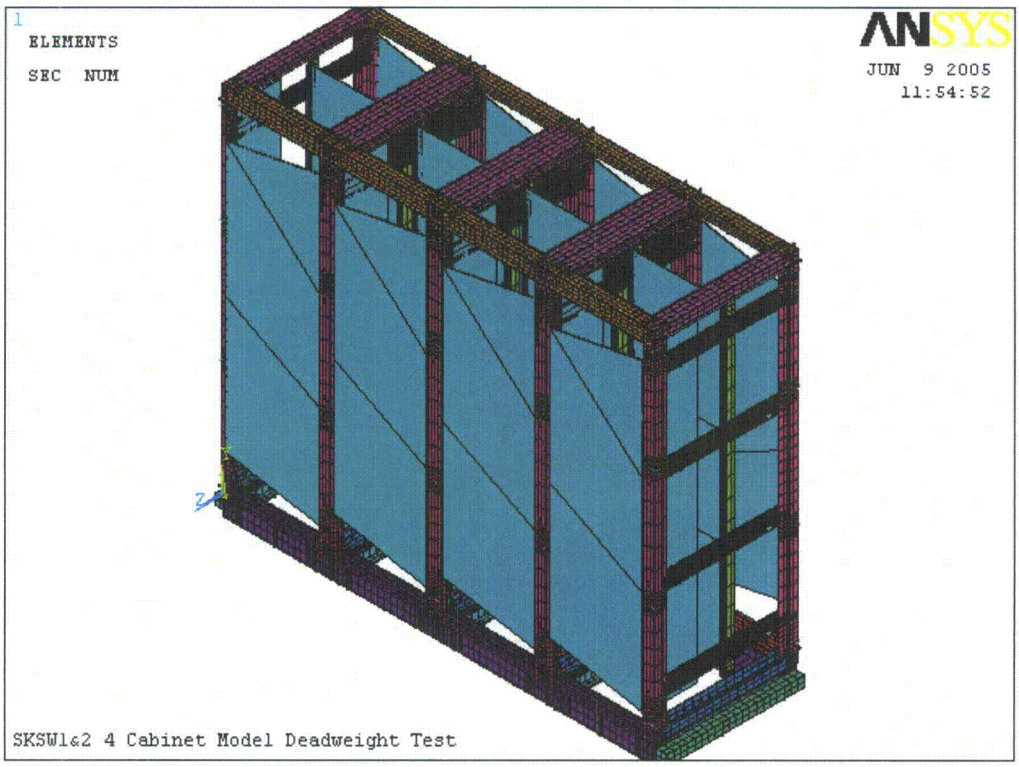


Figure 6.4.3.2-4 PI 4 Cabinet Suite Finite Element Model

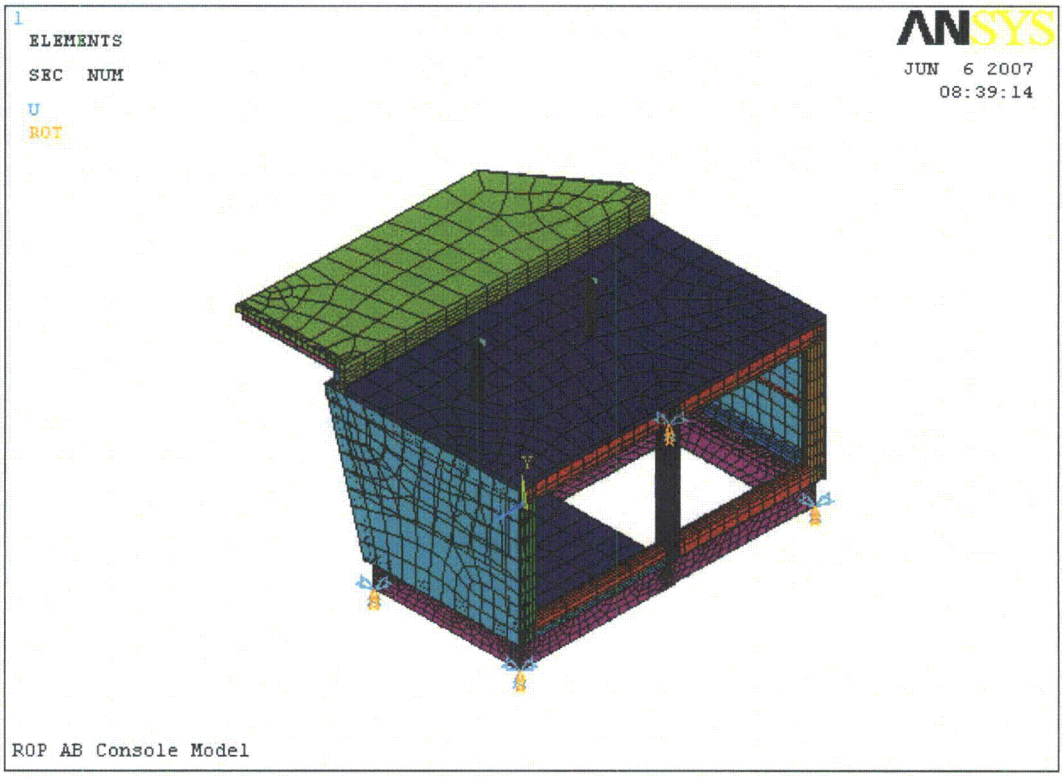


Figure 6.4.3.2-5 ROP Console Finite Element Model

6.4.3.3 Seismic Analysis of Models

6.4.3.3.1 General

The five models are analyzed using low frequency seismic input based on CSDRS and HF inputs based on HRHF seismic requirements. The initial analyses demonstrate that the B13-B16 Panel Line-up has low frequency results that envelope the high frequency results. This is expected as the B13-B16 panel line-up has natural frequencies in the 8 to 9 Hz range. Also noted was the ROP console high frequency results enveloped the lower frequency results in the high frequency region. This was also expected as the ROP console first natural frequency is 38.5 Hz. This supports the initial expectation that equipment without modes in the high frequency range (25 to 50 Hz) is not sensitive to the HRHF excitation.

The following sections provide results for the three remaining models (A01-A05, APC, and PI models – Figures 6.4.3.2-1, 6.4.3.2-2, and 6.4.3.2-4, respectively) which were chosen for the high frequency seismic analysis. The response spectra and time history analyses are performed using ANSYS, Version 11.0. The details of the analyses and a comparison of the results from the high frequency versus the low frequency input for each of the three models are discussed in the following sections. The analyses demonstrate that the HF results are enveloped by the results of the low frequency seismic input, except when the HF input coincides with the predominate natural frequencies of the cabinet.

6.4.3.3.2 Analysis Method and Floor Seismic Requirements

The intent of the study is to generate analytical data to aid in understanding how finite element models respond to low and high frequency inputs and how the dominant natural frequencies of the models affect the results. The evaluation is performed using the steps listed below:

- Determine seismic inputs (low and high frequency)
- Perform response spectra analyses to generate loads and stresses in the structural members and mounting configurations due to both low and high frequency inputs
- Perform time history analysis to generate IERS at the components' mounting due to both low and high frequency inputs
- Compare results from HF seismic input with results from low frequency input and confirm that low frequency results envelope high frequency seismic input results.

Figures 6.4.3.3.2-1 through 6.4.3.3.2-3 show the high and low frequency response spectra considered in this study.

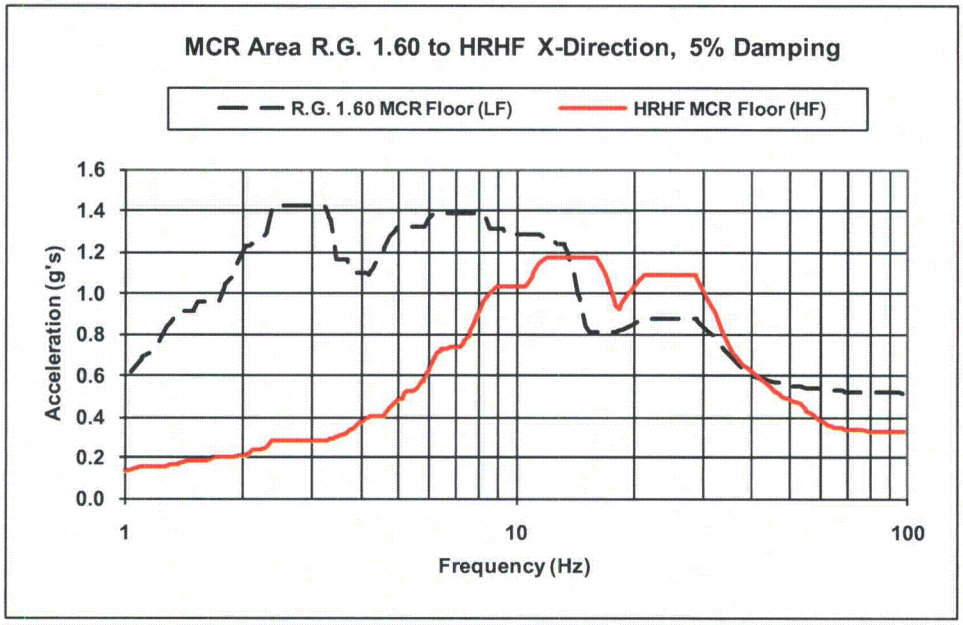


Figure 6.4.3.3.2-1 High/Low Frequency Response Spectra X Direction (Horizontal)
High Frequency Response Spectra Shown in Red
(5% Critical Damping)

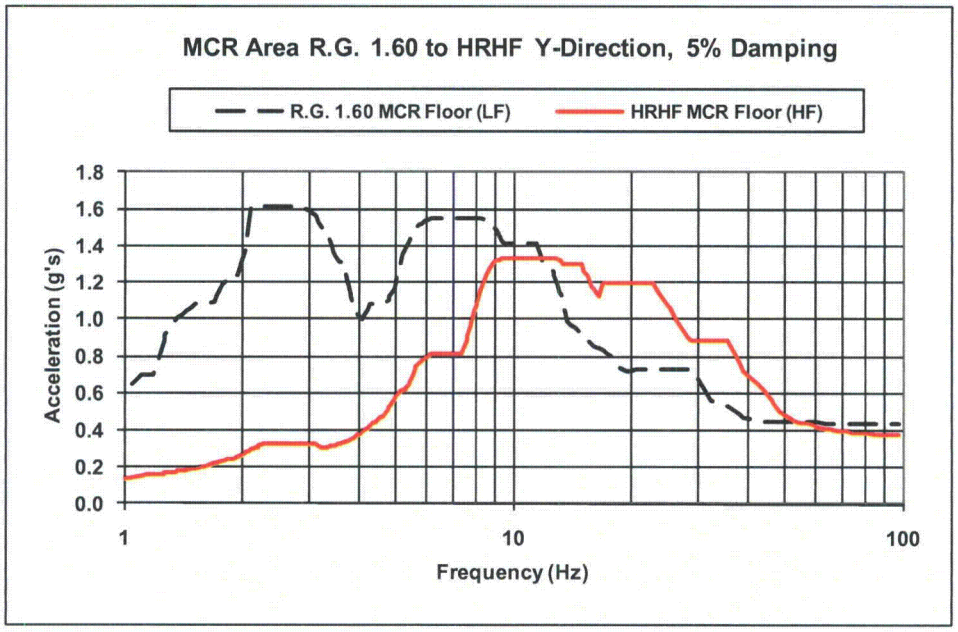


Figure 6.4.3.3.2-2 High/Low Frequency Response Spectra Y Direction (Horizontal)
High Frequency Response Spectra Shown in Red
(5% Critical Damping)

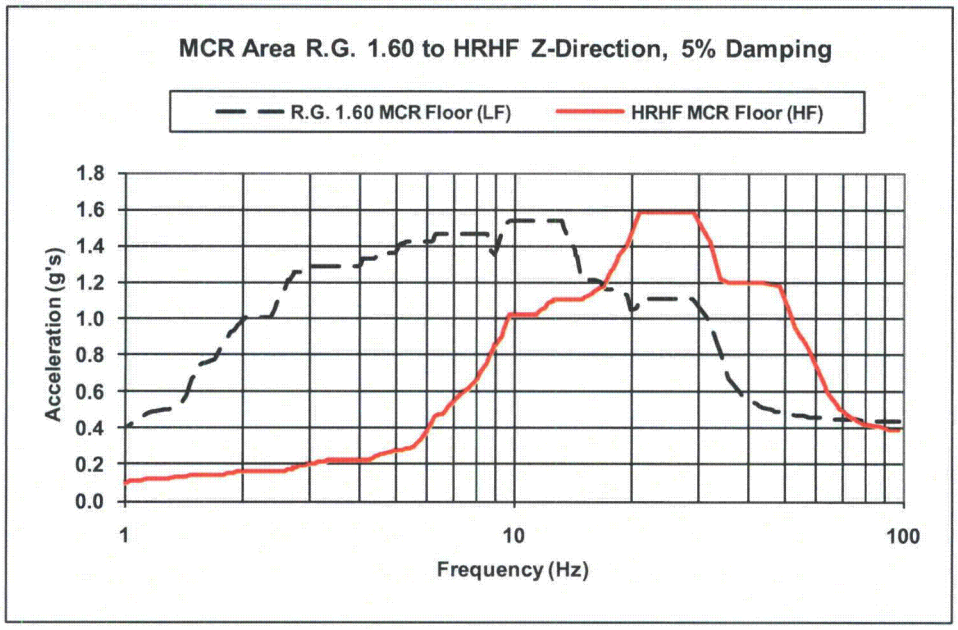


Figure 6.4.3.3.2-3 High/Low Frequency Response Spectra Z Direction (Vertical)
High Frequency Response Spectra Shown in Red
(5% Critical Damping)

6.4.3.3.3 Analysis of A01-A05 Console Line-up Model

Figure 6.4.3.2-1 shows the finite element plot of the A01-A05 console line-up model. The natural frequencies of the model are:

X direction (front-back):	11.4 Hz
Y direction (side-side):	18.0 Hz
Z direction (vertical):	26.8 Hz

The response spectrum analysis determines the model displacements, loads, and stresses resulting from the input response spectra. Tables 6.4.3.3.3-1 and 6.4.3.3.3-2 compare the results of the response spectrum analysis using high frequency input with the results using low frequency input for the maximum console displacement and mounting bolt loads. These results are representative of the seismic response of the console. The results of the evaluation demonstrate that low frequency seismic input resultant loads and stresses envelope most of the results of the HF seismic input.

The time history analysis determined that the IERS at the top corners of the model desktop and the base node where the input time histories are applied to the model. Figures 6.4.3.3.3-1 through 6.4.3.3.3-3 show the comparison of the IERS developed using HF input with the IERS developed using low frequency input.

The IERS produced by HF input are generally enveloped by or equivalent to the IERS produced by low frequency seismic input except in the higher frequencies where the model has natural frequencies. Figure 6.4.3.3.3-2 reveals that the side-side IERS peak at the model side-side natural frequency of 18.0 Hz. Figure 6.4.3.3.3-3 reveals that the vertical IERS peak at the model vertical natural frequency of 26.8 Hz. This supports the conclusion that low frequency seismic IERS predictably envelope those generated by the HF input when the dominant natural frequencies of the equipment do not coincide with the HRHF floor peak accelerations. For this particular instance, the test response spectra (TRS) for the A01-A05 component testing is also shown in Figures 6.4.3.3.3-1 through 6.4.3.3.3-3 and envelopes the HRHF IERS.

Table 6.4.3.3.3-1 Comparison of A01-A05 Maximum Console Displacements

Spectra	Description	UX Max (Console Front-to-Back)		UY Max (Console Side-to-Side)	UZ Max (Console Vertical)	Max. HF/LF Ratio
Low Frequency	Node:	12334	12336	20132	10150	1.08
	Value (mm):	4.16	4.17	1.32	6.30	
High Frequency	Node:	12334	12336	20132	10150	
	Value (mm):	3.96	3.95	1.27	6.81	

Table 6.4.3.3.3-2 Comparison of A01-A05 Maximum Console Mounting Bolt Loads

Spectra	Maximum Tension (N)	Maximum Shear (N)	SRSS (N)	Ratio (HF/LF)
Low Frequency	4635.1	5552.5	7232.9	0.94
High Frequency	4335.2	5216.6	6782.8	

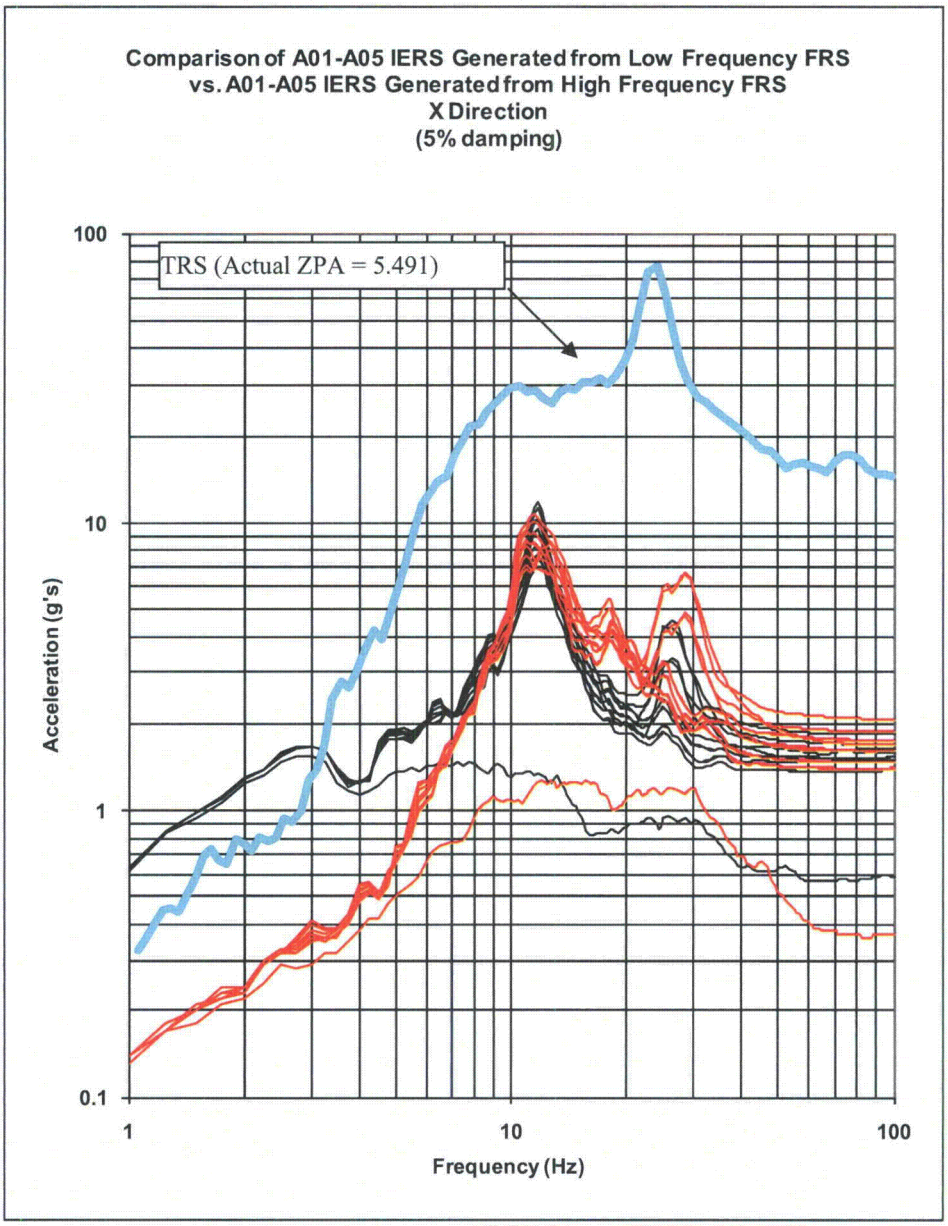


Figure 6.4.3.3.3-1 Comparison of A01-A05 Console Model IERS, X Direction (Front-Back) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Solid Blue (5% Critical Damping)

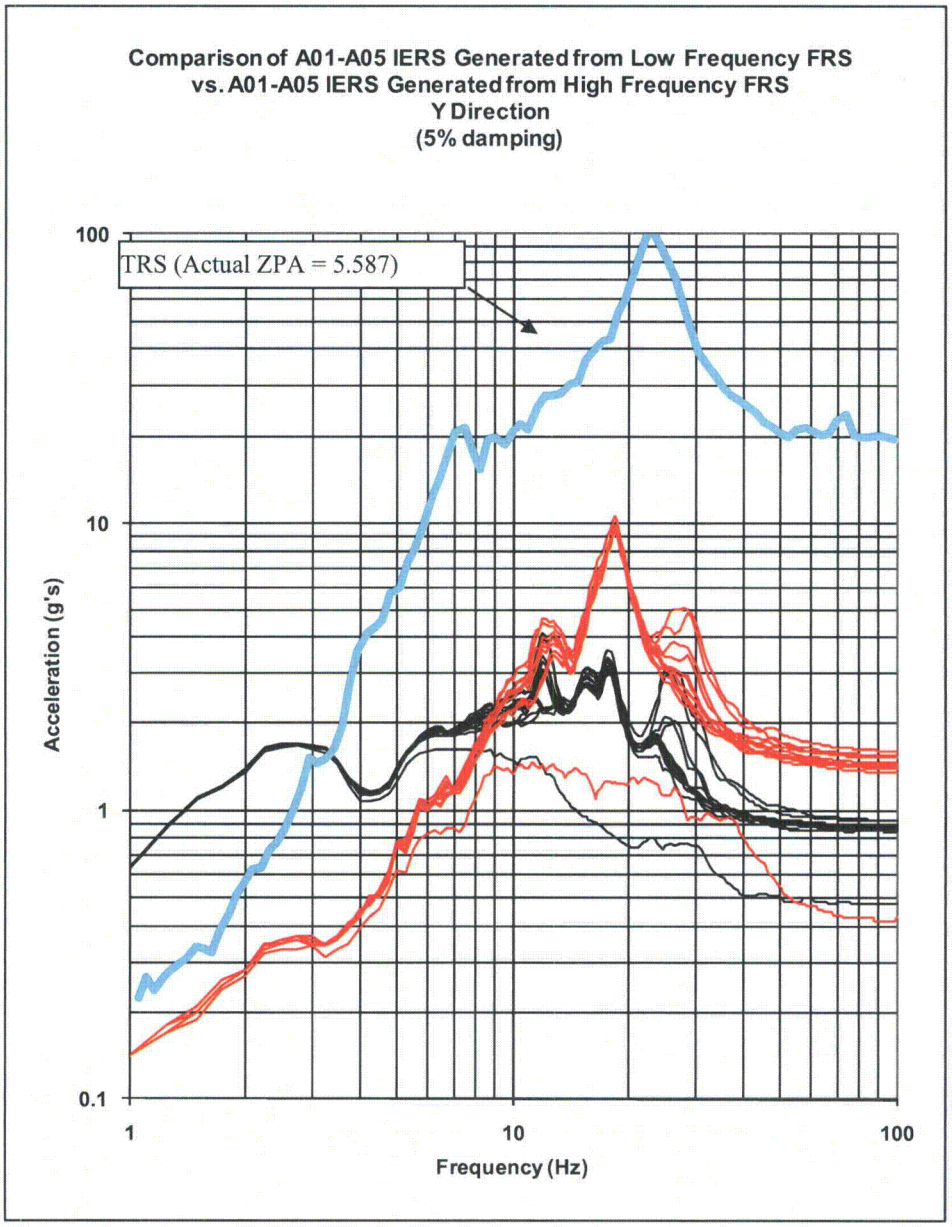


Figure 6.4.3.3.3-2 Comparison of A01-A05 Console Model IERS, Y Direction (Side-Side) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Solid Blue (5% Critical Damping)

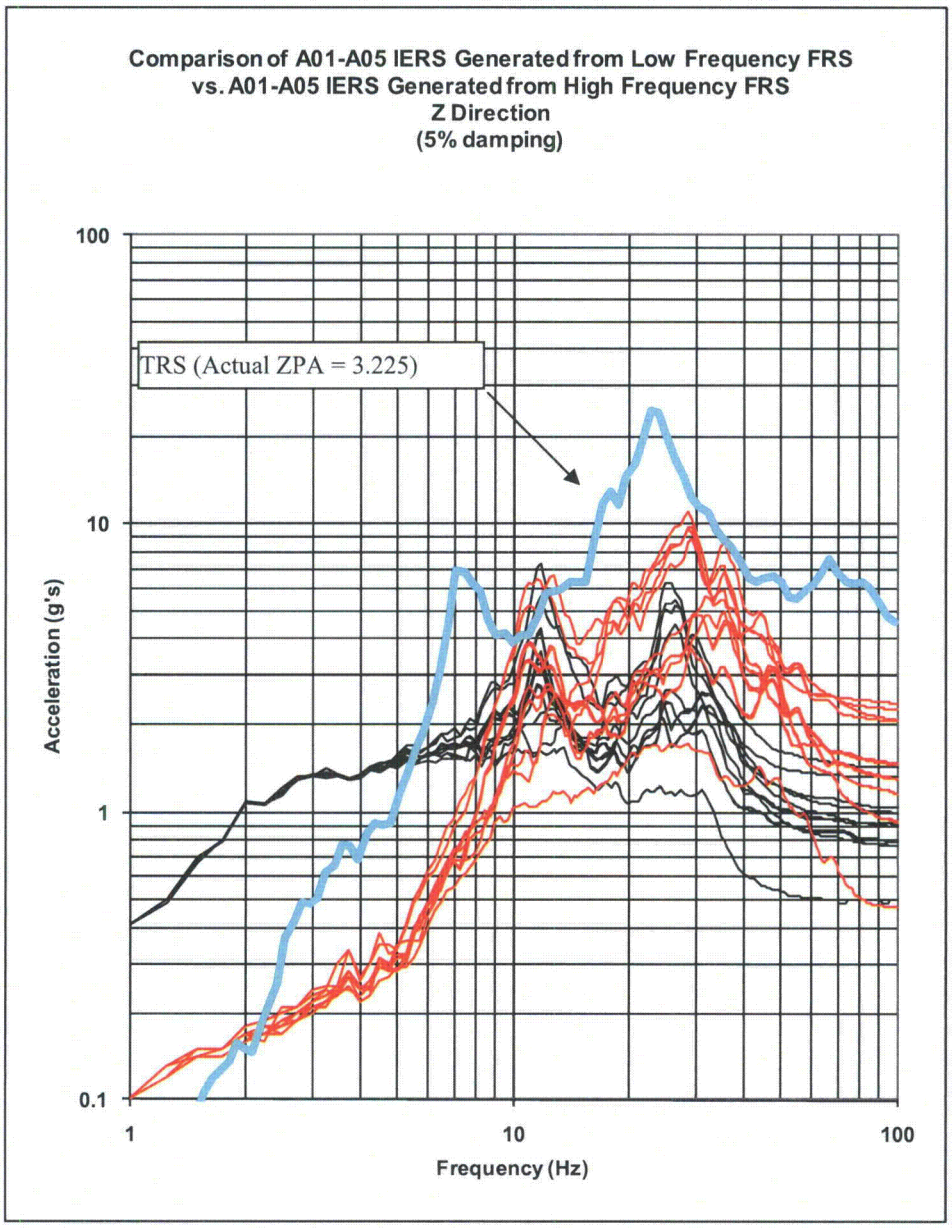


Figure 6.4.3.3.3-3 Comparison of A01-A05 Console Model IERS, Z-Direction (Vertical) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Solid Blue (5% Critical Damping)

6.4.3.3.4 Analysis of APC Finite Element Model

Figure 6.4.3.2-2 shows the APC finite element model. The natural frequencies are computed as:

X direction (side-side):	18.7 Hz
Y direction (front-back):	28.0 Hz
Z direction (vertical):	>33 Hz

The response spectrum analysis determines the model displacements, loads, and stresses resulting from the input response spectra. Tables 6.4.3.3.4-1 and 6.4.3.3.4-2 compare the results of the response spectrum analysis using high frequency input with the results using low frequency input for the APC model.

Table 6.4.3.3.4-1 shows that the maximum displacement of the structure increased from 0.0195 inch (low frequency seismic input) to 0.028 inch (high frequency seismic input) with a maximum ratio of 1.42. This increase is expected as the front-back mode at 28.0 Hz and side-side mode at 18.7 lie within the HF range. It is also noted that this particular cabinet is very stiff and has extremely small displacements that are not of a concern. Also, Table 6.4.3.3.4-2 shows that the mounting bolt loads from the high frequency input envelope those of the low frequency input.

The time history analysis determined the IERS at various points within the model and the base node where the input time histories are applied to the model. Figures 6.4.3.3.4-1 to 6.4.3.3.4-3 show the comparison that the IERS developed using high frequency input with the IERS developed using low frequency input for the APC model. Consistent with expectations, the HRHF IERS are higher than the low frequency IERS at the cabinet resonances in the high frequency range.

The study of the APC model results in the conclusion that when safety-related equipment has dominant natural frequencies in the HRHF exceedance range, additional evaluation is required to verify acceptability.

Table 6.4.3.3.4-1 Comparison of APC Maximum Cabinet Displacements

Spectra	Description	UX Max (Cabinet Side-Side)	UY Max (Cabinet Front-Back)	UZ Max (Cabinet Vertical)	Max. HF/LF Ratio
Low Frequency	Node:	64	80	229	142
	Value (inches):	0.034	0.0195	0.008	
High Frequency	Node:	64	80	229	
	Value (inches):	0.038	0.028	0.009	

Table 6.4.3.3.4-2 Comparison of APC Maximum Cabinet Mounting Bolt Loads

Spectra	Maximum Tension (lb)	Maximum Shear (lb)	SRSS (lb)	Ratio (HF/LF)
Low Frequency	2436.3	970.1	2622.3	1.29
High Frequency	3144.5	1240.1	3380.2	

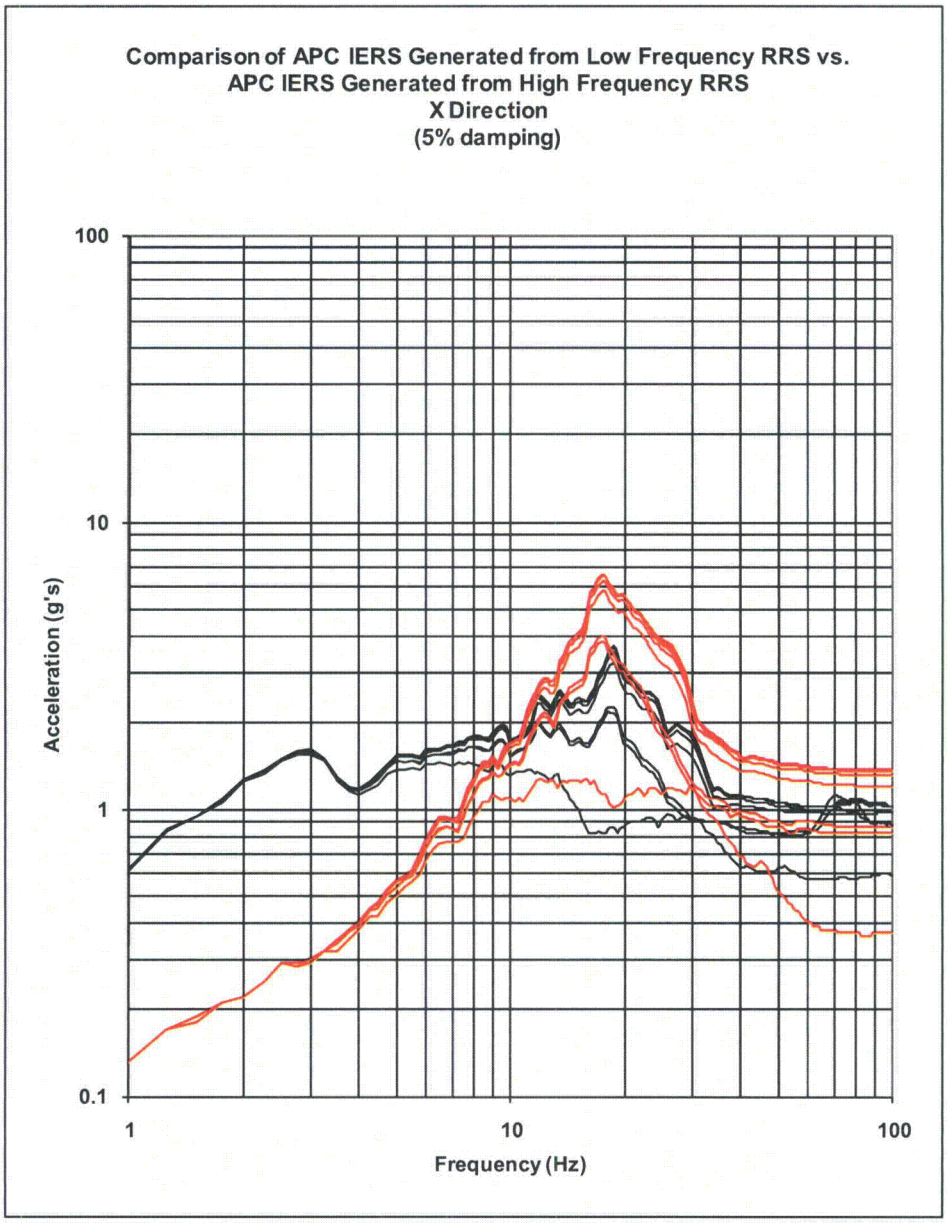


Figure 6.4.3.3.4-1 Comparison of APC Model IERS, X Direction (Side-Side) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

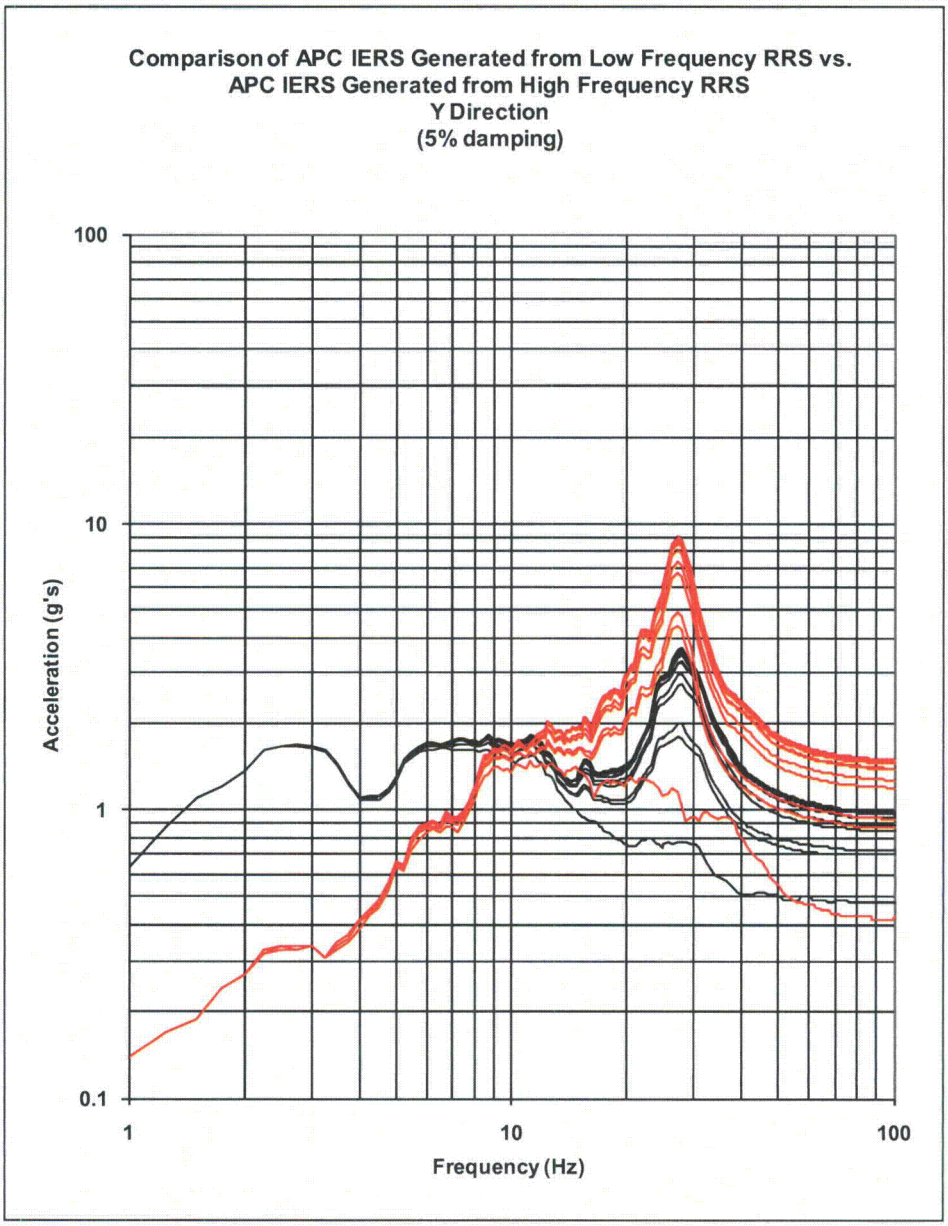


Figure 6.4.3.3.4-2 Comparison of APC Model IERS, Y Direction (Front-Back) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

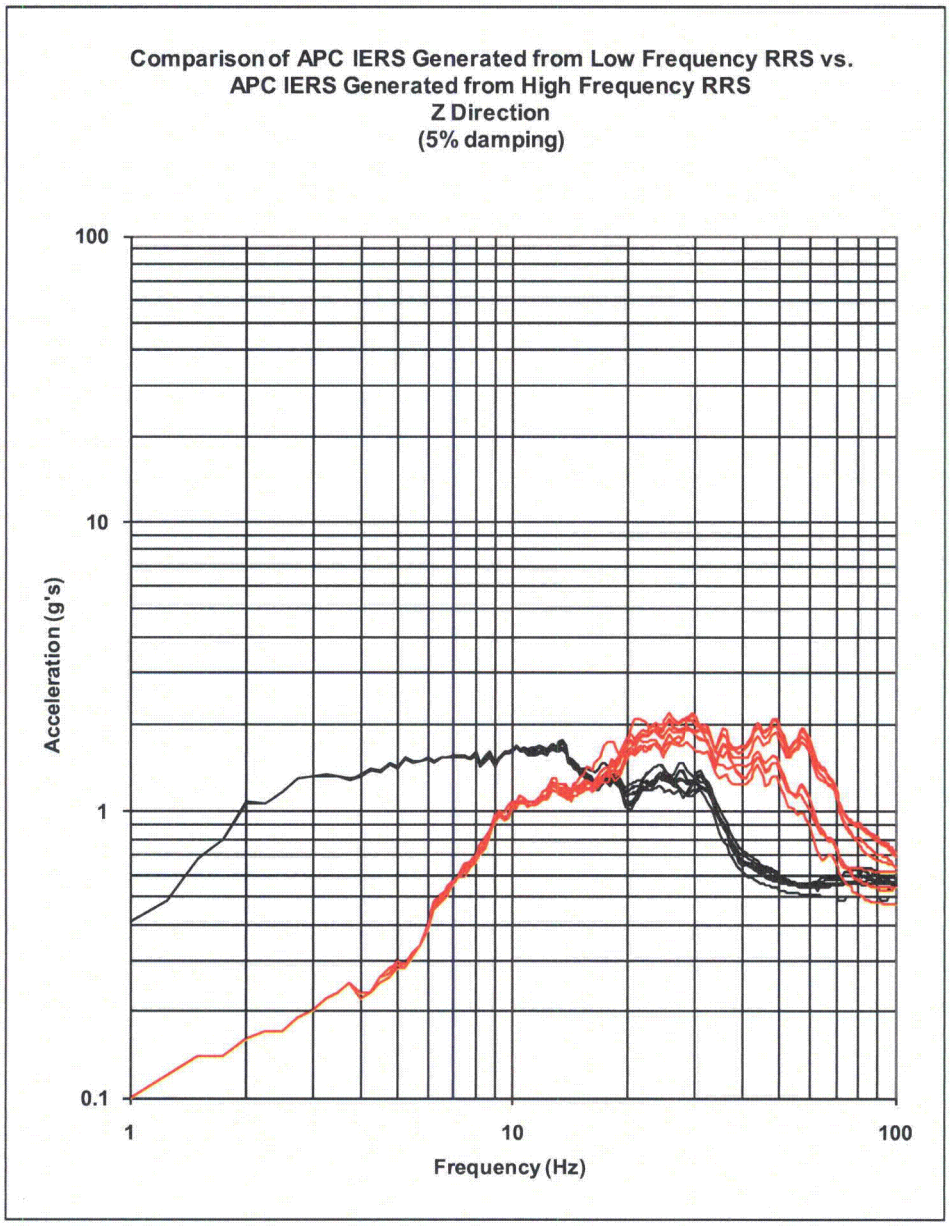


Figure 6.4.3.3.4-3 Comparison of APC Model IERS, Z Direction (Vertical) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

6.4.3.3.5 PI Model

Figure 6.4.3.2-4 shows the PI 4 cabinet suite model. The natural frequencies are:

X direction (side-side):	12.6 Hz
Y direction (front-back):	19.3 Hz
Z direction (vertical):	>33 Hz

The response spectrum analysis determines the model displacements, loads, and stresses resulting from the input response spectra. Tables 6.4.3.3.5-1 and 6.4.3.3.5-2 compare the results of the response spectrum analysis using HF input with the results using low frequency input.

Table 6.4.3.3.5-1 shows that the maximum displacements of the structure are essentially equal between the low frequency seismic input and the high frequency seismic input.

In Table 6.4.3.3.5-2, while the bolts shear loads caused by the HF input are slightly higher than the bolts shear loads caused by the low frequency input (447.0 pounds versus 391.6 pounds), the HF/LF ratio for the square root of the sum of the squares (SRSS) value between shear and tension is1.04. This confirms the low frequency seismic input results are essentially the same as the results of the HF seismic inputs.

The time history analysis determined the IERS at the top corners of the cabinet models and the base node where the input time histories were applied to the model. Figures 6.4.3.3.5-1 through 6.4.3.3.5-3 show the comparison of the IERS developed using HF input with the IERS developed using low frequency input.

Table 6.4.3.3.5-1 Comparison of PI 4 Cabinet Model Maximum Cabinet Displacements

Spectra	Description	UX Max (Cabinet Side-Side)	UY Max (Cabinet Front-Back)	UZ Max (Cabinet Vertical)		Max. HF/LF Ratio
Low Frequency	Node:	67	9347	3072	10143	1.16
	Value (inches):	0.12	0.07	0.007	0.007	
High Frequency	Node:	67	9347	3072	10143	
	Value (inches):	0.11	0.08	0.008	0.007	

Table 6.4.3.3.5-2 Comparison of PI 4 Cabinet Model Maximum Mounting Bolt Loads

Spectra	Maximum Tension (lb)	Maximum Shear (lb)	SRSS (lb)	Ratio (HF/LF)
Low Frequency	1390.4	391.6	1444.5	1.04
High Frequency	1427.5	447.0	1495.8	

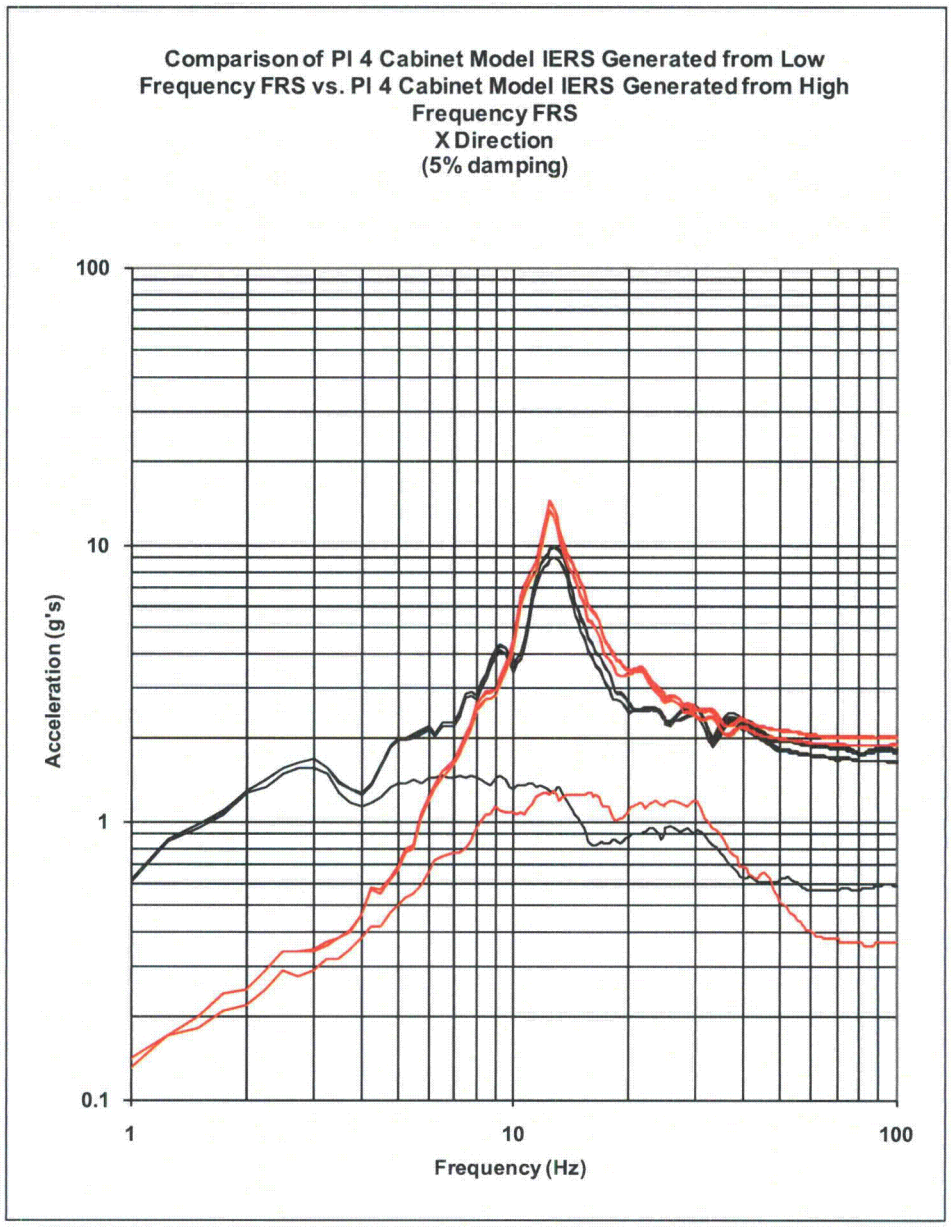


Figure 6.4.3.3.5-1 Comparison of PI 4 Cabinet Suite Model IERS, X Direction (Side-Side) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

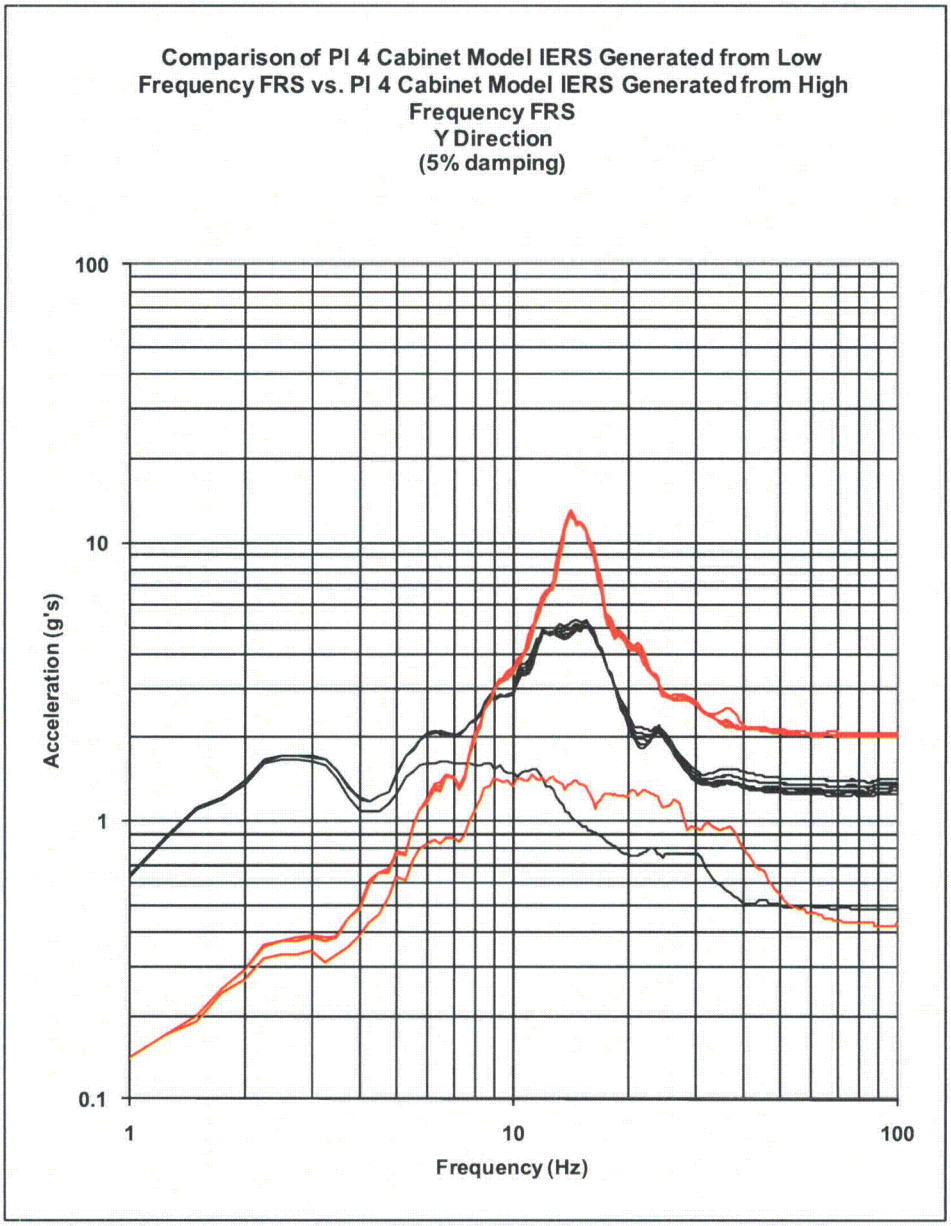


Figure 6.4.3.3.5-2 Comparison of PI 4 Cabinet Suite Model IERS, Y Direction (Front-Back) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

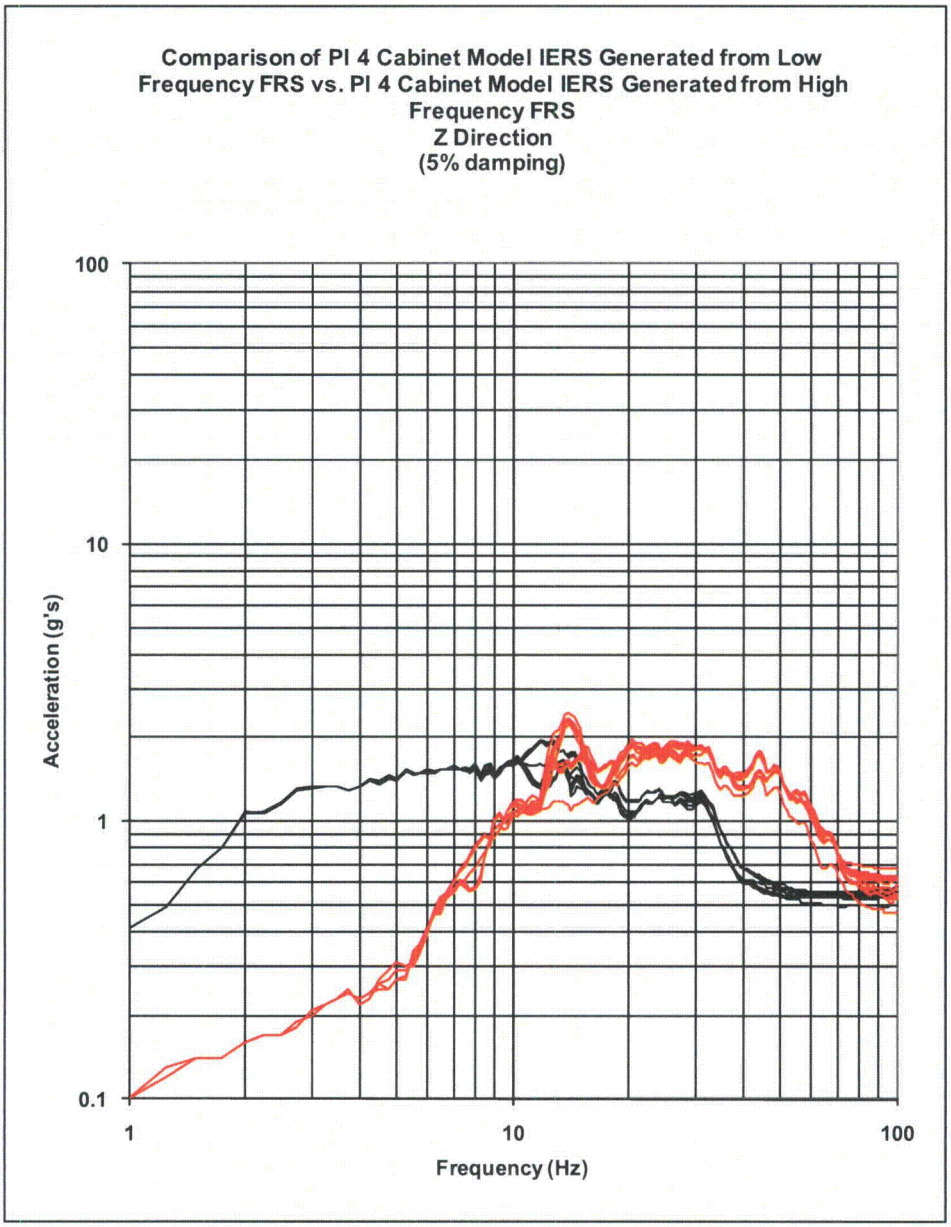


Figure 6.4.3.3.5-3 Comparison of PI 4 Cabinet Suite Model IERS, Z Direction (Vertical) High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

6.4.4 Review of Existing Seismic Test Data

This section presents the results of a study to evaluate low frequency seismic test programs to determine if high frequency excitation is exhibited in the frequency range of 25 to 50 Hz. Two different sets of test data were taken into consideration in this study. The first set was seismic testing performed to meet the standards required of safety-related equipment in IEEE Standard 344-1987 (Reference 6.4-3). Safety related equipment is required to withstand five lower level seismic events followed by at least one SSE event. The second set was testing performed to meet the UBC for commercial equipment supplied in essential industrial facilities. The following test data was reviewed:

1. The seismic TRS in the frequency range of 25 to 50 Hz

2. A lower bound of the spectral acceleration in the frequency range of 25 to 50 Hz where structural integrity and functional operability were demonstrated.

6.4.4.1 Methodology

A total of 14 test reports were reviewed for safety-related test programs which resulted in test data for more than 20 test specimens. In addition, 20 test reports were reviewed for UBC testing, resulting in test data for more than 100 test specimens. The data was reviewed to determine the seismic levels where structural integrity and functional operability were demonstrated. For these successful seismic test runs, the lowest spectral accelerations in the frequency range of 25 to 50 Hz were collected in the three principal directions (front-back, side-side, and vertical). The average was then computed to determine spectral accelerations in the frequency range of interest. Use of the average is considered to be appropriate since the tests considered in the evaluation were not associated with fragility tests. The tests were conducted to seismic levels developed for the specific application and higher seismic levels may have been able to have been achieved by the tested equipment. This process was performed for both sets of testing and in each of the three principal axes.

6.4.4.2 Safety-Related Equipment Seismic Test Data Review

The test data was collected for the 14 test reports based on the criteria in subsection 6.4.4.1. The test reports were studied to calculate the acceptable seismic test levels. The seismic levels that the equipment experienced without anomalies based on the criteria in subsection 6.4.4.1 are as follows:

Front-to-back:	2.50 g
Side-to-side:	2.64 g
Vertical:	2.65 g

Sample TRS of selected test runs are shown in Figures 6.4.4.2-1 to 6.4.4.2-3 compared to the required response spectra (RRS) defined for the testing (which significantly exceed the AP1000 HRHF MCR floor response spectra shown in Figures 6.4.4.4.2-1 through 6.4.4.4.2-3).

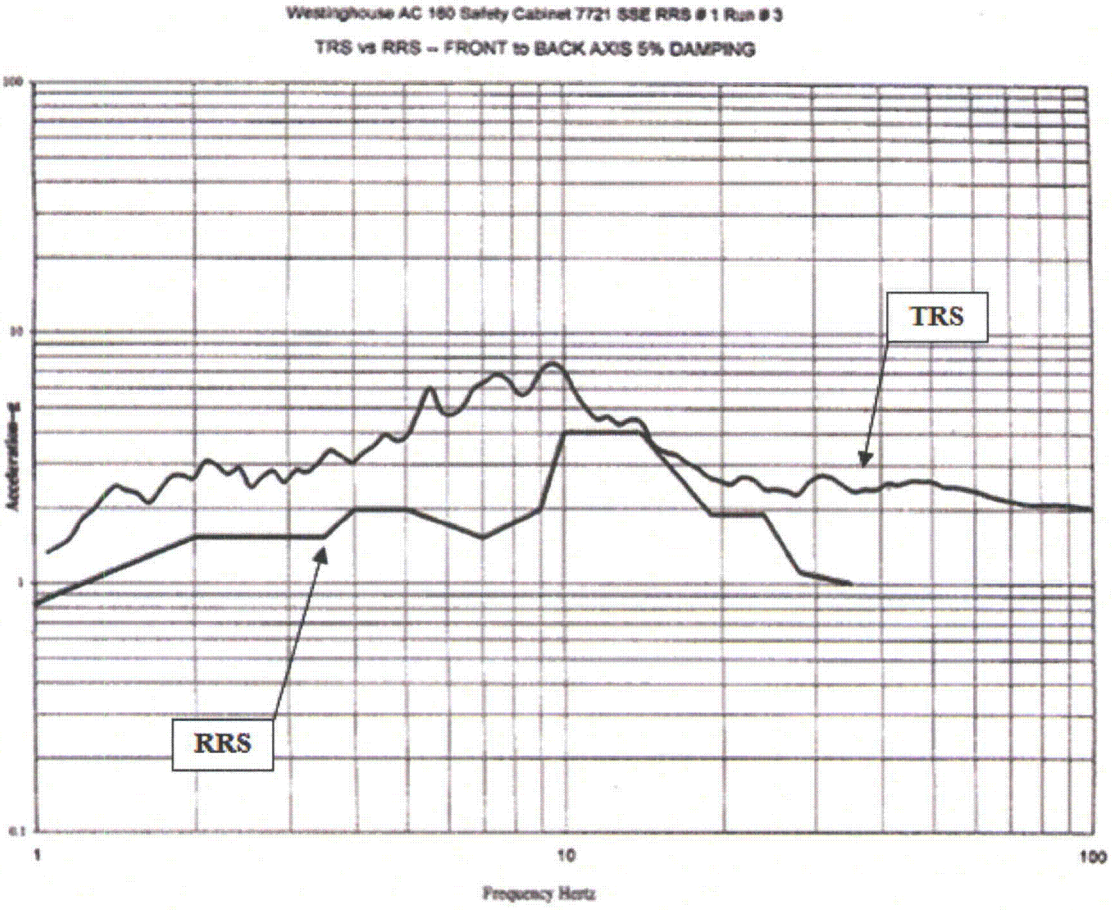


Figure 6.4.4.2-1 ANDI Test Report 6445 Test Run RRS #1 SSE 3 Front-to-Back

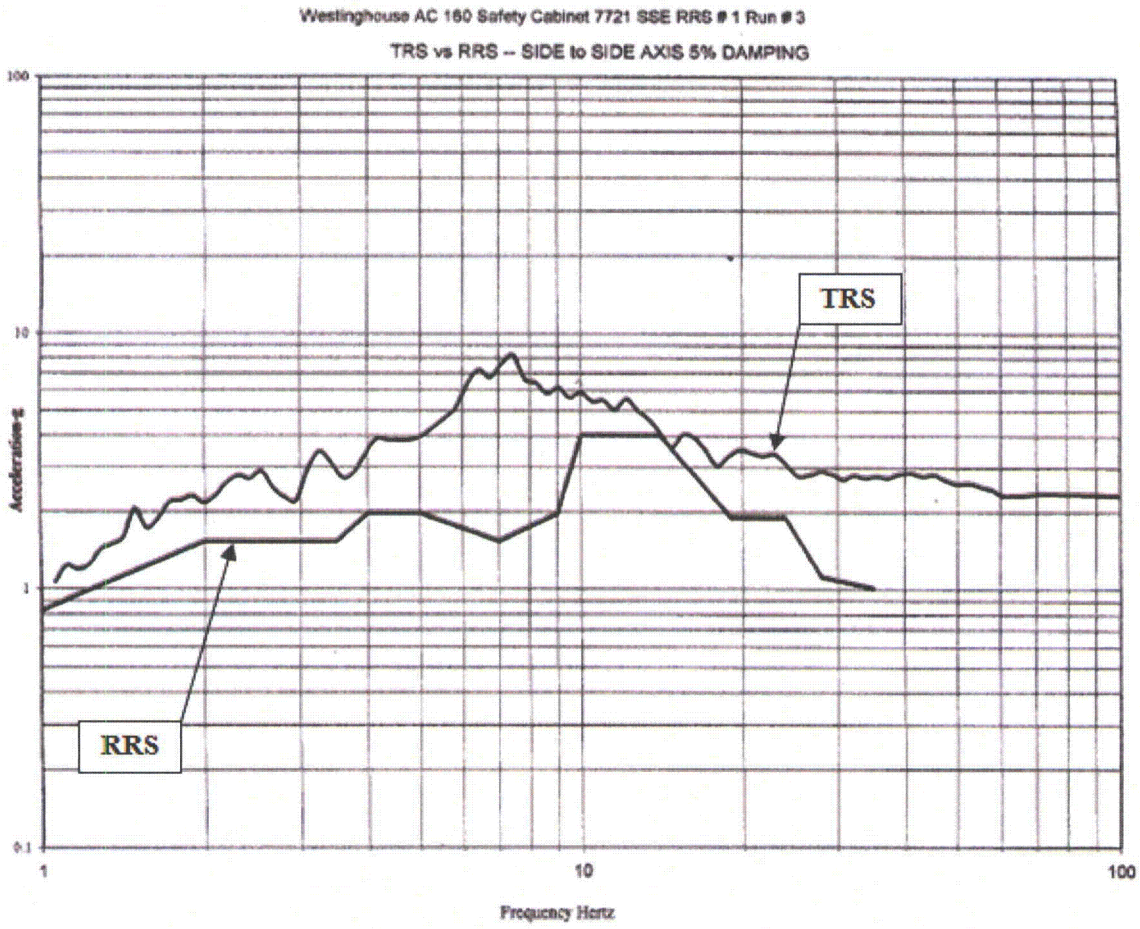


Figure 6.4.4.2-2 ANDI Test Report 6445 Test Run RRS #1 SSE 3 Side-to-Side

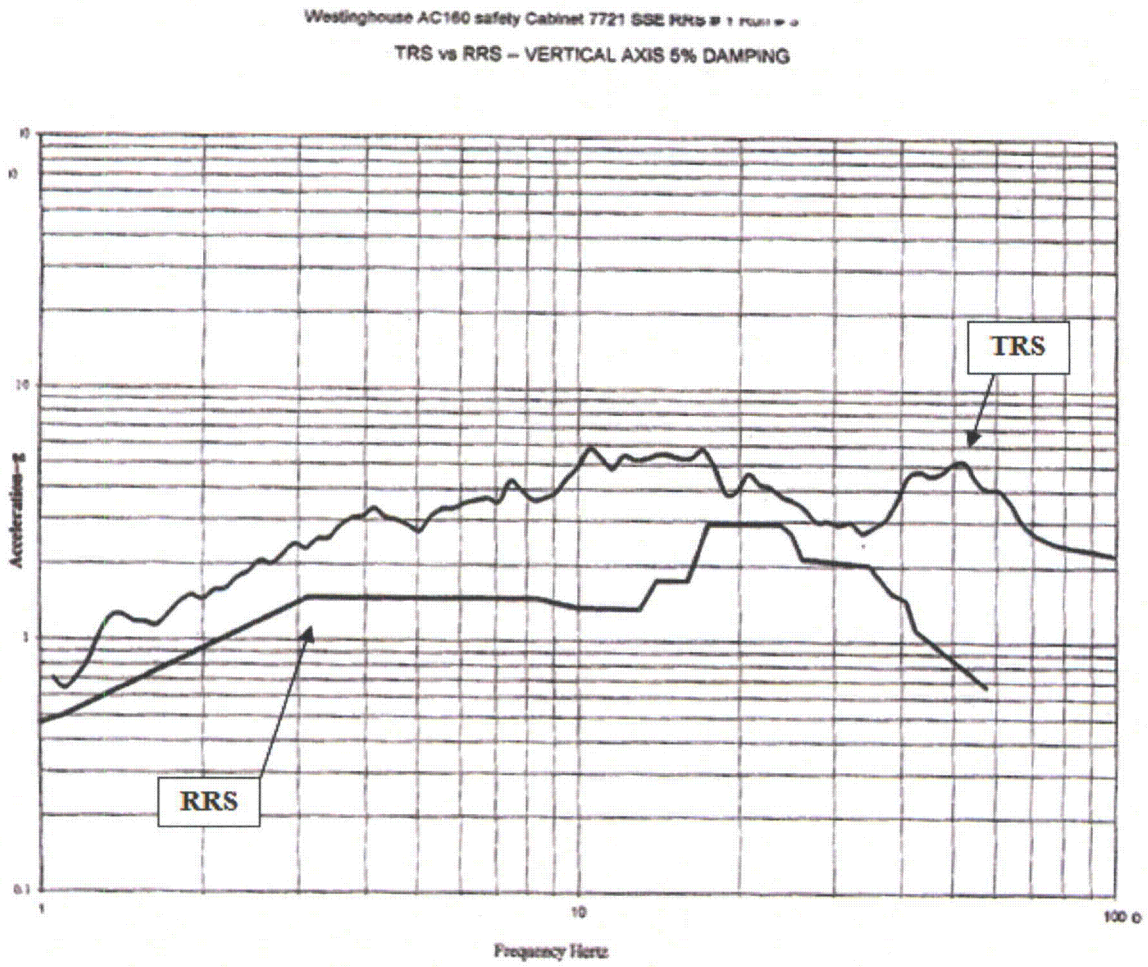


Figure 6.4.4.2-3 ANDI Test Report 6445 Test Run RRS #1 SSE 3 Vertical

6.4.4.3 UBC Test Data

For the UBC test programs, test data was collected for the twenty test reports based on the criteria in subsection 6.4.4.1. The TRS at 5 percent critical damping were reviewed to determine the spectral accelerations in the frequency range of 25 to 50 Hz. Only test runs where structural integrity and functionality were demonstrated were used. The resultant average accelerations in the three principal directions are as follows:

Front-to-back:	1.61 g
Side-to-side:	1.66 g
Vertical:	1.87 g

6.4.4.4 Seismic Test Data Review Conclusions

The data collected for the safety-related equipment shows higher spectral acceleration than the UBC data. To increase conservatism, the average between the UBC and safety-related equipment seismic spectral accelerations noted above were calculated and are listed below.

Front-to-back:	2.06 g
Side-to-side:	2.15 g
Vertical:	2.26 g

This data provides a conservative estimate of the spectral accelerations in the HF region without failure of the equipment. Therefore, it is concluded that spectral levels of 2.0 gs (at 5 percent critical damping) can be used as an upper bound for functionality of equipment in the 25 to 50 Hz frequency range without further testing or evaluation.

6.4.5 Screening Process

The groups of safety-related equipment considered for evaluation are those that may be sensitive to the HF input. This includes cabinet mounted equipment, field sensors, and appurtenances which may be sensitive to HF seismic inputs identified in Table 6.4.5-1. Evaluations have been performed to verify that these cabinets do not have excessive seismic demand on their mounted equipment, the cabinet designs do not require changes due to the HF input, and the cabinets will maintain their structural integrity and functional operability during and after the HF input.

Time history analyses of these typical safety-related cabinets were performed for both the CSDRS and the HRHF seismic inputs so that comparisons could be made to their seismic response from both seismic inputs. This analytical study is presented in subsection 6.4.3. The study concluded that safety-related equipment may be screened and grouped as follows during the seismic qualification efforts to the AP1000 CSDRS:

Screening Process

- Group No. 1:

  Rugged equipment with dominant natural frequencies above 50 Hz. Seismic qualification of this group based on CSDRS seismic requirements is adequate and requires no additional evaluation for HF seismic inputs.

- Group No. 2:

  Cabinets and other equipment which exhibit dominant natural frequencies below HRHF exceedance range. Seismic qualification of this group based on CSDRS seismic requirements is adequate and requires no additional evaluation for HF seismic inputs.

- Group No. 3:

  Safety-related equipment which exhibit dominant natural frequencies in HRHF exceedance range. The safety-related equipment will be subjected to supplemental HF seismic evaluation to verify acceptability.

Table 6.4.5-1 Potential Sensitive Equipment List
• Equipment or components with moving parts and required to perform a switching function during the seismic event (e.g., low and medium voltage circuit breakers, contactors, auxiliary switches, molded case circuit breakers, motor control center starters, and pneumatic control assemblies)
• Components with moving parts that may bounce or chatter such as relays and actuation devices (e.g., shunt trips)
• Unrestrained components
• Potentiometers
• Process switches and sensors (e.g., pressure/differential pressure, temperature, level, limit/position, and flow)
• Components with accuracy requirements that may drift due to seismic loading
• Interfaces such as secondary contacts
• Connectors and connections (including circuit board connections for digital and analog equipment)

6.4.6 Seismic Treatment of Sensitive Equipment

Components and equipment determined to be sensitive to high frequency with potential failure modes involving change of state, chatter, signal change/drift, and connection problems will be demonstrated to be acceptable through the performance of supplemental high frequency screening in accordance with the industry position white paper (Reference 6.4-4). Those components that are sensitive to high frequency which have failure modes associated with mounting, connections and fasteners, joints, and interface are considered to be qualified by traditional low frequency qualification testing per IEEE Standard 344 and/or required quality assurance inspection and process/design controls.

The high frequency screening seismic test is intended as a supplemental evaluation to the required seismic qualification methods performed in accordance with IEEE Standard 344-1987 (Reference 6.4-3) for those plants which have high frequency exceedance of their CSDRS and which therefore require evaluation of equipment and components potentially sensitive to high frequency. High frequency screening tests should be conducted as a supplemental test to low frequency seismic excitation for equipment determined to have natural frequencies coinciding with the peak spectral acceleration of the high frequency RRS when that peak spectral acceleration is greater than 2.0 g (at 5 percent critical damping).

High frequency seismic testing of equipment determined to be sensitive (that is not screened out per subsection 6.4.5) is the preferred screening test method to address HRHF seismic demand and will be conducted as a supplemental test to low frequency seismic excitation. High and low frequency seismic RRS are separate environments and an envelope RRS covering both would not be representative of the design basis event DBE. Testing to a high/low frequency envelope RRS could prove destructive to both the equipment under test and the seismic test table.

The equipment should be subjected to the high frequency SSE testing after completion of the low frequency seismic testing. Low-level cycling fatigue effect requirements should be justified by low frequency seismic input. No additional low-level testing for high frequency excitation is required. One SSE high frequency seismic test will be performed to demonstrate functionality of equipment in its most sensitive electrical configuration.

Acceptance and qualification to the HF input is determined based on the comparison of the test levels that the components have been analyzed or tested to. For those equipment/components determined to have been tested already to high seismic levels in the high frequency region, no additional testing or justification is necessary. A review of seismic testing data is performed to verify that the tested seismic levels envelop the high frequency seismic demand. If these components cannot be shown to be acceptable based on this review, additional testing or justifications may be required to show acceptance.

In addition, the EPRI white paper (Reference 6.4-4) outlines other recommended generic screening procedures to provide that safety-related components that are sensitive to high frequency seismic demand are screened out or shown to be acceptable for their specific application.

6.4.7 Summary and Conclusions

The comparative analysis completed demonstrates that equipment exhibiting natural frequencies below HRHF exceedance range or above 50 Hz do not require any additional treatment for qualification to high frequency seismic requirements. Equipment that exhibits dominant natural frequencies which coincide with the peak spectral acceleration of the high frequency RRS will require additional evaluation to verify acceptability. Review of completed low frequency seismic test programs shows that the current qualification test methods envelop the seismic qualification of equipment for high frequency seismic inputs up to a 2.0 g peak spectral acceleration (at 5 percent critical damping) in the three orthogonal principal axes. This can be used to exclude additional seismic testing to high frequency based inputs below 2.0 g. High frequency seismic testing should be conducted as a supplemental test to low frequency seismic excitation for equipment determined to have natural frequencies coinciding with the peak spectral acceleration of the high frequency RRS when that peak spectral acceleration is greater than 2 g (at 5 percent critical damping).

7 GENERAL CONCLUSIONS

An evaluation was performed for portions of structures, components, piping, and systems for the HRHF seismic response. Using the screening criteria applicable to the SSCs, the sample evaluated consisted of the following:

- Building Structures
  - Auxiliary Building
  - Shield Building
  - Containment internal structures
- Primary Coolant Loop
  - Reactor vessel and internals
  - Primary component supports and nozzles
  - Reactor coolant loop primary equipment nozzles
- Piping Systems
- Safety-Related Electrical Equipment

Representative portions of the building structures are evaluated. Three locations in the Auxiliary Building were selected: the bottom of the wall where the shear would be large; a wall in the vicinity of a floor that is influenced by high frequency response; and a corner intersection of walls. Eight locations on the Shield Building were evaluated that are located on the east, west, north, and south sides. Three areas within the CIS were selected: the southwest wall of the refueling canal; west wall of the steam generator; and the CA02 module wall associated with the IRWST. In all cases it was determined that the loads associated with the CSDRS envelope the HRHF case.

The reactor vessel and internals is chosen for evaluation as representative of major equipment. From the analyses performed, it was found that the CSDRS will have higher loads and stresses than those from the HRHF seismic response.

The primary component supports and the reactor coolant loop primary equipment nozzles were found to have the highest response from the CSDRS.

The piping systems that are the most sensitive to HF input were found to have smaller response from the HRHF input than that associated with the CSDRS seismic response.

It is concluded from the analyses and seismic tests performed in the past that the CSDRS results in higher loads and stresses than the HRHF. Therefore, it is acceptable to design for only the CSDRS. It is recognized that supplemental seismic testing of high frequency sensitive safety-related equipment or implementation of one of the other high frequency screening techniques as outlined in the EPRI White Paper (Reference 6.4-4) may be required to demonstrate acceptability under HRHF seismic demand conditions. The screening process described in subsection 6.4.5 provides a method to address the

potential for HF susceptibilities in equipment and components for those plants which have HF exceedance of the CSDRS. The recommended screening techniques in Reference 6.4-4 also provide that any potentially HF sensitive safety-related components are either screened out or shown to be acceptable for their specific application.

This Technical Report's results show consistency with industry positions and past EPRI reports that high frequency is non-damaging. The report describes the screening criteria used to select the set of sample cases that have been included and, together with other industry comparisons, provide sufficient basis to conclude that the analyzed HRHF spectra produce lower seismic loads than the CSDRS. Thus, it is sufficient to use the CSDRS seismic loads in the AP1000 design. However, as noted in the Introduction (Section 1.0), the evaluation documented in this report is for a site application having HRHF envelope response spectra that is in conformance with the following limitation on shear wave velocity. This shear wave velocity limitation is defined at the bottom of the basemat equal to or higher than 7,500 fps, while maintaining a shear wave velocity equal to or above 8,000 fps at the lower depths.

8 REFERENCES

1.0-1 EPRI Draft White Paper, "Considerations for NPP Equipment and Structures Subjected to Response Levels Caused by High Frequency Ground Motions," Transmitted to NRC March 19, 2007.

1.0-2 "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined Licensed Applications," ISG-01, May 19, 2008.

2.0-1 APP-GW-S2R-010, Revision 5, "Extension of Nuclear Island Seismic Analysis to Soil Sites," Westinghouse Electric Company, LLC.

3.0-1 Ghiocel Predictive Technologies, Inc. (2006). *ACS-SASSI, An Advanced Computational Software for 3D Dynamic Analysis Including Soil-Structure Interaction*, Version 2.2, Pittsford, New York.

6.4-1 Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 1, U.S. Atomic Energy Commission, December 1973.

6.4-2 AP1000 Design Control Document, "Design of Structures, Components, Equipment and Systems,"

6.4-3 IEEE Std. 344-1987, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."

6.4-4 EPRI White Paper, "Seismic Screening of Components Sensitive to High Frequency Vibratory Motions," June 2007.