Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-6306
Direct fax: 412-374-5005
e-mail: sterdia@westinghouse.com

Your ref: Project Number 740
Our ref: DCP/NRC2028

October 19, 2007

Subject: AP1000 COL Standard Technical Report Submittal of APP-GW-GLR-115 (TR 115), Revision 0

In support of Combined License application pre-application activities, Westinghouse is submitting AP1000 Standard Combined License Technical Report Number 115. The primary purpose of Technical Report 115 is to provide an evaluation of the effects of high frequency seismic input on the AP1000 design. The Technical Report revises AP1000 DCD Revision 16, including Appendix 3I, to include the revised hard rock high frequency ground motion response spectra. This report is submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in this report is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

The purpose for submittal of this report was explained in a March 8, 2006 letter from NuStart to the NRC.

Pursuant to 10 CFR 50.30(b), APP-GW-GLR-115, Revision 0, "Effect of High Frequency Seismic Content on SSCs," Technical Report Number 115, is submitted as Enclosure 1 under the attached Oath of Affirmation.

It is expected that when the NRC review of Technical Report Number 115 is complete, Technical Report 115 will be considered approved generically for COL applicants referencing the AP1000 Design Certification.

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

Westinghouse requests the NRC to provide a schedule for review of the technical report within two weeks of its submittal.

D063
D079
NRO

Very truly yours,

A. Sterdis, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Attachment

1. "Oath of Affirmation," dated October 19, 2007

/Enclosure

1. APP-GW-GLR-115, Revision 0, "Effect of High Frequency Seismic Content on SSCs," Technical Report Number 115

cc:	D. Jaffe	-	U.S. NRC	1E	1A
	E. McKenna	-	U.S. NRC	1E	1A
	G. Curtis	-	TVA	1E	1A
	P. Hastings	-	Duke Power	1E	1A
	C. Ionescu	-	Progress Energy	1E	1A
	A. Monroe	-	SCANA	1E	1A
	M. Moran	-	Florida Power & Light	1E	1A
	C. Pierce	-	Southern Company	1E	1A
	E. Schmiech	-	Westinghouse	1E	1A
	G. Zinke	-	NuStart/Entergy	1E	1A
	B. LaPay	-	Westinghouse	1E	1A

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)

NuStart Bellefonte COL Project)

NRC Project Number 740)

APPLICATION FOR REVIEW OF
"AP1000 GENERAL COMBINED LICENSE INFORMATION"
FOR COL APPLICATION PRE-APPLICATION REVIEW

W. E. Cummins, being duly sworn, states that he is Vice President, Regulatory Affairs and Standardization, for Westinghouse Electric Company; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission this document; that all statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.

W. E. Cummins
Vice President
Regulatory Affairs and Standardization

Subscribed and sworn to
before me this 19th day
of October 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Patricia S. Aston, Notary Public
Murrysville Boro, Westmoreland County
My Commission Expires July 11, 2011
Member, Pennsylvania Association of Notaries

Notary

ENCLOSURE 1

APP-GW-GLN-115, Revision 0

"Effect of High Frequency Seismic Content on SSCs"

Technical Report 115

AP1000 DOCUMENT COVER SHEET

TDC: ________ Permanent File: ________ APY: ________

RFS#: ________ RFS ITEM #: ________

AP1000 DOCUMENT NO.	REVISION NO.		ASSIGNED TO
APP-GW-GLR-115	0	Page 1 of 96	W--A. Sterdis

ALTERNATE DOCUMENT NUMBER: WORK BREAKDOWN #:

ORIGINATING ORGANIZATION: Westinghouse Electric Company

TITLE: **Effect of High Frequency Seismic Content on SSCs**

ATTACHMENTS: N/A	DCP #/REV. INCORPORATED IN THIS DOCUMENT REVISION: N/A
CALCULATION/ANALYSIS REFERENCE: N/A	

ELECTRONIC FILENAME	ELECTRONIC FILE FORMAT	ELECTRONIC FILE DESCRIPTION
APP-GW-GLR-115.doc	MS WORD	N/A

☒ WESTINGHOUSE CLASS 3 (NON PROPRIETARY)

Class 3 Documents being transmitted to the NRC require the following two review signatures in lieu of a Form 36.

LEGAL REVIEW T.J. WHITE	SIGNATURE/DATE T. J. White 10-19-07
PATENT REVIEW D. EKKEROTH	SIGNATURE/DATE [signature] 10/19/07

☐ WESTINGHOUSE PROPRIETARY CLASS 2

ORIGINATOR William S. LaPay	SIGNATURE/DATE William S. LaPay 10/17/07		
REVIEWERS Brandon J. Schoonmaker	SIGNATURE/DATE Brandon J. Schoonmaker 10/18/07	Sections 6.0, 6.1, 6.2	
Venki Prabhu	[signature] 10/19/07	Section 6.3	
Mostafa Ahmed	Mostafa A. Ahmed 10/17/07	Section 6.4	
Allan Kuenzel	Allan J Kuenzel 10/18/07	Section 6.2.1	
VERIFIER Keith Coogler	SIGNATURE/DATE [signature] 10/19/2007	VERIFICATION METHOD Detailed review	
AP1000 RESPONSIBLE MANAGER Lee Tunon-Sanjur	SIGNATURE* L. Tunon-Sanjur	APPROVAL DATE 10/19/07	

* Approval of the responsible manager signifies that document is complete, all required reviews are complete, electronic file is attached and document is released for use.

Westinghouse Non-Proprietary Class 3

AP1000 Standard Combined License Technical Report

Effect of High Frequency Seismic Content on SSCs

Revision 0

Westinghouse Electric Company LLC
Nuclear Power Plants
Post Office Box 355
Pittsburgh, PA 15230-0355

Table of Contents

1.0 INTRODUCTION **6**

2.0 HIGH FREQUENCY SEISMIC INPUT **8**

3.0 EVALUATION METHODOLOGY **8**

4.0 GENERAL SELECTION SCREENING CRITERIA **9**

5.0 COMPARISON OF HRHF FLOOR RESPONSE SPECTRA **10**

5.1 ADEQUACY OF CSDRS AND HRHF RESPONSE SPECTRA 10
5.2 COMPARISON OF CSDRS AND HRHF RESPONSE SPECTRA 15

6.0 EVALUATION **22**

6.1 BUILDING STRUCTURES 22
6.2 PRIMARY COOLANT LOOP 28
6.2.1 Reactor Internals *28*
6.2.2 Primary Component Supports and Nozzles *31*
6.3 PIPING SYSTEMS 36
6.3.1 Package Consideration *36*
6.3.1.1 Layout 37
6.3.1.2 Review of Spectra 37
6.3.1.3 Modal Analysis 38
6.3.2 Analysis of Selected Candidates *40*
6.3.2.1 Automatic Depressurization System 4th Stage West and Passive RHR Supply (APP-PXS-PLA-030) 40
6.3.2.2 Normal RHR Heat Exchanger Inlet and Outlet (APP-RNS-PLA-170) 43
6.3.2.3 Analysis Method 46
6.3.3 Results *47*
6.3.3.1 Automatic Depressurization System Stage 4 West (APP-PXS-PLA-030) 47
6.3.3.2 Normal RHR Heat Exchanger Inlet and Outlet between P19 and P20 (APP-RNS-PLA-170) 50
6.3.4 Summary and Conclusions *55*
6.4 SAFETY-RELATED ELECTRICAL EQUIPMENT 55
6.4.1 Introduction *55*
6.4.2 Evaluation Process *56*
6.4.3 Comparative Analyses *57*
6.4.3.1 Seismic Inputs 57
6.4.3.2 Finite Element Model Samples 58
6.4.3.3 Seismic Analysis of Models 63
6.4.3.3.1 General 63
6.4.3.3.2 Analysis Method and Floor Seismic Requirements 64
6.4.3.3.3 Analysis of A01-A05 Console Line-up Model 66
6.4.3.3.4 Analysis of APC Finite Element Model 69
6.4.3.3.5 PI Model 73
6.4.4 Review of Existing Seismic Test Data *78*
6.4.4.1 Methodology 78
6.4.4.2 Safety-Related Equipment Seismic Test Data Review 78
6.4.4.3 UBC Test Data 81
6.4.4.4 Seismic Test Data Review Conclusions 82
6.4.5 Screening Process *82*
6.4.6 Seismic Treatment of Sensitive Equipment *83*
6.4.7 Summary and Conclusions *84*

7.0 GENERAL CONCLUSIONS **84**

8.0 REFERENCES **86**

APPENDIX 3I HAS BEEN MODIFIED AND IS INCLUDED IN THIS APPENDIX. **87**

List of Tables

Table 6.1-1: Auxiliary Building Time History Member Force Comparison 26
Table 6.1-2: Shield Building Time History Member Force Comparison 27
Table 6.1-3: Shield Building Time History Member Force Comparison 27
Table 6.1-4: Refueling Wall Time History Member Force Comparison 27
Table 6.1-5: SW Steam Generator Wall Time History Member Force Comparison 27
Table 6.1-6: CA02 Wall Building Time History Member Force Comparison 28
Table 6.2.2-1: Description of Reactor Coolant Loop Supports 35
Table 6.2.2-2: Reactor Pressure Vessel Support Comparison 35
Table 6.2.2-3: Steam Generator Support Comparison 35
Table 6.2.2-4: Description of Reactor Coolant Loop Nozzle Acronyms 36
Table 6.2.2-5: Reactor Coolant Loop Primary Equipment Nozzle Load Comparison 36
Table 6.3.1-1: Reviewed Lines 39
Table 6.3.3.1-1: Ten Highest AP1000 Design Stress Points for APP-PXS-PLA-030 47
Table 6.3.3.1-2: Ten Highest High Frequency Stress Points for APP-PXS-PLA-030 48
Table 6.3.3.1-3: Valve End Stresses for APP-PXS-PLA-030 48
Table 6.3.3.1-4: Tee Connection Stresses for APP-PXS-PLA-030 48
Table 6.3.3.1-5: Seismic Support Loads for APP-PXS-PLA-030 49
Table 6.3.3.1-6: Seismic Anchor Loads for APP-PXS-PLA-030 49
Table 6.3.3.1-7: Equipment Nozzle Stresses for APP-PXS-PLA-030 49
Table 6.3.3.2-1: Ten Highest AP1000 Design Stress Points for APP-RNS-PLA-170 50
Table 6.3.3.2-2: Ten Highest High Frequency Stress Points for APP-RNS-PLA-170 51
Table 6.3.3.2-3: Valve End Stresses for APP-RNS-PLA-170 51
Table 6.3.3.2-4: Tee Connection Stresses for APP-RNS-PLA-170 52
Table 6.3.3.2-5: Seismic Support Loads for APP-RNS-PLA-170 53
Table 6.3.3.2-6: Seismic Anchor Loads for APP-RNS-PLA-170 54
Table 6.3.3.2-7: Equipment Nozzle Stresses for APP-RNS-PLA-170 54
Table 6.4.3.3.3-1: Comparison of A01-A05 Maximum Console Displacements 66
Table 6.4.3.3.3-2: Comparison of A01-A05 Maximum Console Mounting Bolt Loads 66
Table 6.4.3.3.4-1: Comparison of APC Maximum Cabinet Displacements 70
Table 6.4.3.3.4-2: Comparison of APC Maximum Cabinet Mounting Bolt Loads 70
Table 6.4.3.3.5-1: Comparison of PI 4 Cabinet Model Maximum Cabinet Displacements 74
Table 6.4.3.3.5-2: Comparison of PI 4 Cabinet Model Maximum Mounting Bolt Loads 74
Table 6.4.5-1: Potential Sensitive Equipment List 83

List of Figures

Figure 1.0-1: Comparison of the HRHF horizontal input spectra to the CSDRS 7
Figure 1.0-2: Comparison of the HRHF vertical input spectra to the CSDRS 8
Figure 5.1-1: Comparison of NI20 and NI10 Seismic Response Spectra on roof of Shield Building 12
Figure 5.1-2: Comparison of NI20 and NI10 Seismic Response Spectra for West Side of Shield Building 13
Figure 5.1-3: Comparison of NI20 and NI10 Seismic Response Spectra of South Side of Shield Building 14
Figure 5.2-1: ASB at Elevation 327.4' 16
Figure 5.2-2: Containment Operating Floor (Elevation 134.25') 17
Figure 5.2-3: ASB at Northeast Corner (Elevation 134.5') 18
Figure 5.2-4: ASB at Fuel Building Roof (Elevation 179.56') 19
Figure 5.2-5: FRS Nodes – Elevation 180' 20
Figure 5.2-6: Reactor Coolant Pump 21
Figure 6.1-1: Auxiliary Building Critical Shell Elements 23
Figure 6.1-2: Shield Building Critical Shell Elements 24
Figure 6.1-3: Shield Building Critical Shell Elements 25
Figure 6.1-4: Refueling Wall Shell Elements 25
Figure 6.1-5: SW Steam Generator Wall Shell Elements 26
Figure 6.1-6: CA02 Wall Shell Elements 26
Figure 6.2.1-1: View of Entire System Model including RCL Super Elements 29
Figure 6.2.1-2: View of Model of Core Barrel, RPV, Inlet Nozzles, Outlet Nozzles, and Supports 30
Figure 6.2.2-1: Reactor Coolant Loop Component Supports 32
Figure 6.2.2-2: Reactor Coolant Loop Primary Equipment Nozzles 33
Figure 6.2.2-3: Reactor Coolant Loop Primary Equipment Nozzles 34
Figure 6.3.2.1-1: APP-PXS-PLA-030 Floor Response Spectra X-Direction 41
Figure 6.3.2.1-2: APP-PXS-PLA-030 Floor Response Spectra Y-Direction 41
Figure 6.3.2.1-3: APP-PXS-PLA-030 Floor Response Spectra Z-Direction 42
Figure 6.3.2.1-4: APP-PXS-PLA-030 Cumulative Mass: ADS 4th Stage West 43
Figure 6.3.2.2-1: APP-RNS-PLA-170 Floor Response Spectra X-Direction 44
Figure 6.3.2.2-2: APP-RNS-PLA-170 Floor Response Spectra Y-Direction 44
Figure 6.3.2.2-3: APP-RNS-PLA-170 Floor Response Spectra Z-Direction 45
Figure 6.3.2.2-4: APP-RNS-PLA-170 Cumulative Mass: Normal RHR 46
Figure 6.4.3.1-1: AP1000 Auxiliary and Shield Building Finite Element Model 58
Figure 6.4.3.2-1: MCR (A01-A05) Safety Console Line-up Finite Element Model 59
Figure 6.4.3.2-2: Finite Element Model of Auxiliary Protection Cabinet (APC) 60
Figure 6.4.3.2-3: MCR Large Display (B13-B16) Panel Line-up Finite Element Model 61
Figure 6.4.3.2-4: Process Instrumentation (PI) 4 Cabinet Suite Finite Element Model 62
Figure 6.4.3.2-5: Remote Operator Shutdown Panel (ROP) Console Finite Element Model 63
Figure 6.4.3.3.2-1: High/Low Frequency Response Spectra X-Direction (Horizontal) 64
Figure 6.4.3.3.2-2: High/Low Frequency Response Spectra Y-Direction (Horizontal) 65
Figure 6.4.3.3.2-3: High/Low Frequency Response Spectra Z-Direction (Vertical) 65
Figure 6.4.3.3.3-1: Comparison of A01-A05 Console Model IERS, X-Direction (Front-Back) 67
Figure 6.4.3.3.3-2: Comparison of A01-A05 Console Model IERS, Y-Direction (Side-Side) 68
Figure 6.4.3.3.3-3: Comparison of A01-A05 Console Model IERS, Z-Direction (Vertical) 69
Figure 6.4.3.3.4-1: Comparison of APC Model IERS, X-Direction (Side-Side) 71
Figure 6.4.3.3.4-2: Comparison of APC Model IERS, Y-Direction (Front-Back) 72
Figure 6.4.3.3.4-3: Comparison of APC Model IERS, Z-Direction (Vertical) 73
Figure 6.4.3.3.5-1: Comparison of PI 4 Cabinet Suite Model IERS, X-Direction (Side-Side) 75
Figure 6.4.3.3.5-2: Comparison of PI 4 Cabinet Suite Model IERS, Y-Direction (Front-Back) 76
Figure 6.4.3.3.5-3: Comparison of PI 4 Cabinet Suite Model IERS, Z-Direction (Vertical) 77
Figure 6.4.4.2-1: ANDI Test Report 6445 Test Run RRS #1 SSE 3 79
Figure 6.4.4.3-2: ANDI Test Report 6445 Test Run RRS #1 SSE 3 80
Figure 6.4.4.3-2: ANDI Test Report 6445 Test Run RRS #1 SSE 3 81

1.0 Introduction

The purpose of this report is two fold: (1) to confirm that high frequency seismic input is not damaging to equipment and structures qualified by analysis for the AP1000 Certified Seismic Design Response Spectra (CSDRS); and (2) to demonstrate that normal design practices result in an AP1000 design that is safer and more conservative than that which would result if designed for the high frequency input.

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 hertz 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) is obtained from site-specific probabilistic hazard-based ground motion. Many of the GMRS of the Central and Eastern United States (CEUS) rock sites show higher amplitude at higher frequency than the CSDRS. These seismic response spectra, however, 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 Reg. Guide 1.60-based design spectra. The 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 are non-damaging to virtually all types of nuclear plant structures, systems, and components (SSCs).

Furthermore, it is the belief of much of the engineering community that high frequency vibration will be filtered out due to numerous nonlinear features in the plant design. It is also believed that the analytical high frequency seismic requirements inside the buildings are mainly theoretical rather than real. This is because many nonlinear details exist in equipment mounting configurations and piping support design details that are very difficult and impractical to simulate in finite element models.

Westinghouse agrees with the industry position that HF motions are non-damaging and thus offers in this report an evaluation of the AP1000 nuclear island for high frequency input based on the analysis of a representative sample of structures, components, supports, and piping to further demonstrate that the high frequency seismic response 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% damping. The HRHF exceeds the CSDRS for frequencies above about 15 Hz. Evaluations in this report describe the seismic input at a hard rock site where the nuclear island is founded on hard rock.

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

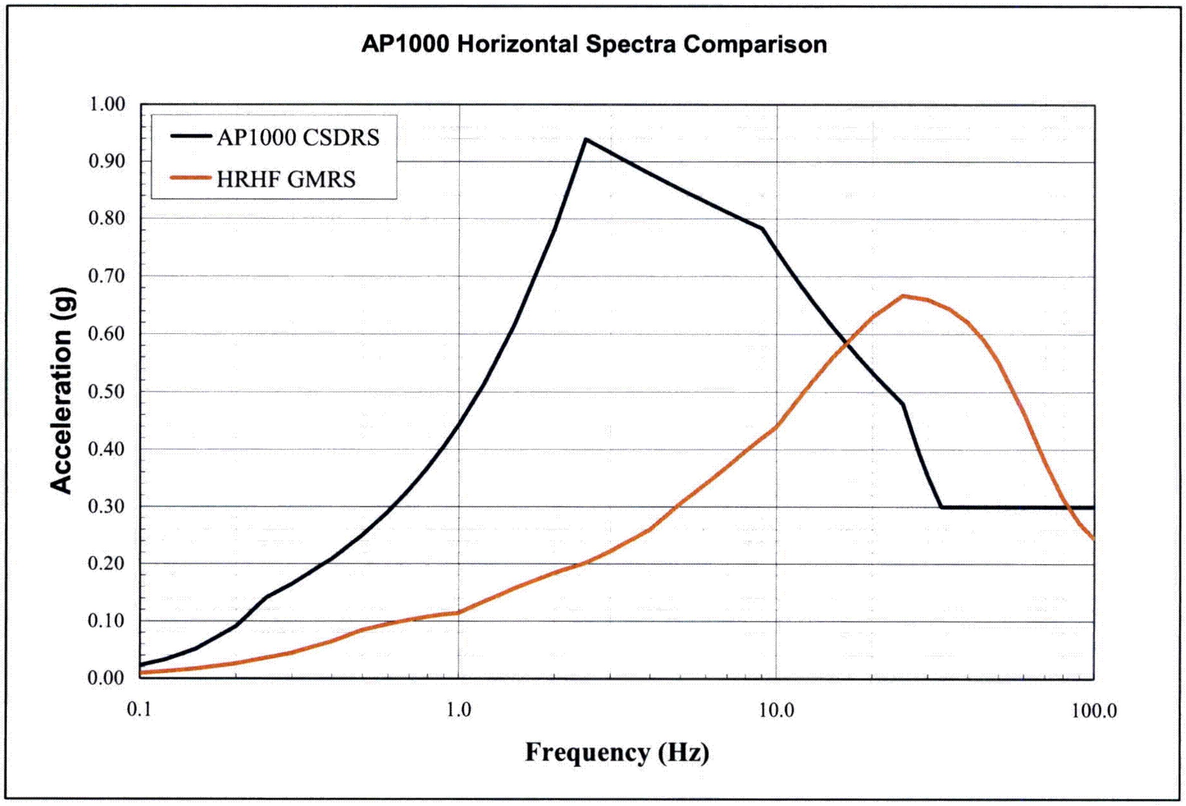


Figure 1.0-1: Comparison of the HRHF horizontal input spectra to the CSDRS

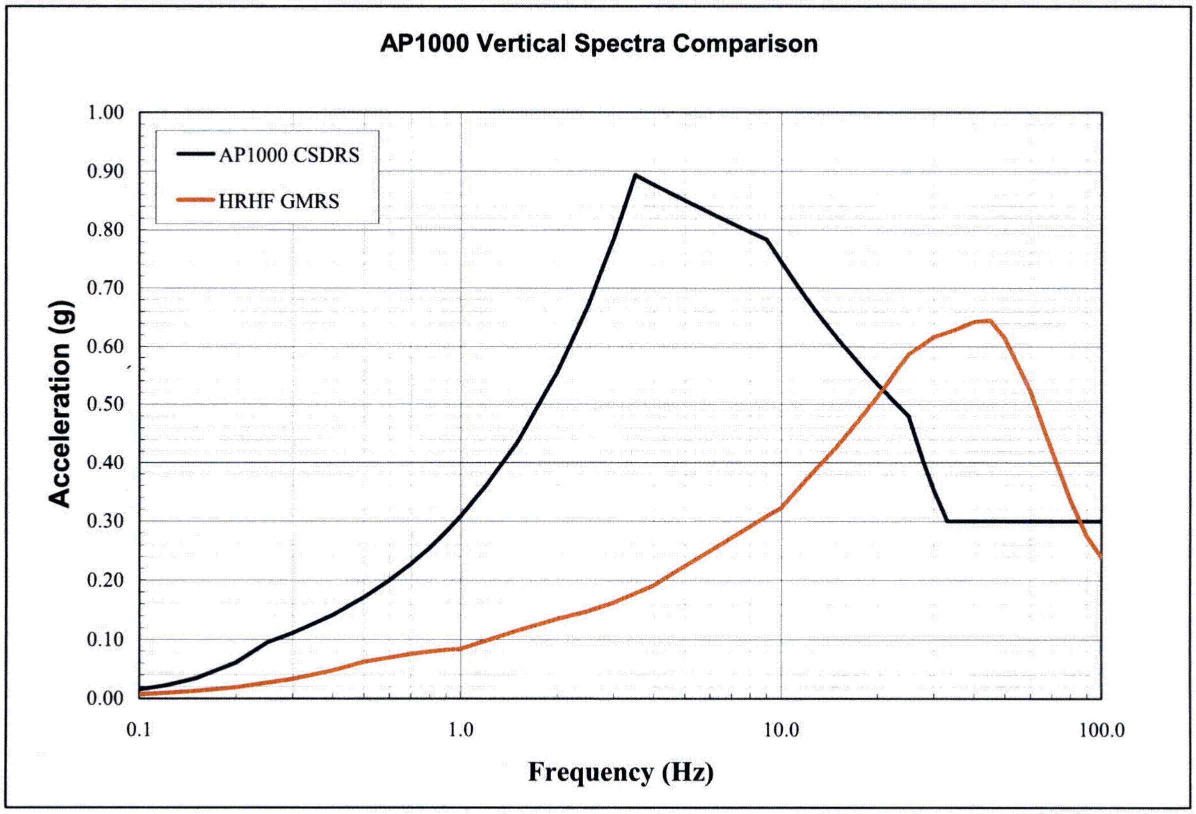


Figure 1.0-2: Comparison of the HRHF vertical input spectra to the CSDRS

2.0 High Frequency Seismic Input

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

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

3.0 Evaluation Methodology

Demonstration that the AP1000 nuclear power plant design is not controlled by the high frequency 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 high frequency 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:

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

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

c. 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)

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

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

f. Perform convolution of complex TF with input control motion Fast Fourier Transform (FFT)

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

h. Compute ISRS (In-Structure Response Spectra) from acceleration time histories at selected structural nodes

i. 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

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 analysis is not appropriate.

4.0 General Selection Screening Criteria

The following general screening criteria are used to identify representative AP1000 SSCs for samples to be evaluated to demonstrate acceptability of the AP1000 nuclear power plant for the high frequency motion.

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

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

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

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

5.0 Comparison of HRHF Floor Response Spectra

5.1 Adequacy of CSDRS and HRHF Response Spectra

The adequacy of the NI20 model is demonstrated by:

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

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

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

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

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

For a maximum analysis frequency (f_{max}) of 80 Hz which must transmit through the finite elements, the shortest wavelength (λ) is 86.26 ft.

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

Four nodes per wavelength are adequate to transmit the high frequency through the finite elements. Therefore, the mesh size of 20 ft (i.e. NI20) is adequate for the Auxiliary and Shield

Building (ASB). The portion of the NI20 model has an element mesh size of ~ 10' for the Containment and Internal Structure (CIS).

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

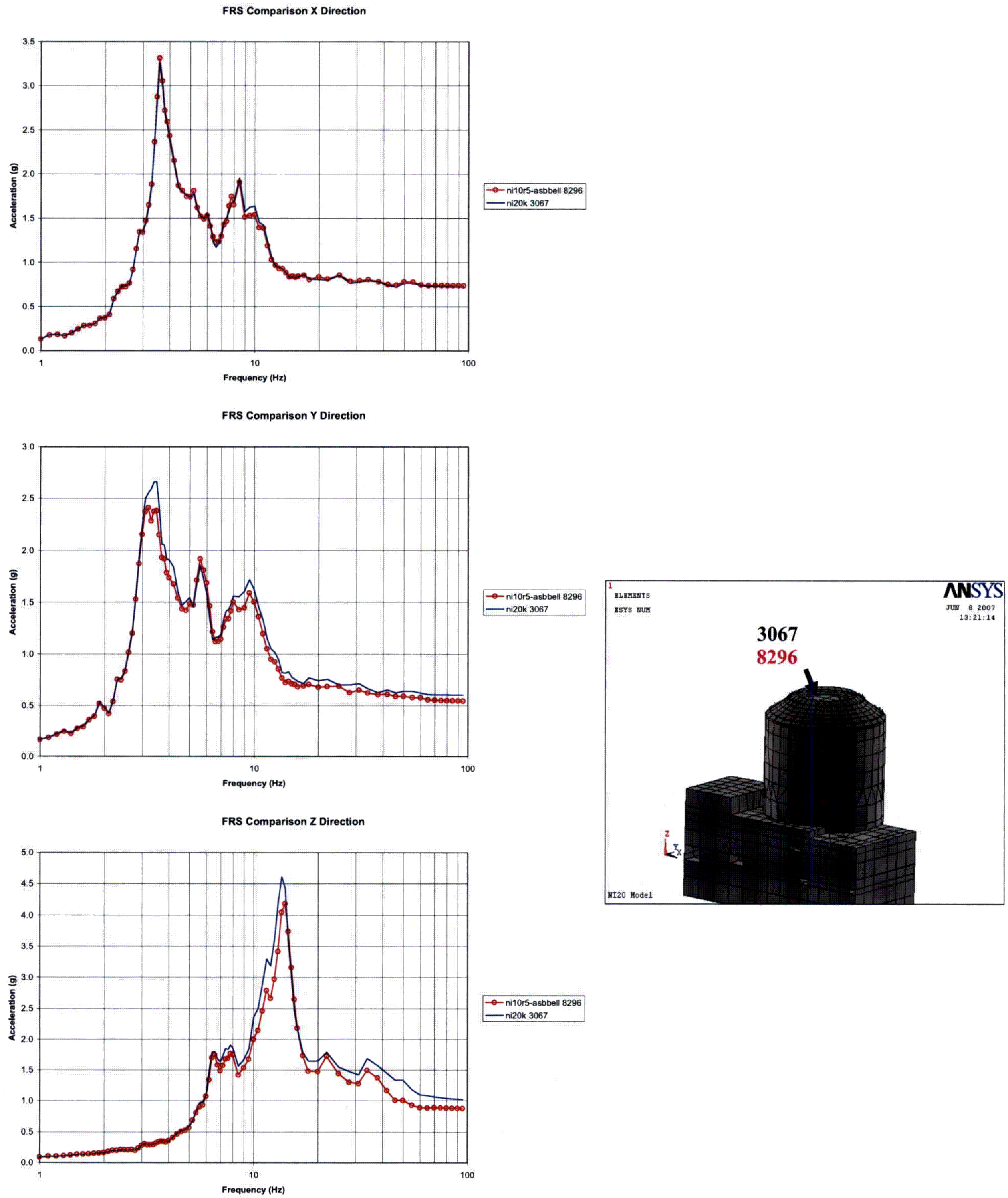


Figure 5.1-1: Comparison of NI20 and NI10 Seismic Response Spectra on roof of Shield Building

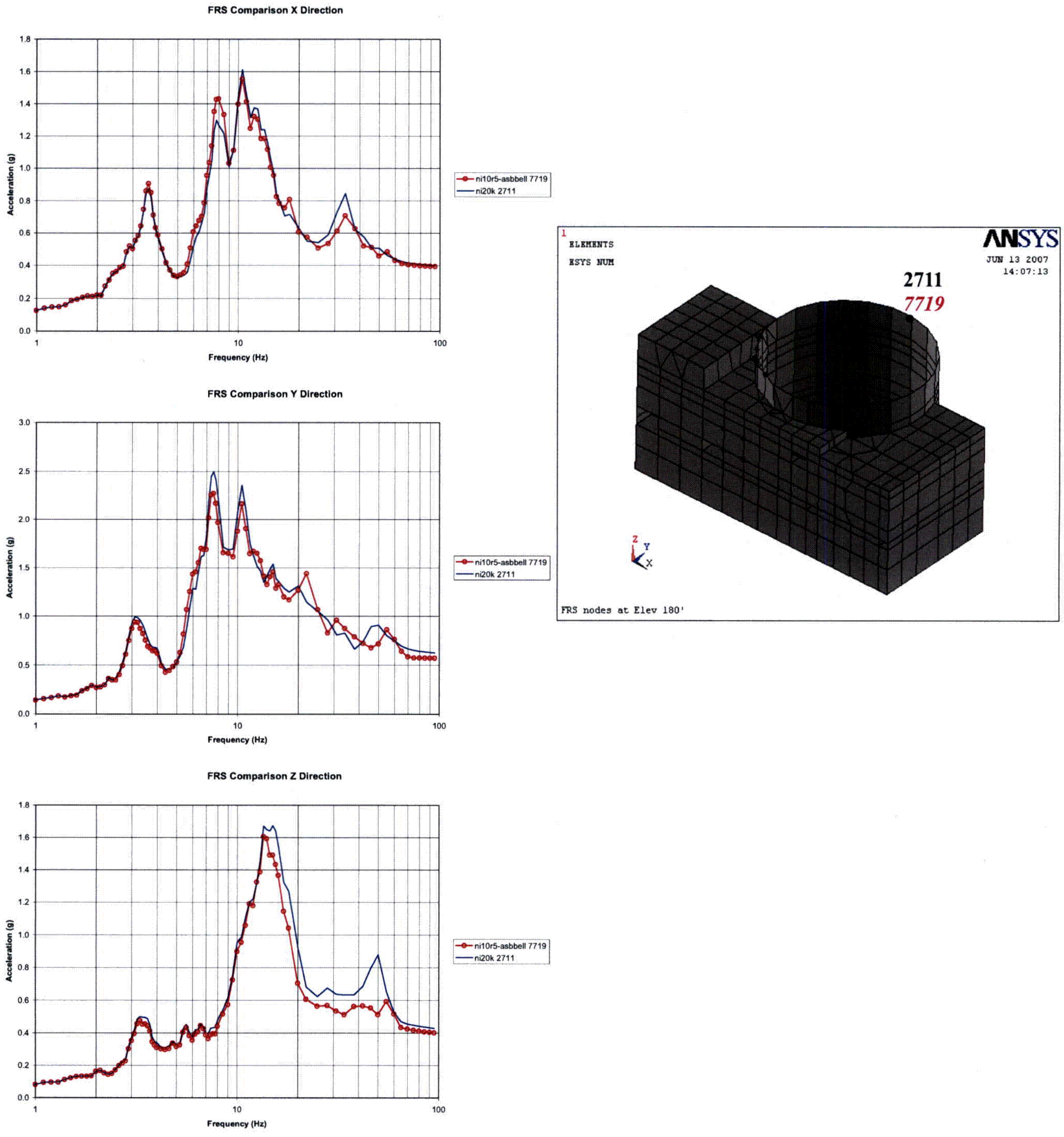
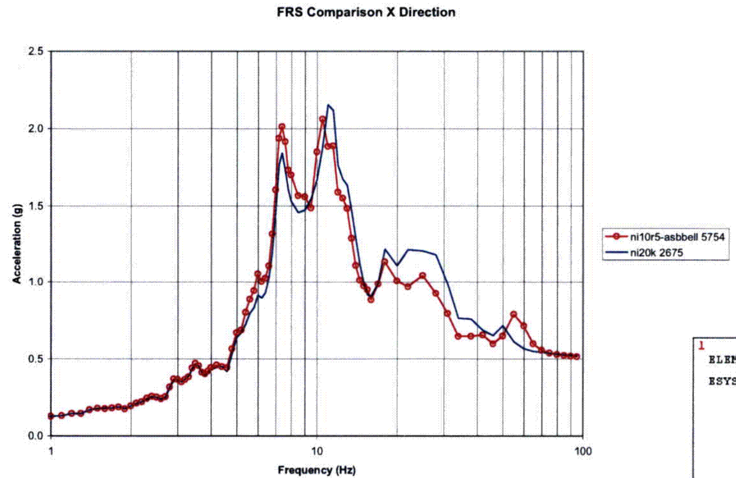
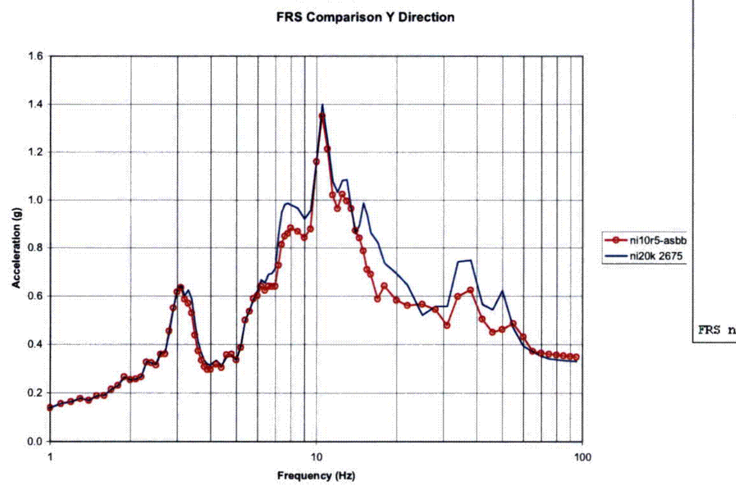
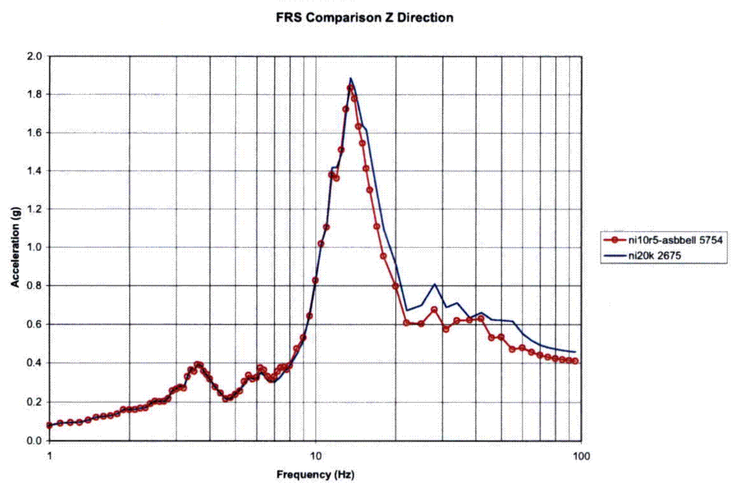


Figure 5.1-2: Comparison of NI20 and NI10 Seismic Response Spectra for West Side of Shield Building







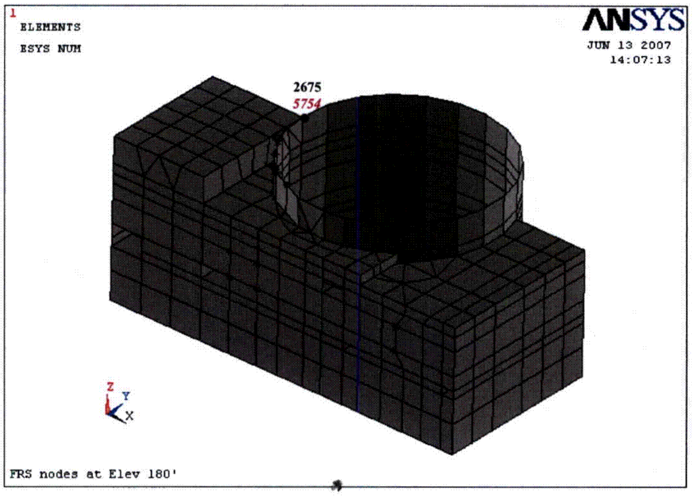


Figure 5.1-3: Comparison of NI20 and NI10 Seismic Response Spectra of South Side of Shield Building

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 5.0-1 through 5.0-6 compare the response spectra 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.

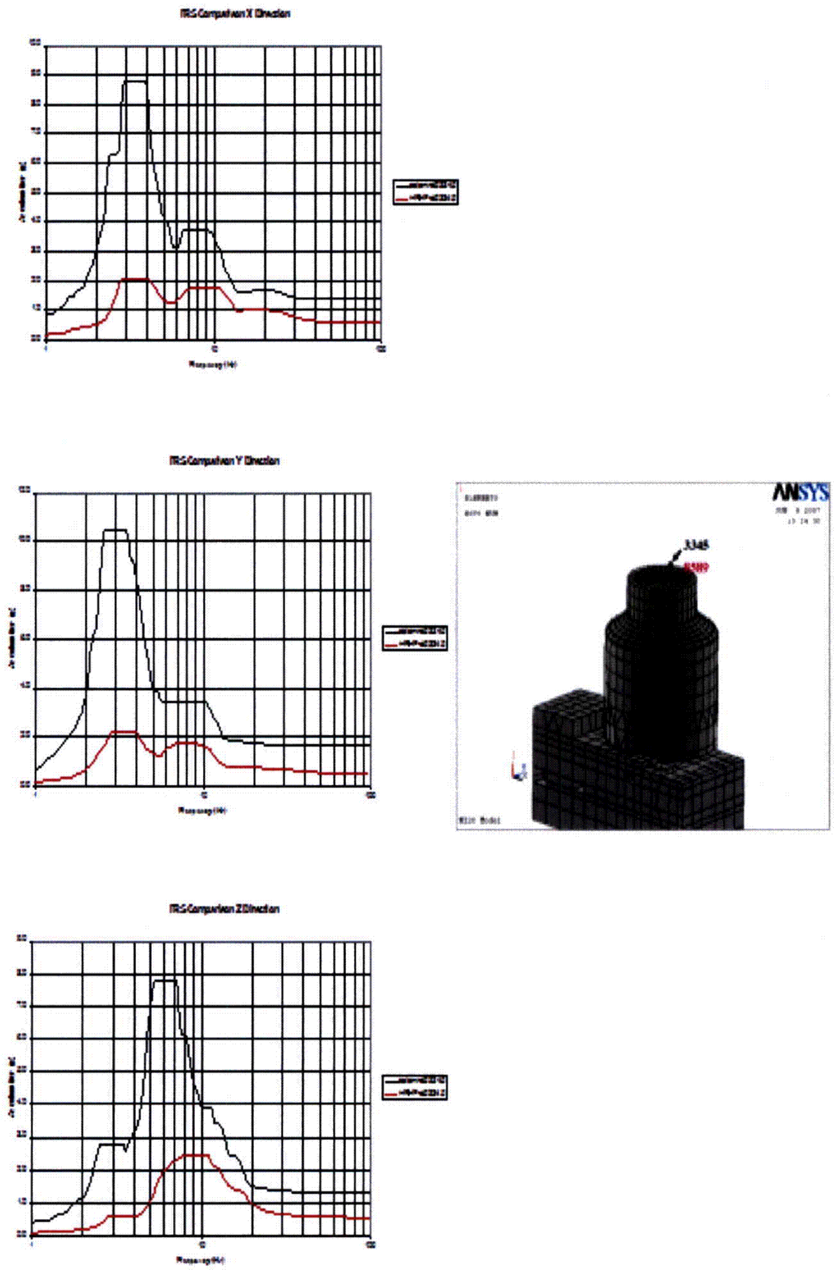


Figure 5.2-1: ASB at Elevation 327.4'

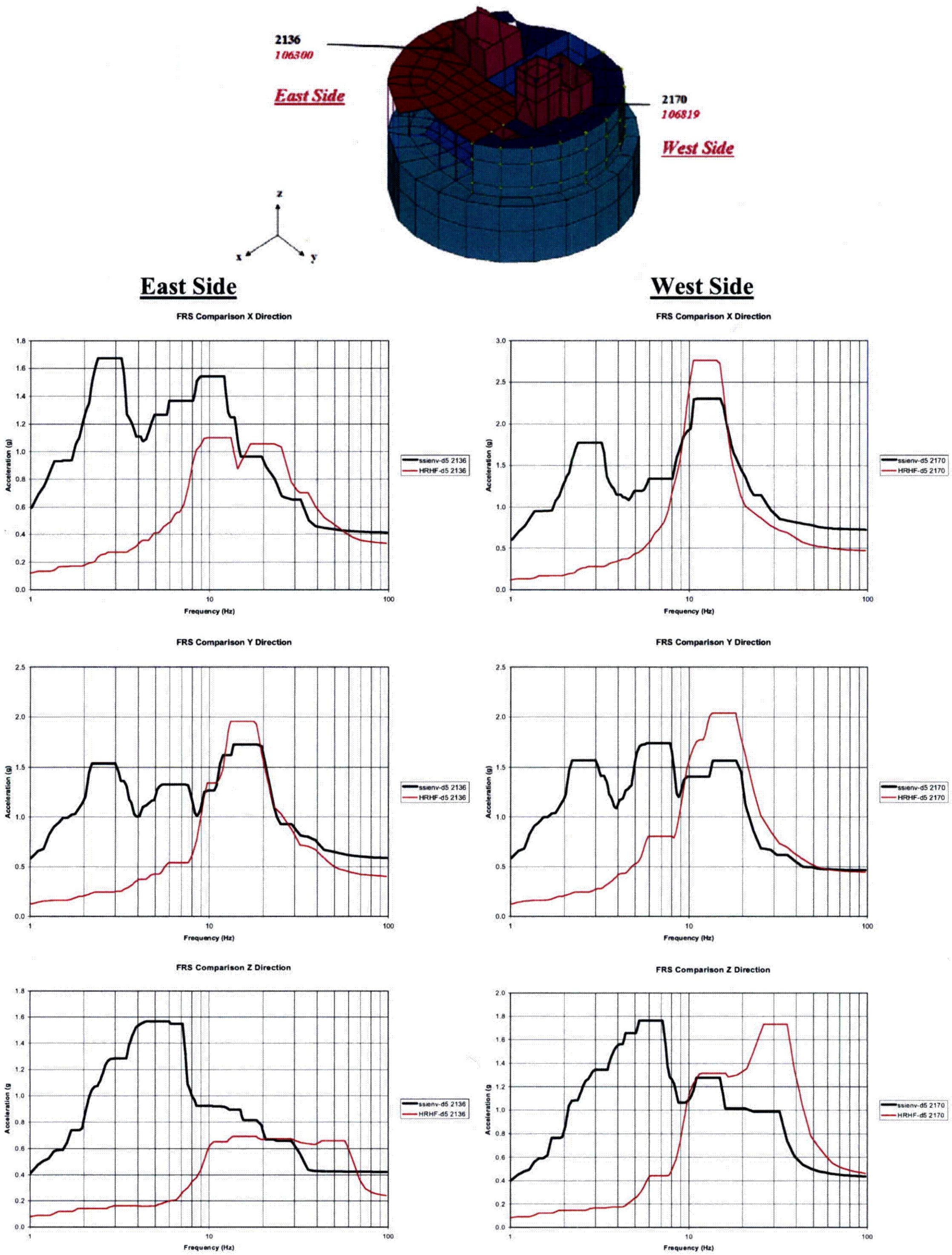


Figure 5.2-2: Containment Operating Floor (Elevation 134.25')

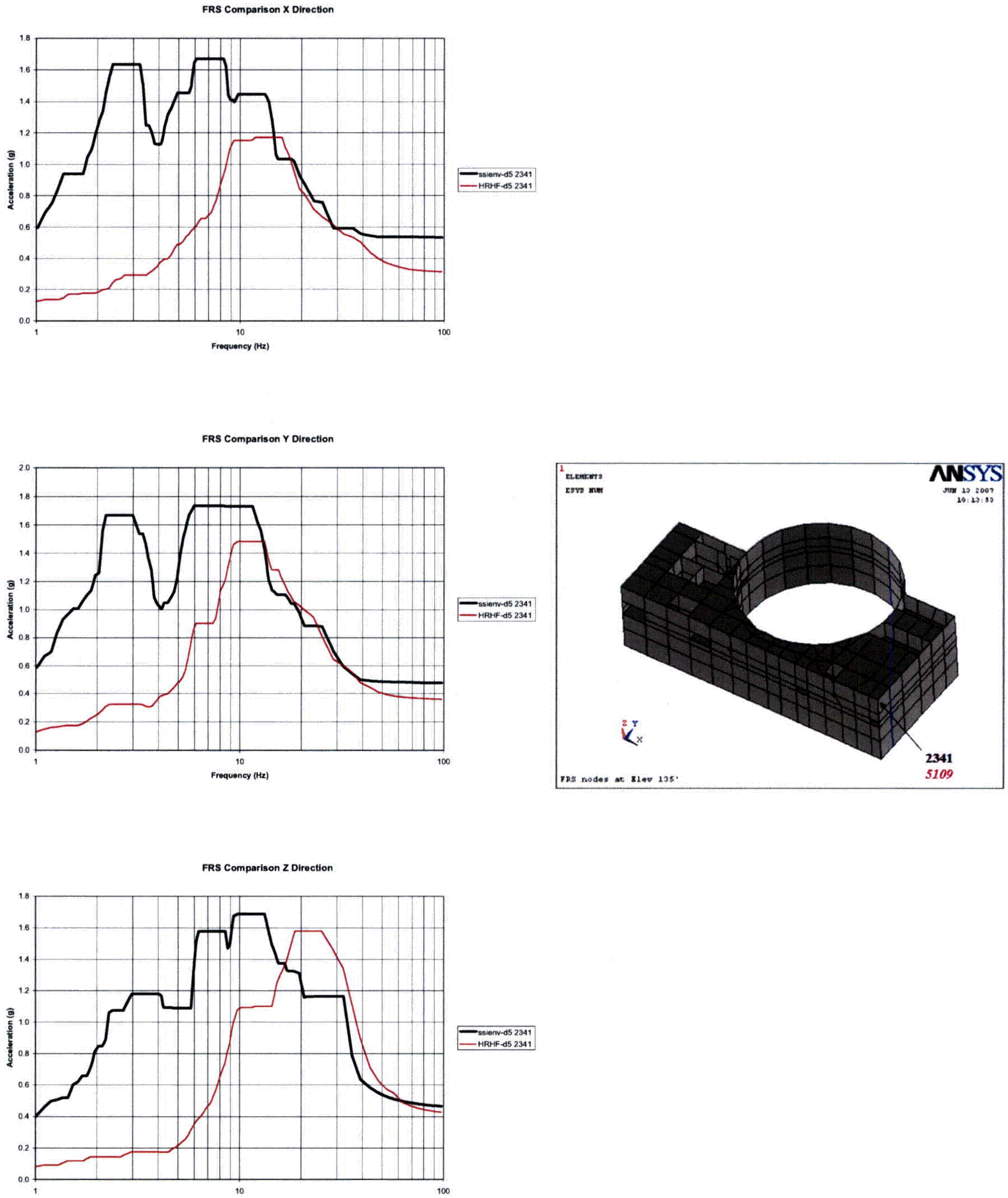
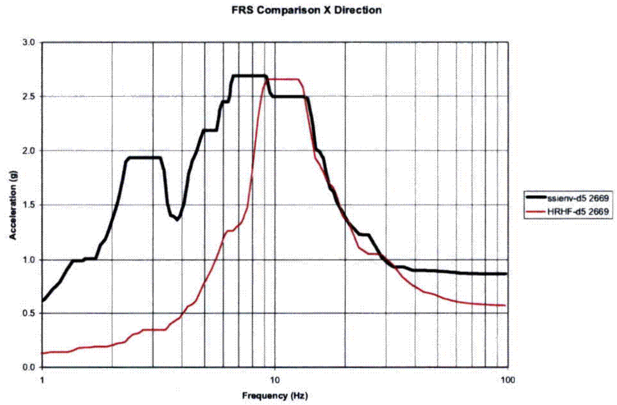
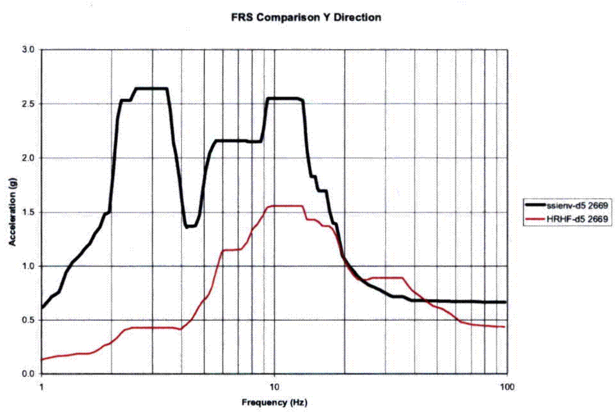
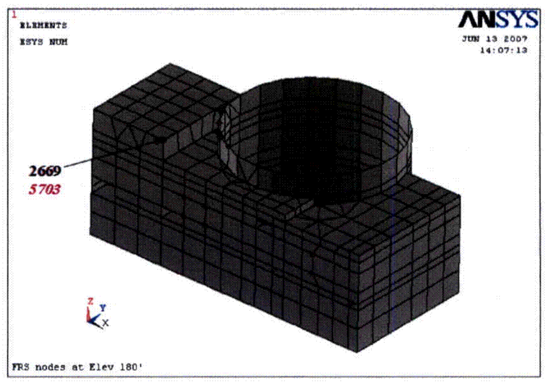


Figure 5.2-3: ASB at Northeast Corner (Elevation 134.5')







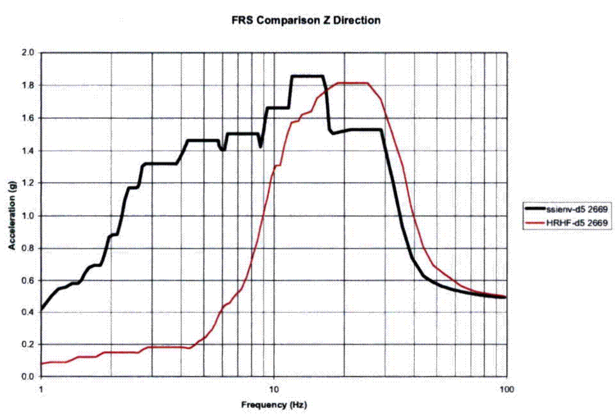


Figure 5.2-4: ASB at Fuel Building Roof (Elevation 179.56')

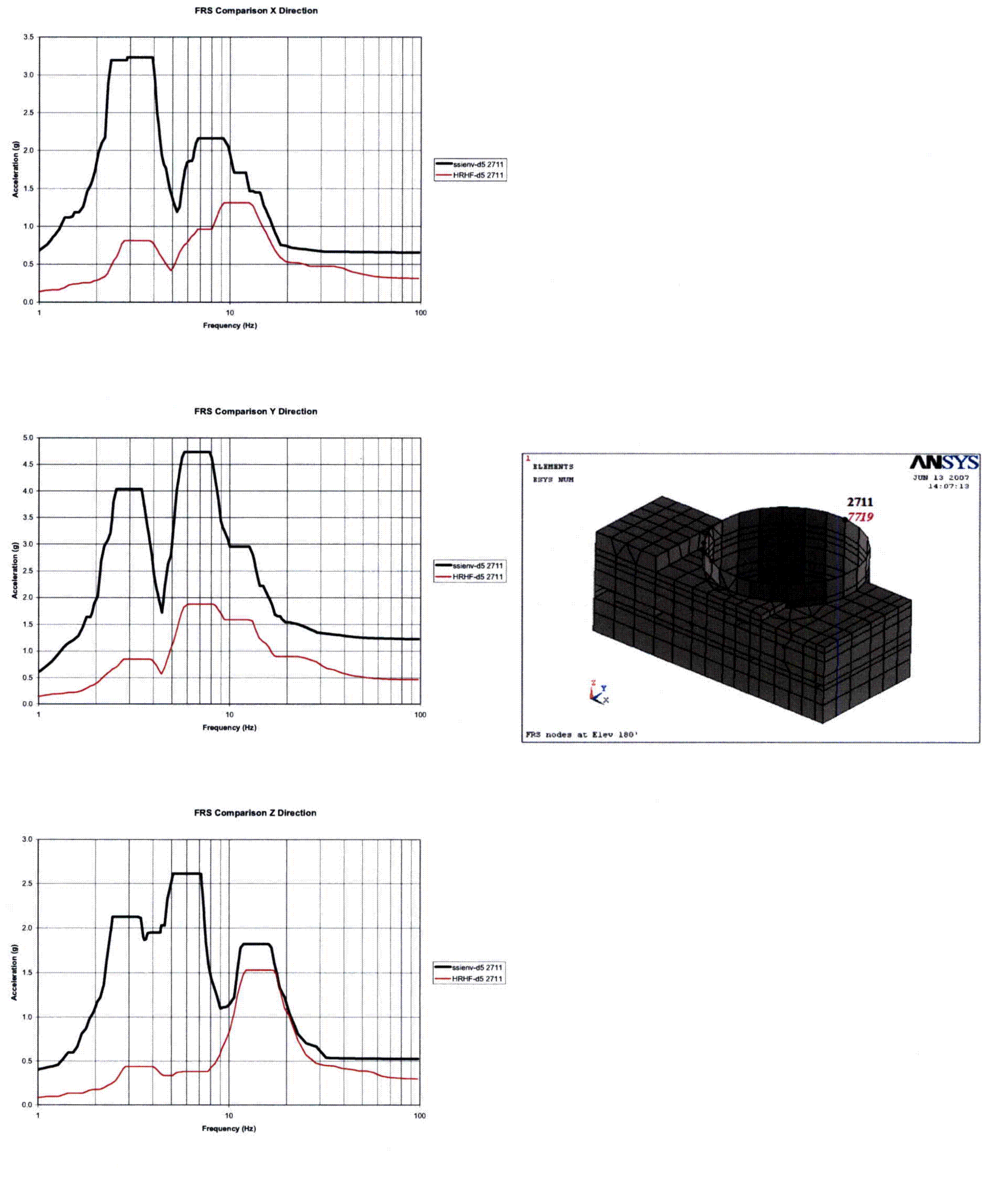


Figure 5.2-5: FRS Nodes – Elevation 180'

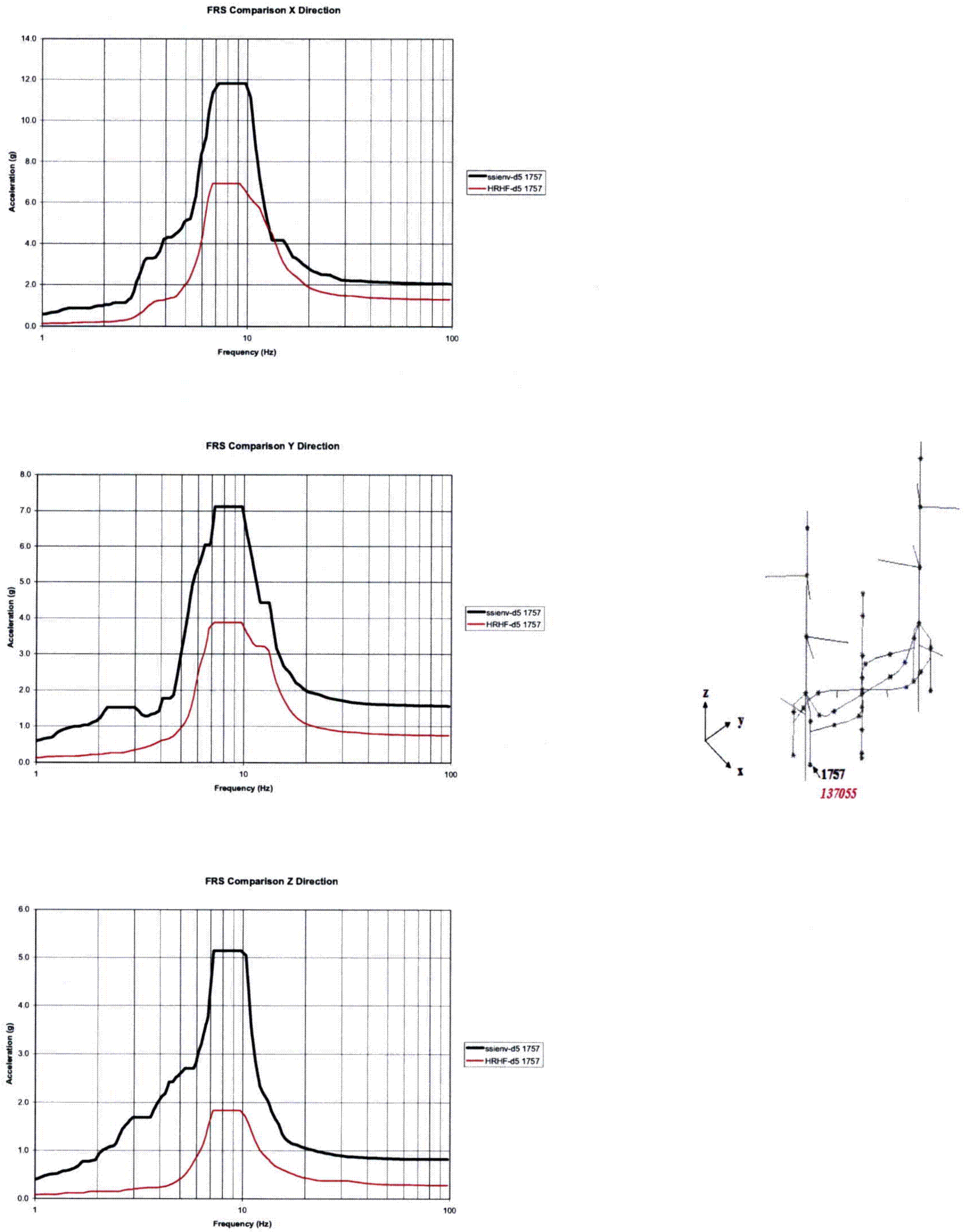


Figure 5.2-6: Reactor Coolant Pump

6.0 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 SSCS, the sample to be evaluated consists of the following:

- Building Structures
  - Auxiliary Building
  - Shield Building
  - Containment Internal Structures (CIS)
- Primary Equipment
  - Reactor Internals
  - Primary Component Supports
  - Reactor Coolant Loop Primary Equipment Nozzles
- Piping Systems – at least two piping analysis packages that might be susceptible to high frequency
- Electro-Mechanical Equipment – Equipment that is potentially sensitive to high frequency input (see Table 6.4.6-1)

These structures, components, 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 high frequency 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' and four at elevation 211'. These locations are located on the east, west, north, and south sides.

Three areas within Containment Internal Structures 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 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 NI building structures are considered qualified for the high frequency input if the seismic loads from the CSDRS envelope those from the high frequency 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 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 high frequency input.

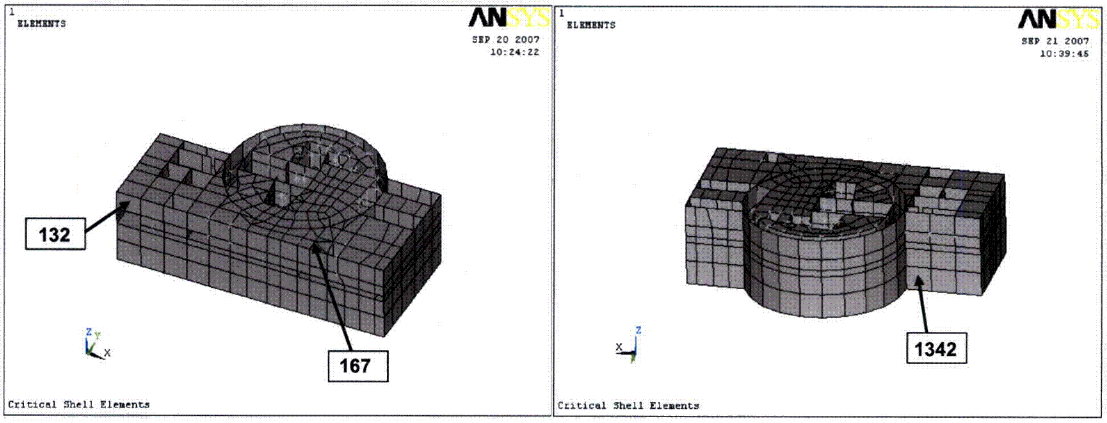


Figure 6.1-1: Auxiliary Building Critical Shell Elements

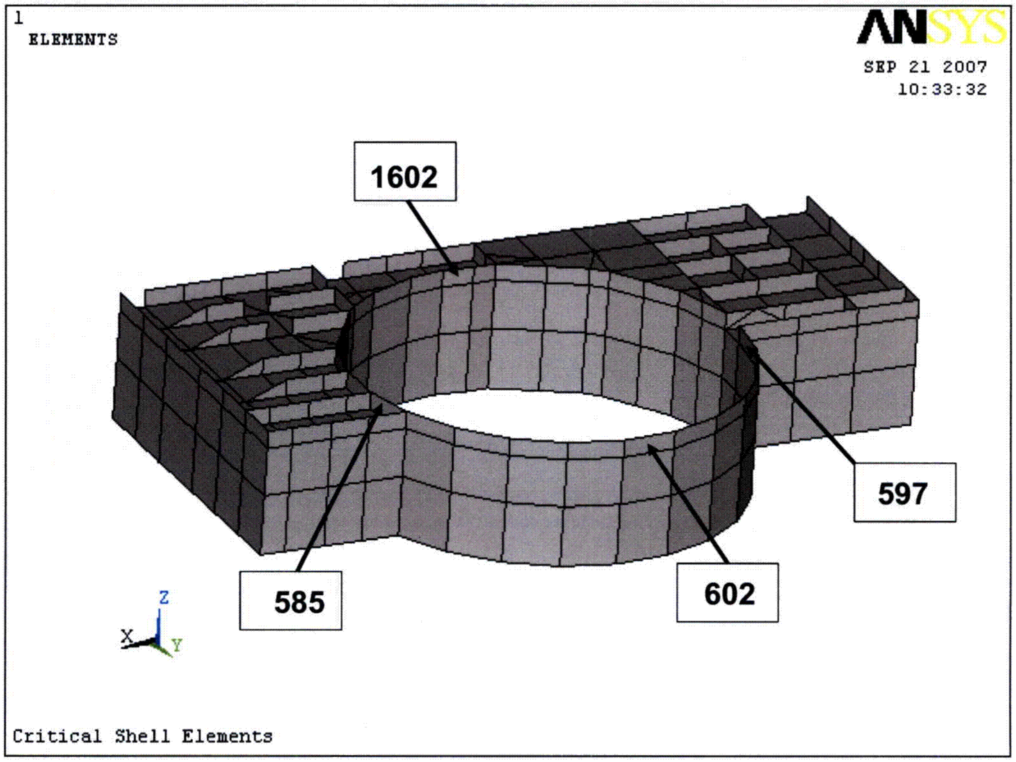


Figure 6.1-2: Shield Building Critical Shell Elements

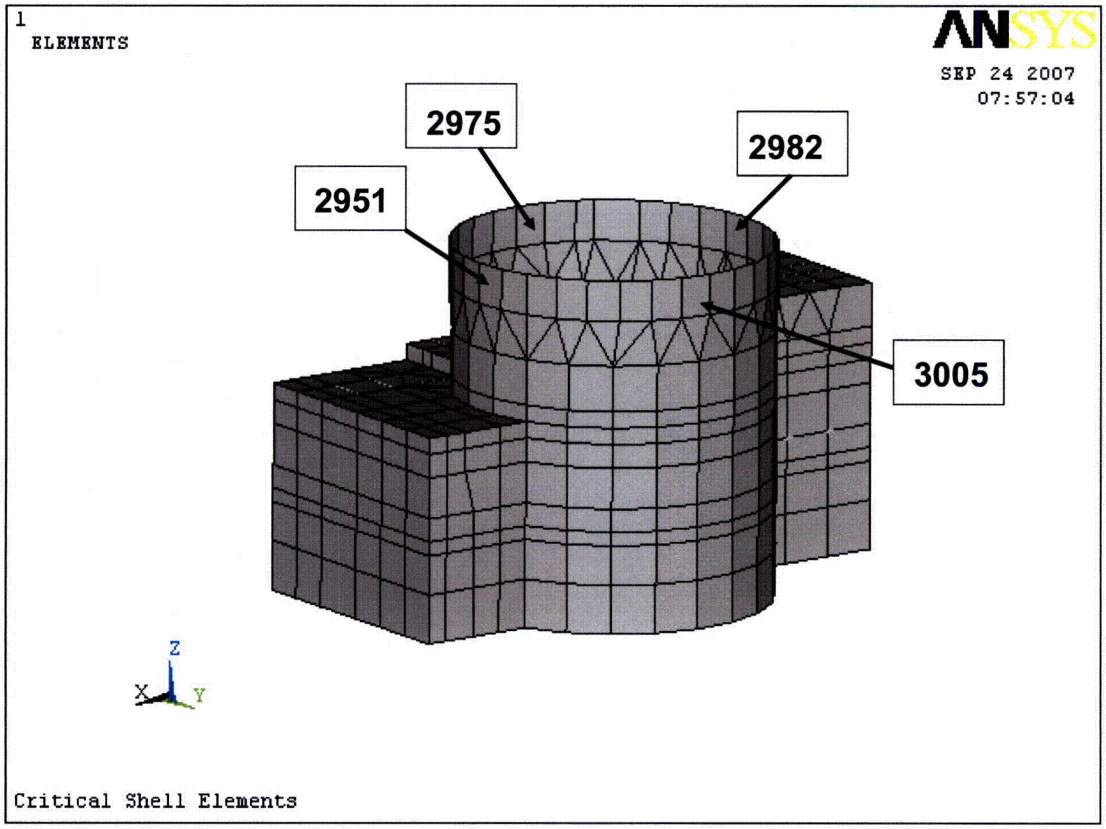


Figure 6.1-3: Shield Building Critical Shell Elements

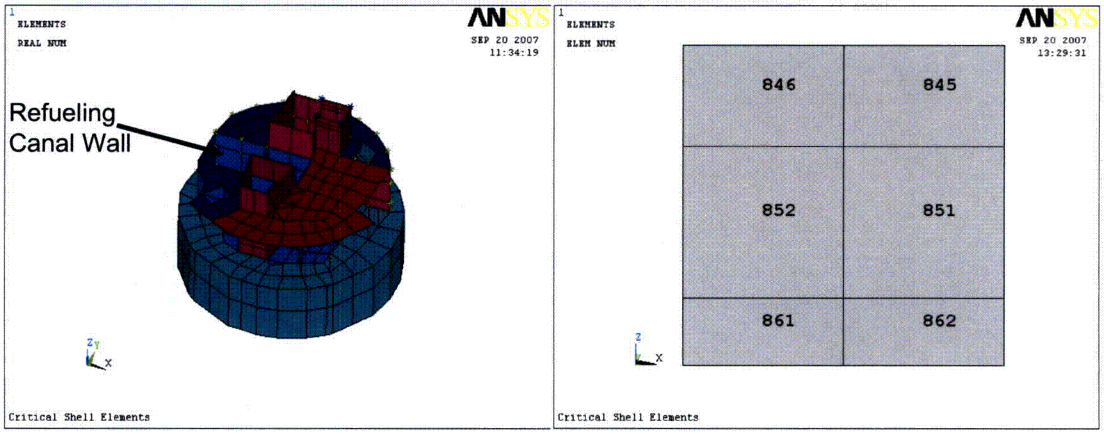


Figure 6.1-4: Refueling Wall Shell Elements

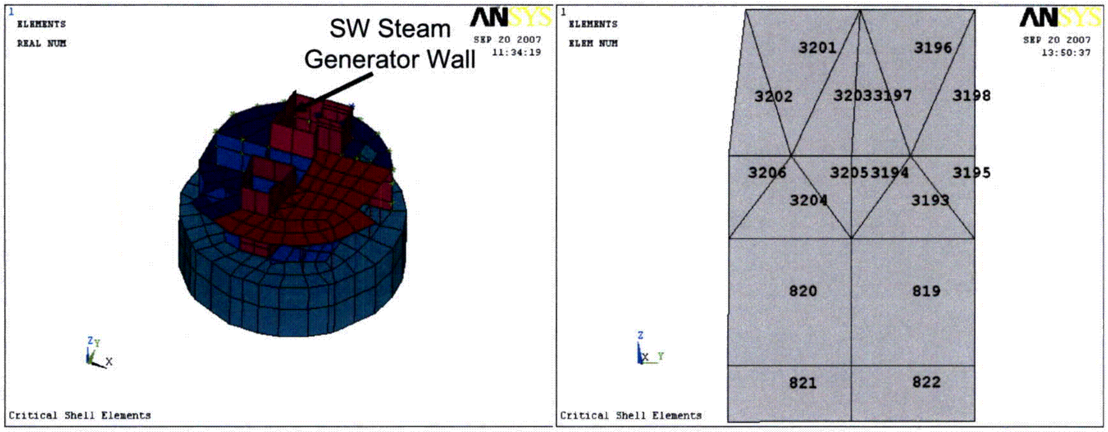


Figure 6.1-5: SW Steam Generator Wall Shell Elements

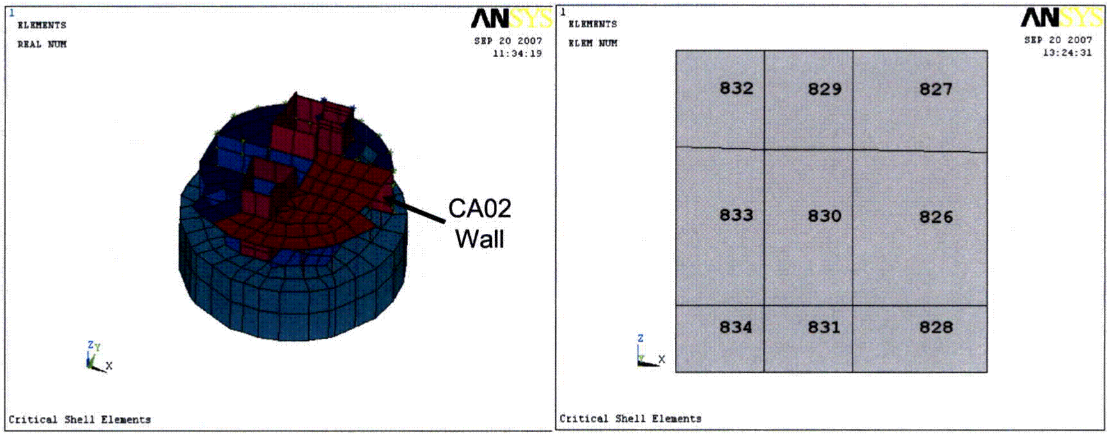


Figure 6.1-6: CA02 Wall Shell Elements

Table 6.1-1: Auxiliary Building Time History Member Force Comparison

	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	TX	TY	TXY	TX	TY	TXY
132	9.2	16.5	10.3	18.8	35.8	26.7
167	2.4	40.1	34.9	15.2	151.4	136.6
1342	27.5	49.9	33.2	107.6	59.9	108.8

Table 6.1-2: Shield Building Time History Member Force Comparison

	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	**TX**	**TY**	**TXY**	**TX**	**TY**	**TXY**
585	8.1	52.8	46.7	31.4	163.2	136.0
597	23.2	67.3	48.3	58.0	248.1	121.2
602	18.2	117.4	57.9	61.5	438.1	216.1
1602	13.2	75.8	23.0	36.5	267.1	40.9

Table 6.1-3: Shield Building Time History Member Force Comparison

	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	**TX**	**TY**	**TXY**	**TX**	**TY**	**TXY**
2951	14.6	47.9	42.6	27.6	192.2	146.7
2975	13.0	44.8	47.3	34.0	153.6	153.7
2982	17.7	53.3	43.8	37.6	208.3	153.7
3005	14.2	48.3	32.4	33.6	160.3	112.9

Table 6.1-4: Refueling Wall Time History Member Force Comparison

	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	**TX**	**TY**	**TXY**	**TX**	**TY**	**TXY**
845	8.1	9.1	23.9	45.3	44.0	46.1
846	8.0	6.4	19.6	30.6	32.7	46.0
851	11.5	12.1	28.4	33.3	32.7	46.1
852	8.2	15.8	25.4	35.9	45.8	45.7
861	15.5	29.6	31.5	47.6	43.3	45.9
862	26.4	24.4	26.1	47.0	36.6	46.0

Table 6.1-5: SW Steam Generator Wall Time History Member Force Comparison

	HRHF (kips/ft)			CSDRS (kips/ft)		
Element #	**TX**	**TY**	**TXY**	**TX**	**TY**	**TXY**
819	7.3	32.3	20.2	30.2	49.6	31.4
820	9.5	10.5	26.2	26.2	21.9	40.3
821	22.2	17.8	18.4	31.1	26	28
822	25.6	57.1	24.2	34.9	77.2	32
3193-3195	25.3	34.4	16.3	30.2	34.9	30.2
3196-3198	14.4	18.6	20	30.2	30.6	31.6
3201-3203	17.1	27.8	19.4	29.9	45.8	32.2
3204-3206	27.5	20.6	17.3	32.8	33.8	30.6

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**
826	4.9	24.1	14.6	26.7	32.6	24
827	3.1	7.4	8.4	20.4	20.4	24
828	10.8	45.8	23.4	20.4	57	33.7
829	6.4	6.3	17.3	20.4	17.2	28.2
830	8.4	18.0	23.2	20.4	26.8	34.8
831	10.0	19.1	24.2	30.8	26.8	34.8
832	10.2	16.8	24.4	19.1	22.7	37.6
833	8.4	13.6	25.2	19.1	26.8	36.7
834	9.5	14.1	25.9	23.7	26.8	38.9

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

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 Internals

The reactor 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 high frequency 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 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. Figure 6.2.1-2 highlights the model of the core barrel, reactor vessel, and the major components within the reactor internals.

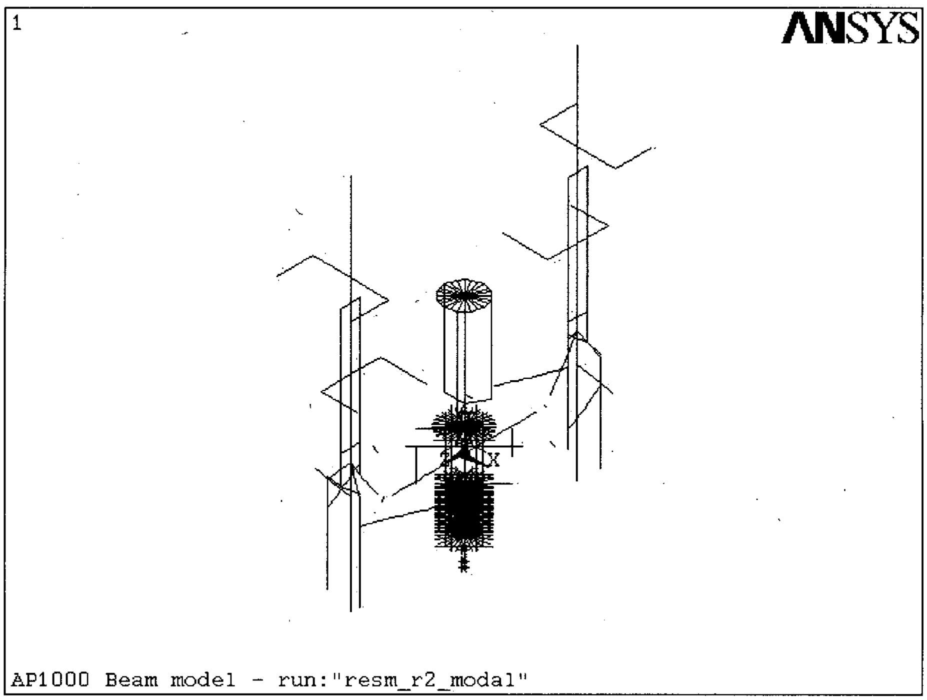


Figure 6.2.1-1: View of Entire System Model including RCL Super Elements

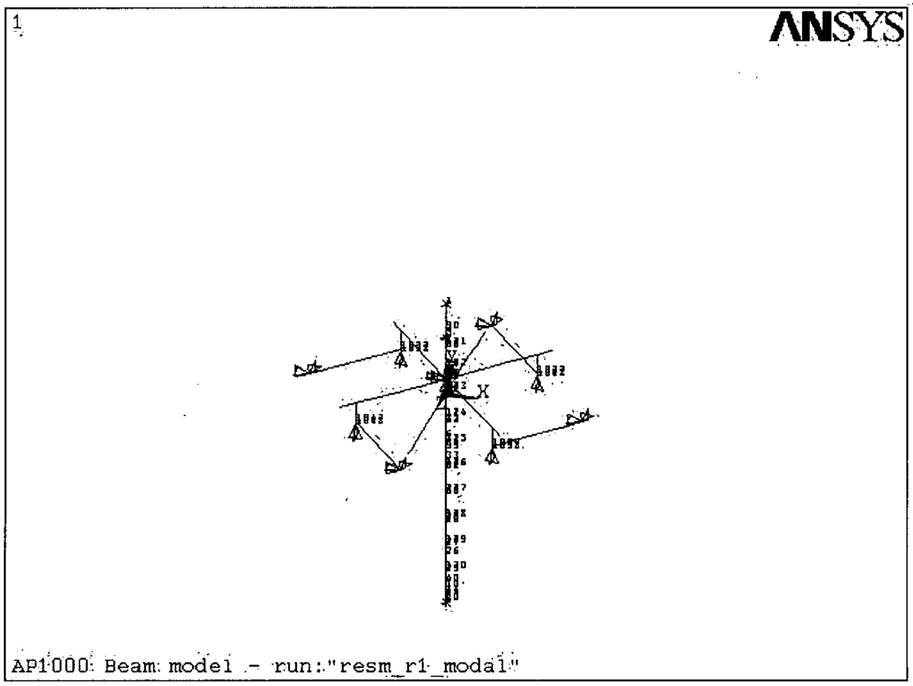


Figure 6.2.1-2: View of Model of Core Barrel, RPV, Inlet Nozzles, Outlet Nozzles, and Supports

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 81% to 29% for the HRHF time history compared to the previous interface loads generated from the CSDRS hard rock time history analysis.

Besides the comparison of the interface loads above, equipment loads in a select list of major internals 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 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, upper bound soft to medium, 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 reactor pressure vessel 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 reactor pressure vessel, 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 reactor coolant loop 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 high frequency 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.

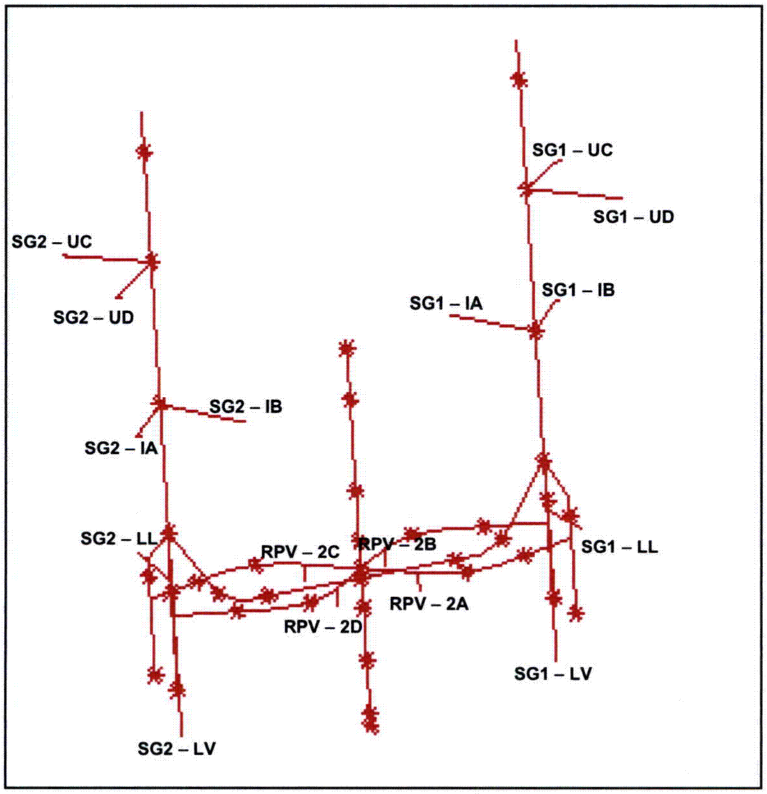


Figure 6.2.2-1: Reactor Coolant Loop Component Supports

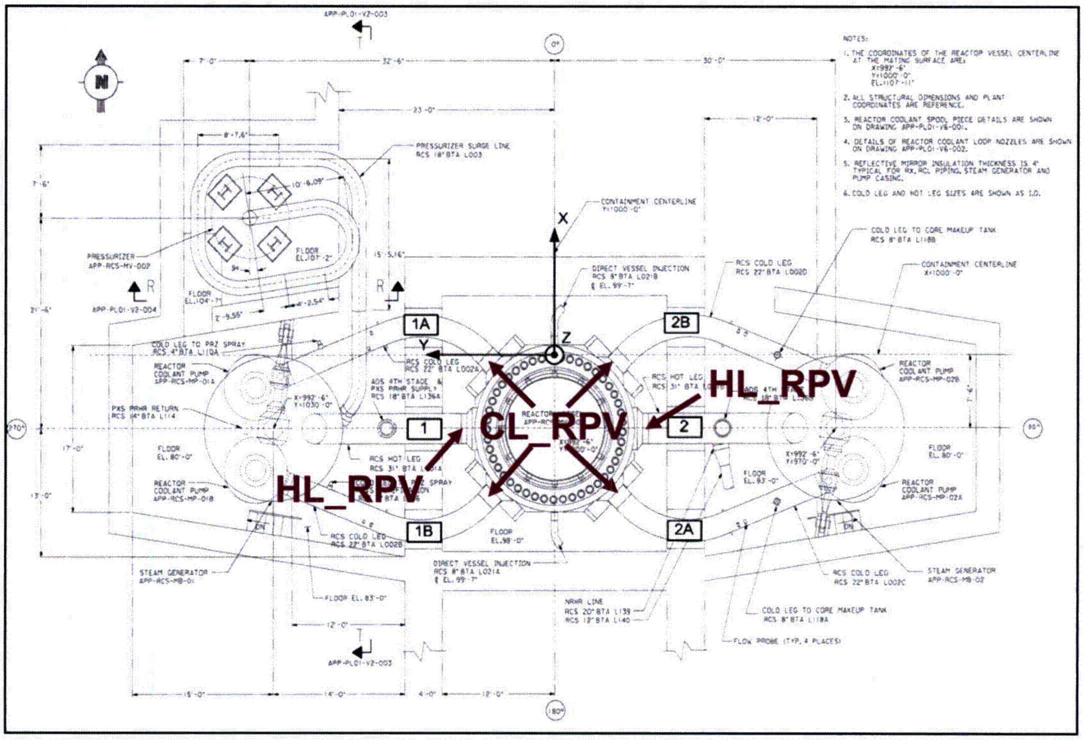


Figure 6.2.2-2: Reactor Coolant Loop Primary Equipment Nozzles

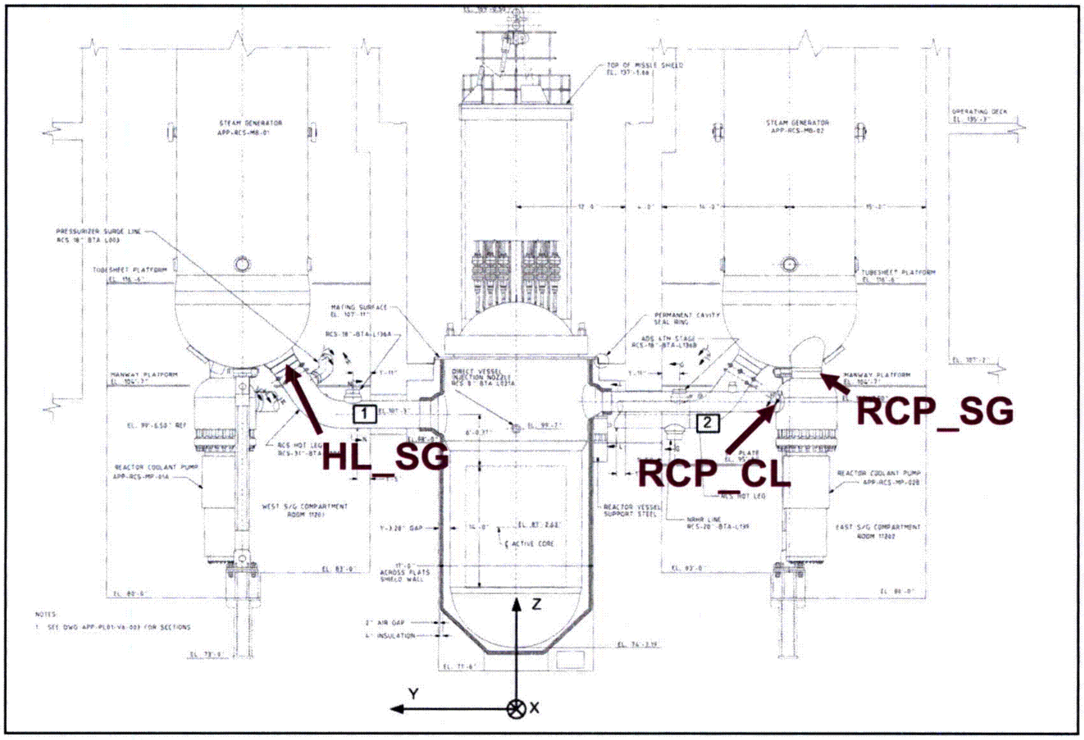


Figure 6.2.2-3: Reactor Coolant Loop Primary Equipment Nozzles

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	642	1447
Vertical	603	992

Table 6.2.2-3: Steam Generator Support Comparison

RCL Support Forces	HRHF Time History Forces (kips)	CSDRS Time History Forces (kips)
Vertical	753	1716
Lower Lateral	486	1060
Intermediate Lateral	341	1134
Upper Lateral	427	913

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	2603	4157
RCP_CL	272	560
CL_RPV	372	706
HL_RPV	712	1684
HL_SG	893	2035

6.3 Piping Systems

To determine the effect of HRHF seismic response spectra on piping, a comparison of stress analyses was made using the PIPESTRESS computer program. The study compared results for HRHF seismic input against the CSDRS basis input. Since piping lines and piping supports are designed throughout the plant using specific guidelines, the stress analysis of a sample of lines is representative of all lines in the plant.

Susceptibility to excitation caused by high frequency input requires a number of factors:

- The local HRHF floor response spectra need to have exceedances relative to AP1000 design spectra in the high frequency range.
- The system must have modes or natural frequencies in the high frequency range.
- The system layout must include valves or other concentrated masses that would require closely spaced supports and therefore, cause high local natural frequencies. This generally yields significant cumulative mass in the high frequency range.

6.3.1 Package Consideration

Packages taken into consideration were those with already completed AP1000 analyses, as outlined in Table 6.3.1-1. Several steps were taken to filter these packages to find the package most susceptible to high frequency excitation. First, a layout of piping lines was inspected to determine if valves or other concentrated masses existed. Then a pair of tasks were performed, in parallel, to further narrow the most eligible packages: 1.) review of the input seismic response spectra for the plant, and 2.) examination of modal mass participation of the systems.

To determine if the initial list of analysis packages was or was not a narrow representation, isometric drawings from the remaining unanalyzed piping analysis packages were reviewed. Piping layout was examined for vertical runs and valves with closely spaced supports. The packages with these vertical runs and valves were then further examined, along with the corresponding local high frequency seismic response spectra. This examination produced no further candidates for analysis.

6.3.1.1 Layout

Layout was examined to determine whether the analyzed piping package could be susceptible to high frequency excitation. The existence of valves usually results in closely spaced supports. Though the mass of such a valve would reduce the natural frequency, the nearby supports could drive that frequency upward.

6.3.1.2 Review of Spectra

The AP1000 CSDRS seismic in-structure response spectra for the HRHF input were reviewed for exceedances of in-structure design in the high frequency region. The location of nodes with exceedances of seismic response spectra in high frequency was examined for patterns across the plant to either highlight or dismiss packages.

The Passive Core Cooling System (PCS) piping packages are located above the Steel Containment Vessel in the Shield Building. This area does not have exceedances in high frequency seismic response spectra, so the PCS packages (APP-PCS-PLA-050, 060, 070, 100, 200, 210, 220, 230, 240, 250, 270, 290, 300, 310, 410, 420, and 430) were eliminated from consideration.

Since the AP1000 is a two loop plant, many of the systems, equipment, and structures are mirrored, at least in functionality, for the two loops. By examining the spectra, pairs of packages were cut in half on the basis of location and the package in the area with greater exceedance was chosen. The area near the West Steam Generator Compartment is stiffer than that of the East Compartment because of the attached Pressurizer Compartment; therefore, seismic response spectra associated with analysis packages in the west side of containment were given more consideration than on the east side of containment. Consequently, Automatic Depressurization Stage 4 East (APP-RCS-PLA-030) was eliminated in favor of the Automatic Depressurization Stage 4 West package (APP-PXS-PLA-030).

Similarly, the offset of containment internal structures stiffens the southern areas of containment. The spectra in these southern areas show greater exceedances than that of the northern areas. Therefore, Direct Vessel Injection B and CMT 2B Supply lines (APP-PXS-PLA-020 and APP-PXS-PLA-060), which are north of the containment internal structures, were eliminated in favor of Direct Vessel Injection A and CMT 2A Supply lines (APP-PXS-PLA-010 and APP-PXS-PLA-050).

6.3.1.3 Modal Analysis

Packages with layouts susceptible to high frequency excitation and exceedances in local seismic spectra had modal extraction run in PIPESTRESS to determine the mass participation factors of the systems. Large equipment, such as heat exchangers and pumps, were decoupled for this analysis to reveal the characteristics of only the system piping. The mass participation factors were then calculated and plotted as a cumulative mass participation against frequency. The cumulative mass represents the accumulated percentage mass of the system excited as the modes are included. Packages determined to be of further interest have significant mass participation among all directions in the high frequency range.

These plots of system behavior were compared against the corresponding plots of local input seismic response spectra. Packages with high frequency behavior shown in the cumulative mass curves but without high frequency input were eliminated. Likewise, packages with high frequency seismic input spectra but without high frequency behavior were eliminated. Only packages with high frequency modal mass participation and corresponding exceedances of seismic response spectra in high frequency were considered.

Table 6.3.1-1 lists the reasons for susceptibility of the analysis packages to high frequency excitation. The table also shows the two packages determined to be most susceptible to high frequency seismic input spectra, and therefore representative of the entire plant; Automatic Depressurization Stage 4 West (APP-PXS-PLA-030) inside containment and Normal RHR Heat Exchanger Inlet and Outlet between containment penetrations (APP-RNS-PLA-170) outside containment.

Table 6.3.1-1: Reviewed Lines

Analysis Package Description	Package Designator	Candidate	Reason
Direct Vessel Injection Line A	APP-PXS-PLA-010	No	Exceedances in high frequency only exist for the Z direction, where modal mass participation is small
Direct Vessel Injection Line B	APP-PXS-PLA-020	No	Because of its location near the northern section of containment, APP-PXS-PLA-010 was considered over APP-PXS-PLA-020.
ADS 4th Stage West and PRHR Supply	APP-PXS-PLA-030	Yes	See section 6.3.2.1
Passive RHR Return Line	APP-PXS-PLA-040	No	Due to the low elevation of APP-PXS-PLA-040, this location does not have exceedances of seismic response spectra in high frequency.
CMT 2A Supply Line	APP-PXS-PLA-050	No	The increases in modal mass and exceedances of high frequency spectra are not aligned at the same frequencies for APP-PXS-PLA-050.
CMT 2B Supply Line	APP-PXS-PLA-060	No	Because of its location near the northern section of containment, APP-PXS-PLA-050 was considered over APP-PXS-PLA-060.
PSADS System (Lower Tier/Upper Tier)	APP-RCS-PLA-010	No	APP-RCS-PLA-010 does not contain significant X and Y modal mass participation in the high frequency region. Modal mass participation in the Z direction is similar to that of the chosen packages.
ADS 4th Stage East	APP-RCS-PLA-030	No	Because of its location in the West Steam Generator and Pressurizer Compartments, APP-PXS-PLA-030 was considered over APP-RCS-PLA-030.
Pressurizer Surge Line	APP-RCS-PLA-040	No	APP-RCS-PLA-040 contains no valves.
Reactor Coolant Loop Piping	APP-RCS-PLA-050	No	This analysis is reviewed in section 6.2 of this report.
Normal RHR Suction Line	APP-RNS-PLA-010	No	APP-RNS-PLA-010 lies in a location that contains no exceedances in the high frequency region
Spent Resin from Cont. Pen.	APP-CVS-PLA-520	No	APP-CVS-PLA-520 lies in the northern half of the Auxiliary Building, where the spectra does not contain exceedances in high frequency.
From SCV Pen. to CVS-12A0007	APP-CVS-PLA-530	No	APP-CVS-PLA-530 lies in the northern half of the Auxiliary Building, where the spectra does not contain exceedances in high frequency.
Hydrogen Supply from CVS-12A0022	APP-CVS-PLA-700	No	APP-CVS-PLA-700 lies in the northern half of the Auxiliary Building, where the spectra does not contain exceedances in high frequency.
HX Inlet and Outlet between P19 & P20	APP-RNS-PLA-170	Yes	See section 6.3.2.2
Main Steam Line A	APP-SGS-PLA-030	No	The valves of these lines reside outside containment in the northern half of the Auxiliary Building, where the spectra does not contain exceedances in high frequency.
Main Steam Line B	APP-SGS-PLA-040	No	
Blowdown Line B from Cont. Pen. to TB	APP-SGS-PLA-090	No	APP-SGS-PLA-090/100 does not contain any valves.
Blowdown Line A from Cont. Pen. to TB	APP-SGS-PLA-100	No	
From SCV Pen. to VFS-12A2004	APP-VFS-PLA-010	No	The increases in modal mass and exceedances in high frequency spectra are not aligned at the same frequencies for APP-VFS-PLA-010/030.
From Cont. Pen. to past Valve V010	APP-VFS-PLA-030	No	
From Cont. Pen. to past Valve V024	APP-WLS-PLA-520	No	The valves of APP-WLS-PLA-520 reside outside containment in the northern half of the Auxiliary Building, where the spectra does not contain exceedances in high frequency.
Supply to Distribution Bucket (Embed)	APP-PCS-PLA-050	No	The PCS system is located at the top of the Shield Building. The spectra at these elevations do not contain exceedances in high frequency.
Recirculation Line inside PCS Tank	APP-PCS-PLA-060	No	
Recirculation Line inside PCS Tank	APP-PCS-PLA-070	No	
PCS Room 12306 (Auxiliary Building)	APP-PCS-PLA-100	No	
Overflow inside PCS Tank	APP-PCS-PLA-200	No	
Vent Line inside PCS Tank	APP-PCS-PLA-210	No	

Room 12701 PCS Tank Vent	APP-PCS-PLA-220	No	
Vent Line inside PCS Tank	APP-PCS-PLA-230	No	
Room 12701 PCS Tank Vent	APP-PCS-PLA-240	No	
Discharge Line inside PCS Tank	APP-PCS-PLA-250	No	
Discharge Line inside PCS Tank	APP-PCS-PLA-270	No	
Discharge Line inside PCS Tank	APP-PCS-PLA-290	No	
Instrumentation Line	APP-PCS-PLA-300	No	
Instrumentation Line	APP-PCS-PLA-310	No	
Overflow Line from PCS Tank	APP-PCS-PLA-410	No	
Supply to Distribution Bucket	APP-PCS-PLA-420	No	
Auxiliary Supply to Distribution Bucket	APP-PCS-PLA-430	No	
From RNS-12A2037 to Spent Fuel Pool	APP-RNS-PLA-100	No	The modal mass and high frequency spectra are not aligned at the same frequencies for APP-RNS-PLA-100.

The two packages determined to be most susceptible to high frequency excitation are Automatic Depressurization System 4th West (APP-PXS-PLA-030) inside containment and Normal RHR Heat Exchanger Inlet and Outlet between containment penetrations (APP-RNS-PLA-170) outside containment. These two packages have layout sensitive to high frequency excitation and local seismic response spectra with exceedances in high frequency.

6.3.2 Analysis of Selected Candidates

6.3.2.1 Automatic Depressurization System 4th Stage West and Passive RHR Supply (APP-PXS-PLA-030)

APP-PXS-PLA-030 has no flexible equipment, so seismic response spectra at 5% damping was used.

APP-PXS-PLA-030 is routed through the West Steam Generator and Pressurizer compartments, which are stiff and result in seismic response spectra with exceedances in high frequency. Figures 6.3.2.1-1 through 6.3.2.1-3 are the plots of local AP1000 design seismic response spectra and HRHF input seismic response spectra with 5% damping and incoherence. The dashed line represents the envelope of high frequency input seismic response spectra used at the multiple support levels.

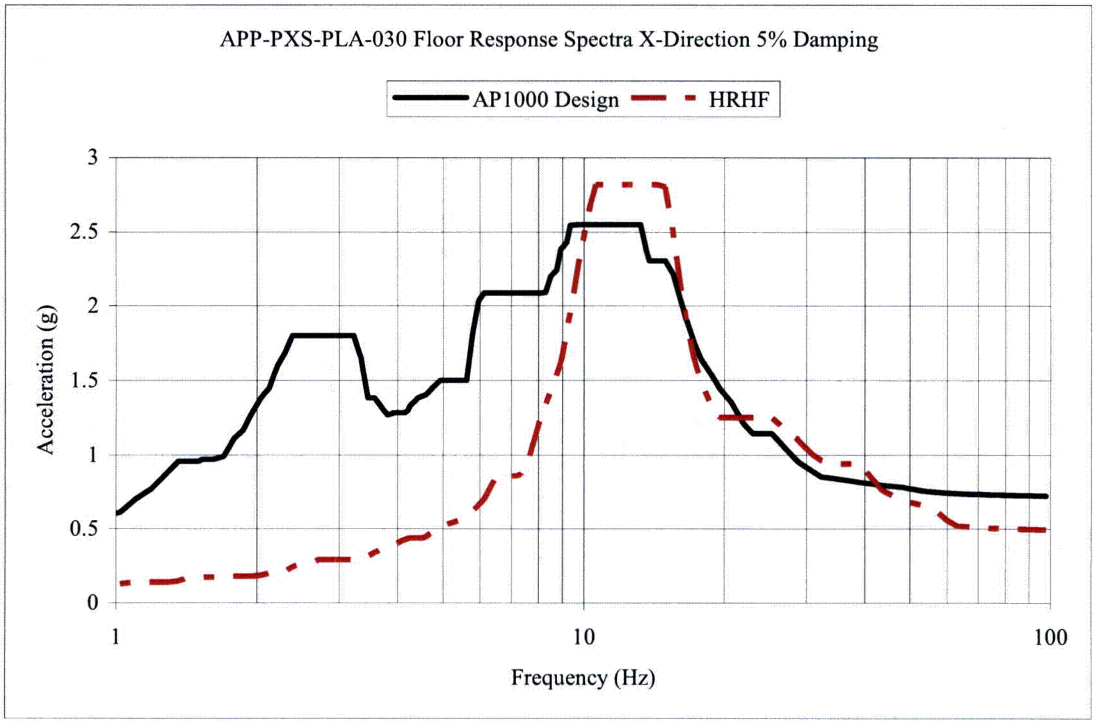


Figure 6.3.2.1-1: APP-PXS-PLA-030 Floor Response Spectra X-Direction

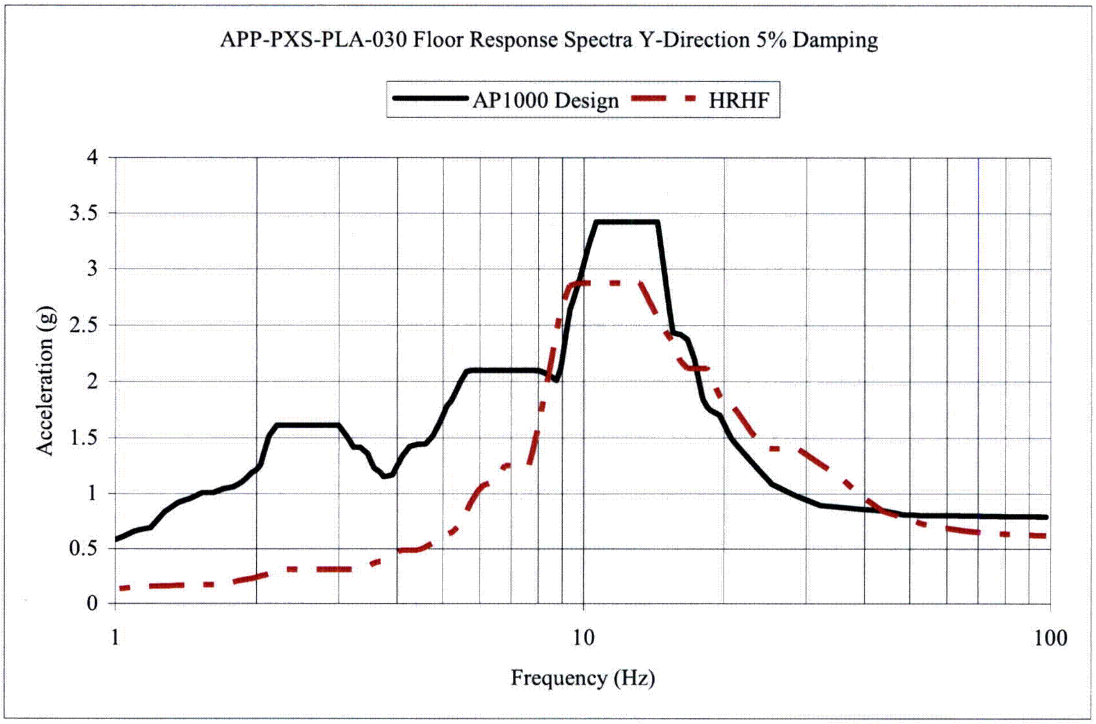


Figure 6.3.2.1-2: APP-PXS-PLA-030 Floor Response Spectra Y-Direction

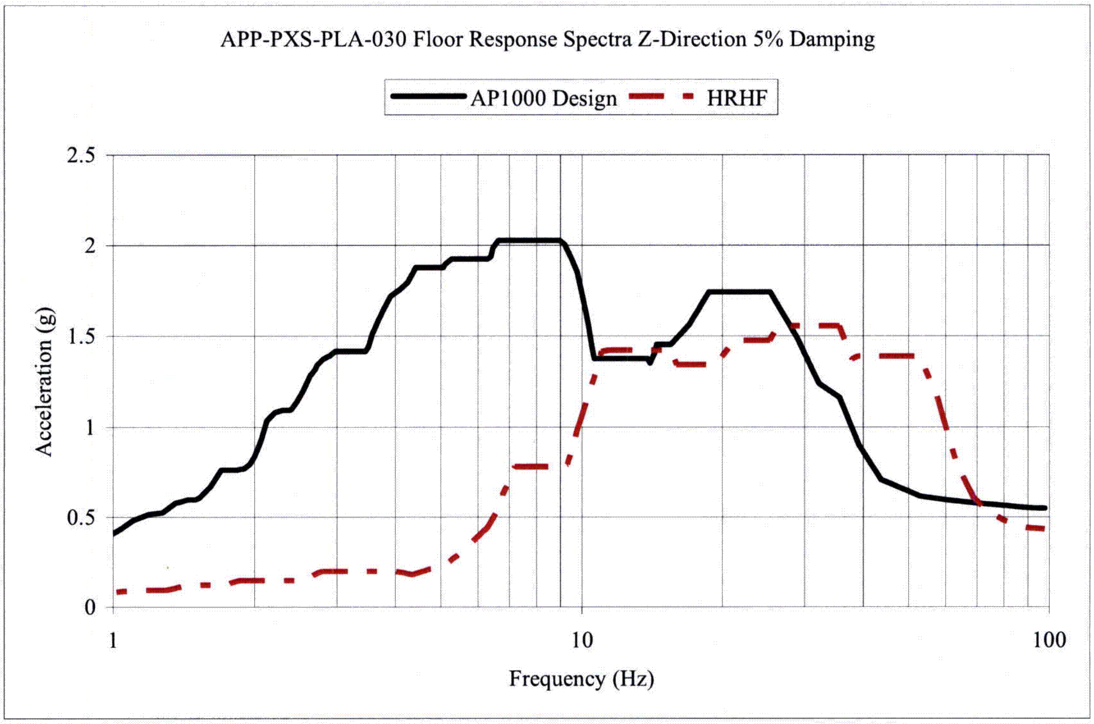


Figure 6.3.2.1-3: APP-PXS-PLA-030 Floor Response Spectra Z-Direction

The layout of APP-PXS-PLA-030 is potentially sensitive to high frequency response; the package spans a very small distance, yet has sixteen supports and anchors. The package also has five large valves, three of which are greater than 10,000 lbs. Figure 6.3.2.1-4 shows the cumulative mass of the analysis package; thirty, sixty, and eighty mass percent of the package (in the X, Y, and Z directions, respectively) is active in the high frequency range.

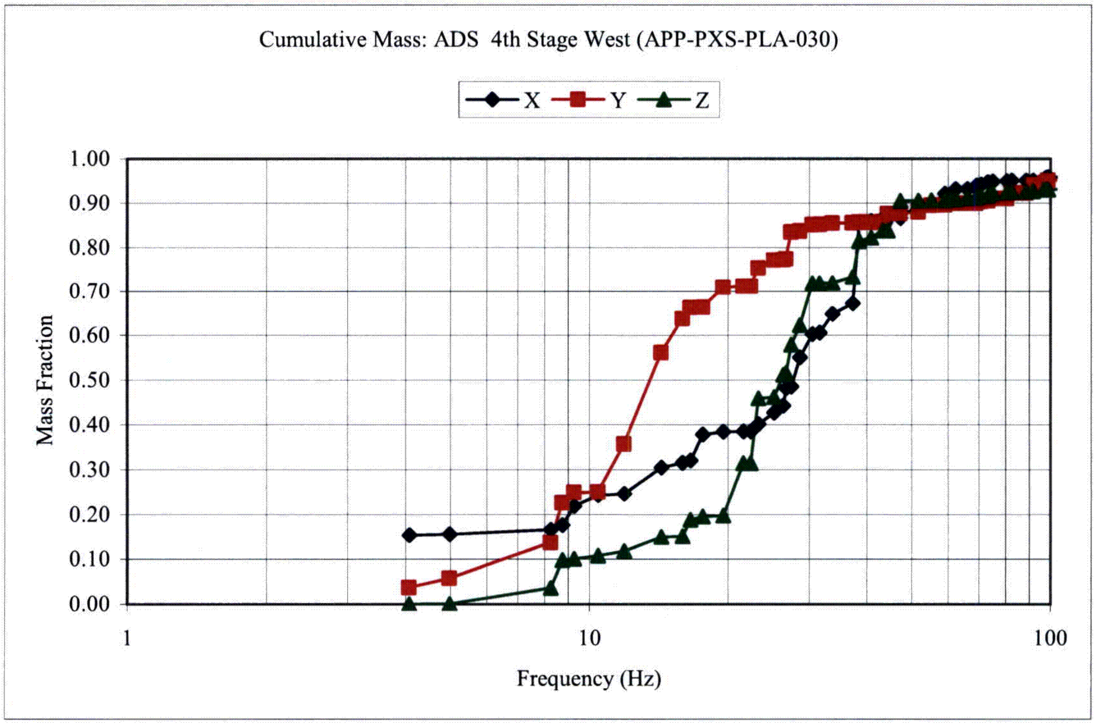


Figure 6.3.2.1-4: APP-PXS-PLA-030 Cumulative Mass: ADS 4th Stage West

Due to exceedances of high frequency seismic response spectra and its high frequency sensitive layout, APP-PXS-PLA-030 is representative of a piping package most susceptible to excitation caused by high frequency input inside containment.

6.3.2.2 Normal RHR Heat Exchanger Inlet and Outlet (APP-RNS-PLA-170)

APP-RNS-PLA-170 has two heat exchangers, ME-01A and B, which are flexible equipment, so seismic response spectra at 4% damping was used.

APP-RNS-PLA-170 resides entirely in the Auxiliary Building except for the two containment penetrations, and spans multiple elevations and causes input seismic response spectra with exceedances in high frequency. Figures 6.3.2.2-1 to 6.3.2.2-3 are plots of local AP1000 design seismic response spectra and HRHF seismic response spectra with 4% damping and incoherence. The dashed line represents the envelope of high frequency input seismic response spectra used at the multiple support levels.

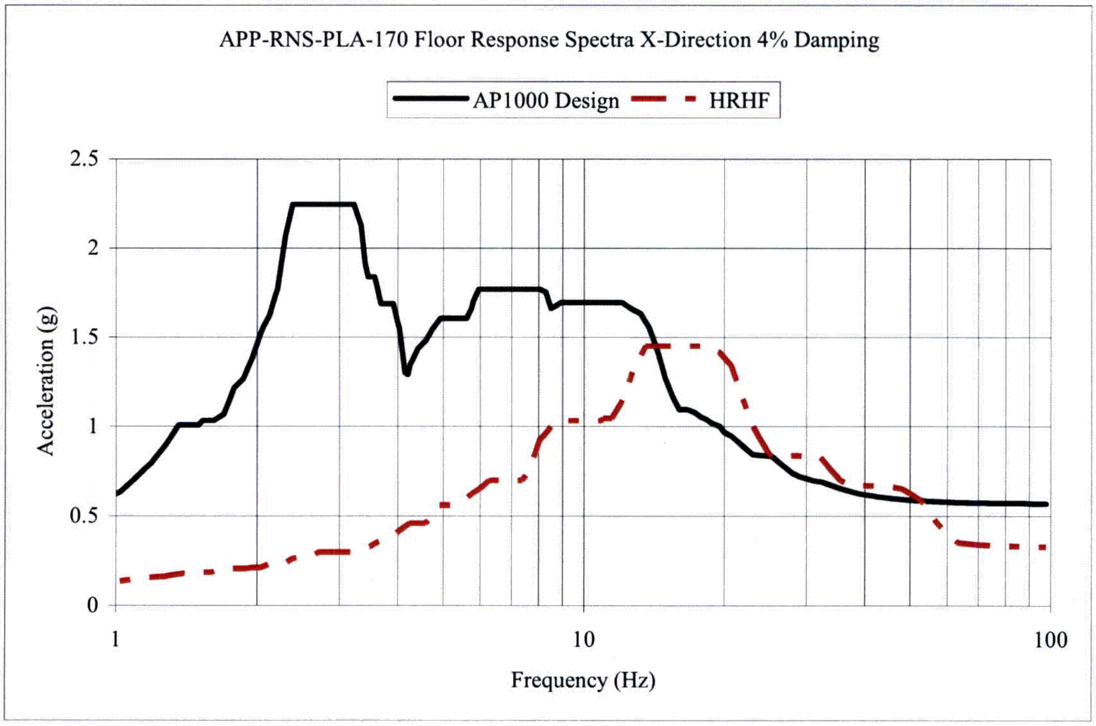


Figure 6.3.2.2-1: APP-RNS-PLA-170 Floor Response Spectra X-Direction

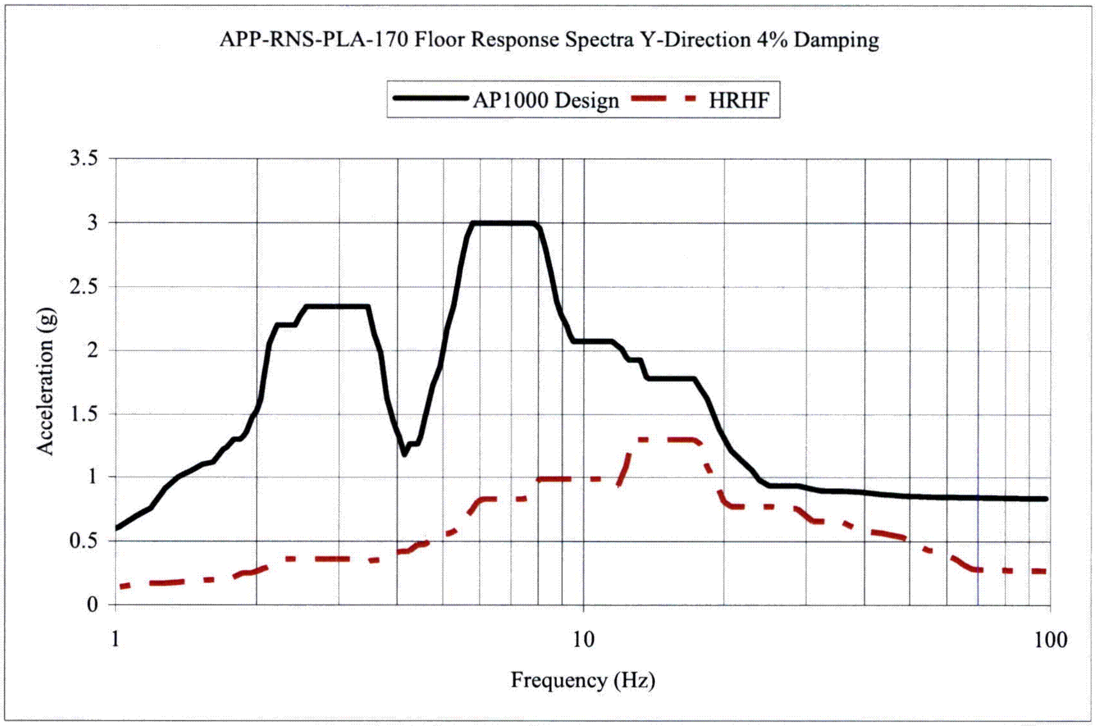


Figure 6.3.2.2-2: APP-RNS-PLA-170 Floor Response Spectra Y-Direction

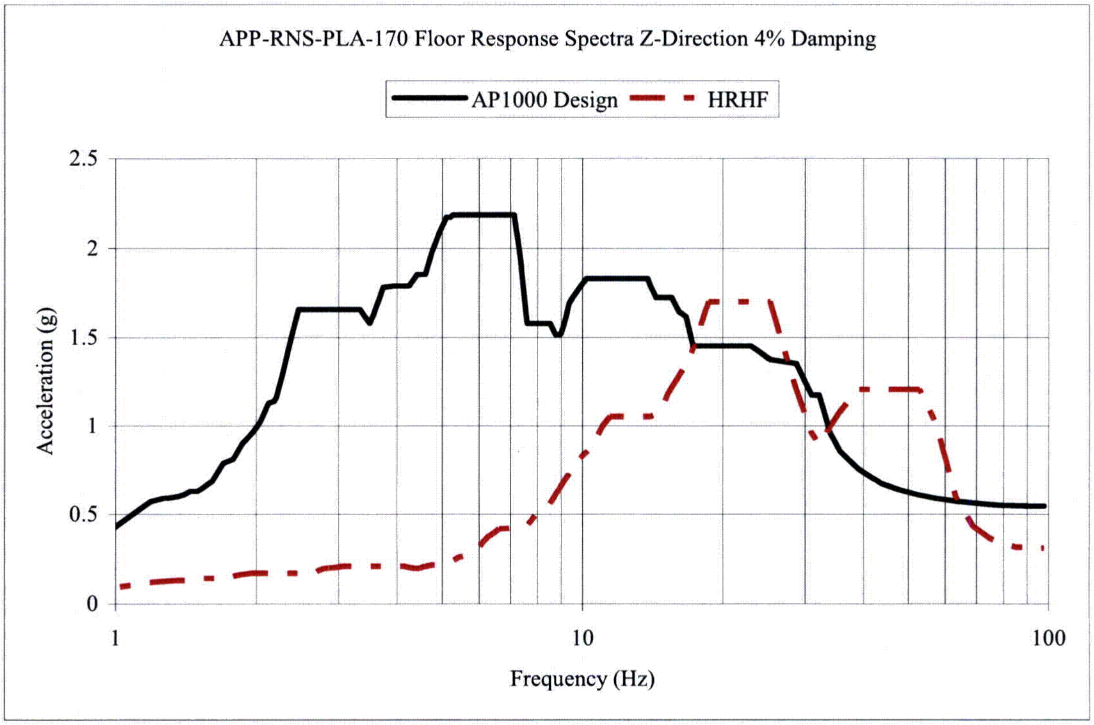


Figure 6.3.2.2-3: APP-RNS-PLA-170 Floor Response Spectra Z-Direction

APP-RNS-PLA-170 is a system with many vertical runs. The package has fourteen valves; as well as eighty-three supports and anchors. The complexity of the package represents a wide number of piping layout configurations, which should encompass the layouts throughout the plant. Figure 6.3.2.2-4 shows the cumulative mass of the analysis package; fifty, sixty, and seventy mass percent of the package (in the X, Y, and Z directions, respectively) is active in the high frequency range.

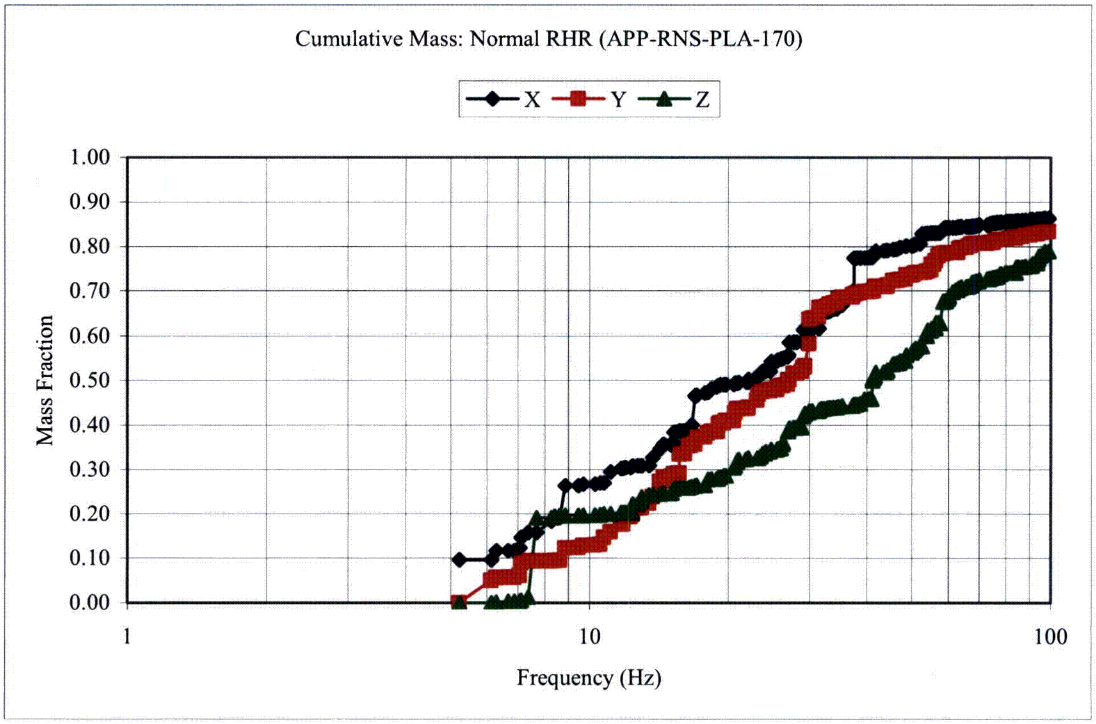


Figure 6.3.2.2-4: APP-RNS-PLA-170 Cumulative Mass: Normal RHR

Due to its location near exceedances of seismic response spectra in high frequency, APP-RNS-PLA-170 is representative of a piping package that is susceptible to excitation caused by high frequency input outside containment.

6.3.2.3 Analysis Method

Identical PIPESTRESS models were run for the two selected analysis packages, with the exception of the input seismic response spectra. The base case used AP1000 design seismic response spectra. Input for the high frequency comes from the HRHF GMRS with incoherence. Only a seismic analysis was performed. Deadweight, pressure, thermal, and other analyses were not performed so that the differences between the two cases are due only to the seismic loads.

The base case was run with an enveloped, 15% peak broadened, floor response spectra at 5% and 4% damping, for APP-PXS-PLA-030 and APP-RNS-PLA-170, respectively. The high frequency case was run as a multiple-level response, 15% peak broadened floor response spectra with incoherence at 5% and 4% damping for APP-PXS-PLA-030 and APP-RNS-PLA-170, respectively. The response from the different support levels is combined using the SRSS method, which is consistent with licensing basis.

6.3.3 Results

The stresses shown are moment stresses for seismic analysis only, calculated with the moment stress term of Equation 9 of the ASME Boiler and Pressure Vessel Code Section III NB-3652 Class 1 1989 Edition up to and including the 1989 Addenda.

Moment stress term of Equation 9:

$$B_2 \frac{M}{Z}$$

6.3.3.1 Automatic Depressurization System Stage 4 West (APP-PXS-PLA-030)

Comparisons of the AP1000 CSDRS seismic response spectra and HRHF analyses are listed in Tables 6.3.3.1-1 to 6.3.3.1-7.

HRHF moment stress results at the 198 points of the model were lower than AP1000 CSDRS seismic response spectra.

Table 6.3.3.1-1 shows the ten highest stressed piping points (not including tees, which are compared in Table 6.3.3.1-4) of the AP1000 design seismic response spectra analysis. Table 6.3.3.1-2 shows the ten highest stressed piping points (not including tees, which are compared in Table 6.3.3.1-4) of the HRHF analysis.

Table 6.3.3.1-3 compares the valve end moment stresses. Table 6.3.3.1-4 compares stresses of tee connections at both the run and branch sides. Tables 6.3.3.1- 5 and 6 compare support and anchor loads, respectively. Support loads are listed for individual restraint directions. Table 6.3.3.1-7 compares the equipment nozzle stresses.

Table 6.3.3.1-1: Ten Highest AP1000 Design Stress Points for APP-PXS-PLA-030

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
TANGENT	13969	4599	-67.1%
LR ELBOW	13089	6789	-48.1%
TANGENT	12594	5595	-55.6%
PIPING	12323	5015	-59.3%
LR ELBOW	12180	6297	-48.3%
TANGENT	11793	5497	-53.4%
TANGENT	11647	6002	-48.5%
TANGENT	11272	4771	-57.7%
TANGENT	11196	3688	-67.1%
TANGENT	11094	4685	-57.8%

Table 6.3.3.1-2: Ten Highest High Frequency Stress Points for APP-PXS-PLA-030

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
LR ELBOW	13089	6789	-48.1%
LR ELBOW	12180	6297	-48.3%
TANGENT	11647	6002	-48.5%
LR ELBOW	11028	5672	-48.6%
TANGENT	12594	5595	-55.6%
TANGENT	11793	5497	-53.4%
LR ELBOW	10118	5414	-46.5%
TANGENT	10360	5370	-48.2%
LR ELBOW	9241	5125	-44.5%
TANGENT	10189	5047	-50.5%

Table 6.3.3.1-3: Valve End Stresses for APP-PXS-PLA-030

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
V101	7241	3700	-48.9%
	9286	4470	-51.9%
V004A	156	80	-48.7%
V004C	8923	4397	-50.7%
	8924	4397	-50.7%
V014A	8431	4167	-50.6%
	8432	4168	-50.6%
V014C	10031	5016	-50.0%

Table 6.3.3.1-4: Tee Connection Stresses for APP-PXS-PLA-030

Type	Branch Stress (psi)			Run Stress (psi)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
WELDING TEE	5299	2399	-54.7%	9001	4361	-51.5%
WELDING TEE	5044	3021	-40.1%	2591	854	-67.0%
WELDING TEE	247	173	-30.0%	9136	4564	-50.0%

Table 6.3.3.1-5: Seismic Support Loads for APP-PXS-PLA-030

Type	Force - X (lb)			Force - Y (lb)			Force - Z (lb)			Resultant Force (lb)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
RIG SUPORT							32156	16958	-47.3%	32156	16958	-47.3%
RIG SUPORT	23611	12201	-48.3%				13632	7045	-48.3%	27263	14089	-48.3%
RIG SUPORT	20945	9937	-52.6%	12092	5737	-52.6%	13963	6624	-52.6%	27927	13249	-52.6%
SNUBBER				43030	17287	-59.8%				43030	17287	-59.8%
RIG SUPORT	29237	13477	-53.9%				16880	7781	-53.9%	33760	15562	-53.9%
RIG SUPORT	27686	13223	-52.2%	10068	4808	-52.2%	17006	8122	-52.2%	34016	16246	-52.2%
RIG SUPORT				35112	15491	-55.9%	35112	15491	-55.9%	49656	21908	-55.9%
RIG SUPORT				47577	24615	-48.3%				47577	24615	-48.3%
RIG SUPORT				34696	13305	-61.7%				34696	13305	-61.7%
RIG SUPORT							17334	10396	-40.0%	17334	10396	-40.0%
RIG SUPORT	36111	17576	-51.3%							36111	17576	-51.3%
RIG SUPORT	4004	2708	-32.4%				10660	7210	-32.4%	11387	7702	-32.4%
RIG SUPORT							36895	20603	-44.2%	36895	20603	-44.2%
RIG SUPORT				52839	30375	-42.5%				52839	30375	-42.5%

Table 6.3.3.1-6: Seismic Anchor Loads for APP-PXS-PLA-030

Point	Force - X (lb)			Force - Y (lb)			Force - Z (lb)			Resultant Force (lb)		
Label	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
West Hot Leg	22572	10991	-51.3%	10960	6758	-38.3%	10136	4903	-51.6%	27062	13803	-49.0%
PRHR HX	17633	8606	-51.2%	18775	8346	-55.5%	21211	10675	-49.7%	33366	16053	-51.9%
Point	Moment - X (ft-lb)			Moment - Y (ft-lb)			Moment - Z (ft-lb)			Resultant Moment (ft-lb)		
Label	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
West Hot Leg	50361	28017	-44.4%	80496	40443	-49.8%	69778	48178	-31.0%	27062	13803	-49.0%
PRHR HX	48429	22601	-53.3%	101714	44823	-55.9%	35436	16873	-52.4%	33366	16053	-51.9%

Table 6.3.3.1-7: Equipment Nozzle Stresses for APP-PXS-PLA-030

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
West Hot Leg	3216	1721	-46.5%
PRHR HX	8095	2943	-63.6%

Results Summary for APP-PXS-PLA-030

- ASME Code Equation 9 moment stresses for HRHF spectra are lower, at all points, than for the AP1000 CSDRS seismic response spectra; see Tables 6.3.3.1- 1, 2, 3, 4 and 7.
- All support loads are lower for HF than AP1000 CSDRS seismic response spectra; see Table 6.3.3.1-5.
- All anchor loads are lower for HF than AP1000 CSDRS seismic response spectra; see Table 6.3.3.1-6.

6.3.3.2 Normal RHR Heat Exchanger Inlet and Outlet between P19 and P20 (APP-RNS-PLA-170)

Comparisons of the AP1000 CSDRS seismic response spectra and HRHF analyses are listed in Tables 6.3.3.2-1 to 6.3.3.2-7.

HRHF moment stresses at all of the 1015 points were lower than AP1000 CSDRS seismic response spectra.

Table 6.3.3.2-1 shows the ten highest stressed piping points (not including tees, which are compared in Table 6.3.3.2-4) of the AP1000 design seismic response spectra analysis. Table 6.3.3.2-2 shows the ten highest stressed piping points (not including tees, which are compared in Table 6.3.3.2-5) of the HRHF analysis.

Table 6.3.3.2-3 compares the valve end moment stresses. Table 6.3.3.2-4 compares stresses of tee connections at both the run and branch sides. Tables 6.3.3.2-5 and 6.3.3.2-6 compare support and anchor loads, respectively. Support loads are listed for individual restraint directions. Table 6.3.3.2-7 compares the equipment nozzle stresses.

Table 6.3.3.2-1: Ten Highest AP1000 Design Stress Points for APP-RNS-PLA-170

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
TANGENT	41855	9492	-77.3%
TANGENT	40948	9268	-77.4%
TANGENT	35625	7509	-78.9%
TANGENT	32645	6513	-80.0%
LR ELBOW	31954	6440	-79.8%
LR ELBOW	30007	6022	-79.9%
TANGENT	29051	6336	-78.2%
TANGENT	25313	5916	-76.6%
TANGENT	25286	10220	-59.6%
TANGENT	24788	5862	-76.4%

Table 6.3.3.2-2: Ten Highest High Frequency Stress Points for APP-RNS-PLA-170

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
TANGENT	24368	11753	-51.8%
TANGENT	23889	11101	-53.5%
TANGENT	25286	10220	-59.6%
TANGENT	24621	10191	-58.6%
TANGENT	19307	9647	-50.0%
TANGENT	41855	9492	-77.3%
TANGENT	40948	9268	-77.4%
TANGENT	17879	8948	-50.0%
TANGENT	16235	8233	-49.3%
TANGENT	15477	7810	-49.5%

Table 6.3.3.2-3: Valve End Stresses for APP-RNS-PLA-170

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
V005A	4363	1260	-71.1%
	7644	2303	-69.9%
V005B	4509	1259	-72.1%
	7221	2108	-70.8%
V006A	6624	2450	-63.0%
	5056	1831	-63.8%
V006B	5851	2795	-52.2%
	6271	2281	-63.6%
V007A	8247	2627	-68.1%
	5941	2088	-64.9%
V007B	5700	2359	-58.6%
	5829	2361	-59.5%
V008A	9855	4213	-57.3%
	12515	4181	-66.6%
V008B	8241	3910	-52.6%
	10079	4134	-59.0%
V011	6402	2255	-64.8%
	9740	2945	-69.8%
V022	8116	2058	-74.6%
	7214	1978	-72.6%
V053	10129	3519	-65.3%
	10380	3466	-66.6%
V055	3277	2475	-24.5%
	9466	6411	-32.3%
V056	6605	1899	-71.2%
	5546	1710	-69.2%
V057A	11864	6414	-45.9%
	15477	7810	-49.5%
V057B	14335	6838	-52.3%
	13334	5933	-55.5%

Table 6.3.3.2-4: Tee Connection Stresses for APP-RNS-PLA-170

Type	Branch Stress (psi)			Run Stress (psi)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
WELDING TEE	11310	4577	-59.5%	12696	4278	-66.3%
WELDING TEE	22238	7521	-66.2%	6338	2439	-61.5%
WELDING TEE	25286	10220	-59.6%	6238	2625	-57.9%
WELDING TEE	16235	8233	-49.3%	8710	2492	-71.4%
WELDING TEE	19307	9647	-50.0%	9765	4005	-59.0%
WELDING TEE	24621	10191	-58.6%	7429	3242	-56.4%
WELDING TEE	14980	3854	-74.3%	25944	5745	-77.9%
WELDING TEE	15240	6264	-58.9%	5735	3094	-46.1%
BRANCH CONN	23889	11101	-53.5%	2666	1063	-60.1%
BRANCH CONN	24368	11753	-51.8%	2726	985	-63.9%
WELDING TEE	9137	3593	-60.7%	15048	4225	-71.9%
WELDING TEE	8511	3723	-56.3%	10786	3130	-71.0%
WELDING TEE	23400	6444	-72.5%	7499	2432	-67.6%

Table 6.3.3.2-5: Seismic Support Loads for APP-RNS-PLA-170

Label	Force - X (lb)			Force - Y (lb)			Force - Z (lb)			Resultant Force (lb)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
RESTRAINT							2446	1283	-47.5%	2446	1283	-47.5%
RESTRAINT	6911	2664	-61.5%							6911	2664	-61.5%
RESTRAINT							1905	1254	-34.2%	1905	1254	-34.2%
RESTRAINT				6732	3171	-52.9%				6732	3171	-52.9%
RESTRAINT							1529	723	-52.7%	1529	723	-52.7%
RESTRAINT				3307	1371	-58.5%				3307	1371	-58.5%
RESTRAINT							1559	720	-53.8%	1559	720	-53.8%
RESTRAINT	6936	2467	-64.4%							6936	2467	-64.4%
RESTRAINT							2086	1021	-51.1%	2086	1021	-51.1%
RESTRAINT				1849	926	-49.9%				1849	926	-49.9%
RESTRAINT							3147	1218	-61.3%	3147	1218	-61.3%
RESTRAINT				2685	1189	-55.7%				2685	1189	-55.7%
RESTRAINT							4506	1303	-71.1%	4506	1303	-71.1%
RESTRAINT	3772	978	-74.1%							3772	978	-74.1%
RESTRAINT				903	504	-44.2%				903	504	-44.2%
RESTRAINT				2201	1234	-43.9%				2201	1234	-43.9%
RESTRAINT				1458	783	-46.3%				1458	783	-46.3%
RESTRAINT							4351	1465	-66.3%	4351	1465	-66.3%
RESTRAINT				2764	1361	-50.8%				2764	1361	-50.8%
RESTRAINT							2269	1182	-47.9%	2269	1182	-47.9%
RESTRAINT							2946	1111	-62.3%	2946	1111	-62.3%
RESTRAINT	5774	2412	-58.2%							5774	2412	-58.2%
RESTRAINT				2507	1189	-52.6%				2507	1189	-52.6%
RESTRAINT	1974	820	-58.5%							1974	820	-58.5%
RESTRAINT				2231	894	-59.9%				2231	894	-59.9%
RESTRAINT	5130	1936	-62.3%							5130	1936	-62.3%
RESTRAINT							2555	1254	-50.9%	2555	1254	-50.9%
RESTRAINT	182	154	-15.4%							182	154	-15.4%
RESTRAINT				224	81	-63.8%				224	81	-63.8%
RESTRAINT							2910	1138	-60.9%	2910	1138	-60.9%
RESTRAINT				1407	599	-57.4%				1407	599	-57.4%
RESTRAINT							1054	501	-52.5%	1054	501	-52.5%
RESTRAINT				812	348	-57.1%				812	348	-57.1%
RESTRAINT							640	303	-52.7%	640	303	-52.7%
RESTRAINT	2229	839	-62.4%							2229	839	-62.4%
RESTRAINT				2144	849	-60.4%				2144	849	-60.4%
RESTRAINT				1215	713	-41.3%				1215	713	-41.3%
RESTRAINT							2459	1329	-46.0%	2459	1329	-46.0%
RESTRAINT	1725	767	-55.5%							1725	767	-55.5%
RESTRAINT				1803	788	-56.3%				1803	788	-56.3%
RESTRAINT							1786	1208	-32.4%	1786	1208	-32.4%
RESTRAINT				1546	856	-44.6%				1546	856	-44.6%
RESTRAINT							924	555	-39.9%	924	555	-39.9%
RESTRAINT	1653	705	-57.4%							1653	705	-57.4%
RESTRAINT							2621	1332	-49.2%	2621	1332	-49.2%
RESTRAINT				1357	513	-62.2%				1357	513	-62.2%
RESTRAINT							1859	963	-48.2%	1859	963	-48.2%
RESTRAINT				754	444	-41.1%				754	444	-41.1%
RESTRAINT							1267	509	-59.8%	1267	509	-59.8%
RESTRAINT	1998	791	-60.4%							1998	791	-60.4%
RESTRAINT							517	271	-47.6%	517	271	-47.6%
RESTRAINT				897	548	-38.9%				897	548	-38.9%
RESTRAINT	5332	2978	-44.1%							5332	2978	-44.1%
RESTRAINT				4707	1769	-62.4%				4707	1769	-62.4%
RESTRAINT				4266	1723	-59.6%				4266	1723	-59.6%
RESTRAINT	14432	4830	-66.5%							14432	4830	-66.5%
RESTRAINT				7488	2436	-67.5%				7488	2436	-67.5%
RESTRAINT							2730	1536	-43.7%	2730	1536	-43.7%
RESTRAINT							3430	2771	-19.2%	3430	2771	-19.2%
RESTRAINT				12461	5582	-55.2%				12461	5582	-55.2%
RESTRAINT							3856	2282	-40.8%	3856	2282	-40.8%
RESTRAINT							3980	1507	-62.1%	3980	1507	-62.1%
RESTRAINT	3570	1243	-65.2%							3570	1243	-65.2%
RESTRAINT							1976	1096	-44.5%	1976	1096	-44.5%
RESTRAINT	1567	922	-41.2%							1567	922	-41.2%
RESTRAINT							1751	741	-57.7%	1751	741	-57.7%

Table 6.3.3.2-6: Seismic Anchor Loads for APP-RNS-PLA-170

Label	Force - X (lb)			Force - Y (lb)			Force - Z (lb)			Resultant Force (lb)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
Penetration P20	2453	1187	-51.6%	1250	824	-34.1%	1728	958	-44.6%	3251	1733	-46.7%
HX ME/01B	152894	39709	-74.0%	165893	40145	-75.8%	50248	32852	-34.6%	231132	65327	-71.7%
HX ME/01A	147594	39195	-73.4%	165230	42220	-74.4%	37392	24269	-35.1%	224685	62512	-72.2%
ANCHOR	1921	614	-68.0%	940	370	-60.6%	889	401	-54.9%	2316	821	-64.6%
ANCHOR	1466	319	-78.2%	1533	340	-77.8%	353	131	-62.9%	2150	484	-77.5%
ANCHOR	626	208	-66.8%	823	194	-76.4%	286	142	-50.3%	1073	317	-70.5%
Pump MP/01A	3457	1661	-52.0%	3837	1286	-66.5%	11950	3204	-73.2%	13019	3831	-70.6%
Pump MP/01B	2625	1291	-50.8%	2588	1166	-54.9%	10875	2753	-74.7%	11483	3257	-71.6%
Penetration P19	9926	3961	-60.1%	7589	1992	-73.8%	2003	1232	-38.5%	12654	4601	-63.6%
ANCHOR	1009	682	-32.4%	1162	697	-40.0%	1055	551	-47.8%	1866	1120	-40.0%
ANCHOR	1703	1419	-16.7%	1879	1181	-37.1%	1709	1276	-25.3%	3058	2244	-26.6%
ANCHOR	1520	1053	-30.7%	4766	3201	-32.8%	1631	1142	-30.0%	5262	3558	-32.4%
Label	Moment - X (ft-lb)			Moment - Y (ft-lb)			Moment - Z (ft-lb)			Resultant Moment (ft-lb)		
	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change	AP1000 CSDRS	HRHF	% Change
Penetration P20	2043	1449	-29.1%	8321	4240	-49.0%	7445	4362	-41.4%	3251	1733	-46.7%
ANCHOR	3868170	862432	-77.7%	3532301	816810	-76.9%	23480	5858	-75.1%	231132	65327	-71.7%
ANCHOR	3819900	849458	-77.8%	3415758	789030	-76.9%	11548	4956	-57.1%	224685	62512	-72.2%
ANCHOR	6748	2239	-66.8%	16885	4893	-71.0%	2548	817	-67.9%	2316	821	-64.6%
ANCHOR	226	112	-50.4%	187	100	-46.5%	300	64	-78.7%	2150	484	-77.5%
ANCHOR	417	160	-61.6%	294	237	-19.4%	216	66	-69.4%	1073	317	-70.5%
Pump MP/01A	34132	9258	-72.9%	14798	6145	-58.5%	17542	6761	-61.5%	13019	3831	-70.6%
Pump MP/01B	30936	8428	-72.8%	12449	5582	-55.2%	10601	5155	-51.4%	11483	3257	-71.6%
Penetration P19	9310	5851	-37.2%	5755	3319	-42.3%	64761	20716	-68.0%	12654	4601	-63.6%
ANCHOR	3989	2105	-47.2%	4603	2805	-39.1%	4997	2480	-50.4%	1866	1120	-40.0%
ANCHOR	8507	5746	-32.5%	3275	2660	-18.8%	2538	1943	-23.4%	3058	2244	-26.6%
ANCHOR	13094	8804	-32.8%	3777	2748	-27.2%	12186	8179	-32.9%	5262	3558	-32.4%

Table 6.3.3.2-7: Equipment Nozzle Stresses for APP-RNS-PLA-170

Label	Moment Stress (psi)		
	AP1000 CSDRS	HRHF	% Change
Pump MP/01A	16912	4707	-72.2%
	7872	2255	-71.4%
Pump MP/01B	9989	4167	-58.3%
	7745	2132	-72.5%
HX ME/01A	4773	1891	-60.4%
	20989	4701	-77.6%
HX ME/01B	7578	3797	-49.9%
	7694	3199	-58.4%

Results Summary for APP-RNS-PLA-170

- ASME Code Equation 9 moment stresses for high frequency spectra are lower, at all points, than for the AP1000 design seismic response spectra; see Tables 6.3.3.2-1, 2, 3, 4, and 7.
- All support loads are lower for high frequency spectra than AP1000 design seismic response spectra; see Table 6.3.3.2-5.
- All anchor loads are lower for high frequency spectra than AP1000 design seismic response spectra; see Table 6.3.3.2-6.

6.3.4 Summary and Conclusions

The layouts of ASME Class 1, 2, and 3 packages were reviewed along with local input seismic response spectra for susceptibility to excitation from HRHF seismic input motion. Two piping packages, APP-PXS-PLA-030 and APP-RNS-PLA-170, inside and outside containment respectively, were chosen as the most susceptible to excitation from HRHF seismic input motion.

PIPESTRESS seismic analyses of the two packages were performed with both AP1000 design seismic response spectra and HRHF seismic input spectra. AP1000 design seismic response spectra analysis was performed with 15% peak broadened and enveloped response spectra. The high frequency analysis was performed with 15% peak broadened, multiple-level HRHF response spectra with incoherence.

The stress results of the HRHF seismic analysis are bounded by the stress results of the AP100 CSDRS seismic analysis. Despite the different layout and locations, both analysis packages showed similar response to high frequency seismic input against AP1000 design seismic response spectra seismic input. Because of the way the sample packages were selected for study, the results are deemed as representative for all safety class piping in the plant. As a result, the effect of high frequency input on piping analysis is found to be bounded by the CSDRS analysis.

6.4 Safety-Related Electrical Equipment

6.4.1 Introduction

This section presents the results of a technical study performed to confirm that seismic qualification to the AP1000 Certified Seismic Response Spectra (CSDRS) envelops the seismic qualification to the hard rock high frequency (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 envelop high frequency input up to 2.0 g spectral acceleration (at 5% critical damping) and no additional seismic testing is required when the HRHF seismic inputs are below this level.

Susceptibility to excitation caused by high frequency 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:

a. 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 envelop most of the seismic loads and accelerations generated by the high frequency 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 an elevation of 116.5 ft. 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 10) computer program.
The evaluation includes:

i. Selection of equipment samples and models
ii. Comparison of the evaluation of analytical models to high and low frequency seismic inputs

iii. Evaluation of the results

b. 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 IEEE Std 344-1987.

The evaluation includes:

i. Selection of existing seismic test programs
ii. Review of seismic test data
iii. Results and conclusions

c. 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:

i. Determination of structural response to high frequency
ii. Identification of sensitive equipment and components
iii. 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 high frequency 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 envelops 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 high frequency 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 Main Control Room (MCR) floor seismic requirements at an elevation of 116.5 ft. 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.

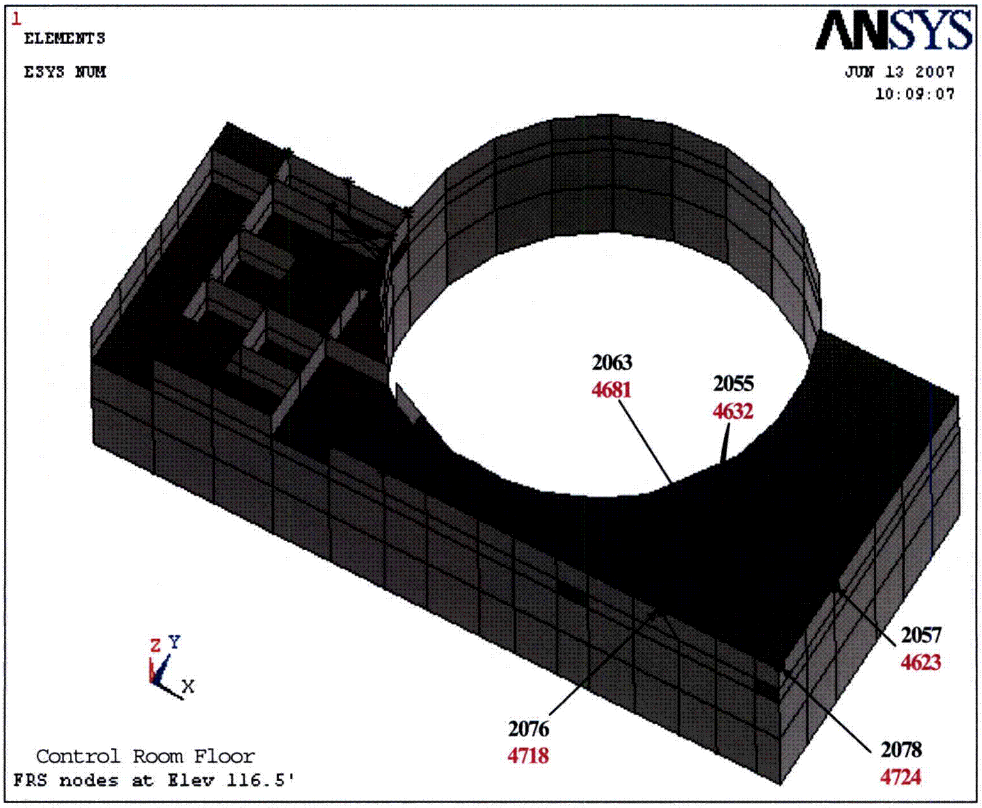


Figure 6.4.3.1-1: AP1000 Auxiliary and Shield Building Finite Element Model

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:

- Main Control Room (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)

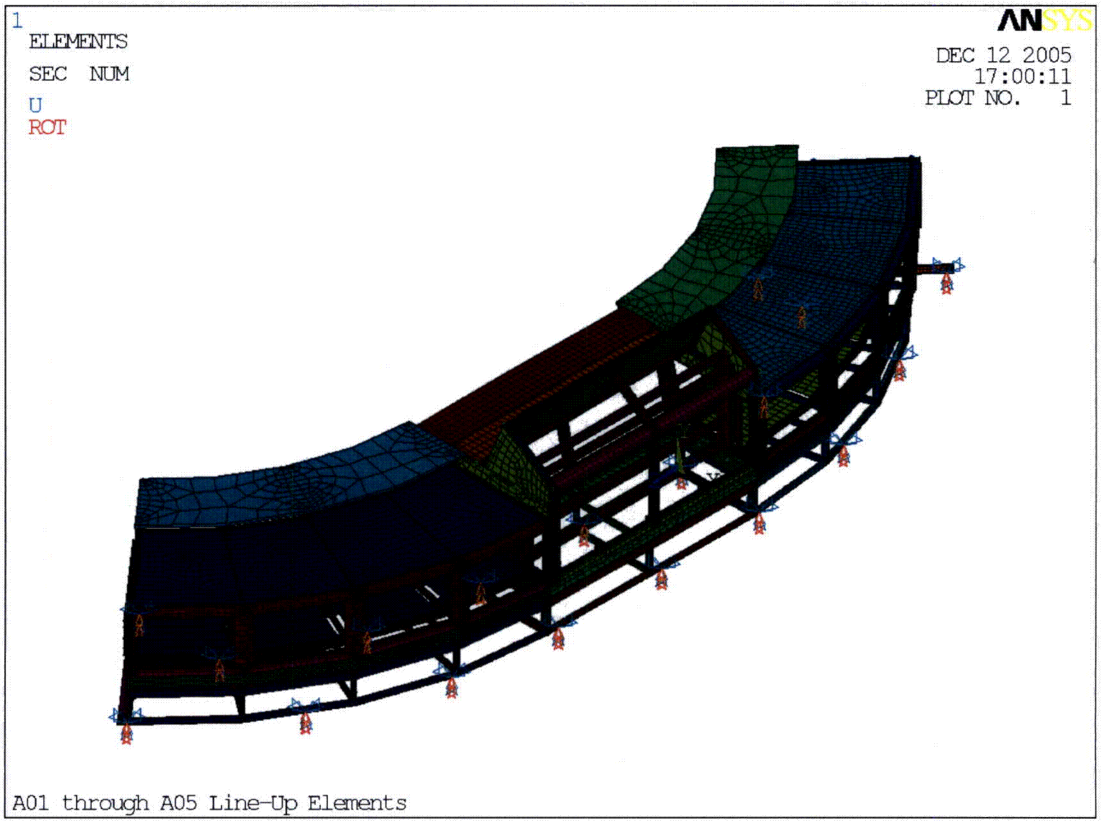


Figure 6.4.3.2-1: MCR (A01-A05) Safety Console Line-up Finite Element Model

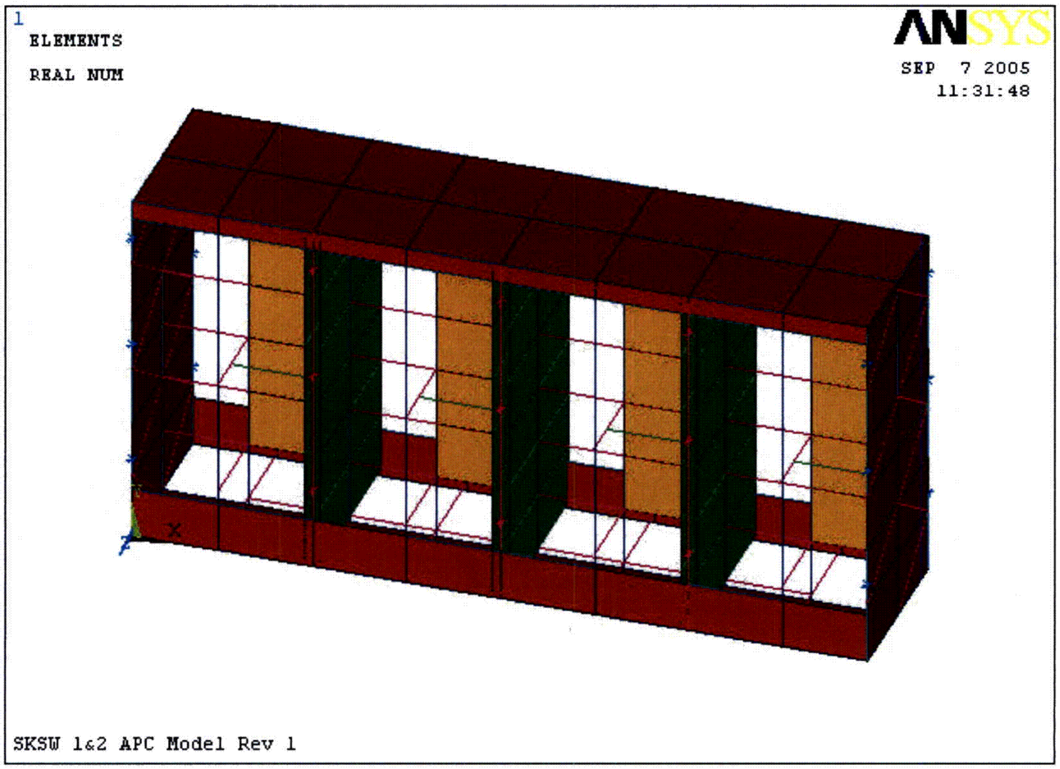


Figure 6.4.3.2-2: Finite Element Model of Auxiliary Protection Cabinet (APC)

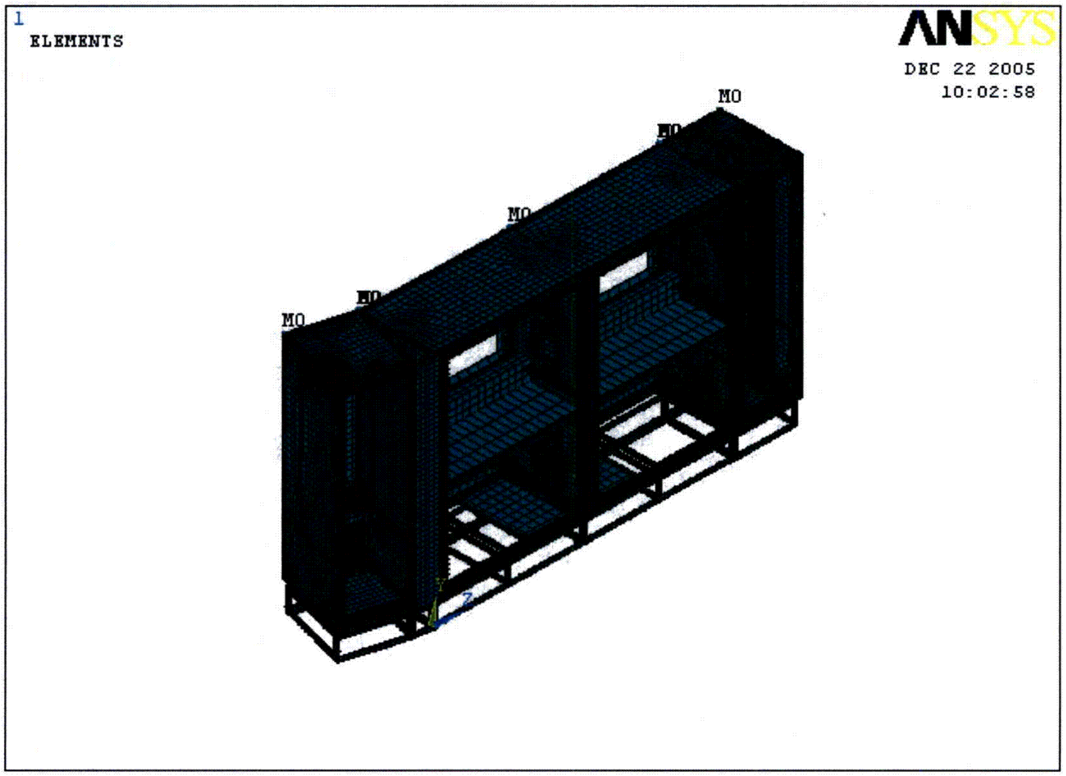


Figure 6.4.3.2-3: MCR Large Display (B13-B16) Panel Line-up Finite Element Model

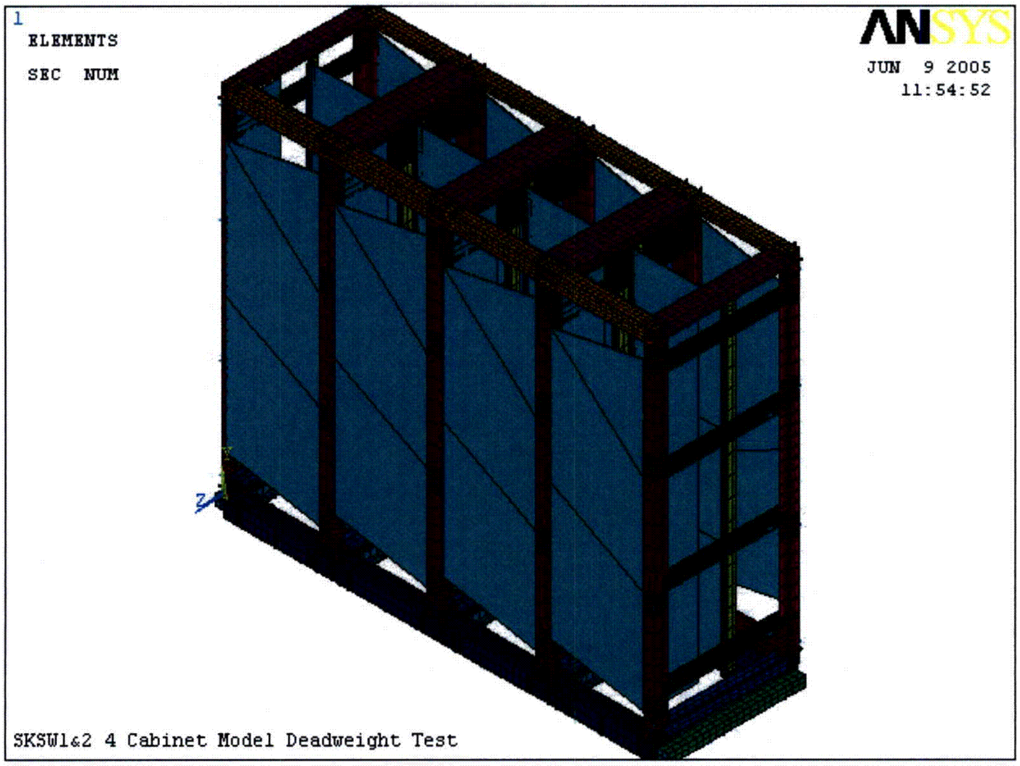


Figure 6.4.3.2-4: Process Instrumentation (PI) 4 Cabinet Suite Finite Element Model

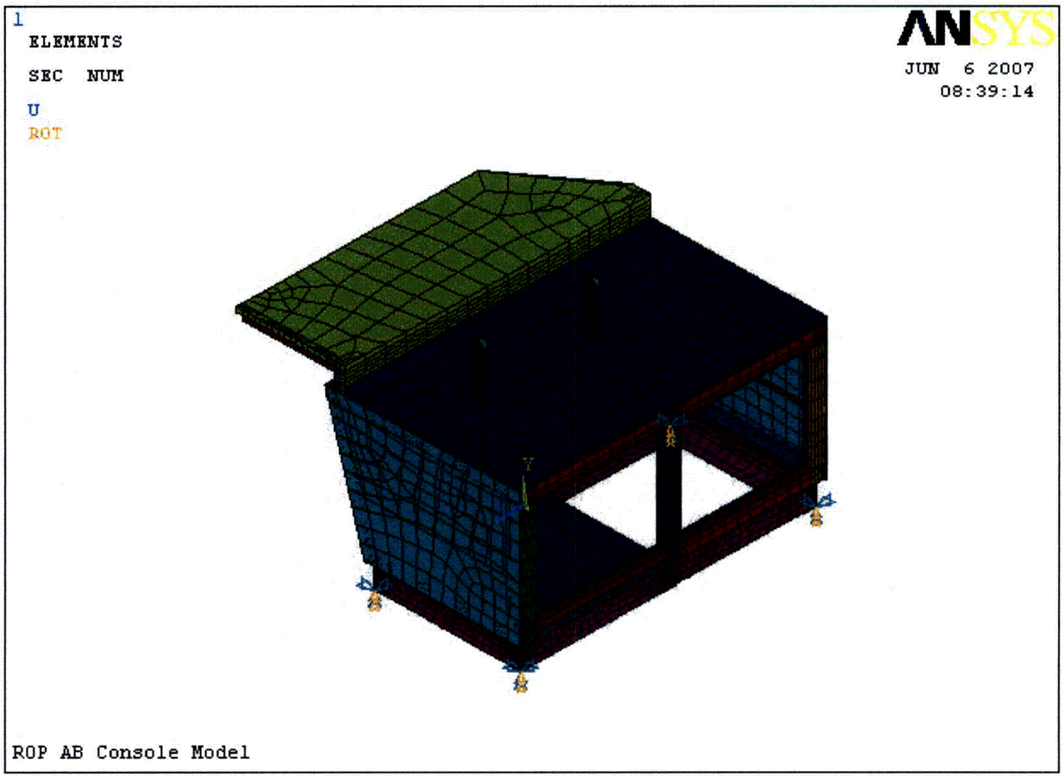


Figure 6.4.3.2-5: Remote Operator Shutdown Panel (ROP) Console Finite Element Model

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 high frequency inputs based on HRHF seismic requirements. The initial analyses demonstrate that the B13-B16 Panel Line-up and the ROP Console have low frequency results that envelop the high frequency results. This is expected as the B13-B16 Panel Line-up has natural frequencies in the 8 to 9 Hz range and the ROP Console is rigid (first natural frequency in excess of 50 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 10.0. 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 high frequency results are enveloped by the results of the low frequency seismic input, except when the high frequency 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 in-equipment response spectra (IERS) at the components' mounting due to both low and high frequency inputs
- Compare results from high frequency seismic input with results from low frequency input and confirm that low frequency results envelop 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.

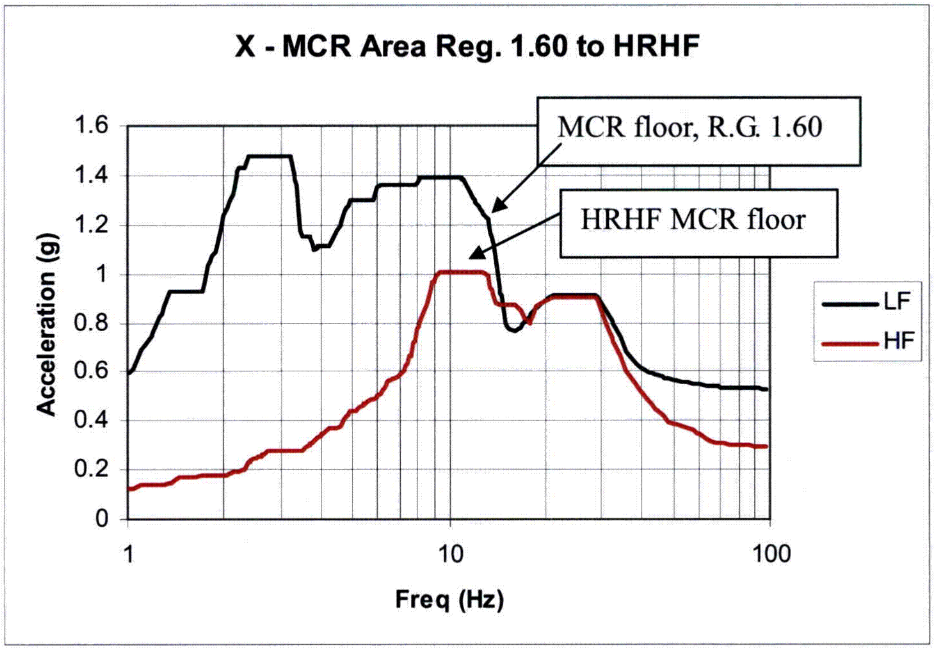


Figure 6.4.3.3.2-1: High/Low Frequency Response Spectra X-Direction (Horizontal)

High Frequency Response Spectra Shown in Red
(5% Critical Damping)

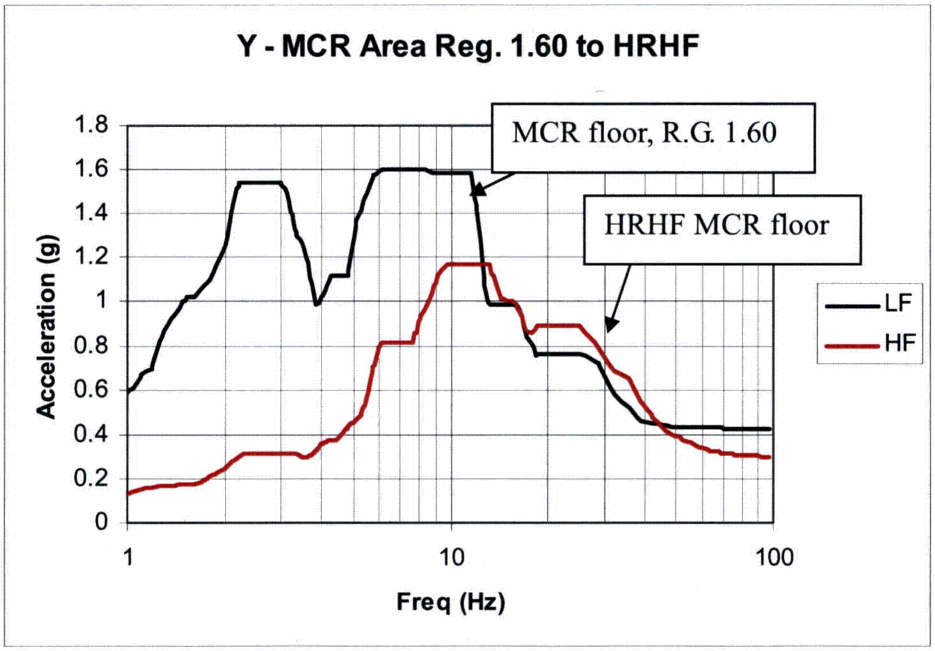


Figure 6.4.3.3.2-2: High/Low Frequency Response Spectra Y-Direction (Horizontal)

High Frequency Response Spectra Shown in Red
(5% Critical Damping)

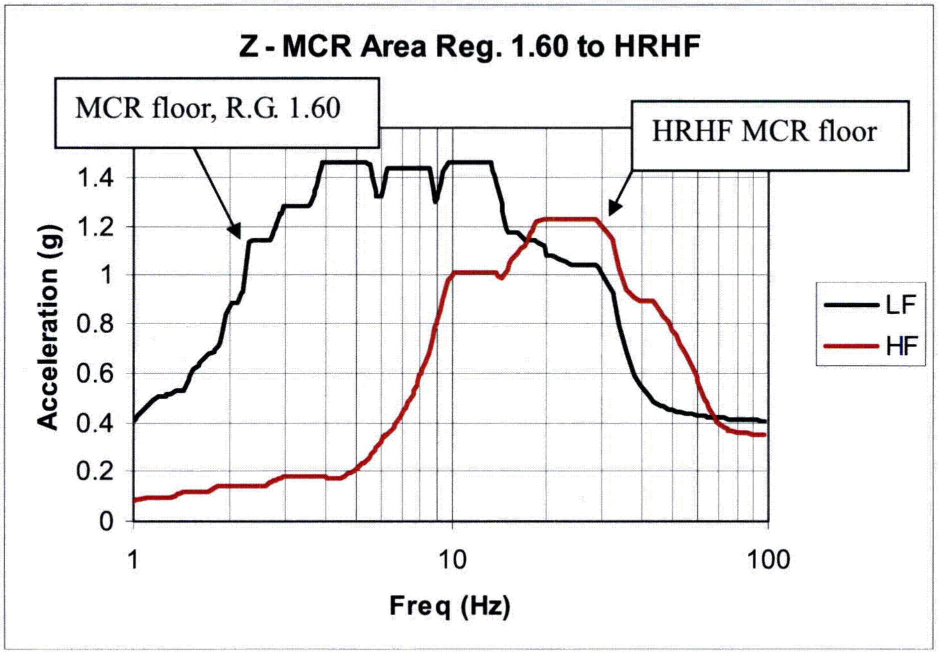


Figure 6.4.3.3.2-3: High/Low Frequency Response Spectra Z-Direction (Vertical)

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 envelop the results of the high frequency seismic input.

The time history analysis determine that the In-Equipment Response Spectra (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 high frequency input with the IERS developed using low frequency input.

The IERS produced by high frequency input are generally enveloped by or equivalent to the IERS produced by low frequency seismic input except for the vertical direction (Figure 6.4.3.3.3-3). 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 envelop those generated by the high frequency 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 envelops 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	12358	20132	10150	0.96
	Value (mm):	4.45	4.40	1.12	5.54	
High Frequency	Node:	12334	12358	20132	10150	
	Value (mm):	3.66	3.67	1.05	5.31	

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	4760.4	5599.2	7349.3	0.82
High Frequency	3957.0	4592.3	6061.9	

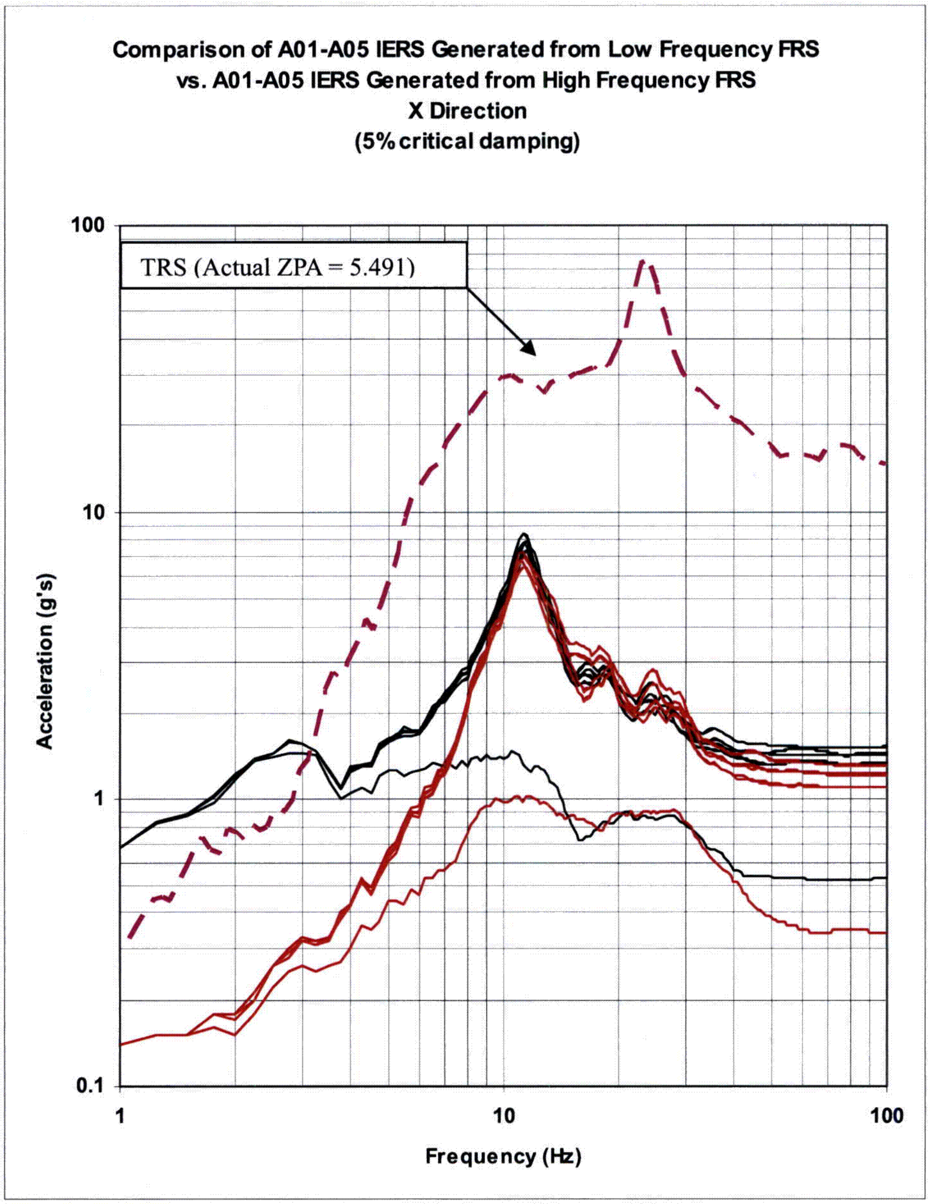


Figure 6.4.3.3.3-1: Comparison of A01-A05 Console Model IERS, X-Direction (Front-Back)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Dashed Pink (5% Critical Damping)

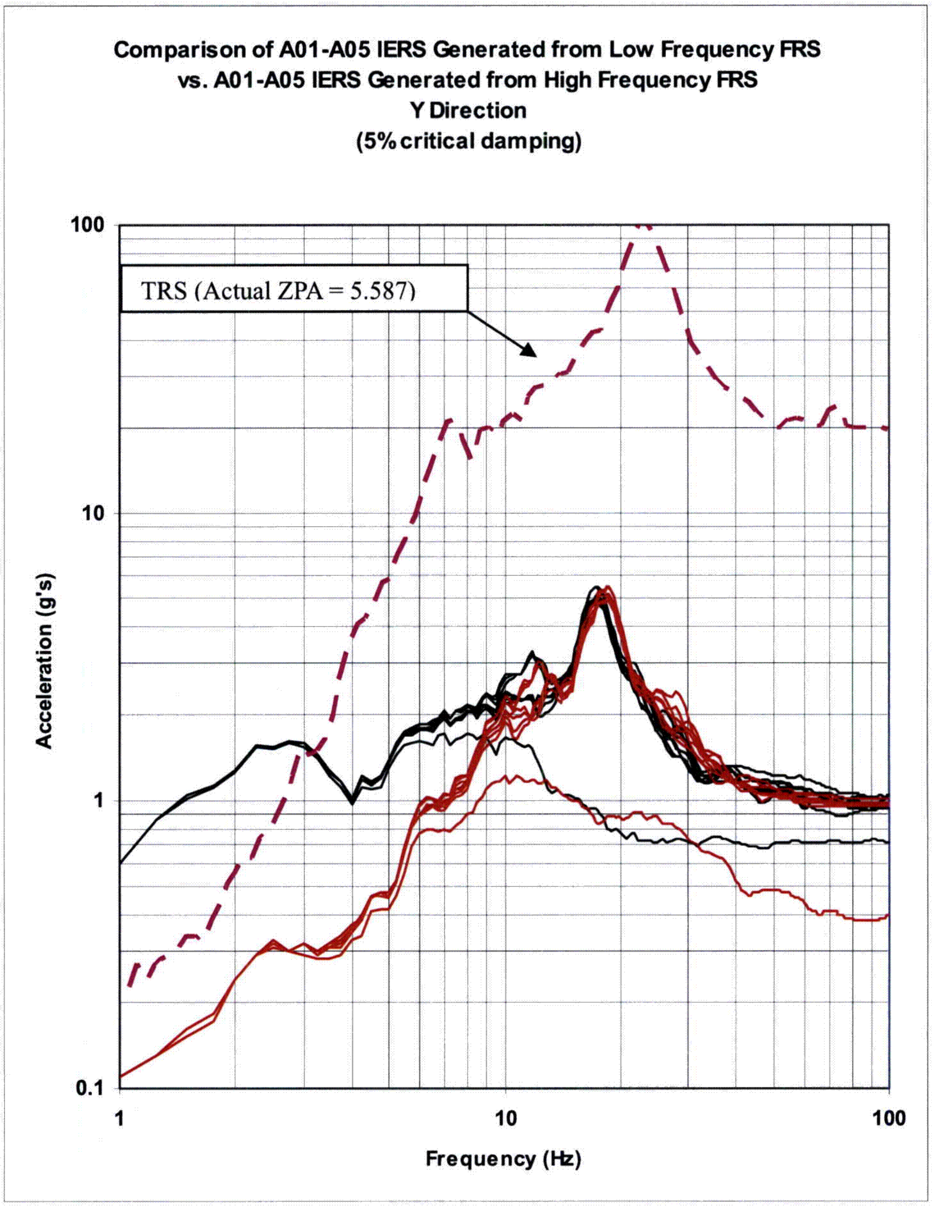


Figure 6.4.3.3.3-2: Comparison of A01-A05 Console Model IERS, Y-Direction (Side-Side)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Dashed Pink (5% Critical Damping)

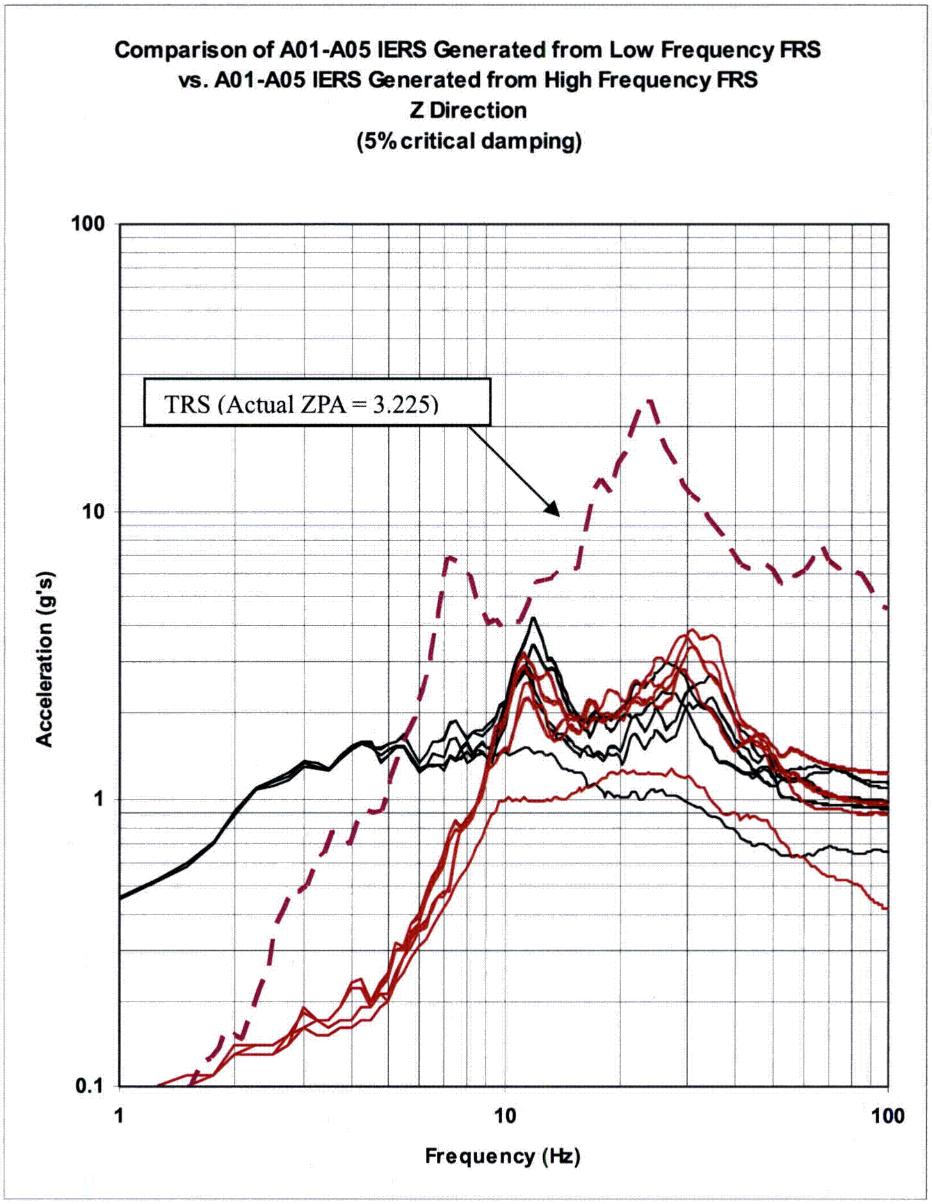


Figure 6.4.3.3.3-3: Comparison of A01-A05 Console Model IERS, Z-Direction (Vertical)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black, Tested Spectra is Shown in Dashed Pink (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 0.013 inch (low frequency seismic input) to 0.014 inch (high frequency seismic input) with a maximum ratio of 1.09. This increase, while expected as the front-back mode at 28.0 Hz lies within the HF range, is very small. 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 low frequency input envelop those of the high 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 through 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-to-Side)	UY Max (Cabinet Front-to-Back)	UZ Max (Cabinet Vertical)	Max. HF/LF Ratio
Low Frequency	Node:	64	80	229	1.09
	Value (inches):	0.040	0.013	0.009	
High Frequency	Node:	64	80	229	
	Value (inches):	0.035	0.014	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	2113.5	932.1	2309.9	0.94
High Frequency	1983.0	861.3	2162.0	

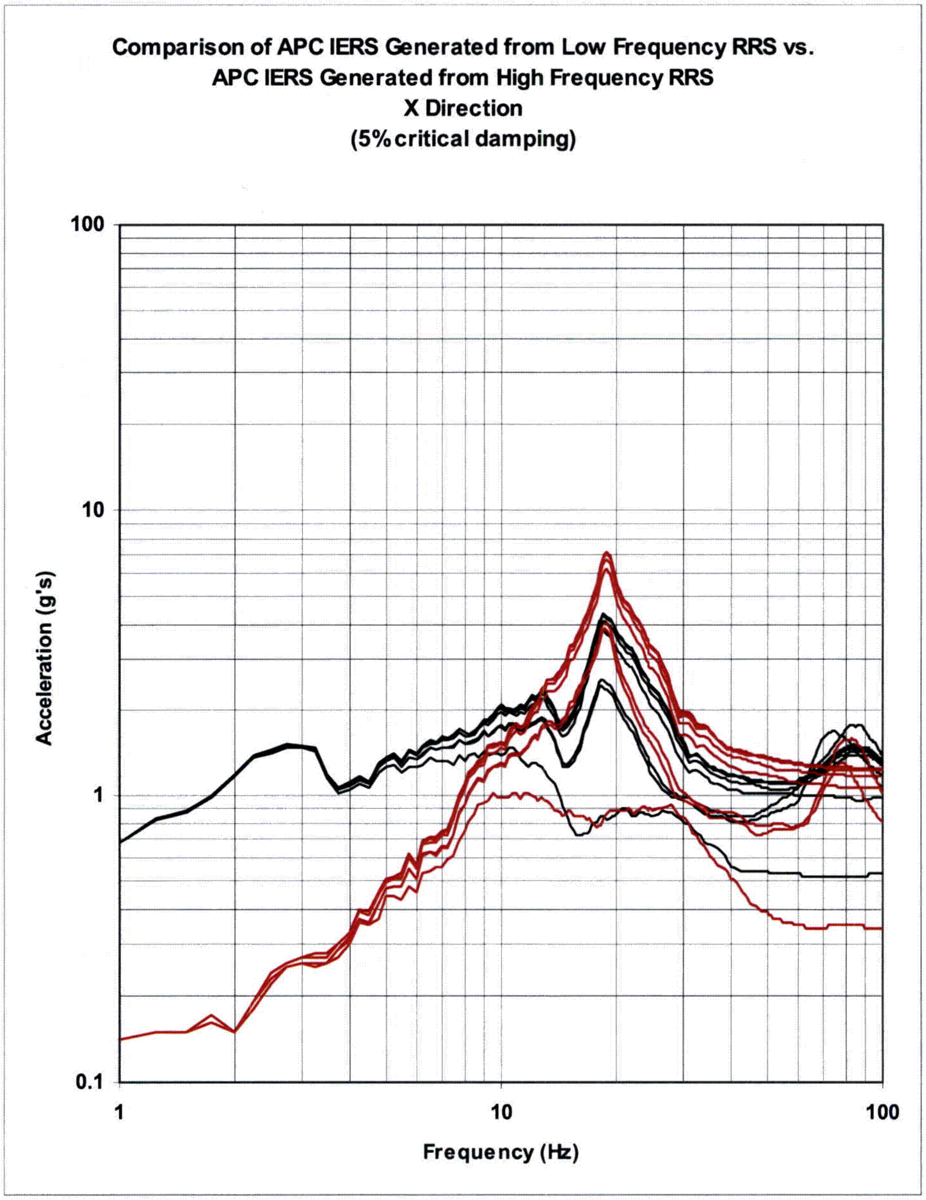


Figure 6.4.3.3.4-1: Comparison of APC Model IERS, X-Direction (Side-Side)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black
(5% Critical Damping)

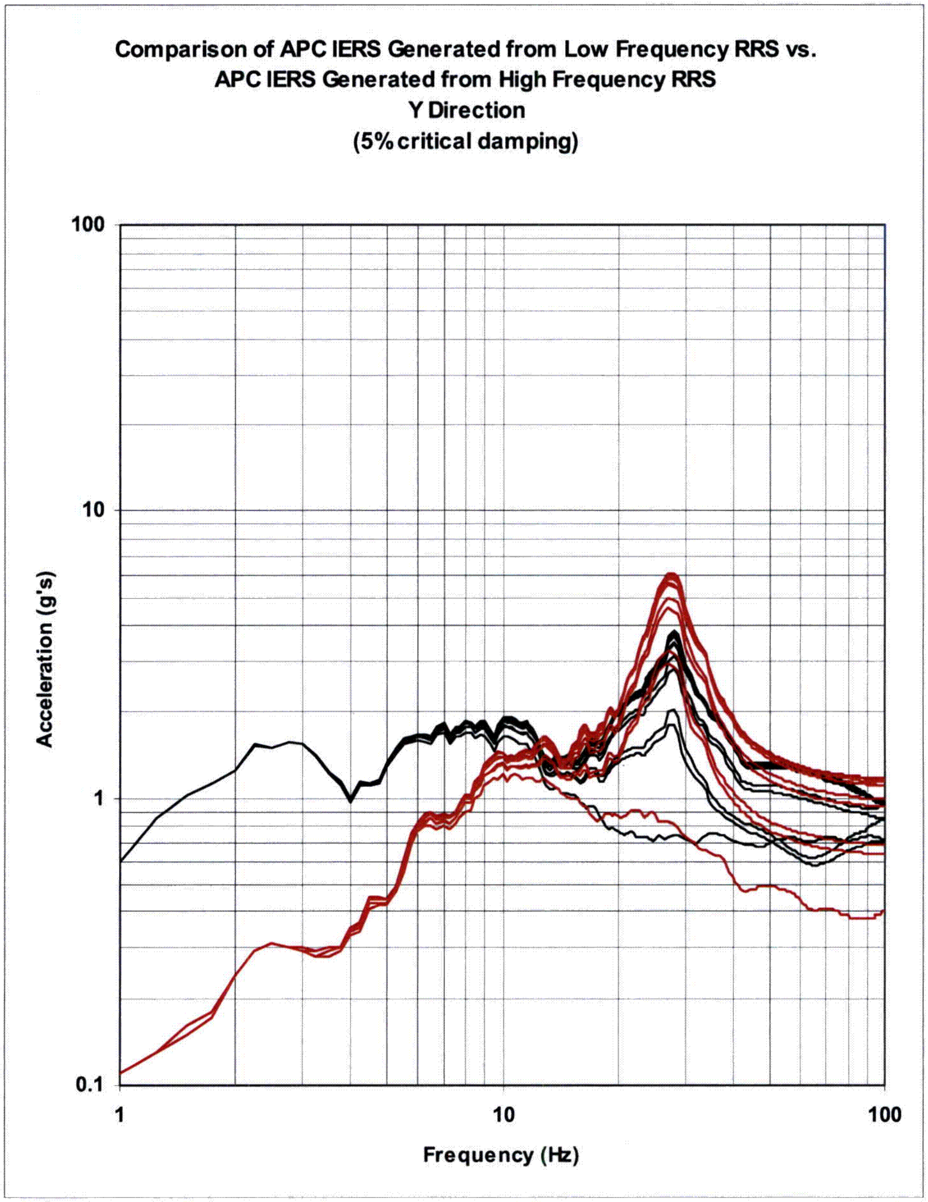


Figure 6.4.3.3.4-2: Comparison of APC Model IERS, Y-Direction (Front-Back)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black
(5% Critical Damping)

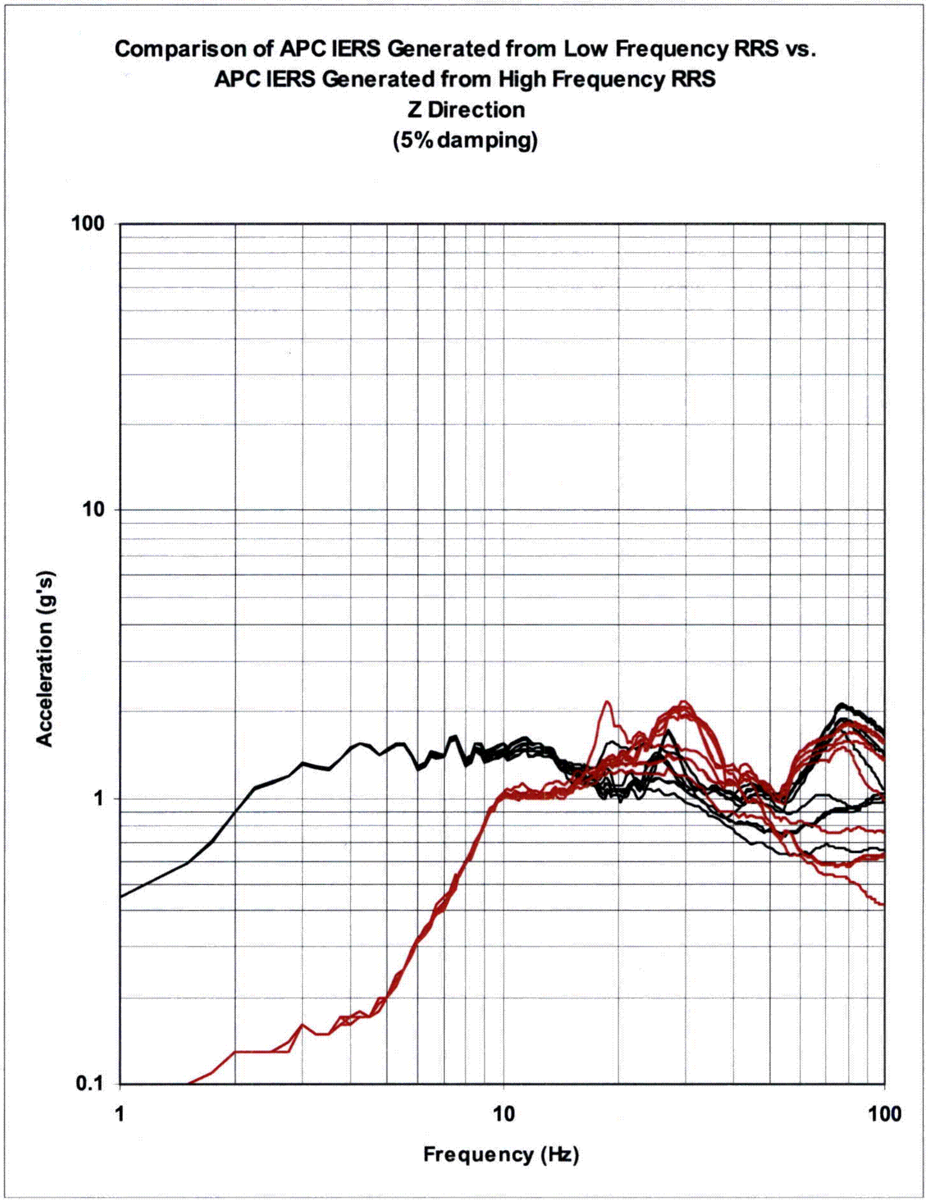


Figure 6.4.3.3.4-3: Comparison of APC Model IERS, Z-Direction (Vertical)
High Frequency IERS Shown in Red, Low Frequency IERS shown in Black
(5% Critical Damping)

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 high frequency 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 high-frequency input are slightly higher than the bolts shear loads caused by the low frequency input (314.6 lbs versus 288.9 lbs), the HF/LF ratio for the SRSS value between shear and tension is 0.92. This confirms the low frequency seismic input results envelop the results of the high frequency 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 high frequency 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-to-Side)	UY Max (Cabinet Front-to-Back)	UZ Max (Cabinet Vertical)		Max. HF/LF Ratio
Low Frequency	Node:	67	9347	5751	10143	1.0
	Value (inches):	0.12	0.05	0.007	0.007	
High Frequency	Node:	67	9347	5751	10143	
	Value (inches):	0.09	0.05	0.006	0.006	

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	1258.5	288.9	1291.2	0.92
High Frequency	1147.2	314.6	1189.6	

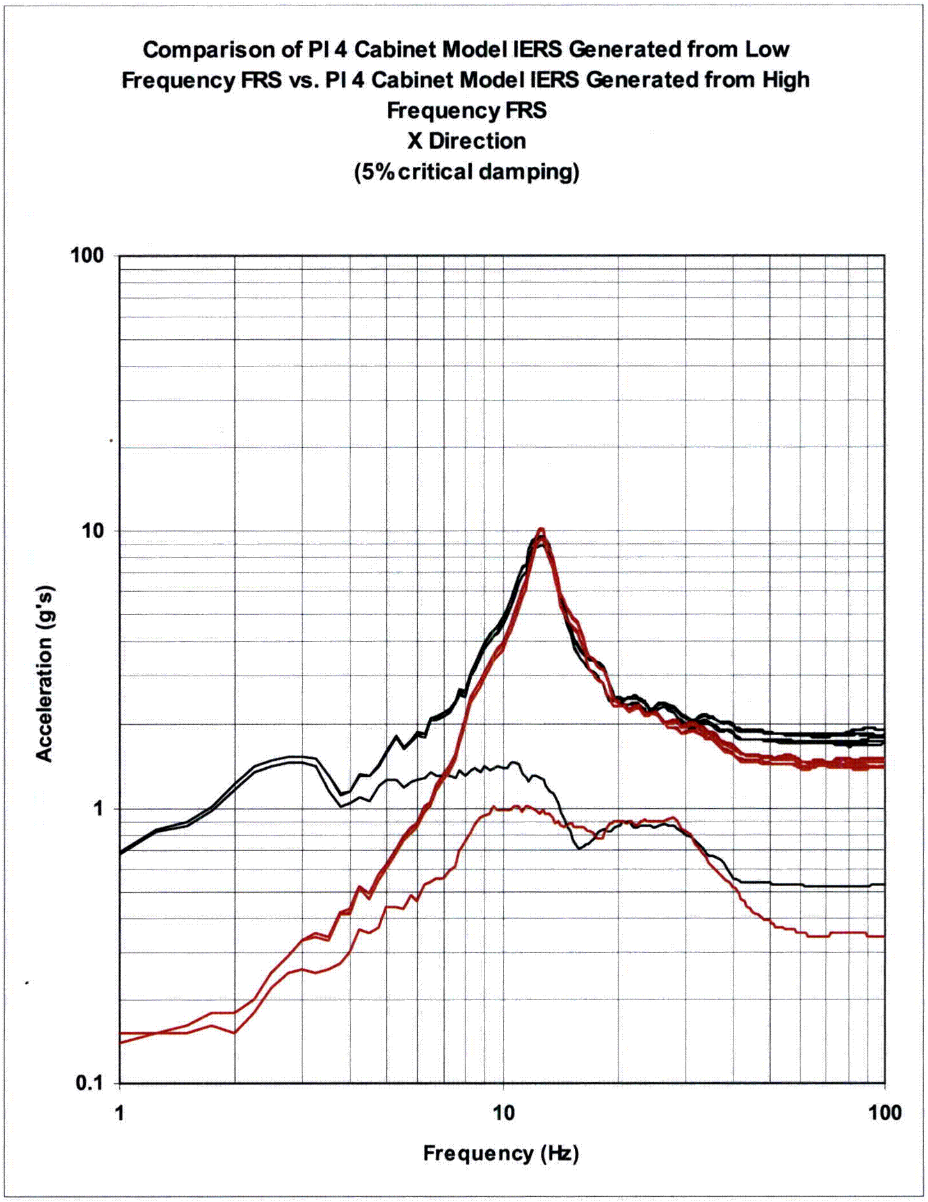


Figure 6.4.3.3.5-1: Comparison of PI 4 Cabinet Suite Model IERS, X-Direction (Side-Side)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black
(5% Critical Damping)

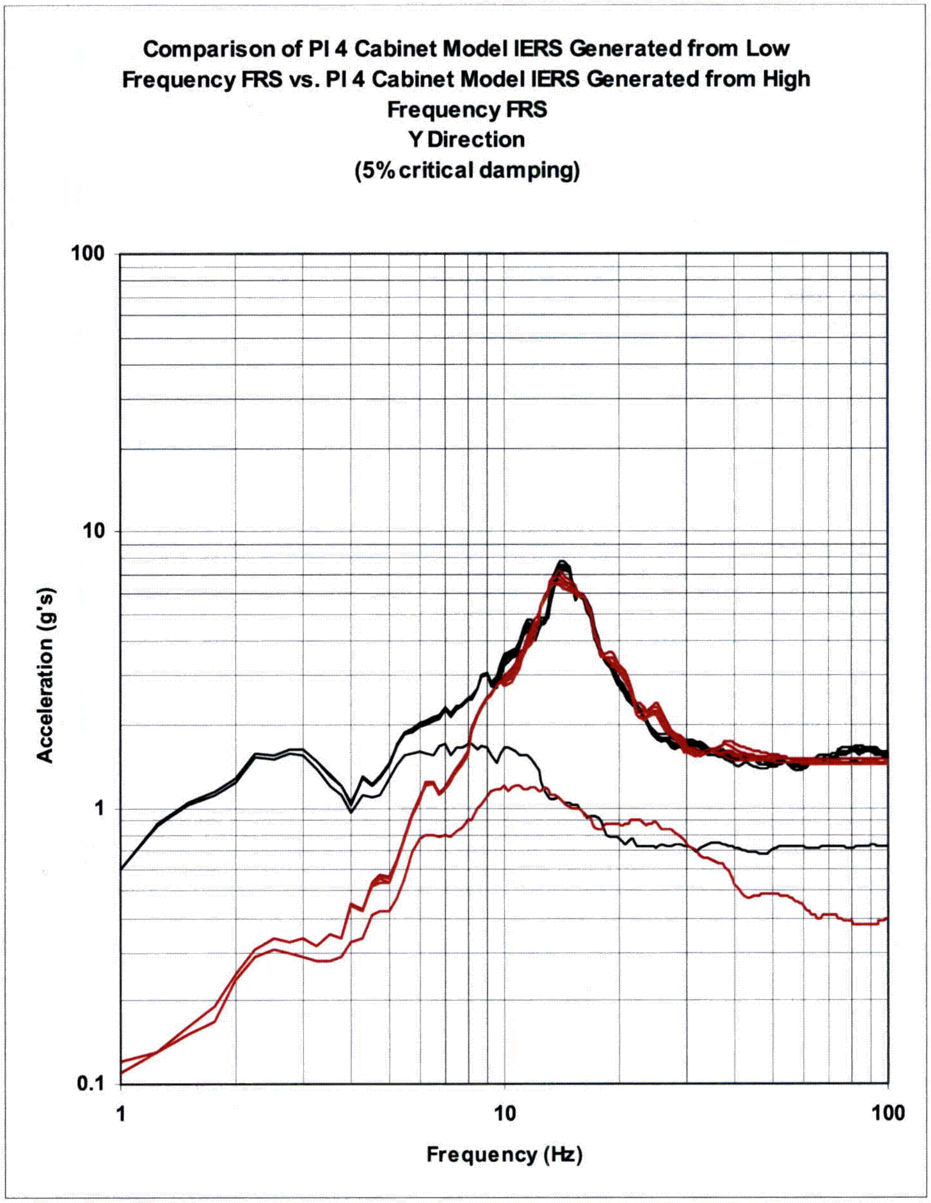


Figure 6.4.3.3.5-2: Comparison of PI 4 Cabinet Suite Model IERS, Y-Direction (Front-Back)

High Frequency IERS Shown in Red, Low Frequency IERS shown in Black (5% Critical Damping)

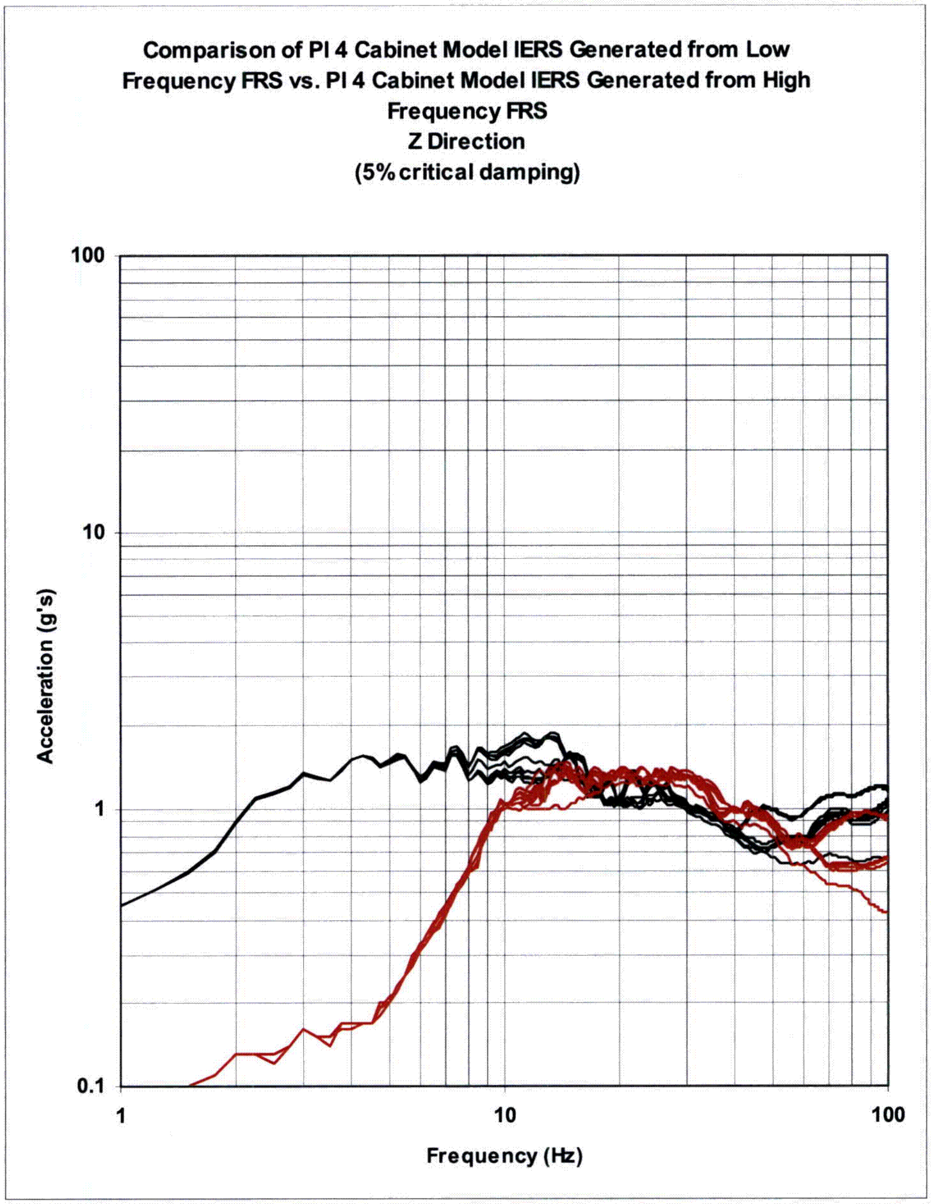


Figure 6.4.3.3.5-3: Comparison of PI 4 Cabinet Suite Model IERS, Z-Direction (Vertical)

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 Std. 344-1987 (Reference 6.4-3). Safety-related equipment is required to withstand five lower level seismic events followed by at least one Safe Shutdown Earthquake (SSE) event. The second set was testing performed to meet the Uniform Building Code (UBC) for commercial equipment supplied in essential industrial facilities. The following test data was reviewed:

a. The seismic test response spectra (TRS) in the frequency range of 25 to 50 Hz
b. 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

Fourteen test reports were reviewed for safety-related test programs which resulted in test data for over 20 test specimens. In addition, twenty test reports were reviewed for UBC testing resulting in test data for over 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-to-back, side-to-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 fourteen test reports based on the criteria in Section 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 Section 6.4.4.1 are as follows:

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

Sample test response spectra (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 6.4.3.3.2-1 through 6.4.3.3.2-3).

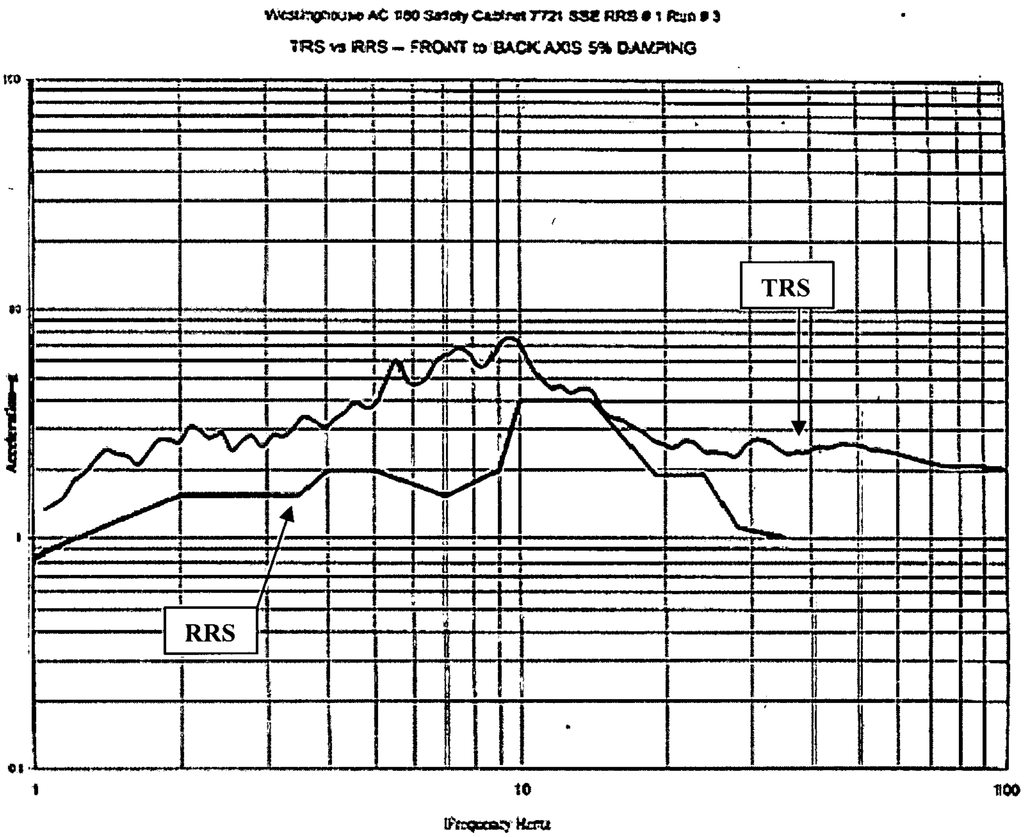


Figure 6.4.4.2-1: ANDI Test Report 6445 Test Run RRS #1 SSE 3 Front-to-Back

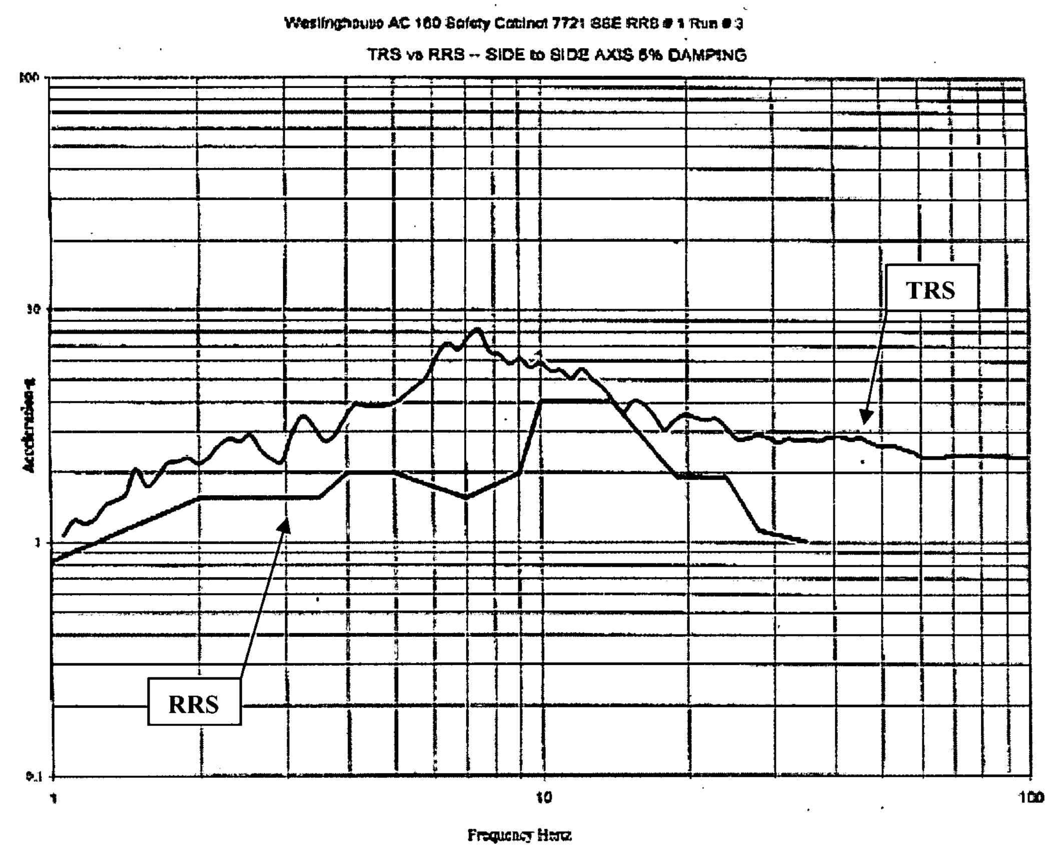


Figure 6.4.4.3-2: ANDI Test Report 6445 Test Run RRS #1 SSE 3 Side-to-Side

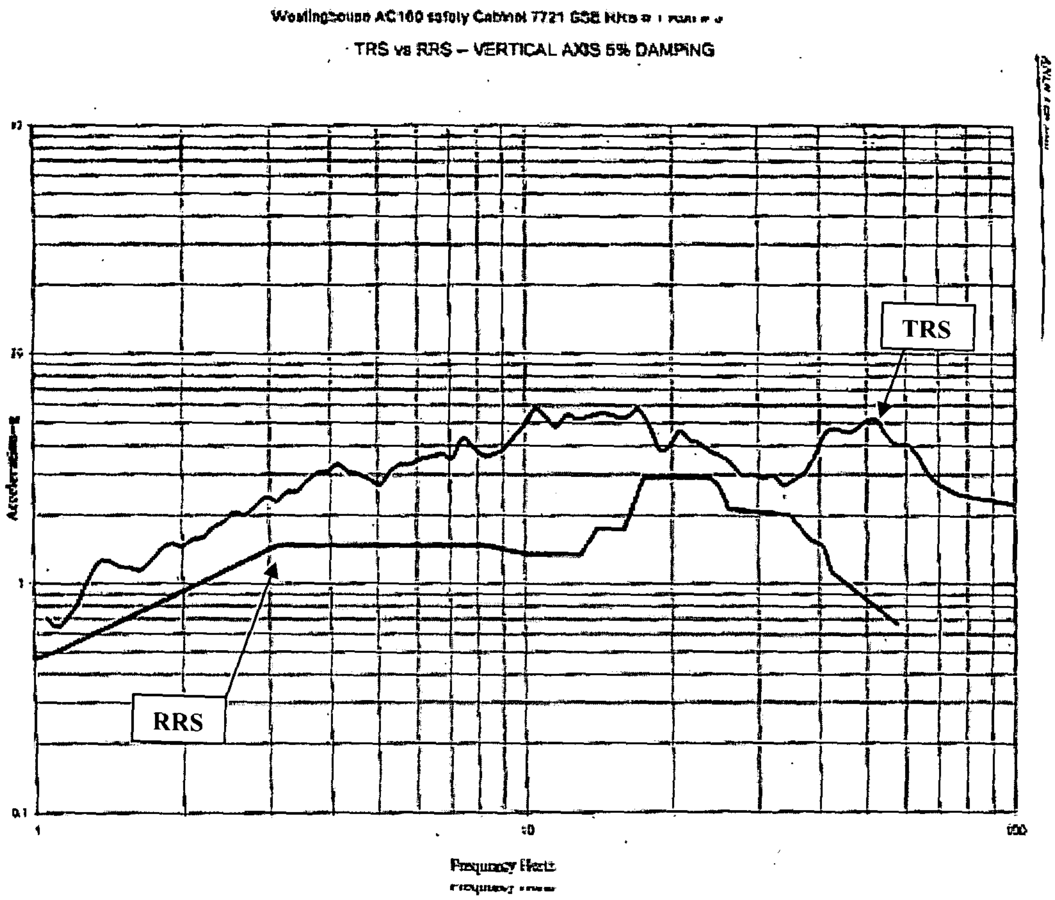


Figure 6.4.4.3-2: ANDI Test Report 6445 Test Run RRS #1 SSE 3 Vertical

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 Section 6.4.4.1. The Test Response Spectra (TRS) at 5% 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 g's (at 5% 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 high frequency input. This includes cabinet mounted equipment, field sensors, and appurtenances which may be sensitive to high frequency 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 high frequency input, and the cabinets will maintain their structural integrity and functional operability during and after the high frequency 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 Section 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 high frequency 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 high frequency 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 high frequency 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 high frequency sensitive 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 high frequency sensitive components having failure modes associated with mounting, connections and fasteners, joints, and interface are considered to be qualified by traditional low frequency qualification testing per IEEE Std 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 Std. 344-1987 (Reference 6.4-3) for those plants which have high frequency exceedance of their CSDRS and which therefore require evaluation of potentially high frequency sensitive equipment and components. High frequency screening test 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% critical damping).

High frequency seismic testing of equipment determined to be sensitive (that is not screened out per Section 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 Required Response Spectra (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 effects requirement 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 high frequency 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 already been tested 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 assure that safety-related components which 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% 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% critical damping).

7.0 General Conclusions

An evaluation was performed for portions of structures, components, and systems for the hard rock high frequency (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 Equipment
  - Reactor Vessel and Internals
  - Primary Component Supports
  - Reactor Coolant Loop Primary Equipment Nozzles
- Piping Systems
- Electro-Mechanical 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 Containment Internal Structures 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 envelop 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 high frequency 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 Section 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 assure 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 HRHF spectra produces lower seismic loads than the CSDRS. Thus, it is sufficient to use the CSDRS seismic loads in the AP1000 design.

8.0 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.

2.0-1 APP-GW-S2R-010, Revision 1, "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 U.S. Atomic Energy Commission, Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 1, December 1973.

6.4-2 AP1000 Design Control Document, "Design of Structures, Components, Equipment and Systems," Revision 16.

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.

Appendix 3I has been modified and is included in this appendix.

The modifications include:

- Revised Figures 3I.1-1 and 3I.1-2
- Introduced the terminology HRHF for Hard Rock High Frequency seismic response
- Replaced the use of the NI10 model with the NI20 for development of HRHF seismic response

APPENDIX 3I Evaluation for High Frequency Seismic Input

3I.1 Introduction

The seismic analysis and design of the AP1000 plant is based on the Certified Seismic Design Response Spectra (CSDRS) shown in subsection 3.7.1.1. These spectra are based on Regulatory Guide 1.60 with an increase in the 25 hertz region. Ground Motion Response Spectra (GMRS) for some Central and Eastern United States rock sites show higher amplitude at high frequency than the CSDRS. Evaluations are described in this appendix for a GMRS with high frequency seismic input at a site where the nuclear island is founded on hard rock. The resulting spectra of this site is shown in Figure 3I.1-1 and Figure 3I.1-2 and compares this hard rock high frequency (HRHF) GMRS at the foundation level against the AP1000 CSDRS for both the horizontal and vertical directions for 5% damping. The HRHF GMRS exceed the CSDRS for frequencies above about 15 Hz.

High frequency seismic input is generally considered to be non-damaging as described in Reference I.1. The evaluation of the AP1000 nuclear island for high frequency input is based on the analysis of a limited sample of structures, components, supports, and piping to demonstrate that the high frequency seismic response is non-damaging. The evaluation includes building structures, reactor pressure vessel and internals, primary component supports, primary loop nozzles, piping, and equipment.

This appendix describes the methodology and criteria used in the evaluation to confirm that the high frequency input is not damaging to equipment and structures qualified by analysis for the AP1000 CSDRS. It provides supplemental criteria for selection and testing of equipment whose function might be sensitive to high frequency. The results of the high frequency evaluation demonstrating that the AP1000 plant is qualified for this type of input are documented in a technical report (Reference I.2). This report will provide a summary of the analysis and test results.

3I.2 High Frequency Seismic Input

Presented in Figures 3.I-1 and 3.I-2 is a comparison of the horizontal and vertical GMRS from the HRHF site and the AP1000 CSDRS. The HRHF GMRS presented is calculated at foundation level (39.5' below grade), at the upper most competent material and treated as an outcrop for calculation purposes.

For each direction, the HRHF GMRS exceeds the design spectra in higher frequencies (greater than 15 Hz horizontal and 20 Hz vertical). The spectra are used for the GMRS. If necessary, the HRHF GMRS spectra are enhanced at low frequencies so that GMRS fully envelopes all of the hard rock sites.

3I.3 NI Model Used To Develop High Frequency Response

The NI20 nuclear island model described in Appendix 3G is analyzed in SASSI using the HRHF time histories applied at foundation level to obtain the motion at the base. The NI20 model has sufficient mesh size to transmit the HRHF input up to 80 Hz. This was confirmed by comparing the dynamic response of the NI20 to that of the NI10 model, a model with a much finer mesh.

3I.4 Evaluation Methodology

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

The high frequency seismic analyses that are performed use time history or broadened response spectra. The analysis is not performed using the envelope spectra of the CSDRS and the GMRS. Separate analyses with each spectra are used.

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

Supplementary analyses are performed as needed to show that high frequency floor response spectra exceedances are not damaging. These analyses can include: gap nonlinearities, material inelastic behavior, and multi-point response spectra analyses where the high frequency response excites a local part of the system. Tests on equipment are specified as needed where function cannot be demonstrated by analysis, or analysis is not appropriate.

3I.5 General Selection Screening Criteria

The following general screening criteria are used to identify representative AP1000 systems, structures, and components (SSCs) for the samples to be evaluated to demonstrate acceptability of the AP1000 nuclear power plant for the high frequency motion.

- Select systems, structures, and components based on their importance to safety. This includes the review of component safety function for the SSE event and its potential failure modes due to an SSE. Those components whose failure modes would result in safe shutdown are excluded.

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

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

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

3I.6 Evaluation

In this section, the portions of structures, components, and systems that are evaluated for the high frequency seismic response are identified. The sample to be evaluated based on the screening criteria applicable to the SSCs consists of the following:

- Building Structures
  - Auxiliary Building – 3 locations
  - Shield Building – 8 locations
  - CIS – 2 locations

- Primary Coolant Loop
  - Reactor Vessel and Internals
  - Primary Component Supports
  - Reactor Coolant Loop Primary Equipment Nozzles

- Piping Systems – at least two piping analysis packages

- Electro-Mechanical Equipment – Equipment that is potentially sensitive to high frequency input (see Table 3I.6-1)

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

3I.6.1 Building Structures

Maintaining the NI buildings structural integrity is important to the safety of the plant. Representative portions of buildings that are evaluated for the effect of high frequency input are selected based on those areas that can experience high seismic shear and moment loads due to the seismic event. Areas chosen are at the base of the Shield Building, in the vicinity of Auxiliary Building floors that have fundamental frequencies in the high frequency region, and the corners of the Auxiliary Building. Three locations are selected in the Auxiliary Building that reflects the bottom of a wall where the shear and moment 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 are evaluated on the Shield Building, four located at elevation 107' and four located at elevation 211'. These locations are located on the east, west, north and south sides. The southwest wall of the refueling canal is evaluated since it is a representative wall on the refueling canal. The CA02 wall in the CIS building is evaluated since it is a representative wall associated with the IRWST.

The evaluation consists of a comparison of the loads from the high frequency input to those obtained from the AP1000 design spectra, shown in Figures 3I.1-1 and 3I.1-2, for these representative building structures. The NI building structures are considered qualified for the high frequency input if the seismic loads from the Regulatory Guide 1.60 (modified) envelope those from the high frequency input. If there is any exceedance, this is evaluated further to confirm that the existing design is adequate.

3I.6.2 Primary Coolant Loop

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

- Reactor vessel and internals
- Reactor vessel supports
- Steam generator supports
- Reactor coolant loop primary equipment nozzles

The reactor vessel and internals are selected since 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 significant vertical amplification at the supports of the reactor pressure vessel. Further, 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 high frequency range.

- Additional high frequencies are associated with nonlinear impact

The evaluation consists of a comparison of the loads from the high frequency input to those obtained from the Regulatory Guide 1.60 (modified) input. Qualification is shown for the high frequency input if the seismic loads from the Regulatory Guide 1.60 (modified) envelope those from the high frequency input. If there is exceedance, then comparison is made for the combination of the seismic with the design basis pipe break loads and steady state loads. Qualification is then shown if the high frequency loads are relatively insignificant compared to the other loads, or there are no required design changes.

Maintaining the integrity of the reactor vessel and steam generator supports is important to preserving the primary component safety function. They are representative of supports on components, and see high loads.

The reactor coolant loop nozzles at the cold and hot leg interfaces of the reactor pressure vessel, 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 reactor coolant loop nozzles consists of a comparison of the loads from the high frequency input to those obtained from the Regulatory Guide 1.60 (modified) input. These items are considered qualified for the high frequency input if the seismic loads from the Regulatory Guide 1.60 (modified) envelope those from the high frequency input. If there is any exceedance, then an evaluation is made combining the high frequency loads with the other load components (e.g., thermal, pressure, dead) and a comparison made to the design loads. If the design loads envelope the load combinations that include the high frequency seismic input, then the nozzles and supports are considered qualified for the high frequency input.

3I.6.3 Piping Systems

Safety class piping analysis packages were reviewed and include a mixture of ASME Class 1, 2, and 3 piping systems. They typically contain at least one valve. The piping systems are mainly large bore of various size (3-inch diameter to 38-inch diameter), and some of small bore (2 inches and lower). The piping systems are in both the containment and auxiliary building.

The piping systems chosen for evaluation are those that are susceptible to high frequency as measured by their mass participation in the higher frequencies, are representative piping systems that contain valves and equipment nozzles, and are located in areas susceptible to high frequency HRHF GMRS spectra level response. At least two candidate piping analysis packages are identified for evaluation that meet these screening criteria.

The pipe stresses, nozzle loads, and valve end loads obtained from both the high frequency input and the Regulatory Guide 1.60 (modified) input are compared. Comparison is also made to the allowable with the seismic stresses combined with the other stresses associated with the seismic load combination that is applicable as necessary. If the high frequency seismic results are below those associated with the Regulatory Guide 1.60 (modified) results, or below the allowable limits, then the piping system is considered qualified. If necessary, more detailed supplementary analyses will be performed considering one or more of the following:

- Multi-point response spectra input
- Non-linear analysis with gap and material nonlinearities
- Calculation of actual support stiffness in locations where a minimum rigid value was used

3I.6.4 Electro-Mechanical Equipment Qualification

The groups of safety-related equipment considered for evaluation are those that may be sensitive to the high frequency input. This includes cabinet mounted equipment, field sensors, and appurtenants which may be sensitive to high frequency seismic inputs identified in Table 3I.6-1.

Sample safety-related cabinets have been identified that are typically sensitive to seismic input. Evaluations will be performed to verify these cabinets do not have excessive seismic demand on their mounted equipment, the cabinet designs do not require changes due to the high frequency input, and the cabinets will maintain their structural integrity during the high frequency input. Time history analyses of these cabinets are performed for both the Regulatory Guide 1.60 (modified) and the high frequency inputs so that comparisons can be made to their seismic response from both seismic inputs. This analytical study is to conclude that safety-related equipment may be screened and grouped as follows:

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 high frequency seismic inputs.

Group No. 2:

Cabinets and other equipment which exhibit dominant natural frequencies below Hard Rock High Frequency (HRHF) exceedance range. Seismic qualification of this group based on CSDRS seismic requirements is adequate and requires no additional evaluation for high frequency 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 high frequency seismic evaluation to verify acceptability.

Qualification Process

In the high frequency screening process, the potential failure modes of high frequency sensitive component types and assemblies are important considerations. The following are potential failure modes of high frequency sensitive components/equipment.

- Inadvertent change of state
- Chatter
- Change in accuracy and drift in output signal or set-point
- Electrical connection failure or intermediacy (e.g., poor quality solder joints)
- Mechanical connection failure
- Mechanical misalignment/binding (e.g., latches, plungers)
- Fatigue failure (e.g., solder joints, ceramics, self-taping screws, spot welds)
- Improperly and unrestrained mounted components
- Inadequately secured/locked mechanical fasteners and connections

Components and equipment determined to be exposed to and are high frequency sensitive with potential failure modes involve change of state, chatter, signal change/drift and connection problems shall be demonstrated to be acceptable through the performance of supplemental high frequency qualification testing. Those high frequency sensitive component having failure modes associated with mounting, connections and fasteners, joints, and interface are considered to be qualified by traditional low frequency qualification testing per IEEE Std. 344 and/or required quality assurance inspection and process/design controls.

High frequency seismic testing for sensitive equipment will be conducted as a supplemental test to low frequency seismic excitation. High and low frequency seismic Required Response Spectra (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.

When high frequency seismic testing is performed following a low frequency seismic testing, the equipment shall be subjected to the high frequency SSE testing after completion of the low frequency seismic testing. Low level cycling fatigue effects requirement shall be justified represented 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 high frequency input is determined based on the comparison of the test levels the components have been analyzed or tested to. For those equipment/components determined to have already been tested to high seismic levels in the high frequency region, no additional testing or justifications will be 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 qualification.

3I.7 References

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.

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

3. Personal correspondence related to approved incoherence function, Abramson – April 2007.

Table 31.6-1

POTENTIAL SENSITIVE EQUIPMENT LIST

- Equipment or components with moving parts and required to perform a switching function during the seismic event (e.g., 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)

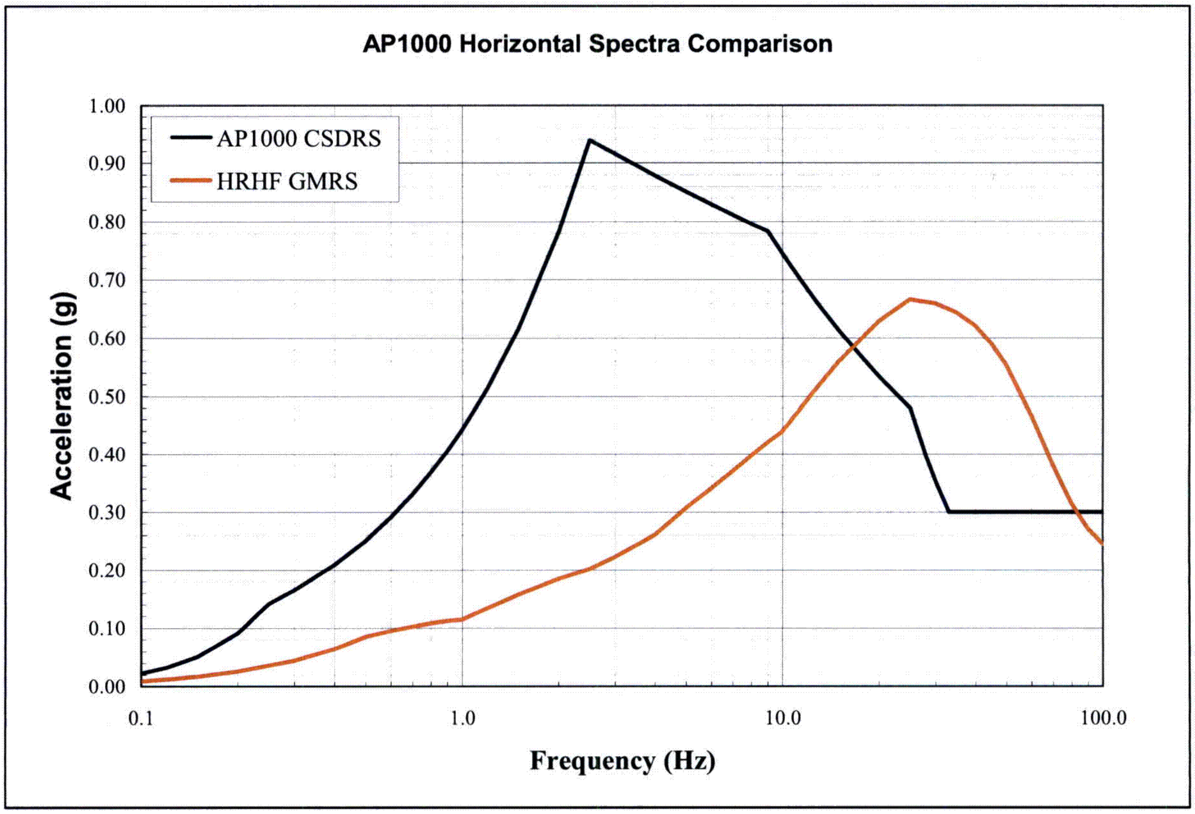


Figure 3I.1-1

Comparison of Horizontal AP1000 CSDRS and HRHF GMRS

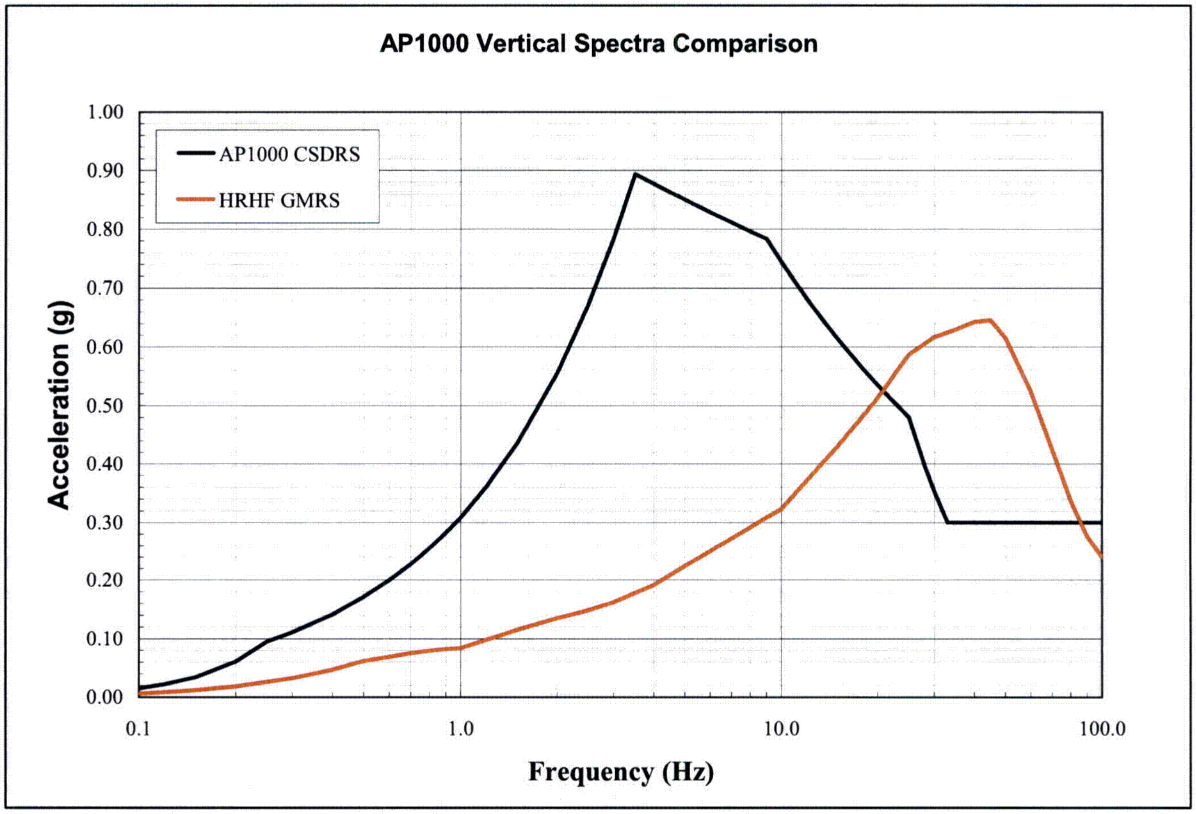


Figure 3I.1-2

Comparison of Vertical AP1000 CSDRS and HRHF GMRS