Evaluation for High Frequency Seismic Input

Westinghouse Electric Company

April 17, 2007

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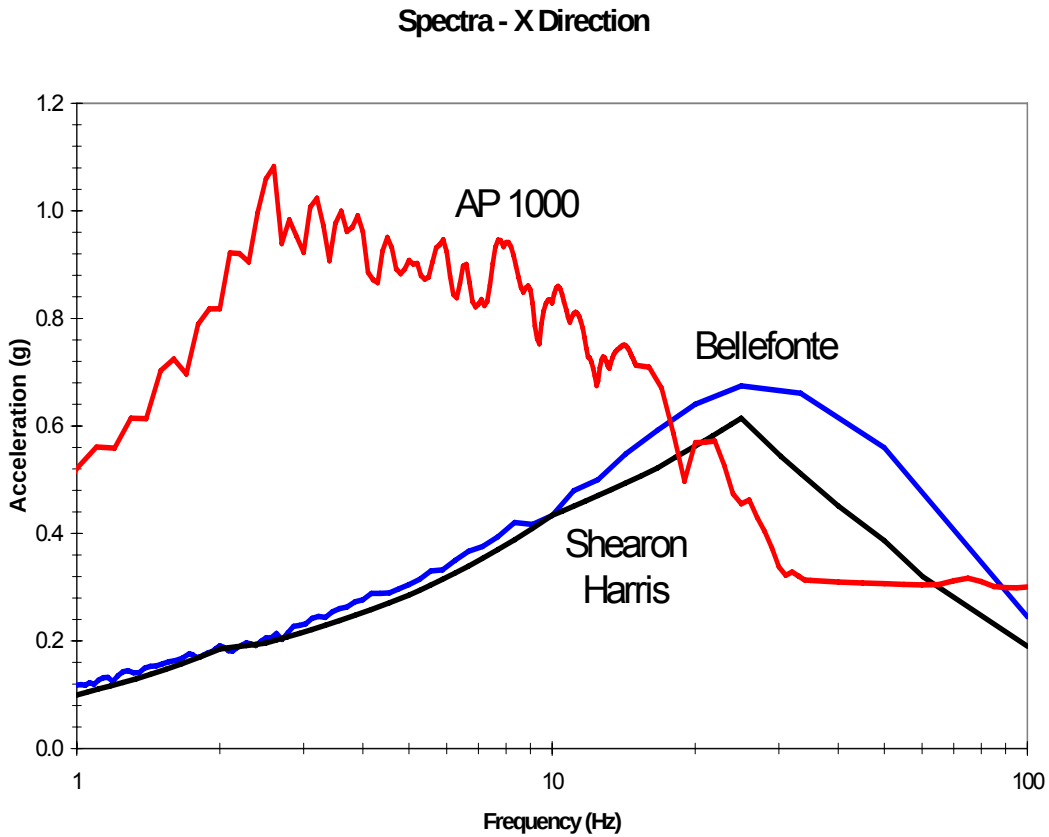
Evaluation for High Frequency Seismic Input Discussion Topics

- **Floor Response Spectra for High Frequency Evaluation**
- **Selection screening criteria and evaluation methodology**
- **Evaluation Studies**
  - *Building Structures*
  - *RPV & Internals*
  - *Primary Component Supports*
  - *Primary Loop Nozzles*
  - *Piping*
  - *Equipment*
- **Contents of technical report**

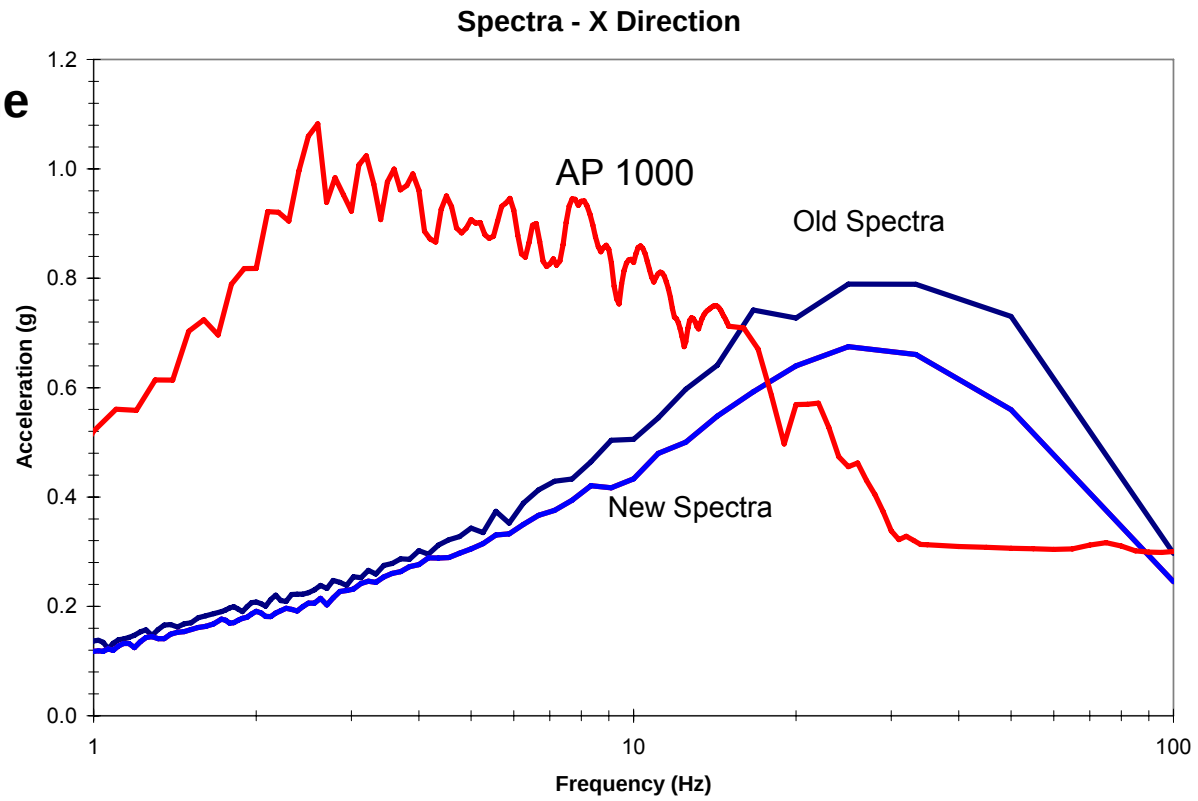
Hard Rock Design Spectra

- **Hard Rock sites (Summer, Lee, Shearon Harris) enveloped by revised Bellefonte spectra**
- **Harris spectra shown w/o CAV filter**
- **Bellefonte shown w/ CAV filter**
- **Bellefonte spectra used for High Frequency comparisons**



Bellefonte Spectra

- **Old spectra was used for the results presented**
- **Anticipate lower results for analysis with new spectra**



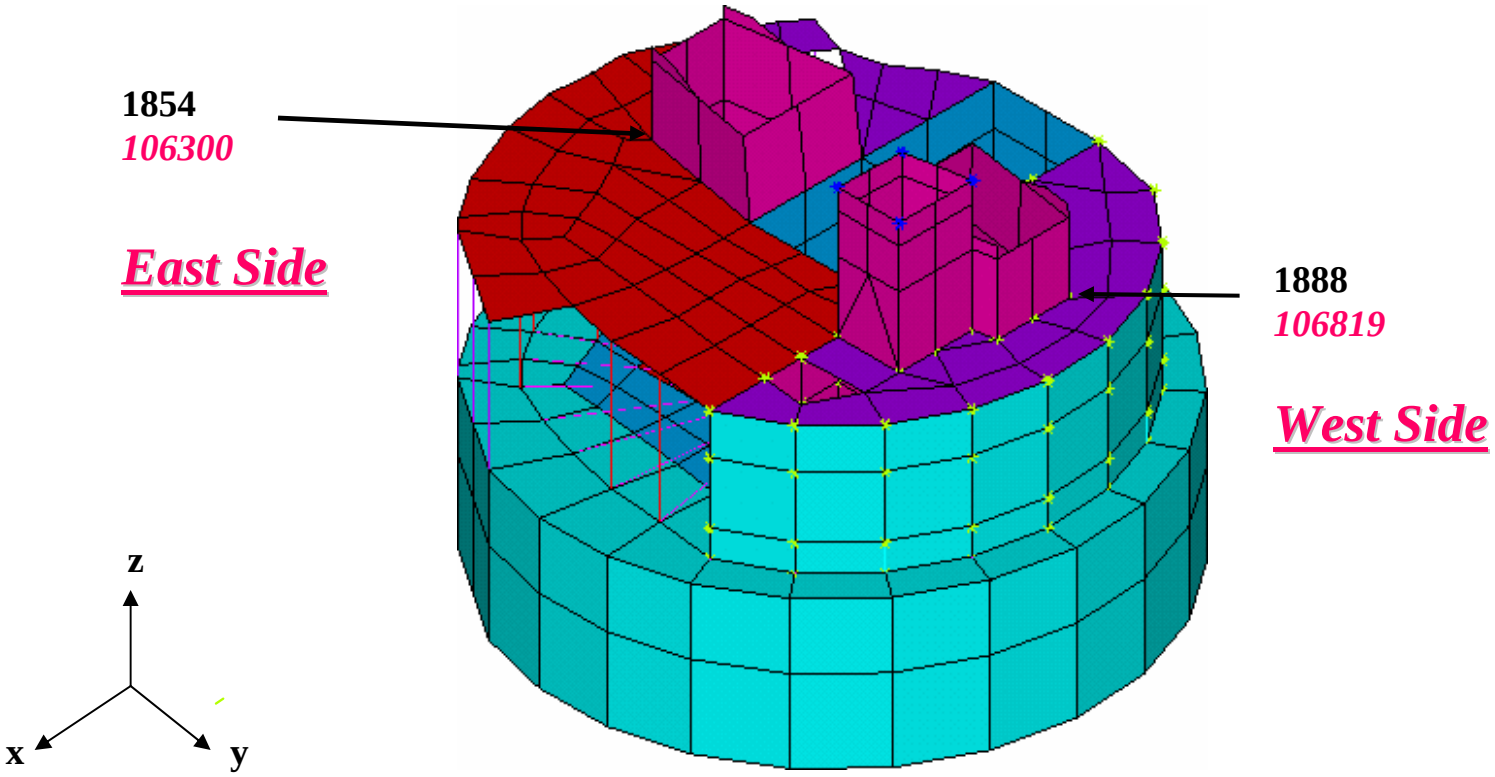
Locations for FRS Comparisons for Bellefonte

- Containment operating floor (Elevation 134.25’)
- ASB at elev. 116.5’ (same elev. as control room)
- ASB at northeast corner (Elevation 134.5’)
- Reactor vessel support (Elevation 100’)

3 Cases Compared

— SSIENV	FRS from AP1000 Design Spectra input, based on the envelope of 3D SASSI soil analyses + ANSYS Hard Rock using ni10 model
— ni20BFinc	3D SASSI soil analyses using ni20 model. Bellefonte Design Spectra input and soil conditions, incoherence effects included (August 2005)
— ni20BF	3D SASSI soil analyses using ni20 model. Bellefonte Design Spectra input and soil conditions, coherent motion

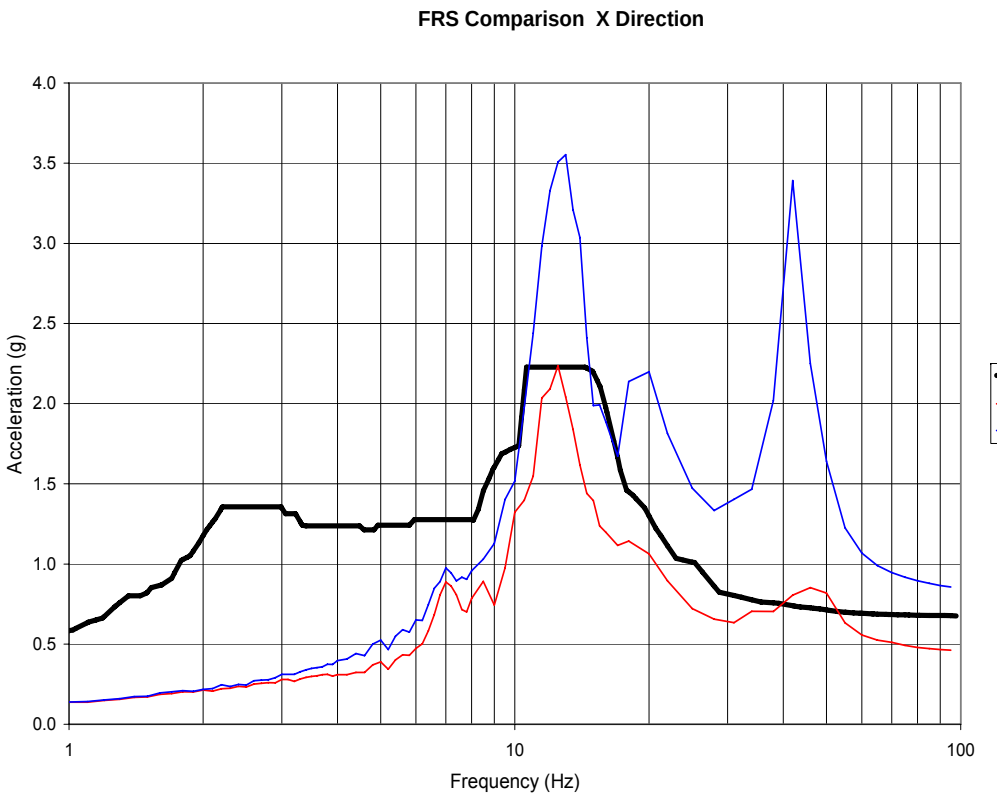
Containment operating floor (Elevation 134.25')



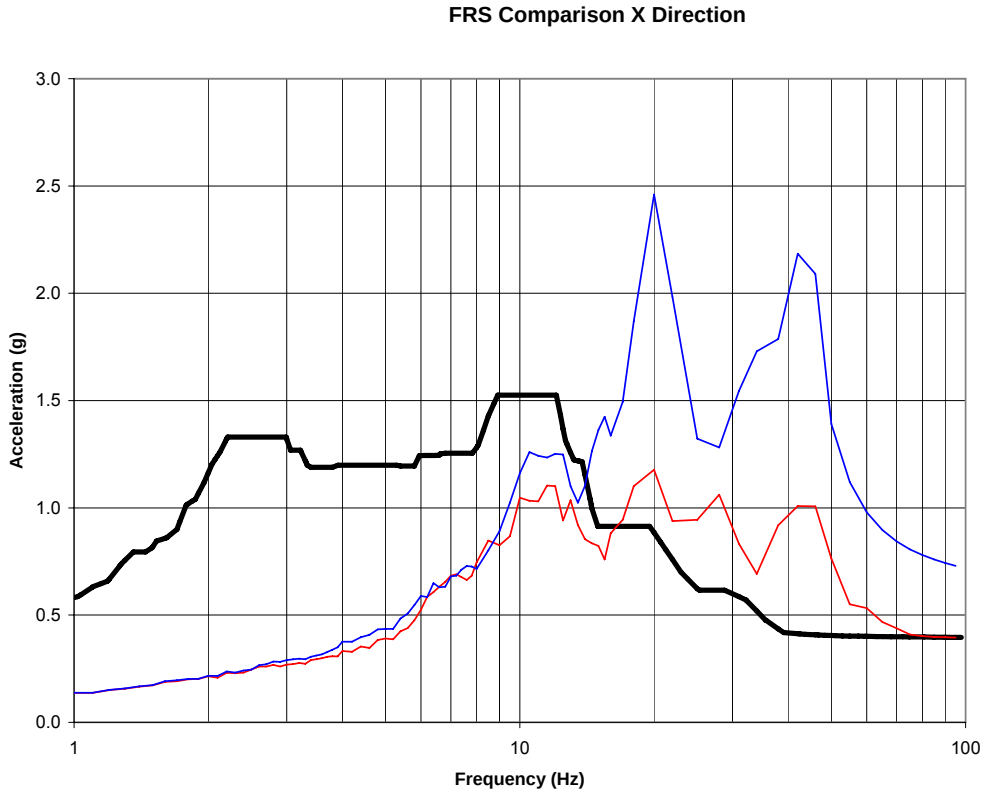
Critical nodes at isometric view

Containment operating floor (Elevation 134.25')

West side

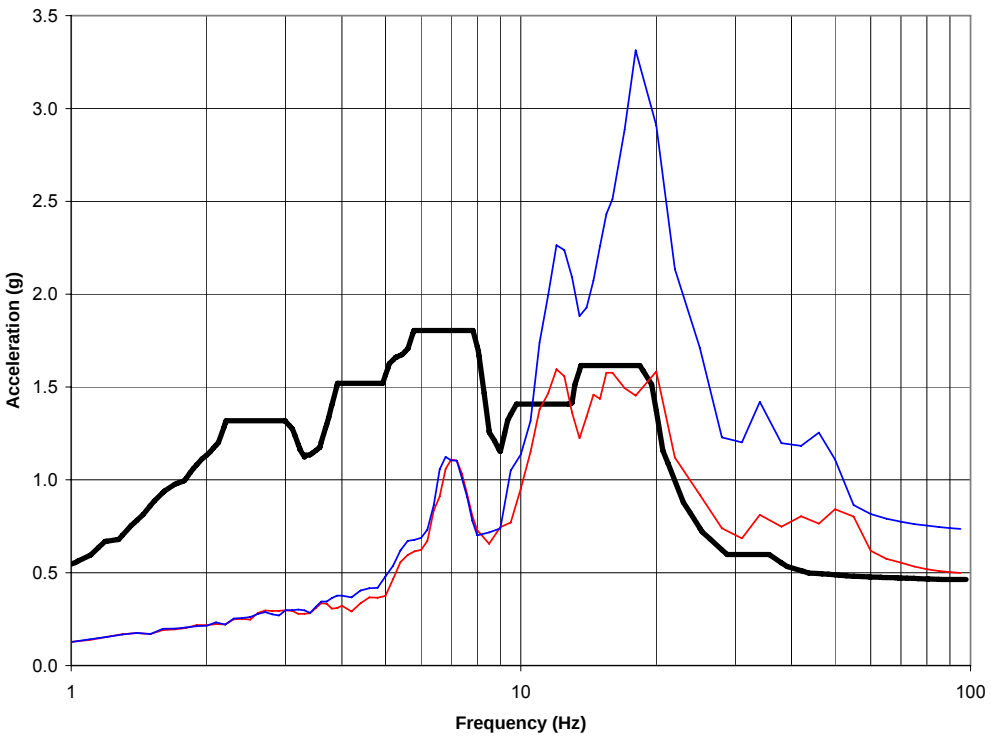


East side

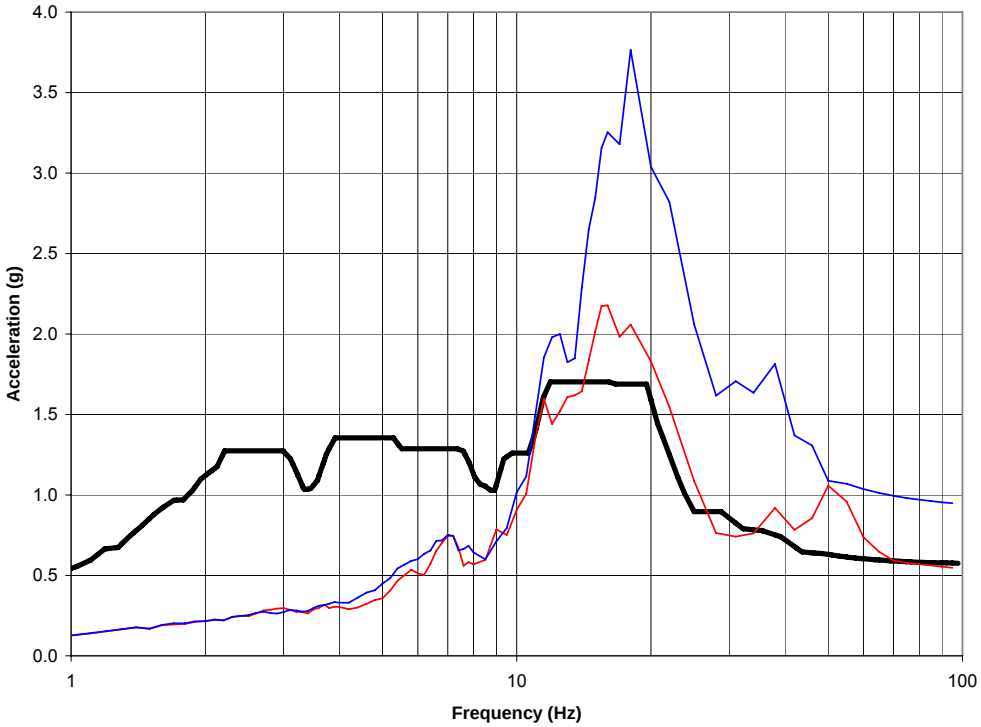


Containment operating floor (Elevation 134.25')

West side



East side



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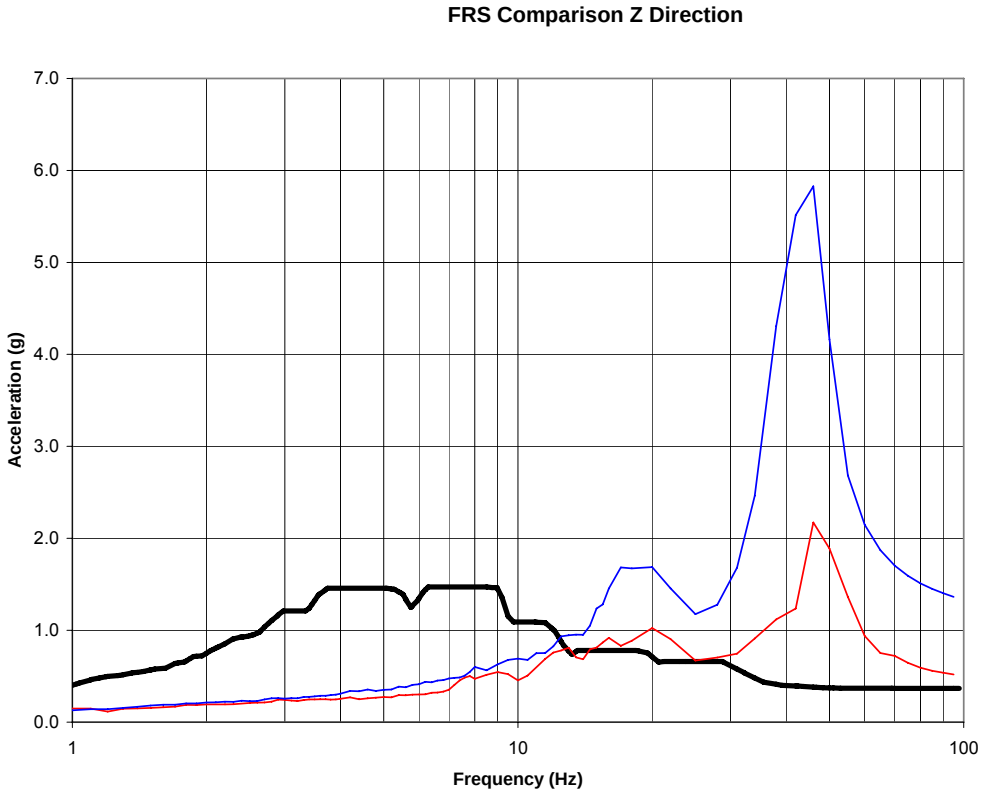
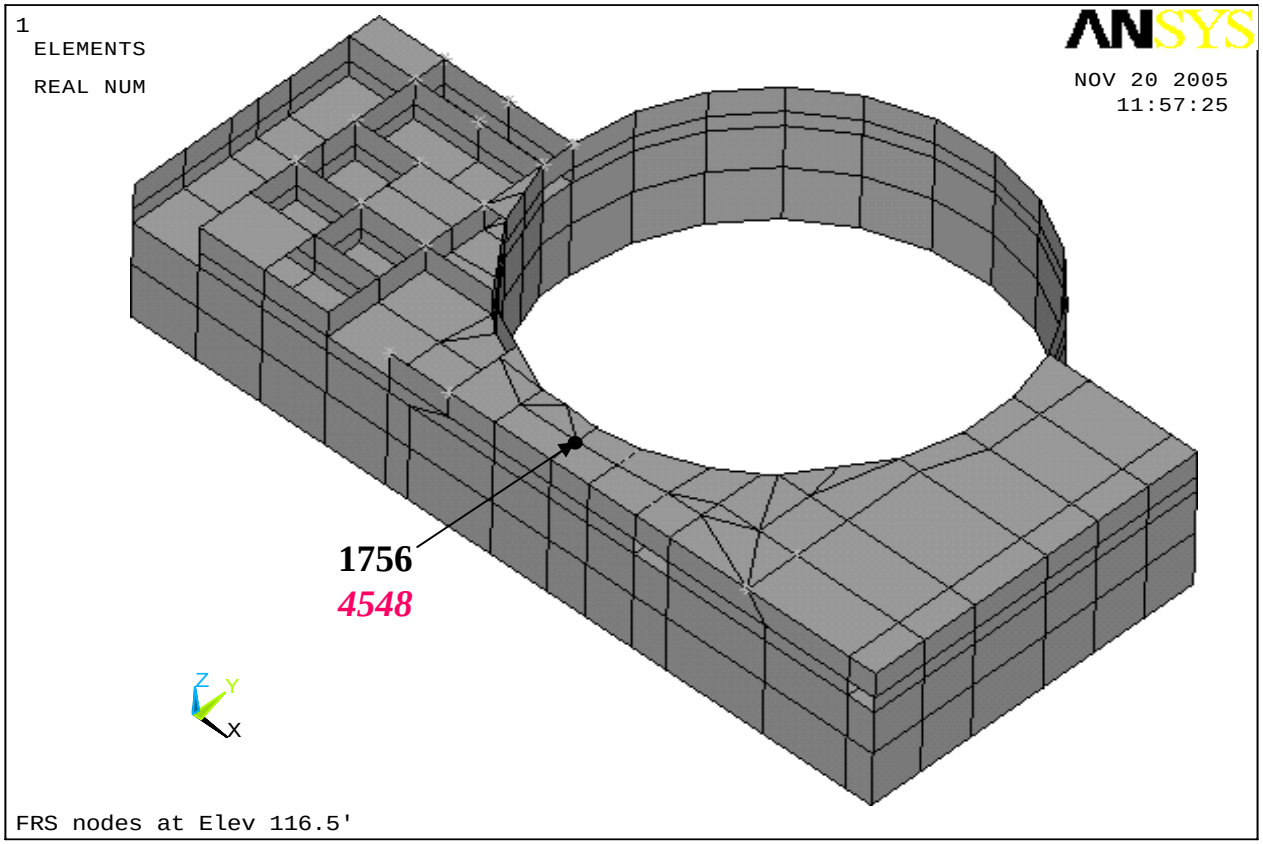


ASB at elev. 116.5’ (same elev. as control room)



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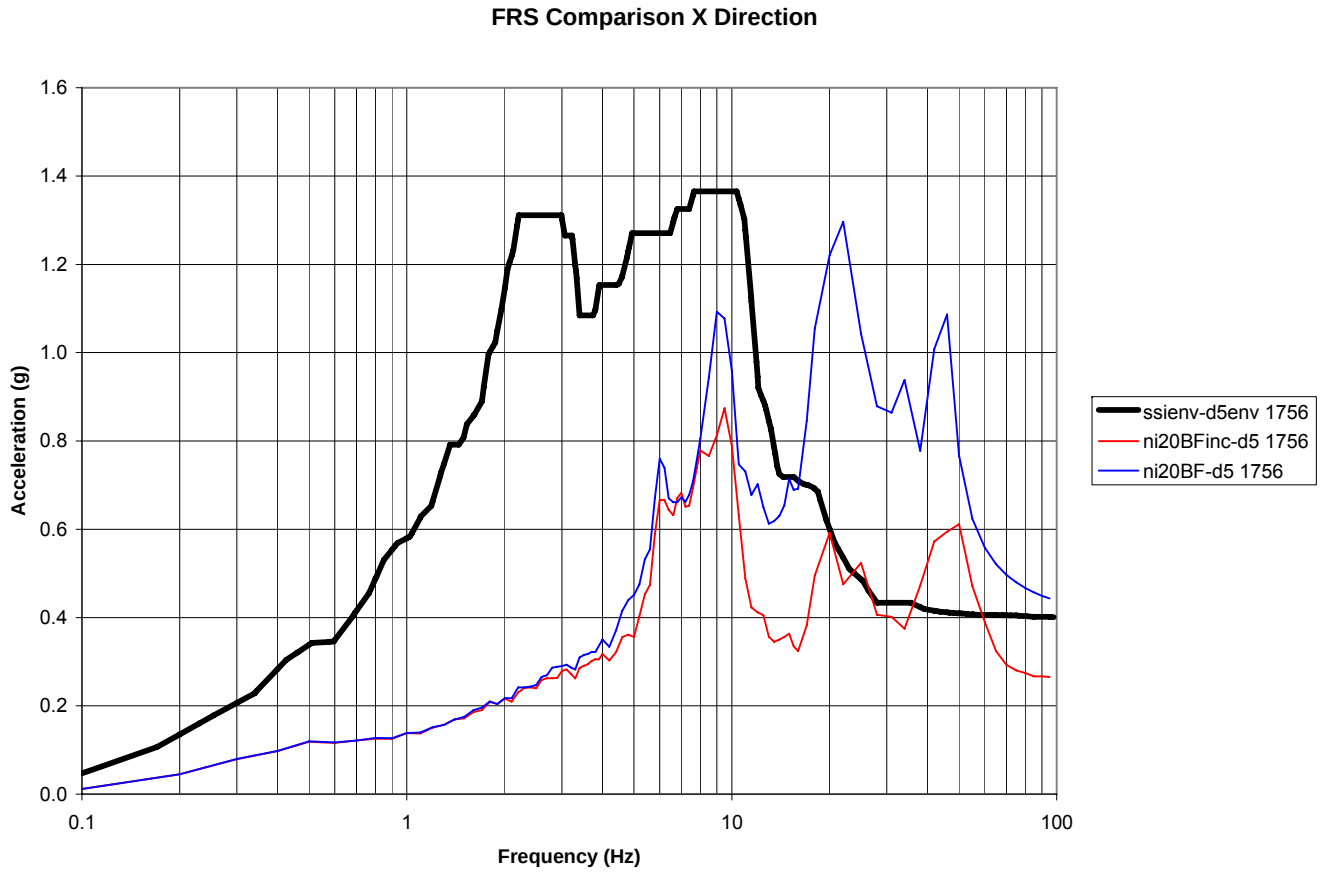

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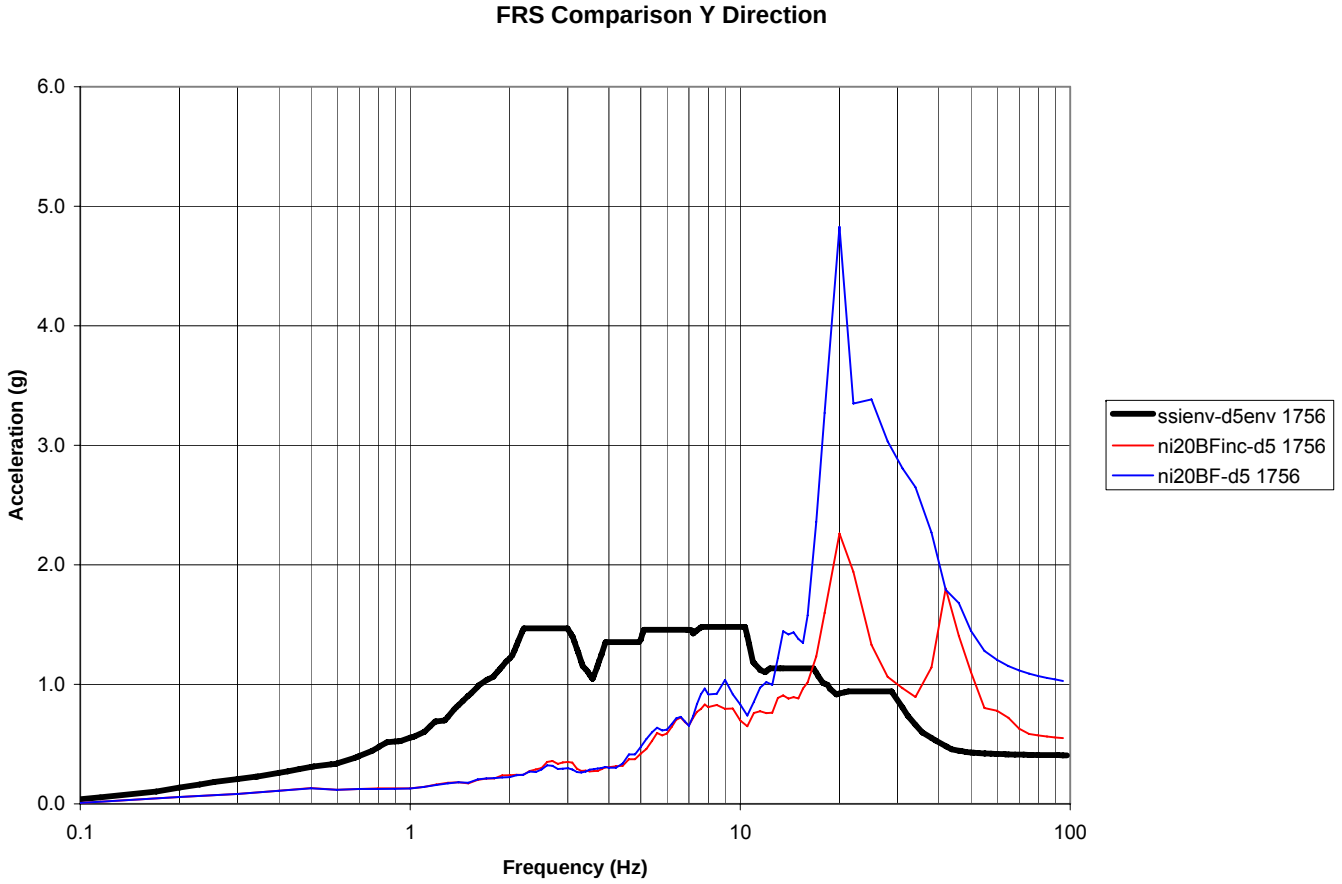

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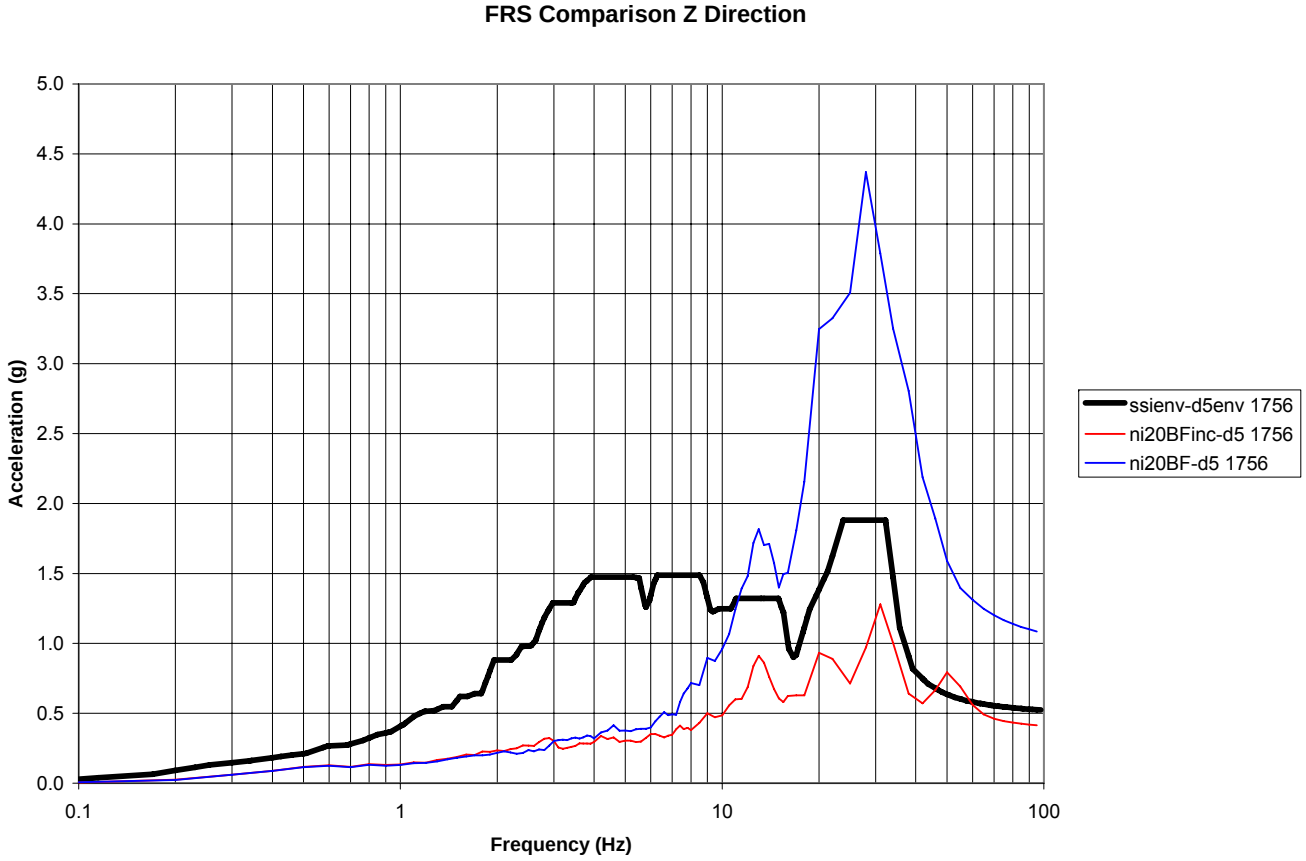
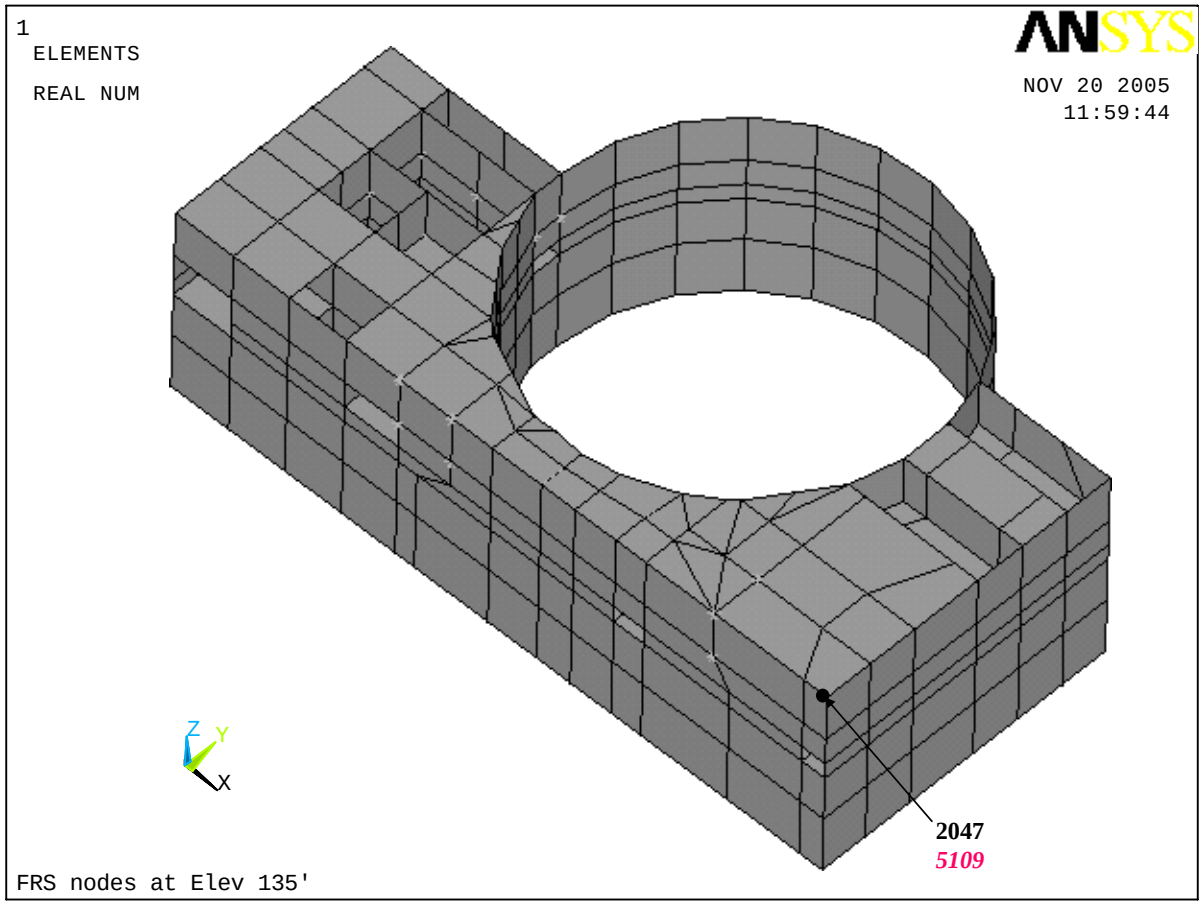


ASB at northeast corner (Elevation 134.5')



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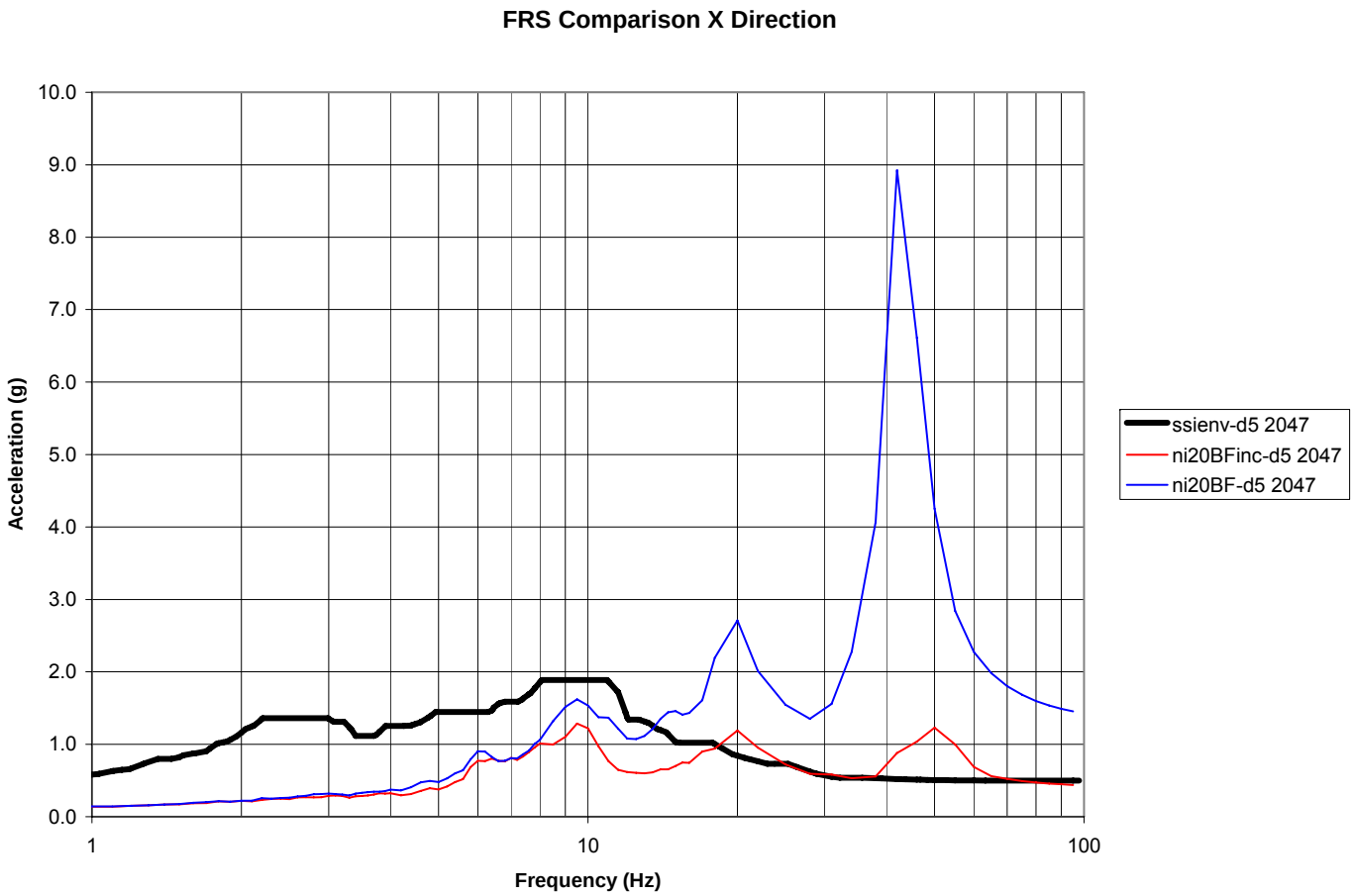

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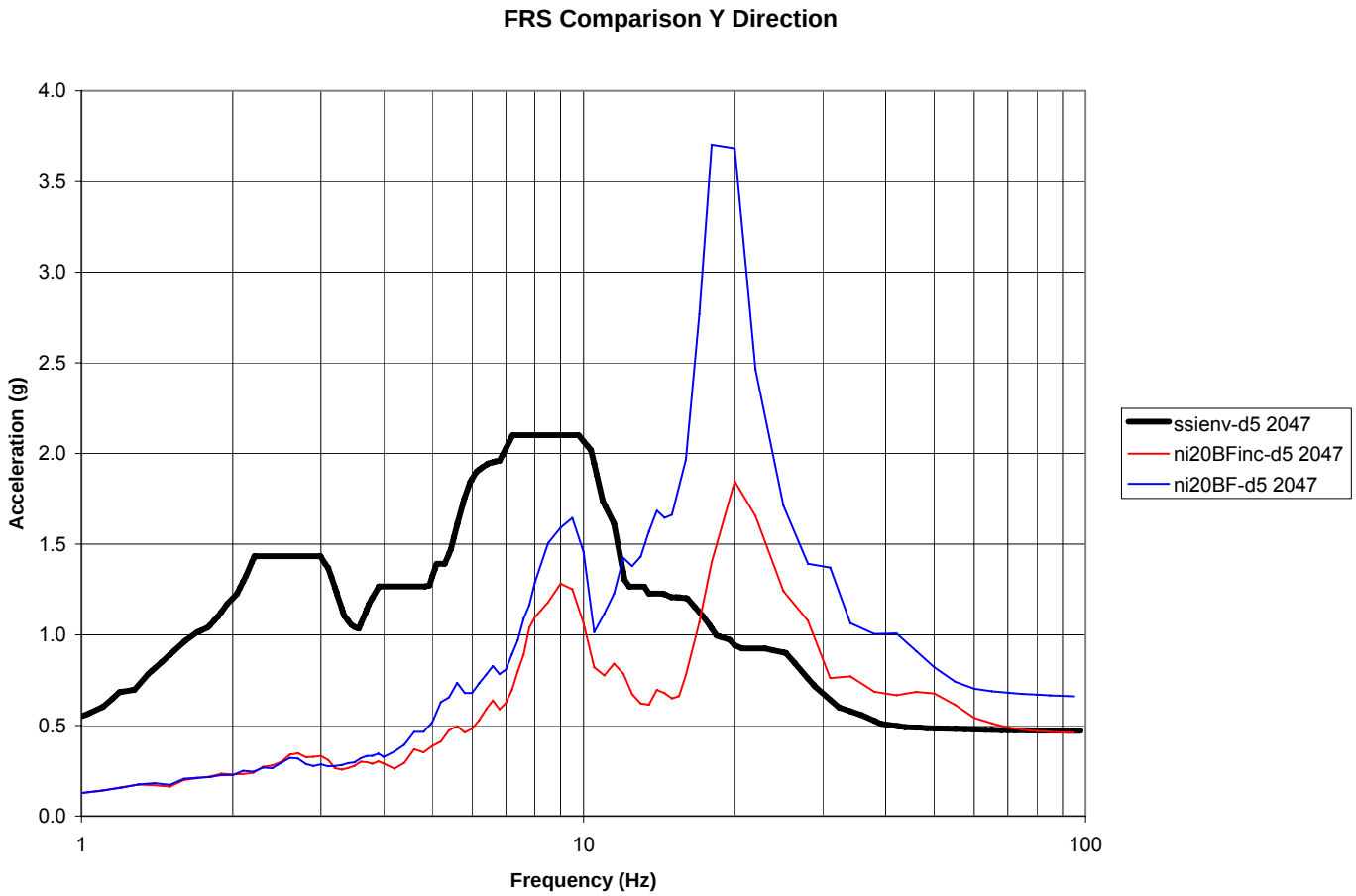

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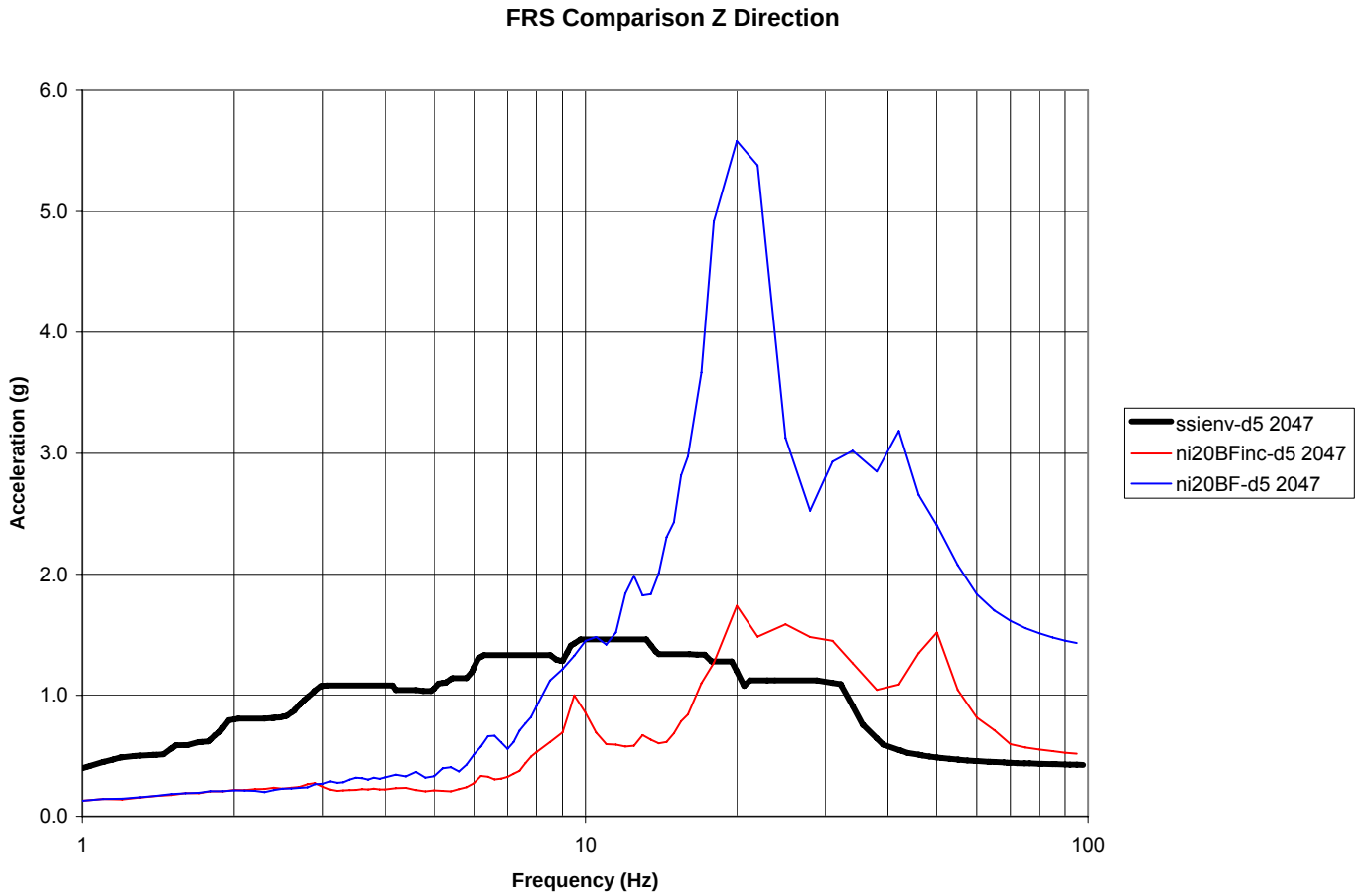
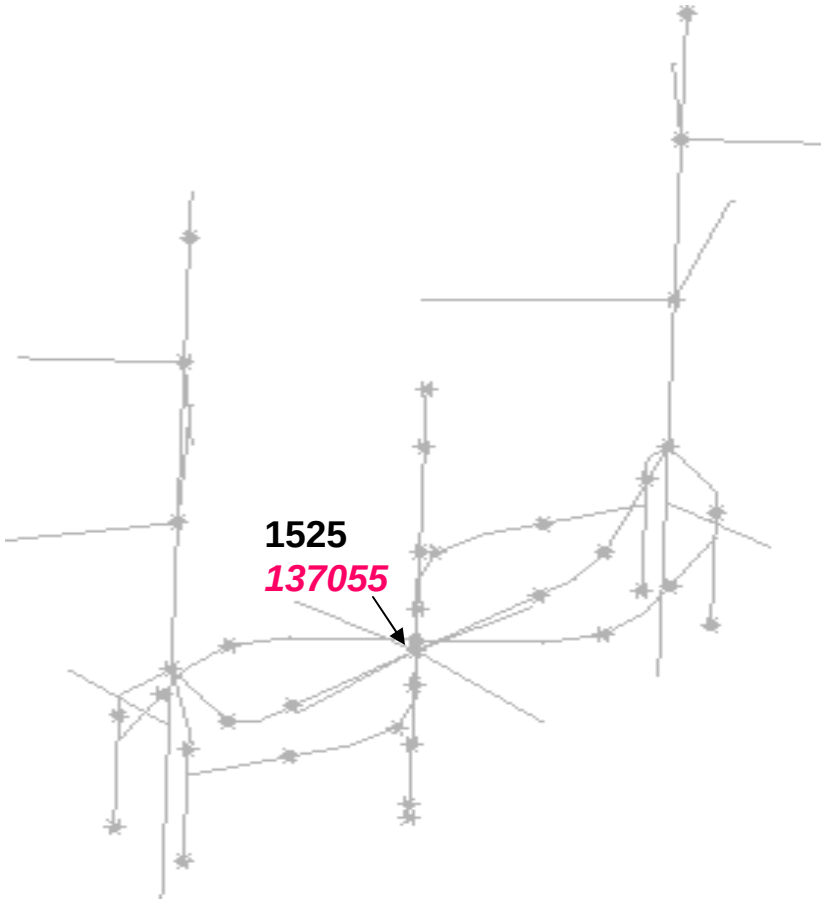
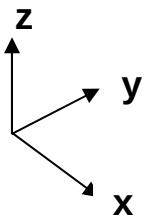


Reactor vessel support (Elevation 100’)





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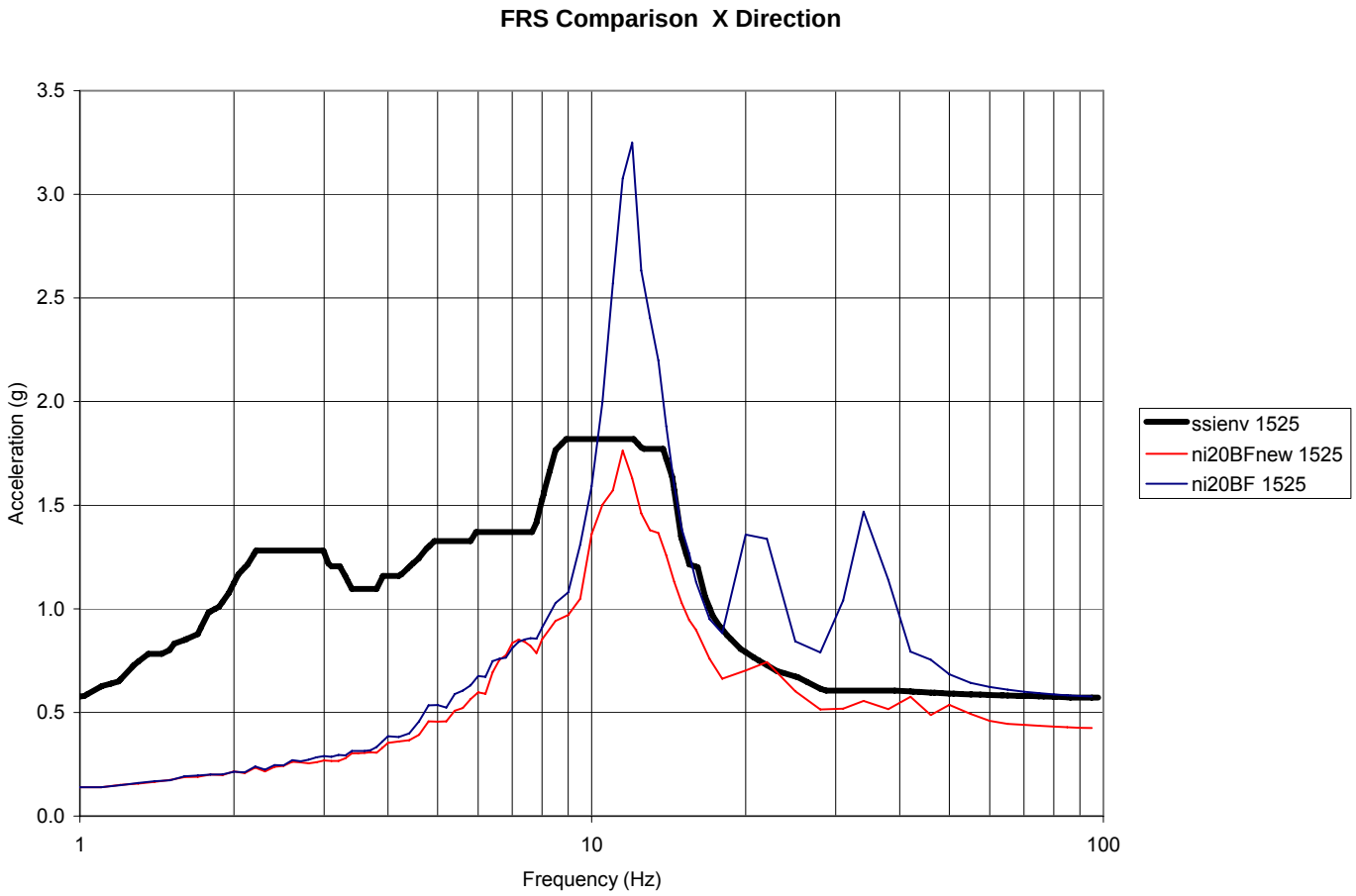

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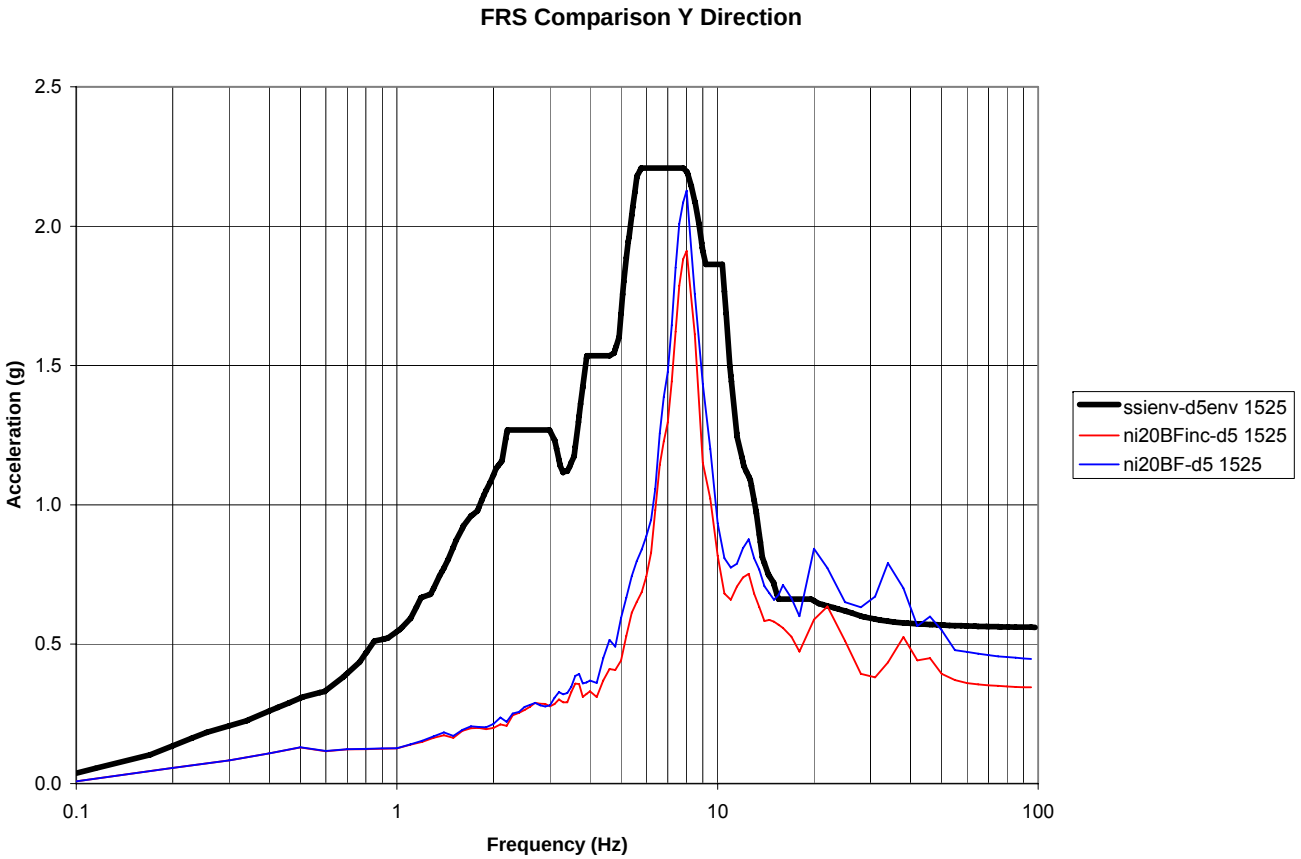
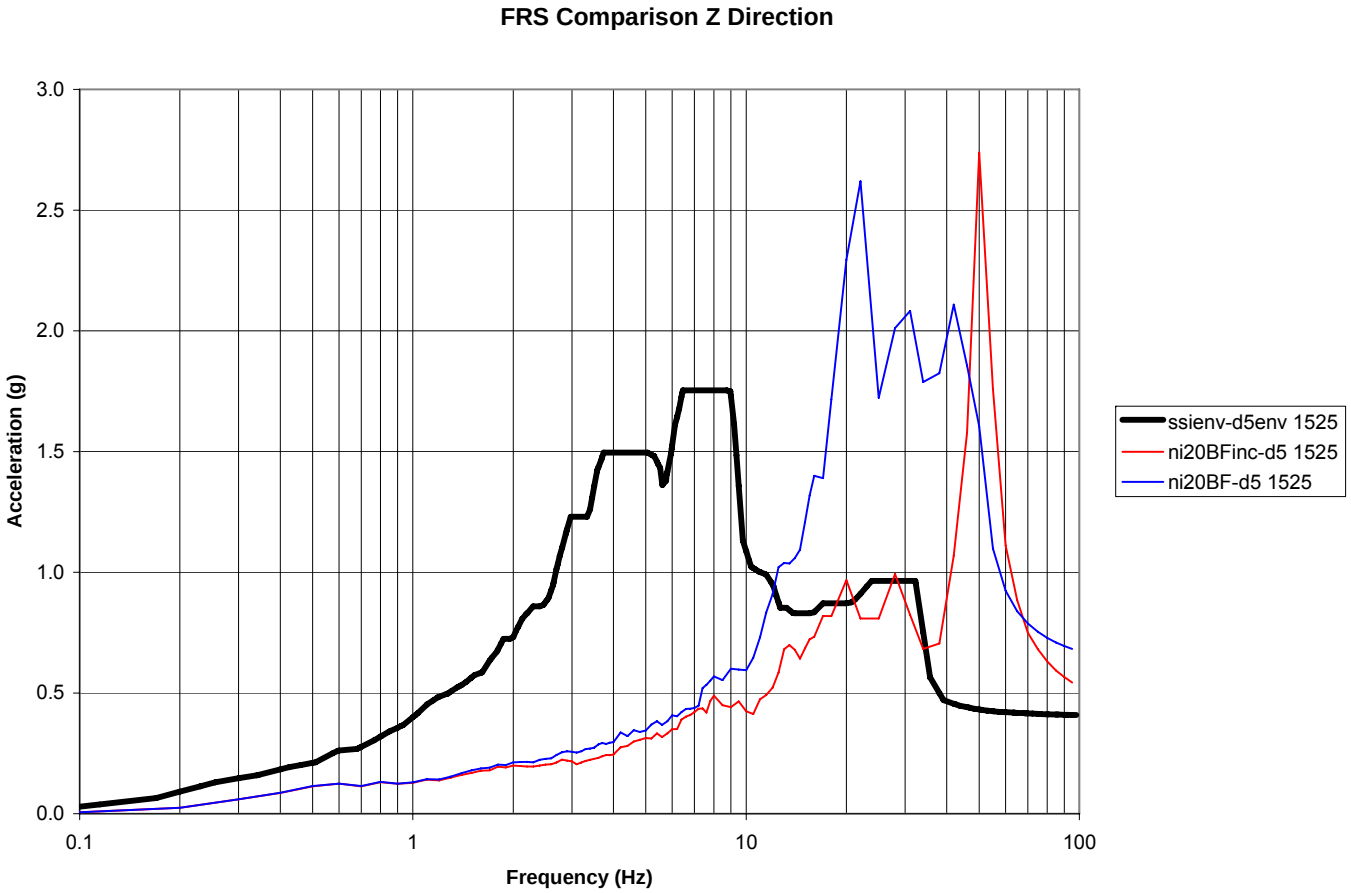


Reactor vessel support (Elevation 100’)



Selection Screening Criteria

- **System, Structure, or Equipment important to safety**
  - *Review component safety function for SSE event and potential failure modes due to SSE.*
  - *Select components whose failure in an SSE could challenge the integrity of reactor coolant pressure boundary or containment.*
  - *Do not select components whose failure modes would result in safe shutdown*
- **Location is in vicinity of peak high frequency response**
  - *Select equipment that is located in areas of plant which experience large high frequency seismic response (such as at high elevations or edges)*
- **Significant modal response within region of high frequency amplification**
  - Significance defined by:
    - *Modal mass*
    - *Participation factor*
    - *Deflection*
    - *Stress*

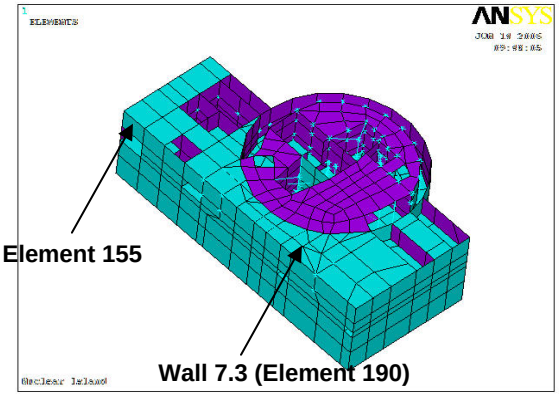
Evaluation Methodology

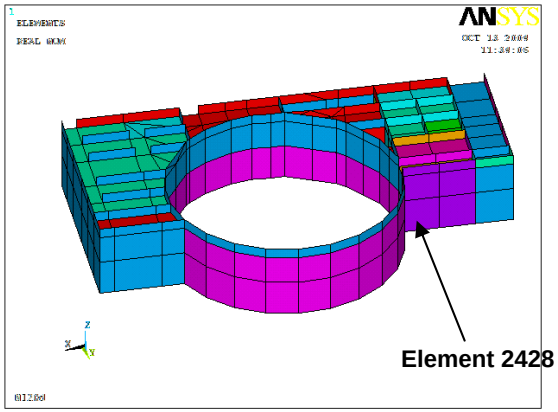
- **Not a total plant Qualification – Evaluation made of representative systems, structures, and components selected by screening as potentially sensitive to high frequency input**
- **Perform analyses using high frequency spectra that is broadened**
  - *Equipment designed for the R.G.1.60 (modified) AP1000 design spectra are evaluated for high frequency spectra for hard rock site such as Bellefonte*
  - *Time history analysis is also acceptable*
- **Assess the ability of the system, structure, or component to maintain safety function**
- **Perform supplementary analyses as needed that reduces high frequency response**
  - *Include gap nonlinearities*
  - *Include material inelastic behavior*
  - *Perform multi point response spectra analyses where the high frequency response excites a system locally*
- **Specify tests on equipment as needed where function cannot be demonstrated by analysis**

Evaluation - Building Structures

- **Representative selection of locations made**
  - *Shield building base shear and overturning*
  - *Areas that may amplify high frequency input*
    - *Floors*
    - *Walls*
- **Building Structures are not expected to be sensitive to high frequency input**
  - *Small displacements*
  - *Low stress*
  - *Ductile behavior*

Evaluation - Building Structures

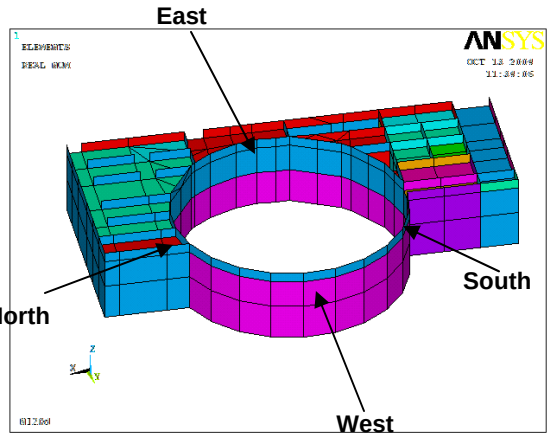


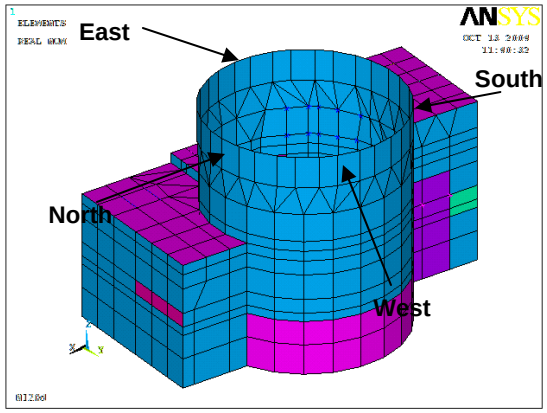


Auxiliary Building

Element #	Bellefonte Time History Forces (Kips/ft)			HR Time History Forces (Kips/ft)		
	TX	TY	TXY	TX	TY	TXY
155	9.0	15.6	9.8	14.5	33.2	18.1
190	3.2	30.7	26.9	3.5	127.4	97.3
2428	8.7	41.2	19.1	11.4	95.3	32.5

Evaluation - Building Structures

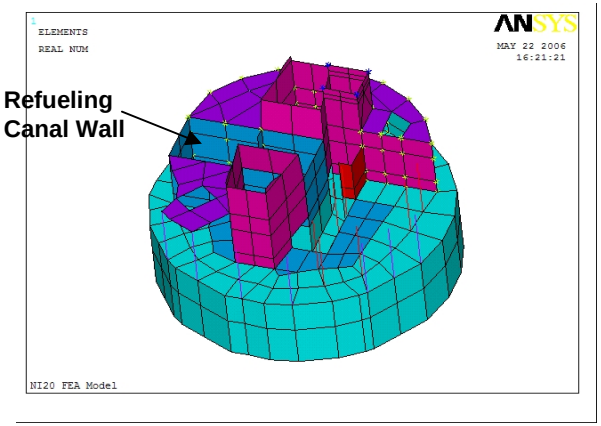


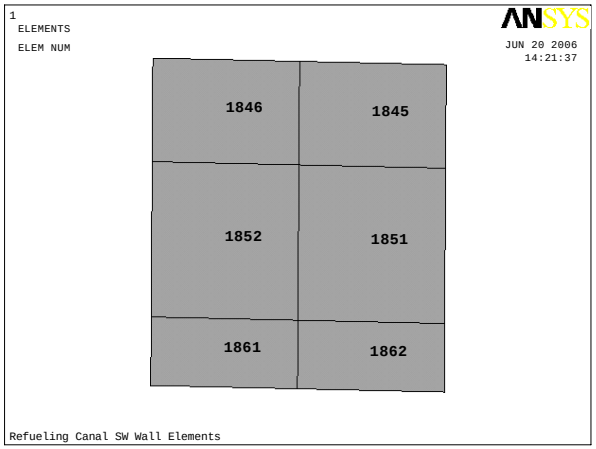


Shield Building

Element #	Location	Bellefonte Time History Forces (Kips/ft)			HR Time History Forces (Kips/ft)		
Elevation 107		TX	TY	TXY	TX	TY	TXY
651	North	6.4	45.0	46.5	16.0	153.1	118.6
2886	East	9.2	63.6	25.6	25.4	197.6	52.2
668	West	10.4	89.5	49.5	43.0	340.8	160.4
664	South	11.1	68.7	35.7	36.5	205.9	95.0
Elevation 211		TX	TY	TXY	TX	TY	TXY
924	North	16.6	45.0	37.7	28.3	188.5	119.3
916	East	13.0	46.4	32.7	26.1	144.8	109.7
900	West	14.0	33.3	25.7	27.4	123.1	95.0
908	South	18.3	60.4	42.7	25.8	172.1	134.2

Evaluation - Building Structures

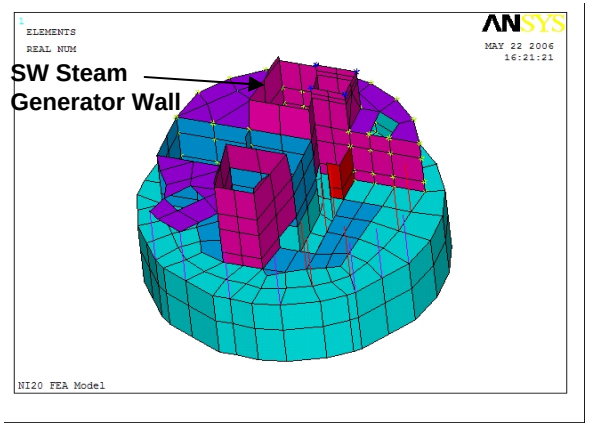


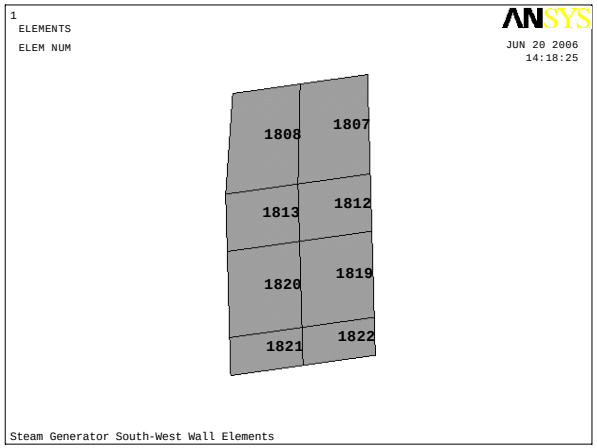


CIS – SW Refueling Canal Wall

Element #	Bellefonte Time History Forces (Kips/ft)			HR Time History Forces (Kips/ft)		
	TX	TY	TXY	TX	TY	TXY
1846	5.8	6.7	12.5	7.8	8.3	23.2
1845	9.1	10.3	19.8	20.9	15.6	42.0
1852	4.7	18.7	21.6	7.7	26.8	35.7
1851	7.9	14.1	28.1	13.5	18.8	42.9
1861	9.3	35.0	28.8	22.2	47.6	41.1
1862	9.6	15.8	31.4	16.7	21.6	45.4

Evaluation - Building Structures

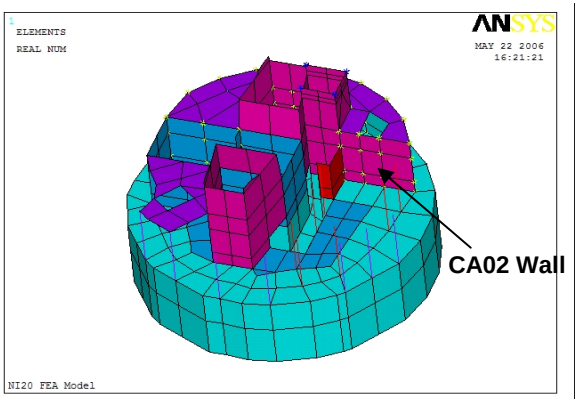


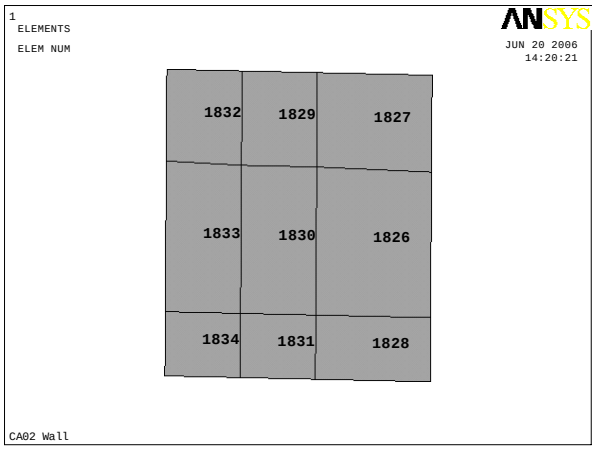


CIS – SW Steam Generator Wall

Element #	Bellefonte Time History Forces (Kips/ft)			HR Time History Forces (Kips/ft)		
	TX	TY	TXY	TX	TY	TXY
1808	13.7	9.5	17.8	22.1	14.5	34.8
1807	15.1	8.2	12.6	25.5	11.9	25.4
1813	6.1	11.3	22.4	7.1	10.4	42.7
1812	8.4	23.3	17.0	9.7	27.5	26.6
1820	6.3	15.9	33.6	12.0	15.8	43.6
1819	5.2	39.2	25.4	6.6	50.7	33.7
1821	12.0	17.5	29.4	25.6	16.3	34.2
1822	11.4	57.9	33.8	28.3	84.2	40.0

Evaluation - Building Structures





CIS – CA02 Wall

Element #	Bellefonte Time History Forces (Kips/ft)			HR Time History Forces (Kips/ft)		
	TX	TY	TXY	TX	TY	TXY
1832	10.9	18.9	29.4	12.6	18.4	31.4
1829	7.8	6.9	20.7	7.8	7.3	21.7
1827	3.9	9.9	8.7	5.6	10.9	10.7
1833	8.0	15.8	25.6	12.8	16.3	36.8
1830	9.1	17.2	25.2	13.8	17.2	33.3
1826	5.0	26.3	13.9	7.6	28.3	17.2
1834	7.9	14.3	28.6	12.8	17.8	44.4
1831	8.4	18.6	24.9	15.3	26.0	37.0
1828	9.8	45.2	20.2	19.6	55.1	28.7

Evaluation - Reactor Vessel and Internals Basis of Selection

- Vertical and horizontal modes of upper internals, and RV modes are in relatively high frequency range.
- High frequencies associated with nonlinear impact
- Vertical amplification is significant at supports of RPV
- Relative complex structural systems including gap nonlinearity and sliding elements
- Representative analysis of major primary system

Evaluation - Reactor Vessel and Internals General Observations of Evaluation

Preliminary time history analysis using conservative input

- *Vertical forces are generally larger from a CEUS event*
- *Horizontal forces are generally lower from CEUS events*
- *Although vertical forces are larger from CEUS events they do not result in liftoff of fuel or increased sliding at core barrel flange*
- *Zero period accelerations (horizontal and vertical) can be larger from CEUS event*
- *Some impact forces observed are slightly larger (upper core plate alignment plates, lower radial restraints)*
- *Fuel grid impact lower for CEUS events*
- *Increases in seismic forces are relatively insignificant when considered in combination with LOCA and steady loads.*
- *There is no expected change in design of reactor vessel and internals as a result of the CEUS response*
- *The RV and internals generally have robust design capable of much higher loads from LOCA*

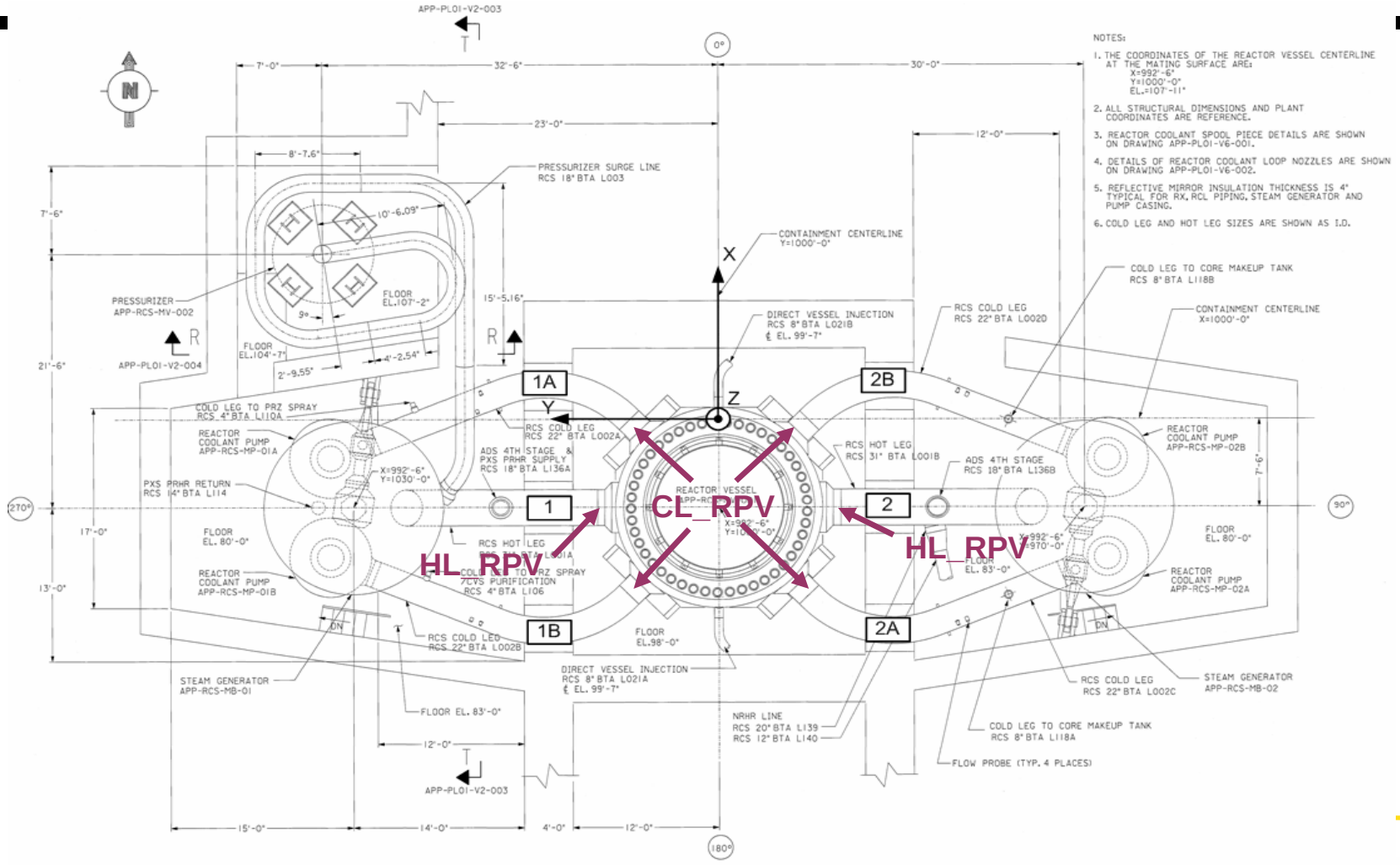
Evaluation - Primary Component Supports
Reactor vessel support (Elevation 100')

RPV Support Forces (kips)	Bellefonte (coherent) (kips)	AP1000 Design (kips)
Tangential	1057	1213
Vertical	494	588

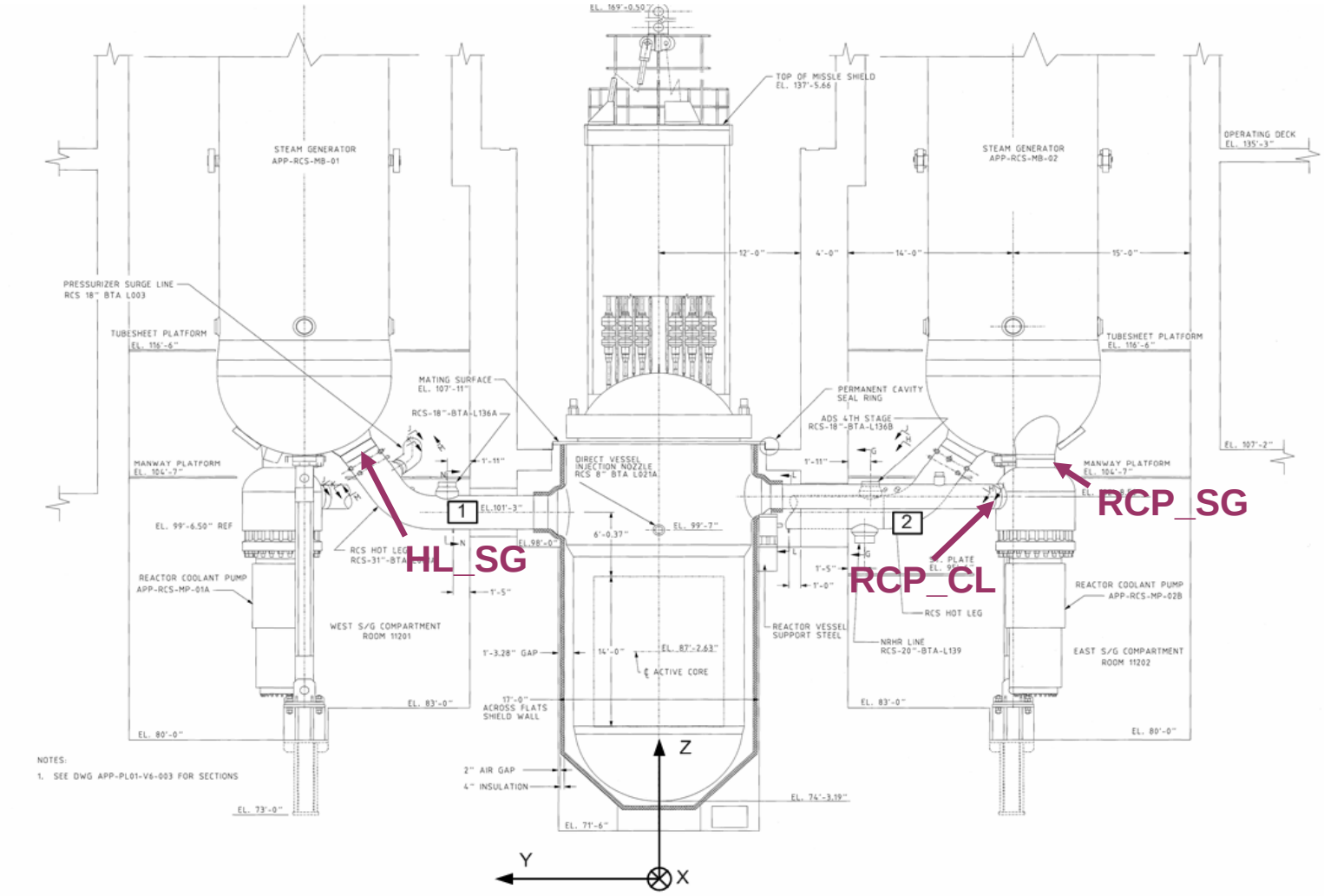
Evaluation - Primary Component Supports
Steam Generator Supports

RCL Supports	Bellefonte (coherent) (kips)	AP1000 Design (kips)
Lower Vertical	852	1922
Lower Lateral	672	1103
Intermediate	633	1162
Upper	491	844

Reactor Coolant Loop Nozzle Locations



Nozzle Locations (cont.)



Evaluation - Reactor Coolant Loop Nozzles

RCL Nozzle	Bending Moment (kip-ft)	
	Bellefonte (Coherent)	AP1000 Design
SG to RCP	2973	7389
CL to RCP	177	1081
CL to RPV	536	1971
HL to RPV	502	2159
HL to SG	964	1946

Evaluation - Equipment Qualification

- **Road Map consists of four elements**
  - *Seismic analysis of representative equipment*
  - *Review of seismic testing data*
  - *Development of a process for screening of seismically sensitive equipment and components*
  - *Development of a methodology for high frequency seismically sensitive equipment*

Evaluation - Equipment Qualification

- **Selection Process**
  - *Typical equipment provided for nuclear power plants*
  - *Safety-related equipment that may be sensitive to high frequency input*
  - *Cabinet type equipment which are relatively sensitive to seismic inputs*
- **Select finite element models of typical safety-related cabinets (MCC or SWGR)**
  - *Develop mathematical relations of cabinets dynamic properties, non-linearity effects, mountings configurations, base isolation and tendency to amplify high frequency inputs*
- **Perform time history analysis**
  - *Subject models to AP1000 Design input (RG 1.60 modified) and high frequency floor RRS (Bellefonte) input separately*
  - *Compare results; in-equipment seismic demand, maximum displacements, structural loads, member stresses and mounting loads*

Evaluation - Equipment Qualification Seismically Sensitive Equipment

- **Screening Criteria**
  - *Evaluate existing test results of hundreds of test units*
  - *Identify components to be used in AP1000*
  - *Develop list of sensitive equipment*

Evaluation - Equipment Qualification
Potential Sensitive Equipment List

- *Equipment or components with moving parts and required to perform a switching function during the seismic event (circuit breakers, contactors, etc.)*
- *Components with moving parts that may bounce or chatter such as relays*
- *Molded case circuit breakers*
- *Unrestrained components*
- *MCC Starters*
- *Potentiometers*
- *Interfaces such as secondary contact interface*
- *Auxiliary switches*
- *Components with accuracy that may drift due to seismic loading*
- *Connectors and connections*

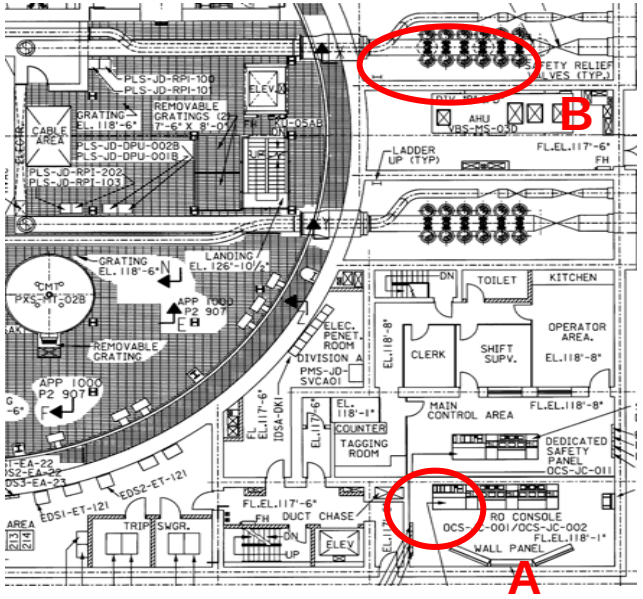
Evaluation - Equipment Qualification
Seismically Sensitive Equipment

- **Seismic Treatment of Sensitive Equipment**
  - *Develop a method for treatment of seismically sensitive equipment*
  - *Equipment or components that can not be screened out, evaluation will be performed*

Evaluation – Piping
Systems Chosen for Evaluation

A: *4” MCR emergency habitability over-pressurization relief valves and piping: Class 3*

B: *1” and 8” containment fan cooler return piping: Class 2 - Containment isolation*

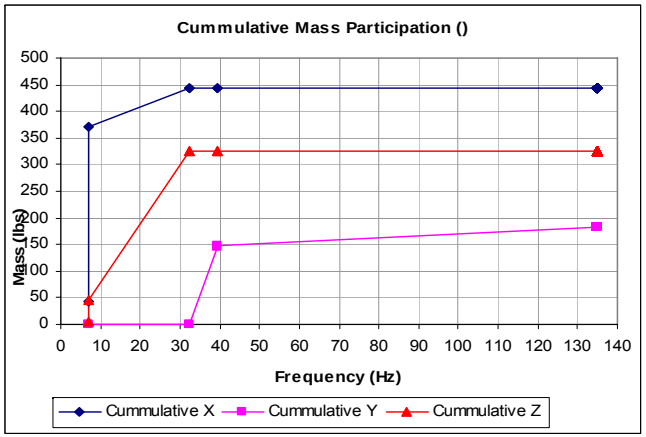


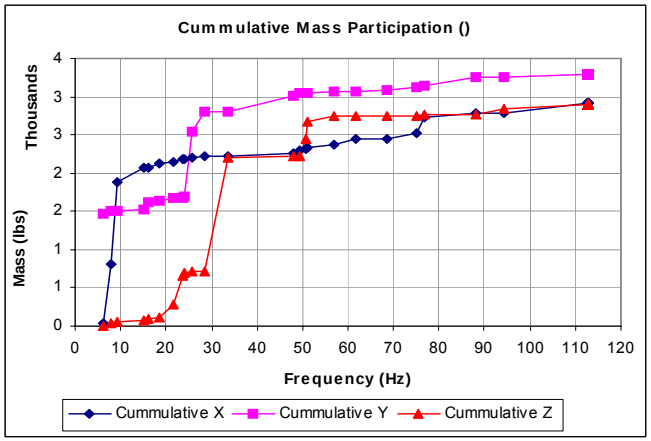
North-West area of NI EL: 117’-6”

Evaluation - Piping

Look for mass participation at higher frequencies

- *Obtain cumulative masses from PIPESTRESS results and graph verses frequency*
  - *4” MCR emergency habitability over-pressurization relief valves and piping*
  - *1” and 8” containment fan cooler return piping*





Evaluation - Piping

- **Perform PIPESTRESS analyses comparing:**
  - *AP1000 Design Spectra (Reg Guide 1.60 spectra modified)*
  - *Spectra having high frequency content (Bellefonte)*
- **Compare results and check allowables**
  - *Valve accelerations*
  - *Pipe stresses*
  - *Nozzle loads*
  - *Support Loads*
- **Perform supplementary analysis as needed**
  - *Multi-Point Response Spectra input*
  - *Non linear analysis with gap and material nonlinearities*

Technical Report
Evaluation for High Frequency Seismic Input

- **Introduction**
  - *Provided in this introduction is the background of the high frequency issue and the purpose of this seismic evaluation. The structures and equipment evaluated are identified.*

- **High Frequency Response**
  - *Rock Design Motion Description*
    - *Describe how the motion was developed*
  - *Structural Models used to develop High Frequency Seismic Motion.*
  - *Comparison of AP1000 Modified Reg. Guide 1.60 spectrum Response and High Frequency Structural Response.*
  - *Provide Floor Response Spectra used for evaluation*

Technical Report
Evaluation for High Frequency Seismic Input

- **Evaluation of Building Structures**
  - *Describe the portions of structures evaluated and the basis of their selection.*
  - *Models used for evaluation and analyses performed*
  - *Show models and dynamic characteristics (modal mass and frequencies)*
  - *Compare member forces in representative elements in SSI analysis due to high frequency response with those from AP1000 modified Reg. Guide 1.60 spectra.*

Technical Report
Evaluation for High Frequency Seismic Input

- **Evaluation of Major Components included in SSI Analyses**
  - *RCL nozzles, RCL supports, CMT supports*
  - *Compare high frequency response with the AP1000 modified Reg. Guide 1.60 spectra*

- **Reactor Vessel and Internals**
  - *Show and describe models.*
  - *Provide dynamic characteristics (modal mass and frequencies)*
  - *Describe models along with the time history analysis*
  - *Compare high frequency results with AP1000 modified Reg. Guide 1.60 spectra*

Technical Report
Evaluation for High Frequency Seismic Input

- **Piping Systems**
  - *Description and Basis of Piping Systems Chosen*
  - *Show and describe models.*
  - *Provide dynamic characteristics (modal mass and frequencies).*
  - *Compare high frequency results with AP1000 modified Reg. Guide 1.60 spectra*
- **Equipment**
  - *Screening Criteria for Equipment*
  - *Equipment Analyzed*
    - *Compare results for both the AP1000 modified Reg. Guide 1.60 spectra and the high frequency spectra*
  - *Equipment Tested*
    - *Compare TRS with RRS (both high frequency & modified Reg. Guide 1.60 spectra)*
  - *Supplemental test specification for potentially high frequency sensitive components*

Summary

- Analyses to be performed for Bellefonte seismic input with incoherent motion
- Structures, RCL supports and nozzles to be evaluated for results from nuclear island time history analyses
- Two piping systems selected for high frequency analyses
- Two cabinets selected for high frequency analyses
- Function of high frequency sensitive components to be confirmed by supplemental testing
- Assuming results of ongoing work demonstrate existing design samples to be acceptable, then AP1000 is acceptable on a hard rock site such as Bellefonte