EPRI Meetings
July 24, 2007 – Palo Alto, CA.

AP1000 Structural Evaluation of Hard Rock Sites

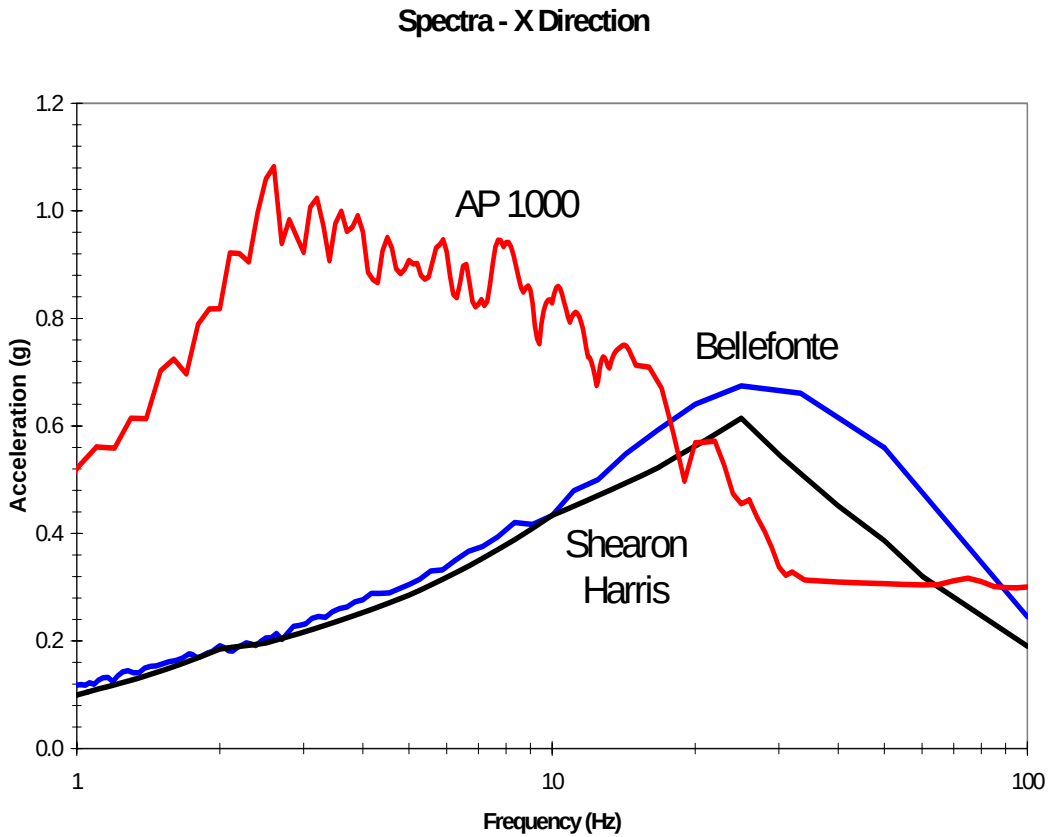
Lee Tunon-Sanjur & Keith Coogler
AP600 & AP1000 projects

HF Evaluation Approach

- **Westinghouse agrees with the numerous industry papers that conclude that High Frequency as non-damaging**
- **Thus, Westinghouse approach is to demonstrate using sample problems that the AP1000 generic analyses have lead to a conservative design.**
- **Proposed FRS generation. NI20 -> NI10.**
- **FRS comparison from NI models**
- **Stress comparison (generic vs bellefonte)**
- **Description of screening criteria**

Hard Rock Design Spectra

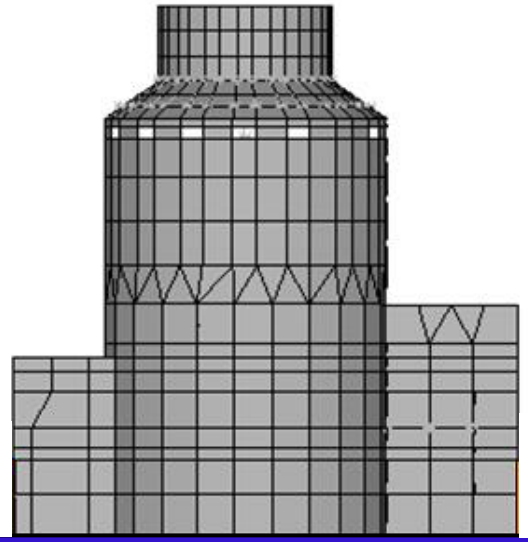
- **Hard Rock sites (Summer, Lee, Shearon Harris) enveloped by revised Bellefonte spectra**
- **Harris spectra shown w/o CAV filter**
- **Bellefonte shown w/ CAV filter**
- **Bellefonte spectra used for High Frequency comparisons**



Bellefonte Site conditions

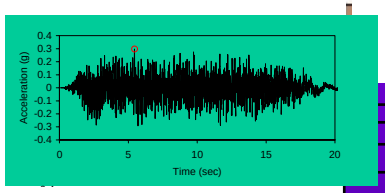
In-column motion is applied at the base of NI20 model with no side soil

NI20



SASSI simulation using the Bellefonte input with High Frequency content will be then used to "filter" and define the foundation motion

Bellefonte Foundation motion

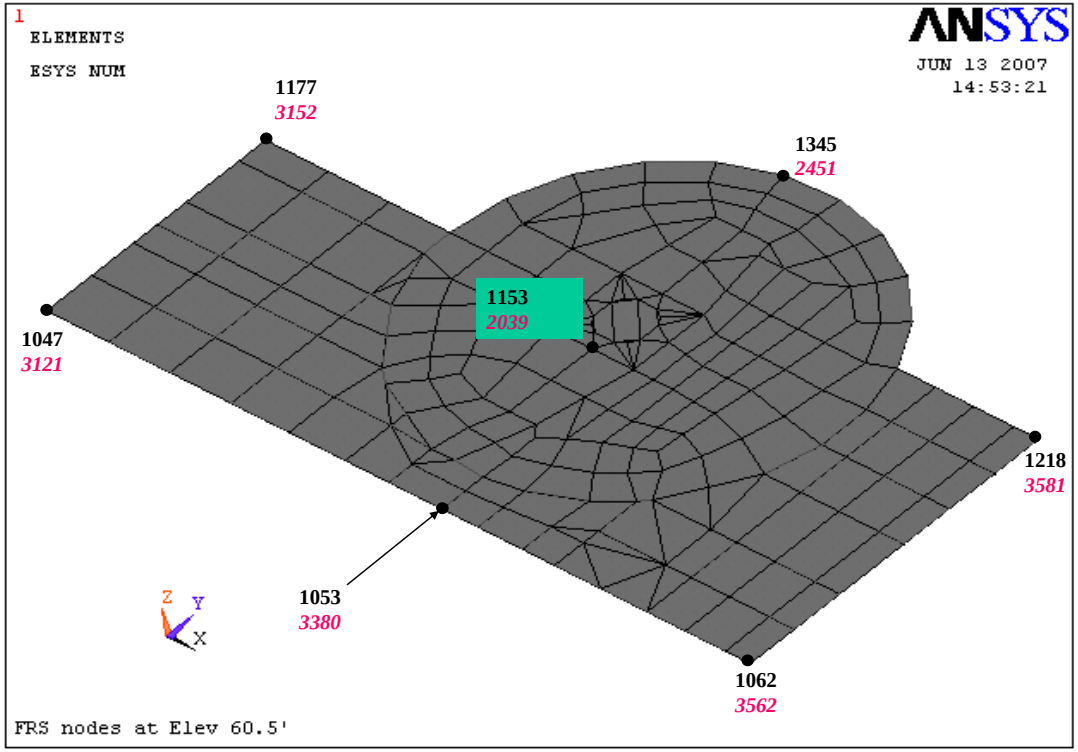


Hard Rock, Vs = 7800 to 9770 fps

FRS Results from SASSI-simulation are averaged at each node

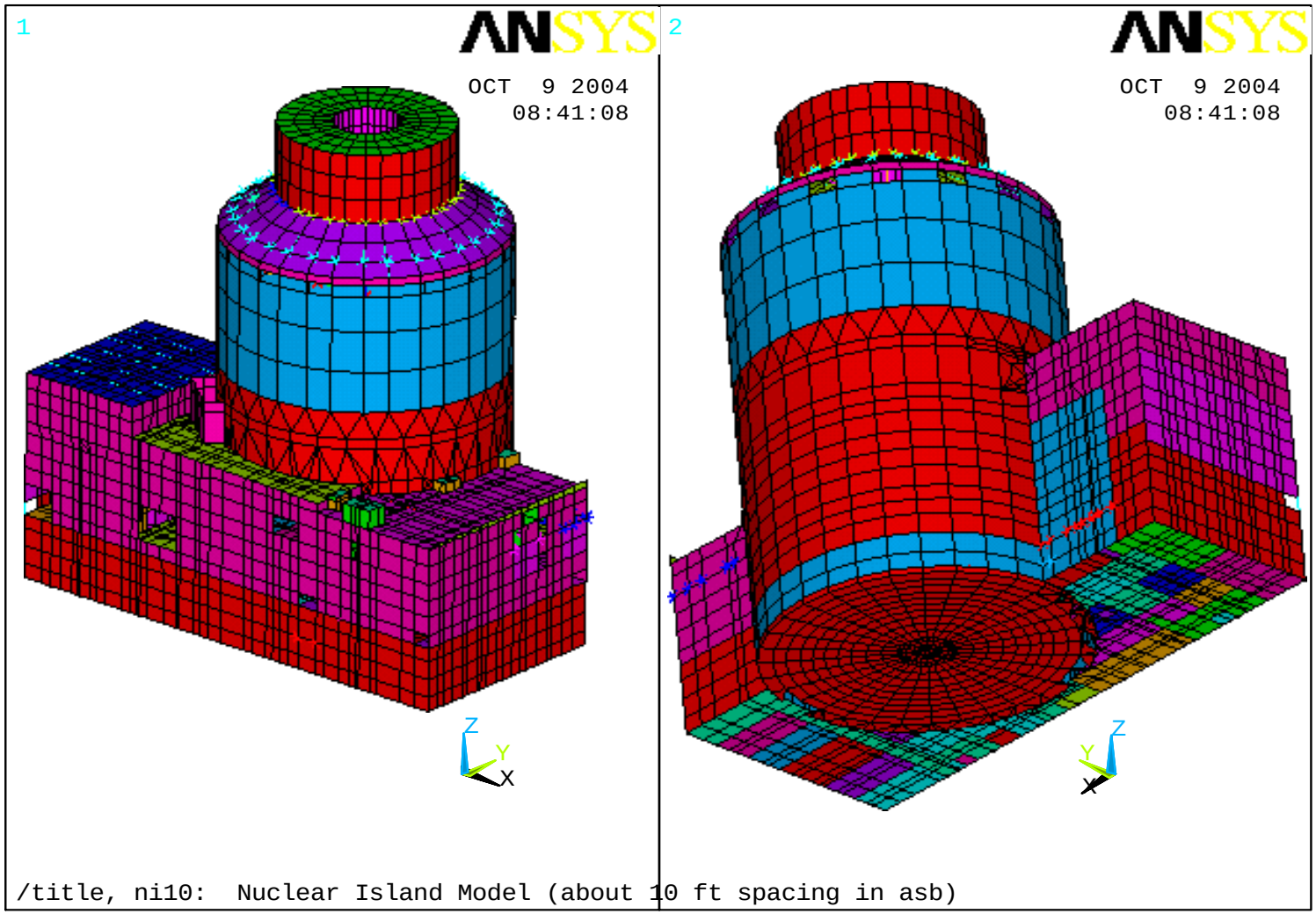
FRS averaged nodal spectra is then enveloped to develop a foundation Response Spectra (FdnRS)

FdnRS is then applied to a more refined model ni10

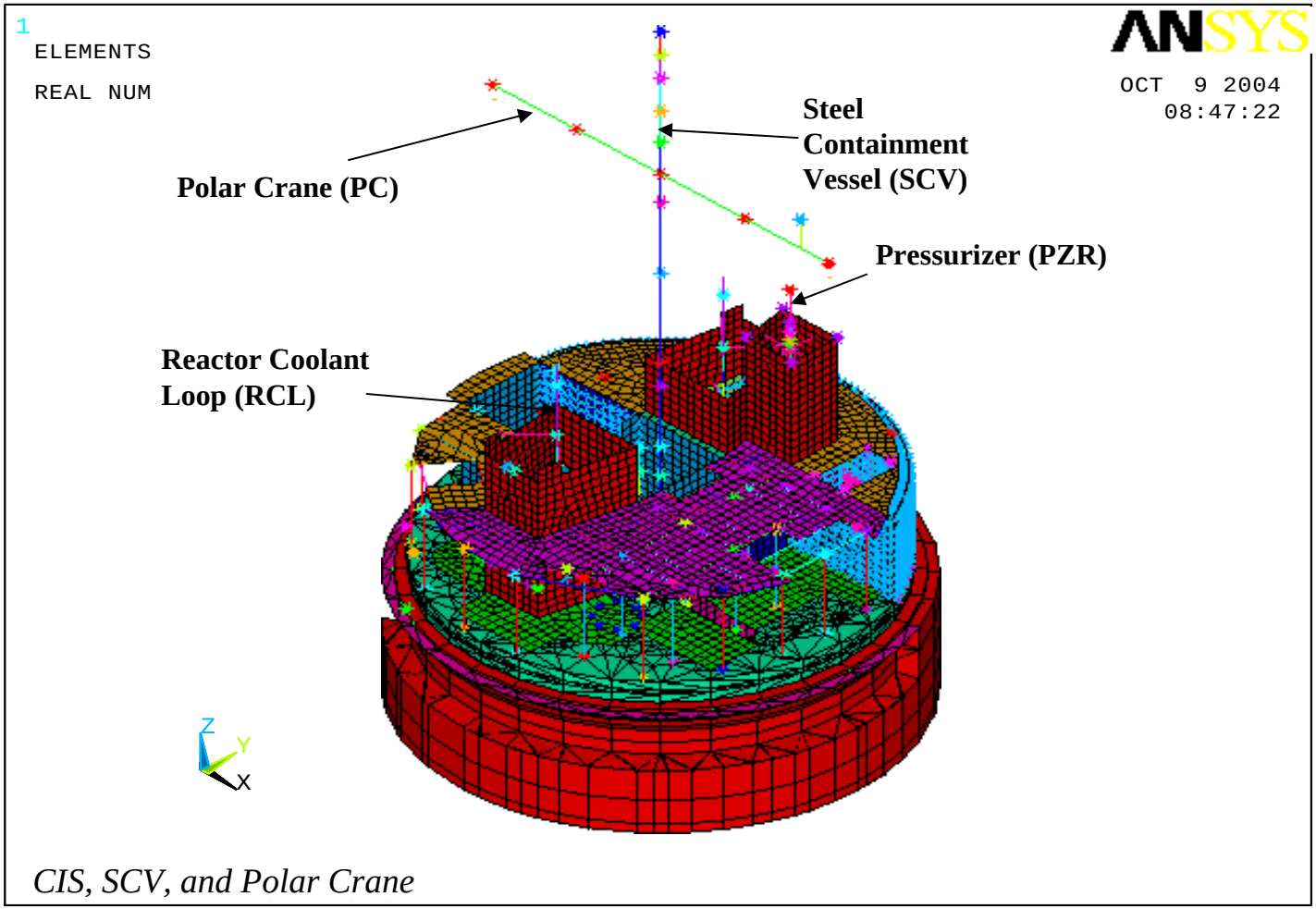


1062
3562

Nuclear Island Fine Model – ni10



Containment Internal Structures



CIS, SCV, and Polar Crane

Locations for FRS Comparisons

- Auxiliary and shield building (ASB) at shield building roof (Elevation 327.4’)
- Steel containment vessel at polar crane support (Elevation 224’)
- ASB at fuel building roof (Elevation 179.56’)
- Containment operating floor (Elevation 134.25’)
- ASB at control room ceiling (Elevation 134.5’)
- Reactor vessel support (Elevation 100’)

2 Cases Compared

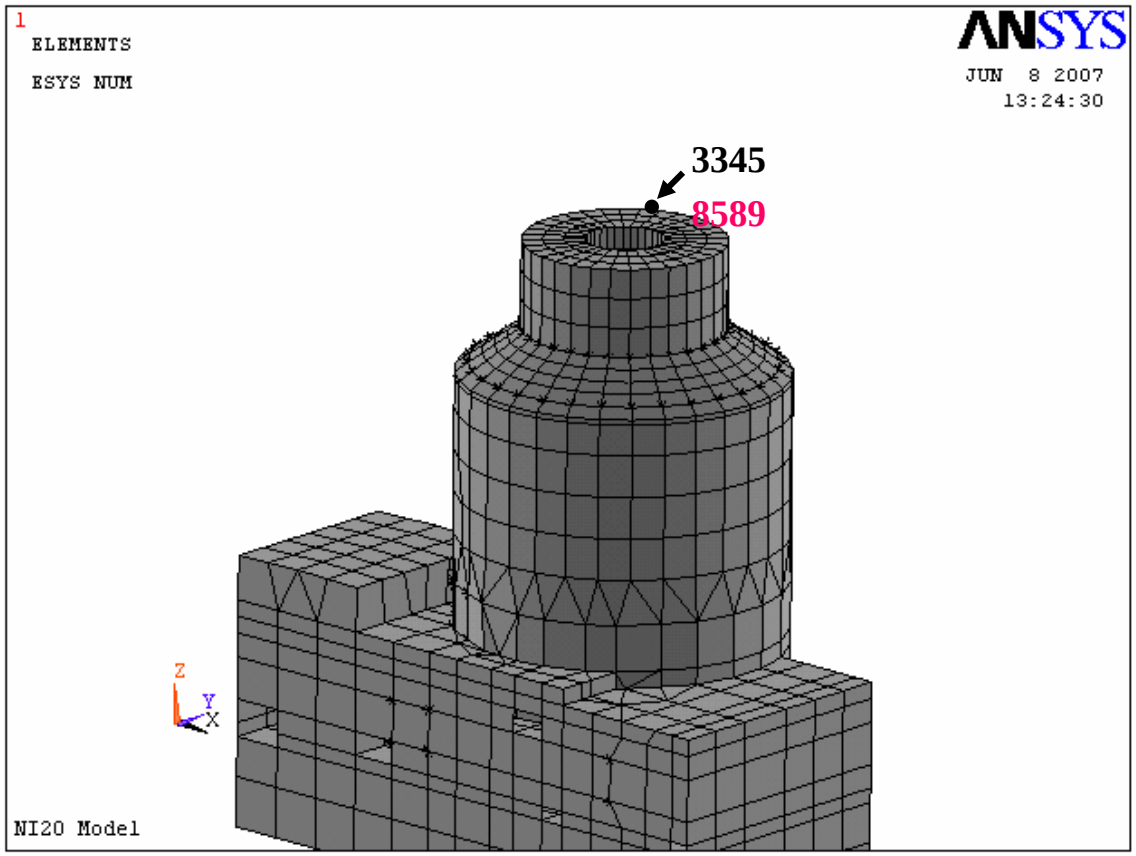
— SSIENV

FRS from AP1000 Design Spectra input, based on the envelope of 3D SASSI soil analyses + ANSYS Hard Rock using ni10 model

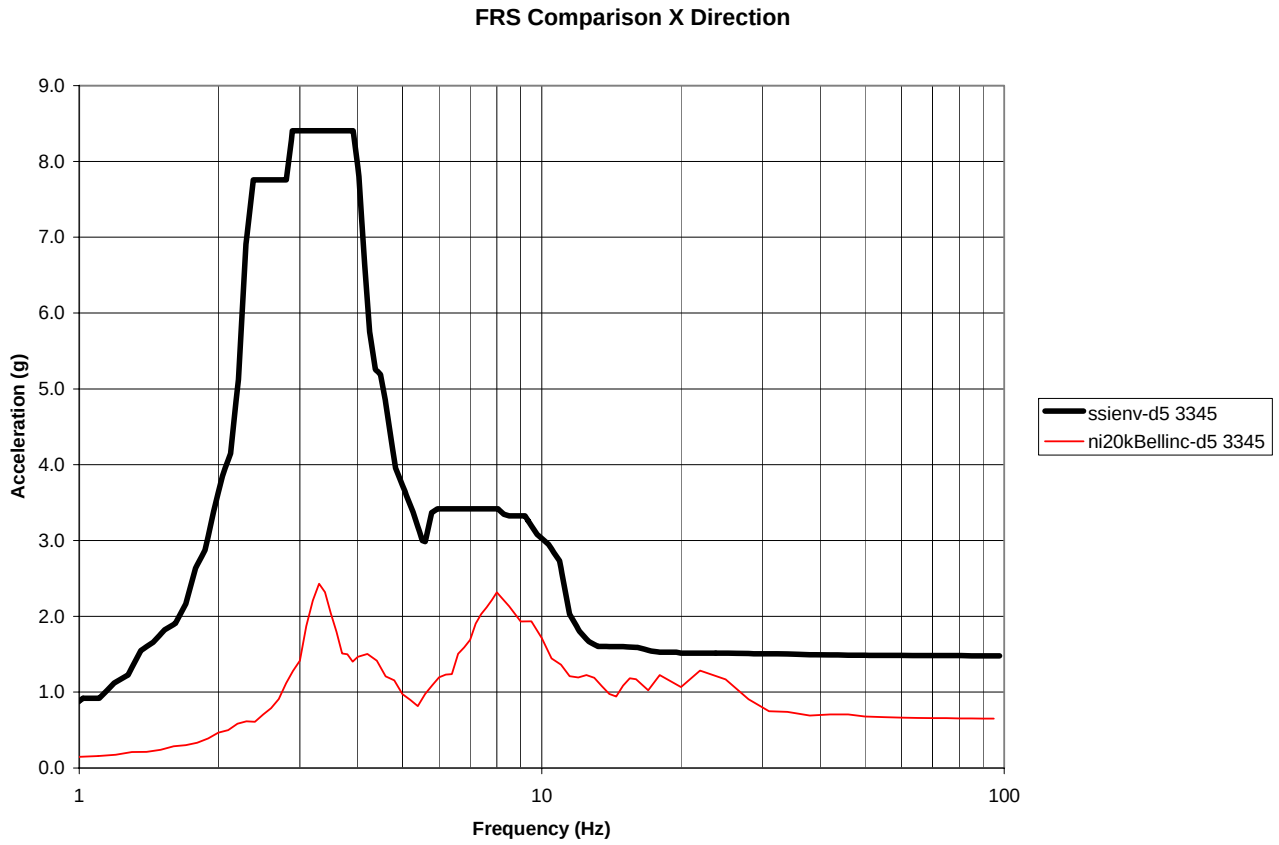
— ni20Bellinc

3D SASSI soil analyses using ni20 model. Bellefonte Design Spectra input and soil conditions, incoherence, CAV + sigma, effects included (Abrahamson 2007 model for HR sites)

Auxiliary and Shield Building (ASB) at Elevation 327.4'



ASB at Elevation 327.4’



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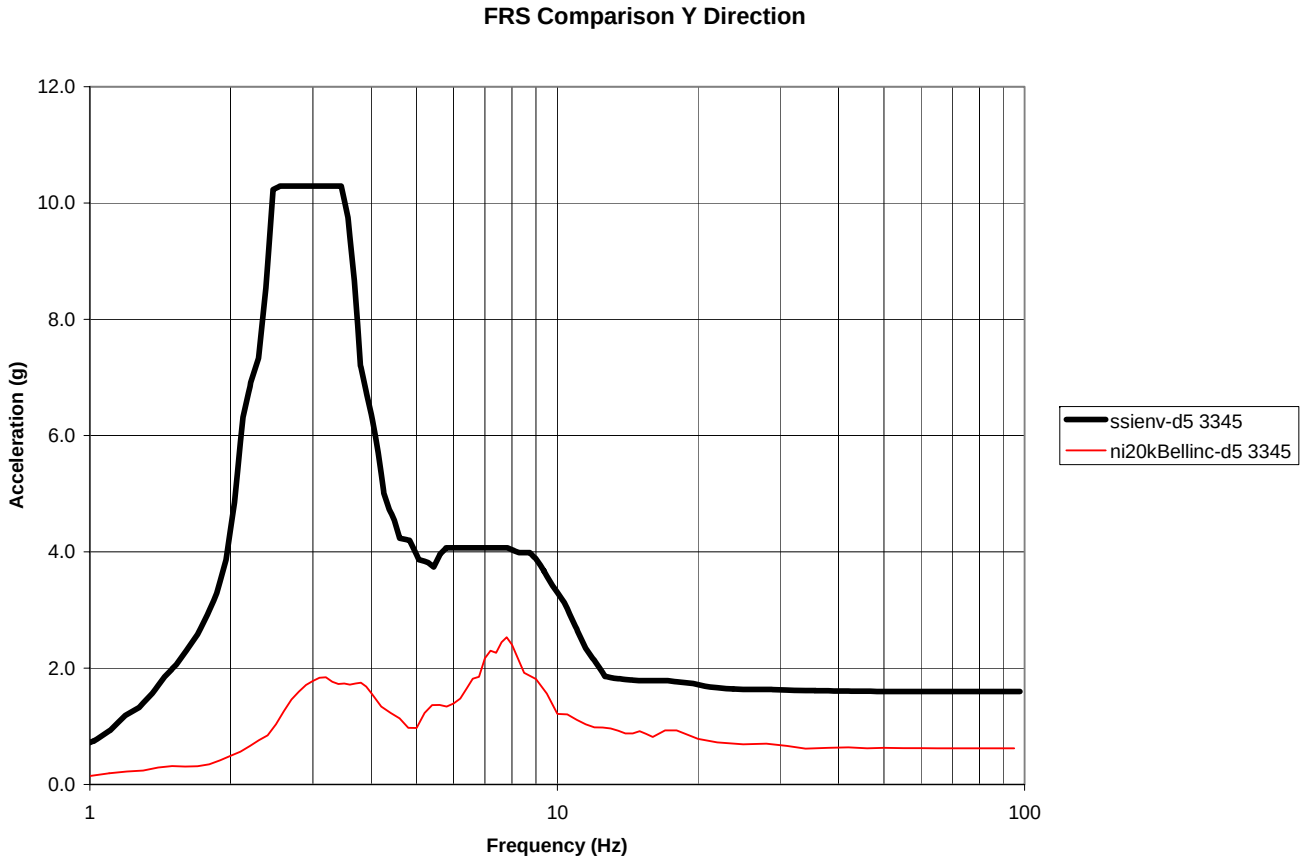

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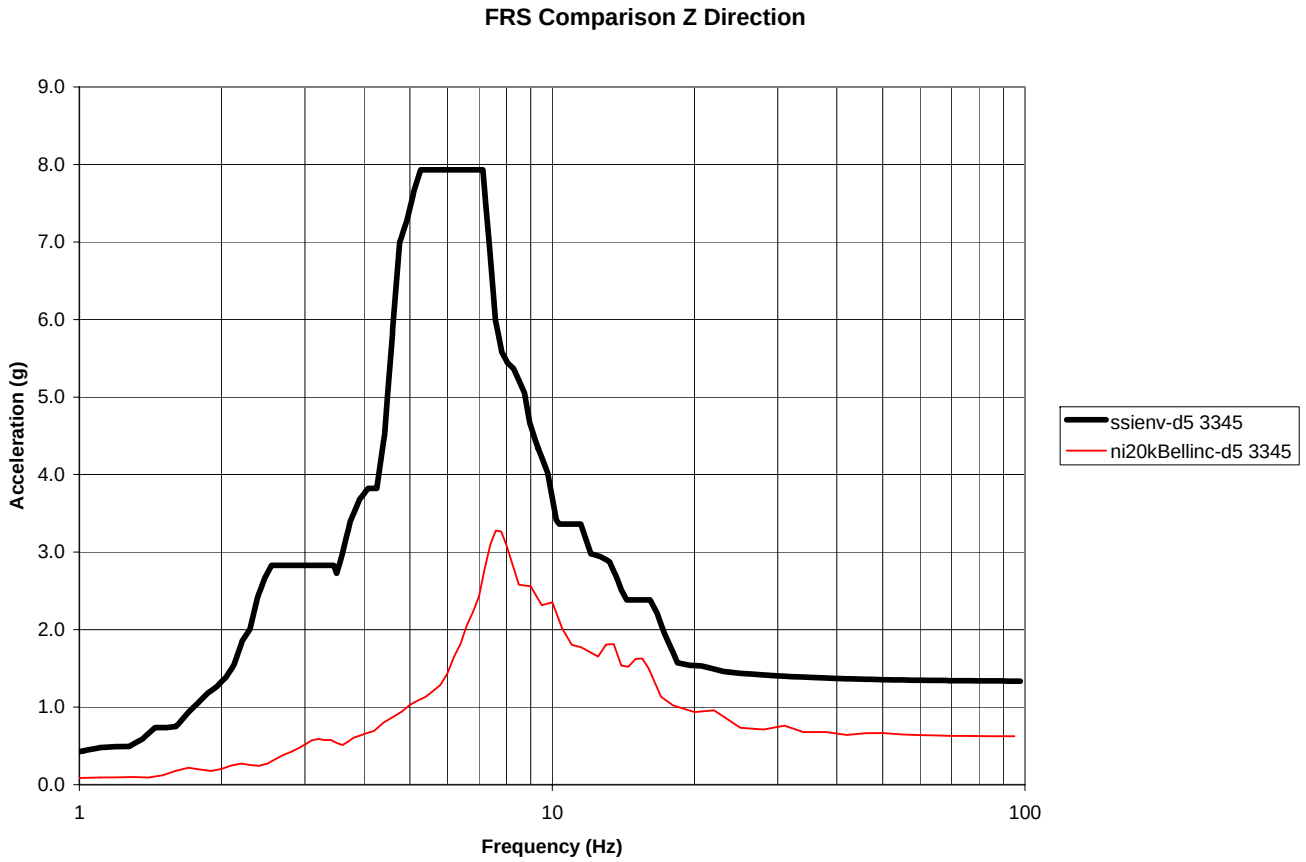
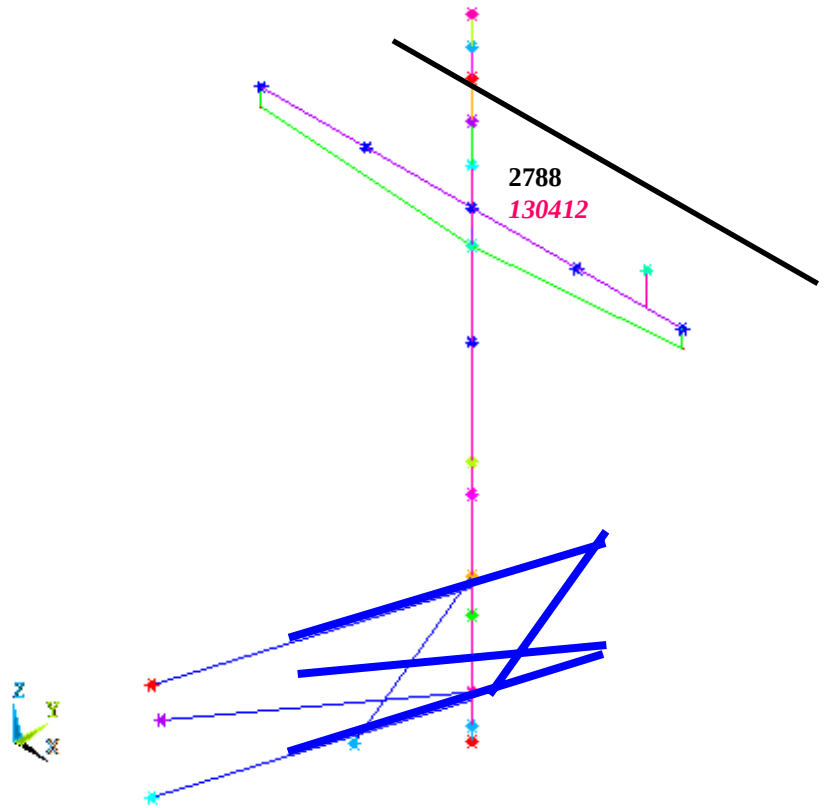
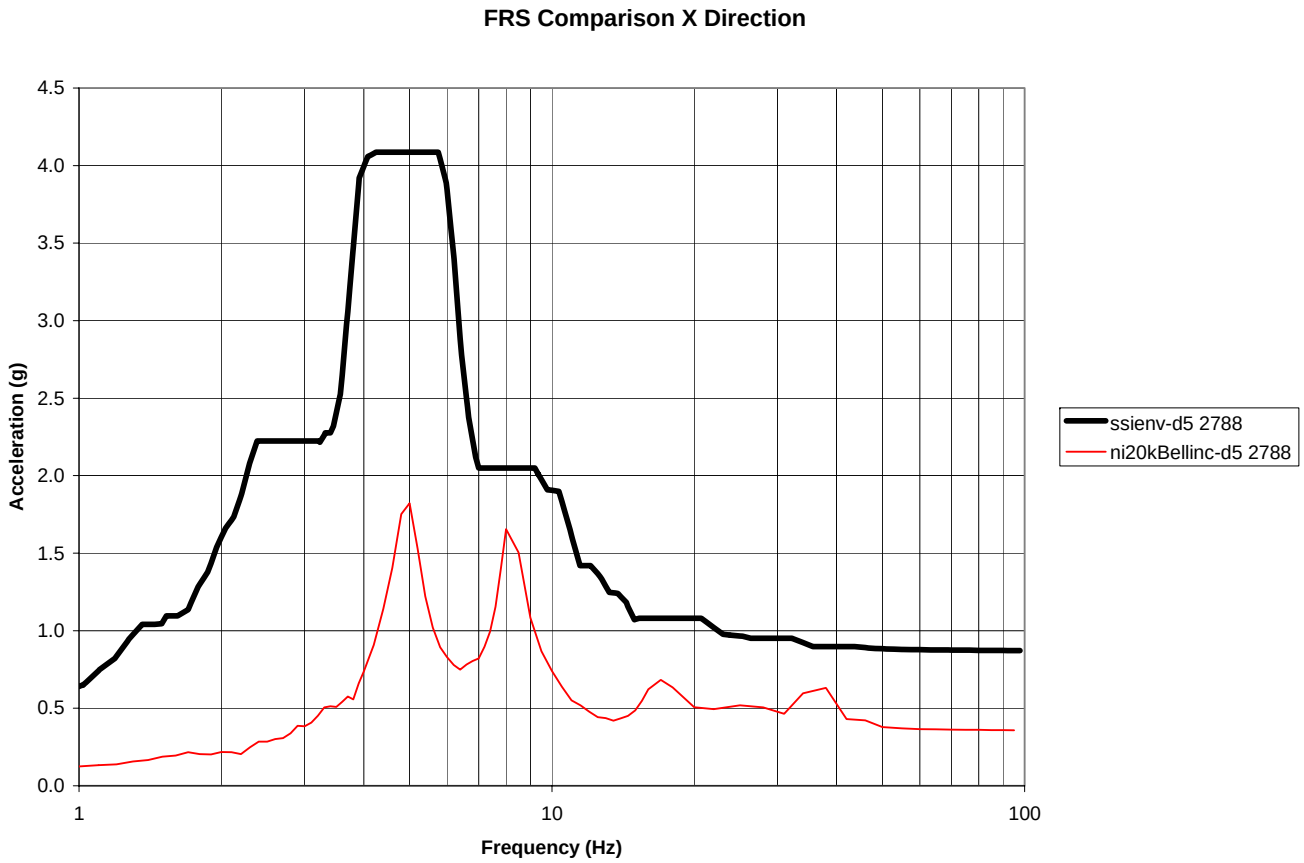


Steel Containment Vessel (SCV) at polar crane support (Elevation 224')

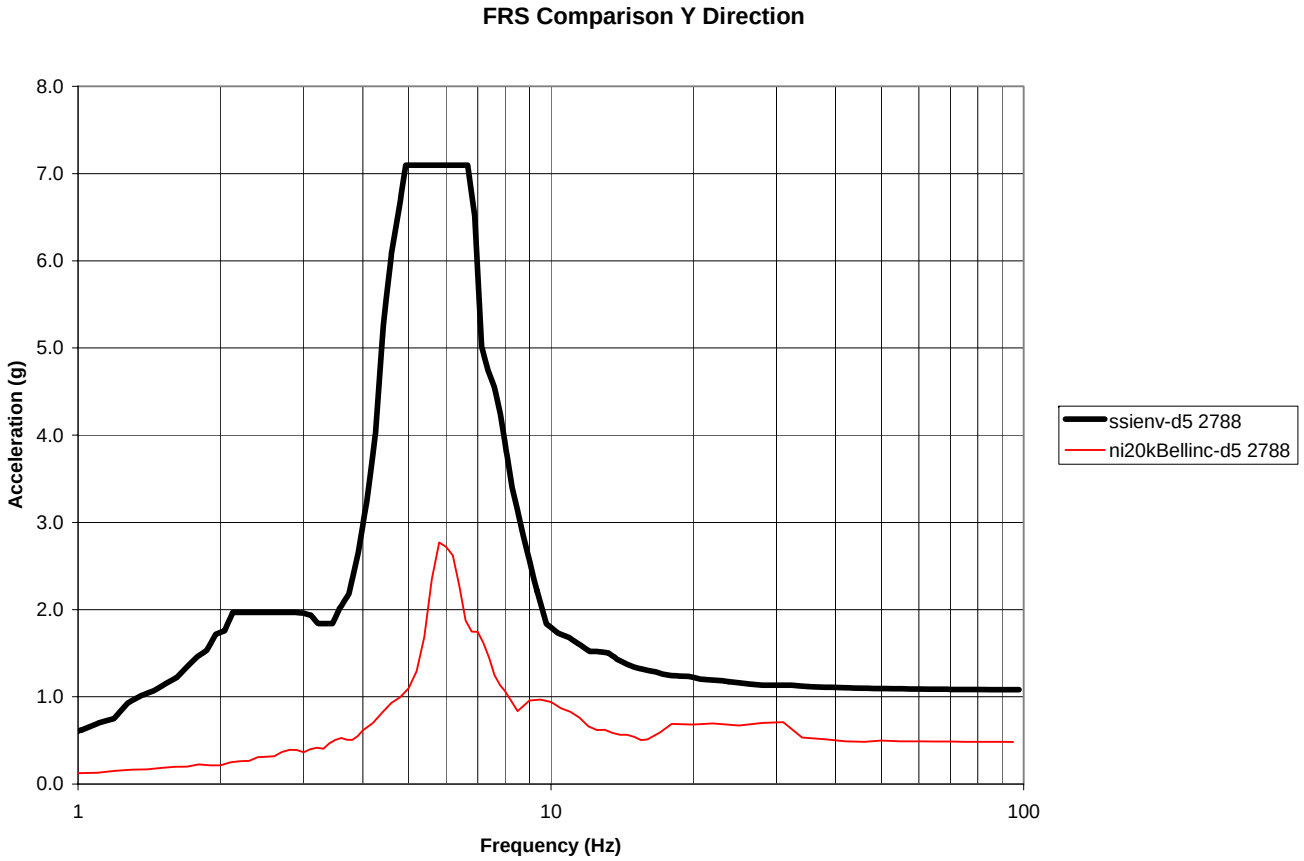


STEEL CONTAINMENT VESSEL AND POLAR CRANE

SCV at polar crane support (Elevation 224')



SCV at polar crane support (Elevation 224')



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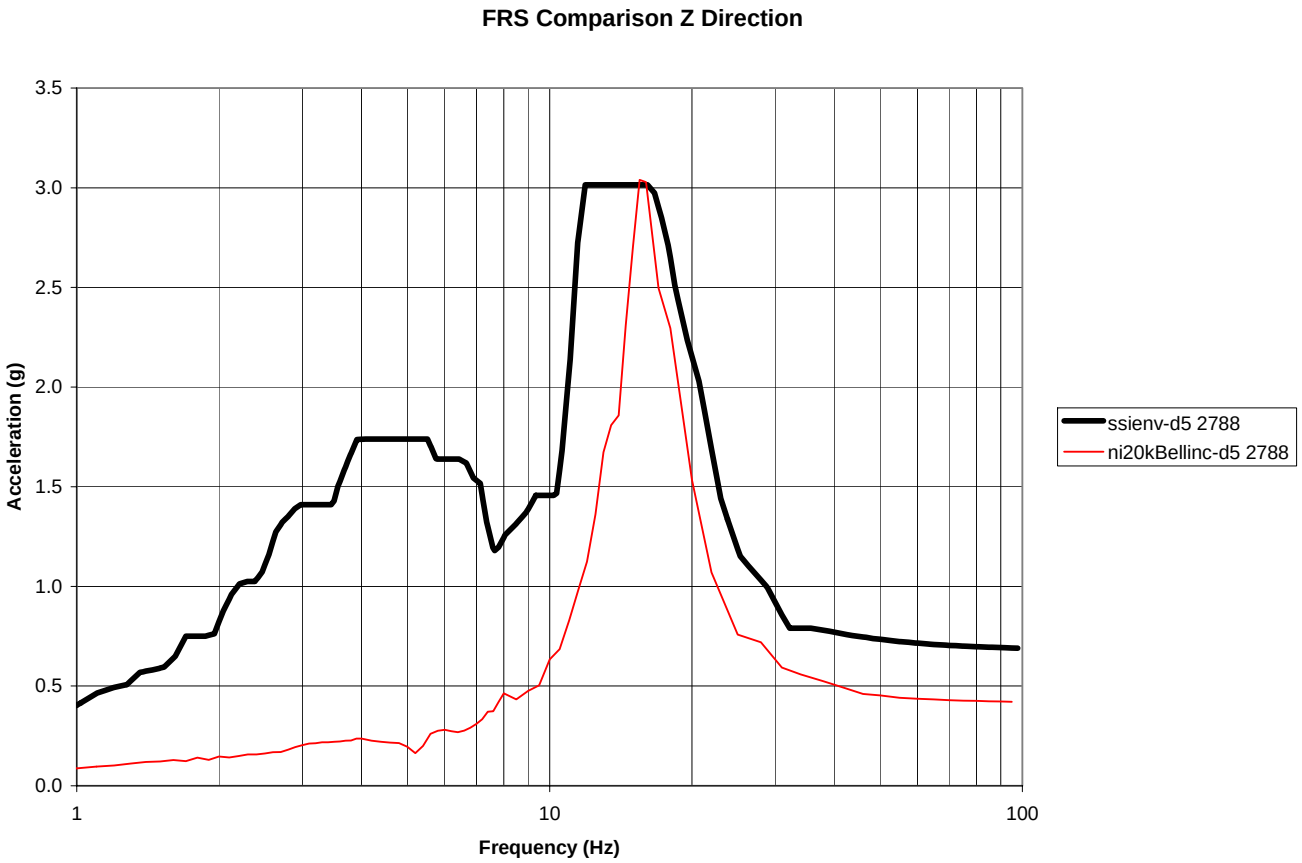
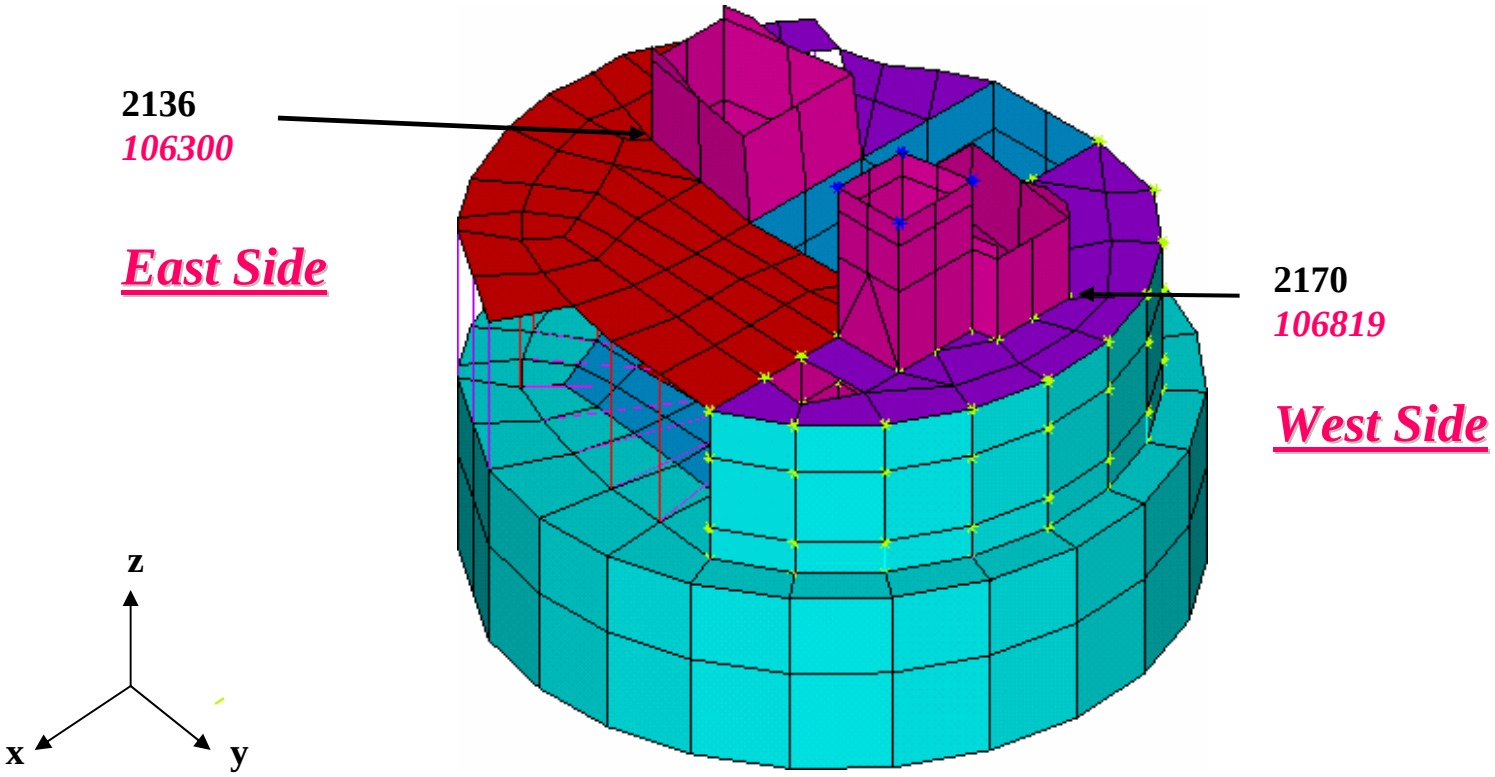


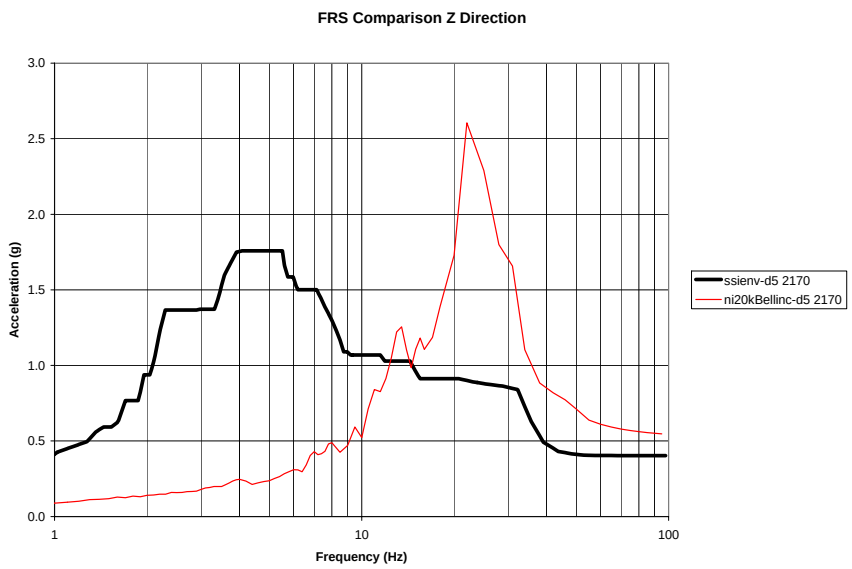
Containment operating floor (Elevation 134.25')



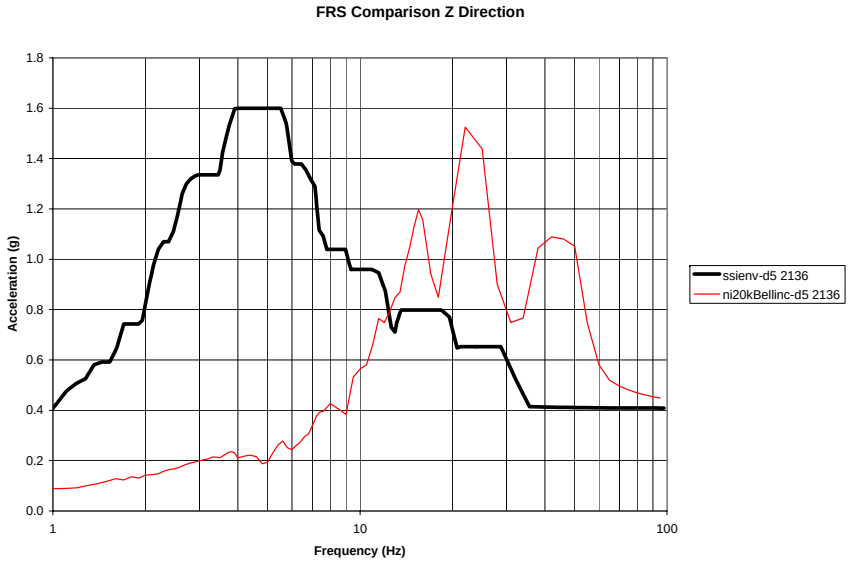
Critical nodes at isometric view

Containment operating floor (Elevation 134.25')

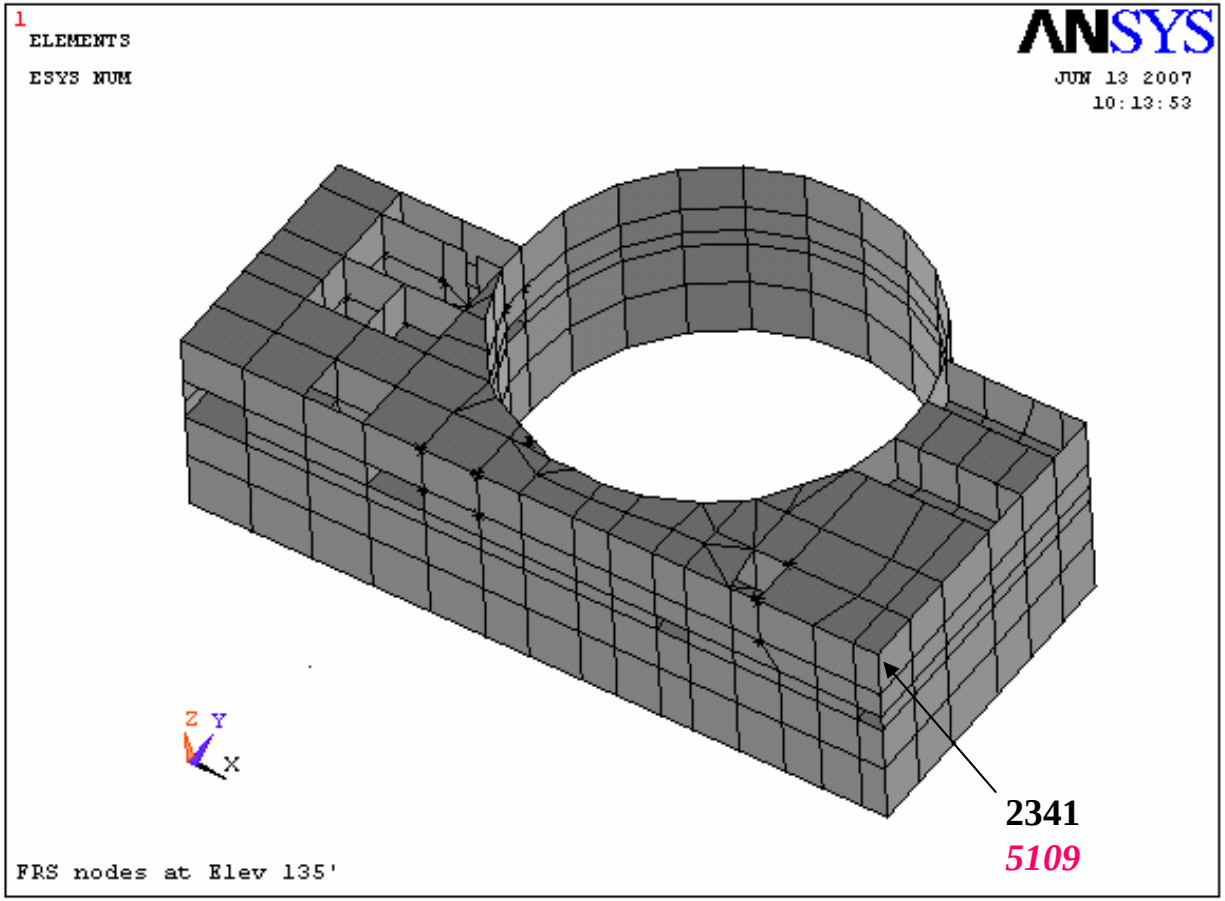
West side



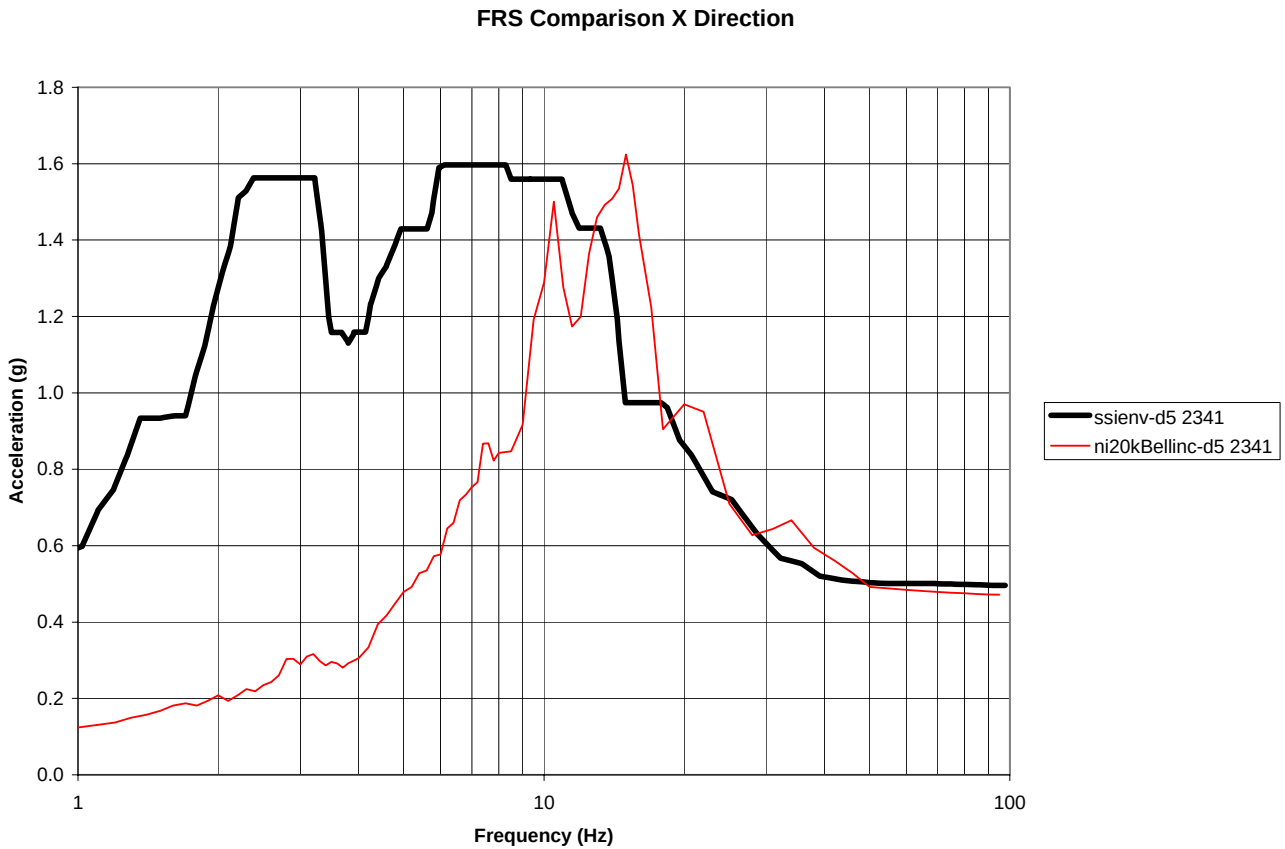
East side



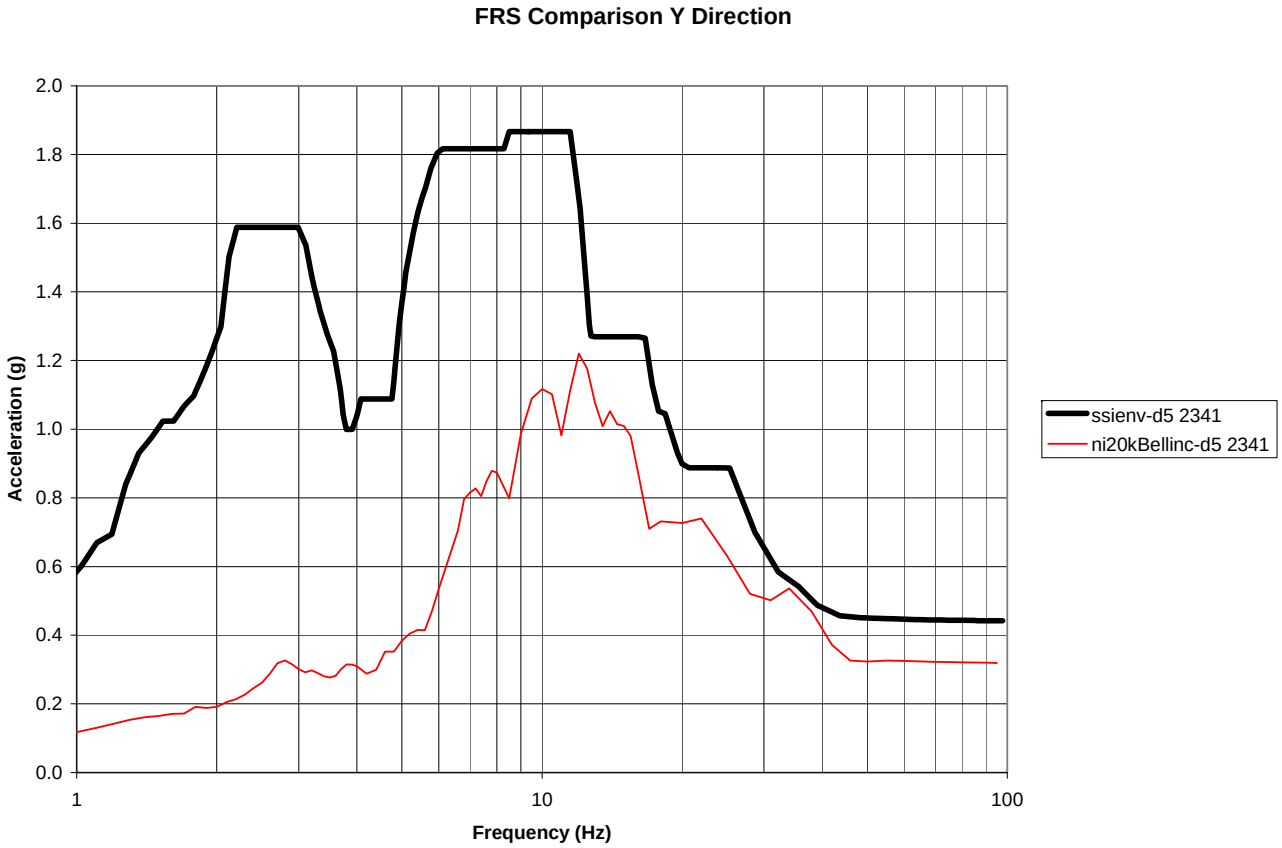
ASB at northeast corner (Elevation 134.5')



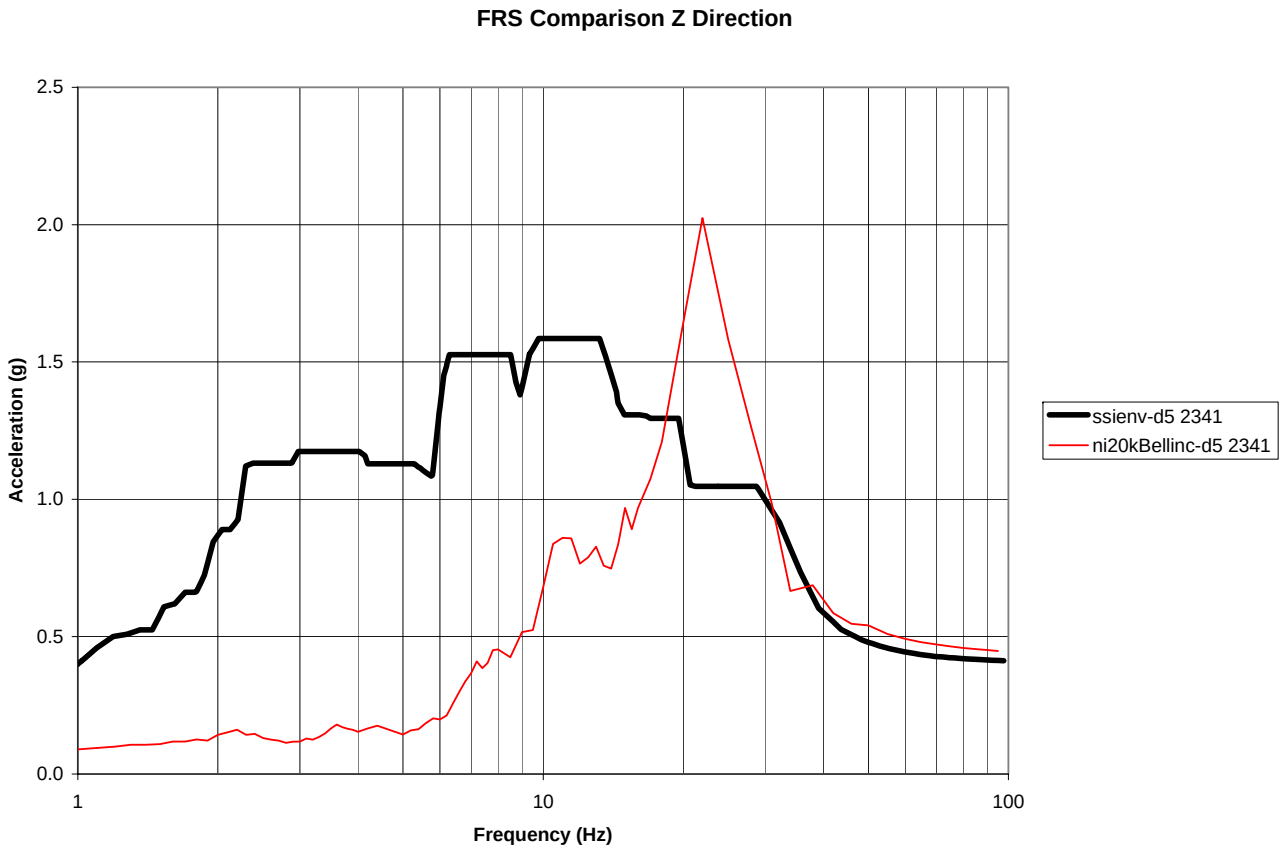
ASB at northeast corner (Elevation 134.5')



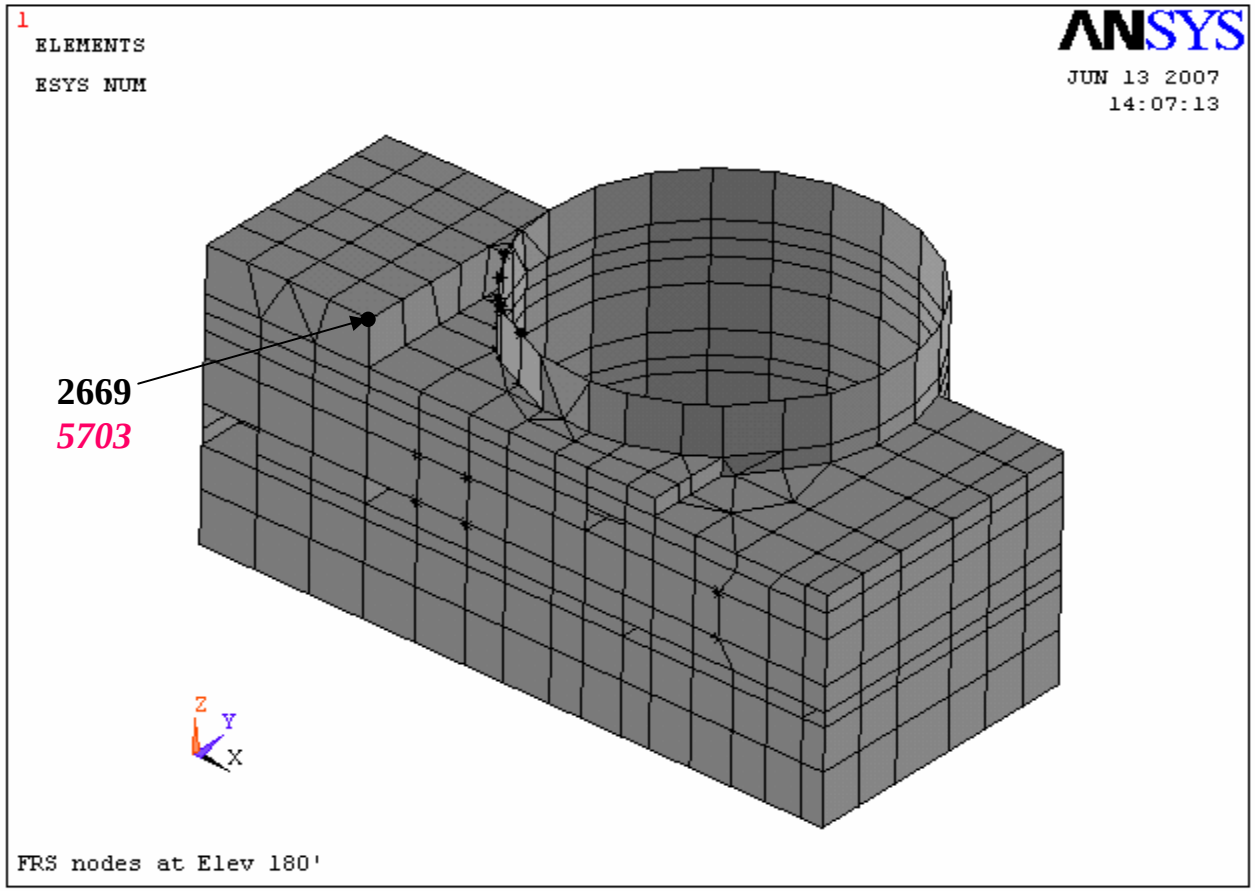
ASB at northeast corner (Elevation 134.5')



ASB at northeast corner (Elevation 134.5')



ASB at fuel building roof (Elevation 179.56')



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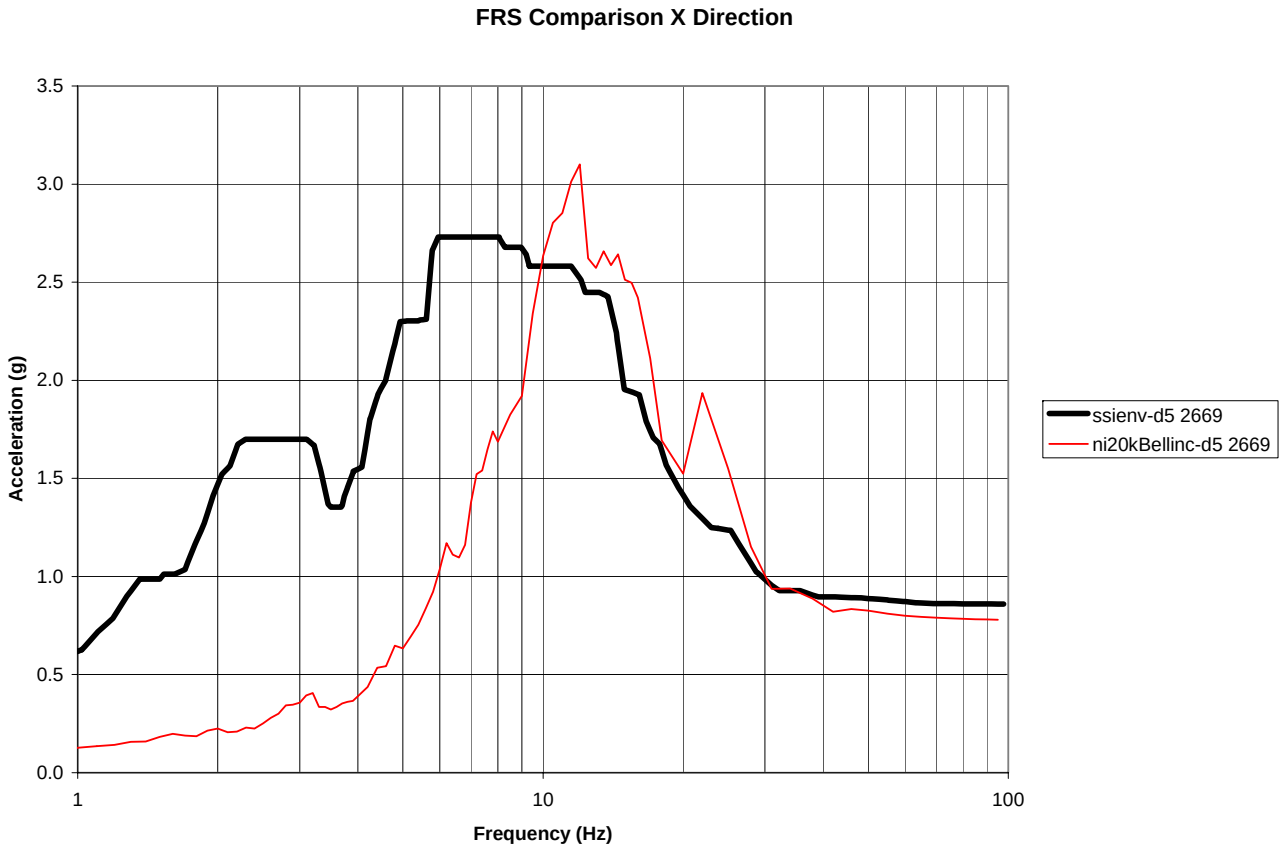

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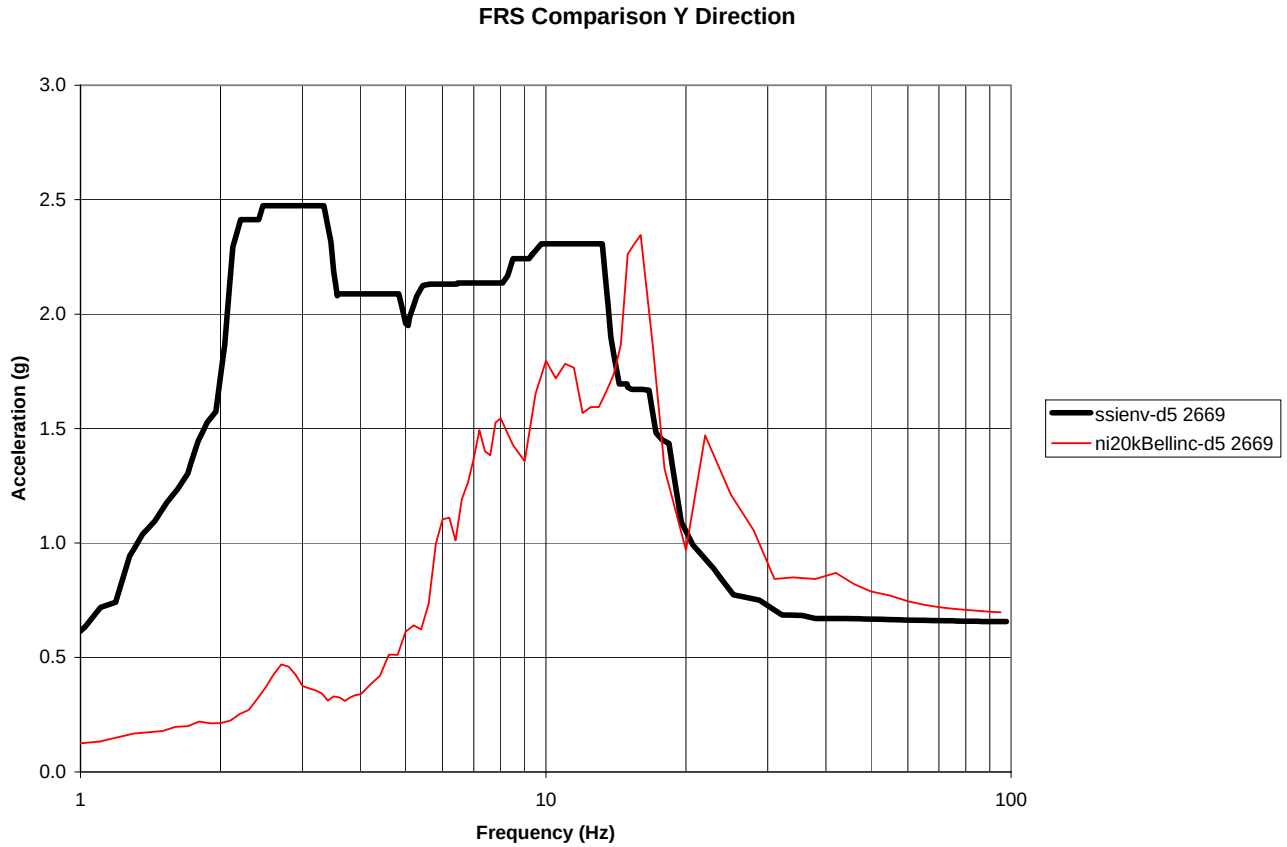

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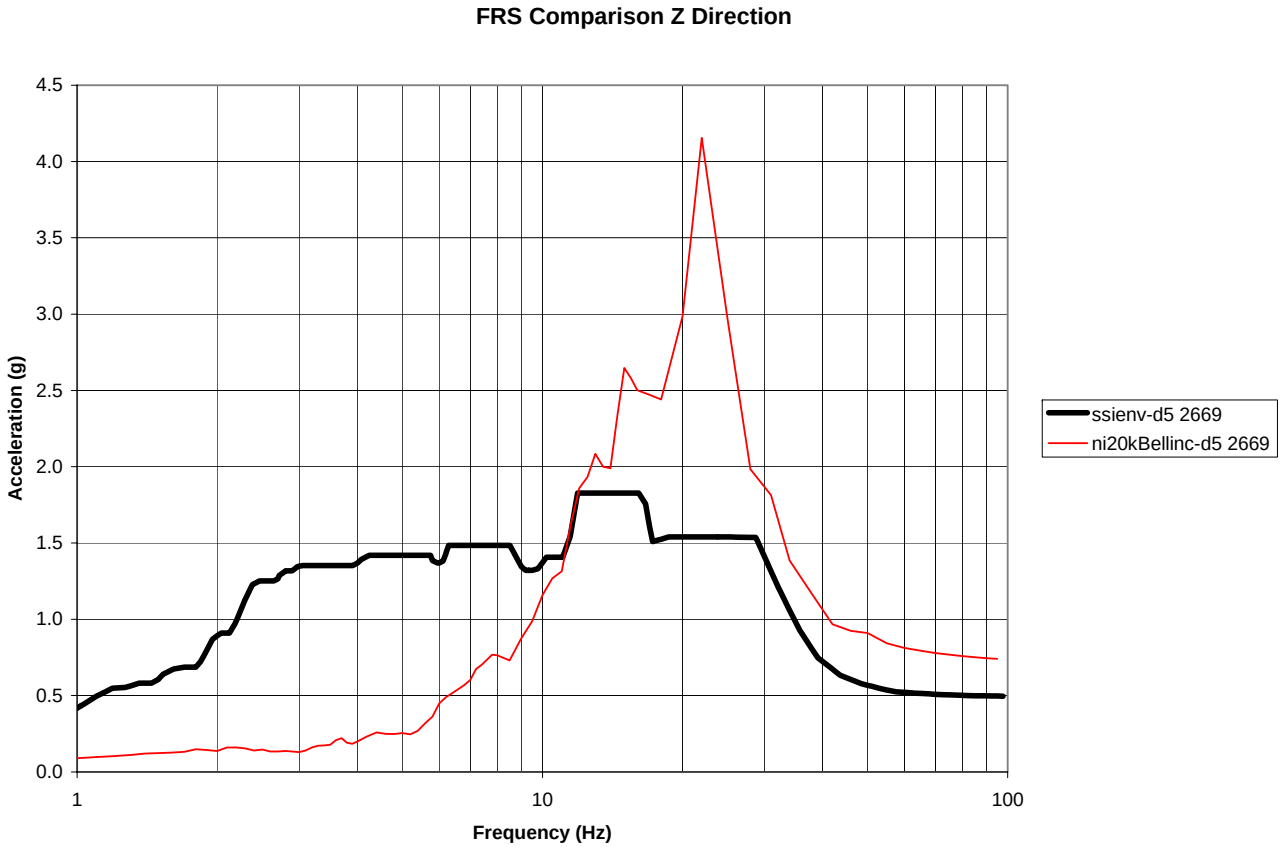
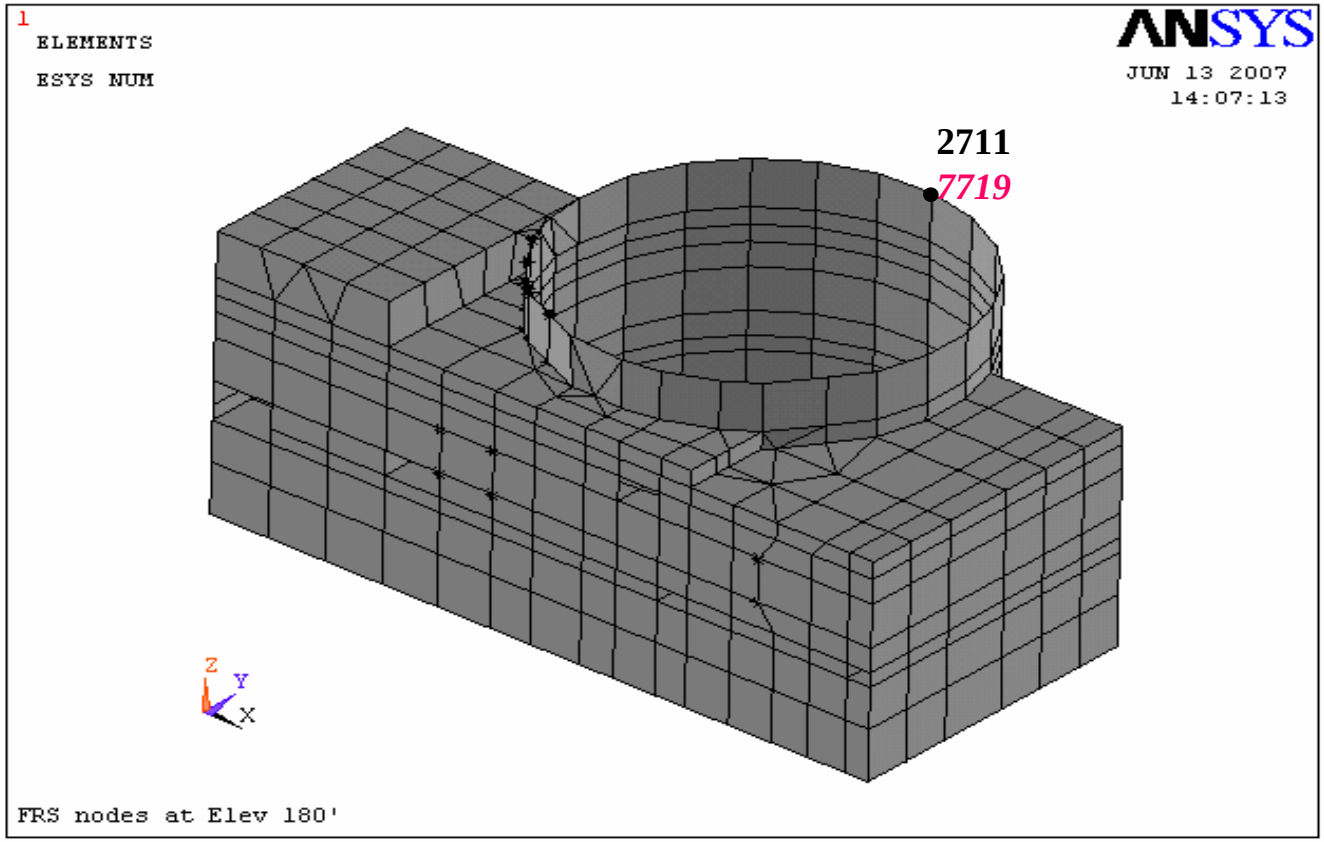
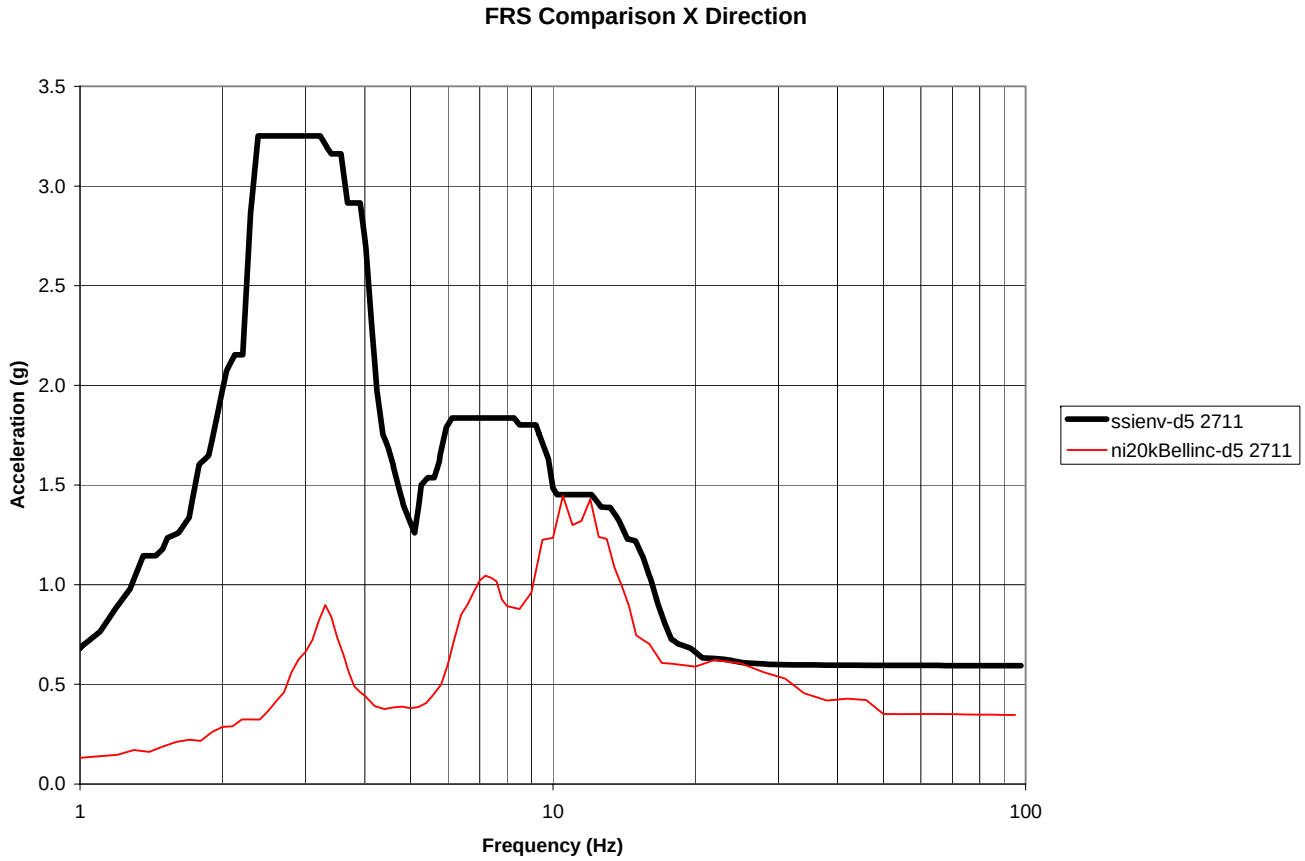


FRS Nodes – El. 180’



FRS Nodes – El. 180’



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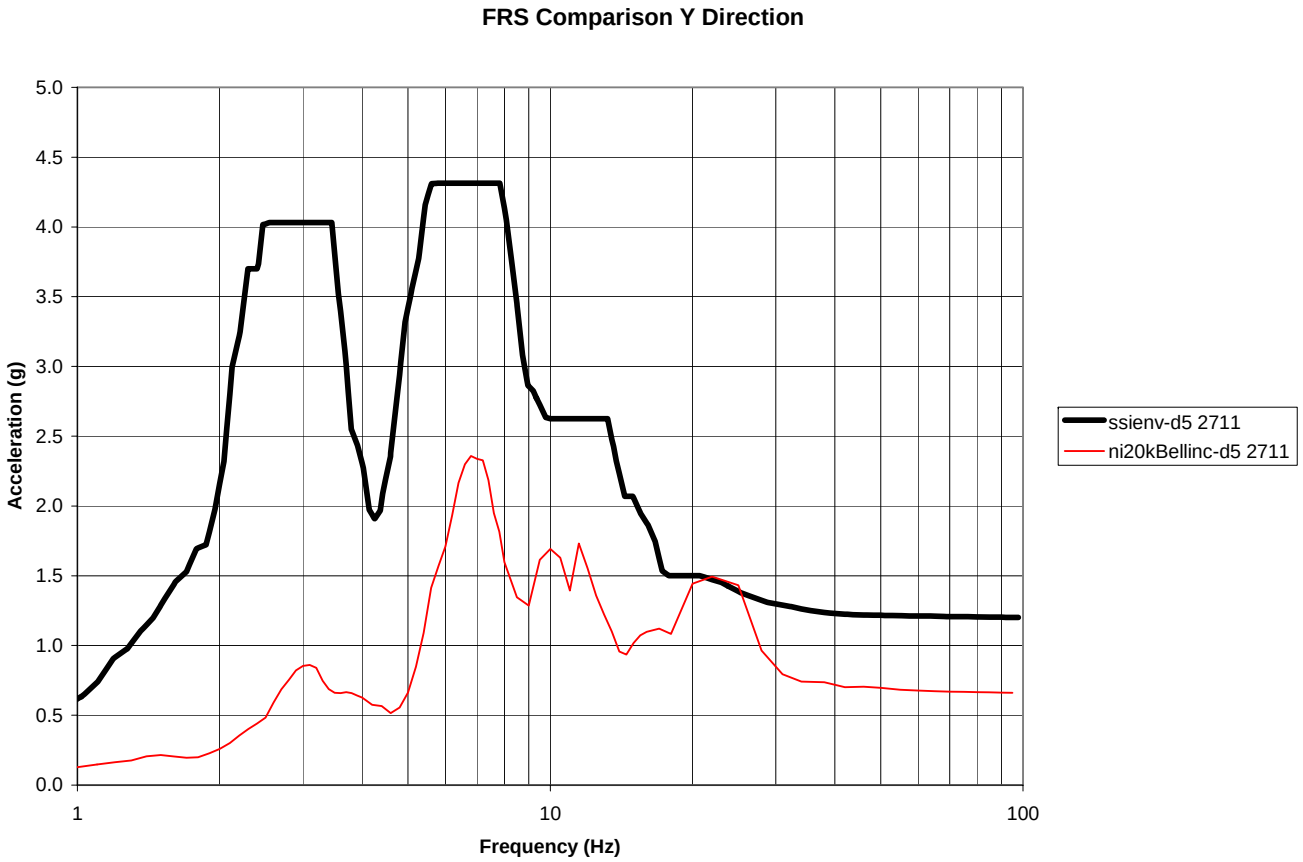
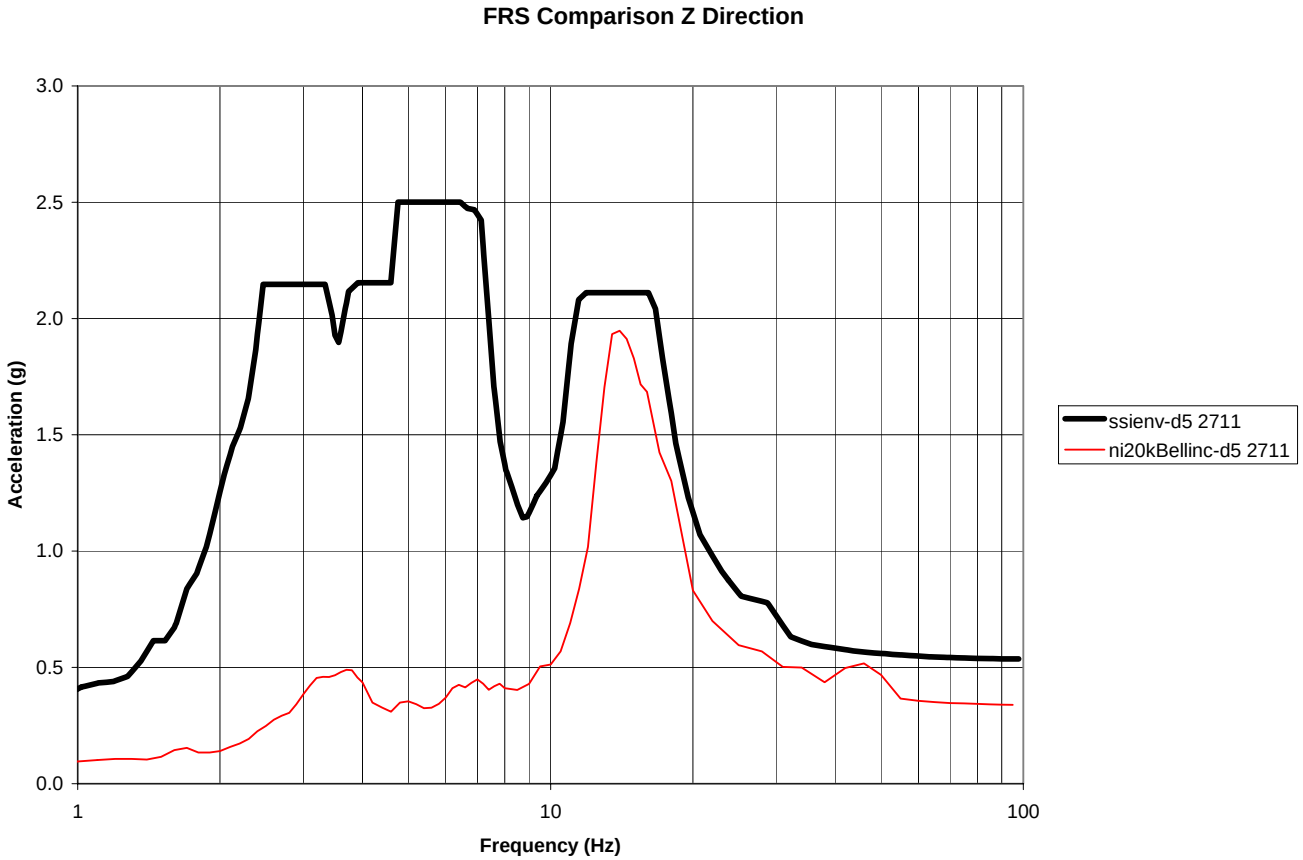
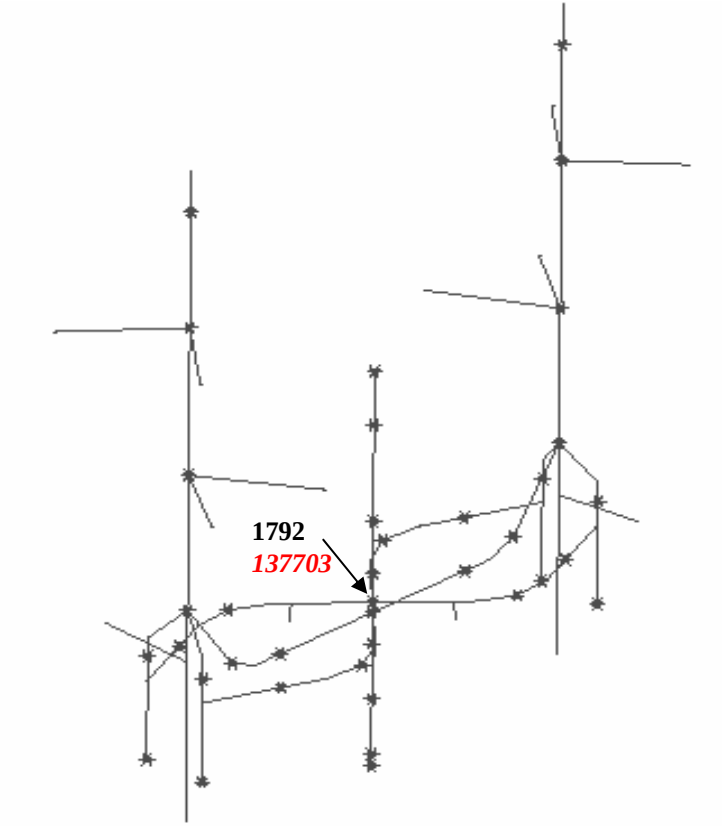


FRS Nodes – El. 180’



Reactor vessel support (Elevation 100’)



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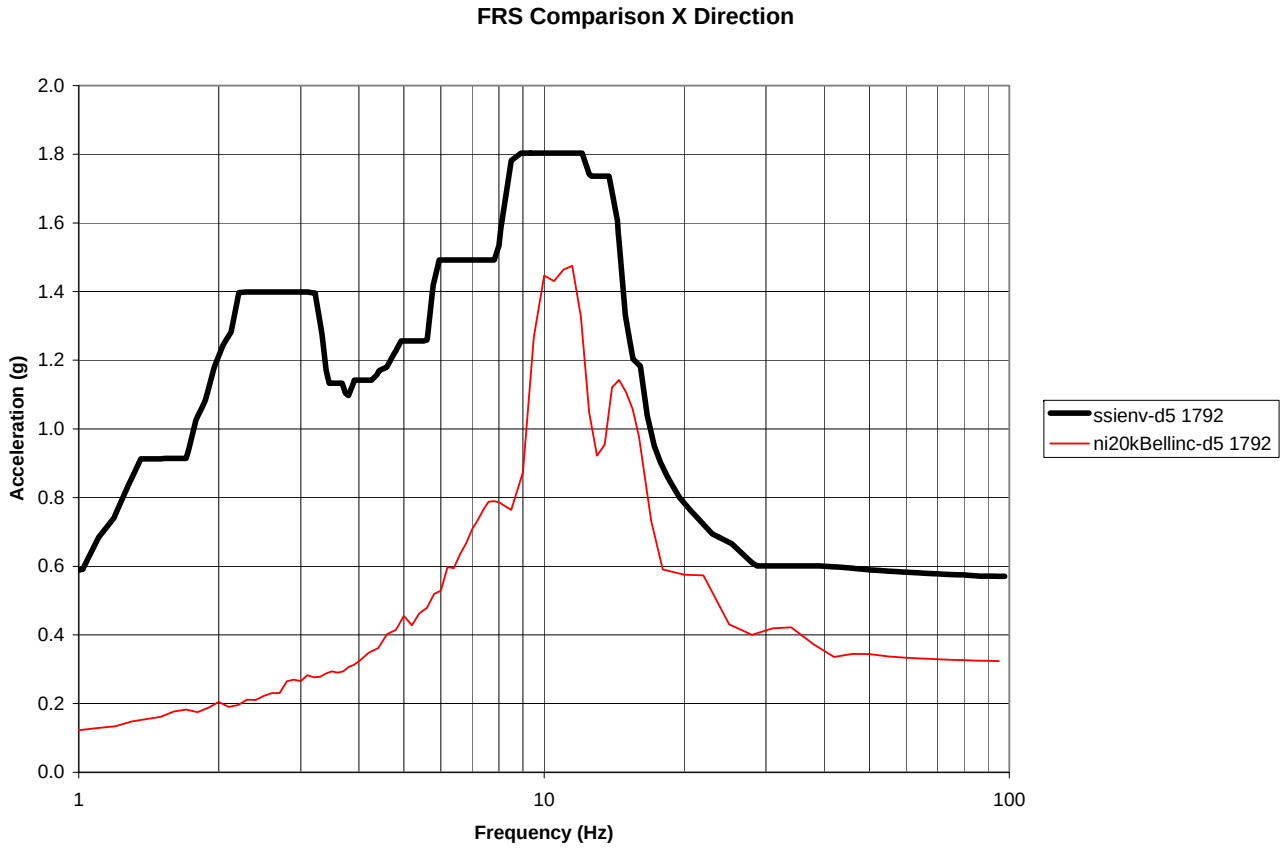

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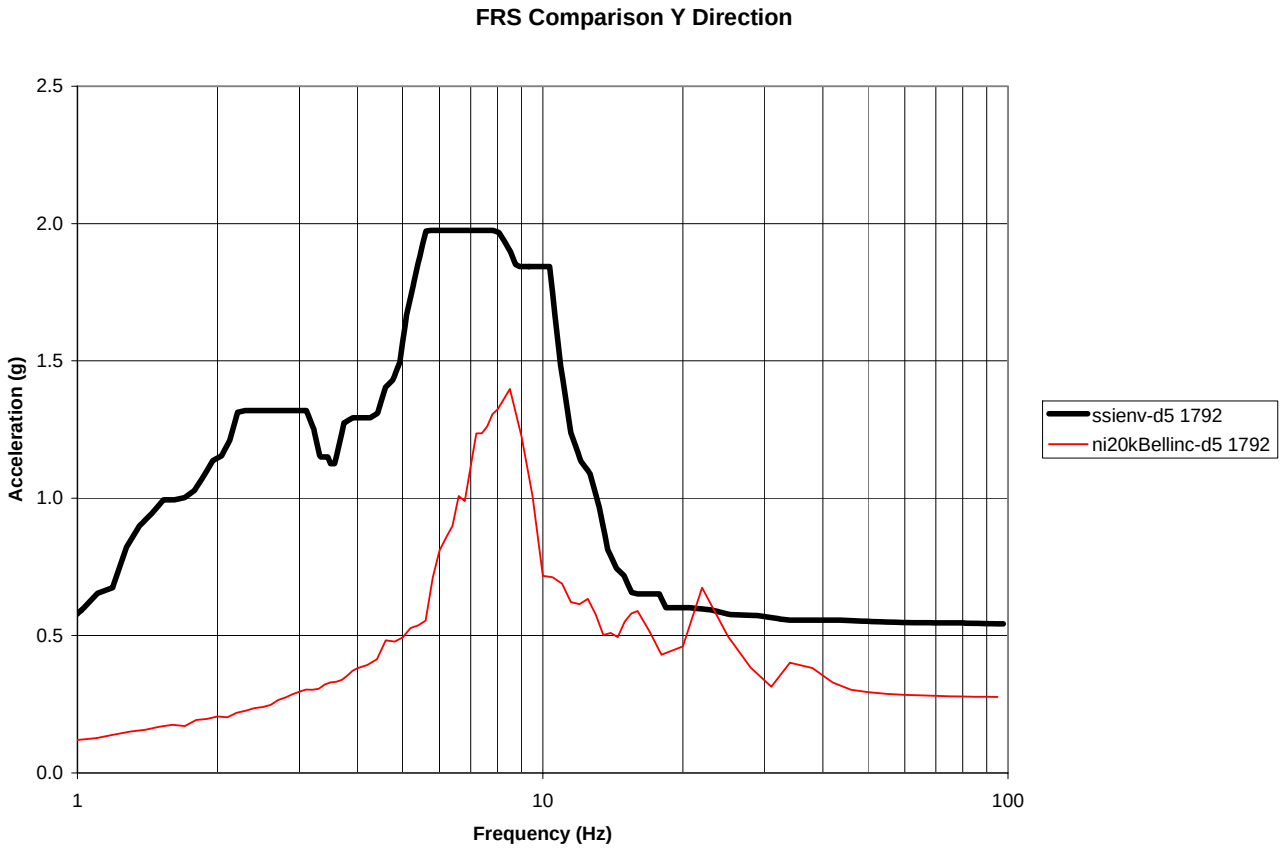
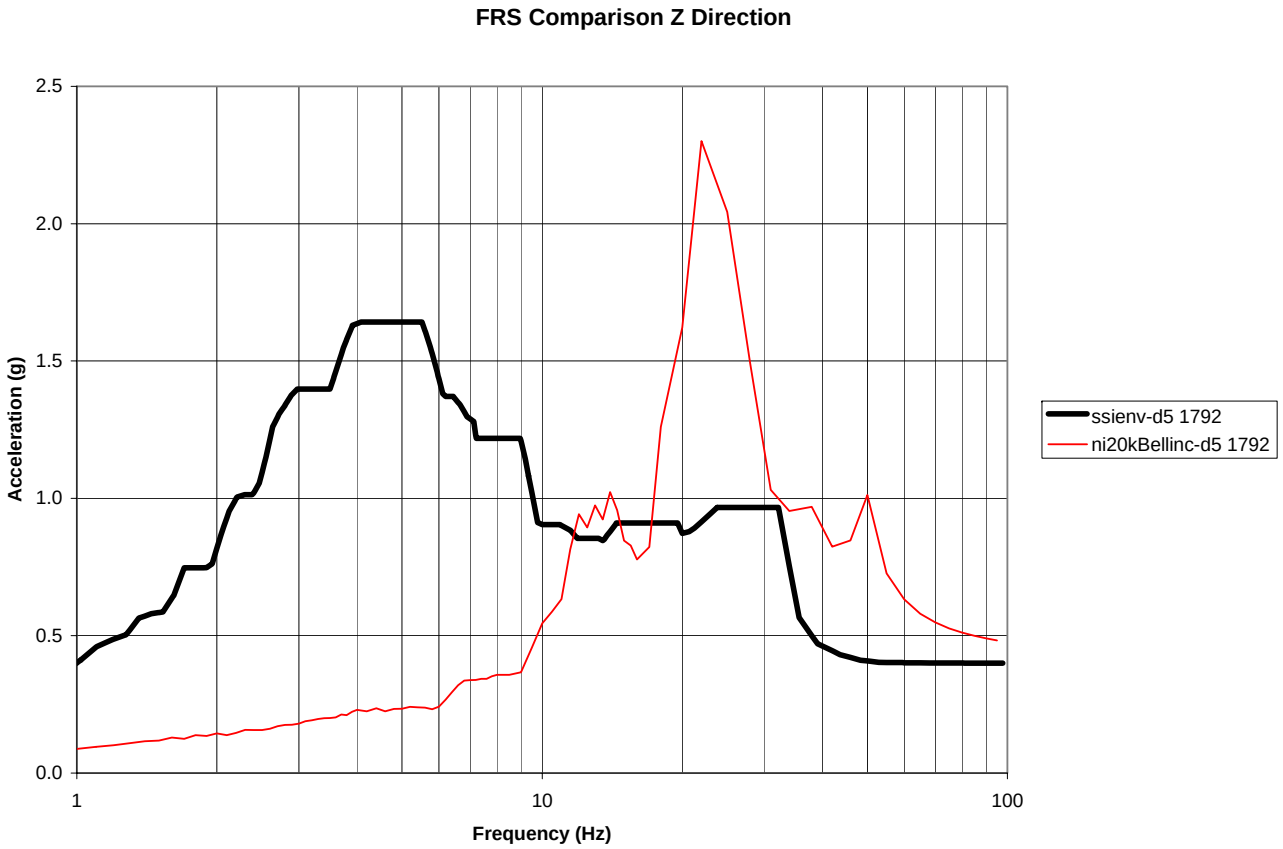


Reactor vessel support (Elevation 100’)



RCL Supports

RCL Supports	AP1000 Design (kips)	Bellefonte-co (3-07) (kips)	Bellefonte (incoherent) (kips)
Lower Vertical	1922	852	917
Lower Lateral	1103	672	562
Intermediate	1162	633	359
Upper	844	491	401

Reactor vessel support (Elevation 100')

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

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 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**

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

- **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

- Bellefonte outcrop motion will be processed through SHAKE, to develop the in-column foundation motion.
- SASSI-Simulation Analyses with the coherent function performed for Bellefonte foundation motion.
- The motion at the base will be averaged at six locations and enveloped

- 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