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March 2, 2010

Subject: AP1000 Response to Request for Additional Information (TR 03)

Westinghouse is submitting responses to NRC requests for additional information (RAI) on Technical Report No. 03. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-TR03-032 R4

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

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
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/Enclosure

1. Response to Request for Additional Information on Technical Report No. 03

D063
NRO

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ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 03

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-032
Revision: 4

Question:

The staff's review of the text and figures in Appendix C of AP1000 Document No. APP-GW-S2R-010, Revision 0, June 2006, "Extension of Nuclear Island Seismic Analyses to Soil Sites," identified the need for a number of clarifications and explanations of the results presented. The staff requests Westinghouse to address the following:

a. In paragraphs 4 and 5, an explanation is provided why the SASSI NI20 model produces higher results in the high frequency region than the ANSYS NI20 model, for a hard rock site condition. The explanation would appear to apply on a generic basis. However, comparison of Figures C-1 through C-6 to Figures C-7 through C-12, respectively, indicates that this effect is not generically demonstrated. Only the first three of the six locations demonstrate this behavior. Please (a) provide a detailed explanation why this effect occurs only at three locations, and not at all six locations; (b) describe how it was determined that the explanation provided in paragraph 4 and 5 is accurate; and (c) confirm that all other potential sources for the differences (e.g., modeling error) have been investigated and eliminated as the source of the difference.

b. Paragraph 2 states:

> "Both finite element models give comparable results below 10 hertz. However, the results from the coarse model are not as good at high frequencies (above about 15 hertz). Therefore the hard rock FRS were generated from the fine NI10 model, and the coarse NI20 model was used for the soil site analyses where frequencies of interest are below 10 hertz."

Paragraph 6 states:

> "In a few cases it is found that the soil cases analyzed in SASSI using the NI20 model give higher results than the hard rock case using the NI10 model for frequencies above 10 Hz (see for example Figure 4.4.3-9). Although these cases <u>are believed to be</u> due to conservatism in the SASSI results at high frequency, the SASSI results are used in developing the broadened envelope design response spectra."

Apparently, the hard rock results obtained from the NI10 ANSYS model do not always envelop the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz, as one might easily conclude from paragraph 2. From paragraph 6, it appears that there is considerable uncertainty about the validity of the SASSI results above 10 hertz. This is in contrast to the "matter-of-fact" statements made in paragraphs 4 and 5. Please clarify the Westinghouse position, including the technical basis, on the validity of SASSI

NI20 model results above 10 hertz for all site conditions, including a hard rock site. Is the NI20 grid sufficiently refined to accurately predict response above 10 hertz? Have any SASSI soil site analyses been performed using a refined grid comparable to the NI10 model, to study the effect of element size on the solution results?

c. Explain what studies were performed to establish that the NI10 model refinement is sufficient to accurately account for high frequency response effects at all critical locations. It is not obvious from the results shown in Figure C-1 that convergence with element size has been achieved.

Additional Request (Revision 4):

Westinghouse will provide justification on how flexible regions (walls, floors, and roof panels) are addressed in TR03 and HRHF. Review and identify responses to less that 33 Hz for CSDRS. Reanalysis of seismic response will correct/clarify values and results will be re-issued as a new revision to RAI-TR03-32.

Westinghouse Response:

a) The NI20 model uses solid elements for the mass concrete below grade inside the shield building. Other parts of the model use shell elements. The difference in ANSYS and SASSI results is most noticeable at the three lowest elevations where the response is most affected by the solid elements below grade.

The explanation provided in Paragraphs 4 and 5 were based on detailed checking of the models and on a series of studies. The explanation was confirmed by a study comparing the SASSI and ANSYS responses using a reduced model with only the solid elements in the NI20 model.

b) Paragraph 2 does not imply that NI10 ANSYS model envelopes the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz. It is discussing the comparison of the NI10 and NI20 models on hard rock. The paragraph states explicitly that the results of the NI20 model on hard rock are not as good at high frequencies.

The RAI is correct when it says that the hard rock results obtained from the NI10 ANSYS model do not always envelop the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz. This can be seen by review of the floor response spectra in Figures 4.4.3-1 to 4.4.3-18. The higher SASSI responses are generally responses in the vertical direction. An extreme example is seen in Figures 4.4.3-9 where the firm rock exhibits a higher response at about 25 hertz. As seen in Figure C-3 on hard rock the NI20 model has a similar higher response so this higher response is due to the coarser

modeling of NI20; however, the higher SASSI results were conservatively enveloped in developing the broadened envelope design response spectra.

The comparisons of the NI10 and NI20 results in Figures C-1 to C-6 show the NI20 model is acceptable for responses above 10 hertz. However, as stated in paragraph 2, the NI10 model gives more accurate results and is used in the fixed base analyses for hard rock. The comparisons of NI10 to NI20 were performed in ANSYS. Analyses have not been performed in SASSI with more refined models than the NI20 model.

The FRS for the NI10, NI20 (ANSYS & SASSI) given in Appendix C are compared on the same plots in Figures RAI-TR03-032-1 to RAI-TR03-032-6. The node numbers are the same as shown in Table C1 of the technical report (Revision 1). The pertinent information from Table C1 is reproduced in Table RAI-TR03-032-1. The NI10 ANSYS FRS are used as the design basis for hard rock.

c) The NI10 model is described in DCD subsection 3.7.2 (Item 5) and is the basis for the vertical floor response spectra for hard rock. The model was reviewed and accepted as part of the hard rock design certification. During development of the model detail studies with greater element refinement were performed for the floor above the control room and the adjacent bays to confirm the adequacy of the model.

Westinghouse Additional Response: (Revision 3)

Based on discussions in the NRC meeting on May 19-23, 2008, revisions to wording in Appendix C of the technical report was modified to state that the NI20 model has higher (conservative) results in the high frequencies compared to the NI10 model.

Table RAI-TR03-032-1– Key Nodes at Location

Location	NI10 Node	NI20 Sassi	Figure ANSYS & SASSI FRS Comparaison	General Area	Elevation (feet)
CIS at Reactor Vessel Support Elevation	130401	1761	RAI-TR03-032-1	RPV Center	100.00
CIS at Operating Deck	105772	2199	RAI-TR03-032-2	SG West compartment, NE	134.25
ASB NE Corner at Control Room Floor	4724	2078	RAI-TR03-032-3	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	5744	2675	RAI-TR03-032-4	NW Corner of Fuel Bldg	179.19
ASB Shield Building Roof Area	8573	3329	RAI-TR03-032-5	South side of Shield Bldg	327.40
SCV Near Polar Crane	130412	2788	RAI-TR03-032-6	SCV Stick Model	224.00

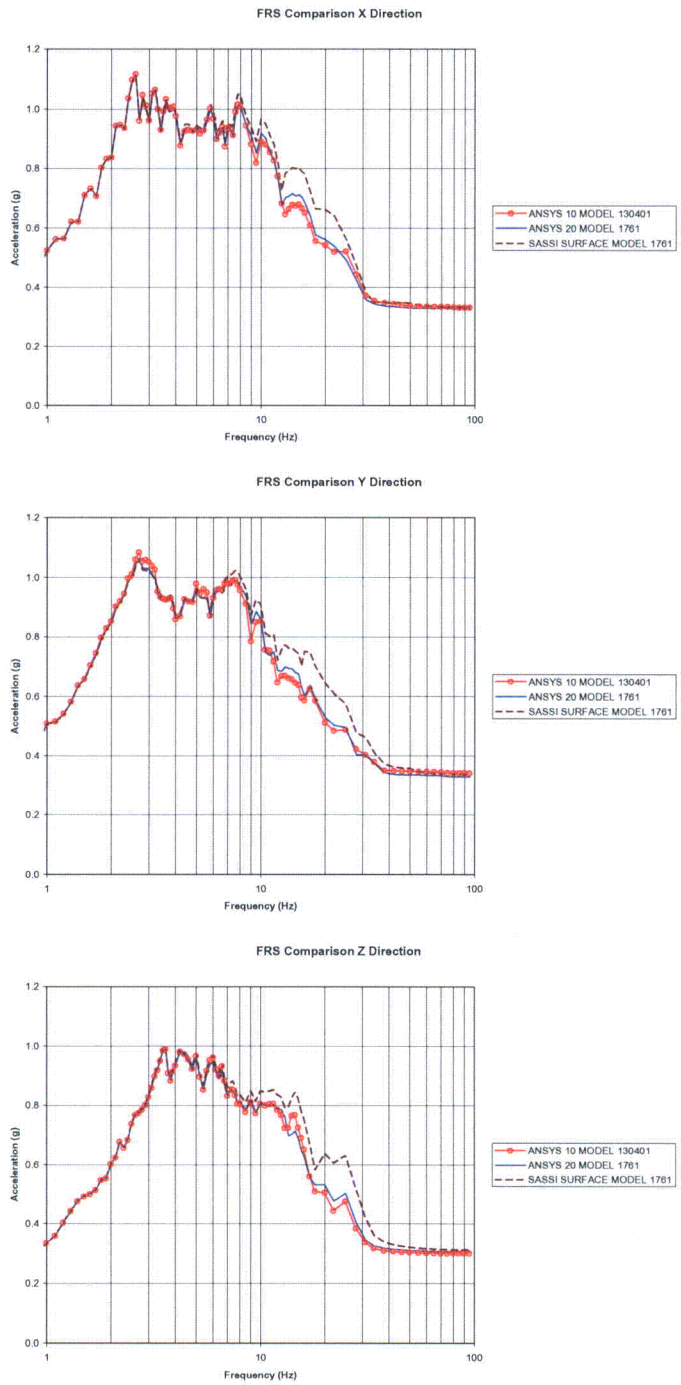

Figure RAI-TR03-032-1 — FRS Comparison at Base of SCV on CIS at RPV Center

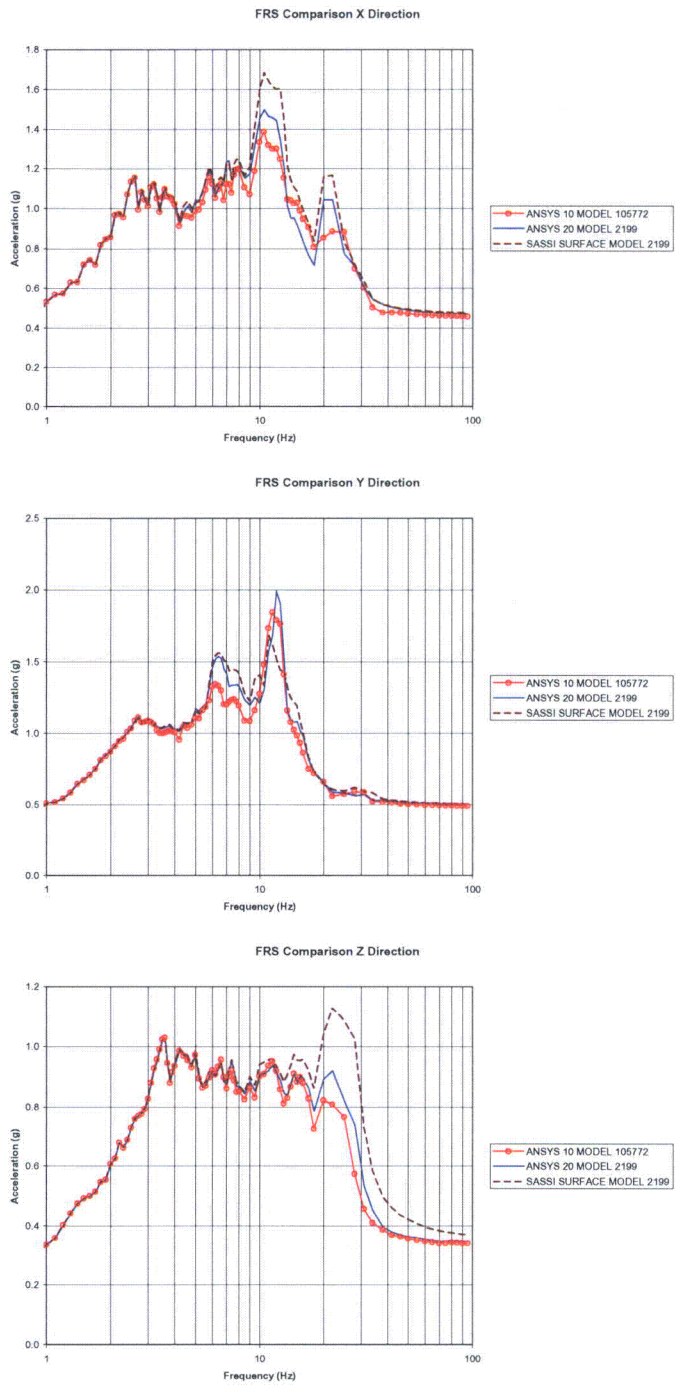

Figure RAI-TR03-032-2 - FRS Comparison at NE Corner of SG West Compartment, El. 134'

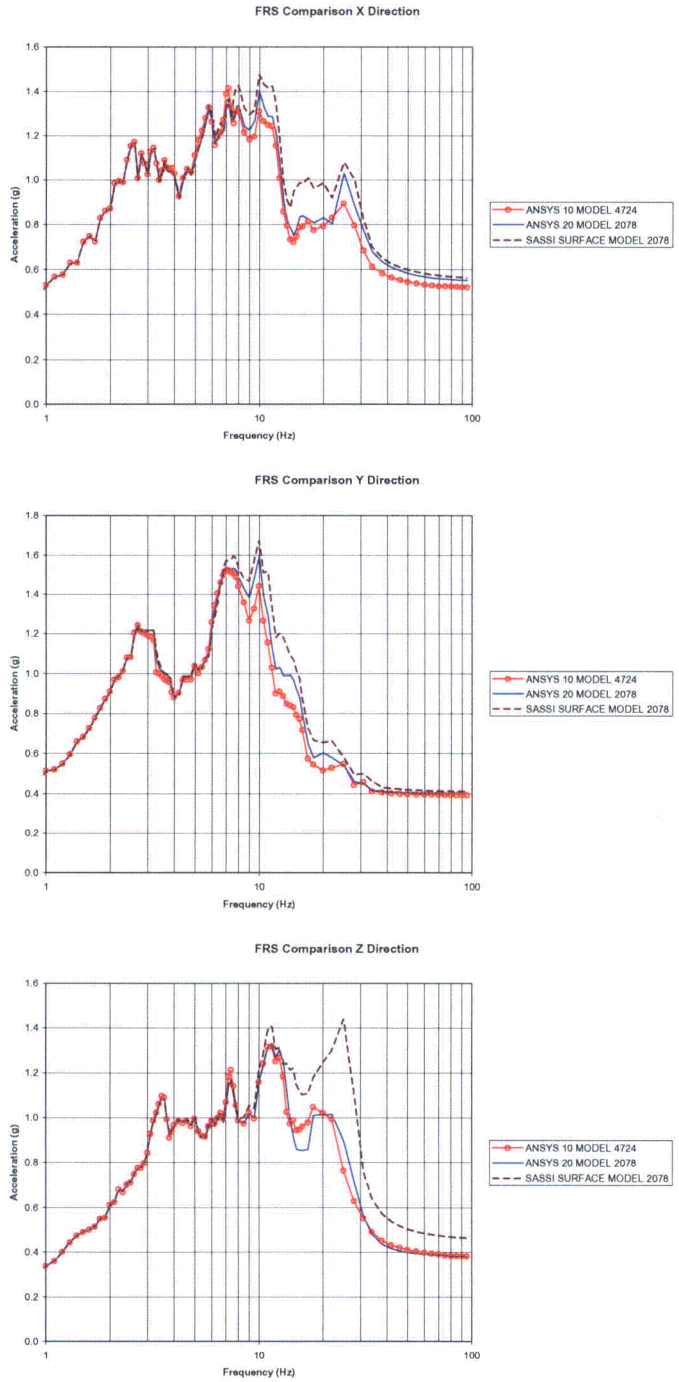

Figure RAI-TR03-032-3 - FRS Comparison at NE Corner of Control Room Floor

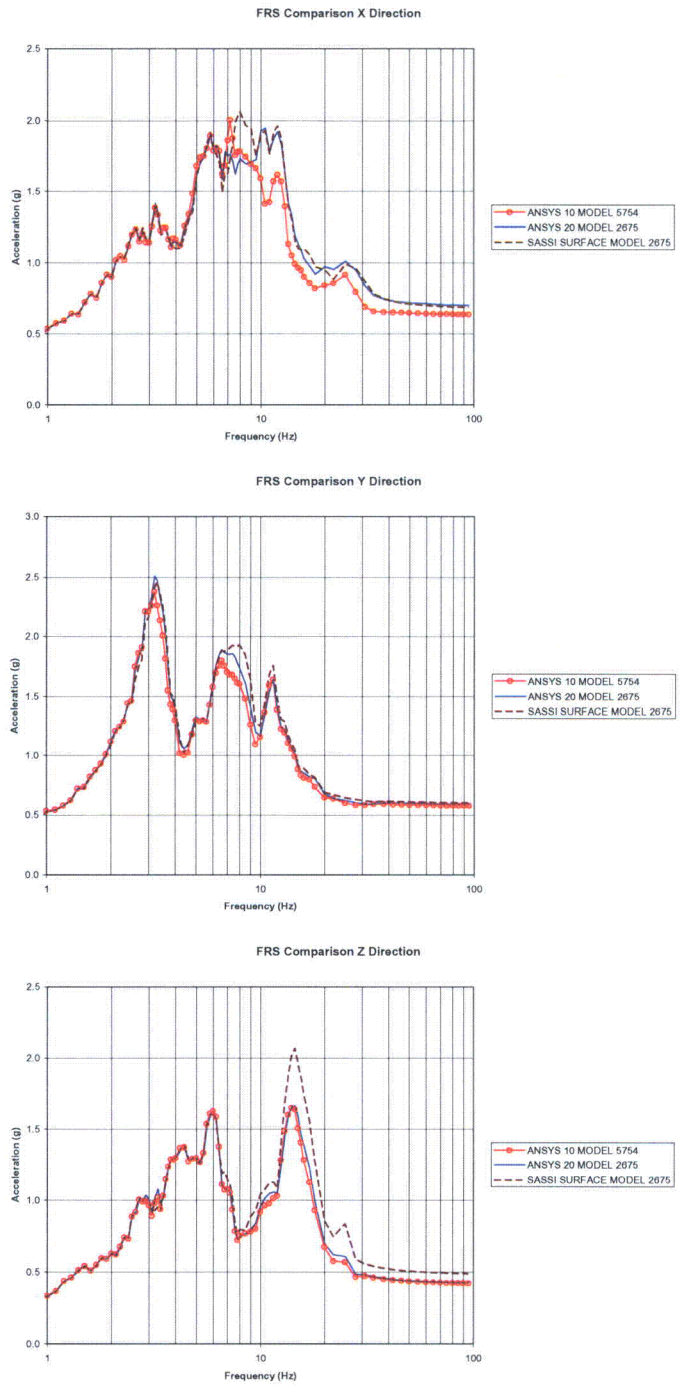

Figure RAI-TR03-032-4 - FRS Comparison at NW Corner of Fuel Building Roof

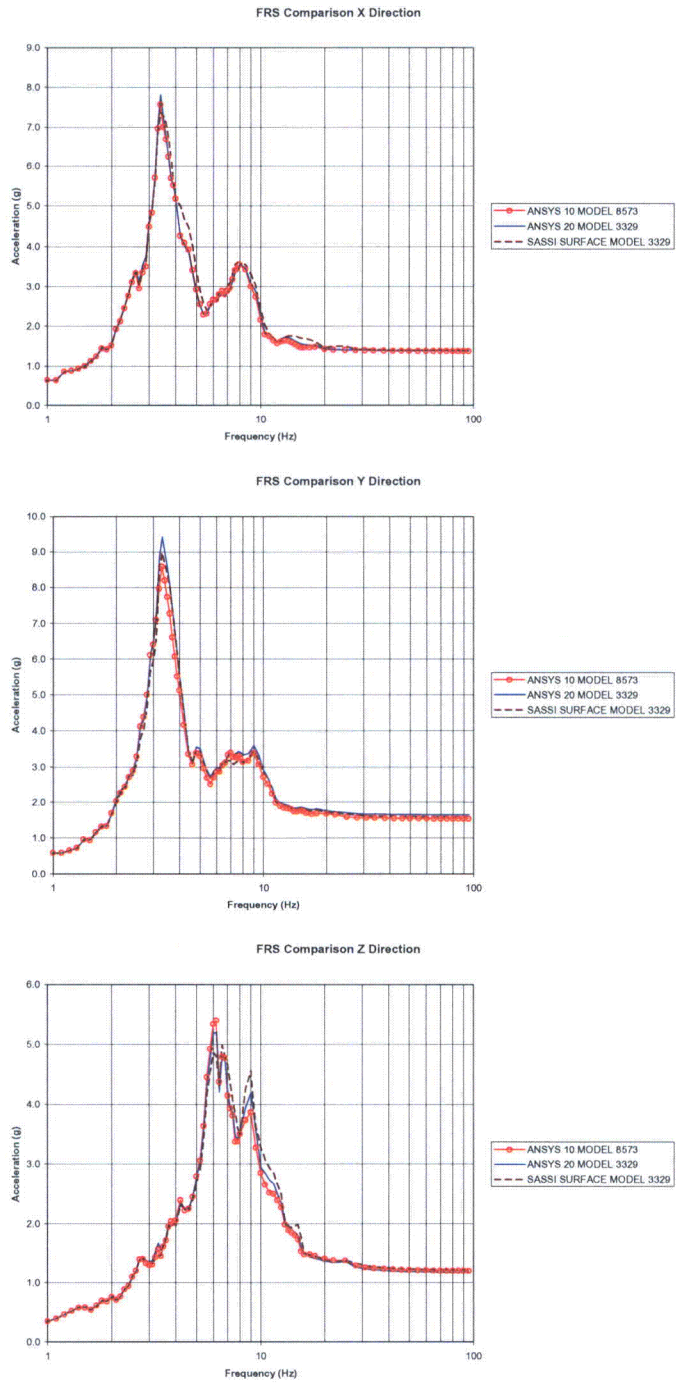

Figure RAI-TR03-032-5 - FRS Comparison at South Side of Shield Building at El. 327.41'

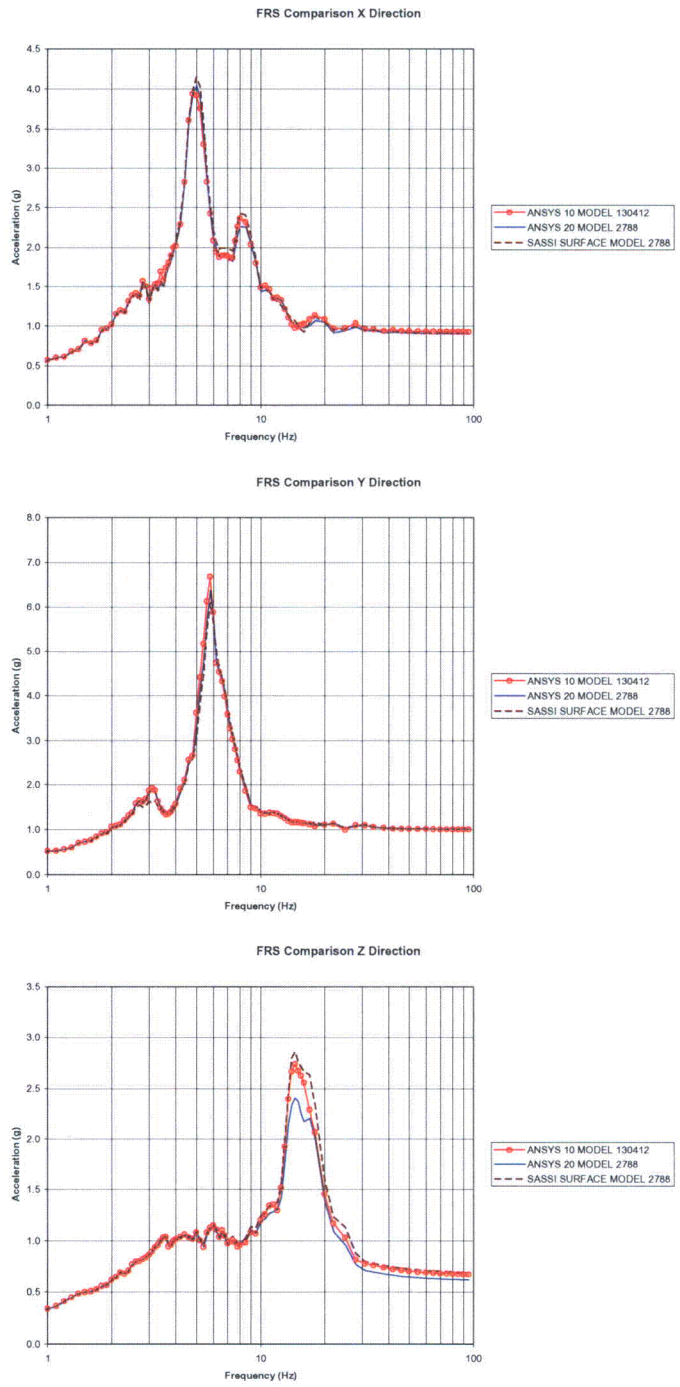

Figure RAI-TR03-032-6 - FRS Comparison on SCV near Polar Crane, El. 224'

Additional Response: (Revision 4)

Flexible areas were identified when the Nuclear Island dynamic model was created. These areas are the following:

- Flexible floor area East of Shield Building to column line I and between column lines 7 to 7.3, EL. 116.5'
- Fuel pool wall L2 between column lines 2 to 4, EL. 92.71' to 135'
- Wall Q between column lines 9.1 to 11, EL. 117.5' to 135'
- Flexible floor East of Shield Building between column lines 4 to 5, EL. 135'
- Flexible floor on North of Shield Building between column lines I to L and 5 to 7.3, EL. 135'
- Flexible floor on North of Shield Building between column lines I to L and 7.3 to 11, EL. 135'
- Wall I between column lines 1 & 4,above EL. 160'
- Wall N between column lines 1 & 4,above EL 160'
- Wall 1 between column line I & N, above EL.160'
- Floor between column lines 7.3 &11 and I to L, EL. 160'
- Roof East of Shield Building to column line I and between column lines 7 to 7.3, EL. 160'
- Roof South side of Aux Building between column lines I & N and column lines 1 to 4, EL. 180'
- Center of Shield Building , EL. 289.2'

Nodes were located within these flexible areas so that the "amplified" response spectra could be developed and used in the design.

In order to address flexible regions, frequencies and mode shapes are being developed using the NI05 model as part of incorporating the shield building modification into the model. Based on the dynamic response information, additional flexible areas are identified and added to the above list. Additionally, the mode shapes from the NI20 model are compared to those from the NI05 model. This is to ensure that there is a node in the NI20 model that is within the area of

amplification that reflects the floor flexibility and corresponding additional amplification. Response spectra are then developed for each of these additional flexible areas (frequencies below 33 hertz) and included in the design in-structure response spectra. This allows the identification of additional flexible regions at frequencies less than 33 hertz.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

Revise Appendix C as shown below:

Appendix C - Comparison of NI10 and NI20 Responses (Changes included with ~~Respnse~~Response Revision 3)

In this appendix the fine (NI10) and coarse (NI20) model seismic responses are compared. Seismic response spectra were developed for both models using a fixed base (hard rock) case. Also in this section the NI10 and NI20 ANSYS ~~is~~ models are compared ~~to~~ using the SASSI analysis results.

Figures C-1 to C-6 compare response spectra for ANSYS analyses of the NI10 and NI20 models at the interface seismic response key nodes (see Section 4.4.3). These locations are given in Table C-1. Also shown in this table are the figures where the comparison spectra are given. Both finite element models give comparable results below 10 hertz. However, the results from the coarse model are ~~not as good~~higher (conservative) at high frequencies (above about 15 hertz). Therefore the hard rock FRS were generated from the fine NI10 model, and the coarse NI20 model was used for the soil site analyses where frequencies of interest are below 10 hertz.

A Time History Analysis for the Nuclear Island SASSI Surface Structure Model and the Embedded Structure Model is carried out with the seismic input in three orthogonal directions. The acceleration response spectra for 5% damping are generated at the interface locations identified in Table C-1. The nodes chosen for "SASSI Surface Model " in Figures C-1 to C-6 compare the Nuclear Island SASSI Surface Structure Model and the Embedded Structure

Model results with the Nuclear Island ANSYS Coarse Model (NI20) results for hard rock conditions.

As seen from the comparison (see Figures C-1 to C-6), for the horizontal response, the SASSI and ANSYS results for NI20 are very similar to about 15 Hz horizontal and about 10 Hz vertical. At the higher frequencies SASSI calculates higher accelerations. The NI20 model uses solid elements for the mass concrete below grade inside the shield building. Other parts of the model use shell elements. The difference in ANSYS and SASSI results is most noticeable at the three lowest elevations where the response is most affected by the solid elements below grade. This behavior was investigated in a study comparing the SASSI and ANSYS responses using a reduced model with only the solid elements in the NI20 model. One reason for this conservatism in the SASSI results is the different formulation in the solid elements. Another difference is due to the different way the two computer programs calculate the dynamic response. ANSYS performs the dynamic response in the time domain. SASSI converts the time history input (time domain) to the frequency domain, solves the response in the frequency domain, and then converts the output back to the time domain.

SASSI also needs to specify key frequencies to perform its transfer function calculations. For such a large model, resting on a very stiff soil (hard rock), SASSI gives conservative results at high frequencies. The significant responses for soil cases occur at less than 10 Hz. Therefore, the SASSI Model is adequate for the AP1000 Soil-Structure Interaction analyses to be performed.

In a few cases it is found that the soil cases analyzed in SASSI using the NI20 model give higher results than the hard rock case using the NI10 model for frequencies above 10 Hz (see for example Figure 4.4.3-9). The reason for this is two-fold: mesh size and SASSI approximation. The NI20 SASSI model is a much coarser model than the NI10, at higher frequencies it cannot capture the local behavior as well as the NI10 and this causes some of the response to be higher. SASSI uses a limited number of transfer functions to obtain the dynamic response. This limited number (up to 100 frequencies) is an adequate approach when the medium that you are considering is soil, where only a few significant modes need to be captured to obtain the building response. At higher frequencies, in a shell models, many modes (or transfer frequencies) are required to obtain the building response. Although these cases are due to conservatism in the SASSI results at high frequency, the SASSI results are used in developing the broadened envelope design response spectra.

Table C-1 – Key Nodes at Location

Location	NI10 Node	NI20 Sassi	Figure ANSYS & SASSI FRS Comparaison	General Area	Elevation (feet)
CIS at Reactor Vessel Support Elevation	130401	1761	C-1	RPV Center	100.00
CIS at Operating Deck	105772	2199	C-2	SG West compartment, NE	134.25
ASB NE Corner at Control Room Floor	4724	2078	C-3	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	5744	2675	C-4	NW Corner of Fuel Bldg	179.19
ASB Shield Building Roof Area	8573	3329	C-5	South side of Shield Bldg	327.40
SCV Near Polar Crane	130412	2788	C-6	SCV Stick Model	224.00

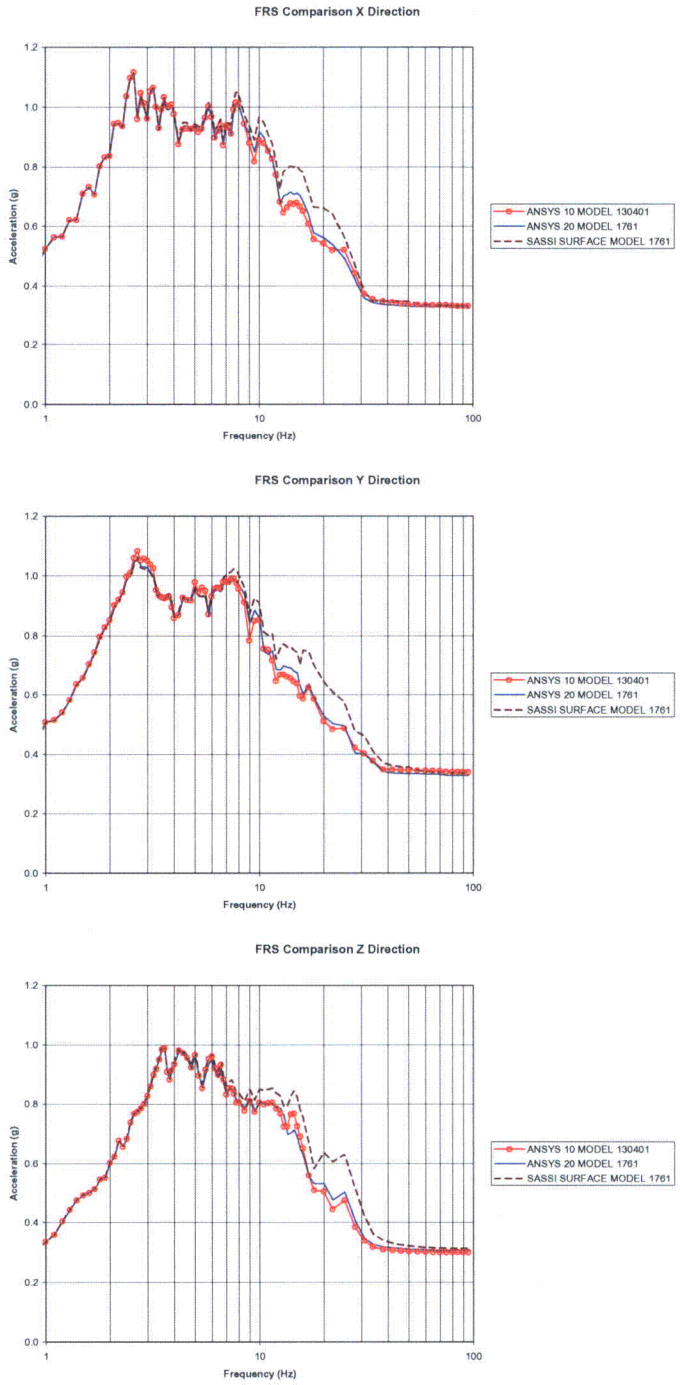

Figure C-1 – FRS Comparison at Base of SCV on CIS at RPV Center

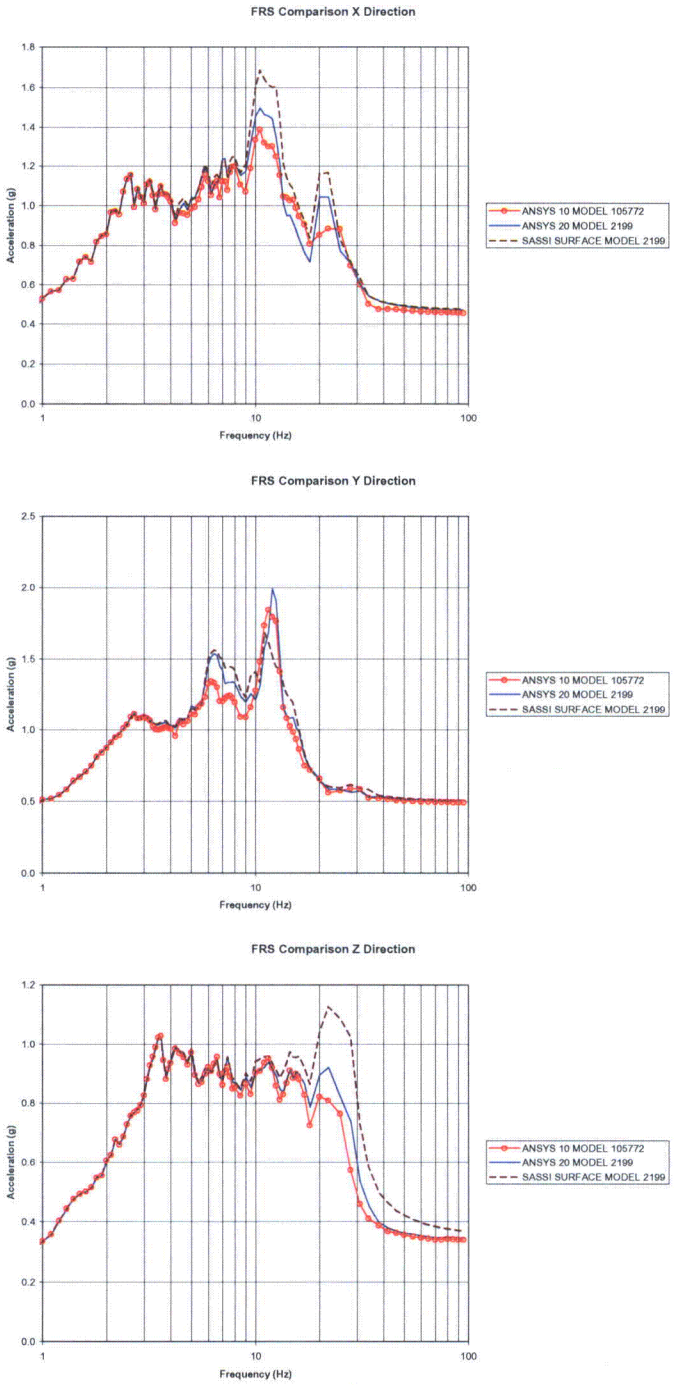

Figure C-2 – FRS Comparison at NE Corner of SG West Compartment, El. 134'

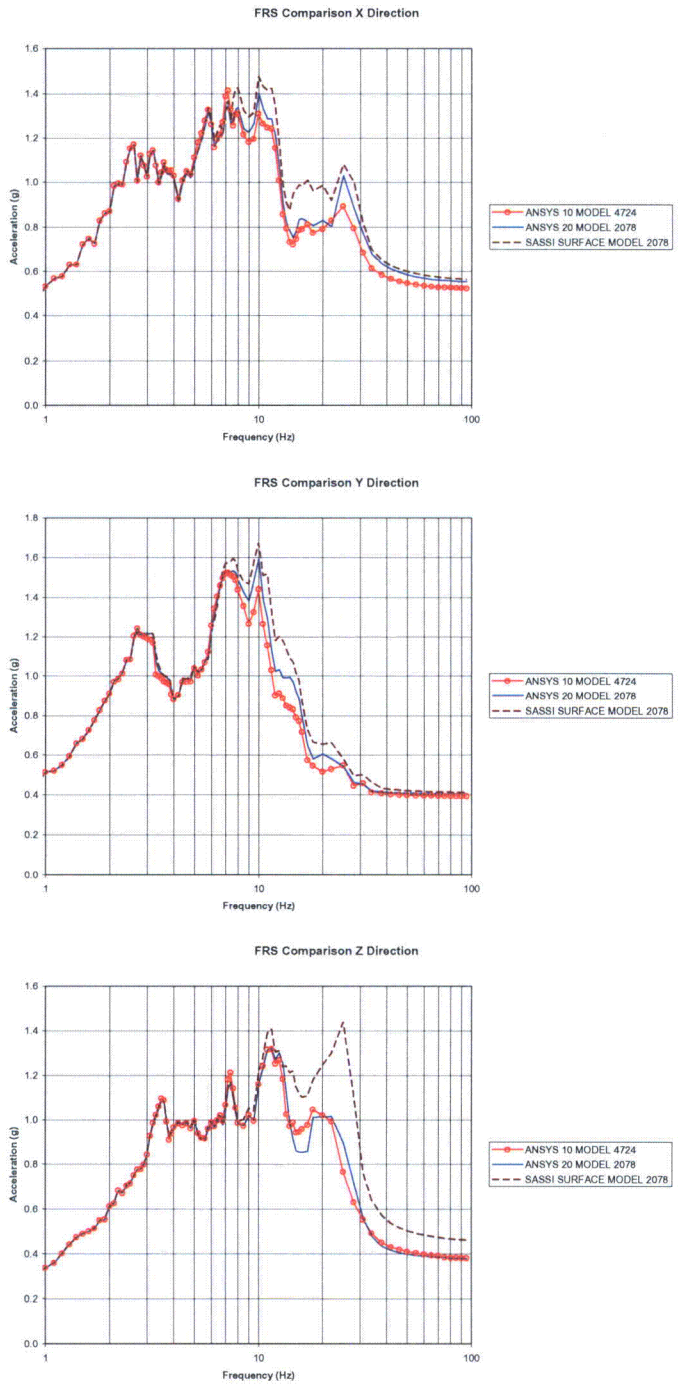

Figure C-3 – FRS Comparison at NE Corner of Control Room Floor

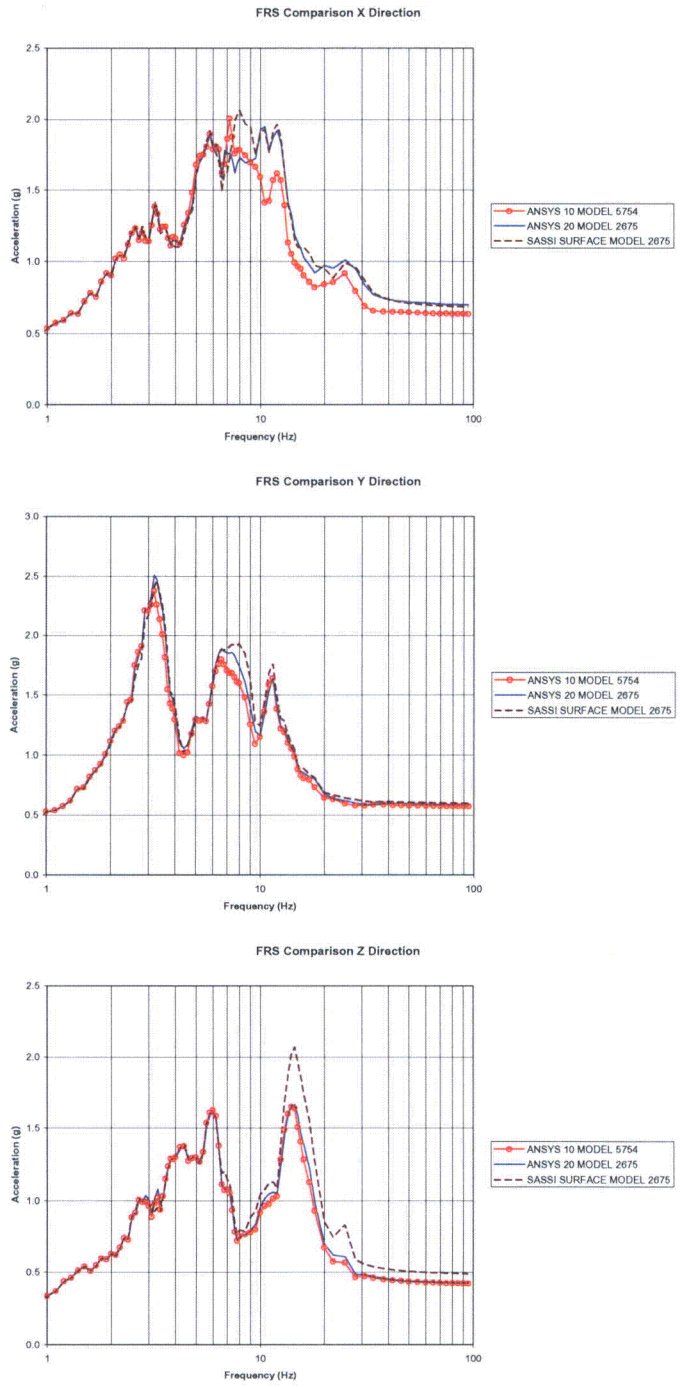

Figure C-4 – FRS Comparison at NW Corner of Fuel Building Roof

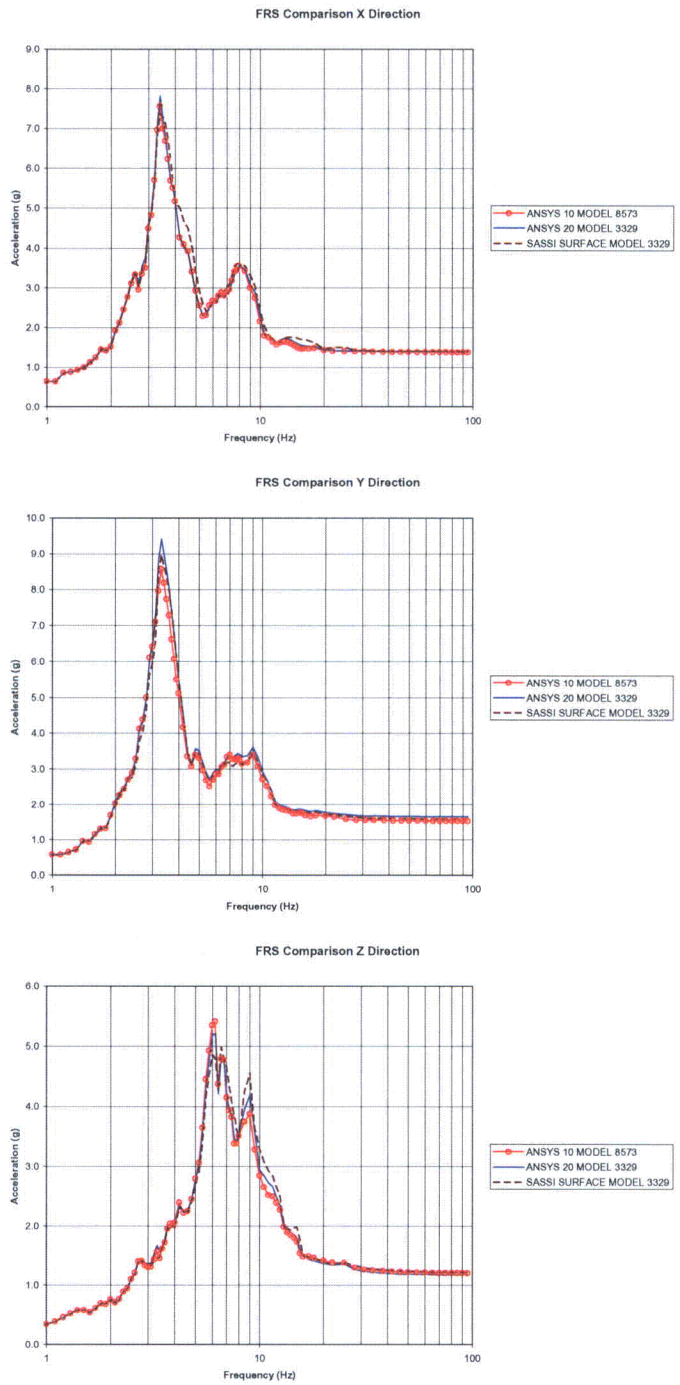

Figure C-5 – FRS Comparison at South Side of Shield Building at El. 327.41'

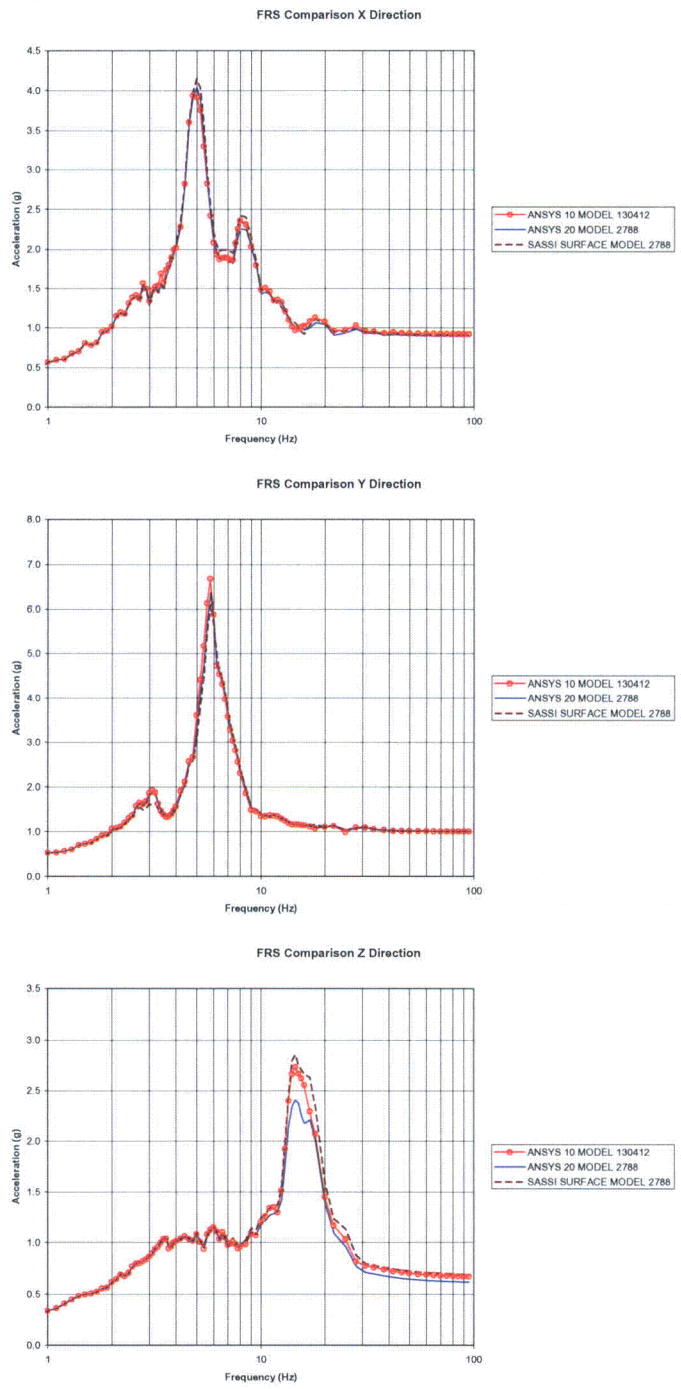

Figure C-6 – FRS Comparison on SCV near Polar Crane, El. 224'