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: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com

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Subject: AP1000 Response to Request for Additional Information (SRP 3)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3. 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 COL03.05.01.04-1 R1
RAI-SRP3.7.1-SEB1-06 R4
OI-SRP3.3.2-SEB1-01 R1
OI-SRP3.7.2-SEB1-02 R1

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

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Request for Additional Information on SRP Section 3

D063
NRO

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	B. Gleaves	-	U.S. NRC	1E
	P. Clark	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Power	1E
	R. Kitchen	-	Progress Energy	1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	D. Lindgren	-	Westinghouse	1E

ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3

RAI Response Number: RAI COL03.05.01.04-1
Revision: 1

Question:

In FSAR Section 3.5.1.4 (VCS SUP 3.5-2), the applicant states that a postulated automobile missile is considered for all elevations of Summer Units 2 and 3 facilities and not just limited to elevations up to and including 30 feet above grade. Since this is a change from the standard AP1000 DCD, please provide the following information:

• Identify all structures, systems, and components (SSCs) that are located on the exterior of the facilities (i.e., intakes, exhausts, vents, valves, piping, etc.) that are higher than 30 feet above grade and require tornado missile protection.

• Provide the location of these SSCs by building, elevation and General Arrangement Drawing.

• Delineate how these SSCs will be further protected against the postulated impact of a postulated automobile missile, without impairing the safety-related functions of these SSCs.

• Since this additional tornado missile protection has the potential of causing additional static and dynamic loads during a postulated seismic event, please provide a preliminary assessment on how these additional loads affect the seismic integrity of the facilities.

Question Revision 1:

During the NRC audit of tornado missile responses the following additional questions were asked about this response

1. Why is the passive containment cooling water tank excluded from the automobile missile? No justification is clearly given why this structure is excluded.
2. The response references Westinghouse's APP-GW-GLR-133. There is no mention in this document of excluding the passive containment cooling water tank. The summary of APP-GW-GLR-133 states: *"Based on the results of the performed calculation, it can be stated that the massive high-kinetic-energy missile (4000-pound automobile) identified in DCD Section 3.5.1.4 is no longer limited to 30 feet above grade. The information contained herein can be used by any Combined License applicant to justify that the nuclear island structure remains satisfactorily intact after being impacted at any elevation by an automobile."*
3. In Westinghouse's APP-GW-GLR-133, Figure 1 (page 4) has the y-axis label blacked-out. What is it?

4. The document states that temporary blockage of the air-inlets in the shield building are not a concern because of the large number of them. However, there is no limitation on the number of tornado missiles, so justification is needed for this statement.
5. In reviewing the GA's on the roof of the North Auxiliary Building appears to be the vents for the main steam safety valves. If an automobile missile impacts these vents, is this a problem?
6. While this has not been made clear, in order to meet the tornado wind loading and pressure drop criteria, I'm assuming that tornado dampers are present in these openings. If these dampers are being used, are they protected from the tornado missiles so that the tornado pressure spike will not be felt inside the plant structures?
7. The Westinghouse response provides a change to DCD Subsection 3.5.4.1. However, whatever change is finally made to DCD Subsection 3.5.4.1, will also require a change to WCAP-15799 (APP-GW-GL-001), SRP 3.5.1.4; and APP-GW-GLR-020, Section 2.2.4 (page 7). [Note, there is an inconsistency between APP-GW-GLR-020, R3 and APP-GW-GL-001, R1. On page 8 of APP-GW-GLR-020 the document references SRP 3.5.3, R3. However, APP-GW-GL-001 states that the AP1000 meets SRP 3.5.3, R1.]
8. Evaluate the global effect of an automobile impact on the shield building including stress transferred to joints. May be bounded by seismic loads

Westinghouse Response:

The following is the generic Westinghouse response to the Summer Units 2 and 3 RAI provided above.

NUREG 0800, for Subsection 3.5.1.4 and RG 1.76 recommends that the automobile tornado missile be considered up to 30 feet above all grade levels within a 1/2 mile of the plant structures. COL applications that reference the AP1000 design certification include sites that have grade elevations within a 1/2 mile of the plant structures higher than the plant grade elevation of 100 ft. The information in the DCD addresses an automobile impacting the auxiliary building or shield building at an elevation up to 30 feet above plant grade elevation of 100 ft. Westinghouse completed an evaluation of the impact of an automobile tornado missile to support the response from SCE&G for Summer Units 2 and 3 at elevations higher than 30 feet above design plant grade. This evaluation is generic and evaluates impact of a wind driven automobile tornado missile at all elevations of the auxiliary and shield buildings up to the junction of outer wall of the passive containment cooling water storage tank with the roof of the shield building, approximately Elevation 293 ft. This includes evaluation of impact of the automobile on the roof of auxiliary building. The evaluation summary report (TR-133) is documented in APP-GW-GLR-133 (Reference 1).

The evaluation of the response of the AP1000 structures to tornado missiles is part of the standard design of the AP1000 and is included in the review of the design certification design. As a result Westinghouse is revising the DCD to include applicability of the evaluation described above to the certified design. COL applications with postulated automobile tornado missiles at elevations as identified above do not require a departure from the standard AP1000 DCD.

- There are no structures, systems, and components (SSCs) located on the exterior of the AP1000 standard design facilities at any elevation that require protection from tornado missiles. The systems and components required to shut down the reactor, address transient conditions, and mitigate postulated accidents are protected by the reinforced concrete walls of the shield building and auxiliary building. Openings created by doors are on the East side of the Nuclear Island. The Annex building provides protection, and the roll-up door at the fuel handling area has no systems in the vicinity that are required for safe shutdown. The air-inlets in the shield building are smaller than the automobile, and therefore, it could not pass through the shield building. Temporary blockage of the air-inlet would not be an issue because of large number of them. Further, secondary missiles that could be potentially created at openings could not cause damage to systems required for safe shutdown due to proximity and low energy of the missile. The PCS ancillary water tank is located at ground level adjacent to the Northwest corner of the auxiliary building and provides water for use by the passive containment cooling system from 72 hours after actuation to 7 days after actuation. This tank must be protected from hurricane missiles; not tornado missiles. A tornado is a local event not a regional event and the plant can count on external resources such as back up power and additional water in the post 72 hour period.

- Systems and components located in the turbine building, annex building, radwaste building, diesel generator building, and associated with external tanks are not required to be protected from impact of tornado missiles. The plot plan for the AP1000 is provided in DCD figure 1.2-2 and shows the arrangement of the buildings.

- Plant specific design modifications to the AP1000 standard plant for tornado missile protection are not required for postulated automobile tornado missiles at all elevations of the auxiliary and shield buildings up to the junction of outer wall of the passive containment cooling water storage tank with the roof of the shield building, approximately Elevation 293 ft

- Evaluation of the postulated automobile missile has not resulted in additional tornado missile protection (enhancements) to the structures. Therefore, there are no additional static or dynamic loads imposed during a seismic event, with no affect on the seismic integrity of the facilities.

Response Revision 1:

1. The PCS tank in the roof of the shield building is above postulated elevation of tornado auto missiles for known sites. Evaluation of the impact of the missile on the tank is more

complicated than evaluation of simple barrier. Although the thickness of concrete for the outside wall and roof of the tank exceed the minimum concrete thickness in Standard Review Plan Section 3.5.3 those minimum thicknesses do not factor in the effect on the stainless steel liner of the tank.

2. Report APP-GW-GLR-133 will be revised to note that the PCS tank is not included in the missile evaluation.

3. The y-axis label for APP-GW-GLR-133, Figure 1 should be force-kips. Report APP-GW-GLR-133 will be revised to fix the label

4. There are more than 230 air inlets in the shield building that provide for air flow over the containment vessel for passive cooling of the containment. The air inlets are located around the entire circumference of the shield building. Given the large number of air inlets and their location around the shield building on both the windward and leeward side relative to tornado winds, it is not credible to cover or obstruct a large fraction of the air inlets with tornado missiles or debris. There is considerable margin in the number of vents provided compared to the vent area needed for passive containment cooling. The rise in temperature and boiling of the water placed on the containment shell by the passive containment cooling system provides the primary mechanism for the cooling of the shell. The function of the air is to remove the water vapor from the area.

5. The steam line safety valves located in the MSIV compartments are not directly connected to the vent pipes that conduct the steam through the roof. Each of the safety valves exhausts through two openings that are directed to the vents that carry the steam through the roof. These vent pipes are open at the bottom of the pipe. The 10-inch discharge pipes for each safety valve discharge pipe exhausts into a 24 inch diameter vent pipe. The vent pipe is 0.38 inch thick and would require considerable force to crush kink or otherwise close off the top of the pipe above the roof. If the vent pipes are blocked or otherwise obstructed above the roof, the discharge of the safety valves will vent into the MSIV compartment. Steam discharged into the MSIV compartment vents to the outside through separate vents.

6. There is a tornado damper in the intake serving the Main Control Room/Control Support Area and the 1E Electrical Division A & C air handling units. The tornado damper is included in this intake to prevent a reduced pressure in the control room in relation to surrounding portion of the building. There are no other tornado dampers in the HVAC systems serving the Nuclear Island. The tornado damper in the Main Control Room/Control Support Area and the 1E Electrical Division A & C intake is located below the roof line in the HVAC ductwork. There is also security damper (a set of steel bars) between the intake opening in the roof and the tornado damper. These bars are sized to limit the size of an object that can pass through the duct. Therefore the damper is not directly subject to damage from a missile impact.

   The auxiliary building is designed to withstand the tornado depressurization. The design tornado load pressure drop is 2.0 psi, and the rate of pressure change is 1.2 psi/sec. The

AP1000 nuclear island designed to meet the requirements 1) "Seismic Category II structures shall be analyzed for the tornado to demonstrate that the primary structural elements do not fail under tornado loads calculated in accordance with the Design Guide for Wind and Tornado for the AP600 Structures.", 2) "The tornado differential pressure load for the nuclear island structures is based on a fully enclosed structure (288 psf).", and 3) tornado loads are included as part of the seismic ductwork design. Therefore, tornado loads would potentially damage seismic Category II ductwork, but if ductwork were damaged the ductwork would not burst, fall, or fail in such a way interfere with any safety equipment operation located in the vicinity of the ductwork.

Equipment and instrumentation relied on to shutdown the reactor and maintain it in a safe condition is largely located in the containment. The systems and components located in containment are not subject to the tornado depressurization experienced by portions of the auxiliary building. The systems included in the auxiliary building used to monitor and control the reactor are not sensitive to a tornado depressurization. The control and protection systems use solid state electronics and integrated circuits. The AP1000 does not include pneumatic control systems. The batteries that supply power to the PMS are not sensitive to tornado depressurization. The AP1000 does not include HVAC systems penetrating the containment shell that are relied on to maintain safe operation or shutdown of the reactor. The HVAC systems that maintain the habitability for the control room are protected with tornado dampers.

In summary, the nuclear island building structures are designed to withstand the maximum tornado loads. Tornado dampers are not required in the HVAC systems, except for the portions supplying the control room, since the nuclear island structure is designed for the maximum pressure differential.

The ductwork in the nuclear island is restrained so that if there is any duct damage it will not interfere with safety systems, or it is in areas that have no safety equipment so duct damage from tornado pressures will not interfere with plant safe shut down.

7. WCAP-15799 (APP-GW-GL-001, AP1000 Conformance with SRP Acceptance Criteria) will not be changed. The conclusion of the conformance assessment for SRP3.5.1.4 remains correct and is not altered. The information provided about the elevated automobile is in excess of what is required to show conformance with SRP 3.5.1.4 for the AP1000 certified design. WCAP-15799 does not generally include statements about exceeding the criteria of the SRP.

   APP-GW-GLR-020, AP1000 Wind and Tornado Site Interface Criteria, provides criteria for the evaluation of site parameters related to tornados. The criteria and information to be provided by the COL applicants are not altered by the evaluation of an elevated auto tornado missile. APP-GW-GLR-020 will not be revised to include the elevated automobile tornado missile.

8. The force on the Nuclear Island from the impact of an automobile tornado missile is used in the evaluation of the global effect of an automobile impact on the shield building. It is shown that the effect of an automobile impacting the shield building will not govern the shield building design. The maximum horizontal impact load, using a dynamic load factor of 2, is used. This load is equal to 770 kips. This load is derived from a time history forcing function of an automobile crash under frontal impact. The automobile is the deformable missile, and the object (structure) impacted is a rigid target. It is the same forcing function that was used in the evaluation of the Nuclear Island for the tornado missile automobile impact above 30'

   The automobile is considered to impact the shield building just below the PCCS tank (El. 293' 9"). This location is chosen so that the largest moment and maximum shear at the RC/SC connection is obtained. The resulting shear force and moment in the vicinity of the RC/SC connection (~ EL. 145') are compared to the seismic demand (shear and moment) at this location.

   The automobile tornado impact loads at the RC/SC location are:

   Shear = 385 x 2 = 770 kips
   Moment = 770 x (293' 9" -145') = 114,540 k-ft

   The seismic demand at this location is given below for the six site cases: hard rock (HR); firm rock (FR); soft rock (SR); upper bound soft to medium (UBSM), soft to medium (SM), and soft soil (SS).

Site Cases	**Shear** 10^3 kips	**Moment** 10^3 k-ft
HR	38.24	4246
FR	37.79	4204
SR	37.61	4349
UBSM	41.04	4831
SM	44.11	4874
SS	23.4	2898

   Comparing the seismic demand to the tornado loads it is seen that the seismic shear load is more than 30 times greater than the automobile tornado impact load, and the resulting moment from the seismic demand is more than 25 times greater. Therefore, the global impact of the automobile on the shield building during a tornado will not govern the shield building design.

Reference

1. APP-GW-GLR-133, Summary of Automobile Missile 30′ Above Grade, July 2007.

Design Control Document (DCD) Revision:

Revise the first bullet under Subsection 3.5.4.1 as follows:

- A massive high-kinetic-energy missile, which deforms on impact. It is assumed to be a 4000-pound automobile impacting the structure at normal incidence with a horizontal velocity of 105 mph or a vertical velocity of 74 mph~~. This missile is considered at all plant elevations up to 30 feet above grade.~~ Grade elevations within half a mile of the plant may be higher than the plant grade elevation; the evaluation of the automobile missile is considered at plant elevations up to the elevation to the junction of outer wall of the passive containment cooling water storage tank with the roof of the shield building.

PRA Revision: None

Technical Report (TR) Revision: None

AP1000 DESIGN CERTIFICATION REVIEW

Response to SER Open Item (RAI)

RAI Response Number: OI-SRP3.3.2-SEB1-01
Revision: 1

Question:

Westinghouse responded to RAI-SRP3.3.2-SEB1-01 regarding the issue of missiles that are produced by the potential blow-off of the siding on the annex building as well as turbine building. In its response, Westinghouse indicated that "The automobile in the missile spectrum included in the AP1000 would appear to bound the mass and energy of sheet metal siding. Also there are no safety related structures, systems, and components outside of the Auxiliary Building and Shield Building. The walls of these buildings are reinforced concrete at least two feet thick. Tornado driven siding would not be expected to be a challenge to reinforced concrete walls." The staff notes that the construction of the shield building is not reinforced concrete and can best be described as "steel-concrete-steel modular wall construction." It is likely that the siding missile can penetrate the steel sheet of the modular wall of the shield building.

Question Revision 1:

During the NRC audit of tornado missile responses the following additional questions were asked about this response

1. Provide quantitative evaluation the damage of a siding missile impact on steel plates and the potential for creating a non-stable crack. Siding is representative, corrugated type siding.
2. Include description of siding missile in DCD.

Westinghouse Response:

The steel sheets referred to in the staff question are ASTM A572 Grade 65 steel plates. The steel plates range in thickness from 0.5 inch to 0.75 inch thick on both the interior and exterior surfaces. They are much stronger than the siding on the annex and turbine buildings; and therefore, no penetration is possible. Further, the shield building wall that is exposed to a potential siding missile is at least 3 feet thick including both the concrete and steel plate. The shield building design for the portion that is exposed to the siding missile is described below:

The portion of the shield building cylindrical wall not protected by the auxiliary building is a composite steel and concrete (SC) construction using 0.5 inch steel surface plates on both the interior and exterior surface acting as reinforcement to the cylindrical shield building wall. The two 0.5 inch steel plates act compositely with 35 inch thick concrete.

In the area of the Air Inlets above the shield building cylinder, the wall is generally 4'-6" thick and tapers down to 3'-0" thick at the cylindrical wall. Instead of ½ inch steel plates, ¾ inch steel plates are used on the exterior and interior faces.

In the area of the Tension Ring above the Air Inlets and below the roof, the wall is 3'-3" thick (including 3/4 inch thick surface steel plates on each face). Concrete is poured in between the plates, and it is designed as an SC structure.

The conical roof is a composite steel and reinforced concrete shell. The reinforced concrete slab above the conical roof steel frame, outside of the Passive Containment Cooling System tank, is 3 feet thick.

Westinghouse Response (Revision 1):

Part 1:

An evaluation of the impact from adjacent building siding during a tornado on the shield building has been performed. The primary concern was that a crack, that is not stable, could be created within the shield building. The concern was that this crack could grow instantaneously, or grow over time from load cycles causing the shield building to not perform its function.

Conservatively, a three foot square portion of siding is assumed to impact the cylindrical portion of the shield building that would result in the maximum impact load. The three foot square was chosen since the siding is in three foot strips, and it is necessary to have the center of gravity of the siding in line with the point of impact so no rotation occurs. Rotation would lessen the effect of the impact. The siding impact on the shield building is shown in Figure OI-SRP3.3.2-SEB1-1.

The siding is steel having 50 ksi yield strength. The thickness ranges from 22 to 18 gage (0.03" to 0.047" respectively). The weight of the 18 gage segment of siding is 17.2 pounds. It is assumed that the siding impacts the shield building at a velocity of 300 mph. The kinetic energy of the impact for the range of thickness is from 397 to 621 in-kip.

The cylindrical portion of the shield building has two three-quarter inch steel plates, with one on the exterior face, and the other on the interior face. Between the plates is concrete that is three feet thick. This design is shown in Figure OI-SRP3.3.2-SEB1-1. The steel plates have yield strength of 50 ksi. The shield building can be considered rigid with respect to the siding that is considered to be the tornado missile.

Since the shield building is stiff compared to the siding during impact, the kinetic energy of the impact is converted to strain energy associated with displacement (deformation) of the siding. Converting the kinetic energy to strain energy, results in a siding displacement of approximately one inch. This causes siding stresses over ten times its yield stress. Therefore, the maximum force that is applied to the shield building from the impact of the siding is limited by the yield stress of the siding (50ksi).

The force from the impact of the siding on the steel plate will be distributed as shown in Figure OI-SRP3.3.2-SEB1-2. As seen from this figure the resulting effective impact area will be larger than that associated with the siding. Therefore, since the steel plate has the same material yield stress as the siding (50 ksi) the steel plate will not reach yield. Further, the crushing of the siding will also increase the compressive area on the surface of the shield building steel plate. This is shown in Figure OI-SRP3.3.2-SEB1-3.

The force on the shield building steel plate from the impact of the siding will not result in stresses equal to or greater than the material yield stress of 50 ksi. Therefore, no crack will be created within the shield building steel plate.

Part 2:

The siding on the adjacent buildings will be corrugated type siding. A missile from this type of siding will result in lower impact loads than that evaluated described in Part 1. This is because:

- This siding type will be more flexible and less stiff than the siding analyzed.
- The center of gravity will not be on the line of impact that is normal to the shield wall as evaluated and documented in part 1. This will cause rotation and greatly reduce the effect of the missile impact.

The evaluation of the siding will be identified in the DCD as a supplementary tornado missile evaluation. The DCD changes that describe the siding evaluation are shown below.

Design Control Document (DCD) Revision: ~~None~~

Modify Tier 2 Section 3.5.1.4, "Missiles Generated by Natural Phenomena," as follows:

- A small rigid missile of a size sufficient to just pass through any openings in protective barriers. It is assumed to be a one inch diameter solid steel sphere assumed to impinge upon barrier openings in the most damaging direction at a velocity of 105 mph.

In addition to the missile spectrum specified above, the impact of tornado driven sheet metal siding on the shield building is evaluated. The evaluation considers siding representative of the siding used on the turbine building, radwaste building, diesel generator building, and portions of the annex building. The evaluation considers a flat steel sheet which bounds the corrugated siding design used on the buildings adjacent to the nuclear island.

PRA Revision: None

Technical Report (TR) Revision: None

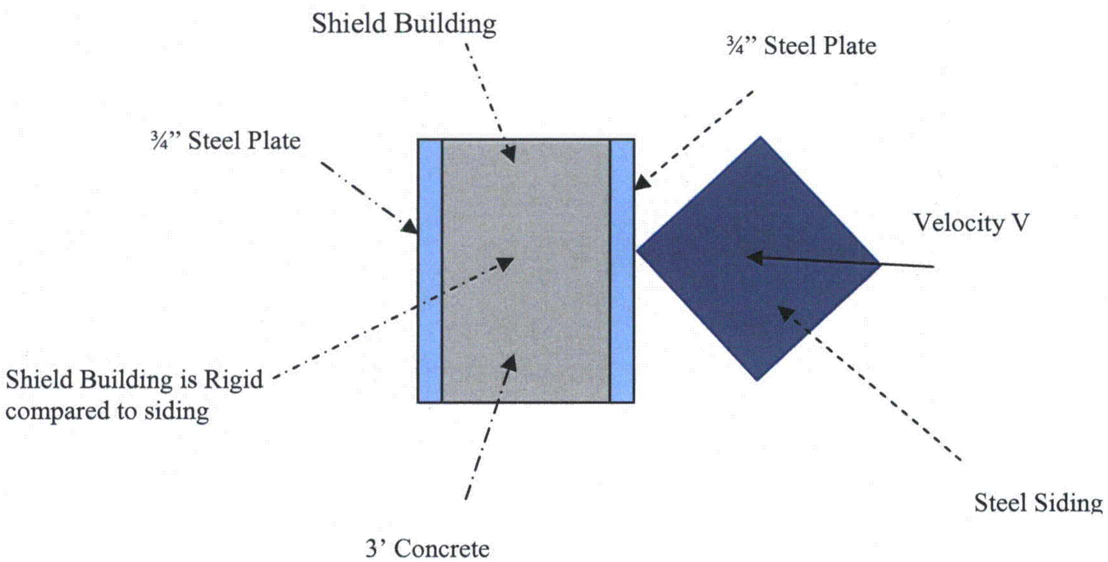

Figure OI-SRP3.3.2-SEB1-01 – Siding Impact on Shield Building

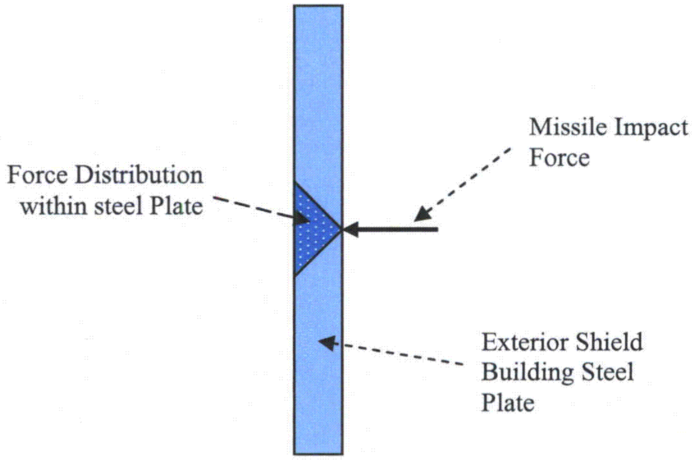

Figure OI-SRP3.3.2-SEB1-02 – Impact Force Distribution within Shield Building

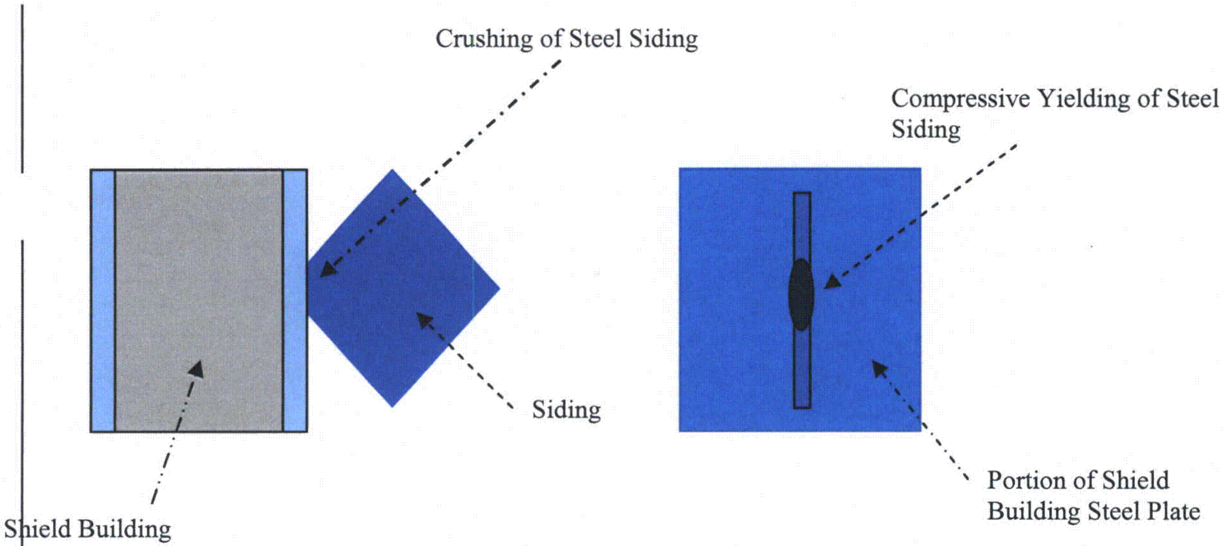

Figure OI-SRP3.3.2-SEB1-03 – Siding Crushing on Shield Building

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.7.1-SEB1-06
Revision: 4

Question:

Westinghouse's calculation in TR-115 indicates 4 points per wavelength for 80 Hz. This is the bare minimum to represent a full cycle of sinusoidal displacement variation. The staff requests that Westinghouse include in Section 5.1 a comparison of frequencies and mode shapes between the NI10 and NI20 models, as an alternate way to demonstrate the adequacy of the NI20 model to accurately predict high frequency modes (up to 80 Hz).

Additional Request (Revision 2):

The staff initially requested that Westinghouse include in Section 5.1 of TR 115, a comparison of frequencies and mode shapes between the NI10 and NI20 models, as an alternate way to demonstrate the adequacy of the NI20 model to accurately predict high frequency modes (up to 80 Hz). In its initial response, Westinghouse pointed out that the final ISG for addressing HRHF GMRS only requires modeling refinement to accurately predict up to 50 Hz. Instead of providing a comparison of frequencies and mode shapes between the NI10 and NI20 models up to 50 Hz, Westinghouse indicated that there are 7 nodes per wavelength in the NI20 model for a 50 Hz. frequency. In a supplement to its initial response, as a result of discussions at the May 2008 onsite audit, Westinghouse presented additional information about the frequency distributions in the NI10 and NI20 models, and claimed that this information demonstrated adequacy of the NI20 model up to 50 Hz.

The staff reviewed this information and concluded (1) it does not demonstrate adequacy of the NI20 model up to 50 Hz; and (2) the information raises additional concern about the possibility of modeling and/or analysis errors.

The staff noted the following, for which Westinghouse needs to provide a detailed technical explanation:

(a) In the 0-10 Hz range, there are 58 modes for NI20 and 69 modes for NI10. In the low frequency range, the correlation would be expected to be near 100%.

(b) In the 10-40 Hz range, the difference in number of modes is very large: 658 for NI20; 1234 for NI10.

(c) In the 40-55 Hz range, the difference in number of modes is relatively small: 484 for NI20; 545 for NI10.

The staff notes that acceptable criteria to demonstrate adequate model refinement is delineated in SRP 3.7.2, Revision 3 (March 2007), Paragraph II.1.A.iv(1). The staff requests that Westinghouse review the SRP criteria, and provide sufficient information on NI20 frequencies and mode shapes so that the staff can independently assess whether NI20 satisfies the SRP criteria, up to 50 Hz.

Additional Request (Revision 3)

Please provide more detail.

Additional Request (Revision 4)

Westinghouse will provide justification on how flexible regions (walls, floors, and roof panels) are addressed in the Hard Rock High Frequency evaluation. Review and identify responses to less that 50 Hz for HRHF. Evaluate the screening locations for HRHF. Reanalysis of seismic response will correct/clarify values and results will be re-issued as a new revision to RAI-SRP3.7.1-SEB1-06).

Westinghouse Response (Revision 0 & 1):

At the December 20, 2007 meeting between the U.S. NRC staff and industry related to the high frequency seismic events, it was agreed that a maximum analysis frequency of 50 hertz would be sufficient to transmit the high frequency response through the model. Using this frequency and the formulas given in Section 5.1 the acceptable mesh size is determined.

Shortest wavelength = $\lambda = Vs / f_{max}$

Vs = 6900 ft/sec (given in Section 5.1)
f_{max} = 50 hertz

λ = 6900 / 50 = 138'

Using the NI20 model (mesh size of 20'), and the shortest wavelength of 138', then close to 7 nodes per wavelength are obtained to transmit the high frequency through the finite elements. This is sufficient accuracy in the building structure model to transmit the high frequency through the finite elements in the NI20 model. Therefore, it is not necessary to include in Section 5.1 a comparison of frequencies and mode shapes between the NI10 and NI20 models.

In addition to the above, a modal response comparison is made between the NI10 and NI20 models to demonstrate the adequacy of the NI20 model to predict high frequency response up to 50 hertz.

Table RAI-SRP3.7.1-SEB1-06-1 shows the comparison of the frequency for each model at certain modes. Due to the increased refinement of the NI10 model, the NI20 reaches higher frequencies at lower modes. This is also shown in Tables RAI-SRP3.7.1-SEB1-06-2 and RAI-

SRP3.7.1-SEB1-06-3. Tables RAI-SRP3.7.1-SEB1-06-2 and RAI-SRP3.7.1-SEB1-06-3 show the highest numbered mode found in each 10 Hz frequency range and also shows how many modes are in each of the aforementioned ranges.

Figures RAI-SRP3.7.1-SEB1-06-1 to RAI-SRP3.7.1-SEB1-06-3 show a summation of the of the effective mass verses frequency for the X, Y and Z directions. The effective masses associated with the NI20 and NI10 models compare closely over the frequency range of 1 to 80 Hz.

From this comparison it can be concluded that the modal response of the NI20 model is very similar to the NI10 model, and therefore, is adequate to predict the high frequency response up to 50 hertz.

Westinghouse Response (Revision 2):

The difference in the number of modes between theNI10 and NI20 models is due to the increased number of degrees of freedom in the NI10 model. Therefore, it is expected that the NI10 model will have more modes within given frequency ranges. It is not possible to easily provide direct comparisons of the mode shapes between the two shell models because of their complexities and size. The best demonstration that the models are responding in a similar manner is by the comparison of modal mass over the frequency range of interest. This comparison has been provided in Figures RAI-SRP3.7.1-SEB1-06-1 to RAI-SRP3.7.1-SEB1-06-3. As seen from the comparison plots the modal response is the same in both models demonstrating the modal response will be similar.

Table RAI-SRP3.7.1-SEB1-06-1: Mode Number vs. Frequency

Mode	Ni20	Ni10
50	9.29	8.29
100	14.05	12.47
150	16.81	14.83
200	20.27	16.73
250	22.61	18.69
300	24.82	21.00
350	26.97	22.37
400	28.72	23.48
450	30.59	24.49
500	32.39	25.37
550	34.23	26.13
600	35.84	26.71
650	37.52	27.48
700	39.38	28.59
750	41.15	29.87
800	42.81	30.96
850	44.34	32.19
900	45.85	33.48
950	47.41	34.48
1000	48.86	35.44
1050	50.10	36.18
1100	51.72	36.99
1150	53.10	37.78
1200	54.55	38.37
2000	N/A	58.8127

Table RAI-SRP3.7.1-SEB1-06-2: Modes Per Range (NI10)

NI10		
Frequency Range	Max Mode in Range	Modes Per Range
0-10	69	69
10-20	277	208
20-30	755	478
30-40	1303	548
40-55	1848	545

Table RAI-SRP3.7.1-SEB1-06-3: Modes Per Range (NI20)

NI20		
Frequency Range	Max Mode in Range	Modes Per Range
0-10	58	58
10-20	193	135
20-30	434	241
30-40	716	282
40-55	1200	484

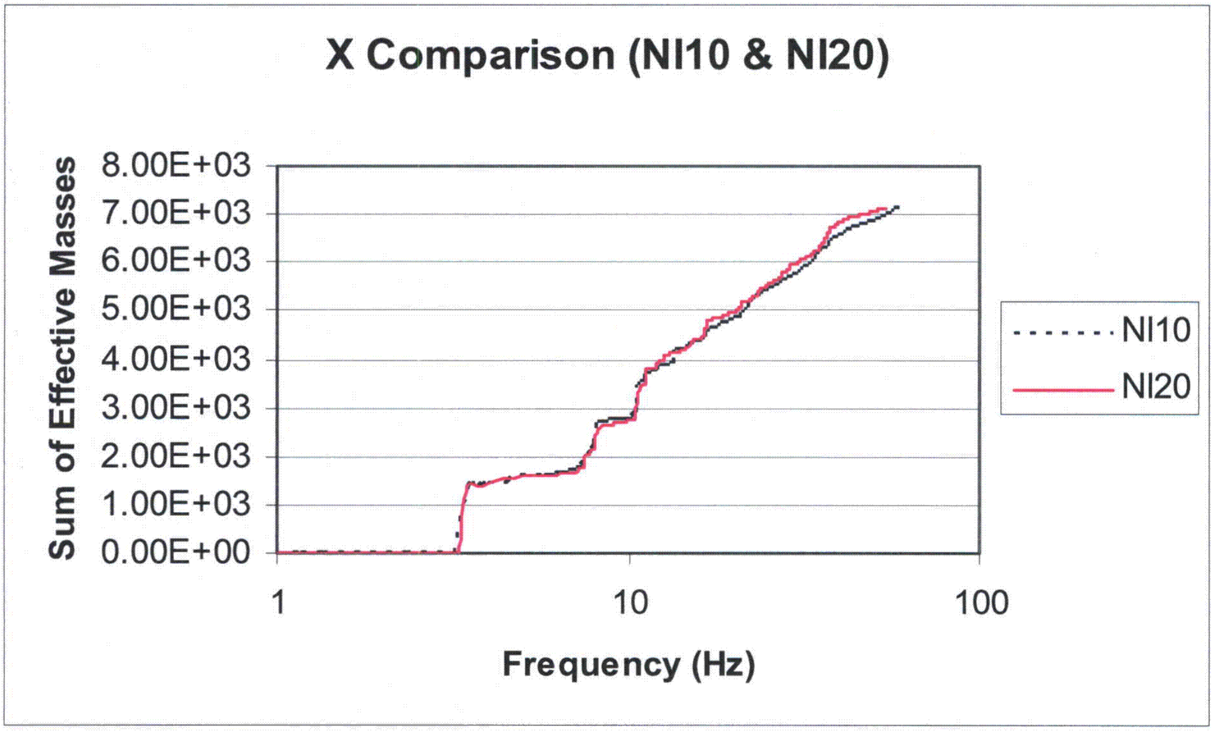

Figure RAI-SRP3.7.1-SEB1-06-1: X-Direction Comparison

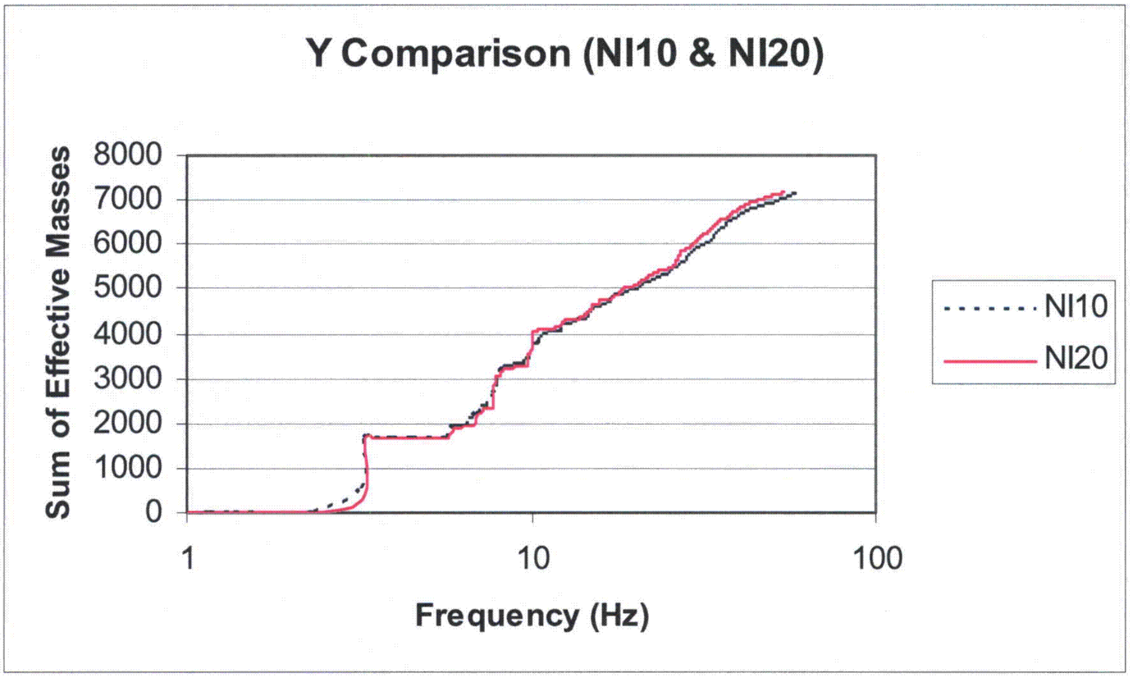

Figure RAI-SRP3.7.1-SEB1-06-2: Y-Direction Comparison

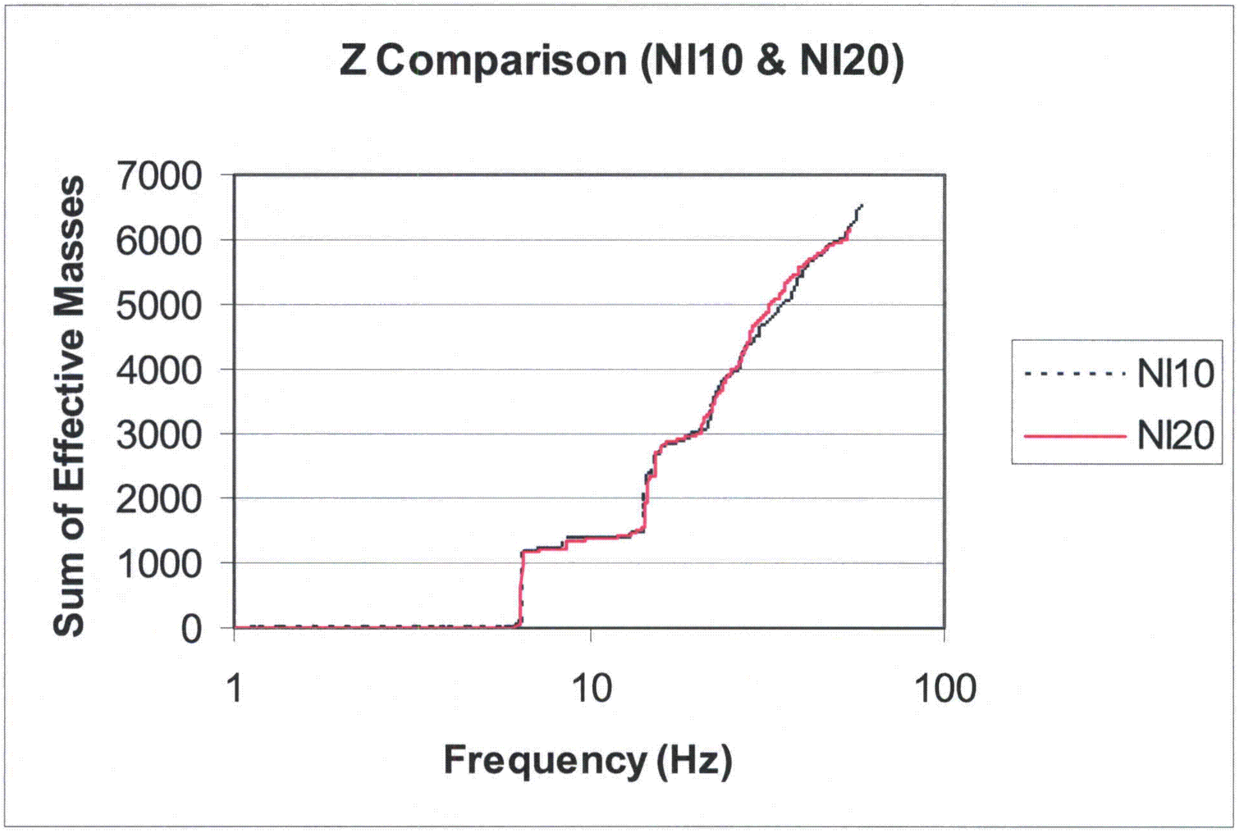

Figure RAI-SRP3.7.1-SEB1-06-3: Z-Direction Comparison

Westinghouse Response (Revision 3):

The Revision 3 response is provided to acknowledge the NRC request to provide more detail.

In addition, to demonstrate that the NI20 model satisfies the SRP criteria up to 50 Hz, the staff has been shown, during two previous audits, mode shapes of both the NI10 and NI20 models. Both models showed similar "breathing" type modes up to 50 Hz.

The HRHF spectra peaks at about 25 Hz. In order to confirm the NI20 model's adequacy for frequencies up to 50 Hz, a time history analysis was performed in ANSYS using the NI20 and NI10 models with the Westinghouse defined Hard Rock High Frequency (HRHF) input time history. The time step for the HRHF time history was changed from 0.005 to 0.003 seconds. This shifts the peak of the input time history to 50 Hz while maintaining the statistically

indeterminate properties of the original HRHF spectra defined in TR115. We shall refer to this as the Hard Rock Super High Frequency (HRSHF) analysis in subsequent discussions.
The HRHF and HRSHF acceleration response spectra have been provided in Figures RAI-SRP3.7.1-SEB1-06-04 and RAI-SRP3.7.1-SEB1-06-05 to show the acceleration peak shift due to the time step change.

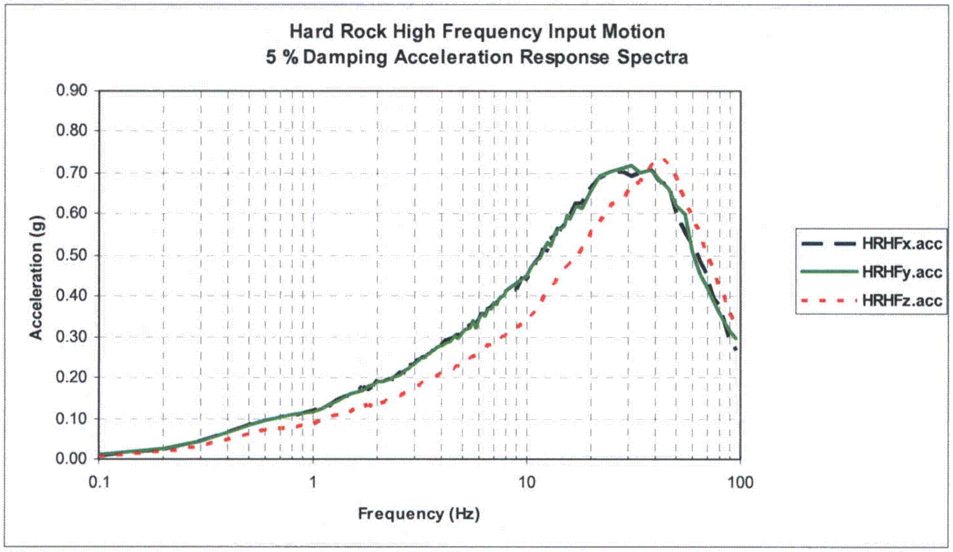

Figure RAI-SRP3.7.1-SEB1-06-04: HRHF Acceleration Response Spectra

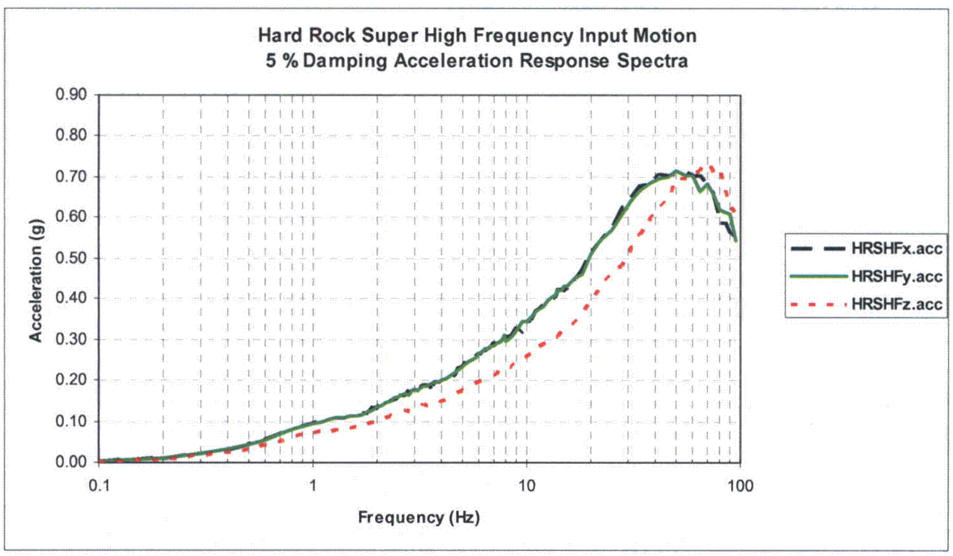

Figure RAI-SRP3.7.1-SEB1-06-05: HRSHF Acceleration Response Spectra

The nodes selected for comparison are presented in Figure RAI-SRP3.7.1-SEB1-06-06.

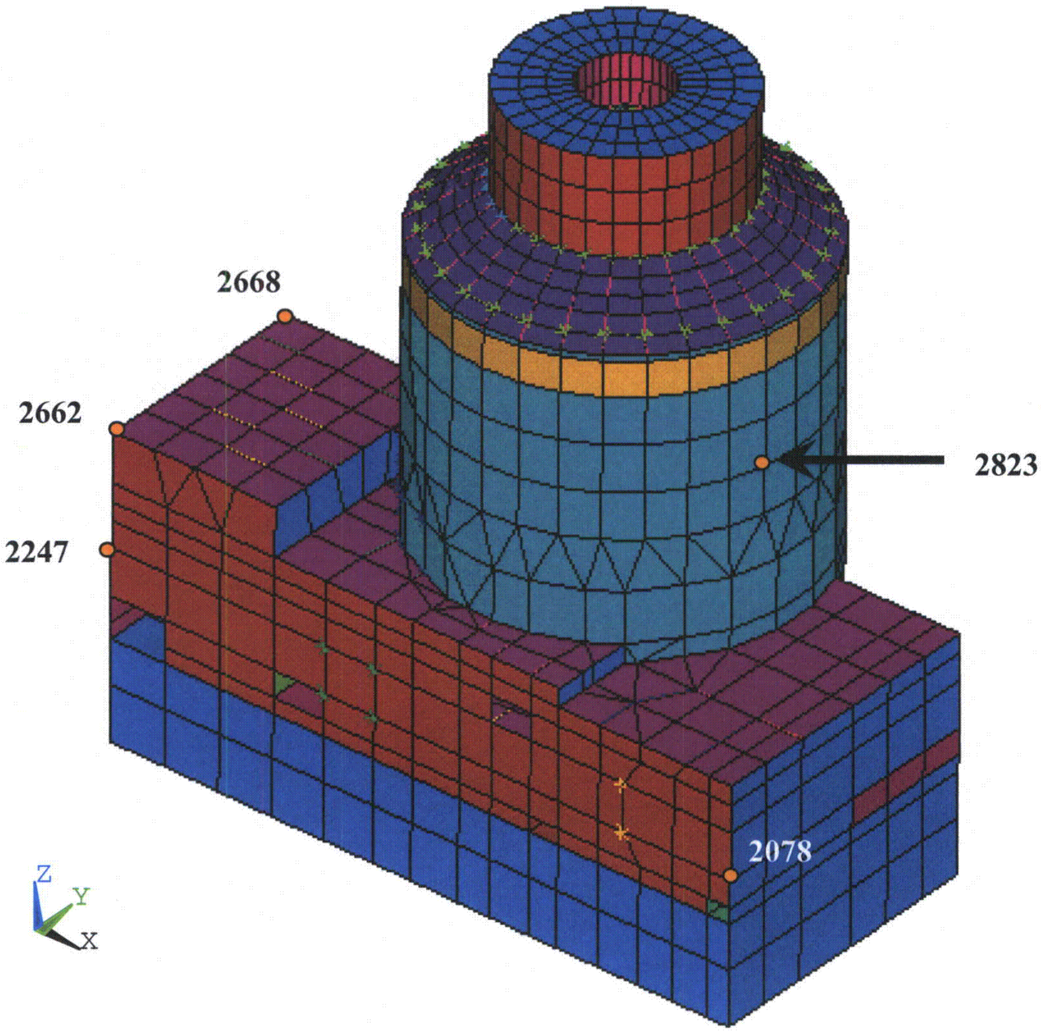

Figure RAI-SRP3.7.1-SEB1-06-06: NI20 ANSYS Auxiliary building locations

The floor response spectra (FRS) of these nodes have been provided in Figures RAI-SRP3.7.1-SEB1-06-07 through RAI-SRP3.7.1-SEB1-06-21. The HRSHF analysis shows that the NI20 ANSYS FRS results are either similar or conservative to the NI10 ANSYS FRS results. The results also show that the NI20 model will respond up to a frequency of 50 Hz.

In conclusion, Westinghouse has shown that the NI20 structural model behaves consistently with the much more refined NI10 model. The NI20 model is adequately refined to sufficiently capture the high frequency content of the HRHF spectra given in Figure RAI-SRP3.7.1-SEB1-06-04. Using the input from the HRSHF which peaks at about 50 Hz, Figure RAI-SRP3.7.1-SEB1-06-05, the NI20 model is shown to have sufficient model refinement to transmit a frequency up to 50 Hz.

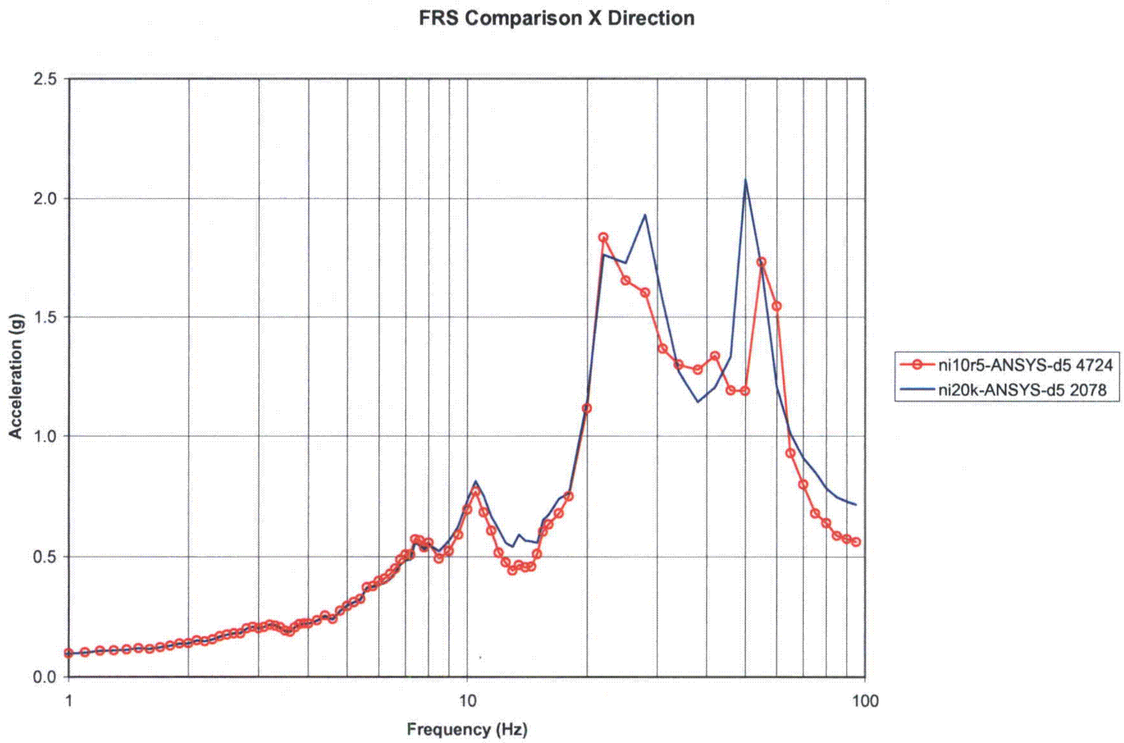

Figure RAI-SRP3.7.1-SEB1-06-07: Node NI20 2078 Direction-X Elevation 116'

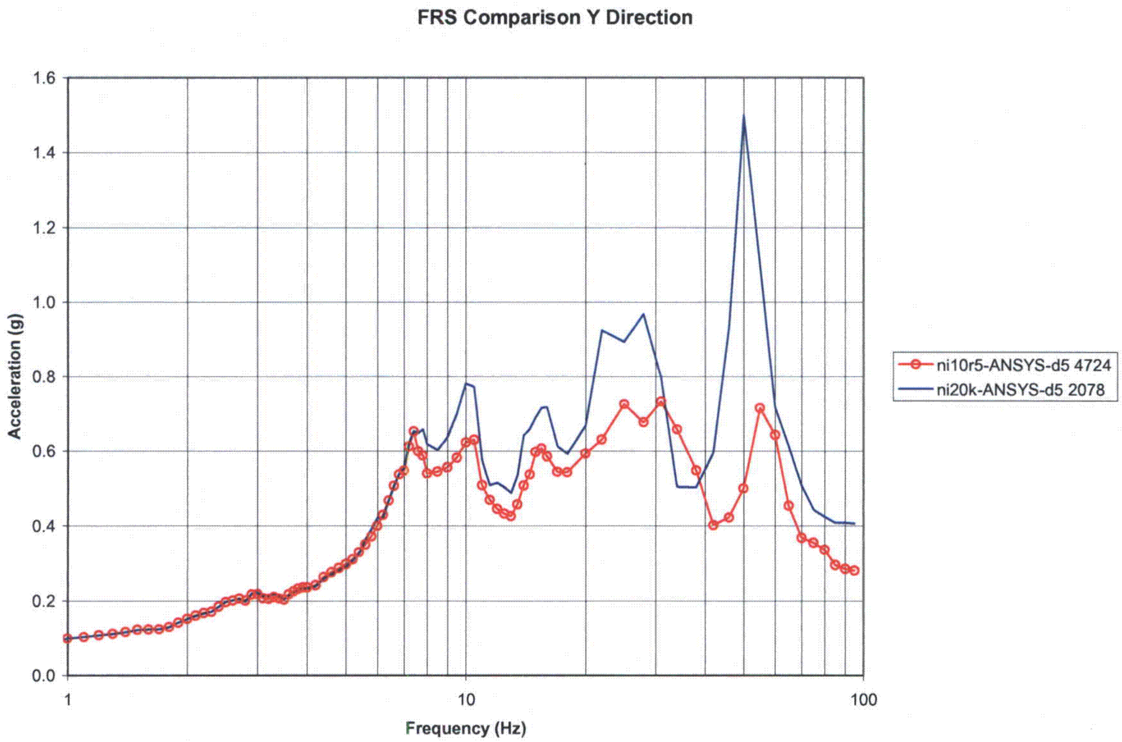

Figure RAI-SRP3.7.1-SEB1-06-08: Node NI20 2078 Direction-Y Elevation 116'

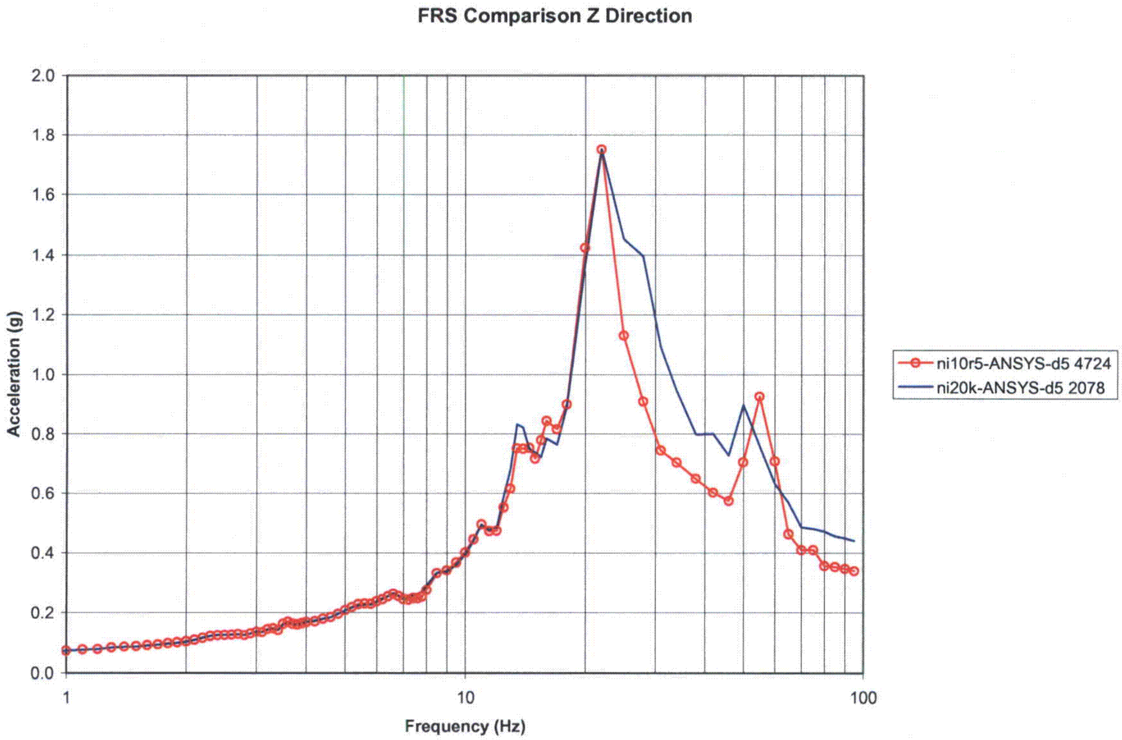

Figure RAI-SRP3.7.1-SEB1-06-09: Node NI20 2078 Direction-Z Elevation 116'

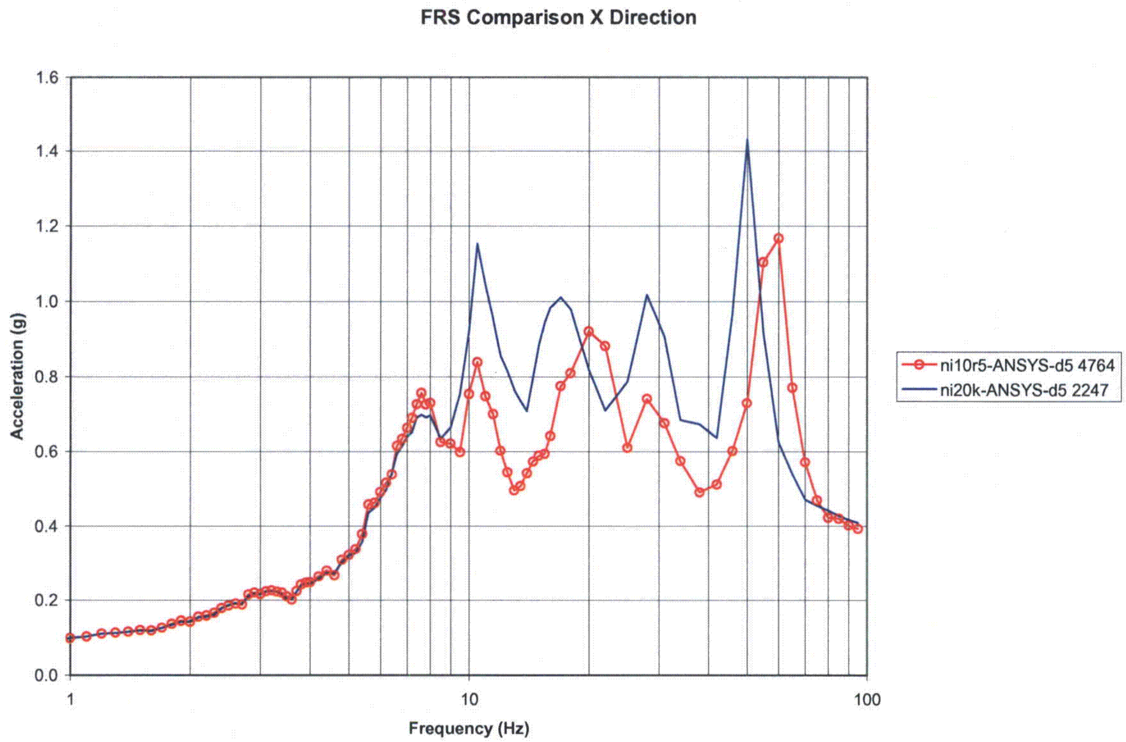

Figure RAI-SRP3.7.1-SEB1-06-10: Node NI20 2247 Direction-X Elevation 135'

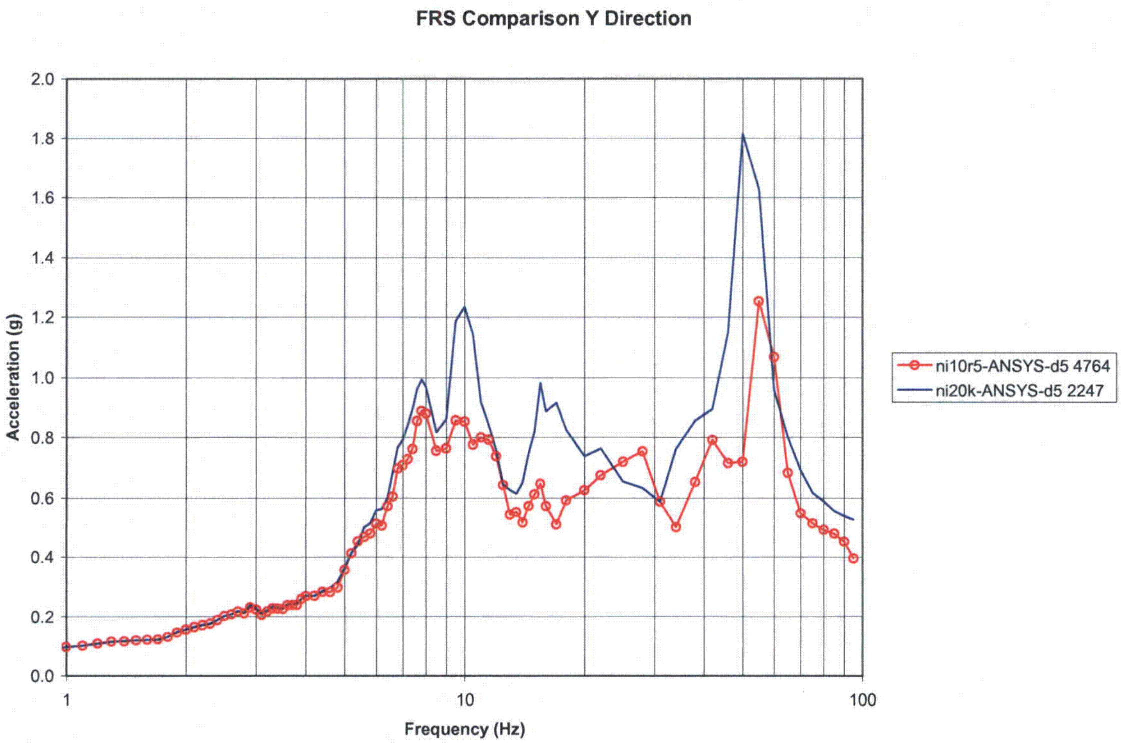

Figure RAI-SRP3.7.1-SEB1-06-11: Node NI20 2247 Direction-Y Elevation 135'

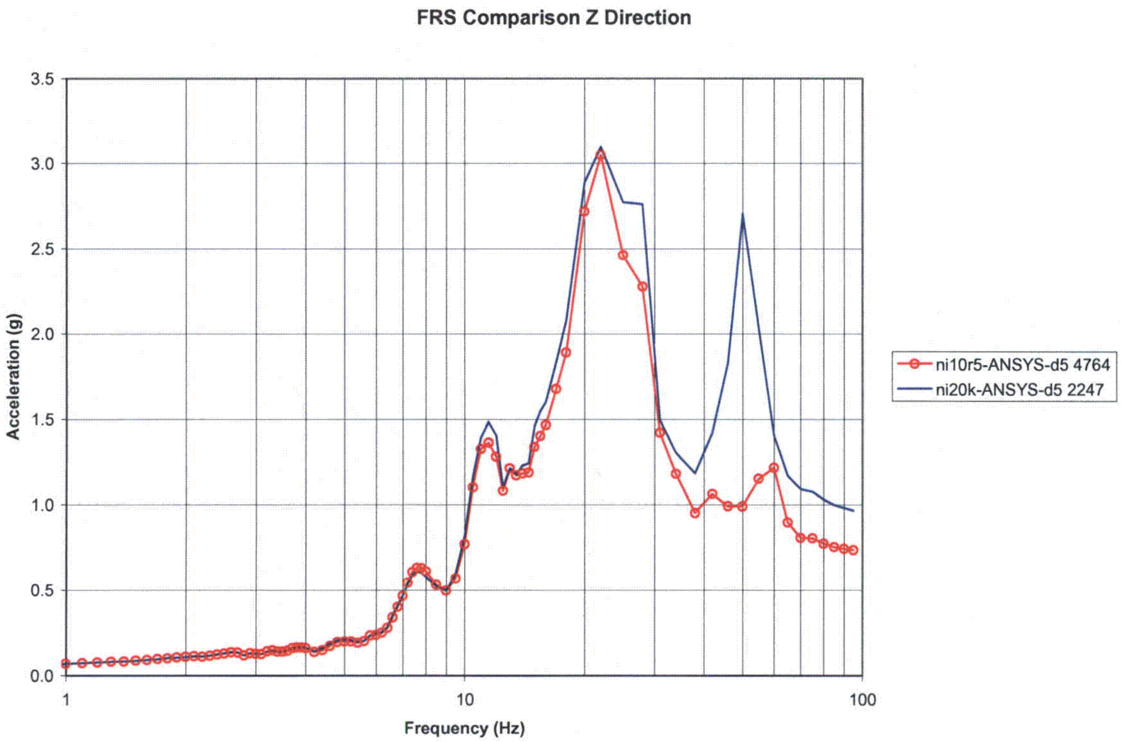

Figure RAI-SRP3.7.1-SEB1-06-12: Node NI20 2247 Direction-Z Elevation 135'

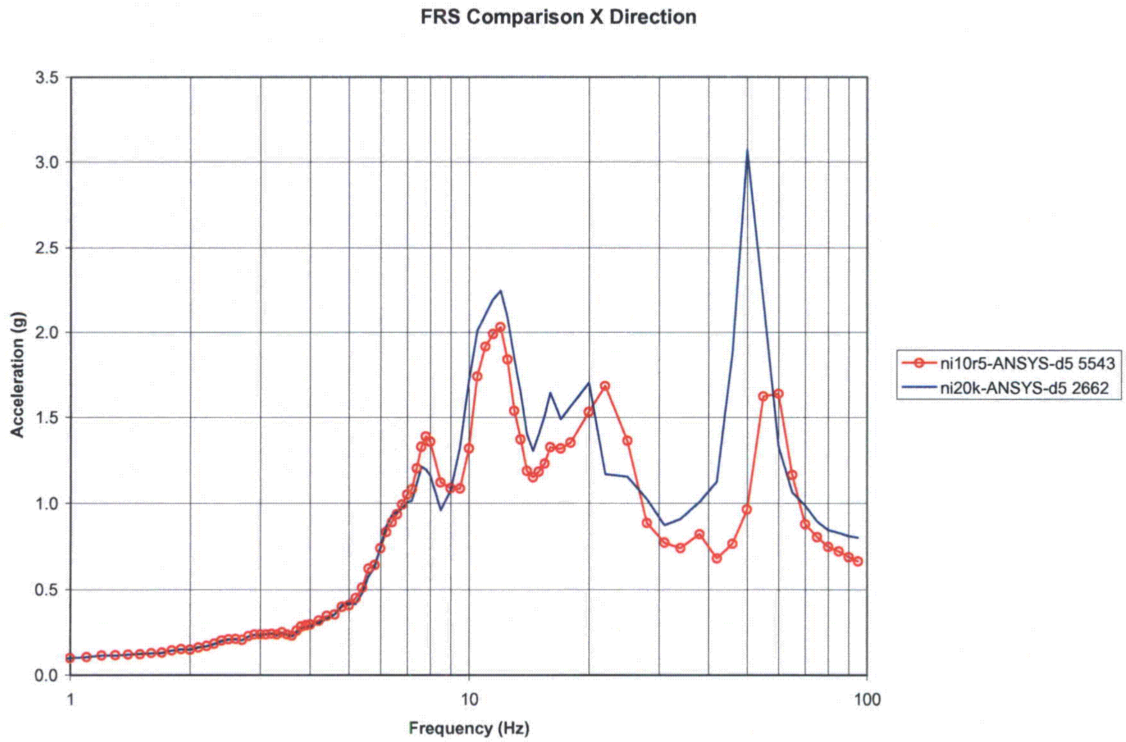

Figure RAI-SRP3.7.1-SEB1-06-13: Node NI20 2662 Direction-X Elevation 179'

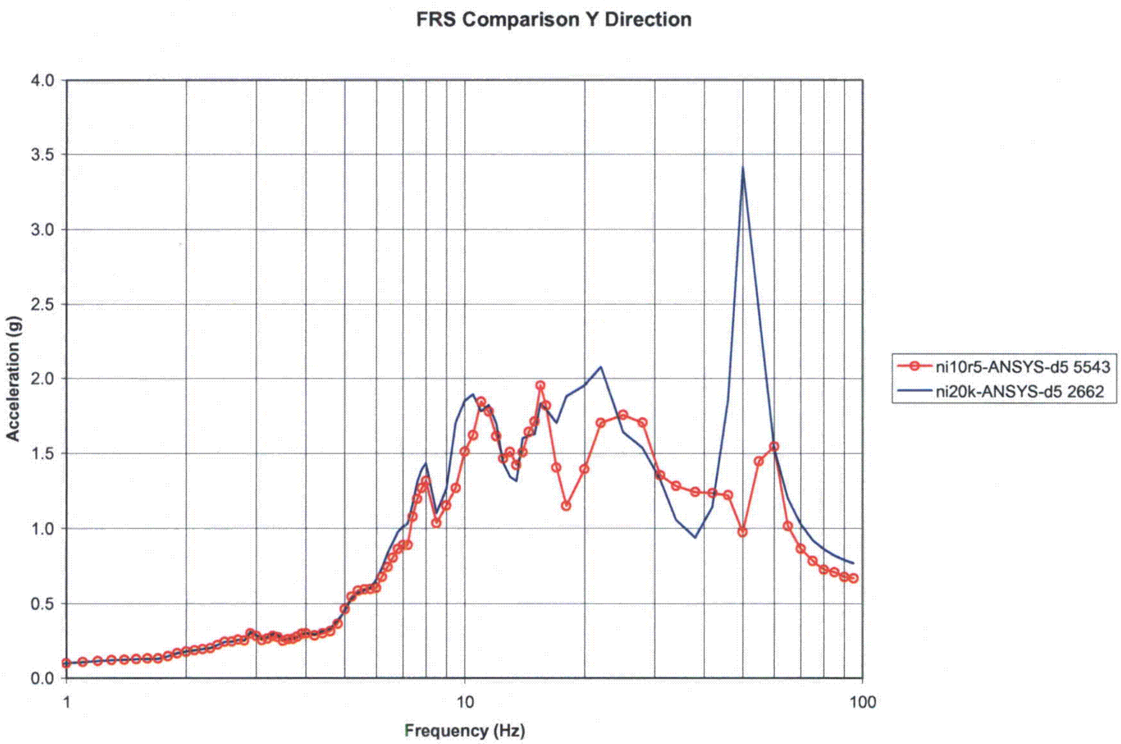

Figure RAI-SRP3.7.1-SEB1-06-14: Node NI20 2662 Direction-Y Elevation 179'

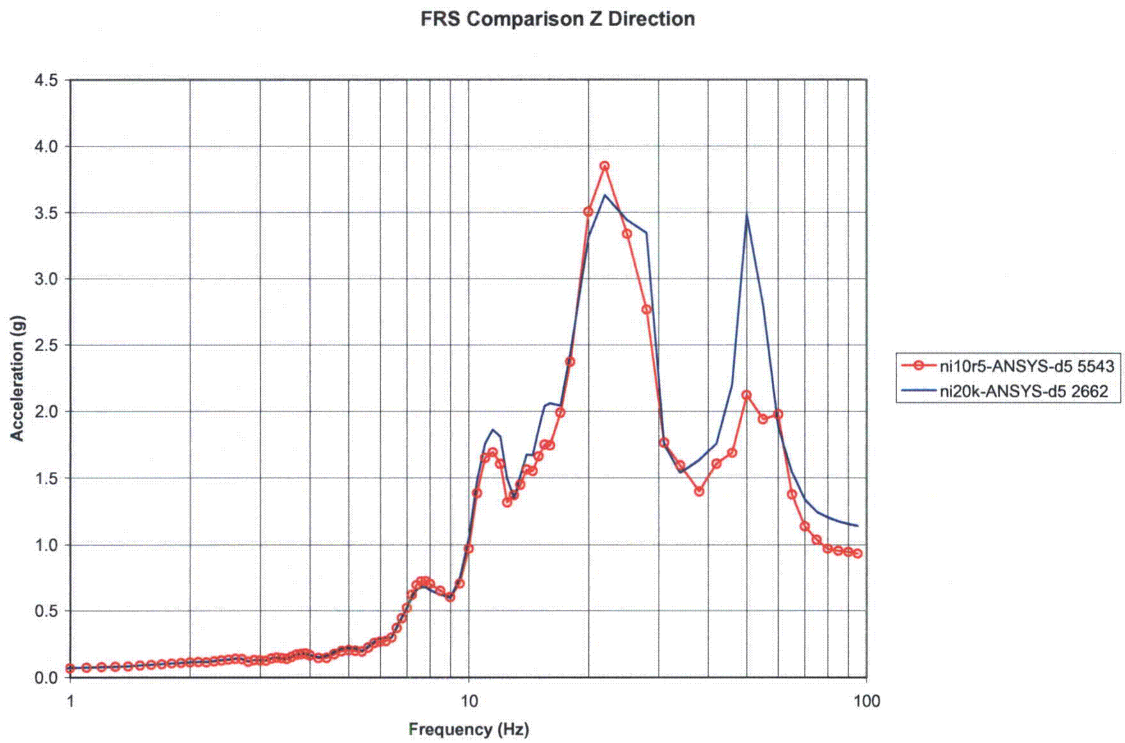

Figure RAI-SRP3.7.1-SEB1-06-15: Node NI20 2662 Direction-Z Elevation 179'

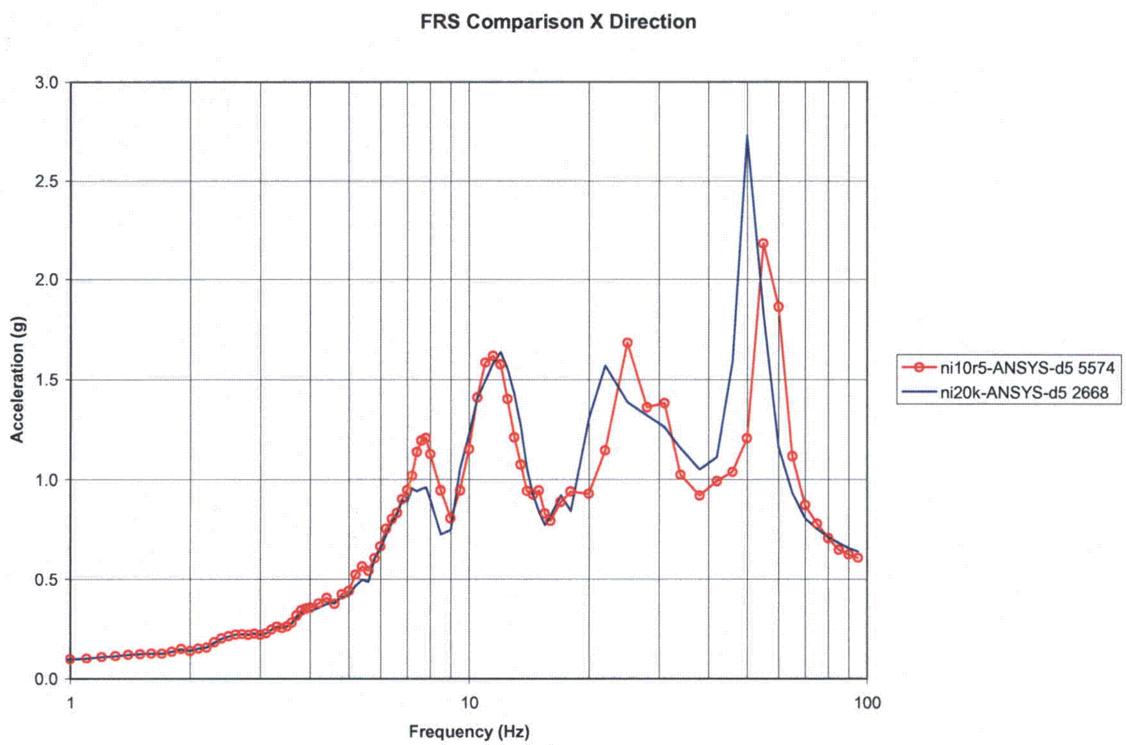

Figure RAI-SRP3.7.1-SEB1-06-16: Node NI20 2668 Direction-X Elevation 179'

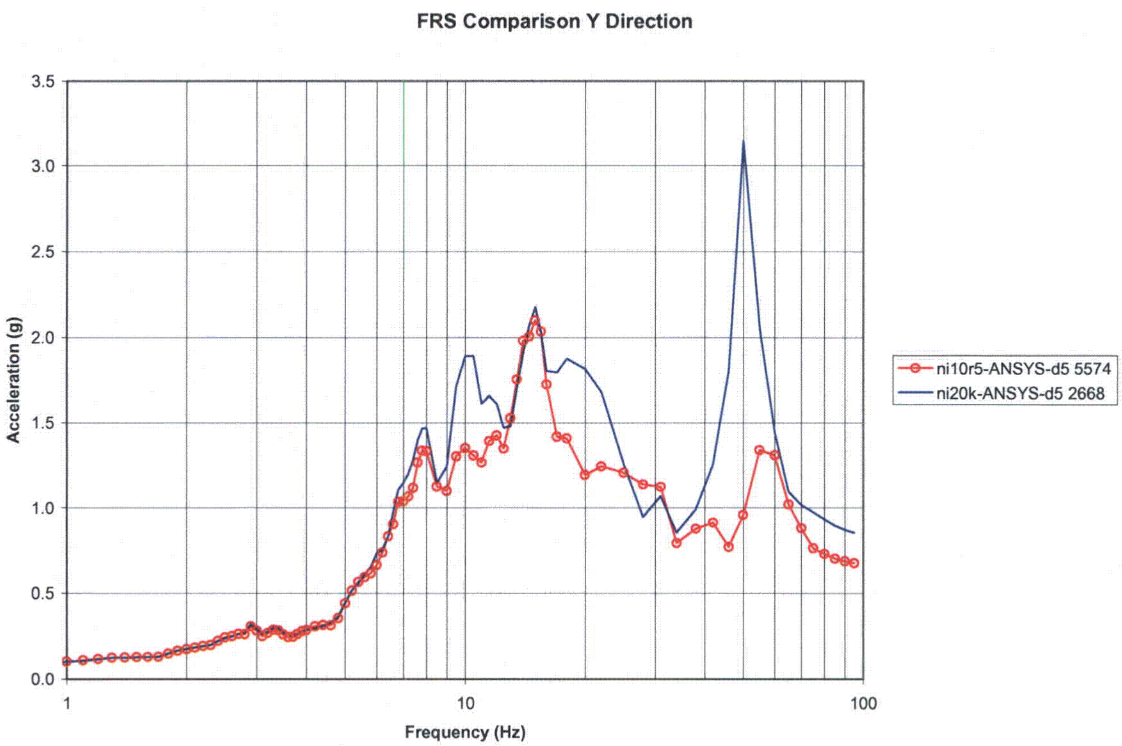

Figure RAI-SRP3.7.1-SEB1-06-17: Node NI20 2662 Direction-Y Elevation 179'

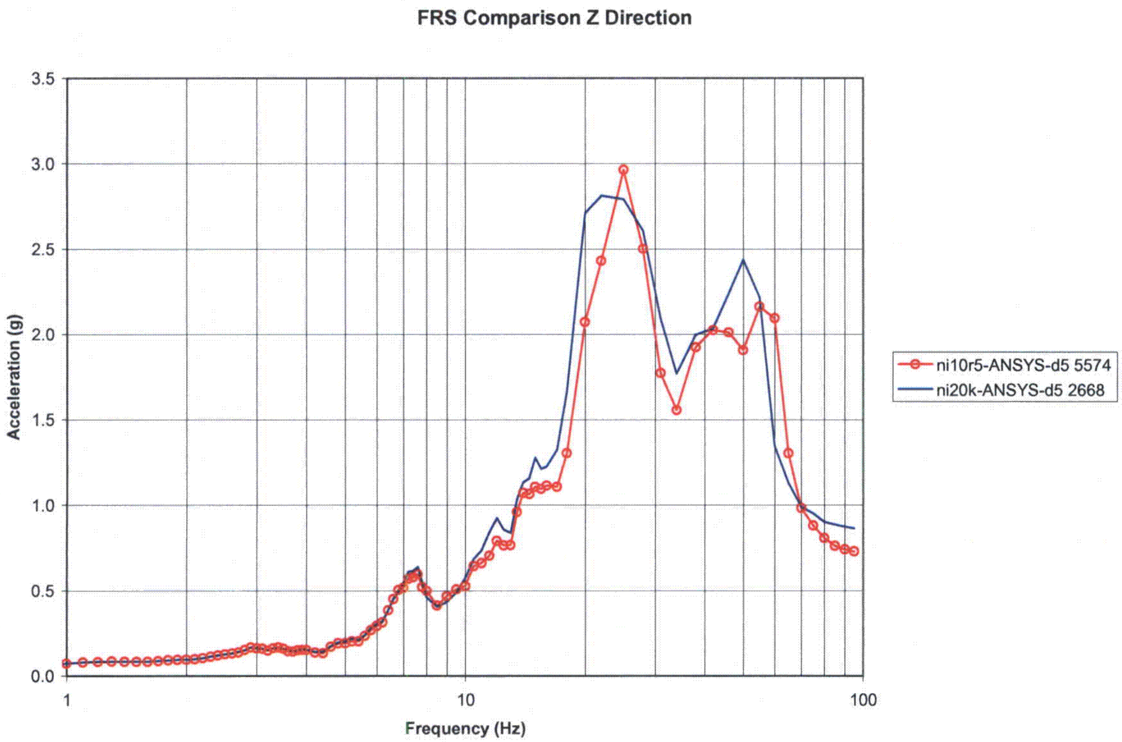

Figure RAI-SRP3.7.1-SEB1-06-18: Node NI20 2662 Direction-Z Elevation 179'

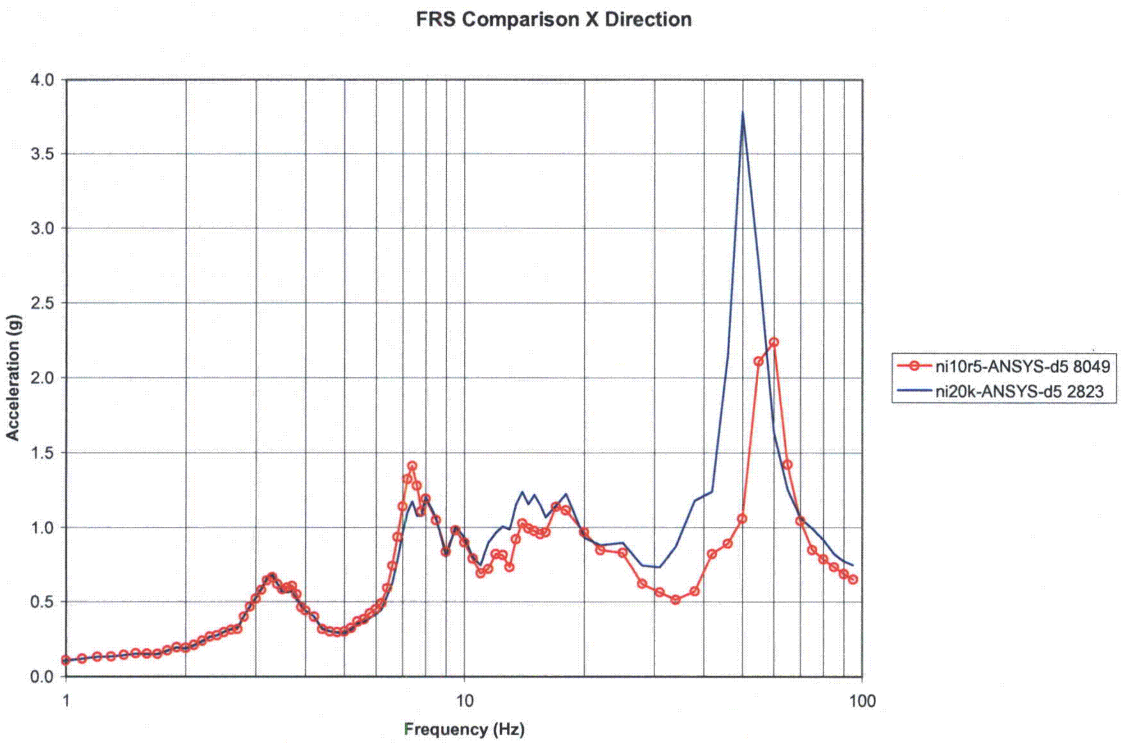

Figure RAI-SRP3.7.1-SEB1-06-19: Node NI20 2823 Direction-X Elevation 236'

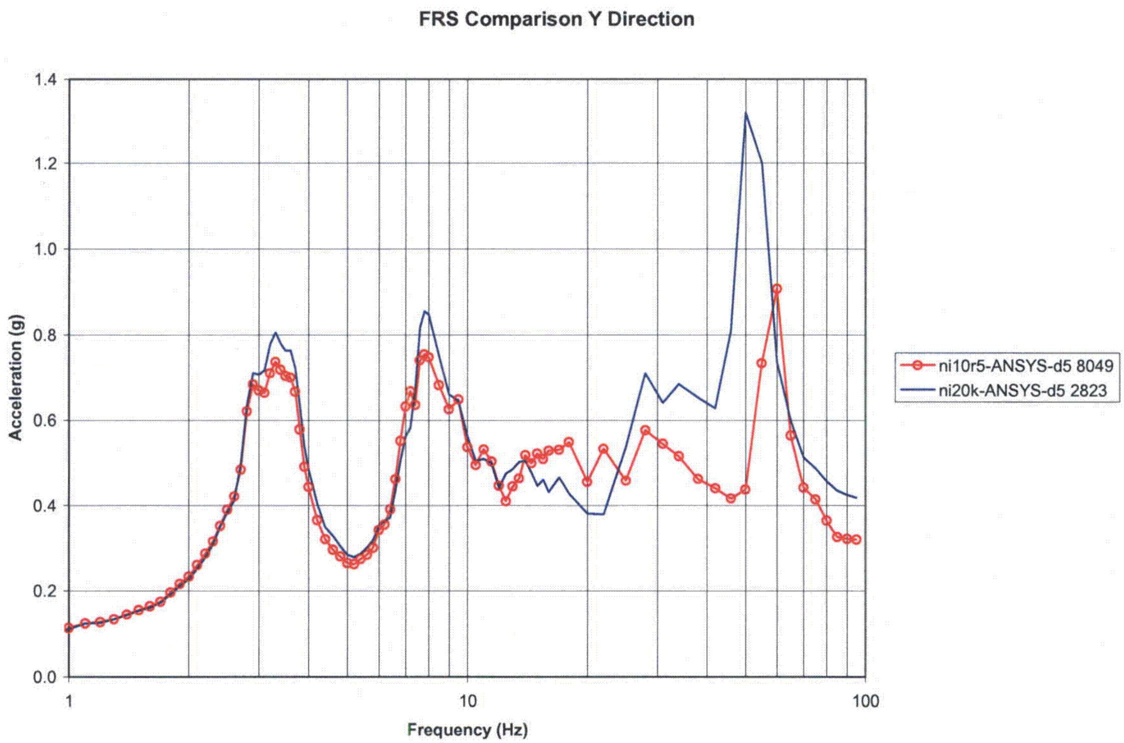

Figure RAI-SRP3.7.1-SEB1-06-20: Node NI20 2823 Direction-Y Elevation 236'

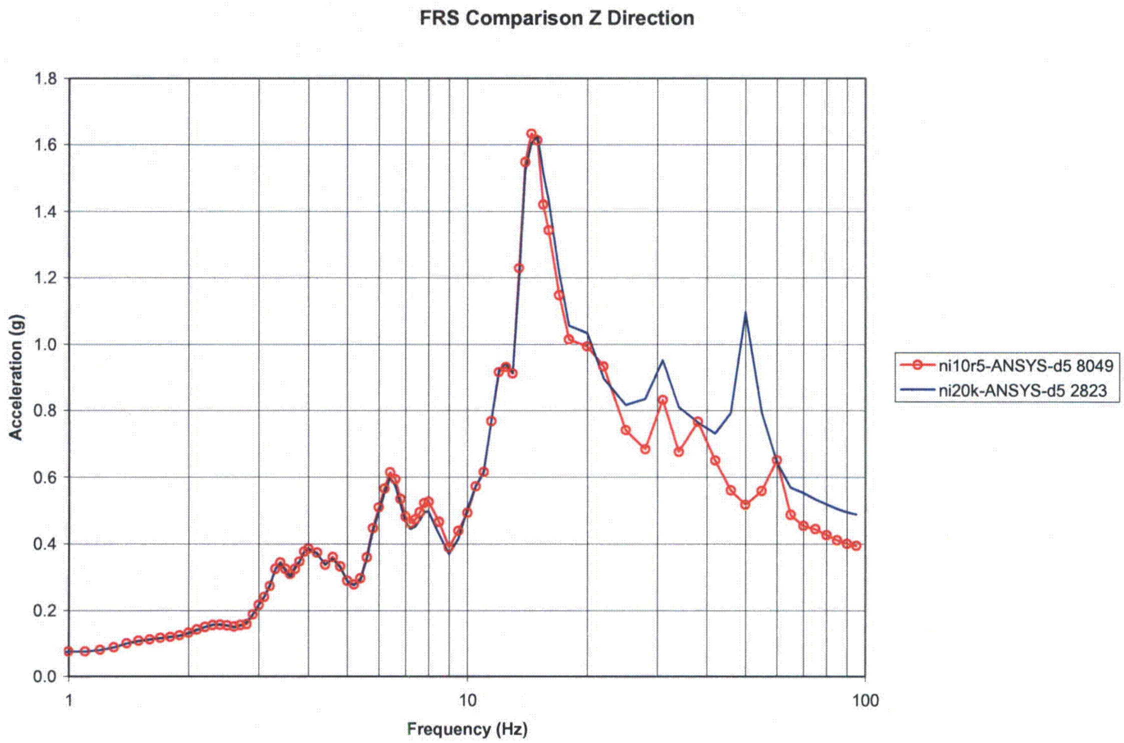

Figure RAI-SRP3.7.1-SEB1-06-21: Node NI20 2823 Direction-Z Elevation 236'

Westinghouse Response (Revision 4):

In order to identify flexible regions considered to have frequencies of significant modal response between 33 hertz and 50 hertz, the NI05 model is used. Based on the dynamic response information, flexible areas are identified that may amplify the high frequency seismic input. The mode shapes from the NI05 model are compared to those from the NI20 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 above 33 hertz and below 50 hertz) and included in the design in-structure response spectra for evaluation of the HRHF seismic event. This allows the identification of additional flexible regions at frequencies above 33 hertz and below 50 hertz to be addressed in Technical Report APP-GW-GLR-115, Revision 2 (TR115).

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision (The changes given below are in Revision 1):

Section 5.1 is revised to reflect the 50 hertz requirement on the dynamic models.

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 50 Hz which must transmit through the finite elements, the shortest wavelength (λ) is 138 ft.

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

Approximately 7 (6.9) nodes per wavelength are available for a mesh size of 20', and this is adequate to transmit the high frequency through the finite elements in the NI20 model. ~~Therefore, the mesh size of 20 ft (i.e. NI20) is adequate for the Auxiliary and Shield Building (ASB). The~~ A portion of the NI20 model has an element mesh size of ~ 10' for the Containment and Internal Structure (CIS).

The discussion of the modal response as presented in the Westinghouse response is added at the end of Section 5.1.

AP1000 DESIGN CERTIFICATION REVIEW

Response to SER Open Item (RAI)

RAI Response Number: OI-SRP3.7.2-SEB1-02
Revision: 1

Question:

The radwaste building was evaluated for its potential collapse on the nuclear island, demonstrating that it would not impair the structural integrity of the nuclear island safety-related structures (see DCD Subsection 3.7.2.8.2, "Radwaste Building"). However, because of the addition of 3 liquid radwaste monitor tanks (see TR-116, Reference 2), which completely alters the structural dynamic characteristics of the building, it is not clear whether this conclusion is still valid. The staff reviewed the Westinghouse response to RAI-SRP3.7.2-SEB1-02, Revision 1, dated October 1, 2008 (ADAMS Accession Number ML082770219), and determined that it was not acceptable because the maximum kinetic energy calculated using Method 3 in DCD Subsection 3.7.2.8.2 (0.6E9 in-lb or 68E6 joules) far exceeded that of auto missile (2E7 in-lb or 2.26E6 joules) and water tank missile (3E5 in-lb or 3.4E4 joules) claimed in the response. The staff's calculation was based on the assumptions that the mass of the radwaste building equals the mass of a single water tank (i.e., 144,781 lbs or 65,673 kg) and the velocity is 150 fps (105 mph or 168 km per hour).

Question Revision 1:

During the NRC audit of tornado missile responses the following additional information was requested for this response

Evaluate the capability of a radwaste monitor tank to remain in place when exposed to tornado wind loads. The evaluation is to be based on the Class D level component analysis and building code structural evaluation.

Westinghouse Response:

A single liquid storage tank equal to 144,781 lbs traveling at 105 mph is not a credible event since the tanks are at the foundation level (plant grade, Elevation 100') near the Auxiliary building protected by the Radwaste building. If the tanks became a missile it would not be possible for the tanks to reach the velocity of 150 fps prior to impact on the Nuclear Island since, per Regulatory Guide 1.76, the trajectories must be unobstructed by the presence of any obstacles. Further, it is not considered a reasonable probability of becoming airborne within the tornado wind field located at the radius of the maximum circumferential wind speeds.

Regulator Guide 1.76 defines design basis tornado missiles. These missiles were defined from a spectrum of tornado missiles considered common objects about a nuclear plant site that have a reasonable probability of becoming airborne within the wind field. Tanks are common mechanical equipment that can be found on the plant site not housed/housed within a structure.

However, tanks were not defined as the design basis massive missile of high kinetic energy that deforms on impact in Regulatory Guide 1.76. The automobile was chosen since it is common on a plant site, and could reach the high velocity of 150 fps. Further, during AP1000 Design Certification there were no additional requirements imposed related to tornado missiles that included tanks.

Therefore, the addition of three liquid radwaste monitor tanks do not impair the structural integrity of the adjacent nuclear island (NI) structures during an extreme environmental event (tornado) since they can not reach high velocities near the NI during such an event, their mass decreases greatly due to the loss of the liquid if they do become a missile, and their impact energy reduces due to deformation of the tank.

In the AP1000 DCD Section 3.3.2.3 it is stated: "The Radwaste Building is a small steel-frame building. If it were to collapse in the tornado, it would not impair the integrity of the reinforced concrete nuclear island."

The three liquid Radwaste monitor tanks do not change the dynamic characteristics of the Radwaste Building since they are at ground level. Therefore it is not necessary to perform a reanalysis of the collapse of the Radwaste Building due to the safe shutdown earthquake reported in AP1000 DCD Section 3.7.2.8.2.

Westinghouse Response (Revision 1):

The Radwaste monitor tanks will not become tornado missiles that could potentially impact the Nuclear Island. This is demonstrated by an evaluation showing that the integrity of the tank supports is maintained when the monitor tanks are subjected to the tornado wind velocity.

The AP1000 Seismic Design Criteria, APP-GW-G1-003, requires that the anchorage of Non-Seismic components shall be designed, using acceptance criteria for commercial structures, for equivalent static horizontal accelerations applied at the center of mass of the system or component. Per the AP1000 seismic design criteria, the seismic accelerations shall be based on the Uniform Building Code, UBC 1997. Therefore, showing that the seismic loads govern the design of the Radwaste monitor tanks and not the tornado loads, it can be concluded that the Radwaste monitor tanks will not become tornado missiles.

The Radwaste monitor tank is shown in Figure OI-SRP3.7.2-SEB1-02-1. It is supported by six supports as shown in Figure OI-SRP3.7.2-SEB1-02-2.

The center of gravity is near the center of the tank as seen in Figure OI-SRP3.7.2-SEB1-02-1. Therefore, the equivalent static load associated with the tornado will act very close to the equivalent static load associated with the seismic load. Therefore, it is only necessary to compare the load acting on the tank due to a tornado and seismic events. If the load from the tornado is enveloped by the seismic load, the overturning moment from the tornado will also be enveloped by the seismic event.

The tornado load on the tank is defined using ASCE 7-98, “Minimum Design Loads for Buildings and Other Structures.” The full tornado wind velocity is assumed to act uniformly on the tanks. No reduction is taken for the tornado close to ground level. The full wind velocity, 300 mph, is used in the evaluation. The resulting tornado load on a monitor tank is 27.35 kips.

The seismic acceleration used in the evaluation is associated with the Radwaste building at ground level (El. 100’). It is conservatively defined with no increase taken for components containing hazardous material. The resulting seismic load is 30.3 kips.

As seen from the calculated loads given above that the supports must resist, the seismic load envelopes the tornado load. It is noted that additional conservatism exists in the support design due to the material stress allowables. Therefore, the monitor tank supports are more than adequate to withstand the affects of the tornado and maintain their structural integrity. Thus, it can be concluded that the Radwaste monitor tanks will remain in place when exposed to tornado wind loads and not become tornado missiles.

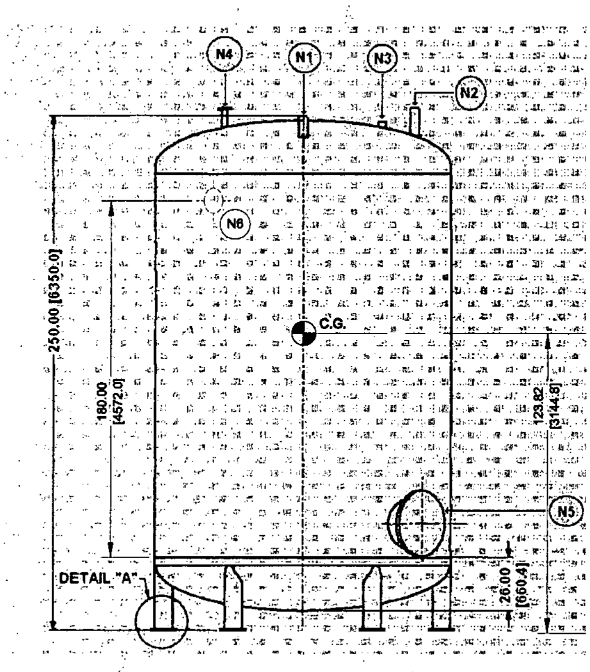

Figure OI-SRP3.7.2-SEB1-02-1 – Radwaste Monitor Tank

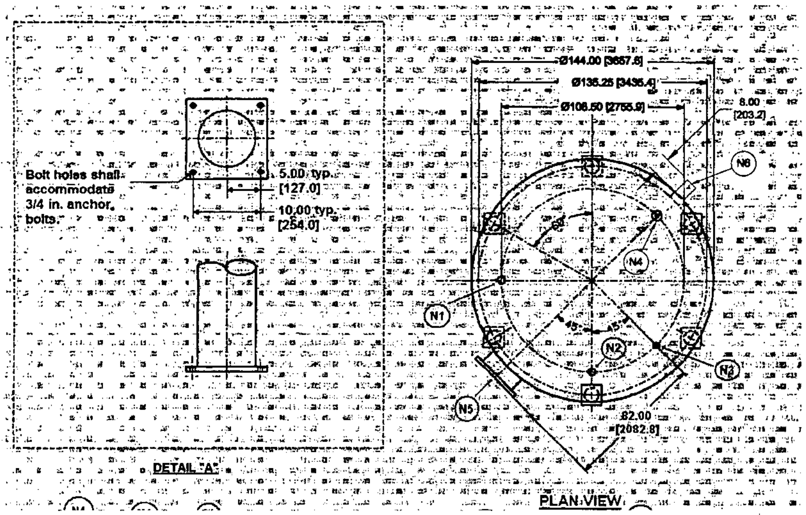

Figure OI-SRP3.7.2-SEB1-02-2 – Radwaste Monitor Tank Support Details

Design Control Document (DCD) Revision:

None

PRA Revision:

None