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Your ref: Project Number 740
Our ref: DCP/NRC1860

April 9, 2007

Subject: AP1000 COL Response to Request for Additional Information (TR #54)

In support of Combined License application pre-application activities, Westinghouse is submitting responses to NRC requests for additional information (RAI) on AP1000 Standard Combined License Technical Report 54, APP-GW-GLR-033, Rev. 0, Spent Fuel Racks Design and Structural Analysis. These RAI responses are submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in the responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

The responses are provided for Requests for additional information TR54-1, TR54-2, TR54-3, TR54-4, TR54-5, TR54-6, TR54-7, TR54-10, TR54-11, TR54-16, TR54-17, TR54-19, TR54-20, TR54-22, TR54-23, TR54-28, and TR54-34, transmitted in NRC letter dated March 29, 2007 from Steven D. Bloom to Andrea Sterdis, Subject: Westinghouse AP1000 Combined License (COL) Pre-application Technical Report 54 – Request for Additional Information (TAC NO. MD2551).

Pursuant to 10 CFR 50.30(b), the responses to requests for additional information on Technical Report 54 are submitted as Enclosure 1 under the attached Oath of Affirmation.

It is expected that when the RAIs on Technical Report 54 are complete, the technical report will be revised as indicated in the responses and submitted to the NRC. The RAI responses will be included in the document.

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,

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

D079

00102-psa.doc

/Attachment

1. "Oath of Affirmation," dated April 9, 2007

/Enclosure

1. Response to Requests for Additional Information on Technical Report No. 54

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

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)

NuStart Bellefonte COL Project)

NRC Project Number 740)

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

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

W E Cummins

W. E. Cummins
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 9th day
of April 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Debra McCarthy, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Aug. 31, 2009
Member, Pennsylvania Association of Notaries

Debra McCarthy
Notary Public

ENCLOSURE 1

Responses to Request for Additional Information on Technical Report No. 54

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-1
Revision:

Question:

Section 2.8.5 indicates that all 3 drop scenarios are from 36 in. above the top of the AP1000 Spent Fuel Storage Rack. Describe the fuel handling operation that leads to this drop height.

Westinghouse Response:

The fuel handling operations for the Section 2.8.5 scenarios are the normal fuel handling operations such as that performed during refueling outages, i.e., core fuel offloaded and reloaded from/to the Reactor Building via the fuel transfer system into and out of the spent fuel pool storage racks. There are also instances where fuel inspection and/or fuel repair will occur which require the fuel to be removed from the spent fuel storage racks and moved to the designated fuel inspection or fuel repair workstation. Also, these fuel handling operations include the transfer of fuel from the rack cells and into the cask area during dry cask storage operations.

The current AP1000 Fuel Transfer System in the Spent Fuel Building which lift and lower the fuel during normal fuel handling operations are the Fuel Handling Machine (FHM) and the Spent Fuel Handling Tool (SFHT). The FHM is a fixed- mast manipulator-type bridge crane similar in design to numerous existing Westinghouse operating plants Reactor Building manipulator crane bridges. The SFHT is a long handled tool which latches onto the fuel assembly top nozzle via a manually actuated gripper. Lifting of the SFHT and attached fuel assembly is performed using an auxiliary hoist on the FHM Bridge. The design of the SFHT is very similar in design to the fuel handling tool currently in use at numerous existing Westinghouse operating plants Spent Fuel Buildings.

The current designs of the AP1000 spent fuel pool, spent fuel storage racks, FHM, and SFHT limit the height that the fuel assembly can be lifted above the spent fuel racks to 9 inches maximum. This height is limited by the water coverage above the fuel assembly and is limited by the physical design of the FHM and SPHT via mechanical stops and/or tool length.

The maximum fuel drop height will be approximately 9 inches, which is bounded by the Section 2.8.5 scenarios of 36 inches.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-2
Revision:

Question:

As described in Section 2.8.5, the objective of the LSDYNA impact analyses is to assess the extent of the permanent damage to the rack and the structural integrity of the spent fuel pool liner. In light of the second "bullet" in Section 2.9 – Conclusions, please clarify whether the analyses are also intended to address the structural condition of the dropped fuel assemblies, which may be more vulnerable than the rack. If intended to address damage to the fuel assemblies, the staff needs additional fuel assembly design details and LSDYNA analysis details. If not, identify where this is addressed in the design control document (DCD) or other topical report.

Westinghouse Response:

The LSDYNA impact analyses are not intended to address the structural condition of a dropped fuel assembly. The analysis addresses the structural condition of the rack and its ability to maintain subcriticality. A fuel handling accident and its radiological consequence is addressed in DCD subsection 15.7.4 Fuel Handing Accident. The fuel handling accident described in subsection 15.7.4 is defined as the dropping of a spent fuel assembly such that every rod in the dropped assembly has its cladding breached so that the activity in the fuel/cladding gap is released.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-Z0C-001, Revision 0,"Analysis of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-3
Revision:

Question:

Section 2.8.5 indicates the impact velocity was calculated considering the resistance of the water and the confinement effect of the rack cell. Explain how these effects were considered with more details and the calculated impact velocities.

Westinghouse Response:

The method used to calculate the fuel assembly impact velocities is explained in the PDF file Attachment for RAI TR 54-3. The calculated impact velocities are also provided.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-Z0C-001, Revision 0,"Analysis of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

Part A: Theory

A.1 Drop of an Object in Water

A dropped object, such as a fuel assembly, is modeled as a single lumped mass under the influence of gravity in a drag inducing medium. The objective of the analysis is to calculate the final velocity of the object dropping through the water of the spent fuel storage pool. The effects of virtual mass, gravity, and fluid drag are accounted for in the model. The virtual mass is conservatively assumed equal to the buoyant mass of the dropped object [1]. The drag force is based on the exposed frontal area of the object. The governing equation for a body of mass subject to gravity and drag effects is

$$\left(M + M_V\right)\cdot\frac{dv}{dt} + \frac{C_D}{2}\cdot d_W\cdot A_D\cdot v^2 = \left(M - M_V\right)\cdot g \qquad \text{(A-1)}$$

where

M equals the dry mass of the object;
M_v equals the virtual mass of the object (buoyant mass);
C_D equals the effective drag coefficient due to all contributing effects;
d_w equals the mass density of water;
A_D equals the area subject to drag forces;
v equals the velocity of the object;
g equals the gravitational acceleration.

If $\varepsilon = M_v/M$, then equation A-1 can be written as follows

$$\frac{dv}{dt} = \frac{1-\varepsilon}{1+\varepsilon}\cdot g - \frac{C_D\cdot d_W\cdot A_D\cdot v^2}{2\cdot M\cdot\left(1+\varepsilon\right)} \qquad \text{(A-2)}$$

The time derivative of velocity, dv/dt, is expressed as

$$\frac{dv}{dt} = v\cdot\frac{dv}{ds}$$

where

$$v = \frac{ds}{dt}$$

If the variable x is defined equal to v^2, then equation A-2 becomes

$$\frac{dx}{ds} + \lambda \cdot x = \beta \qquad \text{(A-3)}$$

where

$$\lambda = \frac{C_D \cdot d_w \cdot A_D}{M \cdot (1+\varepsilon)} \quad ; \quad \beta = 2 \cdot \frac{1-\varepsilon}{1+\varepsilon} \cdot g$$

The constant λ is a measure of the drag forces relative to the inertia forces. If the virtual mass is neglected for conservatism, the above parameters λ and β become

$$\lambda = \frac{C_D \cdot d_w \cdot A_D}{M} \quad ; \quad \beta = 2 \cdot (1-\varepsilon) \cdot g \qquad \text{(A-3A)}$$

The solution to equation A-3, with initial condition $v = v_i$ at $s = 0$, is

$$x = \left(v_i^2 - \frac{\beta}{\lambda} \right) \cdot e^{-\lambda \cdot s} + \frac{\beta}{\lambda} \qquad \text{(A-4)}$$

The term β/λ in the preceding equation is equal to the terminal velocity squared.

A.2 Effects of Fluid Flow in a Storage Cell

For a rod shaped body traveling through a channel, $C_D = C_{D0} + \kappa$, where C_{D0} represents the drag coefficient in unconfined water and κ represents the incremental increase in effective drag coefficient due to the confinement of fluid flow in the channel. The value of κ can be derived based on the concept of loss coefficients as follows.

Figure A-1 defines the various flow areas in the cell. Let p_1, p_2 be the pressures directly ahead of and behind the falling fuel assembly. The retarding force, acting on the fuel assembly, is

$$\frac{F}{A_{fa}} = p_1 - p_2 \qquad \text{(A-5)}$$

Where A_{fa} is the fuel cross-sectional area normal to direction of travel.

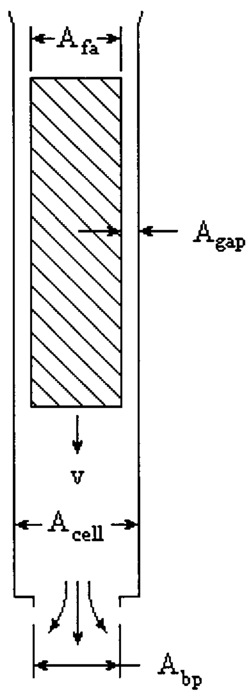


Figure A-1 Flow Areas in a Storage Cell

Apply Bernoulli's principal between point "1", immediately ahead of the fuel assembly, and a point in the annulus, and between a point in the gap annulus and point "2" immediately behind the falling fuel assembly. Conservatively, neglect all pressure drops due to height differences.

$$p_1 + \frac{1}{2}\rho V_1^2 = p_g + \frac{1}{2}\rho V_g^2 + \frac{\rho}{2} K_i V_g^2 \qquad \text{(A-6)}$$

$$p_g + \frac{1}{2}\rho V_g^2 = p_2 + \frac{1}{2}\rho V_2^2 + \frac{\rho}{2} K_o V_g^2 \qquad \text{(A-7)}$$

K_i, K_o are the loss factors at the entrance to the gap and the exit to the gap, respectively.

The fluid velocity magnitude just ahead and behind the fuel assembly is V so that the velocity magnitudes in the vicinity of p1 and p2 are:

$$V_1 = V_2 = V$$

Therefore, from Eqs. (A-6) and (A-7)

$$p_1 + \frac{1}{2}\rho V^2 = p_g + \frac{1}{2}\rho V_g^{\,2} + \frac{\rho}{2} K_i V_g^{\,2}$$

or

$$p_1 + \frac{1}{2}\rho V^2 = p_2 + \frac{1}{2}\rho V^2 + \frac{\rho}{2}\left(K_o + K_i\right) V_g^{\,2} \tag{A-8}$$

Therefore, from (A-8)

$$p_1 - p_2 = \frac{\rho}{2}\cdot\left(K_o + K_i\right)\cdot V_g^{\,2}$$

Therefore, independent of the presence of an opening in the base plate, and independent of how far the fuel assembly is from the baseplate,

$$\frac{F}{A_{fa}} = \frac{\rho}{2}\left(K_o + K_i\right) V_g^{\,2} \tag{A-9}$$

Now apply the continuity of mass flow:

$$A_{fa} \cdot V = A_{gap} \cdot V_g + A_{bp} \cdot V_h + A_{lat} \cdot V_{lat} \tag{A-10}$$

For the case when A_{bp} and A_{lat} are 0.0 (no holes in baseplate or cell wall near the bottom),

$$V_g = \frac{A_{fa}}{A_{gap}} \cdot V \tag{A-11}$$

so that

$$\frac{F}{A_{fa}} = \frac{\rho}{2}\left(K_o + K_i\right)\cdot\left(\frac{A_{fa}}{A_{gap}}\right)^2 \cdot V^2 \tag{A-12}$$

This represents the drag effect due to the gap; any openings in the baseplate or in the cell side walls near the baseplate will reduce the drag effect.

Now, consider the case when there are sets of flow holes in the baseplate and in the cell walls (or walls of the pedestal in the case of a dropped fuel assembly over a pedestal cell). Eqs. (A-9) and (A-10) still apply but we need develop relations between V_{lat}, V_h, and V_g in order to finally solve for V_g in terms of V. We apply the Bernoulli equation from point "1" to the plenum on the other side of the hole in the baseplate, and from point "2" to the top of the fuel cell.

$$p_1 + \rho \cdot \frac{V^2}{2} = p_{inf} + \frac{1}{2} \cdot K_L \cdot \rho \cdot V_h^2 \qquad \text{(A-13)}$$

$$p_2 + \rho \cdot \frac{V^2}{2} = p_{inf} \qquad \text{(A-14)}$$

In the above K_L = total loss coefficient through the baseplate hole and the pressure at "infinity" represents the quiescent reservoir pressure. From Eqs. (A-13) and (A-14), we obtain

$$p_1 - p_2 = \frac{1}{2} \cdot K_L \cdot \rho \cdot V_h^2 \qquad \text{(A-15)}$$

Applying Eq. (A-9) gives

$$\frac{\rho}{2} \cdot (K_o + K_i) \cdot V_{g.}{}^2 = \frac{\rho}{2} \cdot K_L \cdot V_h^2 \qquad \text{(A-16)}$$

Therefore,

$$V_h = e \cdot V_g \qquad \text{(A-17)}$$

where

$$e = \sqrt{\frac{K_o + K_i}{K_L}} \qquad \text{(A-18)}$$

If the same logic is applied following a path from point "1" through the "lateral" holes to another quiescent location, then

$$V_{lat} = el \cdot V_g \qquad \text{(A-18)}$$

where

$$el = \sqrt{\frac{K_o + K_i}{K_{LAT}}} \qquad \text{(A-20)}$$

Using Eqs. (A-17) to (A-20) and (A-10) gives the desired relation between the assembly velocity and the fluid velocity in the annular gap.

$$A_{fa} \cdot V = \left(A_{gap} + A_{bp} \cdot e + A_{lat} \cdot el\right) \cdot V_g \qquad \text{(A-21)}$$

so that

$$\frac{F}{A_{fa}} = \frac{\rho}{2} \cdot \left(K_o + K_i\right) \cdot \left(\frac{A_{fa}}{A_{gap} + A_{bp} \cdot e + A_{lat} \cdot el}\right)^2 \cdot V^2 \qquad \text{(A-22)}$$

or

$$\frac{F}{A_{fa}} = \frac{\rho}{2} \cdot \kappa \cdot V^2 \qquad \text{(A-23)}$$

where

$$\kappa = \left(K_o + K_i\right)\left(\frac{A_{fa}}{A_{gap} + A_{bp} \cdot e + A_{lat} \cdot el}\right)^2 \qquad \text{(A-24)}$$

The total effective drag coefficient is defined as $C_D = C_{D0} + \kappa$.

We note that Eq. (A-24) will overestimate the reduction in the drag (i.e. the value for κ will be less than the correct value), since we have neglected the squeezing effect when the fuel assembly is near the base of the cell.

K_o and K_i can be determined using the following formula [2]

$$K_1 = \left(1 - \frac{A_1}{A_2}\right)^2 \qquad \text{(A-25)}$$

$$K_2 = 0.5 \cdot \left(1 - \frac{A_1}{A_2}\right) \qquad \text{(A-26)}$$

where, K_1 = Contraction coefficient,

K_2 = Expansion coefficient

A_1= Smaller flow area

A_2 = Larger flow area

Part B: Calculation

Note: The following fuel velocity calculations are performed for Region II racks in the spent fuel pool. The rack dimensions used in the calculation is identical for both Region I and Region II racks except that the Region II rack cell is slightly taller than the Region I rack. Therefore, the calculated velocities are either valid or slightly conservative to be used in the drop analysis for Region I racks in the spent fuel pool.

B.0 INPUT DATA

The following parameters are general for all analyses:

Total dropped weight	$W := 3100 \cdot lbf$	[3]
Fuel assembly envelope	$D_{fuel} := 8.404in$	[4]
Height of storage cells	$h_{cell} := 199.5 \cdot in$	[5]
Cell inner dimension	$D_{cell} := 8.8 \cdot in$	[5]
Mass density of water (150° F)	$d_w := \frac{61.196}{g} \cdot \frac{lbf}{ft^3}$	[6]
Weight density of fuel pellet (100% UO_2)	$d_f := 10.96 \cdot 10^3 \cdot \frac{kgf}{m^3}$	[7]
Weight density of stainless steel	$d_{stl} := 8.03 \cdot 10^{-3} \cdot \frac{kgf}{cm^3}$	[6]
Fuel drop height above rack top	$H := 36 \cdot in$	[3]

B.1 Shallow Drop

The following calculation determines the velocity of the dropped fuel assembly at the rack top elevation. Part A provides the theoretical background for this analysis. The nomenclature used herein is consistent with Part A.

B.1.1 Input Data

Drop height $h_s := H$ $h_s = 36\,\text{in}$

Initial velocity of fuel assembly $v_i := 0 \cdot \frac{\text{in}}{\text{sec}}$

B.1.2 Calculations

The following parameters are defined in Part A.

$\varepsilon = \frac{M_v}{M}$ $\varepsilon := \frac{d_w \cdot g}{d_f}$ $\varepsilon = 0.089$

Frontal area subject to drag force $A_D := D_{fuel} \cdot D_{fuel}$ $A_D = 70.6\,\text{in}^2$

For the drop of a fuel assembly to the top of a spent fuel rack, there is no confinement of fluid. From Table 11.4.4 of Marks' Standard Handbook for Mechanical Engineers [6], the drag coefficient, C_D, for a long slender cylinder (l/d > 7) is equal to 0.99.

Drag coefficient $C_D := 0.99$

$\lambda := \frac{C_D \cdot d_w \cdot A_D \cdot g}{W \cdot (1+\varepsilon)}$ $\lambda = 7.332 \times 10^{-4}\,\text{in}^{-1}$ (Eq. A-3)

$\beta := 2 \cdot \frac{(1-\varepsilon)}{(1+\varepsilon)} \cdot g$ $\beta = 645.4\,\text{in} \cdot \text{sec}^{-2}$ (Eq. A-3)

$x := \left(v_i^2 - \frac{\beta}{\lambda}\right) \cdot \exp(-\lambda \cdot h_s) + \frac{\beta}{\lambda}$ (Eq. A-4)

$v_{f\_w} := \sqrt{x}$ $v_{f\_w} = 151.4 \frac{\text{in}}{\text{sec}}$

If we conservatively neglect the virtual mass in the calculation, the impact velocity between the dropped fuel assembly and the top of the rack can be determined as

$\lambda := \frac{C_D \cdot d_w \cdot A_D \cdot g}{W}$ $\lambda = 7.988 \times 10^{-4}\,\text{in}^{-1}$ (Eq. A-3A)

$\beta := 2 \cdot (1 - \varepsilon) \cdot g \qquad \beta = 703.1\,in \cdot sec^{-2}$ (Eq. A-3A)

$x := \left(v_i^2 - \frac{\beta}{\lambda}\right) \cdot \exp(-\lambda \cdot h_s) + \frac{\beta}{\lambda}$ (Eq. A-4)

$v_{f\_s} := \sqrt{x} \qquad v_{f\_s} = 158 \frac{in}{sec}$

If the fuel is dropped in air, the impact velocity between the dropped fuel assembly and the top of the rack will become

$v_{f\_a} := \sqrt{v_i^2 + 2 \cdot g \cdot h_s} \qquad v_{f\_a} = 166.7 \frac{in}{sec}$

B.2 Deep Drop to Baseplate (Away From Pedestal)

The following analysis determines the velocity of the fuel assembly when it starts to collide with the baseplate located away from pedestals. The nomenclature used herein is consistent with Part A.

B.2.1 Input Data

Drop height	$h := h_{cell}$	$h = 199.5\,in$	
Initial velocity of fuel assembly	$v_i := v_{f\_w}$	$v_i = 151.4 \frac{in}{sec}$	
Baseplate hole diameter (bounding)	$D_{hole} := 6.25 \cdot in$		[5]
Lateral cell hole diameter	$D_{lat} := 1.5 \cdot in$		[5]
Number of lateral holes (equivalent)	$N_{lat} := 2$		[5]

B.2.2 Calculations

The following parameters are defined in Part A.

Enclosed area of storage cell $\qquad A_{cell} := D_{cell} \cdot D_{cell} \qquad A_{cell} = 77.4\,in^2$

Fuel assembly frontal area $A_{fa} := D_{fuel} \cdot D_{fuel}$ $A_{fa} = 70.6\,in^2$

Baseplate flow hole area $A_{bp} := \frac{\pi}{4} \cdot D_{hole}^2$ $A_{bp} = 30.7\,in^2$

Area of gap annulus $A_{gap} := A_{cell} - A_{fa}$ $A_{gap} = 6.813\,in^2$

Lateral flow hole area $A_{lat} := \frac{\pi}{4} \cdot D_{lat}^2$ $A_{lat} = 1.767\,in^2$

Loss coefficients for gap

$$K_i := \left(1 - \frac{A_{gap}}{A_{fa}}\right)^2 \qquad K_i = 0.816$$

$$K_o := .5 \cdot \left(1 - \frac{A_{gap}}{A_{fa}}\right) \qquad K_o = 0.452$$

Loss coefficient for baseplate

$$K_{bi} := \left(1 - \frac{A_{bp}}{A_{cell}}\right)^2 \qquad K_{bi} = 0.365$$

$$K_{bo} := .5 \cdot \left(1 - \frac{A_{bp}}{A_{cell}}\right) \qquad K_{bo} = 0.302$$

Loss coefficient for lateral holes

$$K_{li} := \left(1 - \frac{A_{lat}}{A_{cell}}\right)^2 \qquad K_{li} = 0.955$$

$$K_{lo} := .5 \cdot \left(1 - \frac{A_{lat}}{A_{cell}}\right) \qquad K_{lo} = 0.489$$

$$e := \sqrt{\frac{K_i + K_o}{K_{bi} + K_{bo}}} \qquad e = 1.379$$

$$e1 := \sqrt{\frac{K_i + K_o}{K_{li} + K_{lo}}} \qquad e1 = 0.937$$

$$\kappa := \left(K_i + K_o\right)\cdot\left[\frac{A_{fa}}{\left[A_{gap} + \left(A_{bp}\cdot e + N_{lat}\cdot A_{lat}\cdot e1\right)\right]}\right]^2 \qquad \kappa = 2.3 \qquad \text{(Eq. A-24)}$$

$$C_D := 0.99 + \kappa \qquad C_D = 3.29$$

$$\lambda := \frac{C_D\cdot d_w\cdot A_D\cdot g}{W\cdot(1+\varepsilon)} \qquad \lambda = 2.437\times 10^{-3}\,\frac{1}{in} \qquad \text{(Eq. A-3)}$$

$$\beta := 2\cdot\frac{(1-\varepsilon)}{(1+\varepsilon)}\cdot g \qquad \beta = 645.392\,\frac{in}{sec^2} \qquad \text{(Eq. A-3)}$$

$$x := \left(v_i^{\,2} - \frac{\beta}{\lambda}\right)\cdot\exp(-\lambda\cdot h) + \frac{\beta}{\lambda} \qquad \text{(Eq. A-4)}$$

$$v_f := \sqrt{x} \qquad v_f = 340.7\,\frac{in}{sec}$$

If we conservatively neglect the virtual mass in the calculation, the impact velocity between the dropped fuel assembly and the rack baseplate can be determined as

$$\lambda := \frac{C_D\cdot d_w\cdot A_D\cdot g}{W} \qquad \lambda = 2.655\times 10^{-3}\,\frac{1}{in} \qquad \text{(Eq. A-3A)}$$

$$\beta := 2\cdot(1-\varepsilon)\cdot g \qquad \beta = 703.115\,\frac{in}{sec^2} \qquad \text{(Eq. A-3A)}$$

Initial velocity of fuel assembly $\qquad v_i := v_{f\_s} \qquad v_i = 158\,\frac{in}{sec}$

$$x := \left(v_i^{\,2} - \frac{\beta}{\lambda}\right)\cdot\exp(-\lambda\cdot h) + \frac{\beta}{\lambda} \qquad \text{(Eq. A-4)}$$

$v_{f\_d1} := \sqrt{x}$ $\quad$ $v_{f\_d1} = 351.6 \frac{in}{sec}$

The velocity of dropped fuel assembly as it hits the baseplate (away from pedestal) is 351.6 in/sec.

B.3 Deep Drop Over Pedestal

The following analysis determines the velocity of the fuel assembly when it starts to collide with the baseplate directly over the pedestals. The nomenclature used herein is consistent with Part A.

B.3.1 Input Data

Drop height	$h := h_{cell}$	$h = 199.5\,in$
Initial velocity of fuel assembly	$v_i := v_{f\_w}$	$v_i = 151.4 \frac{in}{sec}$
Baseplate/pedestal flow hole diameter	$D_{hole} := 0.0 \cdot in$	[5]
Lateral cell hole diameter	$D_{lat} := 1.5 \cdot in$	[5]
Number of lateral holes (equivalent)	$N_{lat} := 2$	[5]

B.3.2 Calculations

The following parameters are defined in Part A.

Enclosed area of storage cell	$A_{cell} := D_{cell} \cdot D_{cell}$	$A_{cell} = 77.4\,in^2$
Fuel assembly frontal area	$A_{fa} := D_{fuel} \cdot D_{fuel}$	$A_{fa} = 70.6\,in^2$
Baseplate flow hole area	$A_{bp} := \frac{\pi}{4} \cdot D_{hole}^2$	$A_{bp} = 0\,in^2$
Area of gap annulus	$A_{gap} := A_{cell} - A_{fa}$	$A_{gap} = 6.813\,in^2$

Lateral flow hole area $$A_{lat} := \frac{\pi}{4} \cdot D_{lat}^{2} \qquad A_{lat} = 1.767\,in^{2}$$

Loss coefficients for gap $$K_i := \left(1 - \frac{A_{gap}}{A_{fa}}\right)^{2} \qquad K_i = 0.816$$

$$K_o := .5 \cdot \left(1 - \frac{A_{gap}}{A_{fa}}\right) \qquad K_o = 0.452$$

Loss coefficient for baseplate

$$K_{bi} := \left(1 - \frac{A_{bp}}{A_{cell}}\right)^{2} \qquad K_{bi} = 1$$

$$K_{bo} := .5 \cdot \left(1 - \frac{A_{bp}}{A_{cell}}\right) \qquad K_{bo} = 0.5$$

Loss coefficient for lateral holes

$$K_{li} := \left(1 - \frac{A_{lat}}{A_{cell}}\right)^{2} \qquad K_{li} = 0.955$$

$$K_{lo} := .5 \cdot \left(1 - \frac{A_{lat}}{A_{cell}}\right) \qquad K_{lo} = 0.489$$

$$e := \sqrt{\frac{K_i + K_o}{K_{bi} + K_{bo}}} \qquad e = 0.919$$

$$e1 := \sqrt{\frac{K_i + K_o}{K_{li} + K_{lo}}} \qquad e1 = 0.937$$

$$\kappa := \left(K_i + K_o\right) \cdot \left[\frac{A_{fa}}{\left[A_{gap} + \left(A_{bp} \cdot e + N_{lat} \cdot A_{lat} \cdot e1\right)\right]} \right]^{2} \qquad \kappa = 61.7 \qquad \text{(Eq. A-24)}$$

$C_D := 0.99 + \kappa$ $\qquad C_D = 62.69$

$$\lambda := \frac{C_D \cdot d_w \cdot A_D \cdot g}{W \cdot (1+\varepsilon)} \qquad \lambda = 0.046 \frac{1}{in} \qquad \text{(Eq. A-3)}$$

$$\beta := 2 \cdot \frac{(1-\varepsilon)}{(1+\varepsilon)} \cdot g \qquad \beta = 645.392 \frac{in}{sec^2} \qquad \text{(Eq. A-3)}$$

$$x := \left(v_i^2 - \frac{\beta}{\lambda}\right) \cdot \exp(-\lambda \cdot h) + \frac{\beta}{\lambda} \qquad \text{(Eq. A-4)}$$

$$v_f := \sqrt{x} \qquad v_f = 117.9 \frac{in}{sec}$$

If we conservatively neglect the virtual mass in the calculation, the impact velocity between the dropped fuel assembly and the rack baseplate can be determined as

$$\lambda := \frac{C_D \cdot d_w \cdot A_D \cdot g}{W} \qquad \lambda = 0.051 \frac{1}{in} \qquad \text{(Eq. A-3A)}$$

$$\beta := 2 \cdot (1-\varepsilon) \cdot g \qquad \beta = 703.115 \frac{in}{sec^2} \qquad \text{(Eq. A-3A)}$$

Initial velocity of fuel assembly $\qquad v_i := v_{f\_s} \qquad v_i = 158 \frac{in}{sec}$

$$x := \left(v_i^2 - \frac{\beta}{\lambda}\right) \cdot \exp(-\lambda \cdot h) + \frac{\beta}{\lambda} \qquad \text{(Eq. A-4)}$$

$$v_{f\_d2} := \sqrt{x} \qquad v_{f\_d2} = 117.9 \frac{in}{sec}$$

The velocity of dropped fuel assembly as it hits the baseplate at the location directly above the pedestal is 132.9 in/sec, which has reached the terminal velocity of the dropped fuel.

$$\sqrt{\frac{\beta}{\lambda}} = 117.9 \frac{in}{sec}$$

REFERENCES

1. "Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Related Nuclear Structures," ASCE Standard, ASCE 4-86, 1986.

2. "Flow of Fluids Through Valves, Fittings, and Pipe," Crane Technical Paper 410, Crane Co., 1976, page 2-11.

3. AP1000 Central Files, Chapter 9, Received by Eric Bush of Holtec International from J. M. Iacovino of Westinghouse on March 08, 2006.

4. AP1000 Fuel Assembly, Westinghouse Drawing No. APP-FA01-V2-101, Rev. D.

5. Holtec International Drawing No. 4743, Rev. 0.

6. Avallone, E., and Baumeister III, T., Marks' Standard Handbook for Mechanical Engineers, McGraw-Hill International Editions, Tenth Edition, 1997.

7. Handbook of Chemistry and Physics, 46th Edition.

8. PWR Fuel Rack Data Sheet, Rev. 4, April 27, 2006.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-4
Revision:

Question:

Section 2.8.5 indicates that a quarter of the spent fuel rack and a single fuel assembly were modeled appropriately using LSDYNA's shell and solid elements. Since the rack is submerged under the water when an impact occurs, the water-structure interaction might need to be considered. Confirm whether the water-structure interaction has been accounted for or provide an explanation why this effect is not important.

Westinghouse Response:
The fuel assembly drop analyses conservatively neglect the water-structure interaction in the wake of an impact. By assuming that the impact occurs in air, as opposed to water, none of the impact energy is diverted to fluid kinetic energy (i.e., fluid damping), which would attenuate the deformation to the fuel rack.

References:

1. APP-GW-GLR-033, Revision 0, “Spent Fuel Storage Rack Structural/Seismic Analysis,” (Technical Report Number 54)
2. APP-FS02-Z0C-001, Revision 0,”Analysis of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents”

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

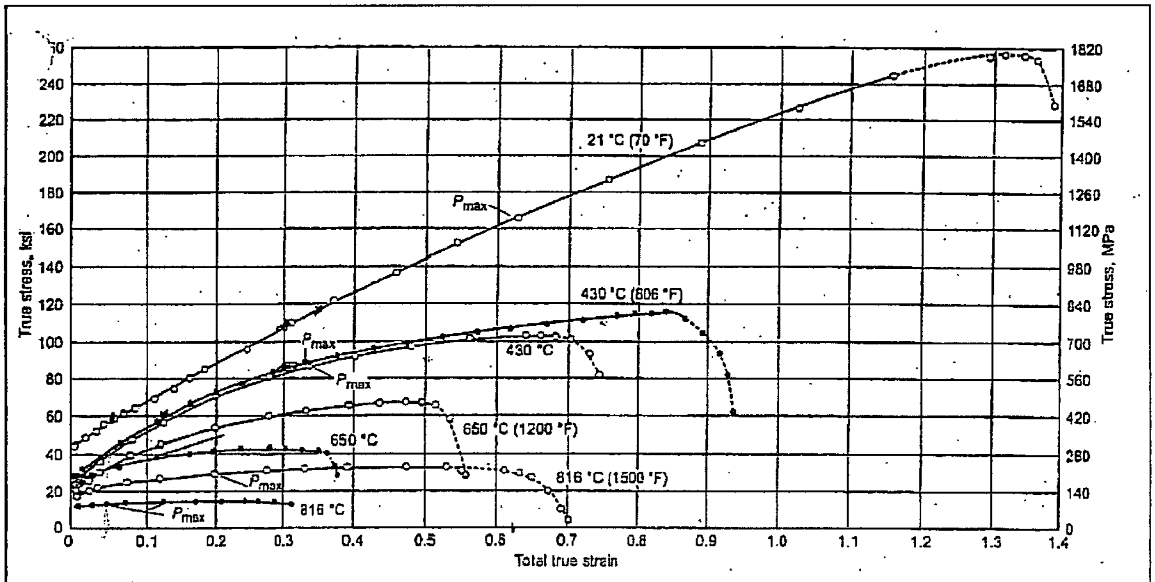
RAI Response Number: RAI-TR54-5
Revision:

Question:

Section 2.8.5 states that appropriate non-linear material properties have been applied to the rack components to permit yielding and permanent deformation. Table 2-6 only provides Young's modulus, yield strength, and ultimate strength, which are not sufficient to define an engineering stress-strain curve. In addition, LSYDYNA requires true stress-strain relation for its nonlinear materials. Therefore, provide the following: (1) a complete description of the material stress-strain curve and confirm that a true stress-strain curve was used in these impact analyses and (2) a description of the fuel assembly model, including the element properties and material properties for the dropped fuel assembly.

Westinghouse Response:

1) The spent fuel racks are fabricated from SA240-304 and SA564-630 stainless steel. For the impact analyses, a true-stress strain curve, which is obtained from Atlas of Stress Strain Curves (2nd Edition, ASM International) and reproduced below as Figure TR 54-5.1, is used to define the strength properties of SA240-304 stainless steel.



SS.044 304 annealed stainless steel bar, true stress-strain curves at room and elevated temperatures

Figure TR 54-5.1 Stress-Strain Curve for SA240-304

The properties of SA564-630, which is used to fabricate the adjustable support pedestals, are input in terms of engineering stress/strain based on material data taken from the ASME Boiler and Pressure Vessel Code. Also, the welds that connect the rack components are modeled as a bi-linear elasto-plastic material having the engineering stress/strain properties of the adjoining base metal (i.e., SA240-304). The material property values, which are used to define the engineering stress-strain curves for SA564-630 stainless steel and the structural welds, are summarized in the table below.

Material Properties	**Material Types**	
	SA240-304 (Welds)	**SA564-630**
Young's Modulus ($10^6 \times$ psi)	27.87	28.77
Yield Stress (ksi)	26.7	109.2
Ultimate Stress (ksi)	73.0	140.0
Failure Strain (in/in)	0.4	0.14

2) The fuel assembly is modeled by a rigid bottom end fitting and a mass at the top (representing the weight of lifting tool) connected by an elastic beam (with a Young's modulus of 1.04×10^7 psi and a Poisson's ratio of 0.3 for typical rod material) that has an equivalent mass and total cross-sectional area of all fuel rods in an AP1000 fuel assembly. In addition, a very thin rigid shell is attached to the bottom end fitting to represent the side surfaces of the fuel assembly that might be in contact with rack cell walls in a shallow drop event. To maximize the damage in the rack, the fuel assembly is only allowed to move in the vertical direction.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-Z0C-001, Revision 0, "Analysis of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-6
Revision:

Question:

The baseplate in Figures 2-7 and 2-8 appears to have only one layer of 8 node brick element through its thickness. It is not clear if a solid or a thick shell element is used. Clarify the type of element used for the baseplate.

Westinghouse Response:

The baseplate is modeled using 8-noded solid elements arranged in a single layer.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-S3C-002, Revision 0, "Spent Fuel Storage Racks Structural/Seismic Analysis"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-7
Revision:

Question:

Section 2.8.5 indicates that the baseplate of the rack is connected to the cells by appropriate welding. However, the cells are described in Sections 2.1.1.1 and 2.1.1.2 as resting on top of the baseplate. Welded connections between the cells and the baseplate would greatly increase the strength of the whole rack system. To assist the staff in its review,

a) Confirm there is a welded connection between the baseplate and the cells.

b) Describe the design details of this connection.

c) Describe how this connection is modeled in LSYDYNA.

Westinghouse Response:

a) The base of every storage cell is welded to the rack baseplate.

b) Each cell is welded to the baseplate on four sides by 1/16" fillet welds having a minimum length of 7".

c) The cell-to-baseplate weld connection is modeled in LS-DYNA by shell elements, which join the bottom of the cell and the baseplate top surface, with a thickness equal to the corresponding throat dimension of the weld.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-Z0C-001, Revision 0,"Analysis of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents"

Design Control Document (DCD) Revision:

None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-10
Revision:

Question:

A vertical movement of 2 in. of a fuel assembly is defined as the criticality limit in Section 2.8.5, and the impact analysis shows that quite a number of fuel assemblies will have more than 2 in. displacement. It appears that a rack design with only a 2 in. space between the bottom of the baseplate and the top of the floor would eliminate this risk. Please explain why the design has a space larger than 2 in.

Westinghouse Response:

Each spent fuel pool rack storage cell is 199.5 (± 0.0625) inches in length and rests on top of a base plate whose top is 5 inches above the spent fuel pool liner. Note that each Metamic poison panel is 172 inches long and has a bottom elevation that is 6.23 inches above the top of the base plate. The active fuel region of each fuel assembly begins at an elevation 8.23 inches above the top of the base plate. Therefore, the bottom elevation of the Metamic poison panel is positioned to be two inches lower than the bottom elevation of the active fuel.

Therefore, the results of the criticality analyses are bounding even if the fuel assembly is vertically displaced downward by up to two inches as a result of the hypothetical fuel assembly drop. The two inch vertical displacement of the fuel assemblies, mentioned above in TR54-10, is not a criticality limit.

The criticality analyses summarized in COL Technical Report APP-GW-GLR-029 Revision 0 "Spent Fuel Criticality Analysis" addressed the hypothetical fuel assembly drop in subsection 2.4.6.3 as follows:

A fuel assembly (with a control rod and attached to the fuel assembly handling tool) is dropped and impacts the baseplate as discussed in subsection 2.8.5. The analysis in subsection 2.8.5 indicates that the base plate deformation will result in the active fuel vertically dropping a maximum of 3.5 inches. For conservatism, the fuel assemblies in 9 storage cell locations will be modeled as vertically dropped by 3.5 inches.

This fuel mishandling event produced a lower reactivity increase than the other postulated accidents. Therefore, the soluble boron necessary to compensate for a more limiting fuel mishandling event covers the hypothetical fuel assembly drop.

Since the criticality analysis demonstrates that the stored fuel assemblies remain subcritical following a hypothetical fuel assembly drop, the space between the bottom of the baseplate and the top of the floor is not designed to control criticality, but to protect the SFP liner from an impact strike. In other words, the rack baseplate is raised high enough above the floor (4.25") to prevent the baseplate from contacting the SFP liner when it deforms under impact.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-GW-GLR-029 Revision 0 "Spent Fuel Criticality Analysis," (Technical Report Number 65)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-11
Revision:

Question:

Figure 2-9 of this report shows the permanent deformation at the top of a cell wall at Region 2. The permanent deformation is measured as 20 in., which is just slightly smaller than the limit of 20.5 in. Since the deformation at the impact location is so close to the limit (i.e., very little margin exists), the mesh should be locally refined, to ensure convergence with mesh size. Therefore, an additional analysis with a finer mesh at the impact region should be performed to confirm that the model is suitable.

Westinghouse Response:

The general acceptance criterion for the 36" fuel assembly drop onto the top of a Region 2 rack is to maintain the stored fuel assemblies in a subcritical configuration. In measurable terms, the permanent deformation of the rack (measured downward from the top of rack) is limited of 20.5", which is equal to the distance from the top of the rack to the top of the neutron absorber panel. This limit is conservative because the active fuel region begins two inches below the top of the neutron absorber panels. Therefore, more margin exists than Technical Report APP-GW-GLR-033 indicates, and a mesh convergence study is not required.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-16
Revision:

Question:

The Westinghouse Report APP-GW-GLR-033, Rev. 0, appears to be a summary type report. However, to adequately perform a technical review of the analysis and design of the spent fuel racks, a more detailed report should have been submitted, similar to those provided in past technical reviews of spent fuel racks for specific nuclear power plants. Therefore, provide the detailed spent fuel storage rack report/calculation for review prior to the planned audit. This type of report has been provided in past reviews; its submittal prior to scheduling the on-site audit may resolve many of the RAIs, and would make the audit much more productive.

Westinghouse Response:

Westinghouse Report APP-GW-GLR-033, Rev. 0, is a summary type report. There are two calculations that form the basis for this COLA Technical Report. The NRC can review these calculations prior to the NRC Audit in mid-April. This can be done either at the Westinghouse Energy Center or at the Westinghouse Rockville Office. Please advise Westinghouse if the NRC would like to review these calculations prior to the mid-April Audit.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-17
Revision:

Question:

Insufficient data is provided regarding the input loads used for the seismic analysis of the spent fuel racks. The following information is requested:

a. Floor response spectra (X, Y, and Z - vertical directions) at or the near the elevation of the top of the fuel racks and near the bottom of the fuel rack or pool floor corresponding to the damping value used for the analysis.

b. Explain why the envelope of these two sets of spectra was not used.

c. The current DCD is applicable for the hard rock site. Therefore, provide further explanation for the range of soil and rock properties used in enveloping the seismic floor spectra. Where are these range of soil/rock properties specified for confirmation by future combined license applicant?

d. For the synthetic time histories, provide plots of the three time histories, the cross correlation coefficients, the comparisons of the spectra from the synthetic time histories to the enveloped target response spectra, and the comparisons of the power spectral density plots to the target power spectral density function associated with the target response spectra.

e. Which time history was used (displacement, velocity, or acceleration)? Were all three directions input simultaneously? Was gravity included in the time history analysis?

Westinghouse Response:

a. Floor response spectra (X, Y, and Z - vertical directions) near the elevation of the bottom of the spent fuel pool floor corresponding to the damping value used for the analysis are provided in the PDF attachment RAI TR54-17a. No floor response spectra are provided near or at the elevation of the top of the spent fuel racks (See response to TR54-17b).

The ASB99 floor response spectra (FRS) represents the enveloping response spectra for the auxiliary and shield building (ASB) at elevation 99 feet for a range of soil/rock condition. FRS of various soil/rock analyses were first enveloped for various locations of the ASB. All of the ASB locations at elevation 99 were then grouped and enveloped to develop the ASB99 floor response spectra. The spent fuel pool is at a lower elevation but the dynamic response is essentially the same as at elevation 99 feet.

b. The spent fuel racks are free-standing in the spent fuel pool. They are not anchored to the spent fuel pool walls. The spent fuel racks are excited in a seismic event by the floor response spectra representing the spent fuel pool floor (ASB99). There is no need to envelope multiple sets of floor response spectra.

c. The range of soil and rock conditions for which the seismic floor spectra applies is described in Westinghouse Technical Report APP-GW- GLR-015 Rev. 1, "Extension of NI Structures Seismic Analysis to Soil Sites"

d. The synthetic time histories, the response spectrum curves, and the power spectral density plots for the Auxiliary and Shielding Building (ASB) at Elevation 99 feet are provided in Figures TR54-17.1 through TR54-17.9. The cross correlation coefficients for the three orthogonal components (East-West, North-South, and Vertical) of the ASB99 synthetic time histories are summarized in the table below.

Description	**Cross Correlation Coefficient**
East-West to North-South	-0.0414
East-West to Vertical	0.0088
North-South to Vertical	0.0536

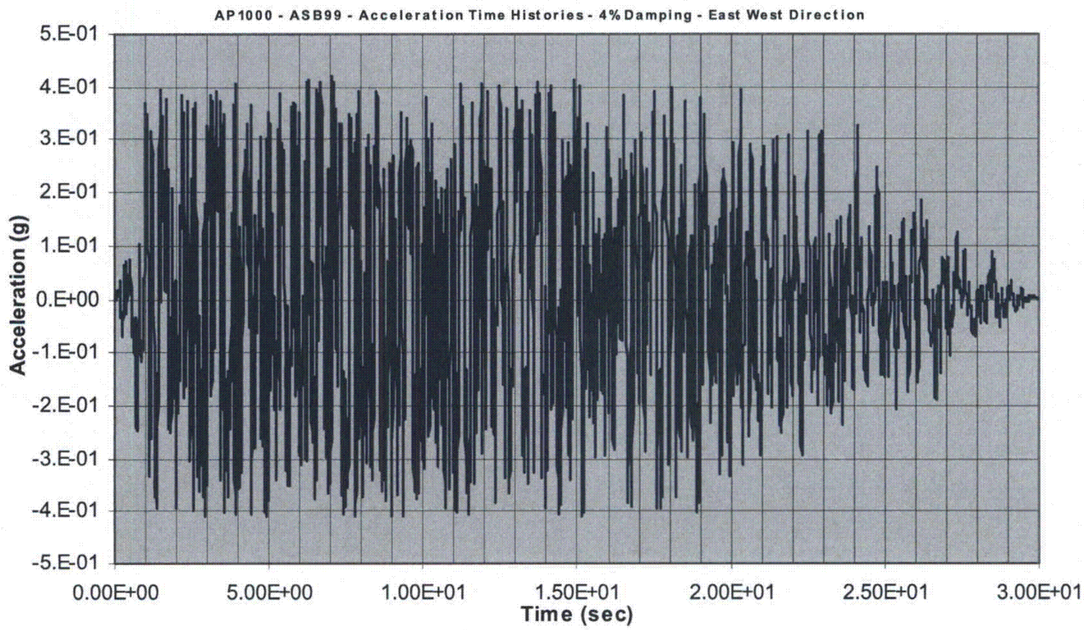


Figure TR54-17.1 ASB99 Acceleration Time History for EW Direction

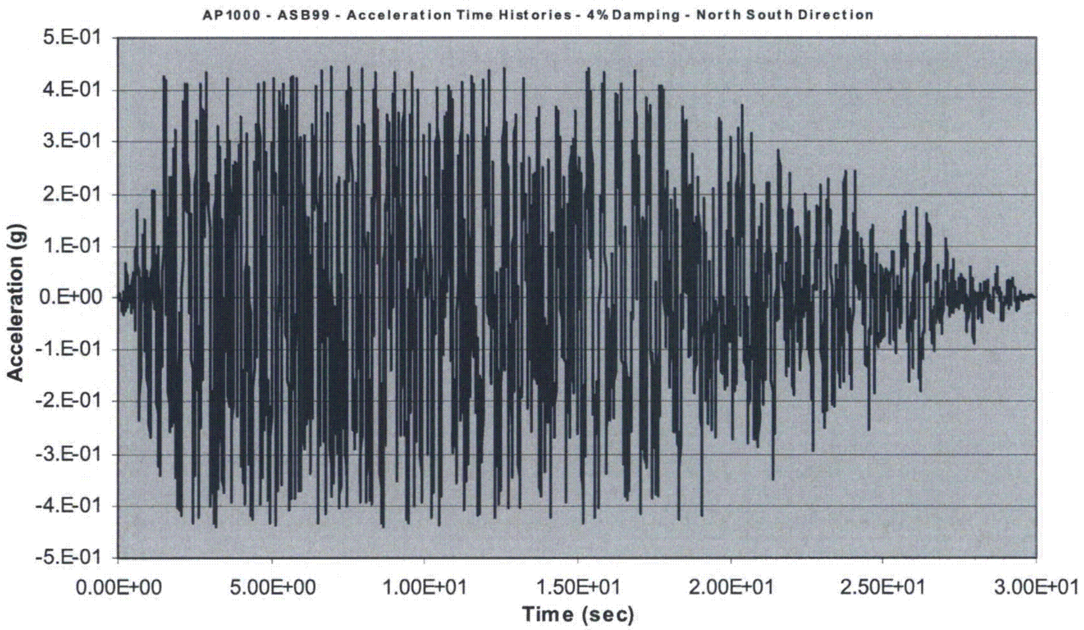


Figure TR54-17.2 ASB99 Acceleration Time History for NS Direction

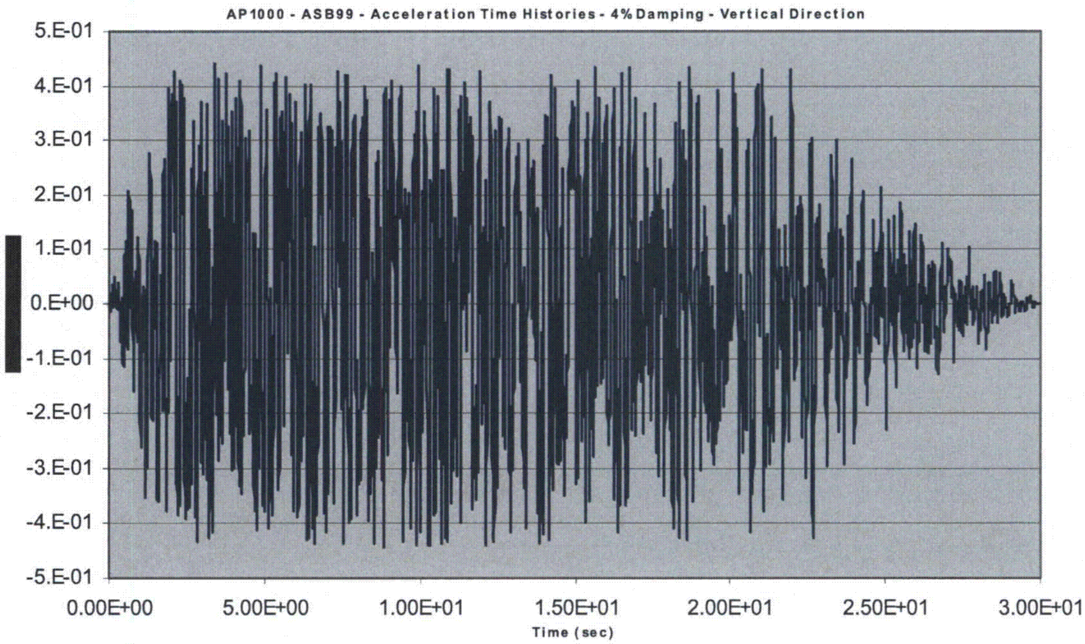


Figure TR54-17.3 ASB99 Acceleration Time History for VT Direction

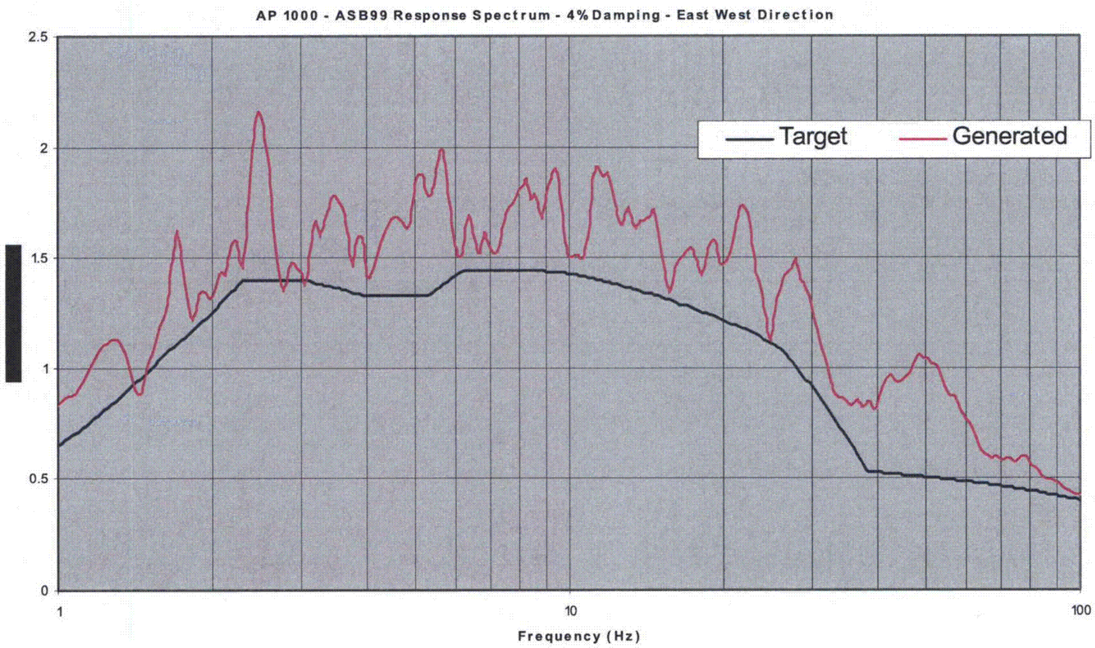


Figure TR54-17.4 ASB99 Response Spectrum for EW Direction

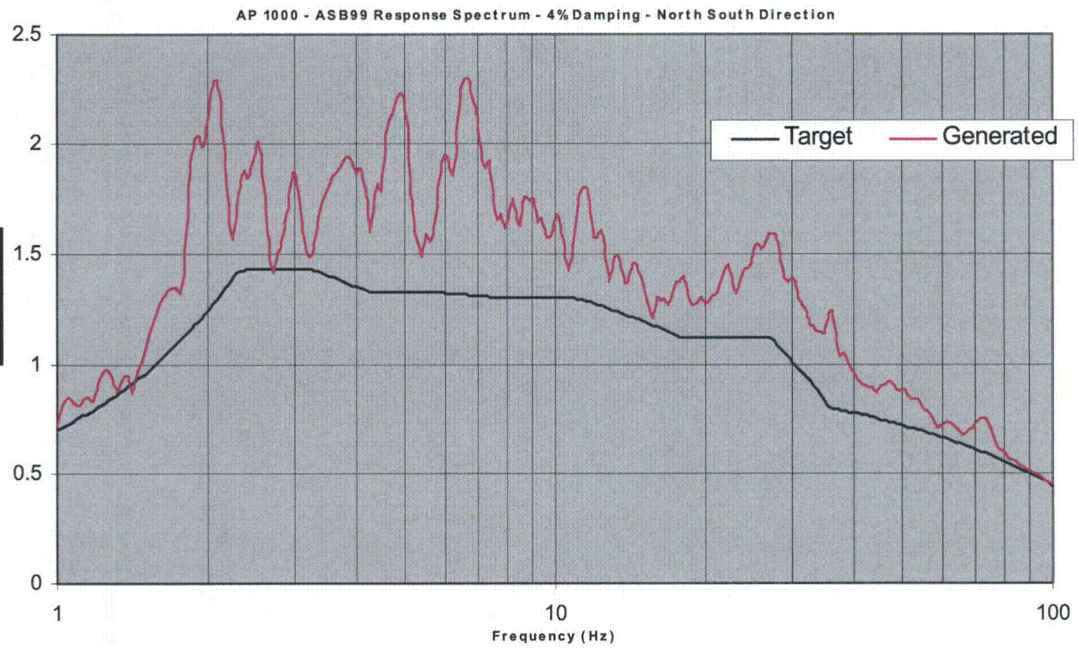


Figure TR54-17.5 ASB99 Response Spectrum for NS Direction

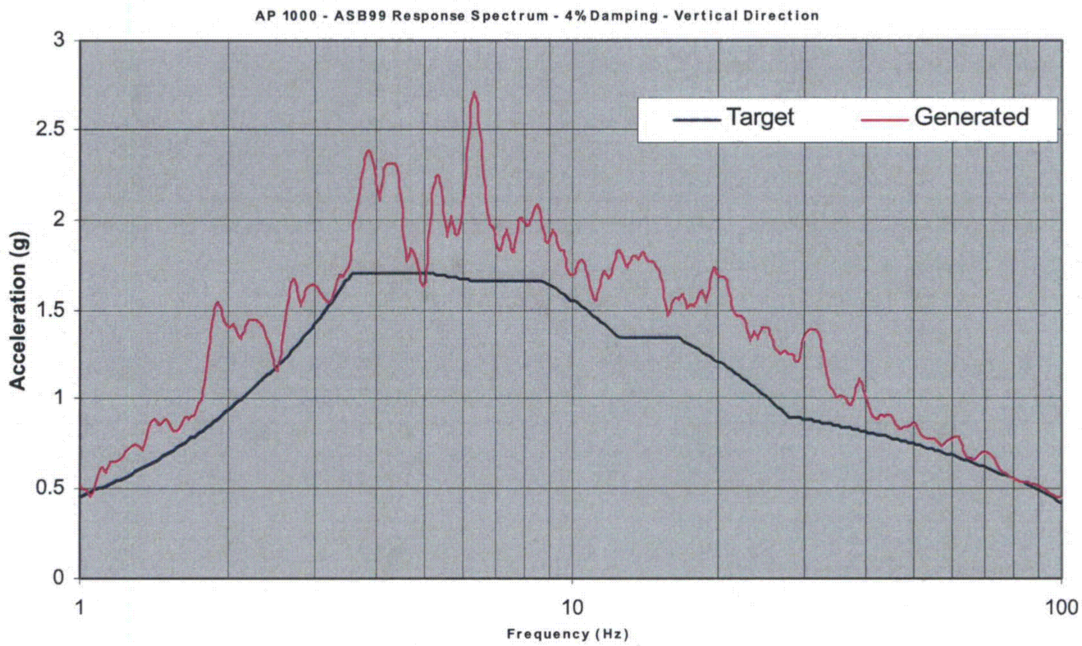


Figure TR54-17.6 ASB99 Response Spectrum for VT Direction

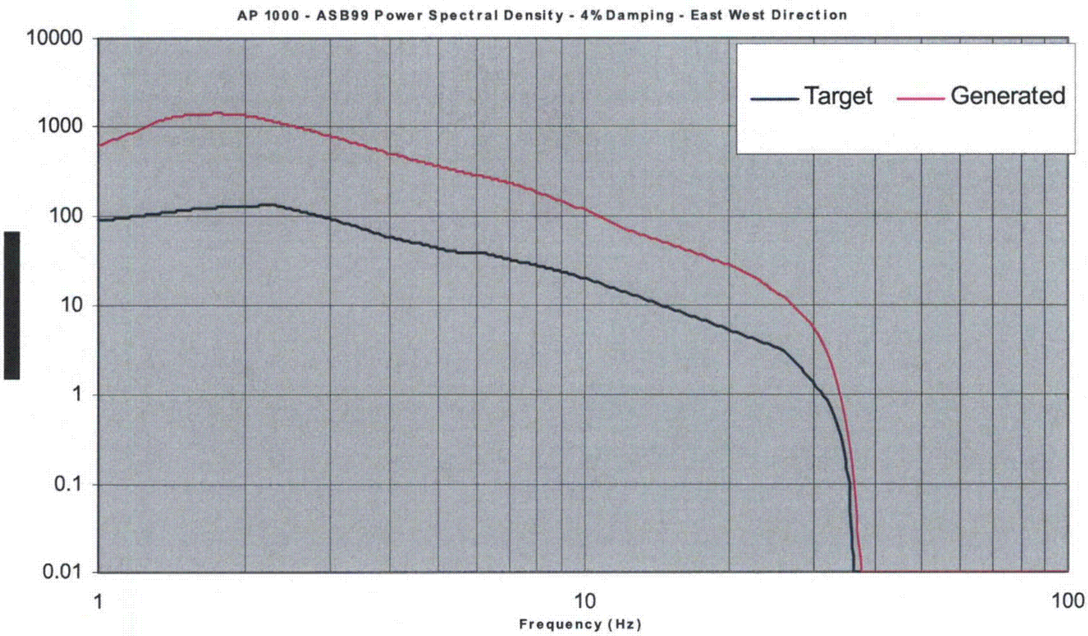


Figure TR54-17.7 ASB99 Power Spectral Density for EW Direction

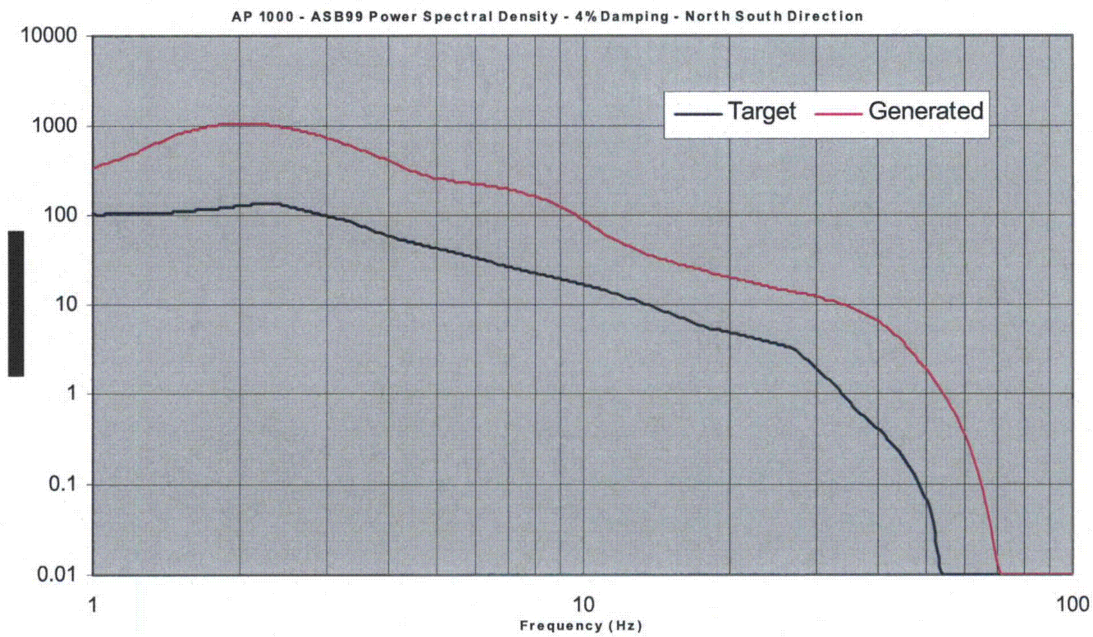


Figure TR54-17.8 ASB99 Power Spectral Density for NS Direction

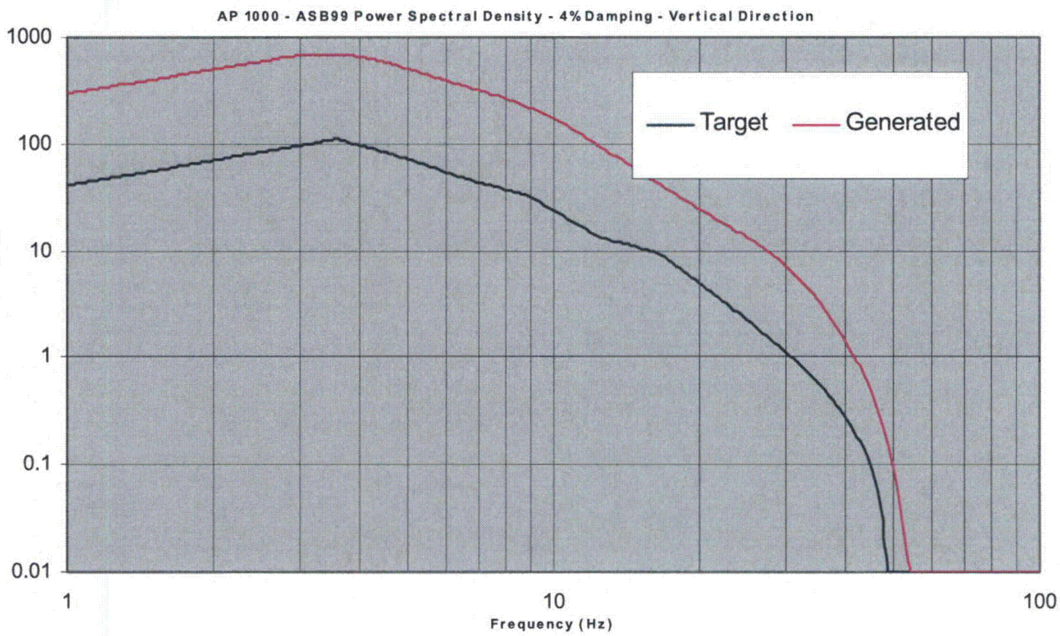


Figure TR54-17.9 ASB99 Power Spectral Density for VT Direction

e. Acceleration time histories are used as the input motion for the seismic analysis of the spent fuel racks. The acceleration input is defined by three orthogonal components, which are input and solved simultaneously. Gravity is also included in the time history analysis.

References:

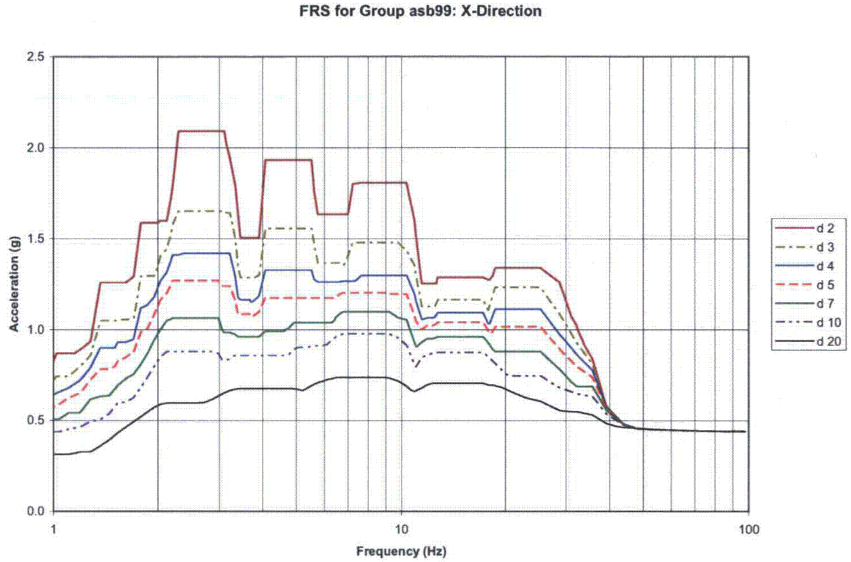
1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-GW- GLR-015, Revision 1, "Extension of NI Structures Seismic Analysis to Soil Sites," (Technical Report 03, Revision 1)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

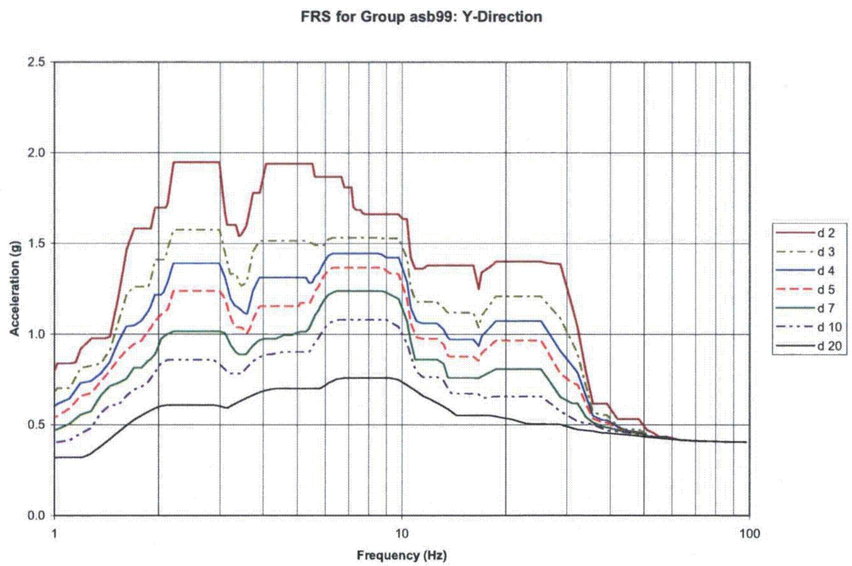
Technical Report (TR) Revision:
None

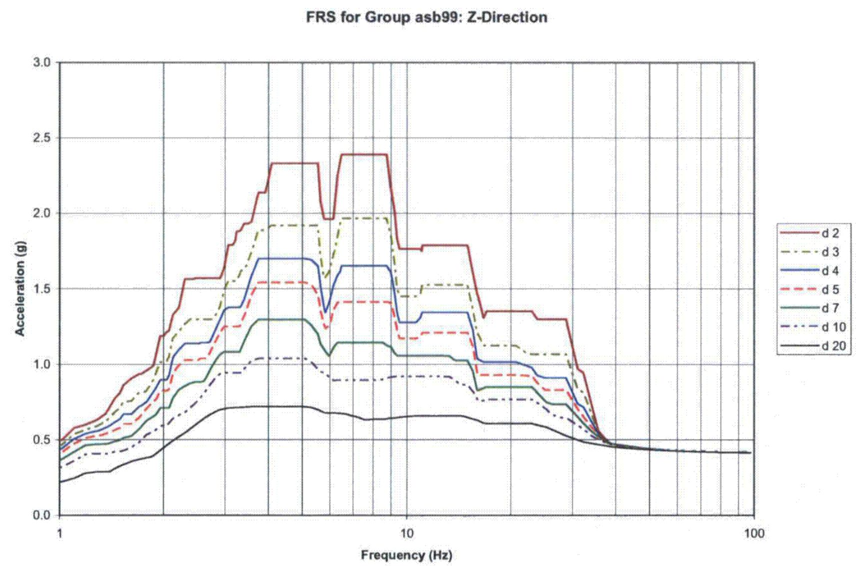
ASB99 Group FRS and Seismic Anchor Motions



ASB99 Group
Seismic Anchor Motions (inches)

	x	*y*	*z*
ASB99	0.060	0.086	0.035





AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-19
Revision:

Question:

Section 2.2.1, first paragraph indicates that the response of the freestanding rack involves a complex combination of motions (sliding, rocking, twisting, and turning). Explain the difference between twisting and turning.

Westinghouse Response:

Twisting refers to an elastic deformation mode wherein the top of the rack rotates relative to the rack baseplate (i.e., torsion). Turning refers to a rigid body mode of displacement wherein the rack rotates about a vertical axis. For example, the rack may pivot (or turn) about a support pedestal.

Reference:

1. APP-GW-GLR-033, Revision 0, “Spent Fuel Storage Rack Structural/Seismic Analysis,” (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-20
Revision:

Question:

Explain the reason for the different type racks (i.e., Region I and Region II). If it is because of different fuel assembly types, then explain how the analysis considers the various types and combinations of fuel assemblies (e.g., mass, sizes, gaps, fluid coupling, etc.).

Westinghouse Response:

The AP1000 uses only one fuel assembly type. The purpose of the Region I racks is to provide storage for up to 243 fresh fuel assemblies with a maximum initial enrichment up to 5.0 w/o U-235. This is accomplished by spacing these storage cells on a pitch equal to 10.9 inches and employing a "flux trap" poison configuration between consecutive storage cells.

The purpose of the Region 2 storage racks is to provide storage for up to 646 fuel assemblies in a high density configuration. These storage cells employ a pitch equal to 9.028 inches and a single poison panel separates consecutive fuel assemblies. Reactivity credits for assembly burnup, plutonium decay time, and soluble boron are employed in order to qualify fuel assembly storage in the Region 2 storage racks.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-GW-GLR-029, Revision 0, "Spent Fuel Criticality Analysis," (Technical Report Number 65)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-22
Revision:

Question:

A number of sections in the report refer to analytical methods in other references, rather than providing sufficient information to explain the approaches used. Therefore, to understand the modeling and analysis approach, provide references 10, 11, 16 and 18.

Westinghouse Response:

References 10, 16 and 18 are attached to this RAI as PDFs. Reference 11 will be available for review at the mid-April audit at Westinghouse.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-23
Revision:

Question:

Section 2.2.2.2 of the report describes some modeling information for a single rack. It indicates that the rack cellular structure elasticity is modeled by a 3-D beam having 3 translational and 3 rotational degrees-of-freedom (DOFs) at each end so that two-plane bending, tension/compression, and twist of the rack are accommodated. Explain why shear stiffness/deformation is not also included. Provide more detailed information about how the beam model of the rack was developed, considering that it is an assembly of many square-celled structures welded at discrete locations.

Westinghouse Response:

Shear deformation is included in the rack dynamic model. The beam model of the rack was developed based on the applicable Codes, Standards and Specifications given in Section IV(2) of the NRC guidance on spent fuel pool modifications entitled, "Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14, 1978, which states that "Design ... may be performed based upon the AISC specification or Subsection NF requirements of Section III of the ASME B&PV Code for Class 3 component supports." The rack modeling technique is consistent with the linear support beam-element type members covered by these codes.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. NRC Letter dated April 14, 1978, Section IV (2), "Review and Acceptance of Spent Fuel Storage and Handling Applications"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-28
Revision:

Question:

Even though a time history analysis was performed, good engineering practice is to also perform a modal analysis for a fixed base single rack to understand its dynamic characteristics. Was this done and what are the natural frequencies and corresponding mode shapes?

Westinghouse Response:

A modal analysis of a fixed base single rack has not been performed; this type of linear analysis cannot accurately predict the non-linear response of a freestanding rack to seismic excitation.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-34
Revision:

Question:

Section 2.3.5 of the report discusses dimensionless stress factors. It states that "R_1 is the ratio of direct tensile or compressive stress on a net section to its allowable value (note pedestals only resist compression)." Explain why this indicates that pedestals only resist compression, since horizontal forces are also generated due to friction during a seismic event? These forces could be quite high and also would introduce shear and moments into the pedestal and rack structure.

Westinghouse Response:

Section 2.3.5 of the report defines seven stress factors (R_1 through R_7), which correspond to the ASME Code Section III, Subsection NF stress limits for Class 3 components. R_1 is defined as the ratio of direct tensile or compressive stress on a net section to its allowable value. Since the spent fuel racks are freestanding, the *net cross section* of the support pedestals can only be subjected to direct compressive stress. This is the explanation for the note in parentheses. Moreover, it is absolutely true that horizontal forces are generated due to friction between the support pedestals and the SFP floor and that these forces produce shear and bending stresses in the pedestals. The shear and bending stresses in the support pedestals, as well as the combined compression and bending stress, are measured by the other six stress factors (i.e., R_2 through R_7), which are defined in Section 2.3.5 of the report.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None