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Your ref: Docket No. 52-006
Our ref: DCP/NRC2121

April 18, 2008

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

Westinghouse is submitting four sets of revised 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 in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the responses are generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

The revised responses are provided for requests for additional information TR54-14, TR54-15, TR54-16, TR54-17, TR54-21, TR54-27, TR54-29, TR54-30, and TR54-35 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). Responses to these RAIs were originally provided in Westinghouse letters DCP/NRC1890 dated May 17, 2007, DCP/NRC1891 dated May 17, 2007, DCP/NRC1860, dated April 9, 2007, and DCP/NRC1929 dated June 8, 2007.

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.

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

D063
NRO

00361psa.doc

/Attachment

1. "Oath of Affirmation," dated April 18, 2008

/Enclosures

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

cc:	M. Miernicki	-	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
	G. Zinke	-	NuStart/Entergy	1E	1A
	E. Schmiech	-	Westinghouse	1E	1A
	J. Iacovino	-	Westinghouse	1E	1A

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)

AP1000 Design Certification Amendment Application)

NRC Docket Number 52-006)

APPLICATION FOR REVIEW OF
"AP1000 GENERAL INFORMATION"
FOR DESIGN CERTIFICATION AMENDMENT 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
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 18th day
of April 2008.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Patricia S. Aston, Notary Public
Murrysville Boro, Westmoreland County
My Commission Expires July 11, 2011
Member, Pennsylvania Association of Notaries

Notary Public

ENCLOSURE 1

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

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-14
Revision: 1

Question:

In accordance with Standard Review Plan (SRP) 3.8.4, App. D, and as indicated in Table 2-5 of the report and the markup for DCD Table 9.1-1, one of the fuel handling accident loads that need to be considered is uplift force on the rack caused by a postulated stuck fuel assembly. Section 2.8.3 of the report states: "An evaluation of a stuck fuel assembly, leading to an upward load of 2,000 lb has been performed. The results from the evaluation show that this is not a bounding condition because the local stresses do not exceed 2,500 psi." The information provided is not sufficient for the staff to reach a conclusion that this load has been adequately considered. Please provide a detailed description of the assumptions, the analyses conducted, the results obtained, and the basis for the conclusion that this is not a bounding condition.

October 8-12, 2007 Audit: ~~Audit~~ Items 2 and 3 below are unresolved since no further information was available~~-~~.

(2) Provide a calculation on the adequacy of the vertical welds along the height between adjoining cells and the horizontal welds at the base (cell walls to baseplate). If the stress levels are higher than those currently presented in the response, then revise the Technical Report accordingly.

(3) The two sentence description of the stuck fuel assembly is presented in Section 2.8.3- "Dead Load Evaluation" of the Technical Report. A more detailed description comparable to the information given in the RAI response should be included in a more appropriate section of the Technical Report since this loading is a fuel handling accident condition not a dead load evaluation.

In addition, W indicated that they will re-evaluate the use of 5,000 lbs (rather than the current 2,000 lbs.) for the uplift force in the Holtec calculations, RAI response, and TR-54 in order to be consistent with the DCD.

Westinghouse Response:

A nearly empty rack with one corner cell occupied is subject to an upward load of 2000 lbf, which is assumed to be caused by the fuel sticking while being removed. The ramification of the loading is two-fold:

1) The upward load creates a force and a moment at the base of the rack;

2) The loading induces a local tension in the cell wall.

The following calculation, which is excerpted from Holtec Report No. HI-2063523, Spent Fuel Rack Structural/Seismic Analysis for Westinghouse AP1000, Rev. 0 (APP-FS02-S3C-001 Rev. 0), determines the maximum stress in the rack cell structure due to a postulated stuck fuel assembly. The terms p, Nx, Ny, Ixx2, and Iyy2 are defined as the cell pitch, the number of storage cells in the horizontal x-direction, the number of storage cells in the horizontal y-direction, the moment of inertia of the rack cell structure about the x-axis, and the moment of inertia of the rack cell structure about the y-axis, respectively.

The term b_e represents the effective width of a cell wall, which is determined in accordance with paragraph NF-3222.2 of the ASME Code, Section III, Subsection NF. The term t_e represents the effective thickness of a cell wall, which for a Region 2 rack is equal to one-half the actual thickness since each cell wall is shared by the adjacent two cells.

Calculation of the Effect of a Stuck Fuel Assembly

$P_{stuck} := 2000 \cdot lbf$ Per Westinghouse design input

Compute maximum stress at base of rack cell structure assuming rack behaves as a cantilever beam

$X := N_x \cdot \frac{p}{2}$ $X = 4.514\ ft$ $I_{xx2} = 9.585 \times 10^4\ in^4$

$Y := N_y \cdot \frac{p}{2}$ $Y = 3.762\ ft$

$\sigma_{grid} := P_{stuck} \cdot \frac{X^2}{I_{xx2}} + P_{stuck} \cdot \frac{Y^2}{I_{yy2}}$ $\sigma_{grid} = 91.12\ psi$

It is clear that the global stress due to a stuck fuel assembly is insignificant. Now, check local stress in cell in tension. Conservatively using the effective width

$A_{celllocal} := 4 \cdot b_e \cdot t_e$ $A_{celllocal} = 0.731\ in^2$

$\sigma_{local} := \frac{P_{stuck}}{A_{celllocal}}$ $\sigma_{local} = 2.736 \times 10^3\ psi$

This local stress is well below the yield stress of the cell wall material (i.e., 21,300 psi per Table 2-6). ~~The value of 2,500 psi will be changed in Subsection 2.8.3 to 3,000 psi for the local stresses resulting from a stuck fuel assembly.~~

The following calculations demonstrate the adequacy of the vertical welds along the height between adjoining cells and the horizontal welds at the base (cell walls to baseplate) to resist the stuck fuel assembly load.

Cell to cell welds

Each storage cell in both the Region 1 and Region 2 spent fuel racks is welded vertically along its height to the adjoining cells by a series of 6" long intermittent fillet welds. The total length of weld over the height of a storage cell, along one corner of the cell, is 36". For conservatism, the entire stuck fuel assembly load is assumed to be resisted by only two 6" long fillet welds at the very top of the rack. Based on this approach, the stress in the cell to cell welds is calculated as follows:

Length of intermittent fillet weld $L_{weld} := 6 \cdot in$

Size of intermittent fillet weld $t_{weld} := \frac{1}{16} \cdot in$

Number of fillet welds that resist load $N := 2$

Effective throat area of fillet welds $A_{weld} := N \cdot L_{weld} \cdot \frac{t_{weld}}{\sqrt{2}}$

$A_{weld} = 0.53\, in^2$

Shear stress in fillet welds $\tau := \frac{P_{stuck}}{A_{weld}}$

$\tau = 3771\, psi$

Per Section 2.3.4.1 of TR-54, the allowable weld stress under normal conditions is 0.3 times the material ultimate strength. From Table 2-6 of TR-54, the ultimate strength of SA240-304L material at 200F is 66,200 psi. Therefore, the allowable weld stress under normal conditions is 0.3 x 66,200 psi = 19,860 psi, which is significantly greater than the weld stress calculated above.

Cell to baseplate welds

Each storage cell in both the Region 1 and Region 2 spent fuel racks is welded to the base plate by four 7" long fillet welds. Since the total length of weld associated with cell to baseplate connection (28") is greater than the length considered in the above cell to cell weld evaluation (12"), and the weld size is the same (1/16"), the stress in the cell to baseplate welds is bounded by the preceding stress calculation for the cell to cell welds.

The two sentence description of the stuck fuel assembly evaluation ~~has been~~will be deleted from Section 2.8.3 of the Technical Report and will be replaced by a more detailed description in the newly added Section 2.8.6 (Stuck Fuel Assembly Evaluation).

Finally,~~Item 4: T~~ the uplift force is being re-evaluated for 5,000lbs rather than the current 2,000lbs. This re-evaluation will appear in the revision of TR-54 addressing the new seismic response spectra.

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:
The two sentence description of the stuck fuel assembly evaluation will be deleted from Section 2.8.3 of the Technical Report and will be replaced by a more detailed description in the newly added Section 2.8.6 (Stuck Fuel Assembly Evaluation).These changes will appear in the revision of TR-54 addressing the new seismic response spectra.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-15
Revision: 1

Question:

Insufficient descriptive information has been included in the spent fuel report to permit an adequate review of the structural/seismic analysis of the spent fuel racks. As indicated in SRP 3.8.4, App. D, provide descriptive information including plans and sections showing the spent fuel racks and pool walls, liner, and concrete walls. All of the major features of the racks including the cell walls, baseplate, pedestals, bearing pads, neutron absorber sheathing, any impact bars, welds connecting these parts, and any other elements in the load path of the racks should be shown on one or several sketches. These sketches should also indicate related information which includes key: cutouts, dimensions, material thicknesses, and gaps (fuel to cell, rack to rack, rack to walls, and rack to equipment area). In addition to the above, for review of postulated fuel handling drop accident and quantification of the drop parameters, sketches with sufficient details for the fuel handling system should be provided to facilitate the review as indicated in SRP 3.8.4, App. D.

October 8-12, 2007 Audit:

Based on the original request made in the RAI, the review of the RAI response and the revised details in Section 9.1 of DCD Rev. 16, the following items still need to be provided or clarified in the TR and DCD:

(1) The key dimensions of the male and female pedestal components and bearing plates should be shown in the figures provided in the RAI response.

(2) The welds connecting the pedestals to the baseplate and the baseplate to the fuel cell walls are not shown. The information for the welds should indicate the type of the weld (e.g., fillet) and whether they are all around or the extent of the welds.

(3) Figure TR54-15.6 (in the RAI response) does not show any leak chase channels in the spent fuel pool floor. W indicated that there are leak chase channels; however they are not shown in rack layout figure. W confirmed that the fuel rack analyses did not consider the possible impact loading of a rack pedestal over the leak chase channel. Therefore, the staff request W to explain why the effects of the leak chase channel were not considered in the fuel rack analyses and the calculation that demonstrates the adequacy of the liner/concrete in the local region around the pedestal which is part of the TR report. Also, Figure TR54-15.6 which will be included in the TR should be revised to show the leak chase channels if they are used.

Westinghouse Response:

Westinghouse has provided sketches in the attachment to RAI TR54-15 response showing the major features of the racks and spent fuel pool. These sketches will be incorporated in Technical Report 54. Westinghouse has not finished the detailed design of fuel handling equipment and detailed sketches are not available at this time. However, the quantification of the drop parameters has been established in the DCD (both maximum drop weights and heights). The DCD drop heights are much greater than what is being designed for the fuel handling equipment. This is stated in the RAI-TR-54-1 response. During the NRC Structural/Seismic audit of April 16th, the complete design drawings of the spent and new fuel racks were available to the NRC for review. Holtec explained how the rack features were incorporated into the seismic/structural models.

October 8-12, 2007 Audit:

Westinghouse has revised the layout figures for Region 1 and Region 2 spent fuel racks as requested. These figures are presented below in the DCD Revision and TR Revision sections below. Leak chases are used in the spent fuel pool. The plates making up the spent fuel pool liner have been designed such that no rack pedestals are over leak chases.

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~~

The spent fuel rack figures in section 9.1 of DCD revision 16 are replaced with the following figures:

Figure 9.1-2 (Sheet 1 of 2) Region 1 Spent Fuel Storage Rack Layout

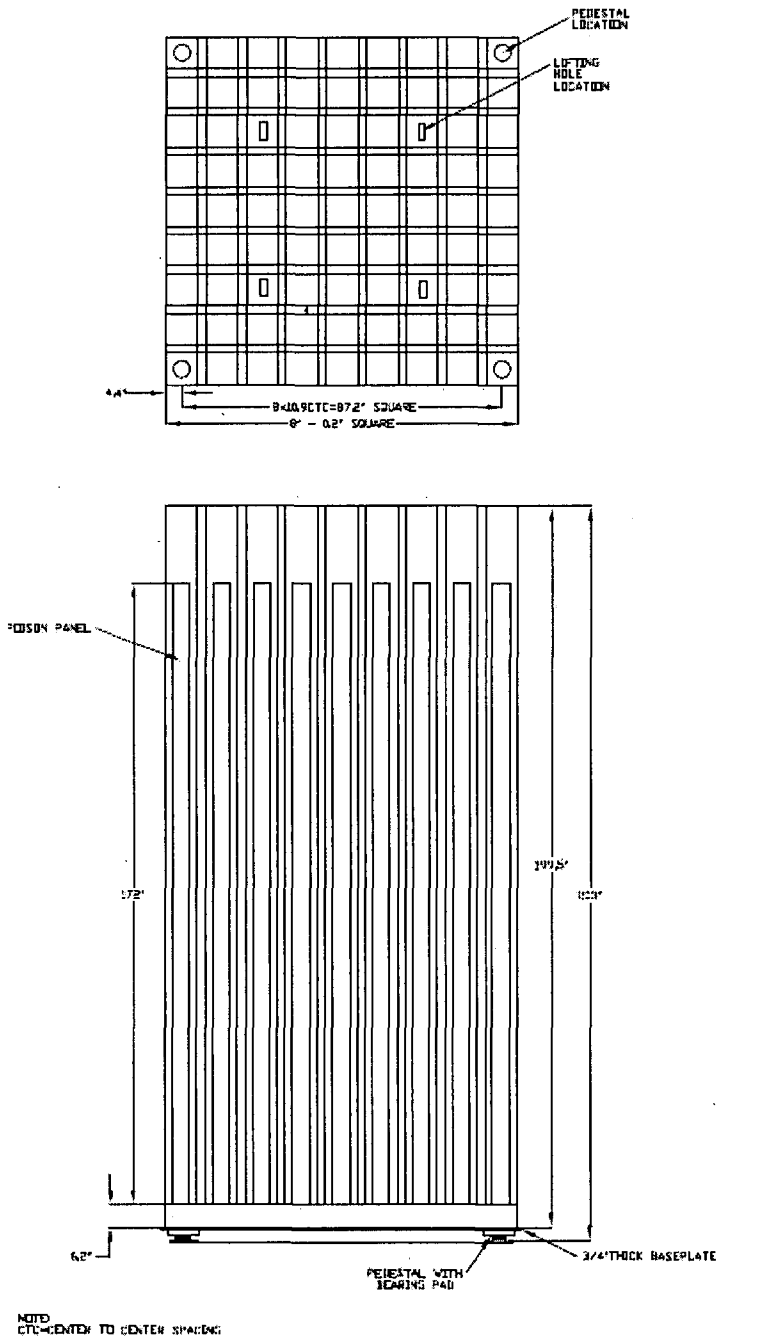


Figure 9.1-2 (Sheet 2 of 2) Region 1 Spent Fuel Storage Rack Cross Section

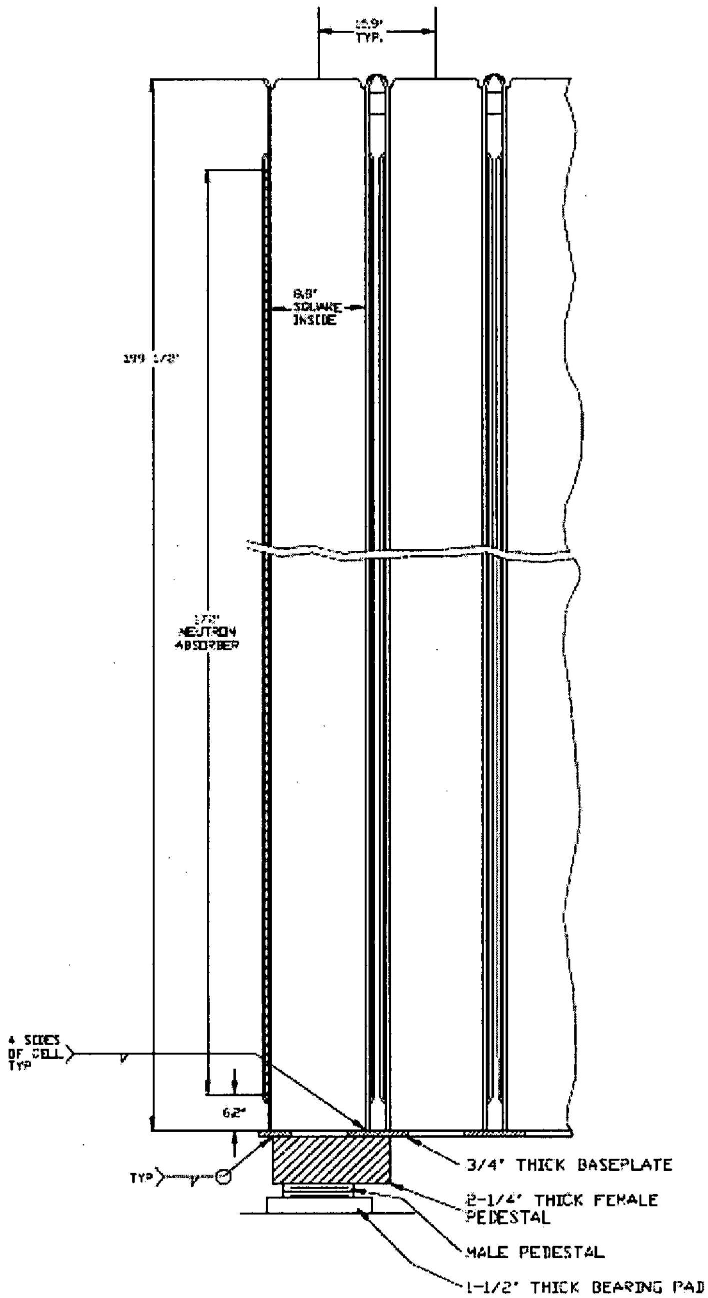
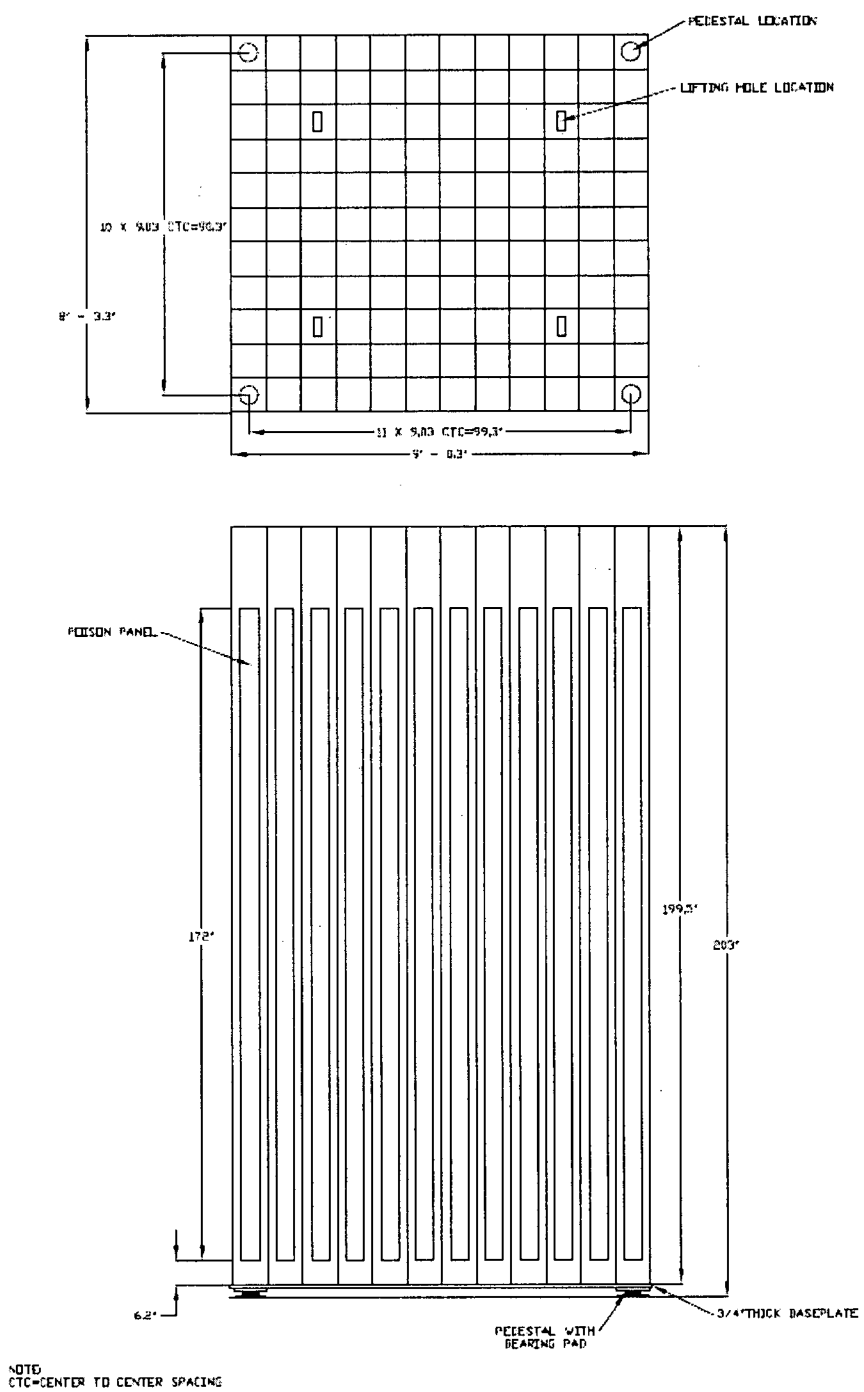


Figure 9.1-3 (Sheet 1 of 2) Region 2 Spent Fuel Storage Rack Layout



<u>Figure 9.1-3 (Sheet 2 of 2) Region 2 Spent Fuel Storage Rack Cross Section</u>

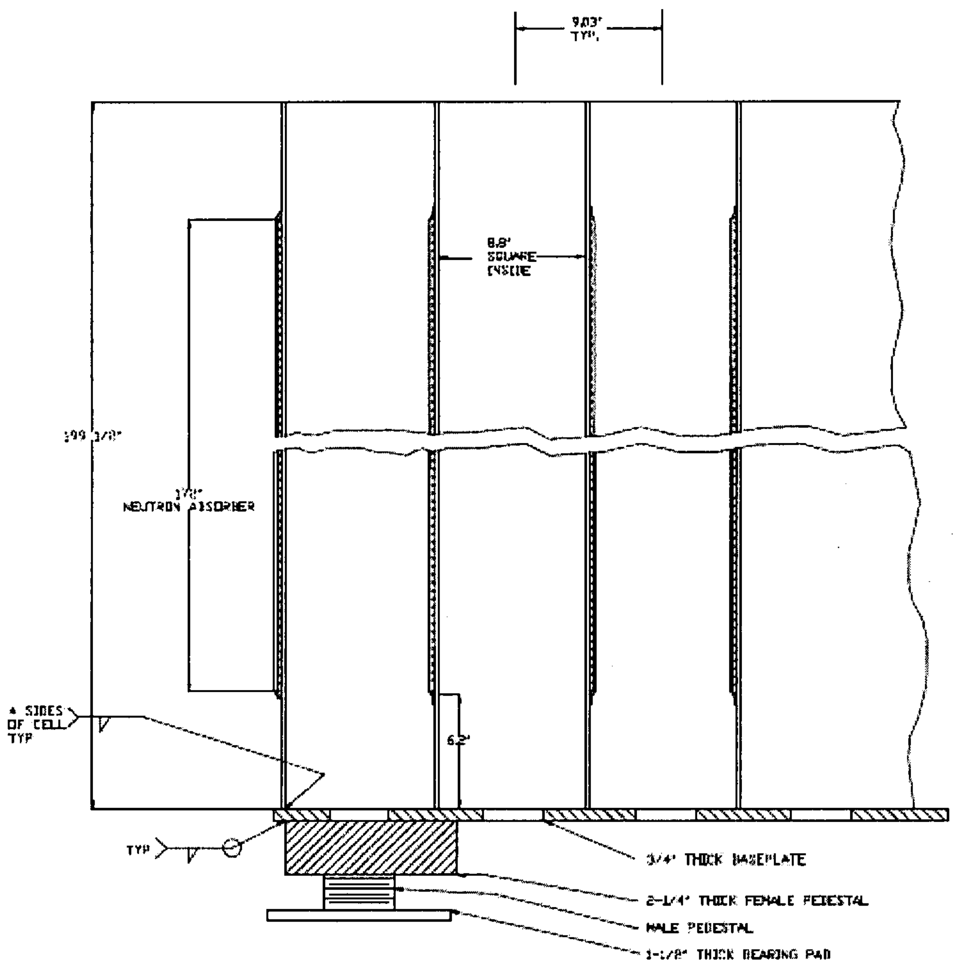
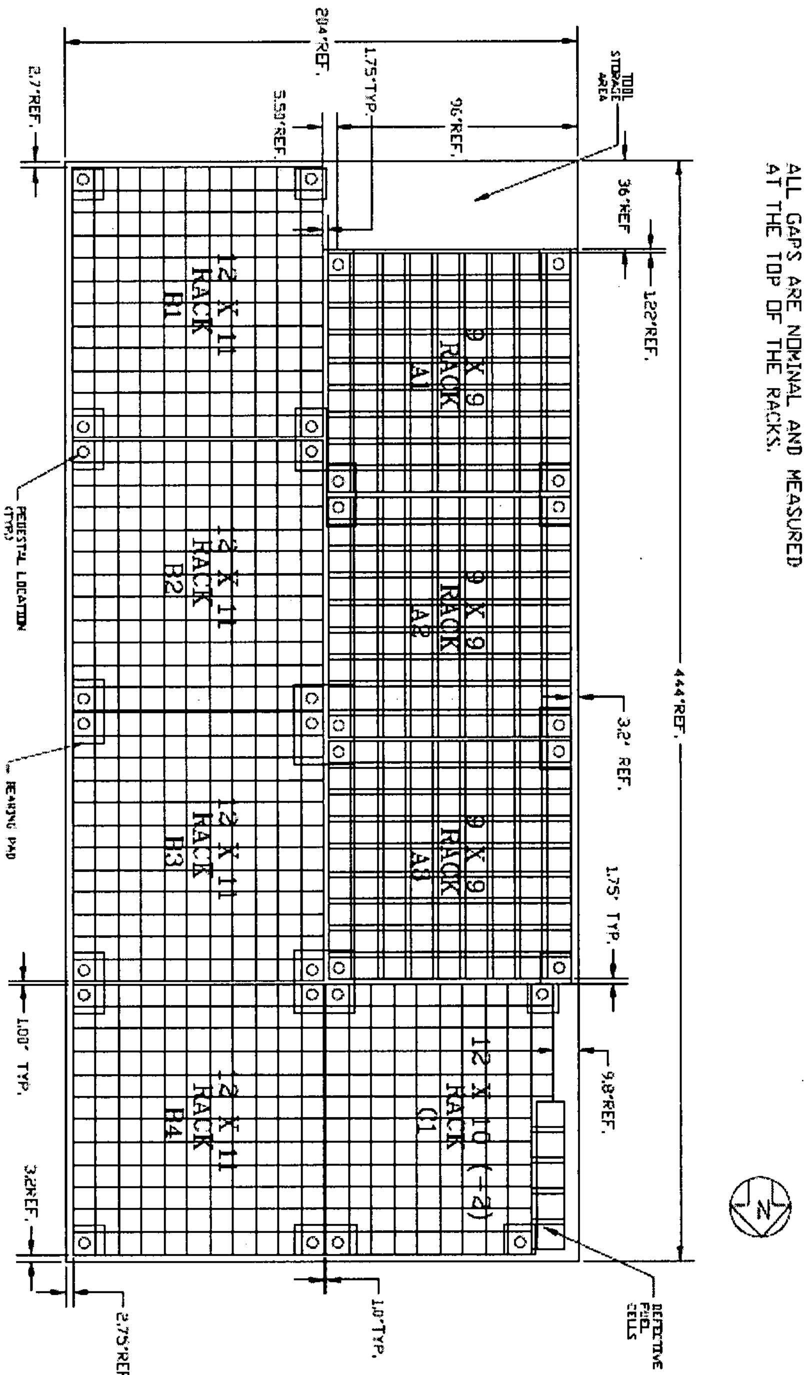


Figure 9.1-4 Spent Fuel Storage Pool Layout (889 Storage Locations)



PRA Revision:

None

Technical Report (TR) Revision:

~~Westinghouse has provide sketches in the attachment to RAI-TR54-15 response showing the major features of the racks and spent fuel pool. These will be incorporated into Technical Report 54 Revision 1.~~
The following Figures have been incorporated into Technical Report 54 Revision 1:

Figure 2-1 Spent Fuel Pool Storage Layout (889 Total Storage Locations)
Note: leak chases shown in phantom

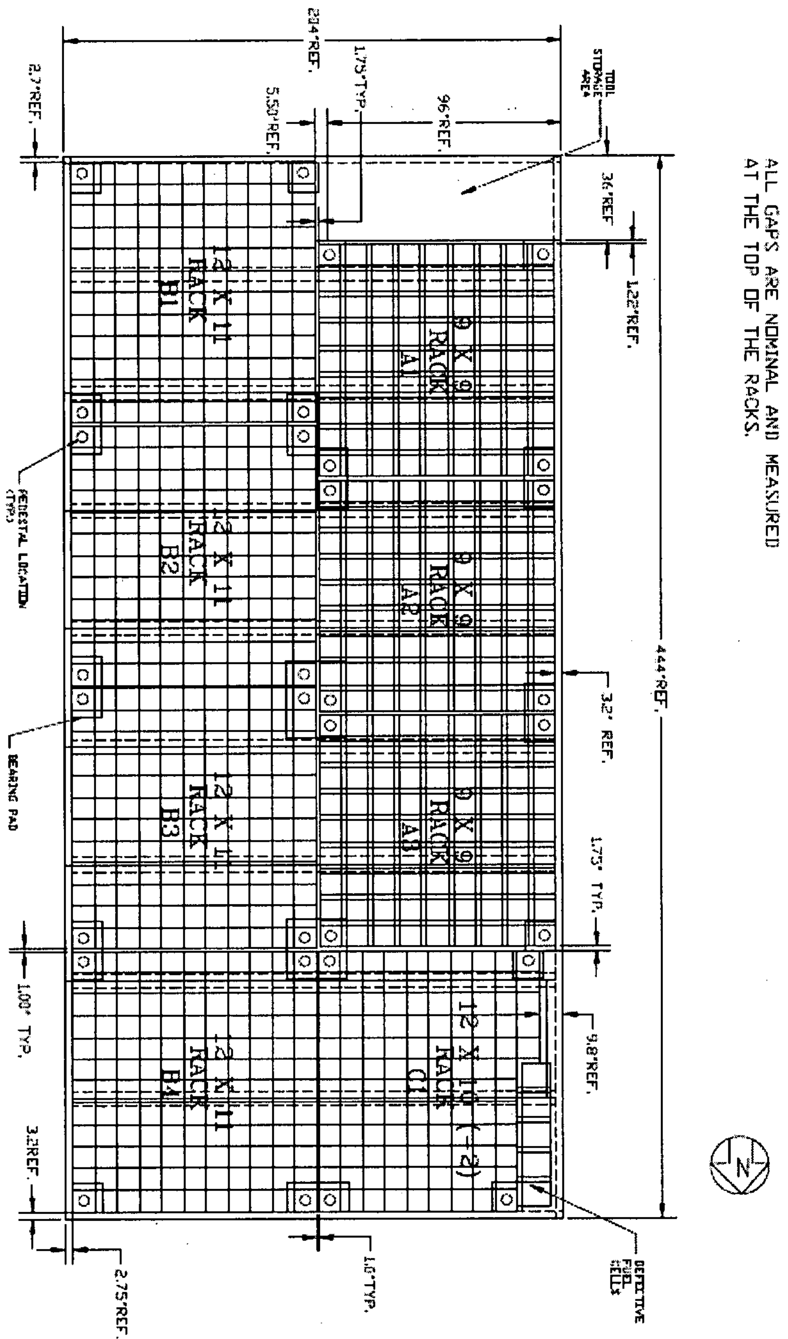
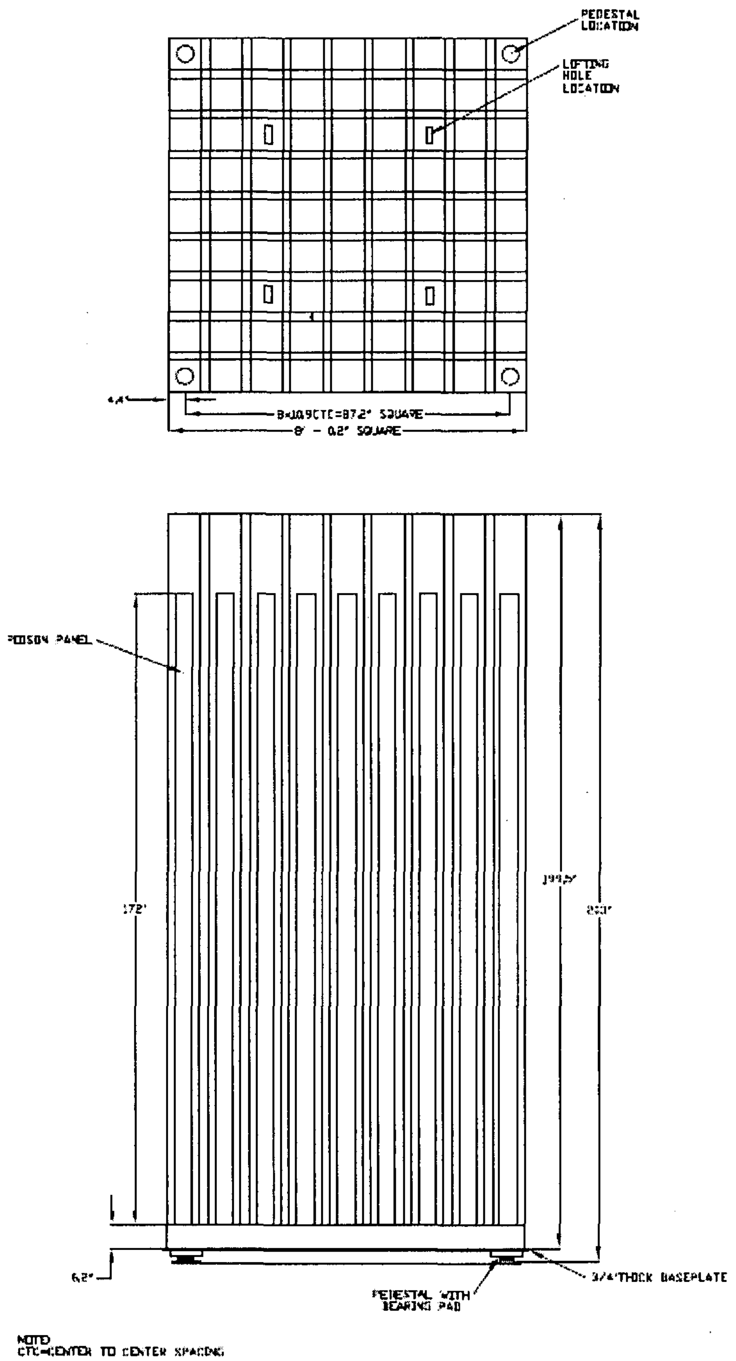
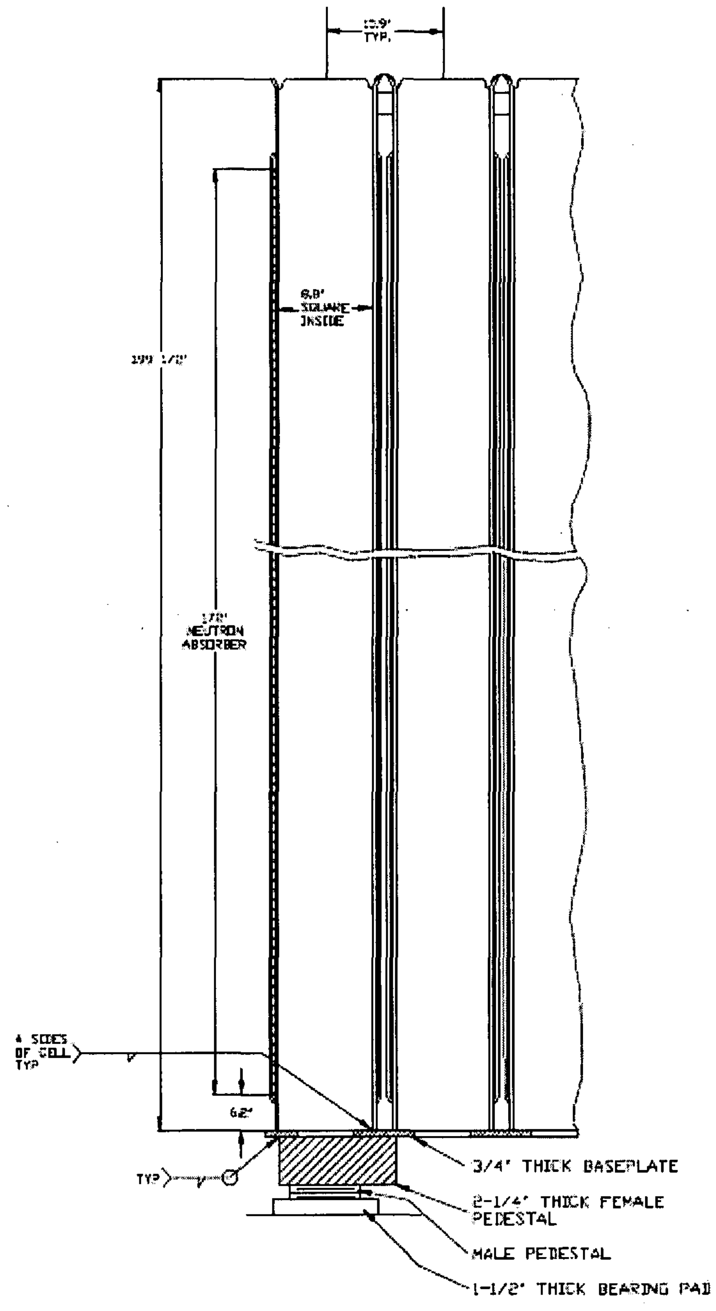


Figure 2-2 Configuration of a Region 1 Storage Cell (Sheet 1 of 2)



PEDESTAL LOCATION
LIFTING HOLE LOCATION
8' - 0.2" SQUARE
6.2"
3/4"THICK BASEPLATE
PEDESTAL WITH BEARING PAD
NOTE
CTC=CENTER TO CENTER SPACING

Figure 2-2 Configuration of a Region 1 Storage Cell (Sheet 2 of 2)



TYP.
6.8"
SQUARE
INSIDE
NEUTRON
ABSORBER
4 SIDES
OF CELL
TYP
6.2"
TYP
3/4" THICK BASEPLATE
2-1/4" THICK FEMALE
PEDESTAL
MALE PEDESTAL
1-1/2" THICK BEARING PAD

Figure 2-3 Configuration of a Region 2 Storage Cell (Sheet 1 of 2)

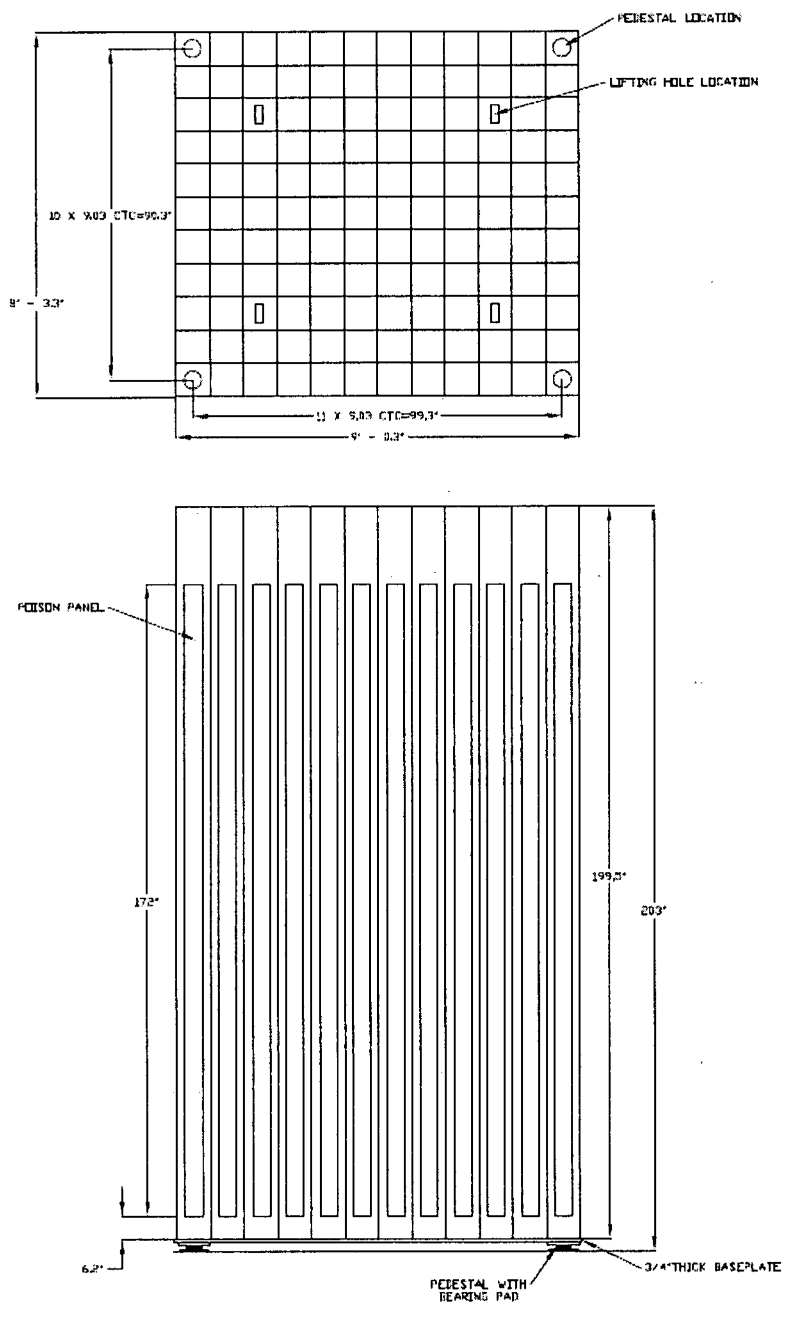
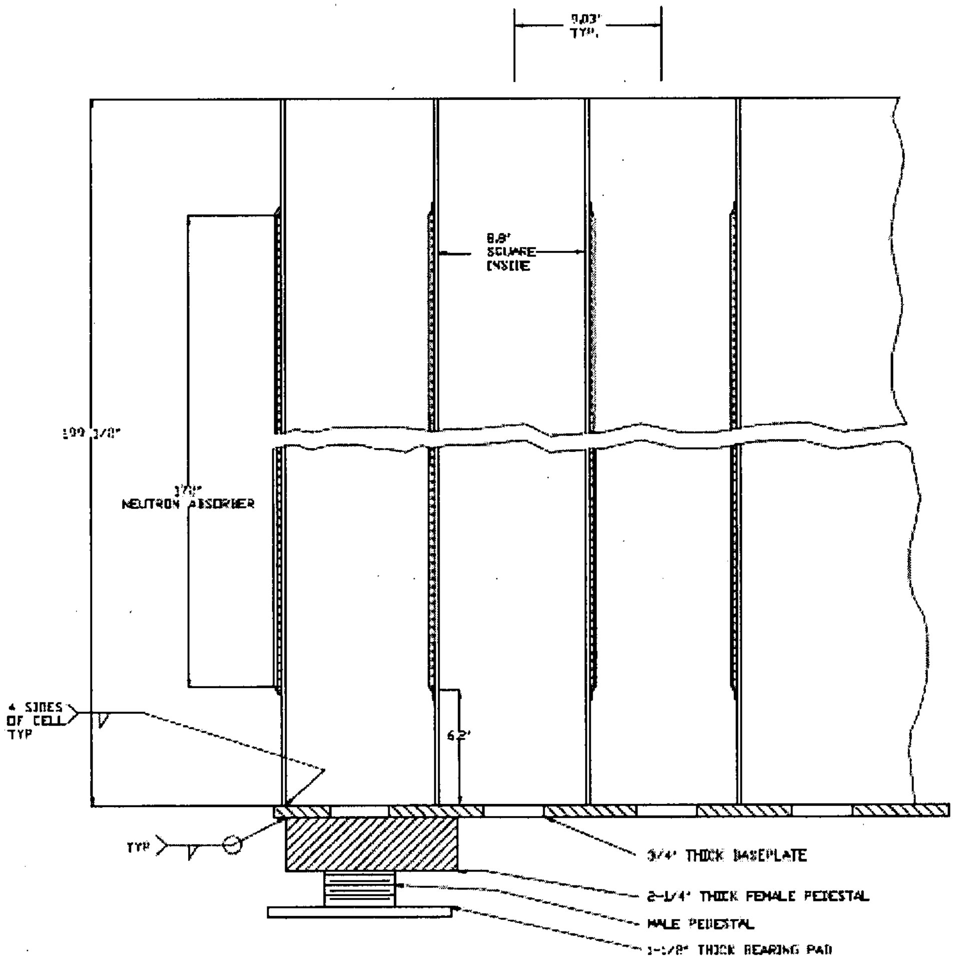


Figure 2-3 Configuration of a Region 2 Storage Cell (Sheet 2 of 2)



AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-16
Revision: 1

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.

October 8-12, 2007 Audit:

Holtec Report No. HI-2063523, Spent Fuel Rack Structural/Seismic Analysis for Westinghouse AP1000, Rev. 0 (Approved 8/15/06, APP-FS02-S3C-001, Rev. 0)

5. ...The staff review of the response spectra shows that at 7Hz the response spectra peak is still flat until about 10 Hz and does not drop off significantly until above 30Hz. Therefore, W is requested to explain why the use of 7 Hz as the highest frequency of interest is appropriate since at higher frequencies, the damping would be lower resulting in higher response,

Holtec Report No. HI-2063519, Analyses of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents, Rev. 0 (Approved 8/15/06, APP-FS02-Z0C-001, Rev. 0)

~~9. Subpart~~ 5. No information was available during the audit to address this item. (Original NRC Question- Since the flow through the hole in the base plate over the pedestal is prevented, how has the increase in temperature considered in the rack design?

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.

October 8-12, 2007 Audit:

Holtec Report No. HI-2063523, Spent Fuel Rack Structural/Seismic Analysis for Westinghouse AP1000, Rev. 0 (Approved 8/15/06, APP-FS02-S3C-001, Rev. 0)

5. The use of 7Hz is justified based on the predicted response of the spent fuel racks under seismic conditions. The figure below shows the displacement of spent fuel rack A3 in the east-west direction, at the top of rack elevation, versus time for the 30-second SSE event. The peak displacement of 1.486" is the maximum "top of rack" displacement for all spent fuel racks from all of the dynamic simulations performed in Holtec Report No. HI-2063523, Spent Fuel Rack Structural/Seismic Analysis for Westinghouse AP1000, Rev. 1 (APP-FS02-S3C-001). Based on visual inspection of the displacement plot, the predominant response frequency of the spent fuel rack due to the design basis SSE loading is below 2Hz. Therefore, it is conservative to use a frequency of 7Hz to calculate the amount of structural damping in the dynamic model, since it results in less input damping (as compared to a frequency of 2Hz) and, in turn, increases the response amplitude (i.e., higher displacements, pedestal loads, etc.).

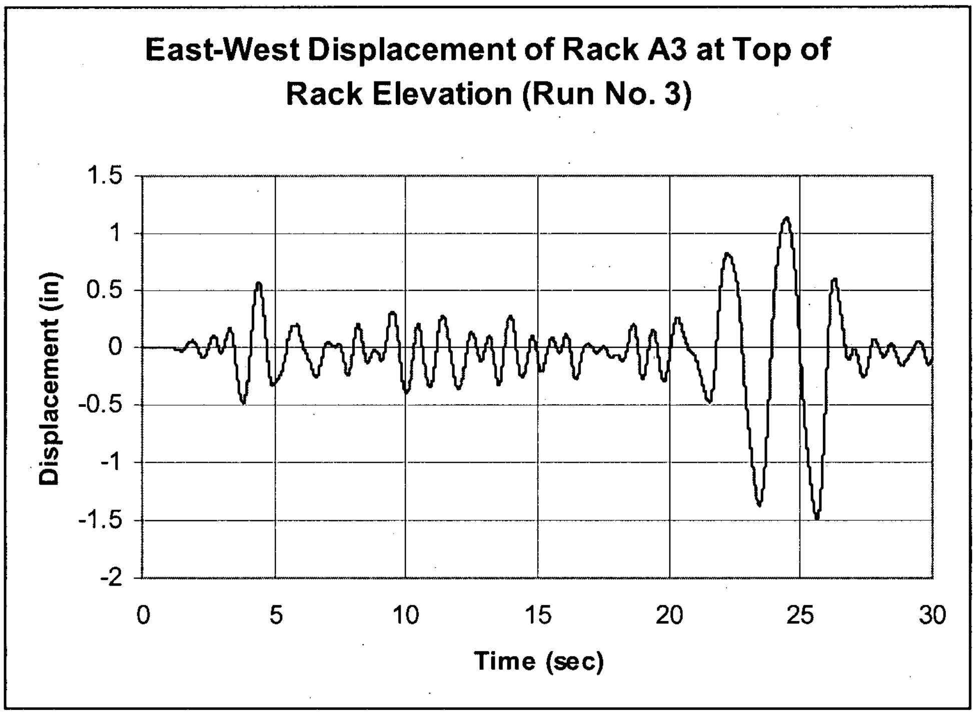


Figure TR54-16.1

Holtec Report No. HI-2063519, Analyses of AP1000 Fuel Storage Racks Subjected to Fuel Drop Accidents, Rev. 0 (Approved 8/15/06, APP-FS02-Z0C-001, Rev. 0)

5. The rack male pedestal does prevent flow through the hole in the base plate; however there are four semi-circular holes at the bottom edge of the cell walls just above the base plate. The thermal-hydraulic analysis of the racks only credits flow through these semi-circular holes, taking no credit for flow through the blocked base plate hole above the pedestal.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. APP-FS02-Z0C-001, Rev 0 "Analysis of AP1000 fuel Storage Racks Subjected to Fuel Drop Accidents" Westinghouse Electric Company LLC., August 2006.

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: 1

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?

October 8-12 Audit Item C-Are the spectra used for the input to the fuel rack analyses appropriate since they are based on the separate W report APP-GW-GLR-015 (typo?), rev. 1 Extension to NI Structures Seismic Analysis to Soil Sites". W needs to finalize the envelope/bounding spectra and check whether report no. is a typo.

Westinghouse Response:

c. The wrong Technical Report number was referenced. The range of soil and rock conditions for which the seismic floor spectra applies is described in Westinghouse Technical Report APP-GW- S2R-010 Rev. 0, "Extension of Nuclear Island Structures Seismic Analysis to Soil Sites."

Reference:

1. APP-GW- S2R-010, Revision 0, "Extension of Nuclear Island Structures Seismic Analysis to Soil Sites," (Technical Report 03, Revision 0)

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-TR54-21
Revision: 1

Question:

How are the different impact stiffness values determined for the fuel to cell wall, rack to rack, rack to wall, and pedestal to floor? Since the impact forces can be greatly affected by the impact spring constant, what is the sensitivity of the impact forces and rack responses to variation in these spring constants? Are impact forces imparted directly onto the cell walls or are there impact bars?

October 8-12, 2007 Audit:

(1) The method used to calculate the fuel to cell wall impact stiffness for the AP1000 racks is consistent with at least 30 previous licensing applications for spent fuel racks, and it has been independently reviewed and accepted in the past by the NRC, Brookhaven National Laboratory, Franklin Research lab, and various customer utilities. As a result of discussions with W, Holtec needs to confirm whether the approach described in the calculations using a point load or a uniform pressure type load over a circular plate region was used to obtain the spring constant for impact loads between the cells, and also provide the basis for this approach.

Westinghouse Response:

The impact stiffness values for the rack to rack, rack to wall, and pedestal to floor are calculated as shown in Attachment RAI-TR54-21 to this RAI response. The fuel to cell wall impact stiffness is determined based on the solution for a simply supported circular plate under a concentrated load applied at its center, where the plate diameter is equal to the cell inner dimension and the plate thickness is equal to the cell wall thickness. The stiffness of the annular plate is then multiplied by the number of loaded storage cells for each rack, since the stored fuel assemblies are assumed to rattle in unison. A sensitivity study has not been performed specifically for the AP1000 spent fuel racks to quantify the effect of variations in the impact stiffness values. However, sensitivity studies have been performed in the past for similar spent fuel rack applications submitted by Holtec, which employed the same method of computing the impact stiffness values, and the impact forces were found to be insensitive to small variations in the stiffness values provided that the integration time step was sufficiently small. There are impact bars around the entire perimeter of each Region 2 spent fuel rack at the top of the rack. These bars prevent impact forces from being imparted directly onto the cell walls, and they reinforce the rack cell structure at the point of impact.

October 8-12, 2007 Audit:

(1) The spring constant for impact loads between the stored fuel assemblies and the cell walls is based on the solution for a circular plate with simply supported edges subjected to a uniform pressure load. Using this approach, the spring constant (K) is calculated as

$$K = \frac{f_a 64 \pi D}{\phi (a/2)^2}$$

where f_a = number of stored fuel assemblies within rack;

$$D = \frac{Et^3}{12(1-\nu^2)};$$

E = Young's modulus of cell wall material = 27.6 x 10^6 psi;

t = cell wall thickness = 0.075";

ν = Poisson's ration = 0.3;

$$\phi = \frac{5+\nu}{1+\nu} = 4.077;$$

a = inside dimension of storage cell = 8.8".

This approach has been used consistently by Holtec since the mid 1980's, when the computer code DYNARACK was first developed. As a result, numerous spent fuel rack licensing applications over the past 20 years have relied on this approach.

Finally, it is noted that, in response to RAI TR54-16, a sensitivity analysis was performed in which all spring constants used in the DYNARACK model were uniformly increased (and decreased) by 20%. The stiffer springs resulted in only a 0.4% increase in the fuel to cell impact load.

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-TR54-27
Revision: 1

Question:

Provide more detailed information about how the fluid coupling was calculated and implemented in the AP1000 simulations. Describe the approaches used for flüid coupling of fuel assemblies to fuel cell walls, rack to rack, and rack to pool wall because there would be some differences among these. For the rack to rack and rack to wall fluid coupling, explain how fluid flow was considered horizontally as well as vertically over the top of the racks and flow to the bottom of the rack. Describe and justify any assumptions made in the approach. For example, small vibratory deflections relative to the gaps are probably assumed and the fluid gaps are not updated according to the rack displacements (see Section 2.4 of the report).

October 8-12, 2007 Audit:

W needs to respond to the original RAI regarding the approach used for fluid coupling of fuel assemblies to fuel cell walls and the justification for this approach.

Westinghouse Response:

A mathematical explanation of the manner in which fluid coupling is calculated and implemented in the AP1000 simulations is provided below.

The problem to be investigated is shown in Figure TR54-27.1, which shows an orthogonal array of 8 rectangles which represent a unit depth of the 8 spent fuel racks in the AP1000 Spent Fuel Pool. The rectangles are surrounded by narrow fluid filled channels whose width is much smaller than the characteristic length or width of any of the racks. The spent fuel pool walls are shown enclosing the entire array of racks.

The dimensions of the channels are such that an assumption of uni-directional fluid flow in a channel is an engineering assumption consistent with classical fluid mechanics principles.

Each rectangular body (fuel rack) has horizontal velocity components U and V parallel to the x and y axes, and the channels are parallel to either the x or y-axes. The pool walls are also assumed to move.

It is conservatively assumed that the channels are filled with an inviscid, incompressible fluid. Due to a seismic event, the pool walls and the spent fuel racks are subject to inertia forces that induce motion to the rectangular racks and to the walls. This motion causes the channel widths to depart from their initial nominal values and causes flow to occur in each of the channels. Because all of the channels are connected, the equations of classical fluid mechanics can be used to establish the fluid velocity (hence, the fluid kinetic energy) in terms of the motion of the spent fuel racks.

For the case in question, there are 22 channels of fluid identified. Figure TR54-27.2 shows a typical rack (box) with four adjacent boxes with the fluid and box velocities identified. The condition of vanishing circulation around the box may be expressed as:

$$\Gamma = \oint_C v_s ds = 0$$

or

$$\int_{-a/2}^{a/2} (u_B - u_T) d\xi + \int_{-b/2}^{b/2} (v_R - v_L) d\eta = 0$$

where the subscripts (L, R, B, T) refer to the left, right, bottom, and top channels, respectively; ξ, η are local axes parallel to x and y; u and v are velocities parallel to ξ, η.

Continuity within each channel gives an equation for the fluid velocity as:

$$w = w_m - \left(\frac{\dot{h}}{h}\right) s$$

where w represents the velocity along the axis of a channel, w_m represents the mean velocity in the channel, s is along either ξ or η, and $\dot{h}$ is the rate of increase of channel width. For example,

$$\dot{h}_R = U_R - U$$

From Figure TR54-27.2, four equations for u_B, u_T, v_R, and v_L in terms of the respective mean channel velocities can be developed so that the circulation equation becomes:

$$a(u_{Bm} - u_{Tm}) + b(v_{Rm} - v_{Lm}) = 0$$

One such circulation equation exists for each spent fuel rack rectangle. We see that the velocity in any channel is determined in terms of the adjacent rack velocities if we can determine the mean fluid velocity in each of the 22 channels. Circulation gives 8 equations. The remaining equations are obtained by enforcing continuity at each junction as shown in Figure TR54-27.3. Enforcing continuity at each of the 15 junctions gives 15 equations of the general form:

$$\sum h\sigma w - \frac{1}{2}\sum L\dot{h} = 0$$

where w is the mid-length mean velocity in a connecting channel of length L and $\dot{h}$ is the relative normal velocity at which the walls move. The summation covers all channels that meet at the junction in question. The sign indicator $\sigma = \pm 1$ is associated with flow from a channel either into or out of a junction.

There are a total of 15 + 8 = 23 equations which can be formally written; one circulation equation, however, is not independent of the other. This reflects the fact that the sum total of the 8 circulation equations must also equal zero, representing the fact that the circulation around a path enclosing all racks is equal to zero. Thus, there are exactly 22 independent algebraic equations to determine the 22 unknown mean velocities in this configuration.

Once the velocities are determined in terms of the rack motion, the kinetic energy can be written and the fluid mass matrix identified using the Holtec International QA-validated pre-processor program CHANBP6. The fluid mass matrix is subsequently apportioned between the upper and lower portions of the actual rack in a manner consistent with the assumed rack deformation shape as a function of height in each of the two horizontal directions. The Holtec International pre-processor program VMCHANGE performs this operation.

The approach used for fluid coupling between the fuel assemblies and the cell walls is presented in Reference [2], and it is based upon Fritz's classical two-body fluid coupling model [3]. References [2] and [3] were previously provided to the NRC as part of the April 9th, 2007 RAI response submittal (Reference 4. Westinghouse Letter DCP/NRC1860). The structural mass effects and the hydrodynamic effect from fluid within the narrow annulus in each cell between the fuel assembly and the cell wall is incorporated using the Holtec International pre-processor program MULTI155.

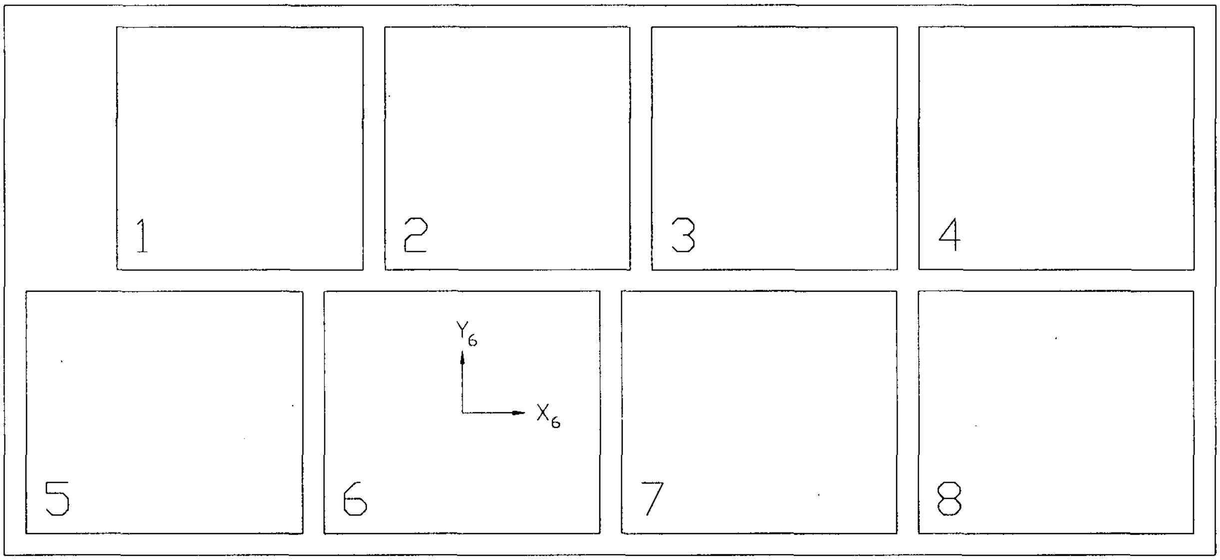


Figure TR54-27.1 Planar View of an 8 Rack Array

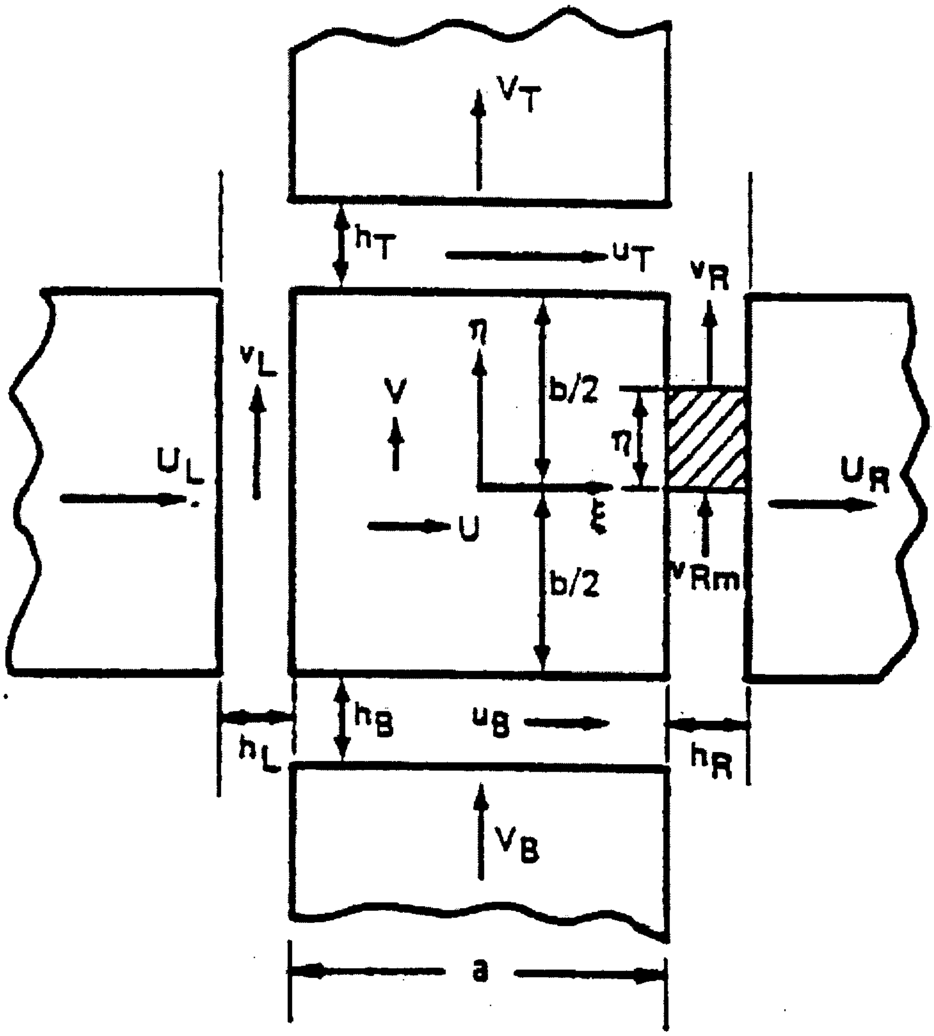


Figure TR54-27.2 Fluid Flow Around a Typical Rack

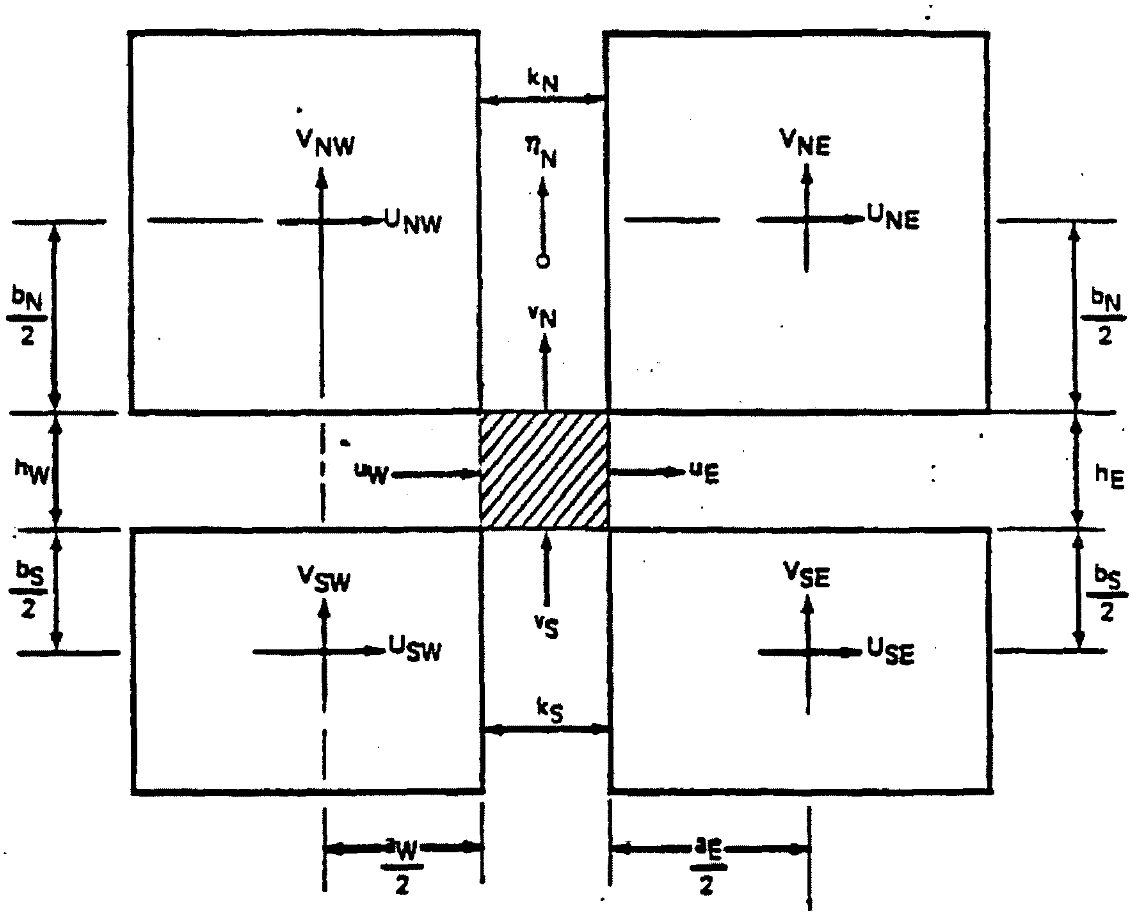


Figure TR54-27.3 Fluid Flow at Channel Junction

References:

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

2. Soler, A.I. and Singh, K.P., "Seismic Responses of Free Standing Fuel Rack Constructions to 3-D Motions," Nuclear Engineering and Design, Vol. 80, pp. 315-329 (1984).

3. Fritz, R.J., "The Effects of Liquids on the Dynamic Motions of Immersed Solids," Journal of Engineering for Industry, Trans. of the ASME, February 1972, pp. 167-172.

4. Westinghouse Letter DCP/NRC 1860 "AP1000 COL Response to Request for Additional Information (TR #54)", April 9, 2007.

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-TR54-29
Revision: 1

Question:

The load combinations specified in Table 2-5 of the subject report and Table 9.1-1 (markup version of the DCD provided with the subject report) do not match SRP 3.8.4, App. D criteria. Therefore, explain or modify the tables to address the following:

a. No load combinations are specified for the spent fuel racks corresponding to service Level A.

b. Temperature conditions T_o and T_a are not included in Table 2-5; however, they are included in the markup DCD Table 9.1-1. A footnote in the markup of DCD Table 9.1-1 states that "For the faulted load combination, thermal loads will be neglected when they are secondary and self limiting in nature and the material is ductile. In freestanding spent fuel racks, thermal effects mainly affect the temperature that is used in specifying the allowable stress and Young's Modulus." Based on this statement:

 (i) Regarding the first quoted sentence above, Table 2-5, Load Combination corresponding to service levels A and B (which are not the faulted condition) should include T_o.

 (ii) regarding the last quoted sentence above, SRP 3.8.4, App. D indicates that thermal loads due to temperature effects and temperature gradients across the rack structure need to be considered. Temperature gradients can occur due to differential heating effects between one or more filled cell(s) and one or more adjacent empty cell(s). The stresses from these types of thermal loads should be considered because they can still lead to localized failure of the structure. When responding to this, consider temperature loads due to normal and accident conditions, as noted in your Table 9.1-1 and SRP 3.8.4, App. D.

c. Table 2-5 in the report and DCD Table 9.1-1 indicate that the load term P_f is the uplift force on the rack caused by a postulated stuck fuel assembly accident condition or the force developed on the rack from the drop of a fuel assembly during handling to the top of the rack or the baseplate through an empty cell. SRP 3.8.4, App. D separates these two accident events into P_f for the uplift force event and P_d for the drop load event. This is necessary because SRP 3.8.4, App. D specifies that the acceptance limits for these two events (in combination with deadweight + live load + thermal) are different.

d. Table 2-5, last load combination with E', does not provide the Service Limit. If the same

Service Limit, D[(1)], as indicated in the load combination above the last load combination was intended, then explain whether the functionality capability requirement in footnote (1) (which is applicable to only the new racks) is in addition to or in-place of Level D limits.

October 8-12, 2007 Audit:

This RAI was not discussed because HOLTEC's audit participation was limited. Also in DCD Section 9.1 related to the design of the fuel racks, reference should be made to SRP 3.8.4 App D not to the older OT position dated 1978 (Westinghouse clarification GL 78-11 "U.S NRC OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications".)

Westinghouse Response:

Table 2-5 of Technical Report 54 and DCD Table 9.1-1 will be revised as follows (which is derived from Appendix D to SRP Section 3.8.4):

Table 2-5 Loading Combinations for AP1000 Spent Fuel Storage Racks	
Loading Combination	**Service Level**
D + L D + L + T_o	Level A
D + L + T_o + P_f	Level B
D + L + T_a + E'	Level D
D + L + F_d	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in Reference 6:

D = Dead weight induced loads (including fuel assembly weight)

L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)

F_d = Force caused by the accidental drop of the heaviest load from the maximum possible height

P_f = Upward force on the racks caused by postulated stuck fuel assembly

E' = Safe Shutdown Earthquake (SSE)

T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions

T_a = Differential temperature induced loads based on the postulated abnormal design conditions

Table 9.1-1

LOADS AND LOAD COMBINATIONS FOR FUEL RACKS

Load Combination	Service Level
D + L D + L + T_o	Level A
D + L + T_o + P_f	Level B
D + L + T_a + E'	Level D
D + L + F_d	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in NUREG-0800, Section 3.8.4 (including Appendix D) of the Standard Review Plan (SRP):

D = Dead weight induced loads (including fuel assembly weight)

L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)

F_d = Force caused by the accidental drop of the heaviest load from the maximum possible height

P_f = Upward force on the racks caused by postulated stuck fuel assembly

E' = Safe Shutdown Earthquake (SSE)

T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions

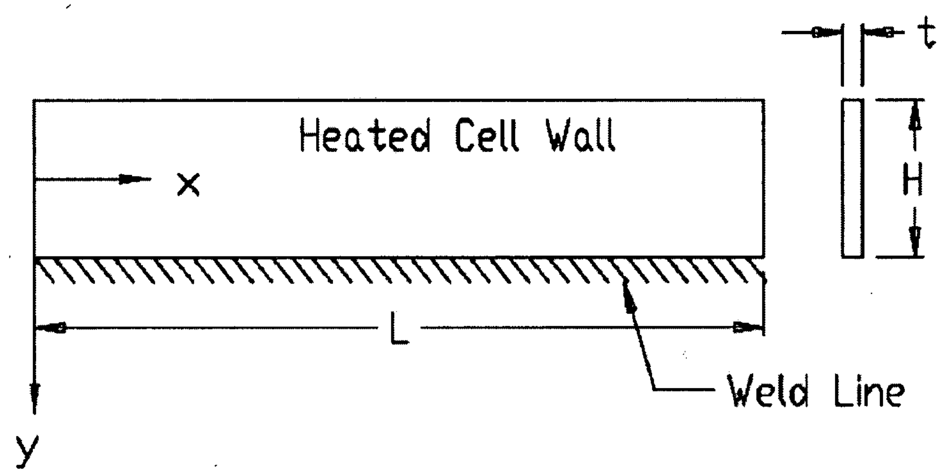
T_a = Differential temperature induced loads based on the postulated abnormal design conditions

a. Table 2-5 of the subject report and DCD Table 9.1-1 will be modified to specify the load combinations D + L and D + L + T_o for Service Level A, as shown above.

b. (i) Table 2-5 of the subject report will be modified to include T_o for Service Levels A and B, as shown above.

(ii) The temperature gradients across the rack structure caused by differential heating effects between one or more filled cells and one or more adjacent empty cells are considered. The worst thermal stress field in a fuel rack is obtained when an isolated storage location has a fuel assembly generating heat at maximum postulated rate and the surrounding storage locations contain no fuel. This secondary stress condition is evaluated alone and not combined with primary stresses from other load conditions.

A thermal gradient between cells will develop when an isolated storage location contains a fuel assembly emitting maximum postulated heat, while the surrounding locations are empty. A conservative estimate of the weld stresses along the length of an isolated hot cell is obtained by considering a beam strip uniformly heated by 50°F, and restrained from growth along one long edge. The 50°F temperature rise envelops the difference between the maximum local spent fuel pool water temperature (174°F) inside a storage cell and the bulk pool temperature (140°F) based on the thermal-hydraulic analysis of the spent fuel pool. The cell wall configuration considered here is shown in figure below.



The strip is subjected to the following boundary conditions:

1. Displacement U_x (x,y) = 0 at x = 0 and at y = H/2 for all x

2. Average force $N_x(x) = 0$ at $x = L$

Using shear beam theory and subjecting the strip to a uniform temperature rise $\Delta T = 50°F$, we can calculate an estimate of the maximum value of the average shear stress in the strip. The final shear stress result for the strip is found to be

$$\tau_{max} = \frac{E \alpha \Delta T}{0.931} \quad \text{(maximum at } x = L\text{)}$$

where $E = 27.6 \times 10^6$ psi, $\alpha = 9.5 \times 10^{-6}$ in/in °F and $\Delta T = 50°F$.

Therefore, we obtain an estimate of maximum weld shear stress in an isolated hot cell, due to thermal gradient, as

$\tau_{max} = 14{,}082$ psi

Since this is a secondary thermal stress, we use the allowable shear stress criteria for faulted conditions (0.42^*S_u=27,804 psi) as a guide to indicate that this maximum shear is acceptable. Therefore, there is a safety factor = 27,804 / 14,082 = 1.97 against cell wall shear failure due to secondary thermal stresses from cell wall growth under the worst case hot cell conditions.

.c. The definition of P_f in Table 2-5 of the subject report and DCD Table 9.1-1 is incorrect. The referenced tables will be revised to clearly distinguish between P_f and F_d, as specified above.

d. ~~d.~~ Level D service limits apply to load combination D + L + T_a + E'. Per Appendix D of SRP Section 3.8.4, the functional capability of the fuel racks should be demonstrated for the accidental drop event (D + L + F_d). This requirement is in place of the Level D service limits since it is recognized that the rack may sustain permanent damage due to the impact force, and therefore it may not be possible to meet Level D service limits at all locations within the rack. The functional capability of the spent fuel racks is generally defined as the continued ability of rack to store spent fuel assemblies in a subcritical arrangement.

October 8-12, 2007 Audit:

Based on the Staff's assessment of the Revision 0 response to RAI TR54-29 (dated 5/17/07), the following additional information is provided:

(1) Table 2-5 of the Technical Report and DCD Table 9.1-1 will be revised, as shown below, to include the loading combination D + L + Ta under Service Level B. The latest changes to Table 2-5 and Table 9.1-1 are shown in ***italic bold font*** for identification purposes.

Table 2-5 Loading Combinations for AP1000 Spent Fuel Storage Racks

Loading Combination	**Service Level**
$D + L$ $D + L + T_o$	Level A
$D + L + T_a$ $D + L + T_o + P_f$	Level B
$D + L + T_a + E'$	Level D
$D + L + F_d$	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in Reference 6:

- D = Dead weight induced loads (including fuel assembly weight)
- L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)
- F_d = Force caused by the accidental drop of the heaviest load from the maximum possible height
- P_f = Upward force on the racks caused by postulated stuck fuel assembly
- E' = Safe Shutdown Earthquake (SSE)
- T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions
- T_a = Differential temperature induced loads based on the postulated abnormal design conditions

Table 9.1-1

LOADS AND LOAD COMBINATIONS FOR FUEL RACKS

Load Combination	Service Level
D + L D + L + T_o	Level A
D + L + T_a D + L + T_o + P_f	Level B
D + L + T_a + E'	Level D
D + L + F_d	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in NUREG-0800, Section 3.8.4 (including Appendix ***D***) of the Standard Review Plan (SRP):

D = Dead weight induced loads (including fuel assembly weight)

L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)

F_d = Force caused by the accidental drop of the heaviest load from the maximum possible height

P_f = Upward force on the racks caused by postulated stuck fuel assembly

E' = Safe Shutdown Earthquake (SSE)

T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions

T_a = Differential temperature induced loads based on the postulated abnormal design conditions

(2) Westinghouse WCAP-15799, "AP1000 Conformance with SRP Acceptance Criteria" (AP1000 Document No. APP-GW-GL-001, Rev. 1) establishes NUREG-0800, SRP 3.8.4, Rev. 1 as the applicable design standard for AP1000. Therefore, Reference 6 of the Technical Report is identified correctly. With regard to DCD Rev. 16, Table 9.1-1 will be revised to refer to "NUREG-0800, Section 3.8.4 (including Appendix D)" as shown above. In addition, DCD Section 9.1 will be revised to include a reference to SRP 3.8.4 Rev. 1.

With regard to item b.(ii) from the Revision 0 response to RAI TR54-29, the following additional information is provided:

(1) The secondary stress condition caused by Ta is not combined with primary stresses from other loads because the allowable stress limits given in Section 2.3.4 of the Technical Report, which are derived from Subsection NF of the ASME Code, are for primary stresses only. Subsection NF has no stipulated limits for thermal stresses (i.e., secondary stresses) when acting in concert with SSE loads (i.e., Service Level D). In fact, paragraph F-1334 of the ASME Code, which applies to Service Level D, ~~which~~ states that:

"Neither peak stresses nor stresses resulting from thermal expansion within the support need be evaluated."

(2) The 0.931 term used in the denominator of the shear stress equation is equal to the following quantity:

$$\sqrt{\frac{2(1+\nu)}{3}} \qquad \text{(where } \nu = 0.3\text{)}$$

This constant term results from the derivation of the shear stress equation, which is given below.

VI. ANALYSIS OF THERMAL STRESSES IN A RACK CELL

A fuel rack situated in an isothermal pool will experience no thermal stresses if the storage locations are loaded with fuels of identical reactivity. The worst case of thermal gradient will develop when an isolated storage location contains a fuel assembly emitting maximum postulated heat while the surrounding locations are empty. The thermal hydraulic calculations will show that the maximum water temperature rise is $\Delta T^{0}F$. We assume that the inside walls of the cell are in contact with water at $\Delta T^{0}F$.

We now estimate weld stresses in one wall of a cell if that wall undergoes a temperature rise and is restrained from vertical growth. We estimate the average weld stress by using beam theory.

Analysis

As an initial stress analysis problem, we consider the strip configuration in Figure 6.1 and determines the shear stress at the wall due to a uniform temperature rise ΔT in the strip. Using shear beam theory, we have the following field equations for the beam strip.

$$U_x(x) = U + \alpha y \qquad |y| \le w/2 \tag{6.1}$$

$$U_y(x) = 0 \tag{6.2}$$

$$\frac{dN}{dx} = \tau(x) \tag{6.3}$$

$$\frac{dM}{dx} - V - \tau(x)\frac{W}{2} = 0 \tag{6.4}$$

$$M = EI\frac{d\alpha}{dx} \tag{6.5}$$

$$V = GA\,\alpha(x) \tag{6.6}$$

$$N = EA\frac{dU}{dx} - \beta\Delta T \quad ; \ \beta = \text{coefficient of thermal expansion} \tag{6.7}$$

We must also enforce the constraint of zero U_x at $y = w/2$.

Thus,

$$U(x) = -\alpha(x)\frac{W}{2} \tag{6.8}$$

so that

$$M(x) = EI \frac{d\alpha}{dx}$$

$$V(x) = GA\ \alpha(x) \qquad (6.9)$$

$$N(x) = -EA \left(\frac{d\alpha}{dx} \frac{W}{2} + \beta\Delta T \right)$$

Since ΔT is assumed independent of x in this analysis, Eq. (6.3) gives

$$\tau(x) = -EA \frac{d^2\ \alpha}{d\ x^2} \frac{W}{2} \qquad (6.10)$$

Therefore, Eq. (6.4) gives the following equation for $\alpha(x)$, the cross section rotation.

$$E\ I^* \frac{d^2\ \alpha}{d\ x^2} - GA\ \alpha(x) = 0 \qquad (6.11)$$

where

$$I^* = I + A \frac{W^2}{4} \qquad (6.12)$$

and

$$I = \frac{AW^2}{12} \quad ; \quad A = w\ t$$

Defining

$$\mu^2 = \frac{G\ A}{E\ I^*} = \frac{A}{2(1 + \mu)\ I^*} = \frac{(1.074)^2}{w^2} \qquad (6.13)$$

yields the solution for $\alpha(x)$ as

$$\alpha(x) = C_1 \sinh\ \mu x + C_2 \cosh\ \mu x \qquad (6.14)$$

To determine C_1, C_2 apply the boundary conditions

$$\alpha(0) = 0, \; N(x)/_{x=L} = 0.$$

We obtain

$$C_2 = 0$$

$$-\beta\Delta T = \frac{W}{2} \quad \mu \cosh \mu L \quad C_1$$

Hence

$$\alpha(x) = -\frac{2\beta\Delta T \sinh \mu x}{W \cosh \mu L} \qquad (6.15)$$

so that the wall shear "stress". $\bar{\tau}(x)$ is given by the expression

$$\bar{\tau}(x) = \frac{\tau(x)}{t} = (E\beta\Delta T)(W\mu)\frac{\sinh \mu x}{\cosh \mu L}$$

The maximum value is at X = L, and assuming $\mu L >> 1$, we find that

$$\boxed{\tau_{max} = E\beta\Delta T(W\mu)} = 1.074\, E\beta\Delta T \qquad (6.16)$$

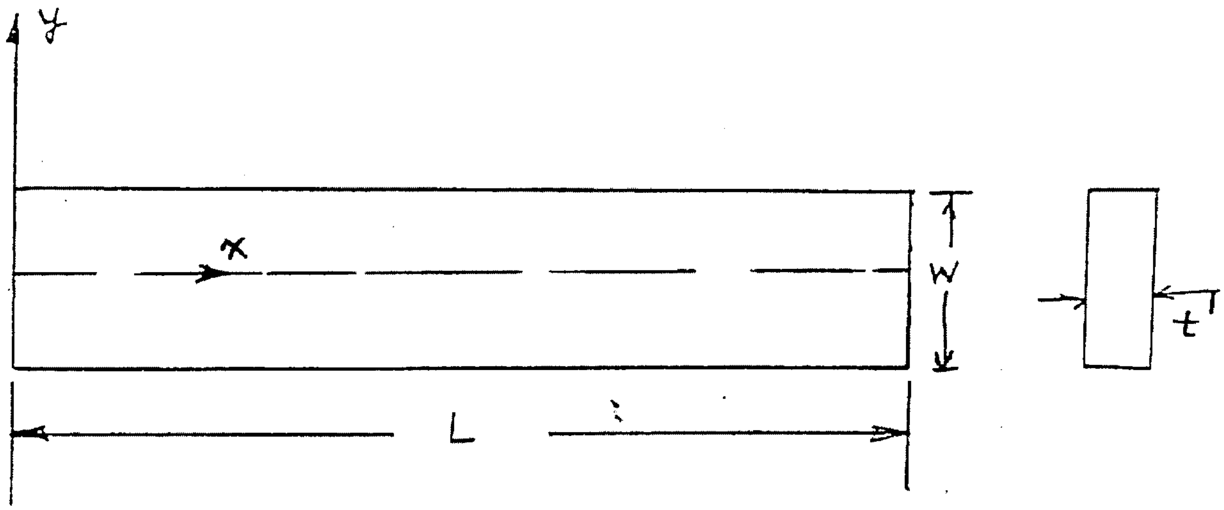


Fig 6.1 Configuration

Reference for analysis of thermal stresses in a rack cell Holtec Report HI-89330, Revision 1 "Seismic Analysis of High Density Fuel Racks Part 3: Structural Design Calculations-Theory", June 1989. (Holtec Proprietary)

(3) Since the shear stress is caused by thermal loading, it is classified by the ASME Code as a secondary stress. Therefore, the maximum calculated stress is compared with 0.42 Su in accordance with note (6) from Table NF-3523(b)-1 of the ASME Code. This is the only stress limit imposed by Subsection NF for the primary plus secondary stress category for Class 3 components. The base metal shear stress limit of 0.72 Sy only applies to primary stresses.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. US NRC Standard Review Plan, NUREG-0800 (SRP 3.8.4, including Appendix D) Revision 1.
3. APP-GW-GL-001, "AP1000 Conformance with SRP Acceptance Criteria," Rev. 1, August 2003.
4. Holtec Report HI-89330, Revision 1 "Seismic Analysis of High Density Fuel Racks Part 3: Structural Design Calculations-Theory", June 1989. (Holtec Proprietary)

Design Control Document (DCD) Revision:
DCD Table 9.1-1 will be revised as shown below.

Table 9.1-1

LOADS AND LOAD COMBINATIONS FOR FUEL RACKS

Load Combination	Service Level
D + L D + L + T_o	Level A
D + L + T_a D + L + T_o + P_f	Level B
D + L + T_a + E'	Level D
D + L + F_d	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in NUREG-0800, Section 3.8.4 (including Appendix D) of the Standard Review Plan (SRP):

D = Dead weight induced loads (including fuel assembly weight)

L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)

F_d = Force caused by the accidental drop of the heaviest load from the maximum possible height

P_f = Upward force on the racks caused by postulated stuck fuel assembly

E' = Safe Shutdown Earthquake (SSE)

T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions

T_a = Differential temperature induced loads based on the postulated abnormal design conditions

PRA Revision:
None

Technical Report (TR) Revision:
Table 2.5 of Technical Report Number 54 will be revised as shown below.

Table 2-5 Loading Combinations for AP1000 Spent Fuel Storage Racks	
Loading Combination	**Service Level**
D + L D + L + T_o	Level A
D + L + T_a D + L + T_o + P_f	Level B
D + L + T_a + E'	Level D
D + L + F_d	The functional capability of the fuel racks should be demonstrated.

Notes:

1. There is no operating basis earthquake (OBE) for the AP1000 plant.
2. The fuel racks are freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. As a result, thermal loads applied to the rack (T_o and T_a) produce only local (secondary) stresses.

Abbreviations are those used in Reference 6:

D = Dead weight induced loads (including fuel assembly weight)

L = Live load (not applicable to fuel racks since there are no moving objects in the rack load path)

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P_f = Upward force on the racks caused by postulated stuck fuel assembly

E' = Safe Shutdown Earthquake (SSE)

T_o = Differential temperature induced loads based on the most critical transient or steady state condition under normal operation or shutdown conditions

T_a = Differential temperature induced loads based on the postulated abnormal design conditions

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-30
Revision: 1

Question:

When utilizing ASME Code, Section III, Subsection NF, are all of the applicable provisions in NRC Regulatory Guide, 1.124, Rev. 1 also satisfied? This should be clearly stated in the report and the DCD.

October 8-12, 2007 Audit:

This RAI was not discussed because HOLTEC's audit participation was limited.

Westinghouse Response:

The following statement "The stress analysis of the spent fuel racks satisfies all of the applicable provisions in NRC Regulatory Guide 1.124, Revision 1 for component supports designed by the linear elastic analysis method" will be added to Technical Report APP-GW-GLR-033 and the DCD.

October 8-12, 2007 Audit:

In the previous RAI response (Rev. 0) a commitment was made to add the following statement to Technical Report APP-GW-GLR-033 and the DCD:

"The stress analysis of the spent fuel racks satisfies all of the applicable provisions in NRC Regulatory Guide 1.124, Revision 1 for component supports designed by the linear elastic analysis method."

The NRC accepted the statement; however, the staff noted that Reg. Guide 1.124 Revision 2 was published in February 2007. However, the licensing basis for the AP1000 is still revision 1 of this Reg. Guide. Reg. Guide 1.124 Revision 1 is referenced in DCD Rev 16 Section 9.1.

The seismic analysis of the spent fuel racks complies with Reg. Guide 1.124 Revision 1 based on the following:

i) The value of S_y at temperature is less than 5/6 S_u for all structural materials specified for the AP1000 spent fuel racks.

ii) The compressive stress in the rack cell structure is demonstrated to be less than 2/3 of the critical buckling limit.

iii) There are no bolts or bolted connections anywhere in the spent fuel racks.

iv) Not analyzed, not applicable because there is no OBE for the AP1000 (For OBE load combinations, the calculated stresses in the spent fuel racks are compared with the stress limits of NF-3220 of Section III).

v) For SSE load combinations, the calculated stresses in the spent fuel racks are compared with the stress limits of NF-3220 of Section III, increased according to the provisions of F-1334 of Section III.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. US NRC Regulatory Guide 1.124, Revision 1, "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports," January 1978.

Design Control Document (DCD) Revision:
No changes

PRA Revision:
None

Technical Report (TR) Revision:
A statement will be added to Technical Report Number 54 stating that the stress analysis of the spent fuel racks satisfies all of the applicable provisions in NRC Regulatory Guide 1.124, Revision 1.

Subsection 2.3.1 Introduction

The AP1000 Spent Fuel Storage Racks are designed as seismic Category I. The U.S. Office of Technology, Position Paper (Reference 5) and the U.S. NRC Standard Review Plan 3.8.4 (Reference 6) state the ASME Code Section III, subsection NF (Reference 12), as applicable for Class 3 components, is an appropriate vehicle for design. The stress analysis of the spent fuel racks satisfies all of the applicable provisions in NRC Regulatory Guide 1.124, Revision 1 for components designed by the linear elastic analysis method (Reference 22).

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-35
Revision: 1

Question:

Section 2.8.1.4 of the report, which describes the impact loads, indicates that these loads do not result in damage to the racks that would prevent retrievability. Confirm that the acceptance criteria for these impacts include both retrievability and the stress limits for Level D in accordance with the ASME Code, Section III, Subsection NF. Provide the stress ratios for the most critical cells adjacent to the worst case impact.

October 8-12 2007 Audit This RAI was not discussed because HOLTEC's audit participation was not limited.

Westinghouse Response:

The ability to retrieve the fuel is based solely on evaluating the rack structure to show that there is no instability that would collapse the cell. Subsection NF stress limits for Level D do not apply to the local stress state in the impacted cells because:

a) the fuel racks are analyzed as linear type supports (i.e., beam type members) in accordance with the OT Position Paper (Ref. 2) and Appendix D of SRP 3.8.4 (Ref. 3);

b) rack-to-rack impact loads near the top of the rack produce secondary stresses, for which there is no prescribed limit in ASME Code, Section III, Subsection NF for Level D.

Away from the point of impact, the rack-to-rack impact loads do produce primary bending and shear stresses in the rack beam, which are reflected in the maximum stress factors reported in Table 2-9.

In order to ensure that fuel retrievability is maintained, the impact loads at the rack top elevation are compared against two-thirds of the critical buckling load for the cell walls as required by Table NF-3523(b)-1 of the ASME Code for primary plus secondary stresses. The critical buckling load is calculated as follows (from Holtec Report No. HI-2063523, Spent Fuel Rack Structural/Seismic Analysis for Westinghouse AP1000, Rev. 0):

The impact load is assumed to spread uniformly over a 6-inch vertical span of the cell wall, which is equal to the minimum length of the intermittent cell-to-cell welds. Hence, the terms b and l_w below are both equal to 6". The term w equals the inside dimension of the storage cell opening.

Buckling Evaluation

$w = 8.8\,in$

Youngs Modulus [11.10] of main report $E := 27600000 \cdot psi$

Length undergoing buckling $a := w$ $a = 8.8\,in$

Thickness of the plate $t = 0.075\,in$

Assuming all edges clamped (Table 35 case 1b of Roark's Formula for Stress and Strain)

This is reasonable because all cell walls are connected at top and sides to other walls or to connecting rounds

a/b = $\frac{a}{b} = 1.467$ therefore the corresponding value for K is $K := 7.2$

Therefore the critical buckling load $\sigma_{cr} := K \cdot \frac{E}{1 - 0.3^2} \cdot \left(\frac{t}{l_w}\right)^2$ $\sigma_{cr} = 34121\,psi$

By comparison, the average compressive stress in the cell walls due to the maximum rack-to-rack impact load is 19,120 psi. Since the calculated stress is less than two-thirds of the critical buckling load, the spent fuel rack design meets the requirements of Table NF-3523(b)-1 of the ASME Code for the primary plus secondary stress category.

References:

1. APP-GW-GLR-033, Revision 0, “Spent Fuel Storage Rack Structural/Seismic Analysis,” (Technical Report Number 54)
2. “U.S. NRC OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications,” GL 78-11 April 14, 1978, and GL 79-04 January 18, 1979, amendment.
3. U.S. NRC Standard Review Plan, NUREG-0800 (SRP 3.8.4, Rev 1).

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None