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Your ref: Project Number 740
Our ref: DCP/NRC1890

May 17, 2007

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

In support of Combined License application pre-application activities, Westinghouse is submitting another set of 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 TR54-9, TR54-12, TR54-13, TR54-14, TR54-25, TR54-26, TR54-27, TR54-29, TR54-30, TR54-31, TR54-33, TR54-35, TR54-37, and TR54-40, 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,

D. F. Hutchings for

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

00134psa.doc

D079

/Attachment

1. "Oath of Affirmation," dated May 17, 2007

/Enclosure

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

cc:	D. Jaffe	-	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
	J. Iacovino	-	Westinghouse	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
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 17th day
of May 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-TR54-009 Rev 1 (includes Part 3)
Revision: 1

Question:

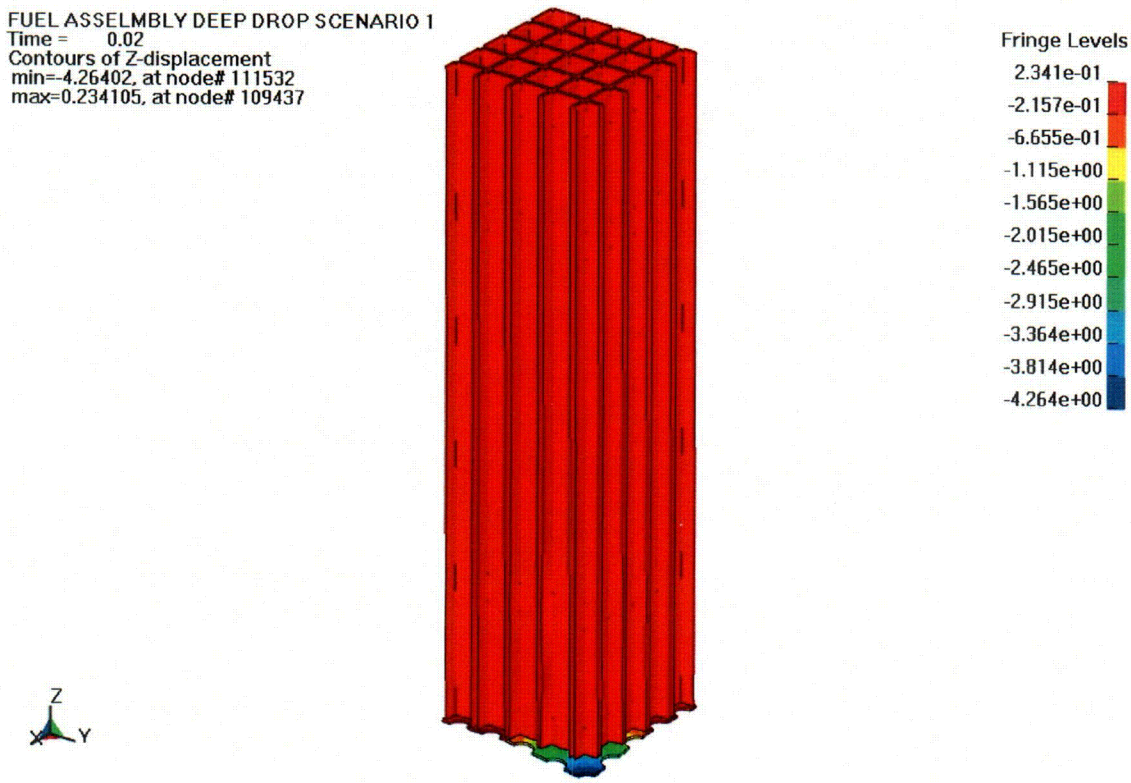
Section 2.8.5 does not indicate whether other fuel assemblies are in place, when a fuel assembly drops through an empty cell and impacts the baseplate at its center. Depending on how the baseplate is designed, a full load of fuel assemblies may introduce progressive deformation after a fuel assembly impacts at the center of the baseplate. The maximum downward deformation of the baseplate is about 4.3", as shown in Figure 2-10. This may be significant enough to initiate a progressive deformation. Therefore, provide: (1) the assumption on the existing fuel assemblies when the impact occurs, (2) the design basis for the baseplate, and (3) a figure similar to Figure 2-10, that shows the cells together with the severely deformed baseplate.

Westinghouse Response:

(1) The spent fuel storage rack is assumed to be empty (i.e., no fuel assemblies in place) when a fuel assembly drops through an empty cell and impacts the baseplate at its center. This is a simplifying assumption, which is reasonable considering that the buoyant weight of a fuel assembly is approximately 1,525 lb whereas the impact load transmitted by the dropped fuel assembly is roughly 268,000 lb based on the LSDYNA solution.

(2) The design basis for the baseplate is to provide vertical support for the stored fuel assemblies and to protect the Spent Fuel Pool liner from a fuel assembly strike. In other words, a dropped fuel assembly should not pierce the baseplate and result in a direct impact with the liner.

(3) The figure below shows the cells together with the severely deformed baseplate for the same LS-DYNA solution as shown in Figure 2-10 of Technical Report 54. Note that the deformation of the cells is not significant compared to the baseplate. This is because the cell-to-baseplate weld connections break as a result of the postulated fuel impact load before the cell walls are permanently deformed.



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-TR54-012
Revision: 0

Question:

Section 2.8.5 indicates that the maximum baseplate deformation occurs in the Region 1 rack for the case of drop to the center of the baseplate. The Region 1 rack is very similar to the new fuel rack, described in report APP-GW-GLR-026, except it is 6.25" taller. The difference in initial potential energy due to gravity is only (199.5-193.25)/(193.25+36) = 2.7%. The water in the spent fuel pool, coupled with the confinement of the cell, will provide a drag force on the dropping fuel assembly. However, the maximum deformation shown in Figure 2-10 is 4.264", compared to 3.795" for the new fuel rack case. The difference is (4.264 - 3.795)/3.795=12.4%. Therefore, please explain how an increase in potential energy of 2.7% causes an increase in deformation of 12.4%. Also describe how drag forces on the fuel assembly were considered in the analysis.

Westinghouse Response:

In general, the deformation of the impacted rack baseplate is proportional to the initial impact energy (i.e., the kinetic energy of the dropped fuel assembly and lifting tools at the beginning of impact). However, because of the nonlinearity involved in the drop event, the rack baseplate deformation may not be linearly proportional to the initial impact energy.

Because the drop weight for Region I rack in the SFP (i.e., specified to be 3,100 lbs) is significantly greater than that involving the new fuel rack (i.e., up to 2027.6 lbs by accounting for the upper tolerance weight based on the specified drop weight of a fuel assembly, control elements and new fuel handling tool), the difference in initial potential energy due to gravity is much greater than 2.7%.

The initial impact velocity between the impactor and the rack baseplate is calculated to be 421.1 in/sec for the new fuel rack and 351.6 in/sec for the Region I rack in the SFP after considering the water resistance for the latter case. Therefore the impact energy difference of the two deep drop events is about 6.6%. It should be pointed out that both impact events lead to small plastic deformation in the baseplate at the impact location. The 6.6% impact energy difference results in a baseplate deformation difference of about 11.4% (=(4.264"-3.826")/3.826") due to greater local plastic deformation in the Region I rack baseplate.

The drag force is considered in determining the initial impact velocity between the dropped object and the impact target for all postulated fuel drop events in the SFP. The equation of motion of the dropped fuel assembly, which includes the drag force term, is used to calculate the impact velocity. For the shallow drop event, the drag coefficient is directly taken from Table 11.4.4, Mark's Standard Handbook for Mechanical Engineers. Under the "deep drop" scenario,

the additional water resistance due to fluid confinement effect in a rack cell, which is represented as the incremental increase in effective drag coefficient, is derived by applying Bernoulli's principal. The same method has been consistently used in many previous Holtec rerack projects approved by the USNRC.

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"
3. Avallone, E., and Baumeister III, T., Marks' Standard Handbook for Mechanical Engineers, Table 11.4.4, McGraw-Hill International Editions, Tenth Edition, 1997.

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-TR54-013
Revision: 0

Question:

There are a total of six (6) impact analyses for the Region 1 and Region 2 racks (3 drop cases for each rack region). The report only presents the results for three (3) analyses, on the basis that these are the bounding conditions. Please explain the technical basis for concluding that these are the bounding conditions, or provide the results for the three (3) analyses not presented in the report.

Westinghouse Response:

The analysis was performed for both the Region 1 and Region 2 racks. The bounding analysis was reported. The shallow drop event involving a Region I rack was analyzed and found to yield a plastic deformation of 15.0 inches measured vertically from the rack top, which is bounded by the reported Region II rack shallow drop analysis with a predicted rack top plastic deformation of 20.0 inches. Similarly, Region II rack baseplate was found to deform less than 3.3 inches, which is smaller than the reported bounding baseplate deformation of 4.264 inches for the Region I rack. Finally, because the Region I rack is lighter than the Region II rack, more impact energy can be transferred into the SFP floor and therefore results in bounding SFP floor damage in an event where the fuel assembly drops directly over a Region I rack pedestal; this bounding case was analyzed and reported.

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-TR54-014
Revision: 0

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.

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 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.

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.

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 value of 2,500 psi will be changed in Subsection 2.8.3 to 3,000 psi.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-025
Revision: 0

Question:

Explain whether only full fuel racks are included in the two simulations, or if several scenarios are considered; i. e., different fill ratios, from partially full to full within a given rack; varying fuel locations within the partially filled rack; varying fill and locations in adjacent racks. Provide the technical justification if only full racks are considered. Also, would it ever be possible to have less than all fuel racks (eight) in the pool. If so, then additional simulations would be needed. If not, is there a requirement in the DCD that specifies all fuel racks must always be in place whenever fuel is stored in any of the racks?

Westinghouse Response:

All spent fuel racks, in both simulations, are assumed to be fully loaded with maximum weight fuel assemblies. This scenario bounds any partially loaded configuration since it (1) maximizes the vertical compression and lateral friction loads on the support pedestals and (2) produces the maximum rack displacements and fuel-to-cell wall impacts. The displacements are larger for a fully loaded rack, as opposed to a partially filled rack, because the dynamic model conservatively assumes that all stored fuel assemblies rattle in unison. Hence, the momentum transferred between the rattling fuel mass and the spent fuel rack is at a maximum for a fully loaded rack. For a partially filled rack, the decrease in rattling fuel mass outstrips the destabilizing effect of an eccentric fuel loading pattern.

The Spent Fuel Pool rack analysis was performed with all eight fuel racks installed during operation of the spent fuel pool, which is consistent with the design intent of the AP1000 Spent Fuel Storage Racks. DCD Rev 16 Section 9.1 will include the statement that all spent fuel racks will be in place in the spent fuel pool whenever fuel is stored in the spent fuel racks.

Reference:

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

Design Control Document (DCD) Revision:
DCD Rev 16 section 9.1 will include the statement that all spent fuel racks will be in place in the spent fuel pool whenever fuel is stored in the spent fuel racks.

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-026
Revision: 0

Question:

What are the gaps and tolerances for each of the gaps between the fuel to cell wall, rack to rack, and rack to wall? What are the assumed initial locations of the various components (fuel assemblies and each rack) and what is the technical basis for this assumption. Were any studies done for different initial conditions (considering tolerances); if not, explain why. What requirements are in the DCD to ensure that the assumed gaps (considering tolerances) will always be maintained throughout the licensing period?

Westinghouse Response:
All gaps between fuel assemblies and cell walls, between racks, and between racks and pool walls are set to match the nominal gaps provided on the Westinghouse Drawing APP-FS02-V2-002 Revision 0 "Discrete Zone Two Region Spent Fuel Rack Pool Layout. The following table summarizes the gap information used in the dynamic analyses.

	Fuel-to-Cell Wall	Rack-to-Rack	Rack-to-Wall
Nominal Gap (inch)	(8.8"-8.1")/2 = 0.35"	1" or 1.25"	North – 3.2" East – 2.75" South – 2.7" West – 3.2"

Fuel is assumed centrally located in cell. This is conservative since minimizing gap on one or two walls will generally produce a larger hydrodynamic coupling effect.

Numerical studies were done on other Holtec rack projects; the results generally showed a small influence on results. A larger influence occurs if the gaps are assumed to be displacement dependent, rather than always being held constant at their initial value. The neglect of this effect is conservative.

Once racks are installed, the "as-built" gaps are reconciled with the gaps initially used for analysis by evaluation of the numerical results and the predicted motions. Once the "as-builts"

are accepted by evaluation of the current results, the only way the gaps would change over time would be by the action of a seismic event. Combined License applicants will have a procedure in place to address measurement of the post design-basis seismic event gaps, and to evaluate the acceptability of the configuration showing it is acceptable, or to take appropriate corrective actions. A statement will be added to both the Technical Report and DCD addressing the design-basis seismic event potential change in gaps between the spent fuel racks.

Reference:

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

Design Control Document (DCD) Revision:
The following statement will be added to DCD section 9.1 addressing the design-basis seismic event potential changes in gaps between the spent fuel racks"Per DCD subsection 3.7.5.2, Combined License applicants will prepare site-specific procedures for activities following an earthquake. An activity will be to address measurement of the post-seismic event gaps between spent fuel racks and to take appropriate corrective actions."

PRA Revision:
None

Technical Report (TR) Revision:
The following statement will be added to Technical Report 54 addressing the design-basis seismic event potential changes in gaps between the spent fuel racks" Per DCD subsection 3.7.5.2, Combined License applicants will prepare site-specific procedures for activities following an earthquake. An activity will be to address measurement of the post-seismic event gaps between spent fuel racks and to take appropriate corrective actions."

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-027
Revision: 0

Question:

Provide more detailed information about how the fluid coupling was calculated and implemented in the AP1000 simulations. Describe the approaches used for fluid 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).

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. Finally, 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.

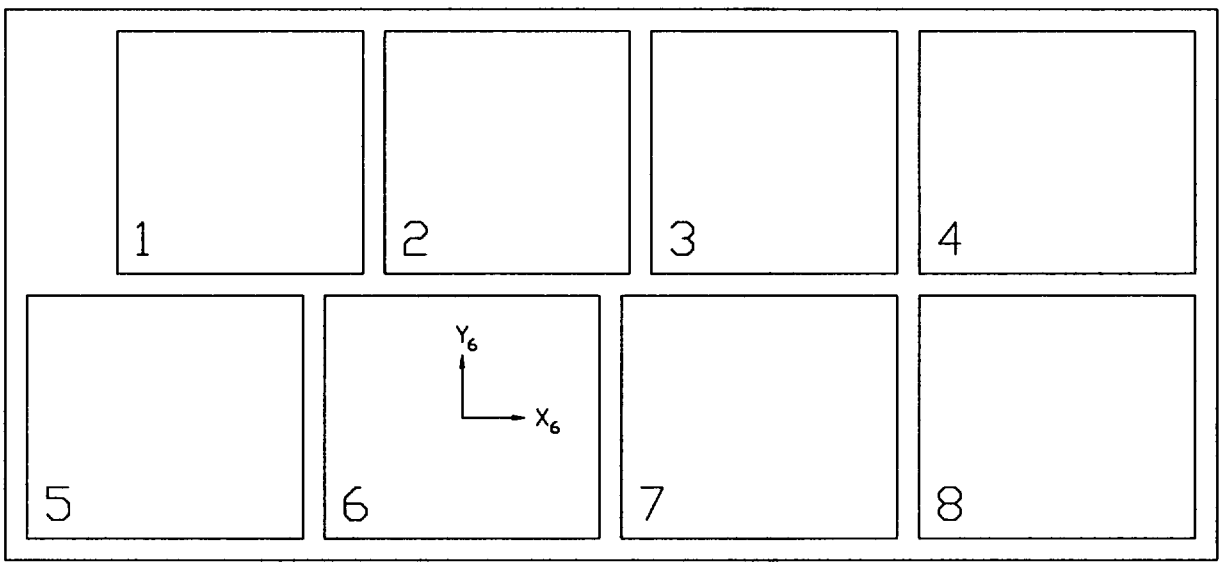


Figure TR54-27.1 Planar View of an 8 Rack Array

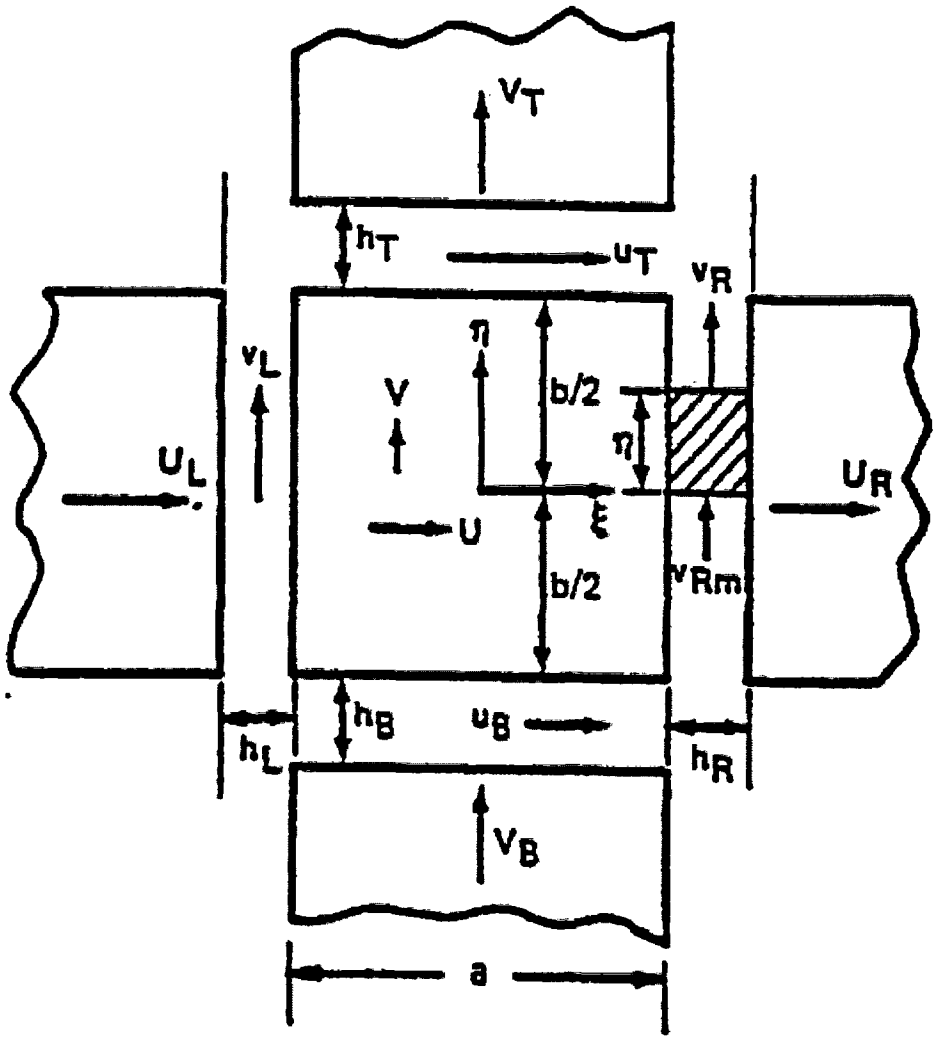


Figure TR54-27.2 Fluid Flow Around a Typical Rack

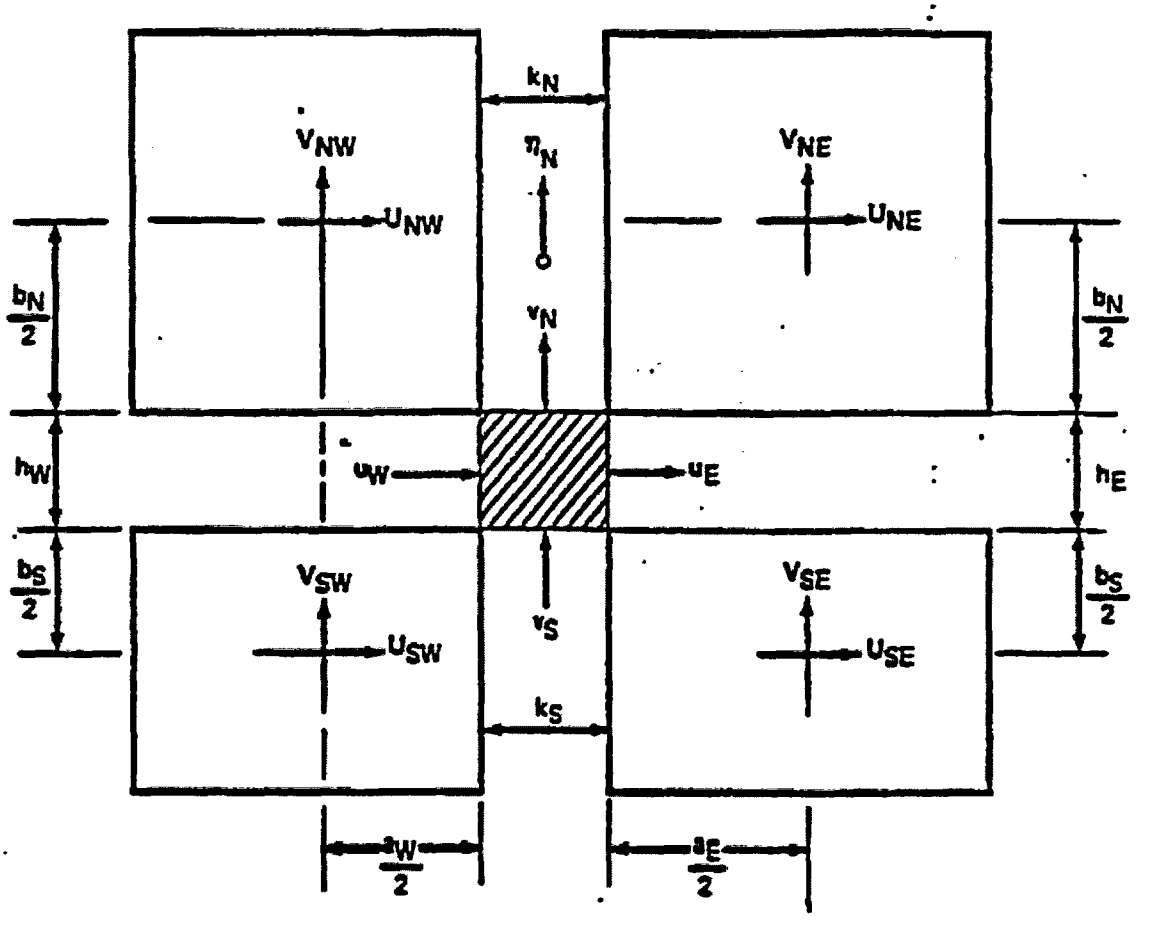


Figure TR54-27.3 Fluid Flow at Channel Junction

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-TR54-029
Revision: 0

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.

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

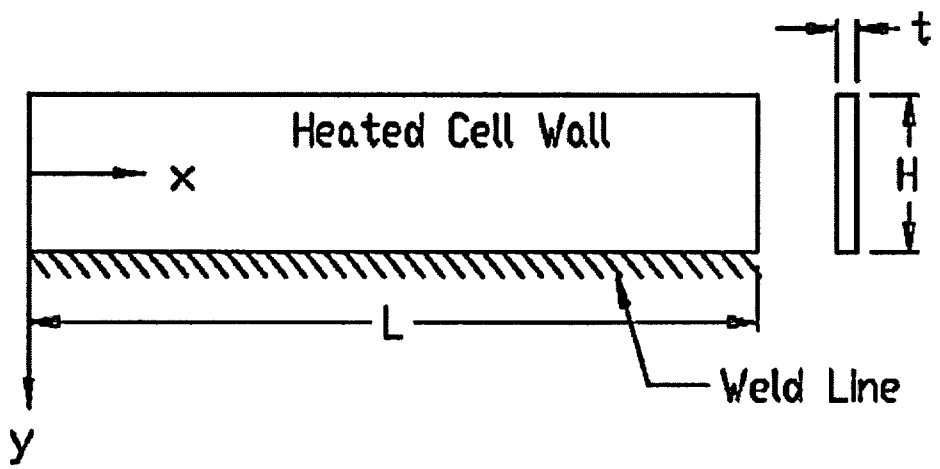
T_a = Differential temperature induced loads based on the postulated abnormal design conditions

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 ΔT = 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

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

where E = 27.6 x 10^6 psi, α = 9.5 x 10^{-6} in/in °F and ΔT = 50°F.

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

τ_{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. 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.

Reference:

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.

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

PRA Revision:
None

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

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-030
Revision: 0

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.

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.

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:
A statement will be added to DCD Subsection 9.1.2.1 stating that the stress analysis of the spent fuel racks satisfies all of the applicable provisions in NRC Regulatory Guide 1.124, Revision 1. Table 1.9-1 (Sheet 10 of 15) "Regulatory Guide/DCD Section Cross-References" will be revised for Regulatory Guide 1.124 to include DCD Subsection 9.1.2.1.

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.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-031
Revision: 0

Question:

The subject report does not discuss any analysis for seismic sloshing effects. Provide a description of the sloshing calculation approach and results for both horizontal directions.

Westinghouse Response:

"Sloshing" may be defined as the dynamic behavior and associated load of the water produced by wave-like motion at the surface of the pool. TID 7024, "Nuclear Reactors and Earthquakes", Chapter 6, is commonly used to evaluate the dynamic response of the water within the Spent Fuel Pool. Figure 6.2(a) of TID-7024 depicts the two masses of water that the total bulk is considered to be split into, as described in the text. The upper portion of the water denoted in the figure as "water in motion" produces convective forces and the lower portion of the water, denoted as "constrained water" produces impulsive forces. The latter bulk of water has an associated mass (identified as weight W_0) and is effectively a rigid body that moves along with the tank (refer to Figure 6.1 and the first paragraph of Section 6.4). The horizontal force produced by this mass of water when accelerated by the earthquake acts at a height of h_0 from the bottom of the tank. This parameter is determined in the table given at the end of Section 6.3 to be equal to 3/8 times the height of the fluid. This height is not dependent upon the magnitude of the earthquake. For the spent fuel pool, the water depth is approximately 40 feet and the height h_0 would be 15 feet (180 inches) from the bottom. Since the impulsive force acts at the approximate centroid of the rigid water mass, the top elevation of this bulk of water is above this point. The racks are approximately 203 inches tall, which is only slightly higher than the height h_0, so the racks reside in the impulsive water mass at the bottom of the pool and the sloshing portion of the water is above this elevation. Therefore, seismic sloshing of the SFP water does not influence the dynamic response of the spent fuel racks in either horizontal direction.

Reference:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis", (Technical Report Number 54)
2. TID 7024, "Nuclear Reactors and Earthquakes," U.S. Atomic Energy Commission, August 1963.

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-TR54-033
Revision: 0

Question:

Section 2.3.4.3, 4th bullet, develops the faulted allowable maximum weld stress for the weld material. Why isn't an allowable maximum weld stress based on the base metal also developed? Normally welds are checked for both weld material and base metal, as was done for Levels A and B in Section 2.3.4.1.

Westinghouse Response:

The required capacity evaluation for Level A conditions are presented below using the material properties associated with the material.

Su = ultimate strength of weld material (assumed equal to that of the base metal for purposes of this calculation); Sy= yield strength of base metal

Al = fillet weld leg area; At = fillet weld throat area = 0.707Al

Using the ASME allowable strengths for weld and base metal in Subsection NF, the shear capacities are:

V(base) = (0.4Sy)Al; V(throat) = (0.3Su)(0.707Al) so that

V(throat)/V(base) = 0.2121Su/(0.4Sy) = 0.53025Su/Sy

The above result for Level A conditions shows that the weld throat controls the capacity only if 0.53025Su < Sy. Therefore, for the AP1000 spent fuel racks,

Su=66.2 ksi; Sy=21.3 ksi at temperature, so that

V(throat)/V(base) = 1.648 indicating that base shear capacity controls the joint for a Level A event.

For Levels B, C, and D, the joint capacities are simply increased by a factor so that the determination of the governing section remains the same.

Appendix F of the ASME Code does not explicitly require weld calculations for Level D events. If, however, the weld capacity evaluations are performed using material strengths inferred by certain sub-sections of Appendix F, Holtec evaluates the capacity of the weld throat by using the amplifier 1.8 on the Level A capacity to obtain

V(throat) = 1.8 (0.2121SuAl) = 0.38278SuAl

ASME Code Appendix F contains the following subsections that refer to allowable strengths for shear calculations. Using the 1998 Edition,

F-1331 – Criteria for Components (F-1331.1(d)) – The average primary shear stress across a section loaded in pure shear shall not exceed 0.42Su.

F-1332 – Criteria for Plate and Shell Type Supports (F-1332.4 Pure Shear) - The average primary shear stress across a section loaded in pure shear shall not exceed 0.42Su.

F-1334 – Criteria for Linear Type Supports (F-1334.2 Stresses in Shear) – The shear stress on the gross section shall not exceed the lesser of 0.72Sy and 0.42Su. Gross section shall be determined in accordance with NF-3322.1(b). [Note that Code reference to NB-3322.1(b) is a typo as the referenced NB section has nothing to do with section evaluation.]

F-1341 – Criteria for Components (using Plastic System Analysis) (F-1341.1(d) - The average primary shear across a section loaded in pure shear shall not exceed 0.42Su.

<u>It is stipulated that F-1334.2 is intended for setting limits for the shear stress in the base metal of gross sections associated with steel structural members and should not be applied to any weld calculation</u> (as can be inferred by the title of Subsection NF-3322 – Design Requirements for Structural Steel Members). Even if one accepts that there is an implied requirement in Appendix F to check weld capacity for Level D events, the appropriate base metal shear stress limit should be 0.42Su (viz. F-1331.1(d), F-1332.4, or F-1334.2), which would therefore give the capacity of the base metal as

V(base) = 0.42SuAl

V(throat)/V(base) = 0.911 indicating that weld throat shear capacity always controls the joint for a Level D event independent of the material. This is why only the weld throat is checked when examining welds in the Level D configuration.

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-TR54-035
Revision: 0

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.

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 and Appendix D of SRP 3.8.4;

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.

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-TR54-037
Revision: 0

Question:

Section 2.8.4 indicates that this subsection presents evaluations for potential cell wall buckling and the secondary stresses produced by temperature effects. The description of secondary stresses produced by temperature effects is not included in this section. Add this information to the report. Regarding the evaluation presented for compressive stress in the cell wall for buckling, confirm whether the R5 stress factor used for this calculation includes the worst impact forces generated, including the impacts at the top of the racks.

Westinghouse Response:

The secondary stresses produced by temperature effects (an isolated hot cell) were inadvertently omitted. Technical Report 54 subsection 2.8.4 will be revised to include an evaluation of secondary stresses produced by temperature effects.

The stress factor R5 is a stress factor that is used to get the vertical stress near the base of a corner cell and includes the effect of lateral impact forces at the top of the rack. That is, at any instant, the rack is under beam action, so that a lateral impact load at the top of a rack develops a vertical load at the base of the rack as the rack resists rocking.

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:
Technical Report 54 subsection 2.8.4 will be revised to include an evaluation of secondary stresses produced by temperature effects.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR54-040
Revision: 0

Question:

Explain what provisions are provided for performance of inservice examination of the rack, as indicated in 10 CFR 50.55a(g)(3) for ASME Class 3 component supports.

Westinghouse Response:

The spent fuel racks are passive structures in the spent fuel pool. They operate in a relatively mild environment compared to reactor coolant system primary components. There are no moving parts on the spent fuel racks, and they do not require any instrumentation. Therefore, there is no compelling need to perform inservice examination of the spent fuel racks. However, the spent fuel racks can be accessed from above by way of an empty storage cell location(s) to enable the performance of inservice examination, as mandated by 10 CFR 50.55a(g)(3) for ASME Class 3 component supports. At the base of each storage cell (except at the four designated lifting locations), there is a 6-inch diameter thru hole in the baseplate, which provides access below the baseplate. Also access below the baseplate can be gained from the portion of the spent fuel pool that does not contain spent fuel racks. In summary, the spent fuel racks are designed to provide access to all surfaces that may come in contact with spent fuel assemblies and to the support pedestals beneath the baseplate to support inservice examinations as needed.

References:

1. APP-GW-GLR-033, Revision 0, "Spent Fuel Storage Rack Structural/Seismic Analysis," (Technical Report Number 54)
2. USNRC 10 CFR 50.55a(g)(3), "In Service Inspection Requirements"

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None