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August 1, 2011
U7-C-NINA-NRC-110105

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Response to Request for Additional Information

Reference: 1) Letter, Scott Head to Document Control Desk, "Response to Requests for Additional Information," dated June 23, 2011, U7-C-NINA-NRC-110084 (ML11178A073)
2) Letter Scott Head to Document Control Desk, "Supplemental Response to Request for Additional Information," dated July 19, 2011, U7-C-NINA-NRC-110098 (ML11202A268)

Attached is the response to the NRC staff question included in Request for Additional Information (RAI) letter number 377 related to Combined License Application (COLA) Part 2, Tier 2, Section 9.1, "Fuel Storage and Handling." Previous responses were submitted on June 23, 2011 (reference 1) and additional responses will be provided on September 15, 2011, to complete the response to letter 377. RAIs in letter 377 related to new fuel storage racks are being answered consistent with a departure deleting the installation and use of new fuel racks (reference 2).

The attachment provides the response to the RAI question listed below:

09.01.02-4

The response to RAI 09.01.02-4 does not require a change to the COLA.

There are no commitments in this letter.

If you have any questions, please contact Scott Head at (361) 972-7136 or Bill Mookhoek at (361) 972-7274.

D091
NRO

STI 32908462

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 8/1/11

Mark McBurnett
Vice-President, Oversight and Regulatory Affairs
South Texas Project Units 3 & 4

jaa

Attachment: RAI 09.01.02-4

cc: w/o attachment except*
(paper copy)

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RAI 09.01.02-4

QUESTION:

Summary: Provide additional information on fuel drop analyses.

10 CFR Part 50, Appendix A, GDC 1, requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. In addition, Section I.4 of SRP 3.8.4, Appendix D, specifies that the fuel pool racks and the fuel pool structure should be evaluated for accident load combinations. Section 8.3 of both Technical Reports addresses fuel drop analysis. However, the staff finds that there is insufficient information for the staff to complete its review in accordance with SRP 3.8.4, Appendix D. Therefore the staff requests the applicant to provide the following additional information, and to update Section 8.3 of the technical reports, as appropriate:

a. For the fuel drop load case, provide details of design checks on baseplate, support plate, as specified in Section I.4 of SRP 3.8.4, Appendix D. Explain whether drop cases producing maximum bending stresses and/or maximum shear stresses in baseplate were considered, and describe the impact locations assumed in the drop cases.

b. Describe the material stress-strain curves used, and identify whether they are "engineering stress-strain" curves or "true stress-strain" curves. Also describe how the curves were adjusted for the ambient temperature. Provide references for the curves used.

c. Explain whether sensitivity studies were performed to confirm the adequacy of the mesh in the finite element model. If no sensitivity studies were performed, provide the technical basis for concluding that the analyzed mesh is sufficiently refined to obtain an accurate solution.

d. Describe how the dropped fuel assembly was modeled. Is it assumed to be infinitely rigid, absorbing no energy by deformation, or is it assumed to be an elastic-plastic member, capable of absorbing energy by deformation? If the latter is assumed, provide figures showing the fuel assembly deformation for both the shallow and deep drop cases, and specify the percent of the initial potential energy that is absorbed by deformation of the fuel assembly.

e. Provide figures showing the deformation shape of cell wall for the controlling shallow drop case and the deformation shape of the baseplate for the controlling deep drop case. Discuss whether baseplate deformation leads to loss of boral shielding of the active fuel zone, and whether this needs to be considered in criticality analysis.

RESPONSE:

a. As stated in response to RAI 09.01.02-2, "The Technical Report for the new fuel storage racks, Westinghouse Electric Company LLC, WCAP-17311-P, Rev. 1, 'Structural Analysis Report for STP Units 3 & 4 New Fuel Storage Rack Baseline Design,' will be withdrawn. The Technical Report, WCAP-17331-P, Rev. 1, 'Structural Analysis Report for STP Units 3 & 4 Spent Fuel Storage Rack Baseline Design,' will be revised to address issues contained in RAIs 09.01.02-2 through 09.01.02-9 for the spent fuel storage racks located in the Spent Fuel Storage Pool."

   Several drop cases and impact locations intended to produce maximum bending and shear stresses in the baseplate and support plates have been considered and are described below.

   a. Maximum bending stresses in the baseplate are judged to occur at an impact location where the span between support pads and/or reinforcing support plates is greatest (See Figure 1, location 'a').

   b. Maximum shear stresses in the baseplate are judged to occur at an impact location immediately adjacent to a support pad that is not reinforced with a support plate (See Figure 1, location 'b').

. Per Section I.4 of SRP 3.8.4, Appendix D, Rev. 2, March 2007 the acceptance criteria for the baseplate and support plates are such that the functional capability of the rack is maintained. To check this, the baseplate and support plates are evaluated using strain acceptance criteria for steel supports as discussed in Section 2.3.4, Paragraph 2.2 of NEI-08-05. The most conservative strain limit is used regardless of the loading condition; namely, that the average total strain is less than 50% of the strain at ultimate stress.

   In addition, the maximum deformation of the baseplate is evaluated to ensure that the intended neutron shielding is maintained (See Response (e) below for further details).

   Figure 1 identifies the selected drop locations with respect to the 10x10 cell rack design.

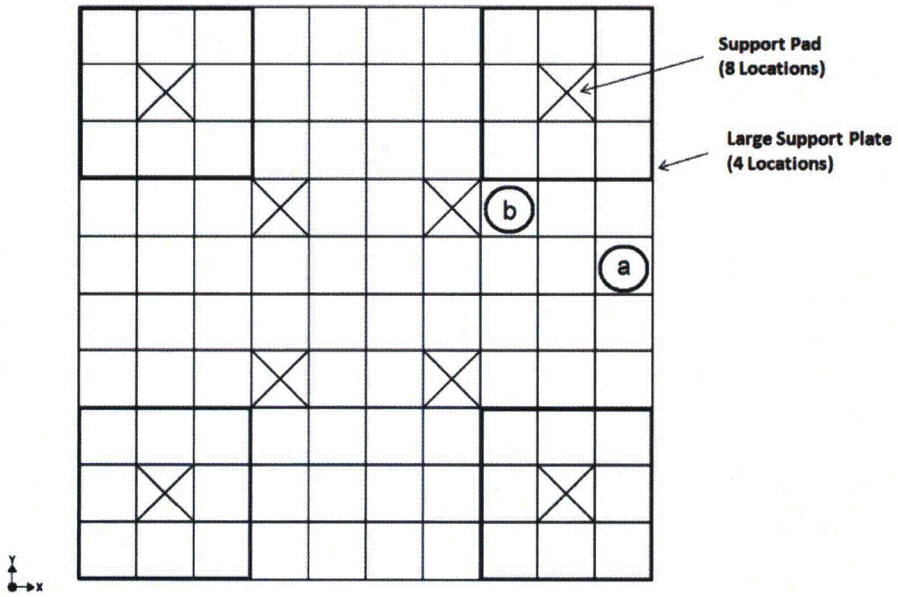

Figure 1: Baseplate and Support Impact Locations

Figure 2 shows the maximum effective plastic strain contour plot for the baseplate for the limiting deep drop case. The peak effective plastic strain is 0.0987 in/in.

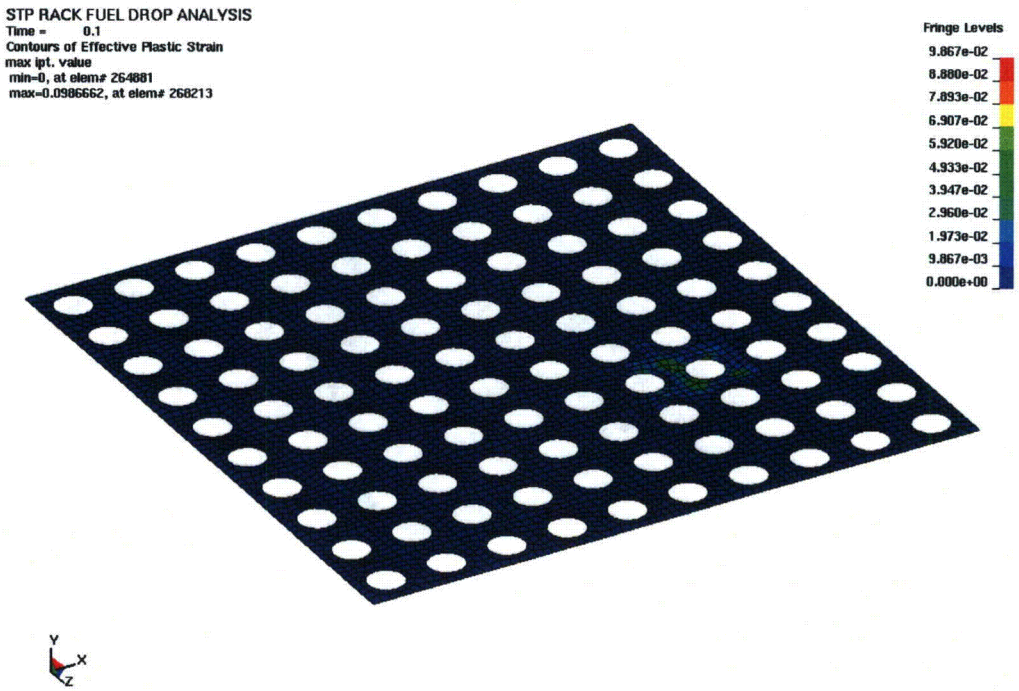

Figure 2: Baseplate Effective Plastic Strain for the Limiting Deep Drop Case

The strain at ultimate stress is based on information provided in "Tensile Stress-Strain Results for 304L and 316L Stainless Steel Plate At Temperature," performed by the Idaho National Laboratory and published in the 2007 ASME Pressure Vessels and Piping Division Conference report. Figure 3 shows the true strain at ultimate stress versus temperature.

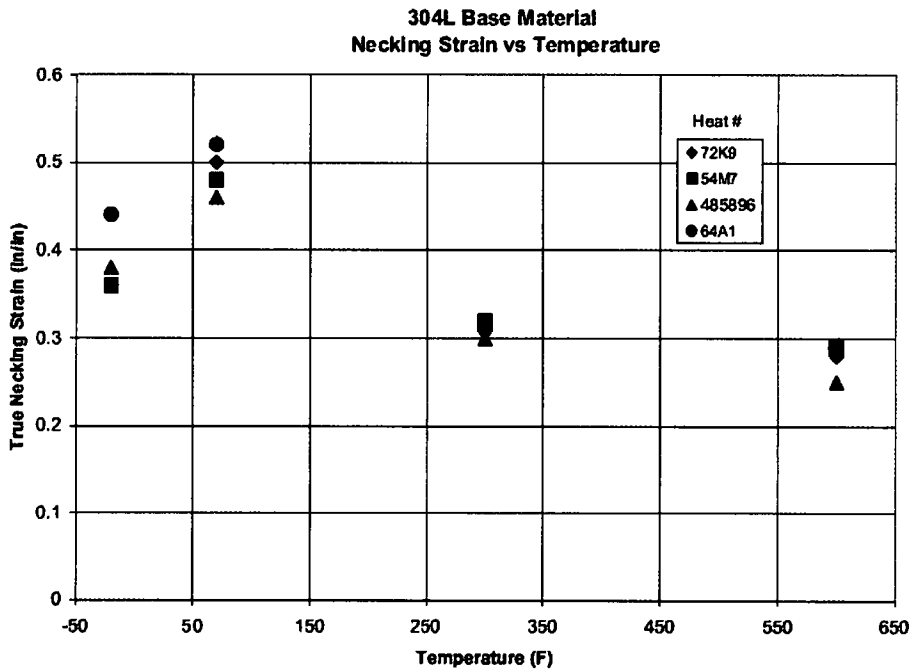

Figure 3: 304L True Strain at Ultimate Stress versus Temperature

Per Figure 3, the strain at ultimate stress is 0.3 in/in at a conservative temperature of 300°F. Therefore, the strain limit used in this evaluation for the Type 304L stainless steel material is 0.15 in/in. As identified in Figure 2, the maximum plastic strain in the baseplate is less than this limit.

Figure 4 shows the effective plastic strain contour plot for the support plates for the limiting deep drop case. The peak effective plastic strain is 0.116 in/in. This is less than the 0.15 in/in limit discussed above.

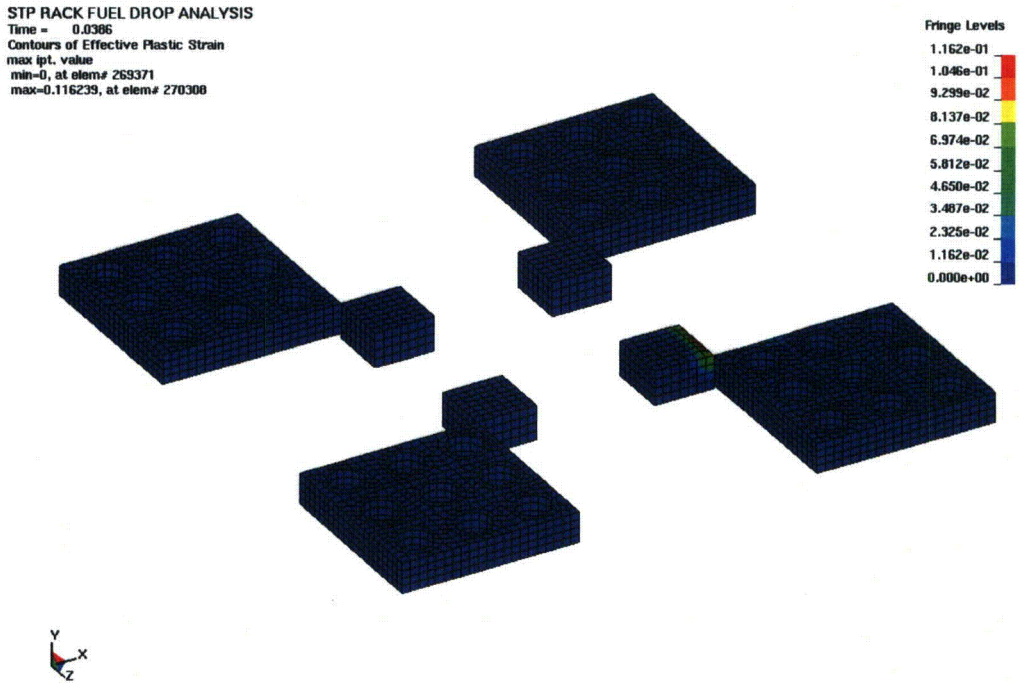

Figure 4: Support Plate Effective Plastic Strain for the Limiting Deep Drop Case

b. The racks, with the exception of the Boral neutron absorbing plates, are composed of ASTM A240 Type 304L stainless steel. It is expected that the rack cells, baseplate, and support plates could potentially undergo permanent deformation due to a fuel drop. A bilinear isotropic material model is used in the analysis to account for this behavior.

Elastic properties for the 304L material are based on material properties identified in Section II, Part D of the ASME BP&V code at a conservative temperature of 200°F. Per the code, the minimum engineering material properties for the Type 304L material are:

- Yield Strength = 21.4 ksi
- Elastic Modulus = 27.5×10^6 psi

Plastic properties are based on "Tensile Stress-Strain Results for 304L and 316L Stainless Steel Plate At Temperature," performed by the Idaho National Laboratory and published in the 2007 ASME Pressure Vessels and Piping Division Conference report. Figure 5 shows the material true stress-strain curves at various temperatures identified in the report. The curve associated with a material temperature of 300°F is conservatively used for the analysis. Additionally, the tangent modulus (dashed line) is calculated using an upper limit total true strain of 1.2 in/in. This is another source of conservatism in the material model, because the difference in area beneath the calculated tangent modulus and the actual curve would otherwise account for increased toughness energy in the material model (e.g., the material would deform less because it would be capable of absorbing more energy per unit deflection).

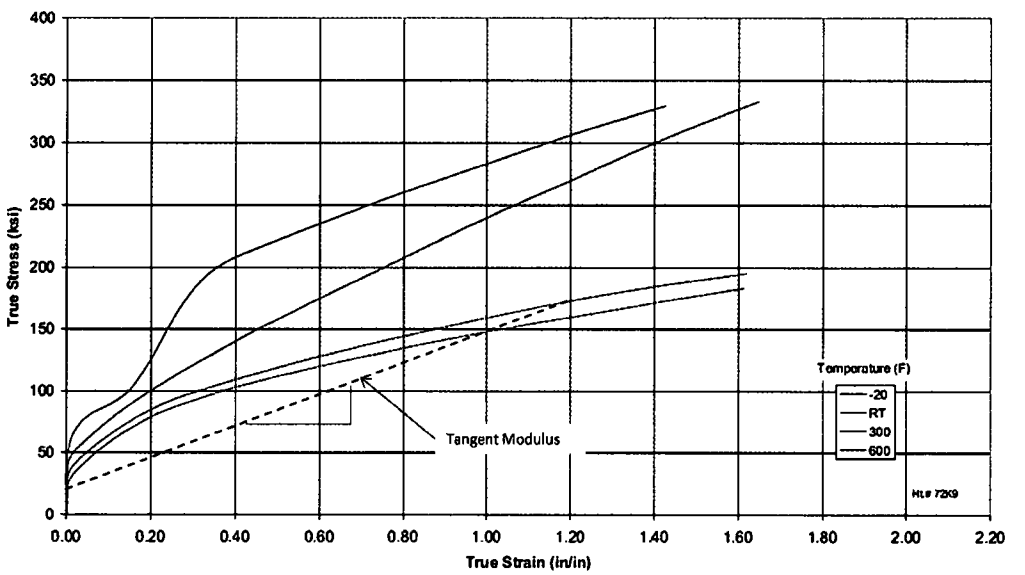

Figure 5: Type 304L Stainless Steel True Stress-Strain Curves at Temperature

c. A mesh sensitivity study was performed to ensure the stability of the mesh. The target element size was varied between edge lengths of 3, 2, and 1 inches (approximately 2, 3, and 6 elements per cell width, respectively). A typical load case analysis was performed and the sets of results compared. The 2-inch and 1-inch element size models yielded results with negligible differences in total deformation at the top of the rack and forces at the bottom of the support pads. The 1-inch element size was chosen for added assurance and because solution efficiency was not significantly compromised by the higher fidelity mesh.

d. The fuel assembly is modeled as an effectively rigid body. That is, the fuel is represented as a meshed, deformable body; however, its elastic modulus has been set an order of magnitude higher than the elastic modulus of the impacted material, i.e., the rack cell walls and baseplate. Figure 6 shows a plot of the total internal energy of the system versus the energy absorbed by the fuel due to deformation for a through-cell drop case. The plot confirms that an insignificant (less than 1%) amount of energy is absorbed by the fuel model during impact.

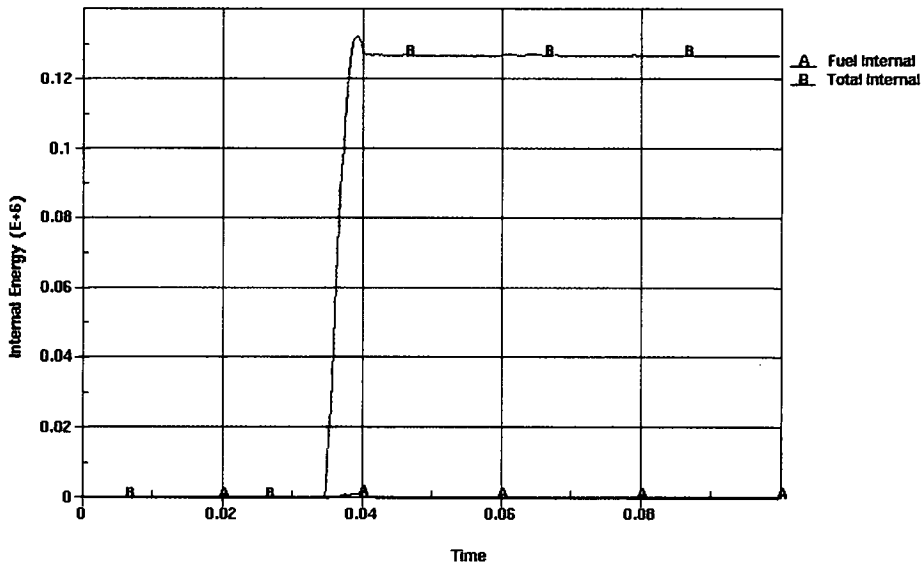

Figure 6: Total Internal Energy vs Energy Absorbed by Fuel

e. Maximum deformation of the cell wall for the shallow drop case occurs at a corner location. Figure 7 shows the deformation shape of the cell wall. The maximum vertical deformation is 7.30 inches. The rack design provides 13.75 inches of clearance between the top of the rack and the top of the neutron absorbing plates. Therefore, it is concluded that the neutron shielding functionality of the rack will not be compromised for a shallow drop case.

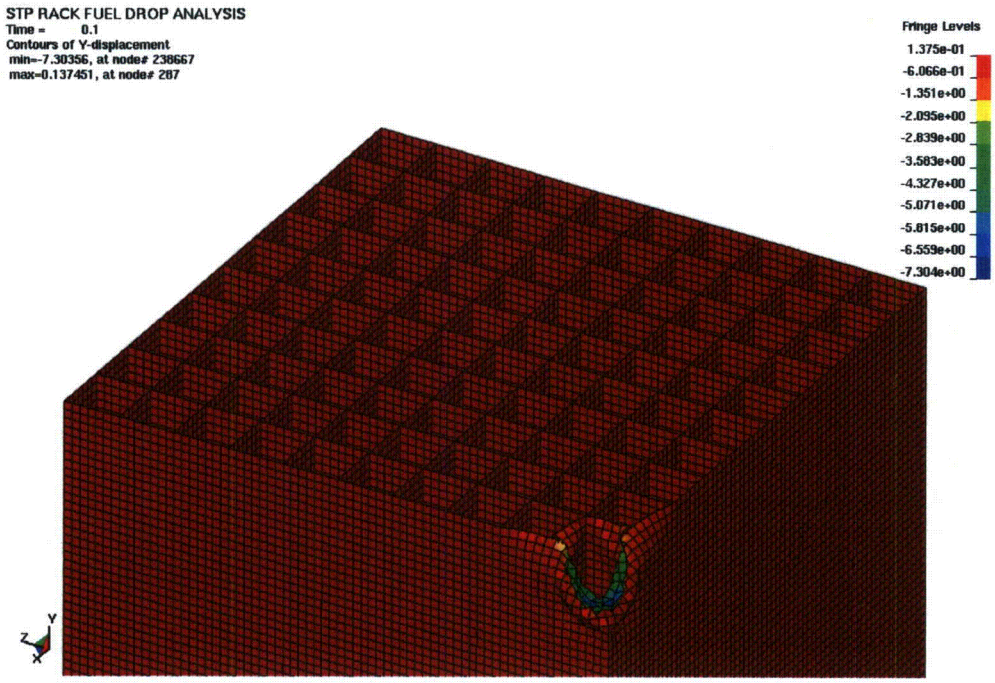

Figure 7: Deformation at Top of Rack for Limiting Shallow Drop Case

Maximum deformation of the baseplate for the limiting deep drop case occurs at a cell location where the span between support plates and pads is greatest (See Figure 1, location (a)). Figure 8 shows the deformation shape of the baseplate. The maximum vertical deformation is 0.87 inches. The rack design provides approximately 2.0 inches of nominal overlap between the neutron absorbing plates and the bottom of the fuel assembly active fuel zone. Therefore, it is concluded that the deformation of the baseplate will not lead to a loss of neutron shielding of the rack.

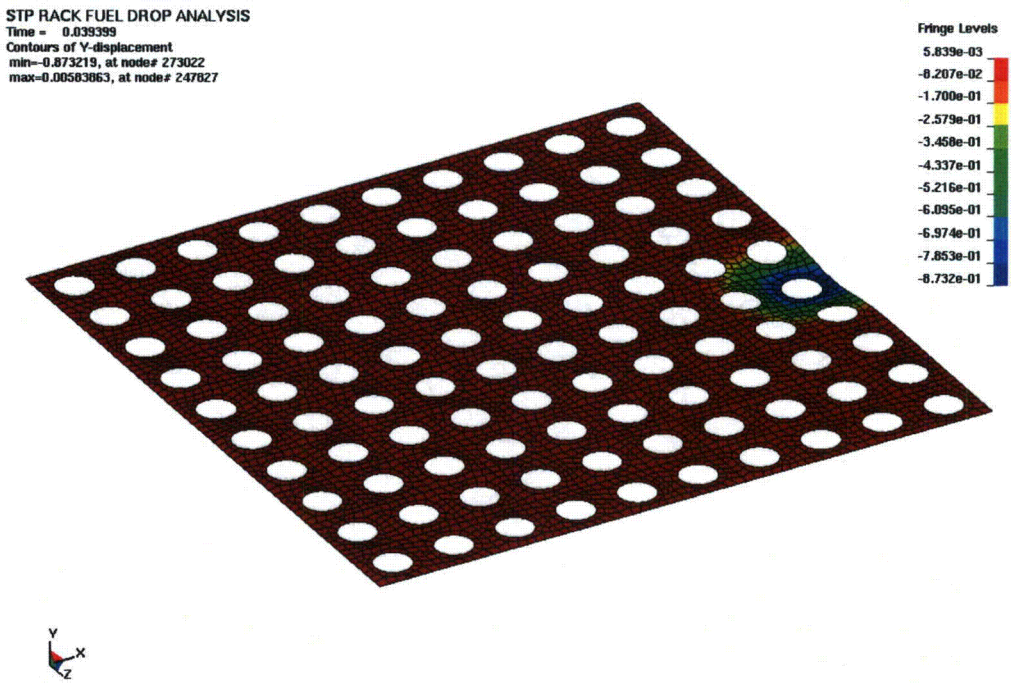

Figure 8: Deformation at Baseplate for Limiting Deep Drop Case

It is noted that the integrity of the welds between the cell walls and baseplate were considered in the evaluations of the deep drop cases. It was found that although the welds that attach the immediate surrounding cell walls could potentially fail, the welds adjacent to this cell will maintain their integrity. Therefore, significant separation between the cell walls and the baseplate will not occur.

No changes to the COLA are required by the responses provided above.