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Your ref: Project Number 740
Our ref: DCP/NRC1740

May 29, 2006

Subject: AP1000 COL Standard Design Change Submittal

In support of Combined License application pre-application activities, Westinghouse has been preparing and reviewing standard changes to the Design Control Document. These changes are intended to be incorporated into FSARs referencing the AP1000 design certification or incorporated into the design certification using supplemental rulemaking when 10 CFR Part 52 is revised to permit such changes.

Criteria in 10 CFR Part 52 Appendix D Section VIII B. 5. a, b, and c provide for changes in Tier 2 of the Design Control Document that do not require prior NRC approval. The changes included in this submitted report satisfy these criteria. The changes are generic and are expected to apply to all projects referencing the AP1000 Design Certification. This information is submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740).

Pursuant to 10 CFR 50.30(b), APP-GW-GLR-026, Rev. 0, "New Fuel Rack Design & Structural Analysis," (Technical Report Number 44), is submitted as Enclosure 1 under the attached Oath of Affirmation.

The reviews of these changes were included in a table of COL technical reports in a March 8, 2006 letter from NuStart to the NRC.

Questions or requests for additional information related to the content and preparation of these reports should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

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

D079

3776alf.doc

/Attachment

1. "Oath of Affirmation," dated May 30, 2006

/Enclosure

1. APP-GW-GLR-026, Rev. 0, "New Fuel Rack Design & Structural Analysis," (Technical Report Number 44)

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DCP/NRC1740
May 29, 2006

ENCLOSURE 1

APP-GW-GLR-026, Rev. 0

"New Fuel Rack Design & Structural Analysis"

Technical Report Number 44

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

Daniel S. Lipman, being duly sworn, states that he is Senior Vice President 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.

Daniel S. Lipman
Senior Vice President

Subscribed and sworn to
before me this 30th day
of May 2006.

Lorraine M. Piplica
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 2007
Member, Pennsylvania Association Of Notaries

AP1000 DOCUMENT COVER SHEET

TDC: _____ Permanent File: _____ APY: _____

RFS#: _____ RFS ITEM #: _____

AP1000 DOCUMENT NO.	REVISION NO.		ASSIGNED TO
APP-GW-GLR-026	0	Page 1 of 1	W-A. Sterdis

ALTERNATE DOCUMENT NUMBER: WORK BREAKDOWN #:

ORIGINATING ORGANIZATION: Westinghouse Electric Company

TITLE: **New Fuel Storage Rack Structure/Seismic Analysis**

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APP-GW-GLR-026
Revision 0

May 2006

AP1000 Standard Combined License Technical Report

New Fuel Storage Rack Structural/Seismic Analysis

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1 INTRODUCTION

This report summarizes the structural/seismic analysis of the AP1000 New Fuel Storage Rack. The AP1000 New Fuel Storage Rack is used to temporarily store fresh fuel assemblies until they are loaded into the reactor core. The requirements for this analysis are identified in the AP1000 Design Control Document (DCD), subsection 9.1.1.2.1 (Reference 1). The completion of this analysis is identified as Combined Operating License (COL) Information Item 9.1-1 (Final Safety Evaluation Report [Reference 2] Action Item 9.1.6-1) in DCD subsection 9.1.6 to be completed by the Combined License applicant.

> COL Information Item 9.1-1: "Perform a confirmatory structural dynamic and stress analysis for the new fuel rack, as described in AP1000 DCD subsection 9.1.1.2.1."

This COLA technical report closes this COL information item. The calculation "AP1000 New Fuel Storage Rack Structural/Seismic Analysis" (Reference 3) is available for U. S. Nuclear Regulatory Commission (NRC) audit. A summary of the criticality analysis for the AP1000 New Fuel Storage Rack is presented in AP1000 Standard Combined License Technical Report, "New Fuel Storage Rack Criticality Analysis" (Reference 4).

Associated with the closure of this COL information item, the description of the AP1000 New Fuel Storage Rack and analysis as discussed in DCD subsection 9.1.1 of Reference 1 is updated.

2 TECHNICAL BACKGROUND

This report considers the structural adequacy of the proposed AP1000 New Fuel Storage Rack under postulated loading conditions. Analyses and evaluations follow the U.S. Office of Technology Position Paper (Reference 5) and the NRC Standard Review Plan (Reference 6). The dynamic analyses use a time-history simulation code used by Holtec International for licensing efforts in the United States and abroad. This report provides a discussion of the method of analyses, modeling assumptions, key evaluations, and results obtained to establish the margins of safety. The objective of this report is to develop the loads on the AP1000 New Fuel Storage Rack and confirm that the loads do not pose a threat to the stored fuel assemblies.

2.1 DESIGN

2.1.1 AP1000 New Fuel Storage Rack and Vault Description

A plan and elevation view of the AP1000 New Fuel Storage Rack is shown in Figure 2-1.

The AP1000 New Fuel Storage Rack is located inside a concrete room (vault) in the Auxiliary Building. The AP1000 New Fuel Storage Rack is centered inside the vault and is an 8x9 array of storage cells, which provides 72 total storage locations. A hatch lid is provided for the vault for security, and for Foreign Material Exclusion (FME). Table 2-1 presents an overview of the construction and materials used in the AP1000 New Fuel Storage Rack.

The individual storage cells of the AP1000 New Fuel Storage Rack are centered on a nominal pitch of 10.9 inches. Each storage cell consists of an inner stainless steel box, which has a nominal inside dimension of 8.8 inches and is 0.075 inches thick. Metamic panels are attached to the outside surfaces of all storage cells except for the outside cell walls directly facing the north and south walls of the vault. No poison is required on these outside cell faces since there is only a small amount of space between the rack and storage vault concrete. However, poison is required on the outside cell faces in the east and west directions (see Figure 2-1) to mitigate the effects of an inadvertent placement of a fuel assembly outside of the rack, but within the vault on these two sides. Each Metamic poison panel is held in place and is centered on the surface of the stainless steel box by an outer stainless steel sheathing panel. There is a small void space between the sheathing and the Metamic panel. The Metamic poison panels are 7.5 inches wide by 0.106 inches thick. The sheathing panels are 0.035 inches thick.

Each storage cell is nominally 193.25 inches long, and it rests on top of a base plate whose top is 5 inches above the concrete floor. Note that each Metamic poison panel is 172 inches long, overlapping the 168-inch active fuel length. The Metamic poison material is a mixture of B_4C nominally 31.0 weight-percent and aluminum 69.0 weight-percent.

2.2 METHODOLOGY

2.2.1 Acceleration Time Histories

The response of a freestanding rack module to seismic inputs is highly nonlinear, and it involves a complex combination of motions (sliding, rocking, twisting, and turning), resulting in impacts and frictional effects. Linear methods, such as modal analysis and response spectrum techniques, cannot accurately replicate the response of such a highly nonlinear structure to seismic excitation. An accurate simulation is obtained only by direct integration of the nonlinear equations of motion using actual pool slab acceleration time-histories as the forcing function. Therefore, the initial step in AP1000 New Fuel Storage Rack qualification is to develop synthetic time-histories for three orthogonal directions that comply with the guidelines of the NRC Standard Review Plan (Reference 7). The synthetic time-histories must meet the criteria of statistical independence, envelope the target design response spectra, and envelope the target Power Spectral Density function associated with the target response spectra.

2.2.2 Modeling Methodology

2.2.2.1 General Considerations

Once a set of input excitations is obtained, a dynamic representation is developed. Reliable assessment of the stress field and kinematic behavior of a rack module calls for a conservative dynamic model incorporating all key attributes of the actual structure. This means that the dynamic model must have the ability to execute concurrent bending, twisting, and other motion forms compatible with the freestanding installation of the module. Additionally, the model must possess the capability to effect momentum transfers that occur due to rattling of fuel assemblies inside storage cells. Since the AP1000 New Fuel Storage Rack is not placed in water, there is no contribution from water mass in the interstitial spaces around the rack module and within the storage cells. Finally, Coulomb friction coefficients at the pedestal to platform surface interfaces may lie in a rather wide range, depending on the design of those interfaces, and the model must be able to reflect their effect. In short, there are a large number of parameters with

potential influence on the rack motion. A comprehensive structural evaluation must be able to incorporate all of these effects, in a finite number of analyses, without sacrificing conservatism.

The three-dimensional (3-D) dynamic model of a single spent fuel rack was introduced by Holtec International in 1980 and has been used in many re-rack projects since that time. These re-rack projects include Turkey Point, St. Lucie, and Diablo Canyon. The details of this classical methodology are presented in Reference 9. The 3-D model of a typical rack handles the array of variables as follows:

- Interface Coefficient of Friction

  Coefficient of friction (COF) values are assigned at each interface, which reflect the realities of stainless steel-to-stainless steel contact. The mean value of coefficient of friction is 0.5, and the limiting values are based on experimental data, which are bounded by the values 0.2 and 0.8 (Reference 20).

- Impact Phenomena

  Compression-only spring elements, with gap capability, are used to provide for opening and closing of interfaces, such as the pedestal-to-bearing pad interface and fuel assembly-to-cell wall interface potential contact locations. For the AP1000 New Fuel Storage Rack, the gap spring elements at rack top to spent fuel storage vault wall interface at the north and south side are zeroed to reflect the addition of shims after the rack is installed, but before fuel is loaded.

- Fuel Loading Scenarios

  The dynamic analyses performed for the AP1000 New Fuel Storage Rack assume that all fuel assemblies within the rack rattle in unison throughout the seismic event, which obviously exaggerates the contribution of impact against the cell wall. An attenuation factor can be used to adjust for the random component of fuel assembly rattling. However, in this analysis, the attenuation factor equals one for all simulations (that is, fuel assemblies conservatively move perfectly in-phase).

- Fluid Coupling

  Since the AP1000 New Fuel Storage Rack is installed in a dry enclosure, no fluid coupling effects are modeled in the dynamic simulations.

2.2.2.2 Specific Modeling Details for a Single Rack

The rack analysis is performed using a 3-D multi-degree of freedom model. For the dynamic analysis, each rack, plus contained rattling fuel, is modeled as a 22 Degree of Freedom (DOF) system. The rack cellular structure elasticity is modeled by a 3-D beam having 12 DOF (three translation and three rotational DOF at each end so that two-plane bending, tension/compression, and twist of the rack are accommodated). An additional two horizontal DOFs are ascribed to each of five rattling fuel masses, which are located at heights 0H, 0.25H, 0.5H, 0.75H, and H, where H is the height of a storage cell above the baseplate. While the horizontal motion of the rattling fuel mass is associated with five separate

masses, the totality of the fuel mass is associated with the vertical motion and it is assumed that there is no fuel rattling in the vertical direction. In other words, the vertical displacement of the fuel is coupled with the vertical displacement of the rack (that is, degree of freedom "P3" in Figure 2-2) by lumping the entire stored fuel mass (in the vertical direction only) with the vertical rack mass at the baseplate level.

The beam model for the rack is assumed supported, at the base level, on four pedestals modeled with non-linear elements; these elements are properly located with respect to the centerline of the rack beam, and allow for arbitrary rocking and sliding motions. The horizontal rattling fuel masses transfer load to the spent fuel rack through compression-only gap spring elements, oriented to allow impacts of each of the five rattling fuel masses with the rack cell in either or both horizontal directions at any instant in time. Figure 2-2 illustrates the typical dynamic rack model with the degrees of freedom shown for both the AP1000 New Fuel Storage Rack and for the rattling fuel mass. In order to simulate this behavior, the stored fuel mass is distributed among the five lumped mass nodes, for all racks, as follows:

- Top of rack (Node 2) 12.5%
- 3/4 height (Node 3) 25%
- 1/2 height (Node 4) 25%
- 1/4 height (Node 5) 25%
- Bottom of rack (Node 1) 12.5%

(See Figure 2-2.)

The stiffness of pedestal springs that simulate rack pedestal to the floor compression-only contact is modeled using contact and friction elements at the locations of the pedestals between pedestal and floor. Four contact springs (one at each corner location) and eight friction elements (two per pedestal) are included in each 22 DOF rack model.

Also shown in Figure 2-2 is a detail of the model of a typical support with a vertical compression-only gap element and two orthogonal elements modeling frictional behavior. These friction elements resist lateral loads, at each instant in time, up to a limiting value set by the current value of the normal force times the coefficient of friction. Figures 2-3 through 2-5 show schematic diagrams of the various (linear and non-linear) elements that are used in the dynamic model of a typical spent fuel rack. Figure 2-3 shows the location of the compression-only gap elements that are used to simulate the rack-to-wall contact at every instant in time. The rack-to-wall (north and south side) impact spring gaps at the top are reduced to zero to reflect the shims that are in place, which absorb the impact load and transmit them to the pool wall. Figure 2-4 shows the four compression-only gap elements at each rattling mass location, which serve to simulate rack-to-fuel assembly impact in any orientation at each instant in time. Figure 2-5 shows a two-dimensional elevation schematic depicting the five fuel masses and their associated gap/impact elements, the typical pedestal friction and gap impact elements. This figure combines many of the features shown in Figures 2-3 and 2-4, and it provides an overall illustration of the dynamic model used for the AP1000 New Fuel Storage Rack.

Finally, Figure 2-6 provides a schematic diagram of the coordinates and the beam springs used to simulate the elastic bending behavior of the rack cellular structure in two-plane bending. Not shown are the linear springs modeling the extension, compression, and twisting behavior of the cellular structure.

Mass Matrix

Since there is no water in the AP1000 New Fuel Storage Rack enclosure, the mass matrix involves only the structural masses associated with the dynamic model.

Stiffness Matrix

The spring stiffnesses associated with the elastic elements that model the behavior of the assemblage of cells within a rack are based on the representation developed in Reference 10. Tension-compression behavior and twisting behavior are each modeled by a single spring with linear or angular extension involving the appropriate coordinates at each end of the rack beam model. For simulation of the beam bending stiffness, a model is used consistent with the techniques of the reference based on a bending spring and a shear spring for each plane of bending, which connects the degrees of freedom associated with beam bending at each end of the rack. Impact and friction behavior is included using the piecewise linear formulations similarly taken from the reference.

The AP1000 New Fuel Storage Rack is subject to the ASB99, Floor Response Spectra for the AP1000 New Fuel Storage Rack (Reference 18). The procedure used is consistent with the seismic analysis methods described in Section 3.7 of the DCD (Reference 1). Three runs are performed to bound possible coefficient of friction values and are summarized in Table 2-2. Since the AP1000 New Fuel Storage Rack is confined from executing any twisting motion at the top of the rack, the fully loaded rack results bound those obtained for any partial load case so that these cases need not be considered.

2.2.3 Simulation and Solution Methodology

Recognizing that the analytical work effort must deal with both stress and displacement criteria, the sequence of model development and analysis steps that are undertaken for each simulation are summarized in the following:

a. Prepare a 3-D dynamic model of the AP1000 New Fuel Storage Rack module.

b. Archive for post-processing appropriate displacement and load outputs from the dynamic model.

c. Perform stress analysis of high stress areas for rack dynamic runs. Demonstrate compliance with American Society for Mechanical Engineers (ASME) Code Section III, subsection NF (Reference 11) limits on stress and displacement. The high stress areas are associated with the pedestal-to-baseplate connection. In addition, some local evaluations are performed for the bounding case to ensure that the fuel remains protected under all impact loads.

For the transient analyses performed, a step-by-step solution in time uses a central difference algorithm. The solver computer algorithm, implemented in the Holtec Proprietary Code MR216 (a.k.a. DYNARACK), is given in Reference 10, and the documentation of MR216 is presented in Reference 12.

Using the 22-DOF rack structural model in each DYNARACK simulation, equations of motion corresponding to each degree-of-freedom are obtained using Lagrange's formulation of the dynamic

equations of motion (Reference 10). The system kinetic energy includes contributions from the structural masses defined by the 22-DOF model.

Results are archived at appropriate time intervals for permanent record and for subsequent post-processing for structural integrity evaluations as follows:

- All generalized nodal displacement coordinate values in order to later determine the motion of the rack
- All load values for linear springs representing beam elasticity
- All load values for compression-only gap springs representing pedestals, rack-to-fuel impact, and rack-to-wall impacts
- All load values for friction springs at the pedestal/platform interface

2.2.4 Conservatisms Inherent in Methodology

The following items are built-in conservatisms:

- All fuel rattling mass at each level is assumed to move as a unit thus maximizing impact force and rack response.
- Spring rates are computed in a conservative manner to use maximum values in the analysis. This tends to conservatively overestimate peak impact forces.

2.3 KINEMATIC AND STRESS ACCEPTANCE CRITERIA

2.3.1 Introduction

The AP1000 New Fuel Storage Rack is designed as seismic Category I. The U.S. Office of Technology Position Paper (Reference 5) and the NRC Standard Review Plan 3.8.4 (Reference 6) state that the ASME Code Section III, subsection NF (Reference 11), as applicable for Class 3 Components, is an appropriate vehicle for design. In the following sections, the ASME limits are set down first, followed by any modifications by project specification, where applicable.

2.3.2 Kinematic Criteria

The AP1000 New Fuel Storage Rack should not exhibit rotations to cause the rack to overturn (that is, in the east-west direction, ensure that the rack does not slide off the bearing pads, or exhibit a rotation sufficient to bring the center of mass over the corner pedestal.

2.3.3 Stress Limit Criteria

For thoroughness, the Standard Review Plan load combinations were used. Stress limits must not be exceeded under the required load combinations. The loading combinations shown in Table 2-3 are

applicable for freestanding racks that are steel structures (note that there is no operating basis earthquake [OBE] event for the AP1000; therefore, loading conditions associated with an OBE event are not considered.).

2.3.4 Stress Limits for Various Conditions Per ASME

Stress limits for Normal Conditions are derived from the ASME Code, Section III, Subsection NF. Parameters and terminology are in accordance with the ASME Code. The AP1000 New Fuel Storage Rack is freestanding; thus, there is minimal or no restraint against free thermal expansion at the base of the rack. Moreover, thermal stresses are secondary, which strictly speaking, have no stipulated stress limits in Class 3 structures or components when acting in concert with seismic loadings. Thermal loads applied to the rack are, therefore, not included in the stress combinations involving seismic loadings.

Material properties for analysis and stress evaluation are provided in Table 2-5.

2.3.4.1 Normal Conditions (Level A)

Normal conditions are as follows:

- Tension

  Allowable stress in tension on a net section is:

  $$F_t = 0.6\ S_y$$

  where S_y is the material yield strength at temperature. (F_t is equivalent to primary membrane stress.)

- Shear

  Allowable stress in shear on a net section is:

  $$F_v = 0.4\ S_y$$

- Compression

  Allowable stress in compression (F_a) on a net section of Austenitic material is:

  $$F_a = S_y(.47 - kl/444r)$$

  where $kl/r < 120$ for all sections and

  l = unsupported length of component.

  k = length coefficient which gives influence of boundary conditions, e.g.
  k = 1 (simple support both ends)

k = 2 (cantilever beam)
k = 0.5 (clamped at both ends)

Note: Evaluations conservatively use k = 2 for all conditions.

E = Young's modulus

r = radius of gyration of component = c/2.45 for a thin wall box section of mean side width c.

- Bending

Allowable bending stress (F_b) at the outermost fiber of a net section due to flexure about one plane of symmetry is:

$$F_b = 0.60\ S_y$$

- Combined Bending and Compression

Combined bending and compression on a net section satisfies:

$$f_a/F_a + C_{mx}f_{bx}/D_xF_{bx} + C_{my}f_{by}/D_yF_{by} < 1.0$$

where:

f_a	=	Direct compressive stress in the section
f_{bx}	=	Maximum bending stress for bending about x-axis
f_{by}	=	Maximum bending stress for bending about y-axis
C_{mx}	=	0.85
C_{my}	=	0.85
D_x	=	$1 - (f_a/F'_{ex})$
D_y	=	$1 - (f_a/F'_{ey})$
$F'_{ex,ey}$	=	$(\pi^2 E)/(2.15\ (kl/r)_{x,y}^2)$

and subscripts x and y reflect the particular bending plane.

- Combined Flexure and Axial Loads

Combined flexure and tension/compression on a net section satisfies:

$$(f_a/0.6\ S_y) + (f_{bx}/F_{bx}) + (f_{by}/F_{by}) < 1.0$$

- Welds

Allowable maximum shear stress (F_w) on the net section of a weld is:

$$F_w = 0.3\ S_u$$

where S_u is the material ultimate strength at temperature. For the area in contact with the base metal, the shear stress on the gross section is limited to $0.4S_y$.

2.3.4.2 Upset Conditions (Level B)

Although the ASME Code allows an increase in allowables above those appropriate for normal conditions, any evaluations performed herein conservatively use the normal condition allowables.

2.3.4.3 Faulted (Abnormal) Conditions (Level D)

Section F-1334 (ASME Section III, Appendix F [Reference 14]), states that limits for the Level D condition are the smaller of 2 or $1.167S_u/S_y$ times the corresponding limits for the Level A condition if $S_u > 1.2S_y$, or 1.4 if $S_u \leq 1.2S_y$ except for requirements specifically listed below. S_u and S_y are the ultimate strength and yield strength at the specified rack design temperature. Examination of material properties for 304L stainless demonstrates that 1.2 times the yield strength is less than the ultimate strength. Since 1.167 * (70,000/25,000) = 2.8, the multiplier of 2.0 controls.

Exceptions to the above general multiplier are the following:

- Stresses in shear in the base metal shall not exceed the lesser of $0.72S_y$ or $0.42S_u$. In the case of the austenitic stainless material used here, $0.72S_y$ governs.

- Axial compression loads shall be limited to 2/3 of the calculated buckling load.

- Combined Axial Compression and Bending - The equations for Level A conditions shall apply except that:

  $$F_a = 0.667 \text{ x Buckling Load/Gross Section Area,}$$

  and $F_{ex,ey}$ may be increased by the factor 1.65.

- For welds, the Level D allowable maximum weld stress is not specified in Appendix F of the ASME Code. An appropriate limit for weld throat is conservatively set here as:

  $$F_w = (0.3\ S_u) \text{ x factor}$$

  where:

  Factor = (Level D shear stress limit)/(Level A shear stress limit)
  $= 0.72 \times S_y / 0.4 \times S_y = 1.8$

2.3.5 Dimensionless Stress Factors

In accordance with the methodology of the ASME Code, Section NF, where both individual and combined stresses must remain below certain values, the stress results are presented in dimensionless form. Dimensionless stress factors are defined as the ratio of the actual developed stress to the specified

limiting value. The limiting value of each stress factor is 1.0 based on an evaluation that uses the allowable strength appropriate to Level A or Level D loading as discussed above.

R_1 = Ratio of direct tensile or compressive stress on a net section to its allowable value (note pedestals only resist compression)

R_2 = Ratio of gross shear on a net section in the x-direction to its allowable value

R_3 = Ratio of maximum bending stress due to bending about the x-axis to its allowable value for the section

R_4 = Ratio of maximum bending stress due to bending about the y-axis to its allowable value for the section

R_5 = Combined flexure and compression factor (as defined in subsection 2.3.4.1)

R_6 = Combined flexure and tension (or compression) factor (as defined in subsection 2.3.4.1)

R_7 = Ratio of gross shear on a net section in the y-direction to its allowable value

At any location where stress factors are reported, the actual stress at that location may be recovered by multiplying the reported stress factor R by the allowable stress for that quantity. For example, if a reported Level A combined tension and two plane bending stress factor is $R_6 = 0.85$, and the allowable strength value is $0.6S_y$, then the actual combined stress at that location is Stress = $R_6 \times (0.6S_y) = 0.51Sy$.

2.4 ASSUMPTIONS

The following assumptions are used in the analysis:

- Fluid damping is neglected as there is no water in the AP1000 New Fuel Storage Rack.
- The total effect of *n* individual fuel assemblies rattling inside the storage cells in a horizontal plane is modeled as one lumped mass at each of five levels in the fuel rack. Thus, the effect of chaotic fuel mass movement is conservatively ignored.
- For the AP1000 New Fuel Storage Rack, there is no temperature differential and no hot cell.

2.5 INPUT DATA

2.5.1 Rack Data

Table 2-4 contains information regarding the AP1000 New Fuel Storage Rack and fuel data that are used in the analysis. Information is taken from the Holtec rack drawings (Reference 8) (unless noted otherwise).

2.5.2 Structural Damping

Associated with every stiffness element is a damping element with a coefficient consistent with 4% of critical linear viscous damping. This is consistent with the ASB99 design basis Floor Response Spectra set for the AP1000 New Fuel Storage Rack provided in Reference 18 and Reference 21.

2.5.3 Material Data

The necessary material data are shown in Table 2-5. This information is taken from ASME Code Section II, Part D (Reference 13). The values listed correspond to a temperature of 100°F, which is appropriate since new fuel does not release any heat.

2.6 COMPUTER CODES

Computer codes used in this analysis are presented in Table 2-15.

2.7 ANALYSES

2.7.1 Acceptance Criteria

The dimensionless stress factors, discussed in subsection 2.3.5, must be less than 1.0. In addition:

- Cell wall stress shall be shown to remain below the critical buckling stress.
- Welds and local stresses must remain below the allowable stress limits corresponding to the material and load conditions, as discussed in greater detail in following sections.

2.7.2 Dynamic Simulations

As discussed earlier, three simulations are performed. The simulations consider the ASB99, Floor Response Spectra and are required to satisfy the stress and kinematic criteria of Reference 5 and Reference 6.

2.8 RESULTS OF ANALYSES

The following subsections contain the results obtained from the post-processor DYNAPOST (Reference 15) for the AP1000 New Fuel Storage Rack single-rack analysis under the ASB99, Floor Response Spectra. With one rack in each model, there are two tables per simulation; the first one details the rack input information and provides overall summary of the analysis, while the second table provides a complete listing of results.

2.8.1 Time History Simulation Results

Table 2-6 presents the results for major parameters of interest for the new racks for each simulation. Run numbers are as listed in Table 2-2.

2.8.1.1 Rack Displacements

The post-processor results tabulated, summarized in Table 2-7, provide the maximum absolute displacements at the top and bottom corners in the east-west horizontal directions, relative to the rack.

2.8.1.2 Pedestal Vertical Forces

The case of COF = 0.8 provides the maximum vertical load on any pedestal. This may be used to assess the structural integrity of the rack under the seismic event.

2.8.1.3 Pedestal Friction Forces

The case of COF=0.8 provides the maximum shear loads; the value is used as an input loading to evaluate the female pedestal-to-baseplate weld (see Table 2-14).

2.8.1.4 Impact Loads

The impact loads, such as fuel-to-cell wall and rack-to-wall impacts, are discussed below.

Fuel-to-Cell Wall Impact Loads

The maximum fuel-to-cell wall impact load, at any level in the rack, occurs for COF = 0.8.

The permissible lateral load on an irradiated fuel assembly has been studied by the Lawrence Livermore National Laboratory. The Lawrence Livermore National Laboratory Report (Reference 17) states that "...for the most vulnerable fuel assembly, the axial buckling load varies from 82g's at initial storage to 95g's after 20 years storage. In a side drop, no yielding is expected below 63g's at initial storage to 74g's after 20 years {dry} storage." The most significant load on the fuel assembly arises from rattling during the seismic event. For the five-lumped mass model (with 25% at the 1/4 points and 12.5% at the ends), the limiting lateral load (F_e) may be determined as:

$$F_e = \frac{(wxa)}{4} = 27{,}248 \cdot \text{lbf}$$

where:

w = weight of one fuel assembly (conservatively taken to be 1,730 lbs)
a = permissible lateral acceleration in g's (a=63)

Therefore, a maximum fuel assembly-to-cell wall impact load will yield a safety factor of 27.98.

Rack-to-Wall Impacts

The solver summary result files from MR216 (Reference 12) in all of the simulations were manually scanned to determine the maximum impact on each side of the rack. The total rack-to-wall impact at any one time instant is derived from the output data and calculated for all three simulations. The maximum

impact load from the set of shims that close the north-south gaps at the top of the rack is summarized in Table 2-8.

2.8.2 Rack Structural Evaluation

2.8.2.1 Rack Stress Factors

With time history results available for pedestal normal and lateral interface forces, the limiting bending moment and shear force at the baseplate-to-pedestal interface may be computed as a function of time. In particular, maximum values for the previously defined stress factors can be determined for every pedestal in the AP1000 New Fuel Storage Rack. The maximum stress factor for the new racks from each simulation is reported in the result tables and Table 2-6. Using this information, the structural integrity of the pedestal can be assessed. The net section maximum (in time) bending moments and shear forces can also be determined at the bottom of the cellular structure. Based on these, the maximum stress in the limiting rack cell (box) can be evaluated.

Tables 2-6 through 2-13 provide limiting stress factor results for the pedestals in each of the simulations detailed in Table 2-2. The tables also report the stress factors for the AP1000 New Fuel Storage Rack cellular cross section just above and below the baseplate. The locations above the base plate (the cellular structure comprising a built-up beam cross section) are referred to as pedestal five in the first sheet of the summary tables for each simulation (that is, 9.M.0 where M stands for run number). These locations are the most heavily loaded net sections in the structure so that satisfaction of the stress factor criteria at these locations ensures that the overall structural criteria set forth in subsection 2.2.3 are met.

The summary of the maximum stress factors for the AP1000 New Fuel Storage Rack for three different coefficients of friction is provided in Table 2-9.

An adjustment factor accounting for the ASME Code slenderness ratio has been calculated. The adjusted factors are identified with * in the Table 2-9.

All stress factors, as defined in Section 2.3, are less than the mandated limit of 1.0 for all racks for the governing faulted condition examined. Therefore, the rack is able to maintain its structural integrity under the worst loading conditions.

2.8.2.2 Weld Stresses

Weld locations in the AP1000 New Fuel Storage Rack are subjected to significant seismic loading are at the bottom of the rack at the baseplate-to-cell connection, at the top of the pedestal support at the baseplate connection, and at the cell-to-cell connections. Bounding values of resultant loads are used to qualify the connections.

a. Baseplate-to-Rack Cell Welds

Note: The calculated maximum weld stress shown in Table 2-10 is conservatively compared to the Level D allowable of SA 240-304L, which can have a lower yield and ultimate strengths. Therefore, the computed stress factors are conservatively higher than if properties for SA 304

were used in the postprocessor. In the calculations below, however, the properties for SA-304 are used.

Reference 11 (ASME Code Section III, subsection NF) permits, for Level A or B conditions, an allowable weld stress $\tau = .3\ S_u$. Conservatively assuming that the weld strength is the same as the lower base metal ultimate strength, the allowable stress is given by $\tau = .3 * (75{,}000) = 22{,}500$ psi. As stated in subsection 3.4.3, the allowable for Level D is $0.54\ S_u$, giving an allowable of 40,500 psi.

Weld stresses are determined through the use of a simple conversion (ratio) factor (based on area ratios) applied to the corresponding stress factor in the adjacent rack material. This stress factor is stated on the summary tables. The 2.1516 value given in the tables is developed from the differences in base material thickness and length versus weld throat dimension and length:

$$\frac{0.075*(8.8+0.075)}{0.0625*0.7071*7.0} = 2.1516$$

where:

0.75	is the cell wall thickness
8.8+0.075	is the mean box dimension
0.0625*0.7071	is the box-baseplate fillet weld throat size
7.0	is the length of the weld

The highest predicted cell to baseplate weld stress is calculated based on the highest R6 value for the rack cell region tension stress factor and R2 and R7 values for the rack cell region shear stress factors (refer to subsection 2.3.5 for definition of these factors). These cell wall stress factors are converted into weld stress values as follows:

- For ASB99 Simulation

$[R6 * (0.6) + R2 * (0.4) + R7 * (0.4)] * S_y * \text{Ratio} =$

$[0.306 * (0.6) + 0.034 * (0.4) + 0.029 * (0.4)] * (25{,}000) * 2.1516 = 11{,}231$ psi

The above calculations are conservative for the following reasons:

1) The directional stresses associated with the normal stress σ_y and the two shear stresses τ_x and τ_y should be combined using square root sum of the squares (SRSS) instead of direct summation.

2) The maximum stress factors used above do not all occur at the same time instant.

Table 2-10 shows that the weld stresses are acceptable and have safety factors greater than 1.

The corresponding maximum base metal shear stress is shown in Table 2-11.

b. Baseplate-to-Pedestal Welds

The rack weld between baseplate and support pedestal is checked using conservatively imposed loads in a separate finite element model. Table 2-12 summarizes the result.

c. Cell-to-Cell Welds

Cell-to-cell connections are by a series of connecting welds along the cell height. Stresses in storage cell to cell welds develop due to fuel assembly impacts with the cell wall. These weld stresses are conservatively calculated by assuming that fuel assemblies in adjacent cells are moving out of phase with one another so that impact loads in two adjacent cells are in opposite directions; this tends to separate the two cells from each other at the weld. Cell-to-cell welds calculation used maximum stress factor from all runs. Both the weld and the base metal shear results are reported in Table 2-13.

2.8.2.3 Pedestal Thread Shear Stress

Tables 2-6 through 2-13 provide limiting thread stresses under faulted conditions for every pedestal. The maximum average shear stress in the engagement region is 17,234 psi, which occurs under Simulation 3. This computed stress is applicable to both the male and female pedestal threads.

The allowable shear stress for Level D conditions is the lesser of: $0.72\ S_y = 21{,}600$ psi or $0.42\ S_u = 31{,}500$ psi. Therefore, the former criterion controls the allowable shear stress and the limiting result is detailed in Table 2-14.

2.8.3 Dead Load Evaluation

The dead load condition is not a governing condition for spent fuel racks since the general level of loading is far less than the safe shutdown earthquake (SSE) load condition. To illustrate this, it is shown below that the maximum pedestal load is low and that further stress evaluations are unnecessary.

Level A Maximum Pedestal Load	lbf
Dry Weight of 9x8 Rack	21,281
Dry Weight of 72 Intact Fuel Assemblies	124,560
Total Dry Weight	145,841
Load per Pedestal	36,460

This load will induce low stress levels in the neighborhood of the pedestal, compared with the load levels that exist under the SSE load condition (that is, on the order of 243,000 lb for this rack). Therefore, there are no primary shear loads on the pedestal and since the Level A loads are approximately 1/6 of the Level D loads, while the Level A limits exceed 1/6 of the Level D limits, the SSE load condition bounds the dead load condition and no further evaluation is performed for dead load only.

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 as the local stresses do not exceed 2,500 psi.

2.8.4 Local Stress Considerations

This subsection presents evaluations for the possibility of cell wall buckling and the secondary stresses produced by temperature effects.

The allowable local buckling stresses in the fuel cell walls (from vertical loading) are obtained by using classical plate buckling analysis on the lower portion of the cell walls. The following formula for the critical stress has been used:

$$\sigma_{cr} = \frac{\beta \times \pi^2 \times E \times t^2}{12 \times b^2 \left(1 - \upsilon^2\right)}$$

Where $E = 27 \times 10^6$ psi, μ is Poison's ratio = 0.3, t = .075", b = 8.8". The factor β is suggested in Reference 16 to be 4.0 for a long panel loaded as shown in Figure 2-7.

For the given data:

$\sigma_{cr} < 7{,}090$ psi

It should be noted that this calculation is based on the applied vertical stress being uniform along the entire length of the cell wall. In the actual fuel rack, the compressive vertical stress comes from consideration of overall bending of the rack structures during a seismic event and as such is negligible at the rack top and maximum at the rack bottom. It is conservative to apply the above equation to the rack cell wall if we compare σ_{cr} with the maximum compressive stress anywhere in the cell wall. This local buckling stress limit is not violated anywhere in the body of the rack modules since the maximum compressive stress in the outermost cell is $\sigma = (0.6)(25{,}000) * R5$ (which is 0.303) = 4,545 psi, which is less than 7,090 psi. Therefore, rack cell wall buckling is not a concern.

Next, the restraint of the AP1000 New Fuel Storage Rack at the top by shims leads to compressive loads in the cellular structure. To ensure that the new fuel suffers no damage during an SSE from excessive rack deformation near the top shim locations, the compressive load was evaluated and shown not to cause buckling in the cell walls near the top of the honeycomb structure. A safety factor of 2.46 is reported for buckling due to the horizontal impact load transferred through the shim.

Since the new fuel does not provide any heat output, differential movement between the AP1000 New Fuel Storage Rack and the surrounding vault occurs solely from the difference in thermal expansion coefficients. To ensure that the shims at the top of the AP1000 New Fuel Storage Rack do not induce excessive compressive stress from differential thermal expansion from environmental temperature change, the installation procedure will ensure that shims are adjusted to their final position prior to first use of the AP1000 New Fuel Storage Rack.

2.8.5 Hypothetical Fuel Assembly Drop Accidents

Two fuel assembly drop accident analyses have been performed in accordance with subsection 9.1.1.2.1 C of Reference 1: 1) A drop of a New Fuel Assembly from 36 inches above the top of the AP1000 New Fuel Storage Rack with subsequent impact on the edge of a cell; and 2) a drop of a New Fuel Assembly from 36 inches above the top of the rack straight down through an empty cell with impact on the rack baseplate. The objective of the analyses is to assess the extent of permanent damage to the rack.

Both analyses are performed using the dynamic simulation code LS-DYNA (Reference 22). A finite element model of one-quarter of the AP1000 New Fuel Storage Rack plus a single fuel assembly is modeled using appropriate shell and solid body elements available in LS-DYNA. Appropriate non-linear material properties have been assigned to the rack components to permit yielding and permanent deformation to occur. Figure 2-8 shows the details of the finite element model in the area where the impacts occur.

For the drop to the top of the AP1000 New Fuel Storage Rack, the fuel assembly is assumed to strike the edge of an exterior cell at a speed corresponding to a 36-inch drop in air and to remain vertical as it is brought to a stop by the resisting members of the rack. The objective is to demonstrate that the extent of permanent damage to the impacted rack does not extend to the beginning of the active fuel region. For the AP1000 fuel, the active fuel region begins approximately 14+ inches below the top of the rack.

For the drop through an empty cell to the baseplate, the baseplate of the rack is connected to the cells by appropriate welding and a portion of the welding is expected to fail during the impact. The energy from the falling fuel assembly is absorbed by weld failure plus deformation of the baseplate toward the floor. The fuel assemblies surrounding the impacted cell will follow the baseplate deformation and the objective is to determine how many fuel assemblies displace an amount sufficient to bring their active fuel region below the limit of the absorbing material attached to each fuel cell wall. In the case of the AP1000 New Fuel Storage Rack, a 2-inch vertical movement of a fuel assembly, relative to the cell wall, will not require any new criticality evaluation.

The results from the analyses are shown in Figures 2-9 and 2-10. For the drop to the top of the AP1000 New Fuel Storage Rack, the extent of permanent damage is limited to a depth of 10.26 inches. Therefore, the active fuel region remains surrounded by an undamaged cell wall and no further criticality evaluation is required.

For the drop to the baseplate of the rack, Figure 2-10 shows that nine fuel assemblies (including the dropped assembly) are moved downward more than 2 inches and expose active fuel on all four sides. An additional 12 fuel assemblies may drop a sufficient distance to expose active fuel on two sides. The consequences to reactivity of this event are discussed in subsection 2.4.2 of Reference 4.

2.9 CONCLUSIONS

From the results of the single-rack analyses, the following conclusions are made regarding the new design and layout of the AP1000 New Fuel Storage Rack.

- All rack cell wall and pedestal stress factors are below allowable stress factor limit of 1.0.

- The impacts between stored fuel assemblies and the cell walls are within the limit for dynamic loading set by the Lawrence Livermore Laboratory (Reference 17).
- The cellular structure that resists the compressive loads from the shims at the top of the rack does not buckle during an SSE event.
- All weld stresses are below the allowable limits.
- A stuck fuel assembly does not cause a bounding stress condition.
- Two fuel assembly drops were analyzed. The drop on to the New Fuel Rack Storage does not require a criticality evaluation. The drop of a fuel assembly straight through an empty cell has been evaluated in Reference 4.

It is therefore considered demonstrated that the design of the AP1000 New Fuel Storage Rack meets the requirements for structural integrity for the postulated Level A and Level D conditions defined.

Table 2-1 AP1000 New Fuel Storage Rack Storage Cell Description

Parameter	Nominal Dimension (in) or Material
Cell Pitch	10.9
Cell ID	8.8
Cell Length	193.25
Cell Wall Thickness	0.075
Cell Wall Material	SS-304
Metamic Width	7.5
Metamic Thickness	0.106
Metamic Composition	B_4C/Al
Sheathing Thickness	0.035
Sheathing Material	SS-304

Table 2-2 Simulation Listing

Coefficient of Friction	Loading Configuration	Seismic Input (Floor Response Spectra)	Run Number
0.2	Fully Loaded	ASB99	1
0.5	Fully Loaded	ASB99	2
0.8	Fully Loaded	ASB99	3

Table 2-3 Loading Combinations for AP1000 New Fuel Storage Rack

Loading Combination	Service Level
Only applicable combo for new fuel rack in Level A is "D"	Level A
D + L	Level B
D + L + P_f D + L + E'	Level D[1]

Notes:

1. The functional capability of the AP1000 New Fuel Storage Rack must be demonstrated.

Abbreviations are those used in Reference 23:

L = Applicable live loads

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

E' = Safe Shutdown Earthquake (SSE)

P_f = Forces on the rack caused by the removal of a postulated stuck fuel assembly or from the accidental drop of a fuel assembly from a height of 36 inches above the top of the rack. In the case of a stuck fuel assembly, this force may be imparted at any angle between horizontal and vertical.

Table 2-4 AP1000 New Fuel Storage Rack and Fuel Data

Geometric Parameter		Dimension (in) Unless Noted
Composite Box Data		
Box ID		8.8 (± 0.04)
Pitch		10.9 (± 0.04)
Wall Thickness		0.075
Rack Module Data		
Cell Length		193.5 (± 0.0625)
Support Height		2.75 (± 0.5)
Female Pedestal Side Dim		12.0 x 12.0 square
Female Pedestal Height		2
Male Pedestal Diameter		4.5
Total Height		198.5 (± 0.5)
Baseplate Thickness		0.75
Baseplate Extension		¼ (+3/16, -0)
Fuel Data		
Dry Fuel Wt (lb)		1,730 lb (Reference 19)
Assembly Size (in)		8.404 (Reference 19)
Rack Details		
Rack	**Array Size**	
New Fuel Rack	9 x 8	21,281 lb

Table 2-5 Material Data (ASME - Section II, Part D)			
Material	Young's Modulus* E (psi)	Yield Strength S_y (psi)	Ultimate Strength S_u (psi)
Rack Material Data (304 SS @ 100°F)			
SA240- 304	27.9×10^6	30,000	75,000
Support Material Data (100°F)			
SA-240, Type 304 (Upper part of support feet)	27.9×10^6	30,000	75,000
SA-564, Type 630 (Hardened at 1100° F)	27.9×10^6	115,000	140,000

Table 2-6 Results Summary					
Coefficient of Friction	Run No.	Max. Stress Factor	Max. Vertical Load (lbf)	Max. Shear Load (lbf) (X or Y)	Max. Fuel-to-Cell Wall Impact (lbf)
0.2	1	0.186	155,000	30,000	807
0.5	2	0.228	200,000	99,800	892
0.8	3	0.306	243,000	111,000	974

Table 2-7 Time History Post-Processor Results		
Location on Rack	Maximum Rack Displacement Relative to Floor (in)	Run Number
Base Plate	2.84	1
Top of Rack	3.9	3

Table 2-8 Rack-to-Wall Impacts		
Coefficient of Friction	Maximum Rack-to-Wall Impact Load on One Side of Rack (lbf)	Run Number
0.2	1.125E+5	1

Table 2-9 Maximum Stress Factors

Coefficient of Friction	Pedestal Stress Factor	Cell Wall Stress Factor	Run Number
0.2	0.072	0.186 $\left(0.186\times\left(\frac{1}{0.774}\right)\right)=0.240$ *	1
0.5	0.089	0.228 $\left(0.228\times\left(\frac{1}{0.774}\right)\right)=0.295$ *	2
0.8	0.094	0.306 $\left(0.306\times\left(\frac{1}{0.823}\right)\right)=0.395$ *	3

Note:

* Adjustment factor accounting for ASME Code Slenderness Ratio

Table 2-10 Baseplate-to-Rack Maximum Weld Stress

Weld Stress (psi)	Allowable Stress (psi)	Safety Factor
11,231	40,500	3.61

Table 2-11 Base Metal Shear Stress

Base Metal Shear Stress (psi)	Allowable Stress (psi)	Safety Factor
7,942	21,600	2.72

Table 2-12 Baseplate-to-Pedestal Welds

Weld Stress (psi)	Run No.	Allowable Stress (psi)	Safety Factor
9250	3	40,500	4.38

Table 2-13 Weld and Base Metal Shear Results

Analysis Type	Stress (psi)	Run No.	Allowable Stress (psi)	Safety Factor
Weld	8,815	3	40,500	4.59
Base Metal Shear	6,233	3	21,600	3.47

Table 2-14 Allowable Shear Stress for Level D

Base Metal Shear Stress (psi)	Allowable Stress (psi)	Safety Factor
17,234	21,600	1.25

Table 2-15 Computer Codes Used for AP1000 New Fuel Storage Rack Structural/Seismic Analysis

Code	Version	Description
GENEQ	1.3	Generates artificial time histories from input response spectra set.
CORRE	1.3	Uses results from GENEQ and demonstrates required statistical independence of time histories.
PSD1	1.0	Uses results from GENEQ and compares regenerated Power Spectral Densities with target.
WORKING MODEL	2004	Is a Rigid Body Dynamics code used to improve baseline correction.
VMCHANGE	4.0	For a dry pool, develops a zero matrix of size = (number of racks x 22 DOF per rack).
MULTI	1.55	Incorporates appropriate non-zero values due to structural effects that are put in appropriate locations in the output matrix from VMCHANGE to form the final mass matrix for the analysis. The appropriate non-zero right-hand sides are also developed.
MASSINV	2.1	Calculates the inverse of the mass matrix.
MSREFINE	2.1	Refines the inverse of the mass matrix.
PREDYNA1	1.5	Generates various input lines for the input file required to run the dynamic solver.
PD16	2.1	Generates rack-to-fuel compression-only impact springs, rack-to-ground impact springs, and rack elastic deflection springs for each rack being analyzed and creates the appropriate lines of input for the solver.
SPG16	3.0	Generates compression-only rack-to-rack impact springs for the specific rack configuration in the pool for the solver.
MR216	2.0	Is a solver for the dynamic analysis of the racks; uses an input file from the cumulative output from PREDYNA, PD16, and SPG16, together with the mass matrix, right-hand side matrix, and the final time histories from GENEQ.
DYNAPOST	2.0	Post-Processor for MR216; generates safety factors, maximum pedestal forces, and maximum rack movements.
ANSYS	9.0	Is a general purpose commercial FEA code.
LS-DYNA	970	General purpose commercial FEA code optimized for shock and impact analyses

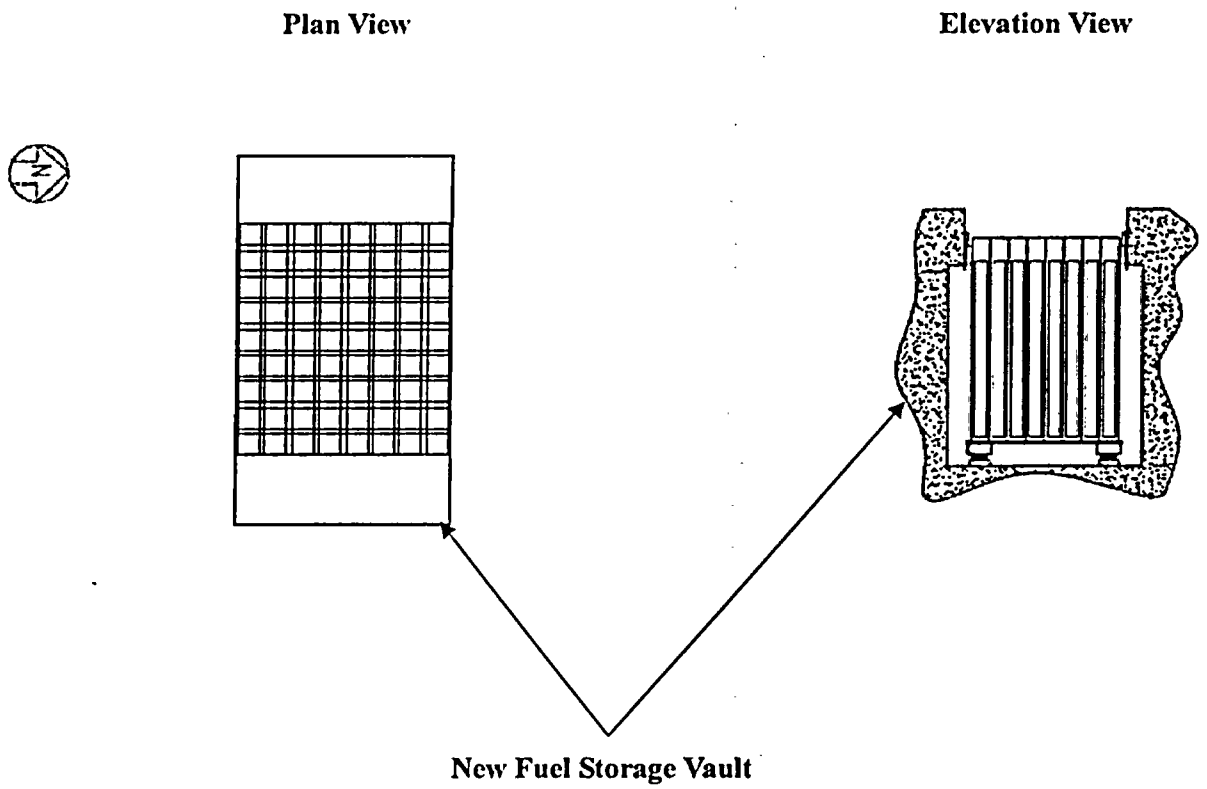

Figure 2-1 Plan and Elevation View AP1000 New Fuel Storage Rack and Vault (Vault Lid Details Not Shown)

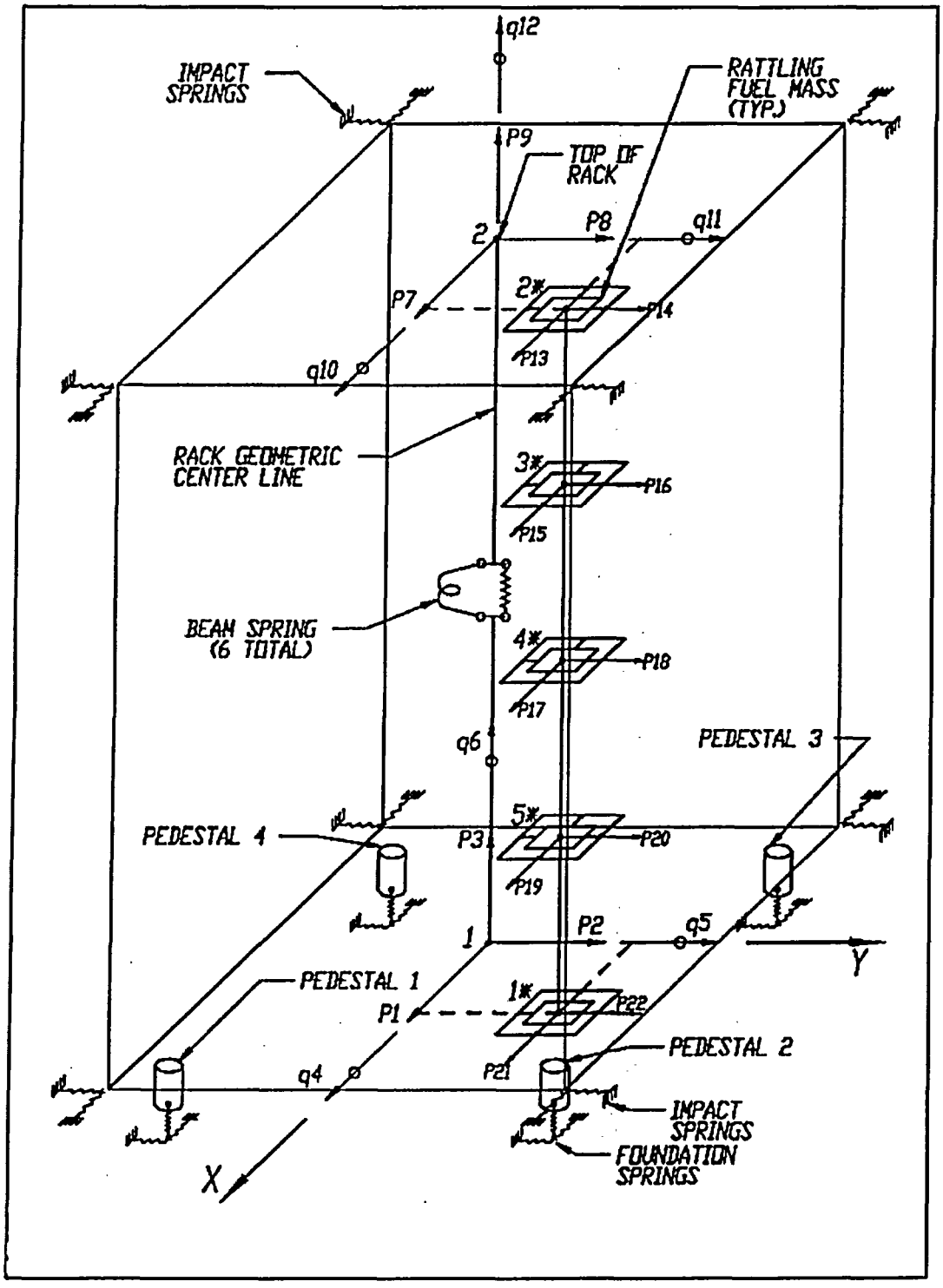

Figure 2-2 Schematic Diagram of Dynamic Model for DYNARACK

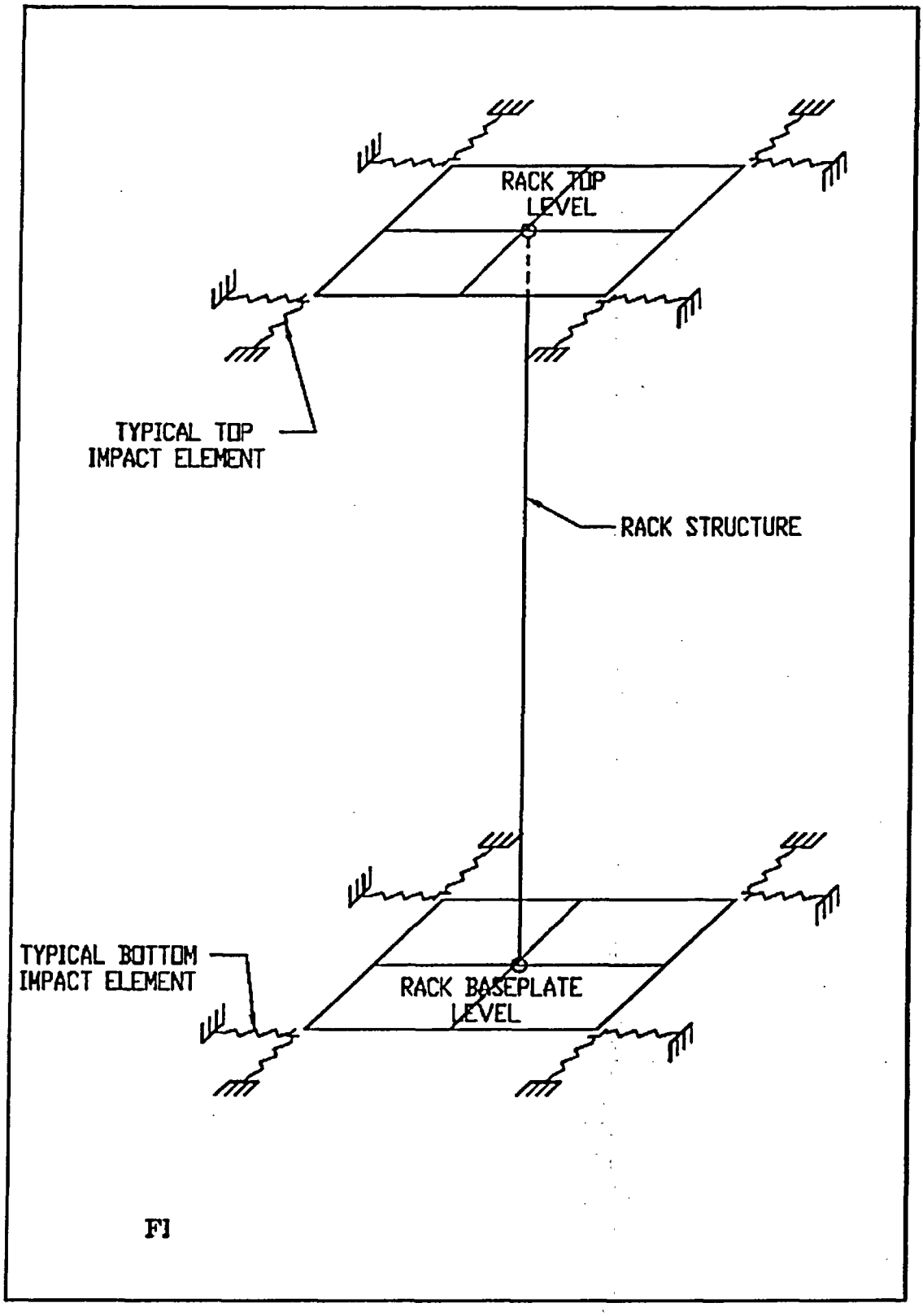

Figure 2-3 Rack-to-Rack Impact Springs

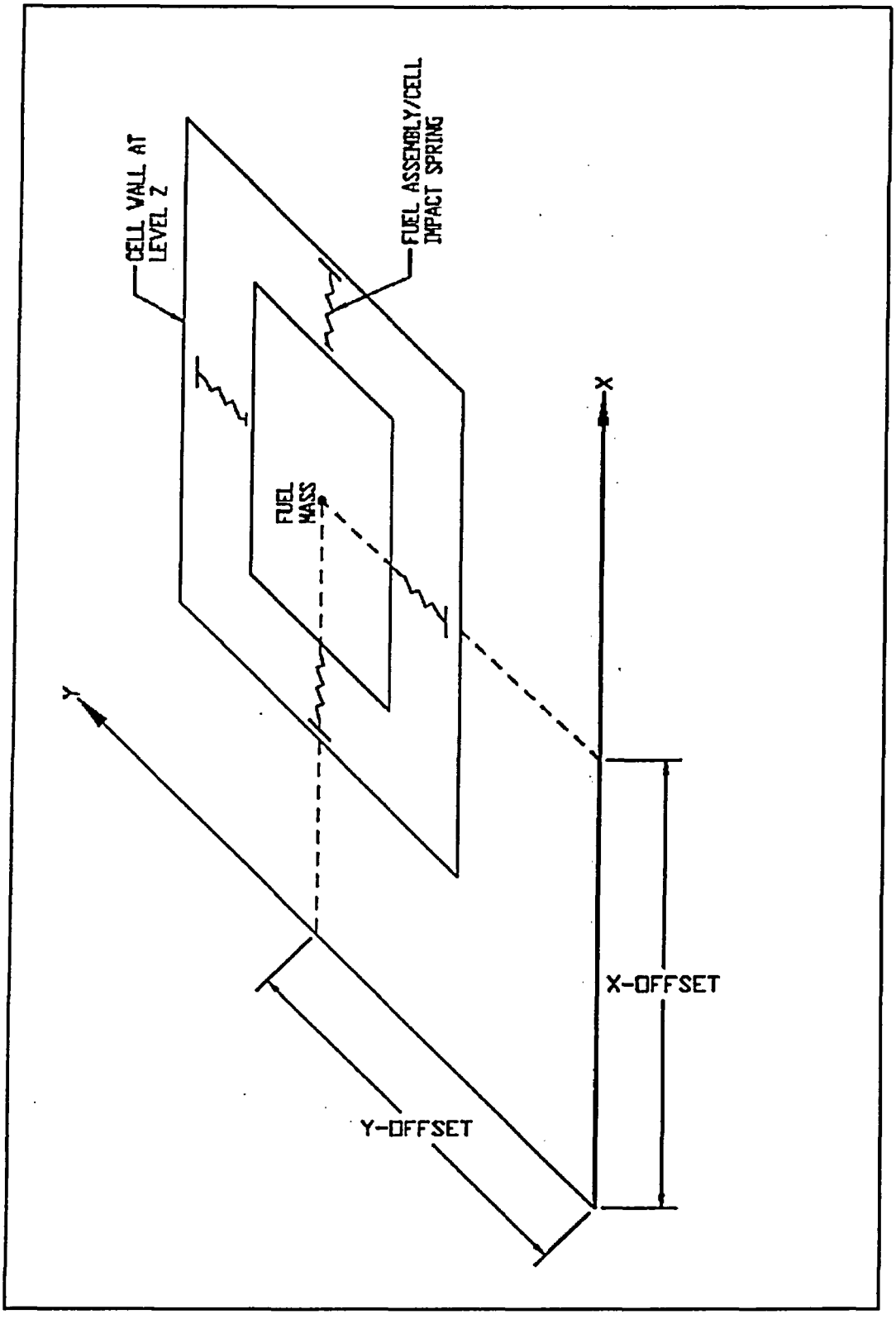

Figure 2-4 Fuel-to-Rack Impact Springs at Level of Rattling Mass

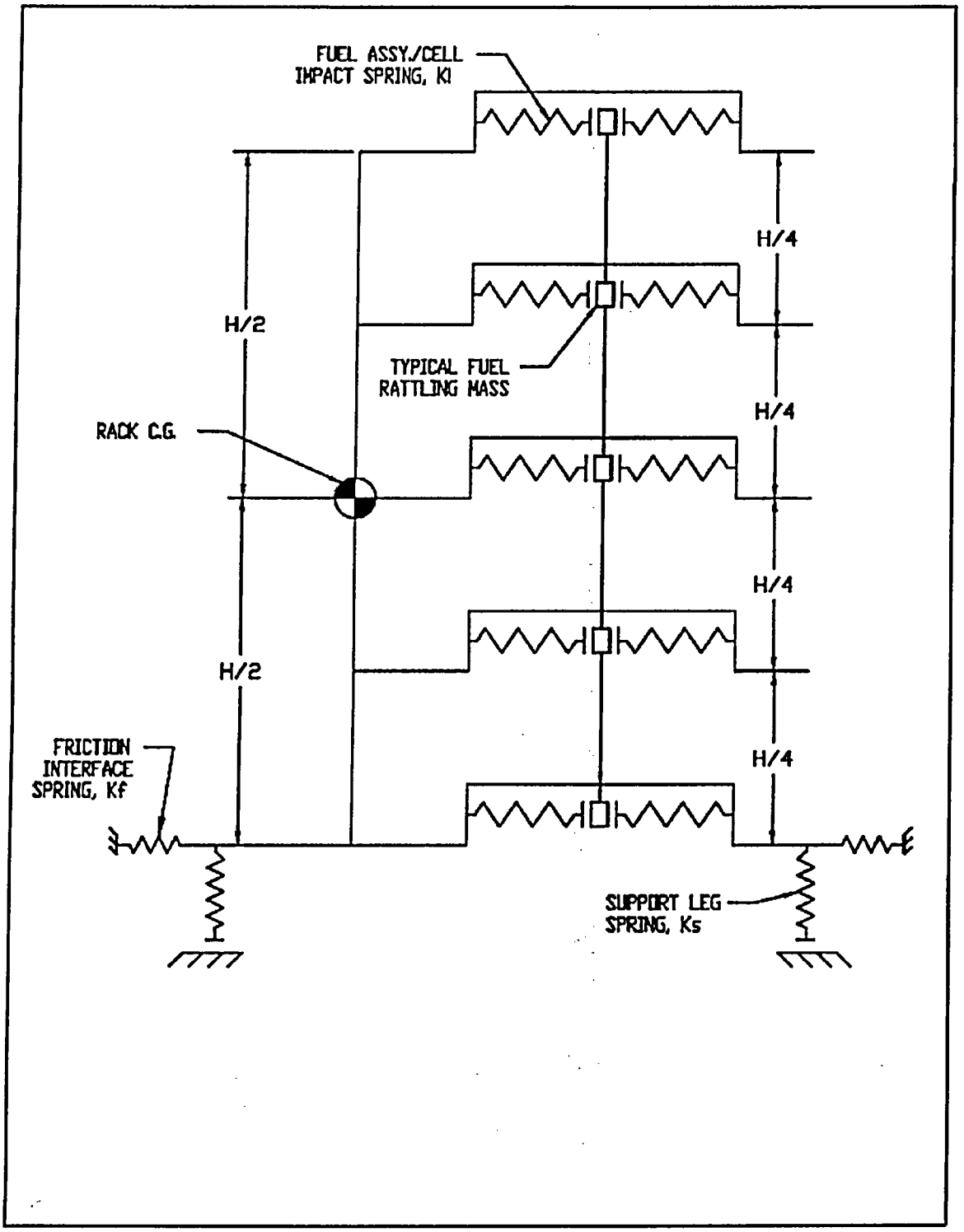

Figure 2-5 Two-Dimensional View of Spring-Mass Simulation

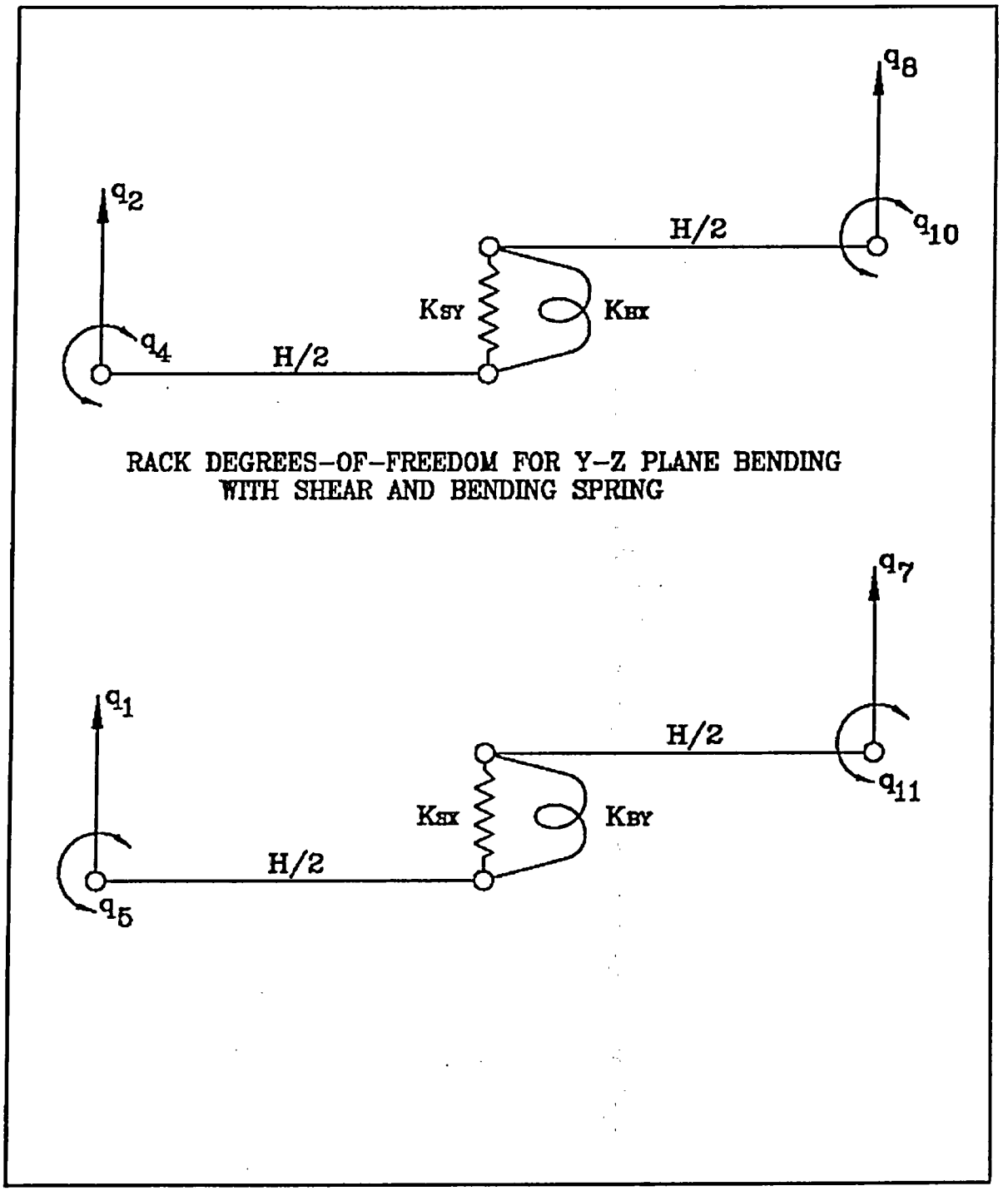

Figure 2-6 Rack Degrees-of-Freedom for X-Y Plane Bending with Shear and Bending Spring

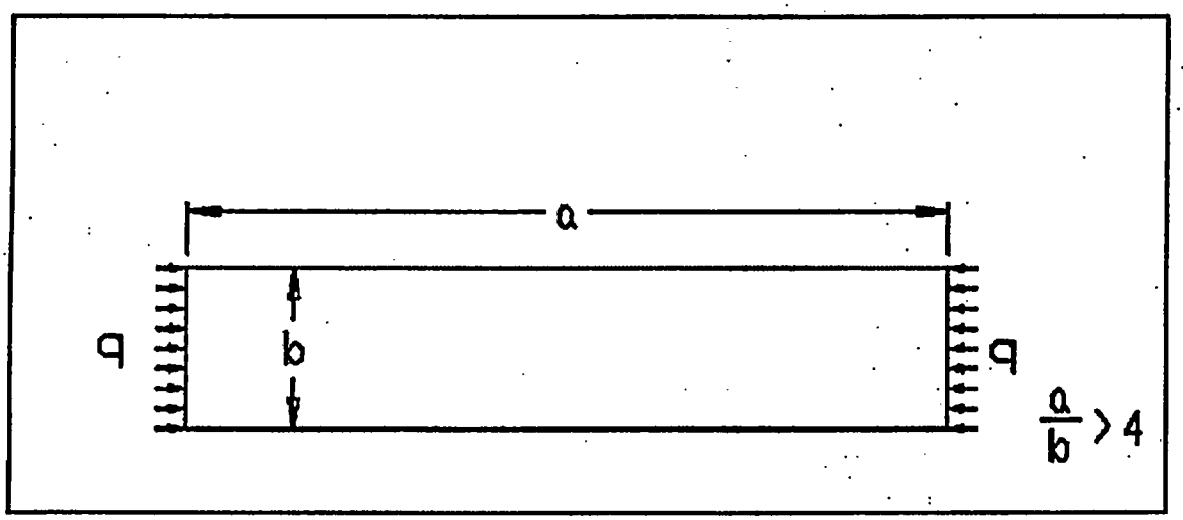

Figure 2-7 Cell Wall Buckling – Loading on Rack Wall

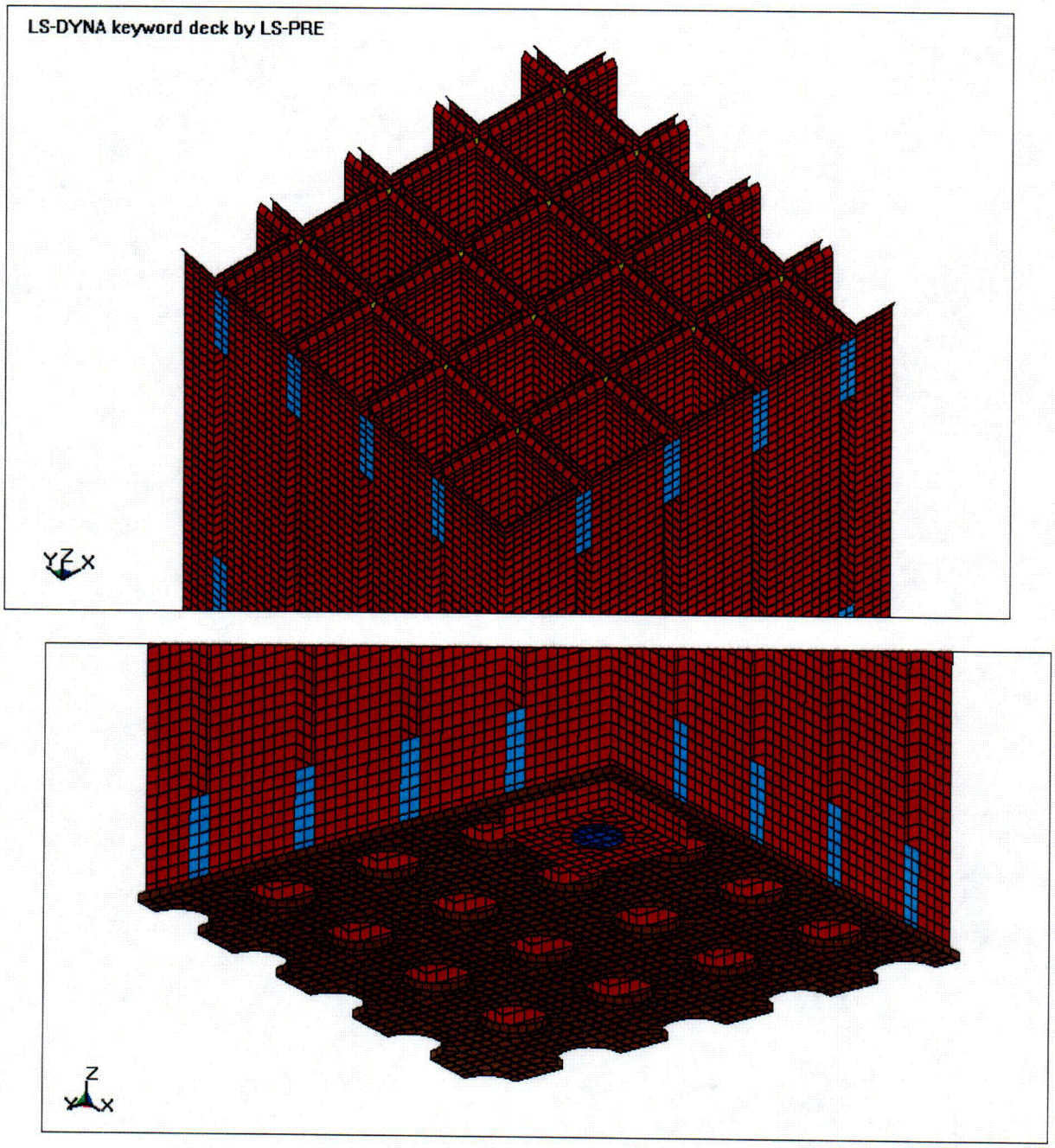

Figure 2-8 LS-DYNA Model of Top and Bottom of AP1000 New Fuel Storage Rack

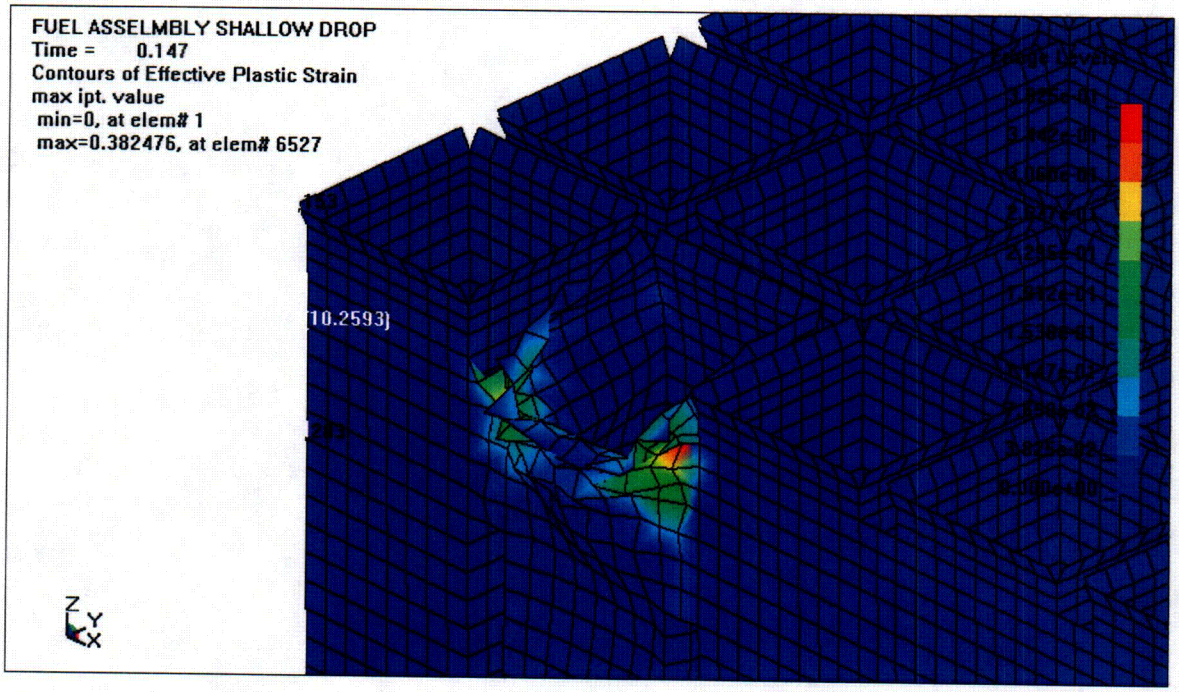

Figure 2-9 Results from Drop on AP1000 New Fuel Storage Rack

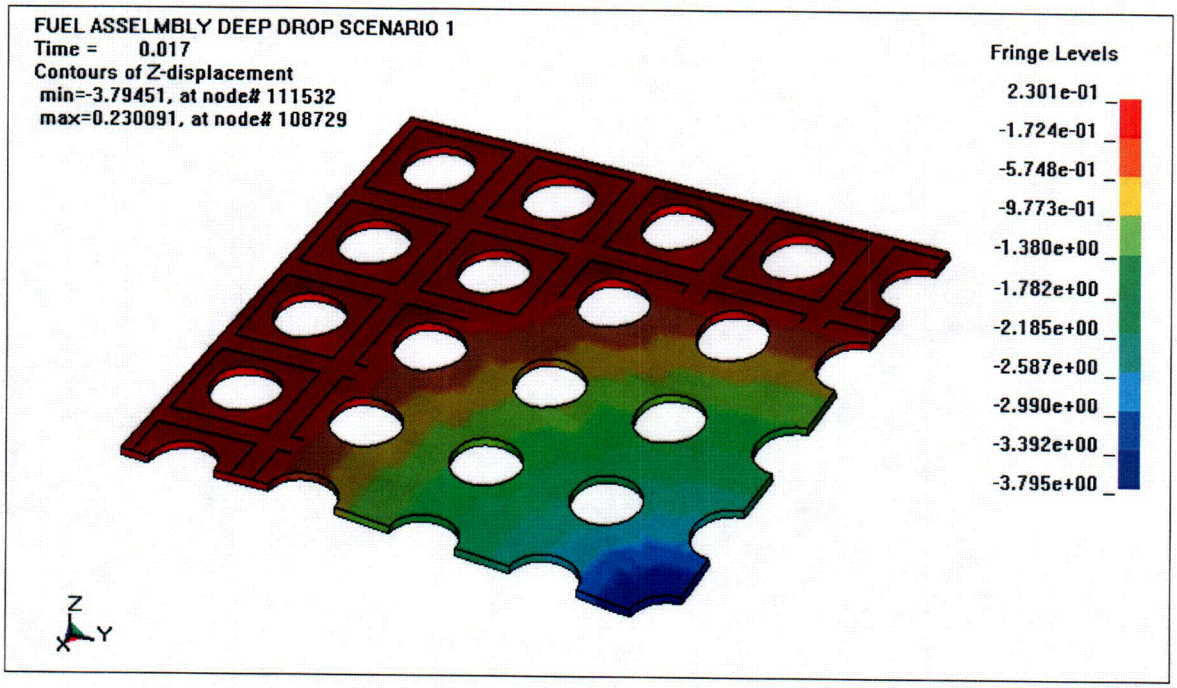

Figure 2-10 Baseplate Deformation Resulting from Fuel Assembly Drop onto Baseplate (3.8 inch Maximum Displacement Directly under Impact Location

3 REGULATORY IMPACT

The structure/seismic analysis of the AP1000 New Fuel Storage Rack is addressed in subsection 9.1.1.2.1, "New Fuel Rack Design," of the NRC Final Safety Evaluation Report (Reference 2). The completion of the structural/seismic analysis for the AP1000 New Fuel Storage Rack is identified in the Final Safety Evaluation Report as COL Action Item 9.1.6-1.

The changes to the DCD presented in this report do not represent an adverse change to the design functions of the AP1000 New Fuel Storage Rack, or to how design functions are performed or controlled. The structural/seismic analysis of the AP1000 New Fuel Storage Rack is consistent with the description of the analysis in subsection 9.1.1.2.1, "New Fuel Rack Design," of the DCD. Therefore, the changes to the DCD do not involve revising or replacing a DCD-described evaluation methodology. The changes to the DCD do not involve a test or experiment not described in the DCD. The DCD change does not require a license amendment per the criteria of VIII.B.5.b. of Appendix D to 10 CFR Part 52.

None of the changes described involve design features used to mitigate severe accidents. Therefore, a license amendment based on the criteria of VIII.B.5.c of Appendix D to 10 CFR Part 52 is not required.

The closure of the COL Information Item will not alter barriers or alarms that control access to protected areas of the plant. The closure of the COL Information Item will not alter requirements for security personnel. Therefore, the closure of the COL Information Item does not have an adverse impact on the security assessment of the AP1000.

4 REFERENCES

1. APP-GW-GL-700, AP1000 Design Control Document, Revision 15.

2. Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, September 2004.

3. Westinghouse Calculation, APP-FS01-S3C-001 Rev. 0, "AP1000 New Fuel Storage Rack Structural/Seismic Analysis," April 2006. (Westinghouse Proprietary)

4. AP1000 Standard Combined License Technical Report, APP-GW-GLR-030, Rev. 0, "New Fuel Storage Rack Design Criticality Analysis," May 2006.

5. "U.S. NRC OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," April 14, 1978, and January 18, 1979, amendment.

6. U.S. NRC Standard Review Plan, NUREG-0800 (SRP 3.8.4).

7. U.S. NRC Standard Review Plan, NUREG-0800 (SRP 3.7.1, Rev. 2).

8. Holtec Drawing No. 4741, "New Fuel Storage Rack Layout," Revision 0. (Holtec Proprietary)

9. 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).

10. Levy, S., and Wilkinson, John, "The Component Element Method in Dynamics," McGraw Hill, 1976.

11. ASME Boiler & Pressure Vessel Code Section III, Subsection NF, 1998.

12. Holtec Computer Code MR216 (multi-rack transient analysis code, a.k.a. DYNARACK), Version 2.00. QA documentation contained in Holtec Report HI-92844. (Holtec Proprietary)

13. ASME Boiler & Pressure Vessel Code, Section II, Part D, 1998.

14. ASME Boiler & Pressure Vessel Code, Section III, Appendices, 1998.

15. Holtec Computer Code DYNAPOST (Analysis Post Processor), v. 2.0. (Holtec Proprietary)

16. "Strength of Materials," S.P. Timoshenko, 3rd Edition, Part II, pp194-197 (1956).

17. Chun, R., Witte, M. and Schwartz, M., "Dynamic Impact Effects on Spent Fuel Assemblies," UCID-21246, Lawrence Livermore National Laboratory, October 1987.

18. AP1000 Letter Number DCP/HII0005, from J.M. Iacovino (Westinghouse Electric Company) to Mr. Eric Bush (Holtec International), March 27, 2006.

19. "PWR Rack Data Sheet AP1000," Rev. 4, Holtec International, April 27, 2006. (Holtec Proprietary)

20. Rabinowicz, E., "Friction Coefficients of Water Lubricated Stainless Steels for a Spent Fuel Rack Facility," MIT, a report for Boston Edison Company, 1976.

21. Westinghouse Document No: APP-GW-G1-003, "AP1000 Seismic Design Criteria," Rev. 0. (Westinghouse Proprietary)

22. LS-DYNA, v. 970 Livermore Software Technology Corporation, 2005.

23. Holtec Report HI-89330 Rev. 1, "A Seismic Analysis of High Density Fuel Racks; Part III: Structural Design Calculations – Theory." (Holtec Proprietary)

5 DCD MARKUP

The following DCD markup identifies how COL application FSARs should be prepared to incorporate the subject change.

Revise the first and second paragraphs of subsection 9.1.1.1 as follows:

9.1.1.1 Design Bases

New fuel is stored in a high density rack which includes integral neutron absorbing material to maintain the required degree of subcriticality. The rack is designed to store fuel of the maximum design basis enrichment. The rack in the new fuel pit consists of an array of cells interconnected to each other at several elevations and to ~~supporting grid structures at the top and bottom elevations~~ **a thick baseplate at the bottom elevation.** This rack module is not anchored to the pit floor, but lateral bracing to the pit wall structures is provided.

The new fuel rack includes storage locations for 72 fuel assemblies. The rack array center-to-center spacing ~~is shown in Figure 9.1-1. This spacing~~ provides a minimum separation between adjacent fuel assemblies which is sufficient to maintain a subcritical array even in the event the building is flooded with unborated water or fire extinguishant aerosols or during any design basis event. The design of the rack is such that a fuel assembly can not be inserted into a location other than a location designed to receive an assembly. An assembly can not be inserted into a full location. Surfaces that come into contact with the fuel assemblies are made of annealed austenitic stainless steel.

Delete Figure 9.1-1, New Fuel Storage Rack.

Revise the second paragraph of subsection 9.1.1.2 as follows:

9.1.1.2 Facilities Description

The dry, unlined, approximately 17-feet deep reinforced concrete pit is designed to provide support for the new fuel storage rack. The rack is supported by the pit floor and laterally supported as required at the rack top ~~grid structure~~ by the pit wall structures. The walls of the new fuel pit are seismic Category I. The new fuel pit is normally covered to prevent foreign objects from entering the new fuel storage rack. Since the only crane that can access the new fuel pit does not have the capacity to lift heavy objects, as defined in subsection 9.1.5, the new fuel pit cover is not designed to protect the fuel assemblies from the effects of dropped heavy objects. Figures 1.2-7 through 1.2-10 show the relationship between the new fuel storage facility and other features of the fuel handling area.

Revise the first paragraph of subsection 9.1.1.2.1 as follows:

9.1.1.2.1 New Fuel Rack Design

A. Design and Analysis of the New Fuel Rack

The new fuel storage racks are purchased equipment. **The new storage rack center-to-center spacing of nominally 10.9 inches provides a minimum separation between adjacent fuel assemblies in conjunction with the neutron absorbing material to maintain a subcritical array.** The purchase specification for the new fuel storage racks will require the vendor to

perform confirmatory dynamic and stress analyses. The seismic and stress analyses of the new fuel rack will consider the various conditions of full, partially filled, and empty fuel assembly loadings. The rack will be evaluated for the safe shutdown earthquake condition against the seismic Category I requirements. A stress analysis will be performed to verify the acceptability of the critical load components and paths under normal and faulted conditions. The rack rests on the pit floor and is braced as required to the pit wall structures.

Revise the third and sixth paragraph of subsection 9.1.1.3. as follows:

9.1.1.3 Safety Evaluation

The new fuel storage racks are purchased equipment. The purchase specification for the new fuel storage racks will require ~~the vendor to perform~~ a criticality analysis of the new fuel storage racks. The criticality evaluation will consider the inherent neutron absorbing effect of the materials of construction, including fixed neutron absorbing "poison" material.

Materials used in rack construction are compatible with the storage pit environment, and surfaces that come into contact with the fuel assemblies are made of annealed austenitic stainless steel. Structural materials are corrosion resistant and will not contaminate the fuel assemblies or pit environment. Neutron absorbing "poison" material used in the rack design has been qualified for the storage environment. Venting of the neutron absorbing material is ~~accomplished through the open corner design of the retaining "wrapper" plate.~~ **provided in the rack design.**

Revise the first paragraph of subsection 9.1.6 as follows:

9.1.6 Combined License Information for Fuel Storage and Handling

Completed. ~~The Combined License applicant is responsible for a~~ A confirmatory structural dynamic and stress analysis for the new fuel rack, as described in subsection 9.1.1.2.1~~.~~, **is provided in APP-GW-GLR-026, Revision 0, AP1000 Standard Combined License Technical Report (Reference 17).**

Revise subsection 9.1.7 by adding a reference as follows:

9.1.7 References

17. APP-GW-GLR-026, Revision 0, "AP1000 Standard Combined License Technical Report New Fuel Storage Rack Structural/Seismic Analysis," Westinghouse Electric Company LLC, May 2006.

Revise Table 9.1-1 as follows:

Table 9.1-1

LOADS AND LOAD COMBINATIONS FOR FUEL RACKS

Load Combination
$D + L$
$D + L + T_o$
$D + L + T_o + P_f$
$D + L + T_a + E'$

Notes:

1. The abbreviations in the table above are those used in NUREG-0800, Section 3.8.4 of the Standard Review Plan (SRP) where each term is defined except for T_a and P_f.

   The term T_a is defined here as the thermal loads due to highest temperature associated with the postulated abnormal design conditions. The term P_f is 1) the uplift force on the rack caused by a postulated stuck fuel assembly accident condition~~.~~: **or 2) the forces developed on the rack from the drop of a fuel assembly during handling to the top of the rack or to the baseplate through an empty cell.**
2. 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 free-standing spent fuel racks, thermal effects mainly affect the temperature that is used in specifying the allowable stress and Young's Modulus.**
3. **Live Loads (L) do not act on freestanding spent fuel racks.**
4. **The first two load combinations satisfy applicable ASME Level A (normal) stress limits; the second two load combinations either satisfy applicable ASME Level D stress limits, or simply require the racks to maintain a configuration that ensures subcriticality of the spent fuel.**
5. **There is no Operating Basis Earthquake (E) for the AP1000 plant.**