maximum loaded cell assembly, grid assembly and the leveling pad assembly to obtain the margins of safety.

The loads described in the seismic analysis section are corrected by load correction factors derived from the nonlinear analysis. The computed stresses are below the allowable stresses as required by the ASME B&PV Code, Section III, Subsection NF.

A fuel handling crane uplift analysis was performed which demonstrated that the rack can withstand the maximum uplift load of 3000 pounds of the fuel handling crane without violating the criticality acceptance criteria. Two accident loading conditions were postulated. The first condition assumed that the uplift load was applied to a fuel cell. The second condition assumed that the load was applied to the top grid. The crane uplift analysis conditions and results are discussed in Table 4-1.

A fuel assembly drop accident analysis was also performed to ensure that, in the unlikely event of dropping a fuel assembly, accidental deformation to the rack does not cause the criticality acceptance criteria to be violated, and the spent fuel pool liner will not be perforated. The accident conditions and final results are discussed in Table 4-2.

Administrative controls prevent heavy loads from being carried over the spent fuel storage racks.

In summary, the results of the seismic and structural analysis show that the H. B. Robinson spent fuel storage racks meet all the structural acceptance criteria adequately.

4.3 FUEL BUNDLE/MODULE IMPACT EVALUATION

An analysis is performed to evaluate the effect of an impact load due to fuel assembly and fuel storage cell interaction during a seismic event. The fuel rack system consists of an array of cells which form the fuel rack structure and fuel assemblies. The fuel rack system is located in the spent fuel pool and is submerged in water.

Since the fuel assembly is stored within the cell, the gap between the fuel assembly grid and cell changes (i.e., opens and closes) during a seismic event. From the equation of motion for such a system, it is evident that the fuel rack system is nonlinear. This condition necessitates that a transient dynamic analysis be performed.

The mathematical features of the nonlinear fuel rack model facilitate the determination of the fuel assembly/cell interaction and hydrodynamic mass (fluid mass) effects on the fuel rack response during seismic excitation. The effect of fuel assembly and fuel storage cell impact force on the rigid body displacements was obtained from the nonlinear analysis. The analysis was conducted with a minimum coefficient of friction of 0.2 and it was shown that the rigid body displacement was minimal (<0.3 inches). Thus, impact between adjacent rack modules or between a rack module and the pool wall is precluded.

The fuel assembly and fuel storage cell impact forces obtained from the nonlinear analysis were used to evaluate the effects on the fuel rack structure and fuel assembly structure. These loads are within the allowable limits of the fuel rack module materials and fuel assembly materials. Therefore, there is no damage to the fuel assembly or fuel rack module due to impact loads.

4.4 EFFECTS OF INCREASED LOADS ON THE FUEL POOL LINER AND STRUCTURES

The new spent fuel racks are free standing and are not connected to either the walls or floor of the pool as are the existing racks. Therefore, the effect of the new racks on the wall liner is less than that imposed by the existing racks. The sliding shear forces imparted to the floor liner under postulated earthquake conditions exceed those produced under the previous design; however, the sliding shear is well within the allowable working stresses of the liner material.

A preliminary investigation indicates that with the addition of two steel columns under the fuel pool floor, as described in Section 6.0, the structure will have adequate capacity to carry the increased loads imposed by the new high density spent fuel storage racks. A final verification will be performed and the results will be provided when available.

The spent fuel pool structure has been evaluated for new loads based on the following criteria:

a) Building Code Requirements for Reinforced Concrete. The ACI 318-63 Code.

b) H. B. Robinson Unit No. 2 Final Safety Analysis Report.

c) USNRC Operating Technical Position for Review and Acceptance of Spent Fuel Storage and Handling Applications.

d) American Standards Association ASA A58.1-1955.

Based on the above criteria the following is a listing of the primary loads considered in the structural evaluation.

a) The dead weight of the structural elements including crane column dead loads and the hydrostatic load from the pool water (D)

b) Live load including crane column live load (fuel cask) with impact and thrust (L_o)

c) Live load of fuel racks and fuel elements (L_1)

d) Equipment load (Cask) (L_2)

e) Wind Load N-S (W-NS)

Wind Load S-N (W-SN)

TABLE 4-1

CRANE UPLIFT ANALYSIS CASE SUMMARY

Number	Case Description	Effect on Reactivity
1.	An uplift load of 3,000 pounds is applied to a fuel cell.	The uplift load will not cause separation of a cell from the rack module, therefore system reactivity is unchanged. K_{eff} <0.95.
2.	An uplift load of 3,000 pounds is applied to the top grid structure of the rack module.	The deadweight of an empty rack module sufficiently exceeds the applied uplift load such that tipping of the module will not occur for any full or partial arrangement of fuel storage. System reactivity is therefore unchanged. K_{eff} <0.95.

TABLE 4-2

FUEL ASSEMBLY DROP ACCIDENT ANALYSIS CASE SUMMARY

Number	Case Description	Effect on Reactivity
1.	A fuel assembly (with RCCA's) drops 30 inches vertically and impacts the top of a fully loaded rack module. The dropped assembly comes to rest horizontally on top of the rack module.	The dropped assembly has more than eighteen inches of water separating it from the active height of the stored fuel which precludes interaction. Since the analysis assumes an infinite vertical length of fuel (no neutron leakage in the vertical dimension) system reactivity remains unchanged. $K_{eff} < 0.95$.
2.	A fuel assembly (with RCCA's) drops from 30 inches above the rack module and strikes a storage cell wall at an oblique angle.	Localized storage cell damage will occur. Conservatively assuming complete removal of one neutron absorber plate, criticality calculations show that K_{eff} for this case remains less than 0.95.
3.	A fuel assembly (with RCCA's) drops from 30 inches above the rack module, enters an empty storage location, and falls to the bottom of the storage position.	Structural analysis for this case assumes gross failure of rack module base plate welds such that pool floor liner is impacted. Compressive stress in the liner plate is within allowable limits so that liner perforation does not occur. Concurrent fuel displacement by approximately six inches below neutron absorber plates for a square array of six fuel assemblies results in a calculated K_{eff} less than 0.95.

B_{part} = bias to account for poison particle self-shielding.

$KS_{nominal}$ = 95/95 uncertainty in the method bias.

Substituting calculated values, the result is K_{eff} = 0.9242

Since K_{eff} is less than 0.95 including uncertainties at a 95/95 probability/confidence level, the acceptance criteria for criticality is met.

7.4 POSTULATED ACCIDENTS

Most accident conditions will not result in an increase in K_{eff} of the rack. Examples are the loss of cooling systems (reactivity decreases with decreasing water density) and dropping a fuel assembly on top of the rack (the rack structure pertinent for criticality is not deformed and the dropped assembly has more than 18 inches of water separating it from the active fuel height which precludes interaction). The results of fuel assembly drop accidents are summarized in Table 4-2.

However, accidents can be postulated which would increase reactivity. Therefore, for accident conditions, the double contingency principle of ANS N16.1-1975 is applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for accident conditions, the presence of soluble boron in the storage pool water can be assumed as a realistic initial condition since its absence would be a second unlikely event.

The presence of approximately 2000 ppm boron in the pool water will decrease reactivity by about 30% Δk. In perspective, this is more negative reactivity than is present in the poison plates (25% Δk), so K_{eff} for the rack would be less than 0.95 even if the poison plates were not present. Thus, for postulated accidents, should there be a reactivity increase, K_{eff} would be less than or equal to 0.95 due to the combined effects of the dissolved boron and the poison plates.

The "optimum moderation" accident is not a problem in spent fuel storage racks because possible water densities are too low ($\leq$0.01 gm/cm^3) to yield K_{eff} values higher than for full density water and the rack design prevents the preferential reduction of water density between the cells of a rack (e. g., boiling between cells). Further, the presence of poison plates removes the conditions necessary for "optimum moderation" so that K_{eff} continually decreases as moderator density decreases from 1.0 gm/cm^3 to 0.0 gm/cm^3 in poison rack design.

Generally, the acceptance criteria for postulated accident conditions can be $K_{eff} \leq 0.98$ because of the accuracy of the methods used coupled with the low probability of occurrence. For instance, in ANSI N210-1976 the acceptance criteria for the "optimum moderation" condition is $K_{eff} \leq 0.98$. However, for storage pools which contain dissolved boron, the use of the realistic initial conditions ensures that $K_{eff} \ll 0.95$ for postulated accidents. Thus, for simplicity, the acceptance criteria for all conditions will be $K_{eff} \leq 0.95$.

region of the racks has been chosen such as to maximize this flow area. Each storage cell has a large flow opening as shown in Figure 8-3. The use of large flow holes virtually eliminates the possibility that all flow into the inlet of a given cell can be blocked by debris or other foreign material that may get into the pool. In order to determine the impact of a partial blockage on the thermal-hydraulic conditions in the cells, an analysis is also performed for various assumed blockages.

The analyses that have been described only address the flow through the storage cells. As noted in the discussion of criteria, it is also required that the flow and temperatures in the axial gap between adjacent storage cells be evaluated. In order to preclude the possibility of stagnant conditions in these gaps, flow relief areas are provided at the location of the grid support structures as shown in Figure 8-4. This flow area also ensures that air or steam cannot be trapped in the rack structure. The thermal hydraulic conditions in the gap region are evaluated by using a parallel path thermal-hydraulic model of the gap and cell under consideration. This analysis considers the gamma heat generation in the cell enclosure, poison material and cell wrapper in addition to the decay heat input. Using the cell flow velocity and driving pressure differential obtained from the previously described pool analyses, the flow velocity in the gap and the axial temperature distributions of the coolant and structure are determined. The radial temperature distributions through the various components are also considered.

8.5.2 RESULTS

Normal Operation

Basis:

a. Cooling System Operational

b. 118 hours after shutdown-Decay Heat = 55.8 BTU/second/assembly

c. Uniform decay heat loading in pool - No credit for lower actual heat input

d. Peak Rod has 60% more heat output than average rod

e. All storage cells filled.

Results of the analysis show that no boiling occurs at any point within the storage racks when the normal cooling system is in operation or whenever pool temperature is maintained within its allowable limits. Water temperatures in the gap between cells are lower than inside the cells, and boiling does not occur in the inter-cell gaps. Although the normal water level is 24 feet above the top of the racks, a level of only 10 feet is required for a saturation temperature of 225°F which is greater than the cell outlet temperature, and no boiling occurs.

Flow Blockage Analysis

Basis:

a. 118 hours after shutdown

b. Temperature of water at inlet to storage racks = 150°F

Results of the analysis show that should up to 75% flow blockage occur, there would be no boiling in the water channels between the cells or in the cells. Because of the large flow openings that are used in the Westinghouse storage racks, it is very improbable that a complete blockage could occur.

Abnormal Condition

Under postulated conditions where all non-Category I spent fuel pool cooling systems become inoperative, there is an alternative method for cooling the spent fuel pool water. Although it is highly unlikely that a complete loss of cooling capability could occur, the racks are analyzed to this condition.

Basis:

a. No pool cooling implies that temperature of water at inlet to spent fuel racks is 212°F which corresponds to the saturation temperature at the pool surface.

b. The nominal water level of 24 feet above the top of the racks is maintained.

c. A conservative fuel loading case is assumed. The pool is completely filled with fuel based on a full core discharge at one month following a normal refueling. Previous refuelings of one-third core from each unit are assumed to have occurred at one year intervals.

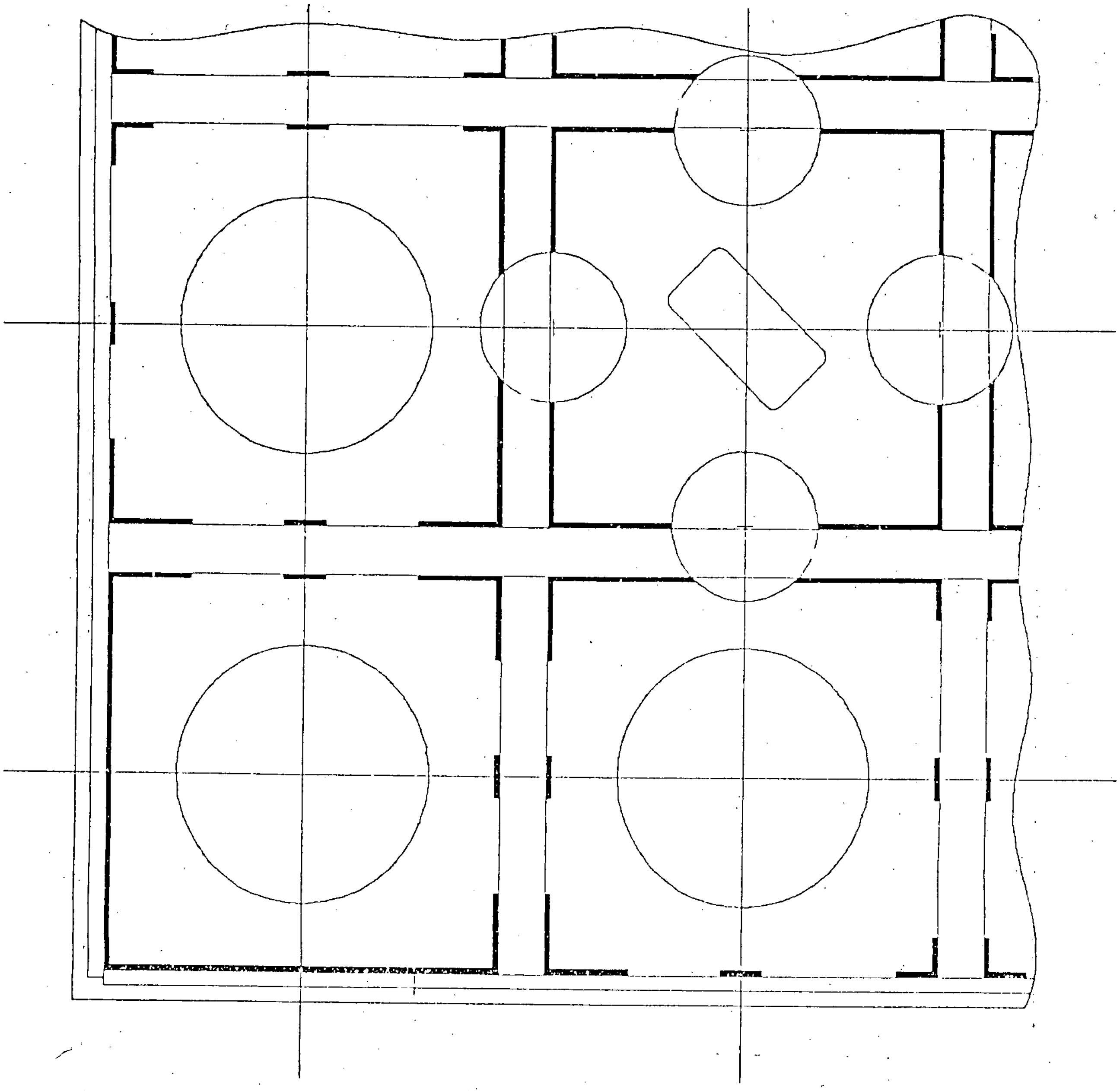
d. The assemblies that are evaluated are initially put into the pool at 118 hours after shutdown.

e. The peak rods are assumed to have 60% greater heat output than average rods.

f. All storage cells are filled and all downflow occurs in the peripheral gap.

Results of this analysis show that due to the effects of natural circulation, the fuel cladding temperatures are sufficiently low to preclude structural failures. No boiling in the water channels between the fuel assemblies and within the storage cells occurs.

Since the saturation temperature is approximately 239°F and the maximum cell outlet temperature at 118 hours after shutdown is about 227°F, boiling does not occur in the water channels between fuel assemblies. As decay heat decreases, the cell outlet temperatures also continue to decrease.



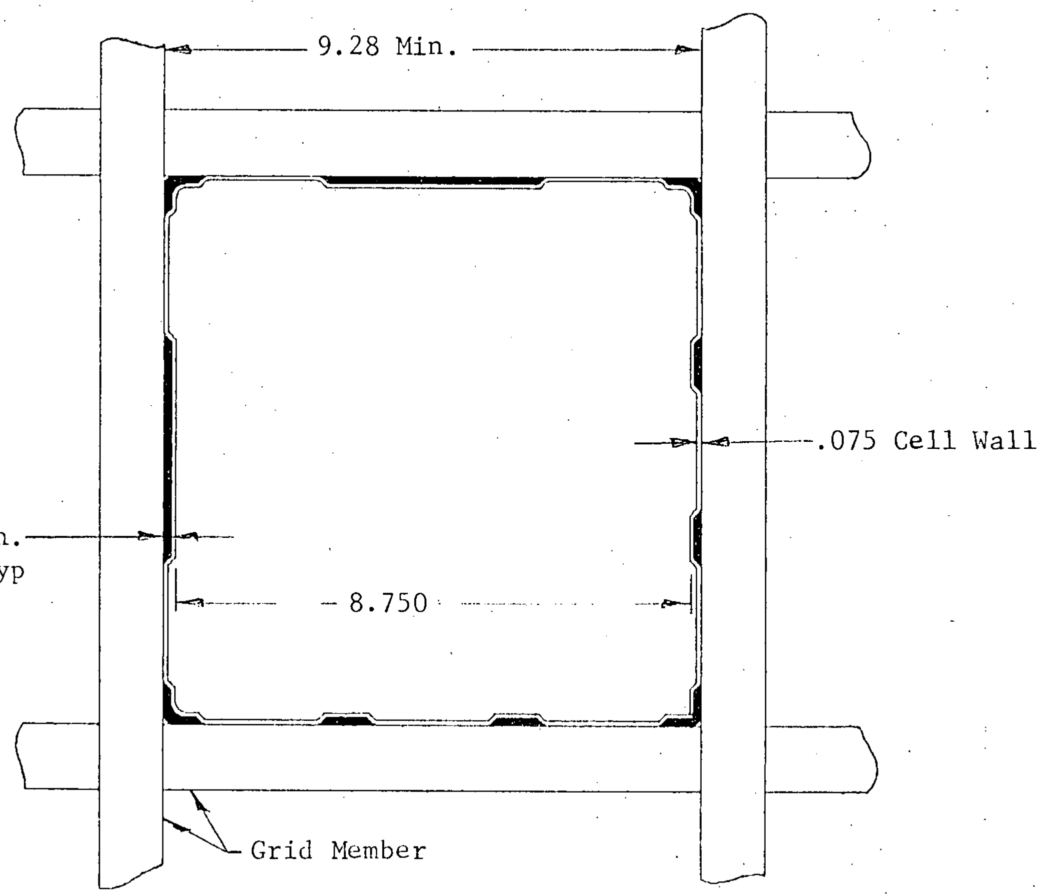
H. B. ROBINSON STEAM
ELECTRIC PLANT, UNIT NO. 2

Carolina
Power & Light Company

SPENT FUEL POOL
STORAGE EXPANSION

SPENT FUEL RACK INLET FLOW AREAS

FIGURE 8-3



GAP FLOW AREA AT SUPPORT = 1.94 $IN.^2$

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2 Carolina Power & Light Company SPENT FUEL POOL STORAGE EXPANSION	INTERCELL FLOW AREA	FIGURE 8-4