7.0 MECHANICAL ACCIDENTS

7.1 Introduction

The USNRC OT position paper [7.1.1] specifies that the design of the rack must ensure the functional integrity of the spent fuel racks under all credible fuel assembly drop events.

This chapter contains synopses of the analyses carried out to demonstrate the regulatory compliance of the proposed racks under postulated accidental drop events germane to the St. Lucie Plant (Unit 1 & Unit 2) cask pits; namely, that of a fuel assembly.

The proposed change does not impact assumptions in the current licensing basis on the potential fuel damage due to mechanical accidents.

7.2 Description of Mechanical Accidents

Analyses are performed to evaluate the racks subsequent to a fuel assembly impact under various fuel assembly drop scenarios. Two categories of accidental drop events are considered.

In the so-called "shallow" drop event, a fuel assembly, along with the portion of handling tool, which is severable in the case of a single element failure, is assumed to drop vertically and hit the top of the rack. Inasmuch as the new racks are of honeycomb construction, the deformation produced by the impact is expected to be confined to the region of collision. However, the "depth" of damage to the affected cell walls must be demonstrated to remain limited to the portion of the cell above the top of the "active fuel region", which is essentially the elevation of the top of the Boral neutron absorber. Stated in quantitative terms, this criterion implies that the plastic deformation of the rack cell walls should not extend more than 35.75 inches (downwards) from the top. In order to utilize an upper bound of kinetic energy at impact, the impactor is assumed to weigh 2,000 lbs and the free-fall height is conservatively assumed to be 36 inches.

It is readily apparent from the description of the rack modules in Section 3 that the impact resistance of a rack at its periphery is considerably less than its interior. Accordingly, the limiting shallow drop scenario, which would produce maximum cell wall deformation, consists of the case where the fuel assembly impacts the peripheral cell wall, as shown in Figure 7.2.1.

The second class of fuel drop event postulates that the impactor falls through an empty storage cell impacting the fuel assembly support surface (i.e., rack baseplate). This so-called "deep" drop event threatens the structural integrity of the baseplate. If the baseplate is pierced, and fuel assembly impacts the rack platform or drops onto the liner, then an abnormal condition of the enriched zone of fuel assembly outside the "poisoned" space of the fuel rack may develop. To preclude damage to the cask pit liner and to avoid the potential of an abnormal fuel storage configuration in the aftermath of a deep drop event, it is required that the baseplate remain unpierced and that the maximum lowering of the baseplate is shown to be acceptable by the criticality evaluations.

The deep drop event can be classified into two scenarios, namely, drop in an interior cell away from the support pedestal, as shown in Figure 7.2.2, and drop through cell located above a support leg, as shown in Figure 7.2.3. In deep drop scenario 1, the fuel assembly impacts the baseplate away from the support pedestal, where it is more flexible. Severing or large deflection of the baseplate leading to a secondary impact with the cask pit liner or rack platform are unacceptable results. In deep drop scenario 2, the baseplate is buttressed by the support pedestal and presents a hardened impact surface, resulting in a high load. The principal design objective is to ensure that the rack platform bottom does not tear the liner that overlays the reinforced concrete cask pit slab.

7.3 Incident Impact Velocity

[redacted]

[redacted]

7.4 Mathematical Model

In the first step of the solution process, the velocity of the dropped object (impactor) is computed for the condition of underwater free fall in the manner of the formulation presented in the above section. Table 7.4.1 contains the computed velocities for the various drop events.

[redacted]

7.5 Results

7.5.1 Shallow Drop Event

For the shallow drop event, the dynamic analysis shows that the top of the impacted region undergoes localized plastic deformation. Figure 7.5.1 shows an isometric view of the post-impact geometry of the rack. The maximum depth of plastic deformation is limited to 12.5 inches, which is below the design limit of 35.75 inches.

7.5.2 Deep Drop Events

The deep drop through an interior cell does produce some deformation of the baseplate with no severing of the baseplate/cell wall welds. Figure 7.5.2 shows the deformed baseplate configuration. The fuel assembly support surface is lowered by a maximum of 1.96 inches, which is much less than the distance of 4.25 inches from the baseplate to the rack platform. The deformation of the baseplate has been determined to be acceptable with respect to lowering the fuel seating position and the resulting criticality consequences, as discussed in Chapter 4.0.

The deep drop event wherein the impact region is located above the support pedestal is found to produce a maximum stress of 3,933 psi in the liner, which is less than the yield stress of the liner material, as shown in Figure 7.5.3. Finally, the maximum compressive stress of 1,260.3 psi in the concrete slab is less than the concrete compressive strength of 3,000 psi, as shown in Figure 7.5.4. Therefore, there will be no abrupt or uncontrollable loss of water from the cask pit.

7.6 Conclusion

The drop events postulated for the St. Lucie Plant cask pits were analyzed and found to produce localized damage well within the design limits for the racks. The shallow drop event is found to produce some localized plastic deformation in the top of the storage cell, but the region of permanent strain is limited to the portion of the rack structure situated above the top of the active fuel region. The analysis of the deep drop event at cell locations selected to maximize baseplate deformation indicates that the downward displacement of the baseplate is limited to 1.96 inches, which ensures that unacceptable criticality consequences would not occur. The deep drop case analyzed for the scenario to produce maximum pedestal force indicates that the pedestal axial load is sufficiently small to preclude liner and concrete slab damage. Therefore, there will be no uncontrollable loss of cask pit water inventory. In conclusion, the new Holtec high-density spent fuel racks for the St. Lucie Plant cask pits possess acceptable margins of safety under the postulated mechanical accidents.

7.7 References for Chapter 7.0

[7.1.1] "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14, 1978, and addendum dated 1979.

[7.4.1] NUREG/CR-6608, "Summary and Evaluation of Low-Velocity Impact Tests of Solid Steel Billet Onto Concrete Pads", dated February 1998.

Table 7.4.1

IMPACT EVENT DATA

Case	Impactor Weight (lb)	Impactor Type	Drop Height (in)	Impact Velocity (in/sec)
1. Shallow drop event	2,000	Fuel assembly & handling tools	36	150.9
2. Deep drop event scenario 1 (away from pedestal)	2,000	Fuel assembly & handling tools	216	273.7
3. Deep drop event scenario 2 (above pedestal)	2,000	Fuel assembly & handling tools	216	101.7 †

---

† Note that the velocity for the drop above a pedestal is much less than the condition away from the pedestal, since the hydraulic resistance is significantly increased because the pedestal blocks the baseplate flow hole.

Table 7.4.2

MATERIAL DEFINITION

Material Name	Material Type	Density (pcf)	Elastic Modulus (psi)	Stress		Strain	
				First Yield (psi)	Failure (psi)	Elastic	Failure
Stainless Steel	SA240-304L	490	2.782e+07	2.278e+04	6.772e+04	8.188e-04	3.800e-01
Stainless Steel	SA240-304	490	2.782e+07	2.700e+04	7.260e+04	9.705e-04	3.800e-01
Zircaloy	--	404	1.040e+07	8.05e+04	8.05e+04	1.000e-02	1.500e-02
Stainless Steel	SA564-630	490	2.782e+07	1.098e+05	1.400e+05	3.947e-02	3.800e-01
Concrete †	f'_c=3,000 psi	150	3.122e+06	--	3.000e+03	--	--

---

† The concrete is modeled as recommended in NUREG /CR-6608 [7.4.1].

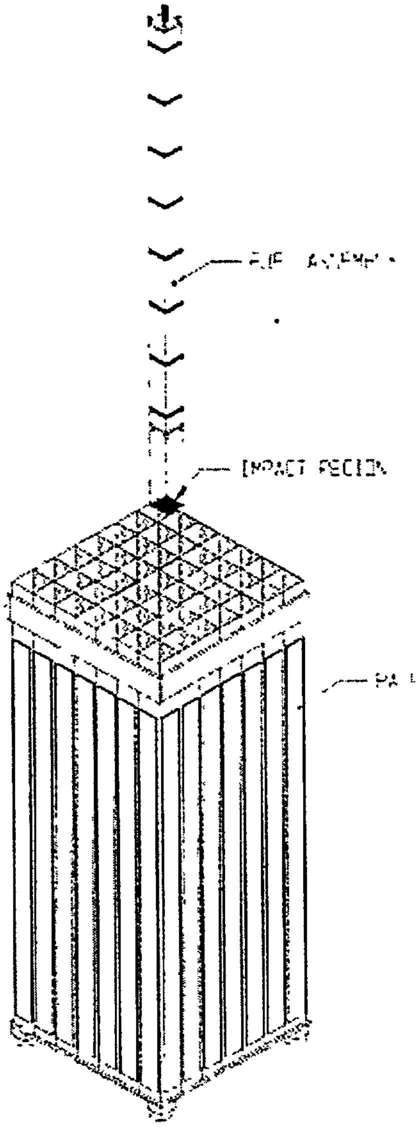


Fig. 7.2.1 Schematics of the "shallow" drop event

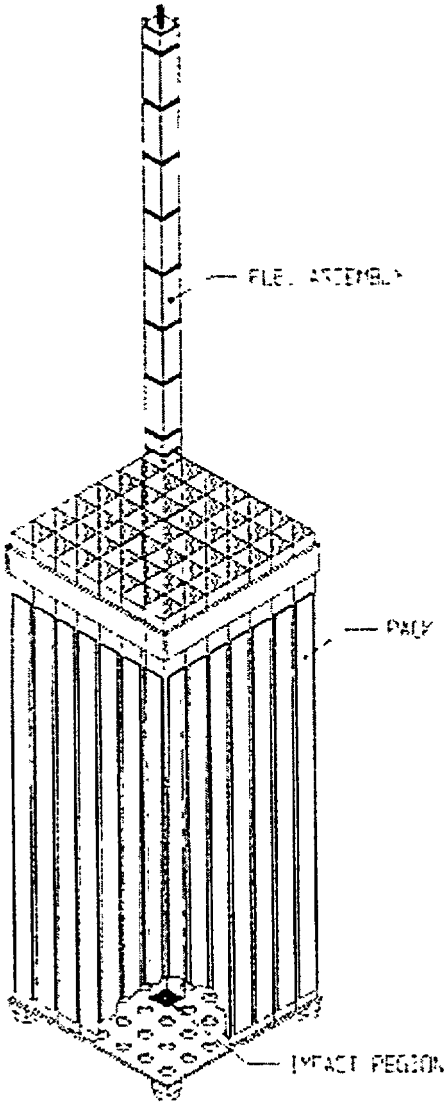


Fig. 7.2.2 Schematics of the “deep” drop scenario 1

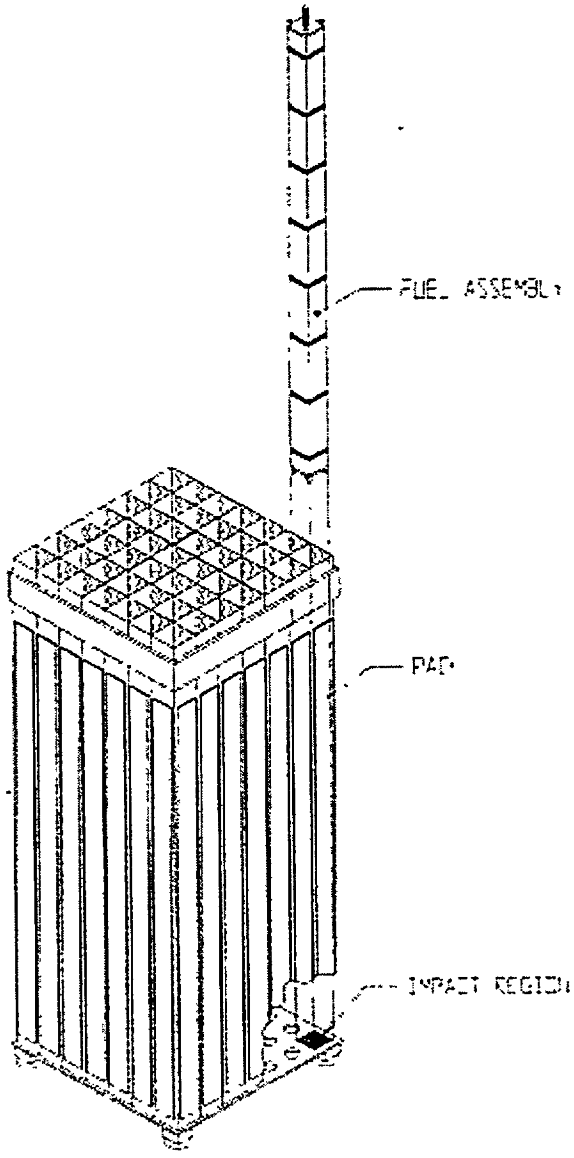


Fig. 7.2.3 Schematics of the "deep" drop scenario 2

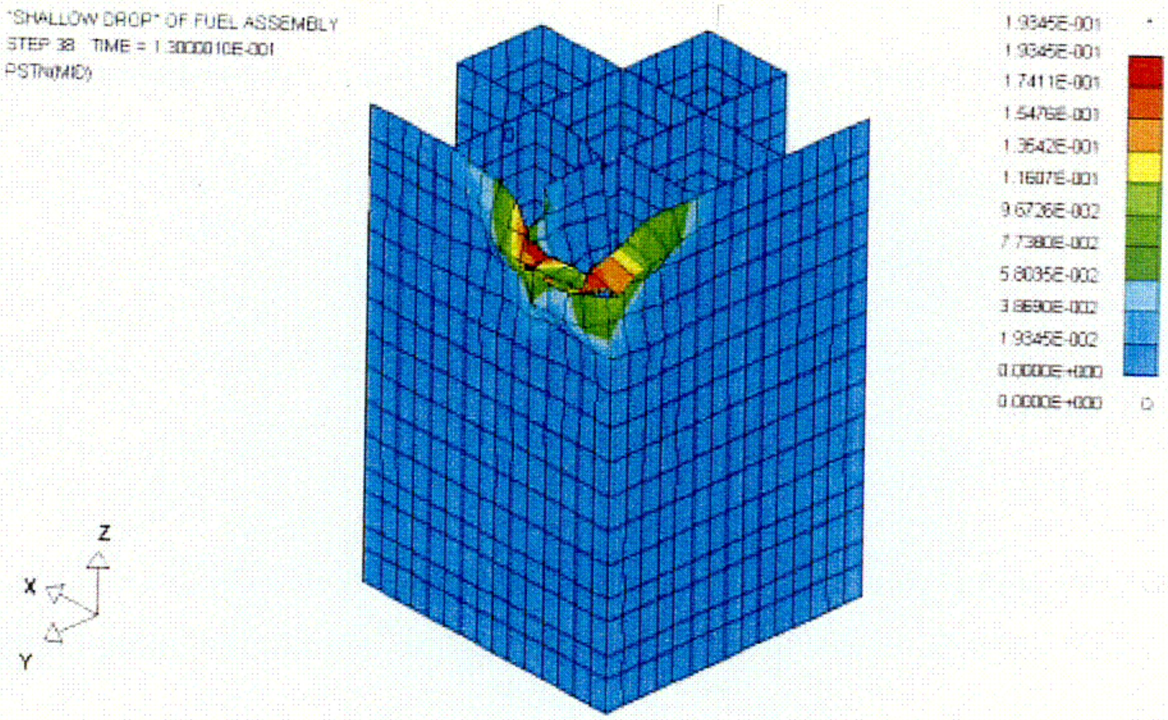


Fig. 7.5.1 "Shallow" Drop: Maximum Plastic Strain

C01

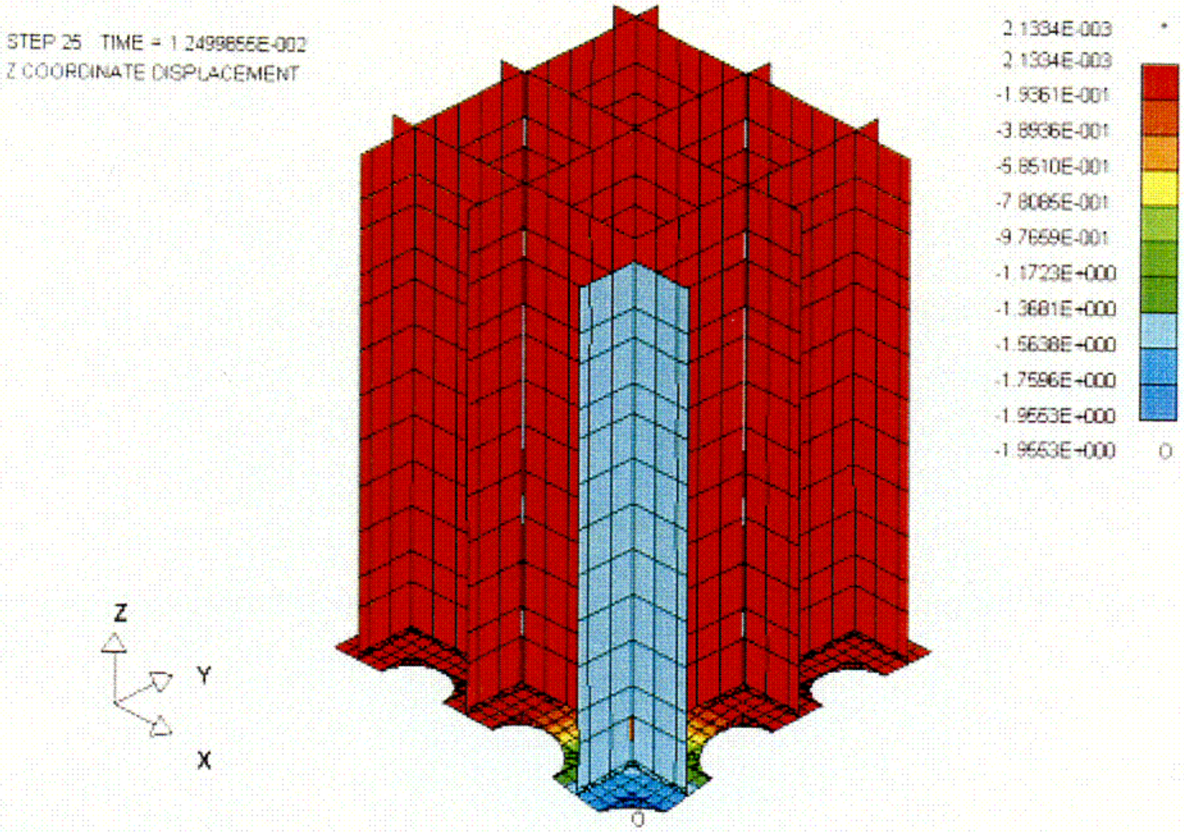


Fig. 7.5.2 “Deep” Drop Scenario 1: Maximum Vertical Displacement

C02

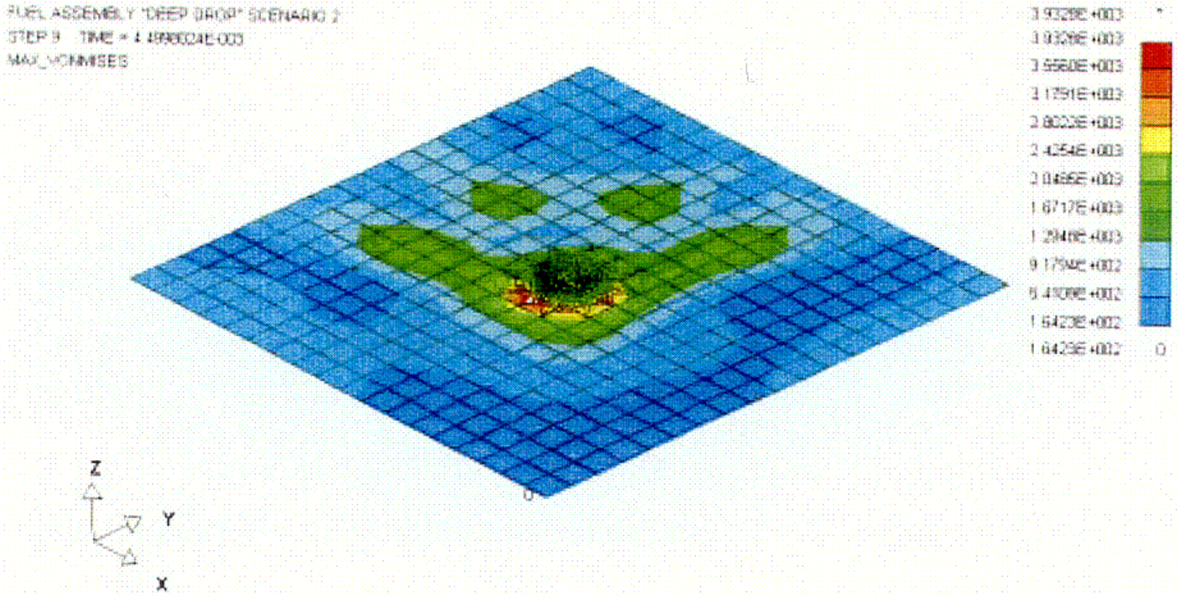


Fig. 7.5.3 "Deep" Drop Scenario 2: Maximum Von Mises Stress – Liner

C03

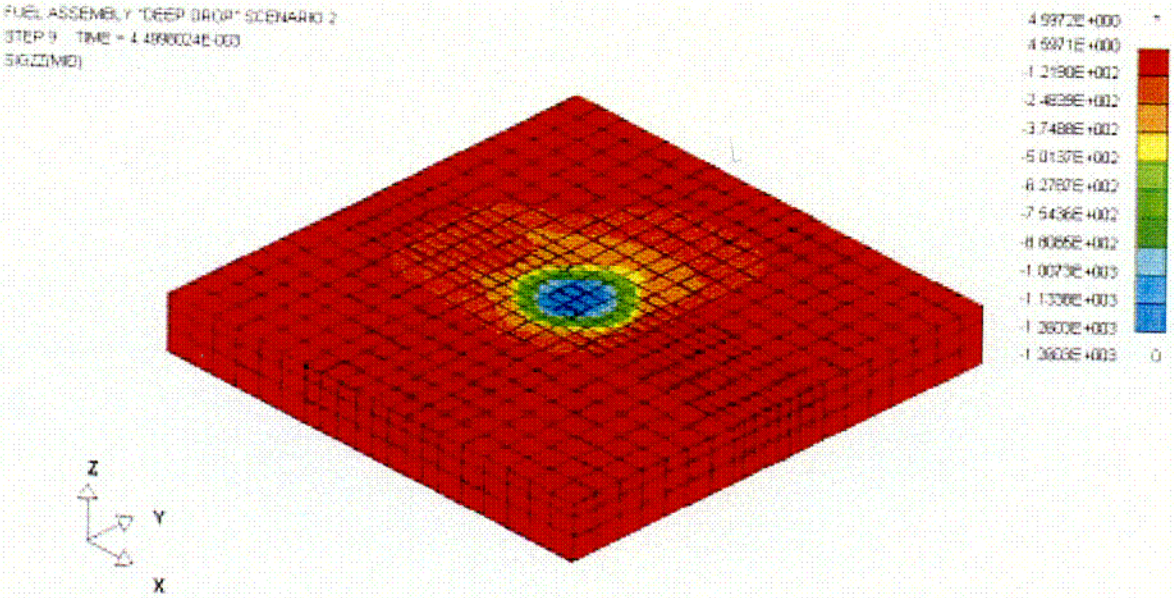


Fig. 7.5.4 "Deep" Drop Scenario 2: Maximum Compressive Stress – Concrete

8.0 FUEL HANDLING BUILDING STRUCTURAL INTEGRITY EVALUATIONS

Structural integrity evaluations of the regions of the reinforced concrete structure affected by the proposed capacity expansion (Cask Pit (CP) and portions of the Spent Fuel Pool (SFP) exterior walls in Units 1 and 2) are summarized in this section. For purposes of structural evaluation, the exterior walls of the SFP are also the exterior walls of the Fuel Handling Building (FHB), and the terms are used interchangeably. Since the two units have some geometric and load differences, and are governed by different structural design requirements, the evaluations are summarized in separate sub-sections.

8.1 Unit 1 Evaluation

8.1.1 Introduction

The St. Lucie Unit 1 Cask Pit is in the northeast corner of the Fuel Handling Building (FHB), which is a safety related, Seismic Category I, reinforced concrete structure. The Cask Pit is adjacent to the SFP, and the two areas share common exterior walls on the north and east sides of the FHB. Spent fuel is to be placed within a new storage rack located in the Cask Pit. Also, the Spent Fuel Handling Crane outside the Fuel Handling Building (FHB) will be upgraded to single-failure proof, resulting in new design tornado and seismic loads on some portions of the exterior walls (mainly the east exterior wall of the FHB is affected). This section summarizes the analysis to demonstrate structural adequacy of the Cask Pit and structural adequacy of the building walls subject to the revised loadings from the fully loaded cask pit[1] and crane. Because the south and west walls of the SFP are unaffected by the addition of the rack in the Cask Pit or the upgraded crane loads, they are not included in this evaluation.

Figure 8.1.1 shows a horizontal section through the Unit 1 FHB above the spent fuel pool slab. The structural evaluation of the affected portion of the Unit 1 FHB is conducted using a finite element model of the north exterior wall (between row lines RAA and RAC) and the east exterior wall (between column lines FH2 and FH4) extending the width of the spent fuel pool. These are the walls affected by addition

---

[1] The analysis considers a fully loaded cask pit rack and rack platform bearing on the cask pit floor (124 tons for Unit 1 and 181.6 tons for Unit 2). These weights bound those of commercially available spent fuel transfer casks such as the Holtec HI-TRAC or HI-STAR.

of the new spent fuel rack and by the increased loading from the upgraded fuel cask crane. The east exterior wall extends above the spent fuel pool operating deck at El. 62'(between column lines FH2 and FH4) to the fuel handling building roof (up to El. 94'), and this portion is also included in the evaluation since additional loads from the overhead crane are applied on this wall (at column line FH3). The column line RAC, at the juncture of the west exterior wall and the north exterior wall, is also a location where revised loadings from the building crane are imposed. These loads impart minimal bending loading to the building exterior north and west walls; the effect of these loads on the SFP walls is negligible.

Results for individual load components are combined using the factored load combinations mandated by the St. Lucie Unit 1 UFSAR [8.1.1], and are based on the "ultimate strength" design method. Bending moment capabilities are checked for appropriate sections on each wall in each direction (vertical and horizontal) for concrete structural integrity. The appropriate relationships between bending moment capacity and axial tension or compression loads are utilized in accordance with design procedures permitted by the governing ACI 318-63 Code [8.1.2]. Shear capability is evaluated along the horizontal base of the affected walls. Since the slab is founded on grade and is 5.5' thick, bending of the slab in the Cask Pit due to the addition of the new spent fuel rack is not a limiting load condition, and calculations for the slab are confined to bearing integrity and to liner stress evaluation. Load Combinations and structural capacity assessments follow requirements of the Unit 1 UFSAR [8.1.1] and the American Concrete Institute Code (ACI 318-63) [8.1.2].

The thermal loading in the reinforced concrete structure is considered in the manner specified in the applicable codes. Surface temperatures on the opposite surfaces of the pool walls are computed to reflect normal operating temperature gradients. Consistent with the standard design practices, the temperature gradient established for the pool walls is intended to subsume local thermal effects such as direct heat deposition into the concrete from the absorption of gamma radiation from the stored spent fuel.

8.1.2 Description of Cask Pit Structure and Exterior Building Walls

The analyzed reinforced concrete structure consists of the north exterior wall up to El. 62' (wall thickness = 6'), the east exterior wall up to El. 62' (wall thickness = 6') and the east wall above El. 62'. The east wall above El. 62' is modeled as a 2' thick wall except at the column line FH3 where the concrete thickness is increased to 3' over a 4' wide region to accommodate additional column reinforcement. The south and west pool walls are not modeled, as these receive no additional direct loading from the added cask pit rack or the revised crane loads. The Cask Pit for Unit 1 is enclosed on the west and south sides by built-up steel walls extending approximately 1/3 of the height of the SFP concrete walls. These walls are not exposed to significant loading as they are fully submerged in the pool and hydrostatic loads will be balanced across the walls. Therefore, these interior cask pit walls are conservatively not included in the finite element analysis. The finite element grid for the analysis of the Unit 1 structure is shown in Figure 8.1.2 with approximate concrete elevations used for the Unit 1 model included on the figure. Note that the Cask Pit floor at El. 17'is lower than the SFP slab at El. 20.5'. The top of the operating floor is at elevation 62'-0". Dimensions in the model are approximated to a convenient whole number to ensure a uniform element size in the analysis. Figure 8.1.3 shows the model with boundary conditions included. Connections to the south and west walls are appropriately modeled to reflect restraint of lateral displacement and rotation about the vertical axis at the respective junctions. The north and east walls are considered as planar plates fixed at the base to the supporting SFP and Cask Pit slab and to the adjacent south and east walls. The upper edge of the north wall at El. 62' is considered as a free edge; no new loadings are imposed on the upper portion of the north wall by the proposed modifications. The boundary of the east wall, above El. 62' is assumed restrained against lateral motion at column line FH4 by the adjacent wall structure.

8.1.3 Analysis Procedures

The reinforced concrete walls are subjected to individual "unit" load cases covering the service conditions (the structural weight of the concrete structure, the hydro-static water pressure and the temperature gradient), seismic induced loads (structural seismic loads, hydro-dynamic water loads, and rack-structure interaction dynamic loads) for OBE and SSE conditions, and tornado loads. The service condition loads are considered as static acting loads; the seismic induced loads for both OBE and SSE seismic events are obtained from the application of bounding-two-directional acceleration spectra (vertical and one horizontal) appropriate to the base of the SFP with input seismic acceleration amplifier defined on the basis of a frequency analysis of the structure. Finally, tornado loadings are derived from applicable information on wind speeds and differential pressures given in the St. Lucie UFSAR [8.1.1]. Results from the seismic and tornado load cases are combined algebraically and then combined with the static load.

The reinforced concrete is considered elastic and isotropic. The elastic characteristics of the concrete are independent of the reinforcement contained in each structural element for the mechanical load cases when un-cracked cross-sections are assumed. This assumption is valid for all load cases with the exception of the thermal loads, where for a more realistic description of the reinforced concrete cross-section behavior the assumption of cracked concrete is used. To simulate the variation and the degree of cracking patterns, the original elastic modulus of the concrete is reduced in accordance with the methodology suggested by ACI 349 [8.1.3]. Table 8.1.1 summarizes the concrete properties employed in the structural evaluation of Unit 1.

8.1.4 Definition of Loads Included in Structural Evaluation

8.1.4.1 Static Loading (D = Dead Loads)

1) Dead weight includes the weight of the north and east walls and crane reactions
2) Dead weight of Cask Pit spent fuel rack fully loaded with fuel and rack platform. (this total dry weight of 124 tons only affects the Cask Pit floor slab concrete bearing evaluation).
3) The hydrostatic water pressure acting on the walls.

8.1.4.2 Seismic (E = OBE; E' = SSE) and Tornado Induced Loads (Wt)

1) Vertical loads transmitted by the spent fuel rack to the slab during a seismic event (only affects the Cask Pit floor slab bearing evaluation).

2) Horizontal hydrodynamic inertia loads due to the contained water mass and sloshing loads in the entire SFP (considered in accordance with [8.1.4]) that arise during a seismic event.
3) Horizontal hydrodynamic pressures between spent fuel rack and Cask Pit walls caused by rack motions during a seismic event.
4) Seismic inertia force of the walls from the wall mass.
5) Seismic or Tornado loads from the fuel building crane acting on the east wall.
6) Tornado loading on the north and east exterior walls from wind force and differential pressure.

8.1.4.3 Thermal Loading

The thermal load case is defined by the interior bulk temperature, the exterior air temperature, and convection heat transfer coefficients at the concrete surfaces; this data suffices to determine a temperature gradient across the wall. The normal operating pool water bulk temperature is 134.5°F. This temperature is the poolside wall temperature up to El. 62'. The east wall, above El. 62' is assumed to be exposed to a maximum inside air temperature of 106.75°F; inclusion of an appropriate free convection heat transfer coefficient results in an inside wall temperature of approximately 84.9°F where exposed to the building air. For the Fuel Handling Building structural evaluation, a suitable outdoor temperature is 41F, which represents the 99% value for West Palm Beach [8.1.5] (meaning that there would only be approximately 22 hours a year (not necessarily consecutive) at or below the temperature of 41F). Assuming still air for the purposes of computing an outside surface film coefficient, the corresponding airside (outside) wall temperature is approximately 62.8°F for the outside wall above the pool and 63.9°F for the outside walls below the pool operating floor.

8.1.4.4 Load Combinations and Acceptance Criteria

No live loads are defined for the areas under consideration. Results from a suite of unit load analyses are used to form appropriate load cases and then combined in accordance with the load combinations specified in Subsection 3.8.1.5 of the St. Lucie Unit 1 UFSAR [8.1.1].

The final load combinations evaluated for structural integrity are:

For "Normal Operation and OBE Condition" the following load combinations are considered:

- Load Combination No. 1 = 1.5* D +1.5* To
- Load Combination No. 2 = 1.25* (D+ To + E)
- Load Combination No. 3 = 1.25* (D+ To - E)

For the "SSE Condition", "Wind (Tornado) Condition", the load combinations are:

- Load Combination No. 4 = 1.05*(D + Ta) + E'
- Load Combination No. 5 = 1.05*(D + Ta) - E'
- Load Combination No. 6 = 1.05*(D + Ta) + Wt
- Load Combination No. 7 = 1.05*(D + Ta) – Wt

where:

D = dead loads;
To = thermal load during normal operation;
Ta = thermal load concurrent with seismic or tornado = To
E = OBE earthquake induced loads combined in accord with the Unit 1 UFSAR;
E' = SSE earthquake induced loads combined in accord with the Unit 1 UFSAR;
Wt = Tornado Loading

Note that seismic loads and tornado loads are considered to be applied in either direction and include both direct effects and loads from the overhead crane. Note also that load combinations with hurricanes (194 mph) wind are not governing as they provide surface pressure loadings that are the same order or less than the seismic pressures and/or the tornado pressures.

Moments and shears computed for each load combination are compared with their respective capacities. Consistent with the intent of the guidance provided in the ACI literature, and recognizing that there is always load re-distribution occurring in a concrete structure designed in accordance with ultimate strength methods, characteristic section widths (horizontal and vertical) are established over which moments and shears are averaged and then compared with the averaged section capacity. Similarly, the transverse shear is averaged over the same section width to define the "section shear".

The ratios of the moment and shear capacities to their respective "section" values are referred to as the safety factor (SF). In computing the safety factor for section moments and shears in the presence of in-plane loads, the appropriate interaction relationships are employed using ACI guidance or specific formulas found in the Code.

8.1.5 Results of Unit 1 Reinforced Concrete Analyses

8.1.5.1 Building East Wall Above Elevation 62'

The structural evaluation of the east wall above 62' is evaluated and the axial forces, the bending moments and the shear forces were computed for all load combinations. The reinforced concrete cross-sectional capacities were determined and used to obtain the safety factors of the structural elements for each load combination considered. Safety factors are defined as the allowable load divided by the computed load and continued acceptability is ensured if the safety factor exceeds 1.0. The calculated minimum safety factors for the sections of the east wall (above El. 62') for each load combination for the wall and for the intermediate vertical column FH3 strengthening the wall against lateral loads are:

East Wall Bending	Cross-section normal to vertical direction	3.86 (load case 6)
	Cross-section normal to horizontal direction	2.90 (load case 2)
East Wall Base Shear	8.31 (load case 6)	

Vertical Column FH3 Bending	4.31 (load case 1)
Vertical Column FH3 Shear	1.21 (load case 6)

8.1.5.2 North and East SFP Walls Below Elevation 62'

The limiting safety factors from all section locations on both walls and for all load combinations are:

East and North Wall Bending	Cross-section normal to vertical direction	2.44 (load case 1)
	Cross-section normal to horizontal direction	1.17 (load case 2)
East and North Wall Base Shear	2.87 (load case 2)	

8.1.6 Pool Liner-Cask Pit Floor Bearing Evaluation

The pool liner is subject to in-plate compressive strains due to differential thermal load arising from the different coefficient of thermal expansion ascribed to the liner and the underlying concrete in the Cask Pit. An in-plane stress is also developed in the liner to resist lateral loads arising from friction between the liner and the Cask Pit platform pedestals during a seismic event. Conservatively using a bounding 150-degree F water for this specific evaluation, the in-plane mean thermal stress in the Cask Pit slab liner, due to differential thermal expansion, is below 5200 psi. The additional in-plane stress to resist lateral forces during a seismic event is below 2300 psi. The liner will not tear or buckle under this bounding combined stress level and no tensile cracking of the concrete slab occurs from mean thermal expansion. The combined in-plane stress (7500 psi) is below the appropriate stress limit for the seismic load condition.

Concrete bearing strength requirements are satisfied by conservatively assuming the factored vertical load from the most highly loaded platform shim plate of the Cask Pit platform supporting the Cask Pit spent fuel rack and assuming that a leak chase is positioned directly below the shim plate. The allowable bearing stress for the confined concrete under the shim plate is $2(1.9\times0.25)f_c'$ in accordance with ACI 318-63 limits, where $f_c'=5200$ psi is the slab concrete compressive strength. It is appropriate to consider the concrete as confined since the leak chase cutout is small and restricted to a 1.5" depth below the surface. The calculated safety factor (allowable strength based on confined concrete/calculated average compressive concrete stress) is:

SF(concrete bearing) = 2.42

8.1.7 Conclusions for Unit 1

Regions affected by loading the Cask Pit with a new rack fully-loaded with fuel assemblies and uprated crane support loads are examined for structural integrity under bending and shearing action. It is determined that adequate safety margins exist when the factored load combinations are checked against the appropriate structural design strengths. To ensure that safety factors in excess of 1.0 were maintained in the presence of a moderate wind outside the plant, the temperature gradients were increased to reflect an outside surface heat transfer coefficient appropriate to a 9 knot steady wind. For the most limiting load combination, the minimum safety factor remained above 1.0. Finally, it is also shown that local loading on the liner does not compromise liner integrity and that concrete bearing strength limits are not exceeded.

8.2 Unit 2 Evaluation

8.2.1 Introduction

The St. Lucie Unit 2 cask pit is located in the NE corner of the Fuel Handling Building (FHB), which is a safety related, Seismic Category I, reinforced concrete structure. Spent fuel is to be placed within the new storage rack located in the cask pit. Also, the Spent Fuel Cask Handling Crane outside the Fuel Handling Building (FHB) will be replaced, resulting in new design tornado and seismic loading loads being applied on some portions of the exterior walls above the SFP and the Cask Pit. This section summarizes the analysis to demonstrate structural adequacy of the Cask Pit and the affected building walls subject to the revised loadings from the new rack and Spent Fuel Cask Handling Crane. Portions of the spent fuel pool beyond the confines of the Cask Pit are unaffected by the addition of the rack in the Cask Pit and are not reconsidered herein. Views of the Unit 2 Cask Pit area are shown in Figures 8.2.1-8.2.3.

The structural evaluation of the Cask Pit is conducted using a finite element model of the Cask Pit; additional support from the spent fuel pool structure beyond the Cask Pit is conservatively neglected. Results for individual load components are combined using the factored load combinations mandated by the St. Lucie Unit 2 UFSAR [8.2.1], and are based on the "ultimate strength" design method. The east exterior wall, above the spent fuel pool operating floor (El. 62'), is also evaluated using a separate finite element model since additional loads from the overhead crane are applied on this wall and transferred to the Cask Pit. Applicable loadings are considered and the wall evaluated in the same manner as described for the Cask Pit. Resultant loads at the base of the east exterior wall (at El. 62') are transferred to the top of the Cask Pit and included in the Cask Pit load combination evaluation.

The column line designating the juncture of the west exterior wall and the north exterior wall is also a location where revised loadings from the building crane are imposed. These loads impart minimal bending loading to the building exterior walls; the effect of these loads on the SFP walls is negligible and no analysis is required.

Moment capabilities are checked on each affected wall in each direction (vertical and horizontal) for concrete structural integrity. Moment capacities are computed including the effects of axial tension or compressive loads at the location considered and are evaluated in accord with the applicable guidance of the Unit 2 design code, ACI 318-71[8.2.2]. Shear capability is evaluated along the base of the affected components. As the slab is founded on grade and is 8.5' thick, bending of the slab in the Cask Pit is not a limiting load condition, and calculations for the slab are limited to concrete bearing integrity and to liner stress evaluation. All structural capacity calculations are made using applicable design formulas following the guidance of the applicable American Concrete Institute code.

8.2.2 Description of Cask Pit Structure and Exterior Building Walls

The Cask Pit reinforced concrete structure is comprised of the four full height perimeter walls of the Cask Pit and is assumed isolated from the remainder of the FHB and the SFP. The structure is conservatively considered as an independent structure. The structural evaluation focuses on the four reinforced concrete walls surrounding the Cask Pit. These four 45'-6" high reinforced concrete walls are supported at the floor elevation of 16'-6" by a massive (8'-6" thick) reinforced concrete mat, which is founded on grade. Figures 8.2.1-8.2.3 show the area of interest and the major structural dimensions of the Unit 2 Cask Pit. The top of the operating floor is at elevation 62'-0". The west wall of the Cask Pit has a 3' wide gate opening extending down to El. 36.25'. The thickness of the walls surrounding the Cask Pit are 6'-0" for the north and east exterior walls, and 5'-6" for the south and west interior walls. The floor liner covering the Cask Pit base mat is 1" thick.

The east wall of the Fuel Handling Building (from column line 2FH2 and extending to the south to column line 2FH5) is separately modeled from El. 62' up to the roof at El. 95' in order to capture the effect of the revised overhead crane loading and other environmental loads acting on the wall and on the Cask Pit structure below El. 62'. The east wall above El. 62' is 2' thick except at the column lines where the concrete thickness is increased to 3' over a 4' wide region to accommodate the additional column rebar reinforcement.

The four walls surrounding the Cask Pit are considered as planar plates connected to form a rectangular box up to the bottom of the fuel transfer gate opening at El. 36.25' and fixed at the base to the supporting mat. The remaining edge at the upper elevation is considered as a free edge (no lateral support is assumed from the adjacent operating floor at El. 62'). Figure 8.2.4 shows the finite element grid utilized for the Cask Pit analysis for Unit 2.

For the Unit 2 analysis, the wall above El. 62' is separately modeled as a plate structure. The individual plate elements making up the model have increased wall thickness at the locations of the concrete columns to properly simulate the increased stiffness at the column lines 2FH3 and 2FH4. The boundary at El. 62' is fixed as most of the wall is connected to the thicker structure below El. 62'. The remaining three sides of the plate structure are considered to support lateral load but not bending moment. Figure 8.2.5 shows the finite grid and boundary conditions utilized for the model of the east wall above El. 62'.

With a spent fuel rack in the Cask Pit, the Cask Pit will always be filled with water so that hydrostatic loads will be balanced across the two interior walls separating the Cask Pit from the main pool. Thermal gradients across these walls will be reduced or eliminated due to inter-pool water mixing through the gate opening. Thus, the addition of a spent fuel rack in the Cask Pit promotes increased safety factors on the south and west interior walls separating the pit from the main pool since there is no pressure differential from the pool water. However, the exterior north and east walls (6' thick) will be subject to dynamic water loads and thermal gradients due to the addition of the rack. Therefore, even though the four walls of the Cask Pit are modeled, the focus of the analyses is to predict the margins in the exterior walls bounding the Cask Pit and in the east wall above the spent fuel pool. The north wall above the spent fuel pool is not modeled as it is unaffected by the new loadings considered herein.

8.2.3 Analysis Procedures

The Cask Pit reinforced concrete walls and wall above El. 62' are modeled separately. These walls are subjected to individual "unit" load cases covering the service conditions (the structural weight of the concrete structure, the hydro-static water pressure and the temperature gradients), seismic induced loads (structural seismic loads, hydro-dynamic water loads, and rack-structure interaction dynamic loads) for

OBE and SSE conditions, and tornado loads. The service condition loads are considered as static acting loads; the seismic induced loads for both OBE and SSE seismic events are obtained from the simultaneous application of the three-directional acceleration spectra appropriate to elevation 16'-6" with input seismic acceleration amplifier defined on the basis of a frequency analysis of the structure. Finally, tornado loadings are derived from applicable information on wind speeds and differential pressures given in the UFSAR. As required by the Unit 2 UFSAR [8.2.1], results from seismic or tornado loading in each direction are first combined by the SRSS method and then added to static load results in applicable load combinations.

The reinforced concrete is considered elastic and isotropic. The elastic characteristics of the concrete are independent of the reinforcement contained in each structural element for the mechanical load cases when un-cracked cross-sections are assumed. This assumption is valid for all load cases with the exception of the thermal loads, where for a more realistic description of the reinforced concrete cross-section behavior the assumption of cracked concrete is used. To simulate the variation and the degree of cracking patterns, the original elastic modulus of the concrete is reduced in accordance with the methodology suggested by ACI 349 [8.1.3]. Table 8.2.1 summarizes the concrete properties employed in the structural evaluation of Unit 2.

8.2.4 Definition of Loads

Cask Pit direct loading considered the following discrete components:

8.2.4.1 Static Loading (D = Dead Loads)

1) Dead weight of Cask Pit structure includes the weight of the four walls constituting the Cask Pit and the weight of the north and east walls above the Cask Pit.
2) Dead weight of Cask Pit spent fuel rack fully loaded with fuel and rack platform (this total dry weight of 181.6 tons only affects bearing stress under the Cask Pit liner).
3) The hydrostatic water pressure.

8.2.4.2 Seismic (E = OBE; E' = SSE) and Tornado Induced Loads (Wt)

1) Vertical loads transmitted by the spent fuel rack to the slab during a seismic event (only affects the Cask Pit floor slab bearing).
2) Hydrodynamic inertia loads due to the contained water mass and sloshing loads (considered in accordance with [8.1.4]) that arise during a seismic event.
3) Hydrodynamic pressures between spent fuel rack and Cask Pit walls caused by rack motion in the Cask Pit during a seismic event.
4) Seismic inertia force of the walls from the wall mass.
5) Seismic or Tornado loads from the fuel building crane acting on the east walls.
6) Tornado loading on the north and east exterior wall of the Cask Pit up to El. 62'.
7) Seismic or tornado loads transferred from the east exterior wall above the Cask Pit

8.2.4.3 Thermal Loading

With the addition of a rack in the Cask Pit, the Cask Pit concrete walls are subject to a thermal gradient plus a mean temperature rise above the assembly temperature. The gradient through the exterior north and east walls is the difference between the bulk temperature of the water in the Cask Pit and the exterior air temperature. The normal and accident operating condition (in the presence of a seismic or tornado event) conservatively considers the bulk Cask Pit temperature T_o to be 150°F (which exceeds the computed bulk pool temperature). The ambient temperature outside of the structure is considered to be 41°F (per discussion in Sub-section 8.1.4.3). The thermal gradient across the interior walls is assumed to be 10°F since both sides of the interior walls are subject to essentially the same bulk temperature corresponding to the water in the pit and the water in the main spent fuel pool. These temperatures and the computed thermal gradients are chosen to represent bounding conditions or conservative extremes.

Loadings applied to the separately modeled exterior east wall (from El. 62' to El. 95') above the Cask Pit are:

8.2.4.4 Static Loading (D = Dead Loads)

1) Dead weight of wall

8.2.4.5 Seismic (E or E') or Tornado Induced Loads (Wt)

1) Vertical and Lateral seismic inertia loads acting on the wall
2) Tornado pressure load
3) Seismic and tornado loading from the overhead crane transferred at the crane support.

8.2.4.6 Thermal Loading Above Elevation 62'

The east wall, above El. 62' is exposed to a maximum inside air temperature of 108°F; the inside wall temperature is approximately 78°F. This is combined with the outside air temperature of 41°F and a conservatively computed surface heat transfer coefficient to establish a lower bound outside wall temperature of 45°F.

8.2.4.7 Load Combinations

Results from a suite of unit load analyses are used to form appropriate load cases and then combined in accordance with the load combinations specified in Subsection 3.8.4.3.2.1 of the St. Lucie Unit 2 UFSAR [8.1.2].

The final load combinations evaluated for structural integrity are:

For "Normal and Severe Environmental Conditions" the following load combinations are:

- Load Combination No. 1 = 1.4* D +1.3* To
- Load Combination No. 2 = 1.4* D+ 1.3* To + 1.9*E

- Load Combination No. 3 = 1.4* D+ 1.3* To - 1.9*E
- Load Combination No. 4 = 1.2*D + 1.9*E
- Load Combination No. 5 = 1.2*D - 1.9*E

For "Extreme Environmental and Abnormal/Severe Load Conditions" the load combinations are:

- Load Combination No. 6 = D + Ta + E'
- Load Combination No. 7 = D + Ta - E'
- Load Combination No. 8 = D + Ta + Wt
- Load Combination No. 9 = D + Ta – Wt
- Load Combination No. 10 = D + Ta + 1.25*E
- Load Combination No. 11 = D + Ta – 1.25*E

where:

D = dead loads;
To = thermal load during normal operation;
Ta = thermal load concurrent with seismic or tornado event = To;
E = OBE earthquake induced loads;
E' = SSE earthquake induced loads.
Wt = Tornado Loading
L = Live loads; no live loads are considered applicable for this analysis

Note that seismic loads and tornado loads are considered to be applied in either direction and include both direct effects and loads from the overhead crane and wall above the Cask Pit that are transferred into the Cask Pit at El. 62'. Note also that load combinations with hurricanes (194 mph) wind are not governing in any factored load combination as they provide surface pressure loadings that are the same order or less than the seismic pressures and/or the tornado pressures.

The same load combinations are applied to the separate east wall model (above El. 62') except that thermal gradient loading is based on the maximum interior air temperature above the spent fuel pool, and no loads are imposed from fuel racks.

The ACI Code sets limits for representative section widths of a wall. The determination of the appropriate section width follows the same rational discussed in Subsection 8.1.4.4 for the Unit 1 analysis. Safety factors are defined as the allowable load divided by the computed load and continued acceptability is ensured if the safety factor exceeds 1.0 for the characteristic width associated with the wall section. Safety factors for horizontal sections in the cask pit walls and the upper east wall are computed based on a section width of 12', which is the span between opposite cask pit walls. Safety factors for the column (in the east wall above El. 62') are conservatively based on averaging over the 4' column width. Vertical sections of the cask pit walls are evaluated at limiting sections in the lower 20' width (below the gate in the west wall).

8.2.5 Results of Unit 2 Reinforced Concrete Analyses

8.2.5.1 Building Wall Above Elevation 62'

The structural evaluation of the east wall above 62' was performed and the axial forces, the bending moments and the shear forces were computed for all load combinations. The reinforced concrete cross-sectional capacities, including the effects of axial load at the particular location were determined and used to obtain the safety factors of the appropriate wall sections for each load combination considered. The calculated minimum safety factors for the limiting sections of the east wall (above El. 62') for all evaluated load combinations for the wall and for the intermediate vertical column 2FH3 strengthening the wall against lateral loads are:

East Wall Bending	Cross-section normal to vertical direction	1.30 (Load Combination 2)
	Cross-section normal to horizontal direction	1.66 (Load Combination 2)
East Wall Base Shear	2.76 (Load Combination 9)	

Vertical Column Bending	1.42 (Load Combination 8)
Vertical Column Shear	1.16 (Load Combination 8)

8.2.5.2 Cask Pit

The structural evaluation focused on the four reinforced concrete walls pertaining to the Cask Pit. The axial forces, bending moments and shear forces were computed for each load combination and included the effects of the factored load combinations from the portion of the east wall above El. 62'. The reinforced concrete cross-sectional capacities including axial force effects were determined and used to obtain the safety factors for the limiting section widths in each wall of the pit. The calculated minimum safety factors for all load combinations considered are:

North Wall Bending	Cross-section normal to vertical direction	2.12 (Load Combination 2)
	Cross-section normal to horizontal direction	2.0 (Load Combination 2)
North Wall Averaged Shear		3.05 (Load Combination 4)
East Wall Bending	Cross-section normal to vertical direction	1.76 (Load Combination 6)
	Cross-section normal to horizontal direction	1.68 (Load Combination 2)
East Wall Averaged Shear		4.7 (Load Combination 2)
South Wall Bending	Cross-section normal to vertical direction	2.33 (Load Combination 2)
	Cross-section normal to horizontal direction	3.09 (Load Combination 2)
South Wall Averaged Shear		2.4 (Load Combination 1)
West Wall Bending	Cross-section normal to vertical direction	1.44 (Load Combination 2)
	Cross-section normal to horizontal direction	1.4 (Load Combination 2)
West Wall Averaged Shear		2.13 (Load Combination 2)

8.2.6 Pool Liner-Cask Pit Floor Bearing Evaluation

The pool liner is subject to in-plate compressive strains due to differential thermal load arising from the different coefficient of thermal expansion ascribed to the liner and the underlying concrete in the Cask Pit. An in-plane stress is also developed in the liner to resist lateral loads arising from friction between the liner and the Cask Pit platform shim plates during a seismic event. Assuming a conservative 150-degree F water temperature in the Cask Pit, the in-plane mean thermal stress in the liner due to the differential thermal expansion is below 6000 psi. The additional in-plane stress to resist lateral forces during a seismic event is below 3250 psi. The liner will not tear or buckle under this stress level. The combined in-plane stress level (9250 psi) is below the appropriate stress limit for the seismic load condition.

Bearing strength requirements are satisfied by conservatively assuming the factored vertical load from the most highly loaded shim plate of the Cask Pit platform supporting the Cask Pit spent fuel rack and assuming that a leak chase is directly below the shim plate. The allowable bearing stress for the confined concrete under the pedestal is 2(0.85)(0.7)fc, where fc=5000 psi is the slab concrete compressive strength per the UFSAR [8.2.1]. The small depth of the leak chase (1.5") does not alter the assumption of confinement of the concrete under bearing action. The computed safety factor (allowable strength/calculated average compressive concrete stress) is:

SF(concrete bearing)=1.88

8.2.7 Conclusions for Unit 2

Regions affected by loading the Cask Pit with a high-density rack loaded with fuel assemblies and additional crane support loads are examined for structural integrity under bending and shearing action. It is determined that adequate safety margins exist when the factored load combinations are checked against the appropriate structural design strengths. It is also shown that local loading on the liner does not compromise liner integrity and that concrete bearing strength limits are not exceeded.

8.3 References

[8.1.1] St. Lucie Nuclear Plant, UFSAR (Unit 1).

[8.1.2] ACI 318-63, Building Code Requirements for Reinforced Concrete, American Concrete Institute, Detroit, Michigan.

[8.1.3] ACI 349-85, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute, Detroit, Michigan.

[8.1.4] "Nuclear Reactors and Earthquakes, U.S. Department of Commerce, National Bureau of Standards, National Technical Information Service, Springfield, Virginia (TID 7024).

[8.1.5] ASHREA Handbook, Fundamentals, Chap. 24, Table 1, 1989.

[8.2.1] St. Lucie Nuclear Plant, UFSAR (Unit 2).

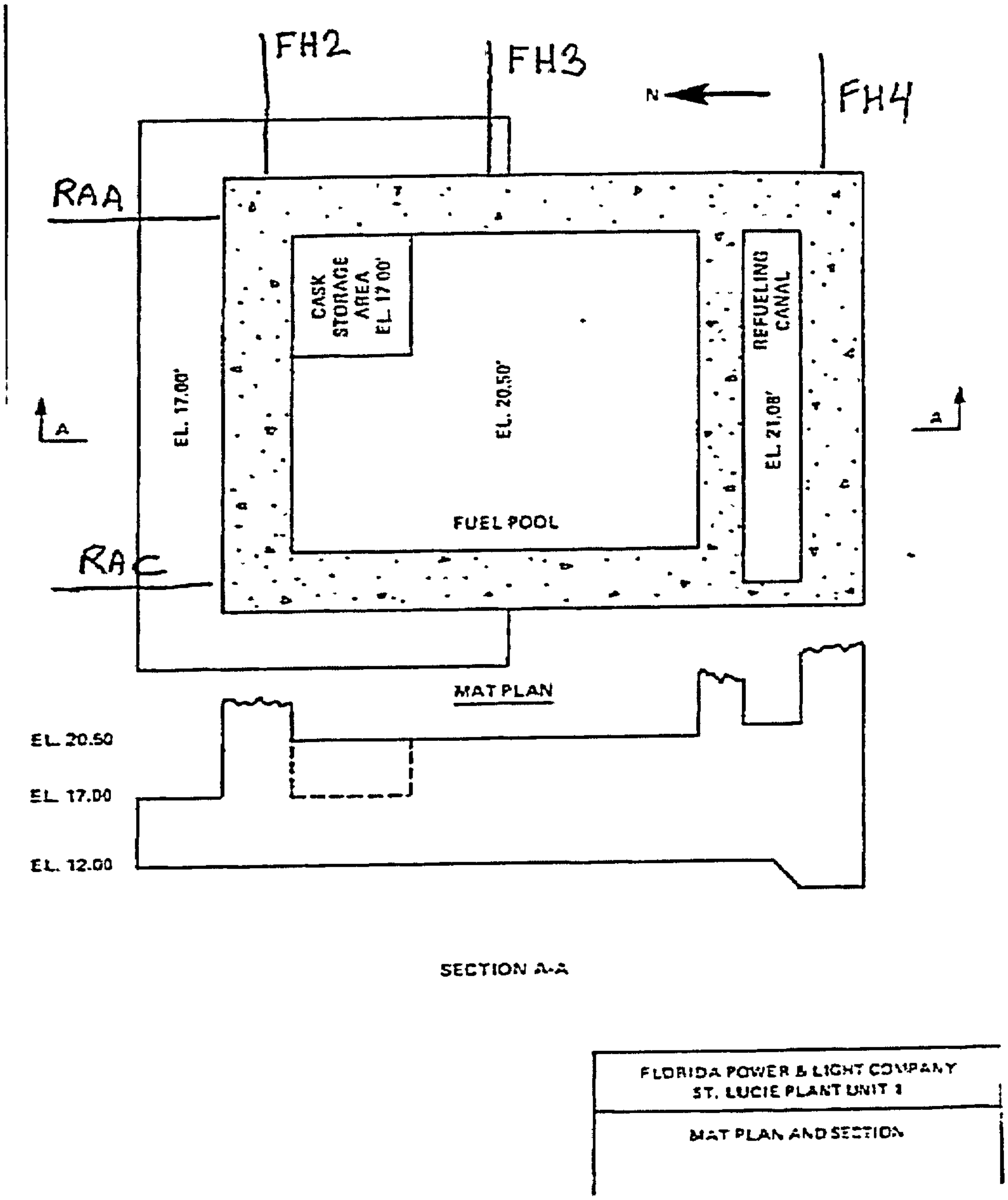
[8.2.2] ACI 318-71, Building Code Requirements for Reinforced Concrete, American Concrete Institute, Detroit, Michigan.

Table 8.1.1 Unit 1 Concrete and Rebar Properties

Parameter	Value
Concrete Compressive Strength (psi)	5.200E+03
Un-Cracked Concrete Elastic Modulus (psi)	4.110E+06
Concrete Poisson's Ratio	0.16
Concrete Weight Density (lb/ft^3)	150.0
Concrete Thermal Expansion Coefficient (in./(in.-degree F))	5.500E-06
Reinforcement Yield Strength (psi)	4.000E+04
Reinforcement Elastic Modulus (psi)	2.900E+07

Table No. 8.2.1 Unit 2 Concrete and Rebar Properties

Parameter	Value
Concrete Compressive Strength (psi)	4.000E+03
Un-Cracked Concrete Elastic Modulus (psi)	3.605E+06
Concrete Poisson's Ratio	0.16
Concrete Weight Density (lb/ft^3)	150.0
Concrete Thermal Expansion Coefficient (in./(in.-degree F))	5.500E-06
Reinforcement Yield Strength (psi)	6.000E+04
Reinforcement Elastic Modulus (psi)	2.900E+07



Note that Elevations refer to concrete. Liner plate floor elevations are typically one foot higher due to grout and liner plate thickness.

Figure 8.1.1 Plan View of Unit 1 FHB

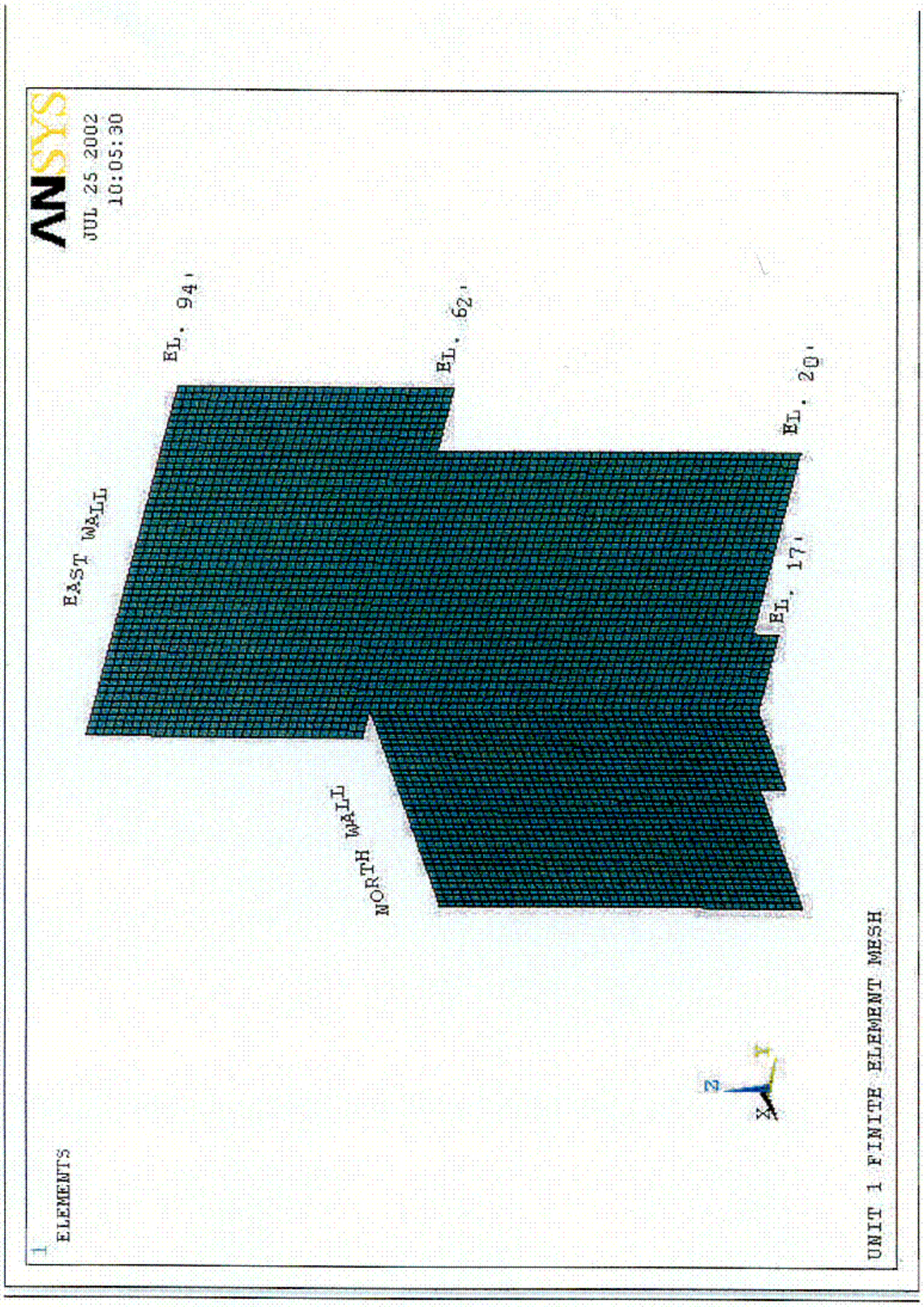


Figure 8.1.2- Unit 1 Finite Element Mesh

C05

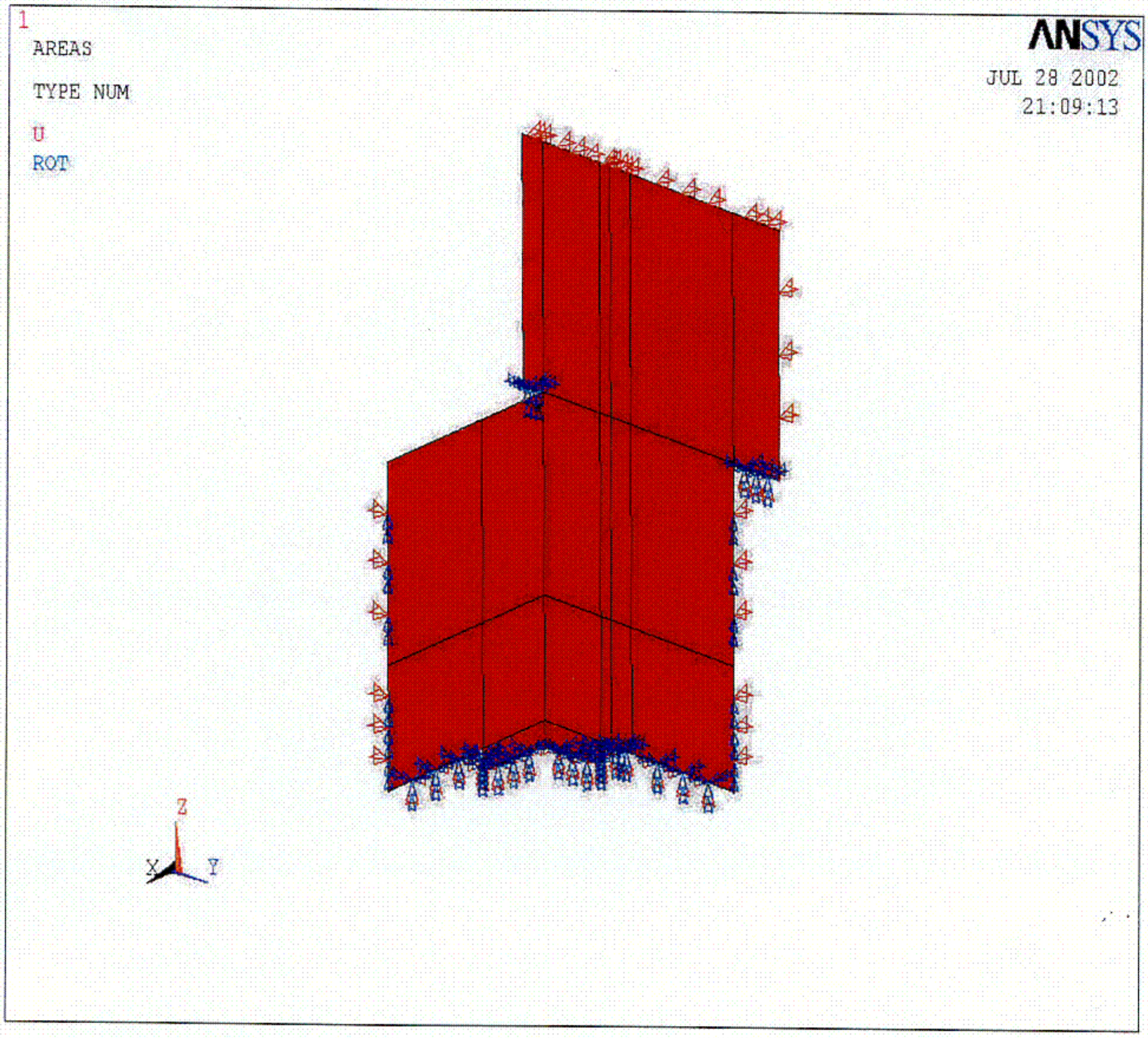
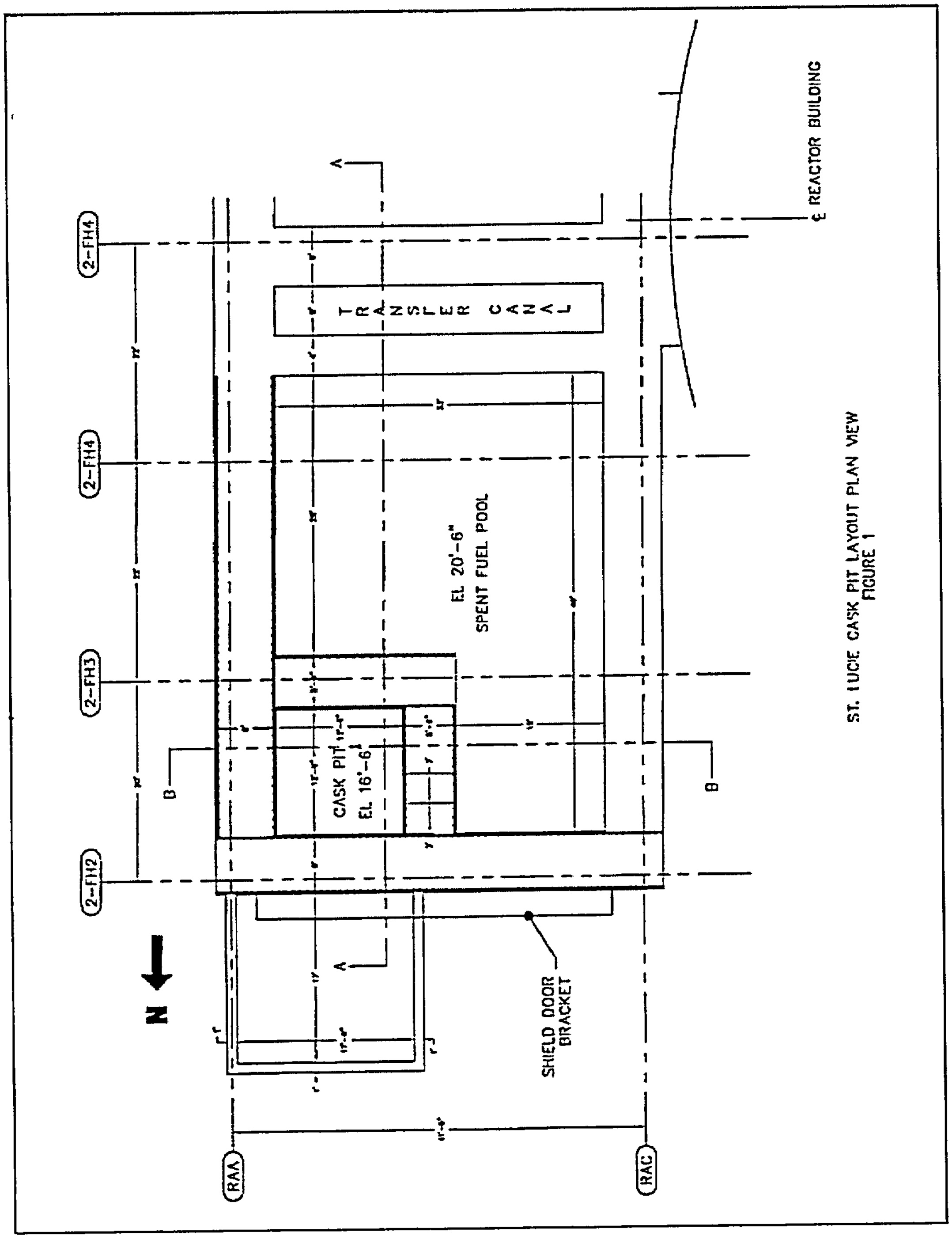


Figure 8.1.3 Unit 1 Finite Element Boundary Conditions

C06



Note that Elevations refer to concrete. Liner plate floor elevations are typically one foot higher due to grout and liner plate thickness.

Figure 8.2.1 Plan View of Unit 2 FHB

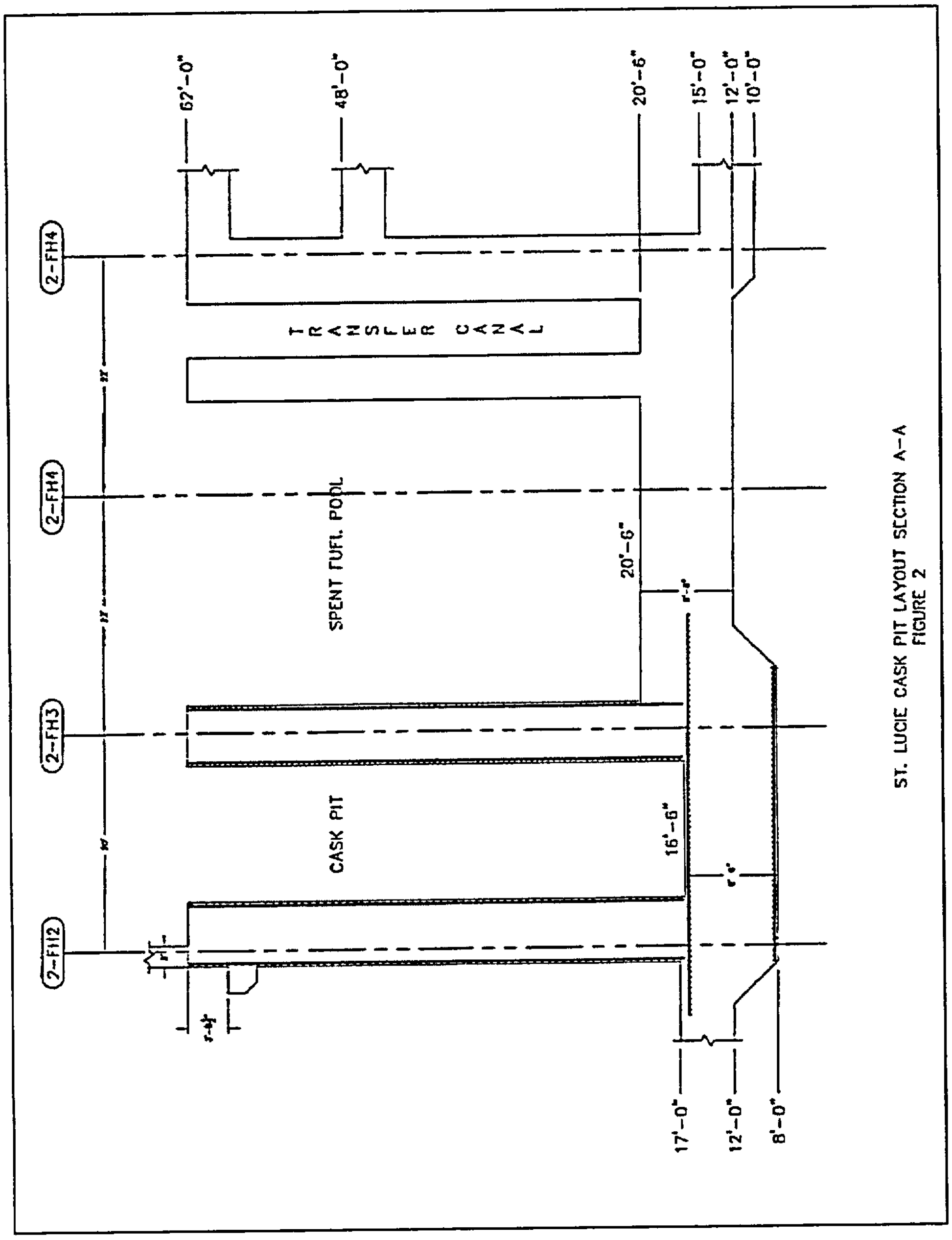


Figure 8.2.2 View Through Section A-A

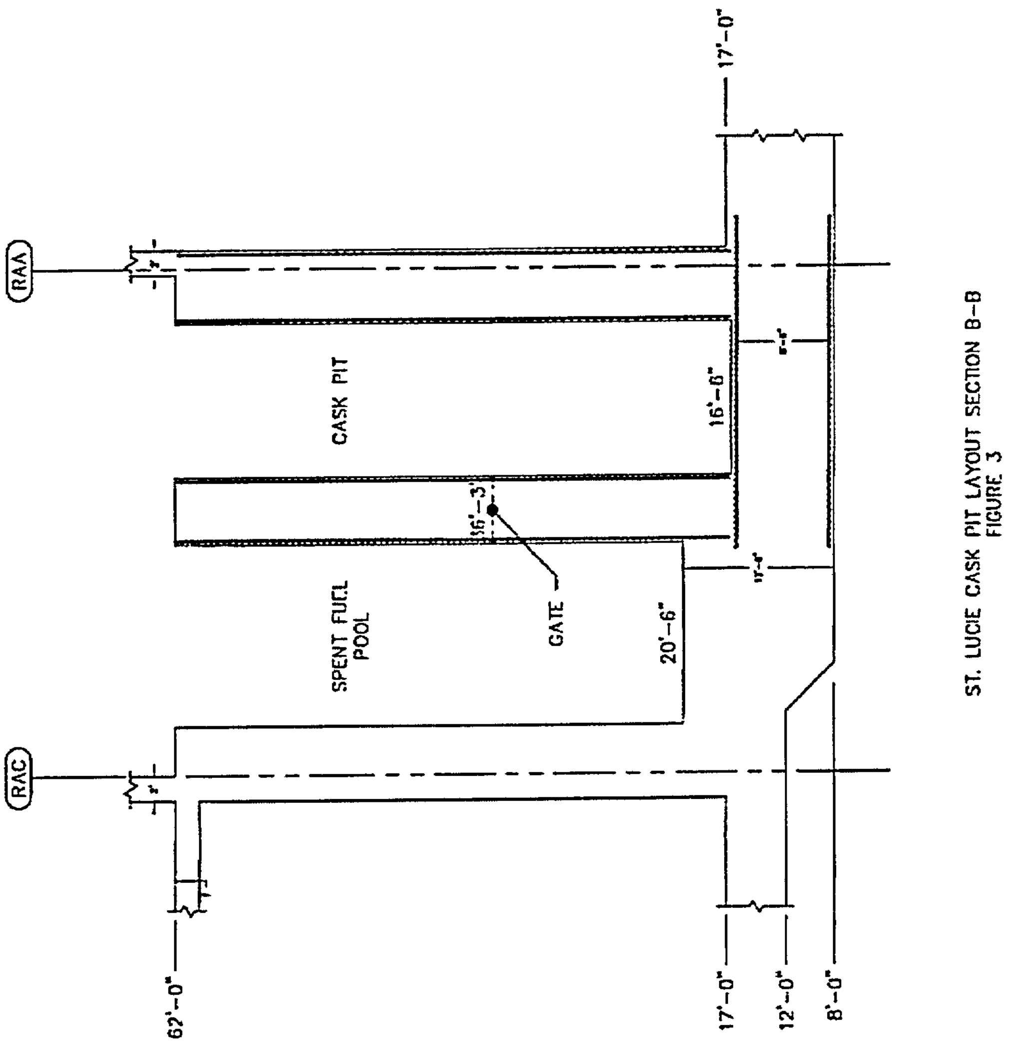


Figure 8.2.3 View Through Section B-B

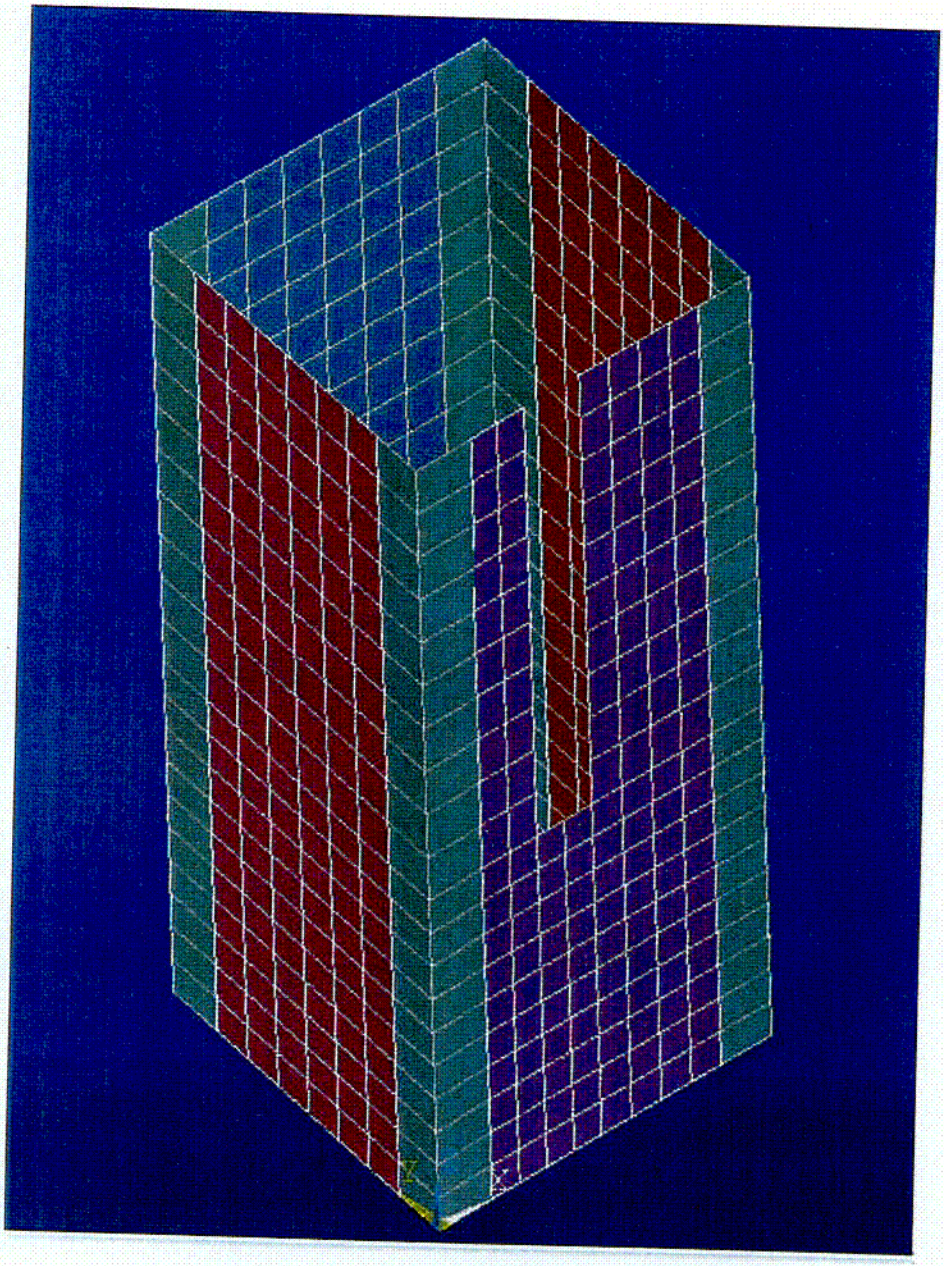


Figure 8.2.4 Unit 2 Cask Pit Finite Element Grid

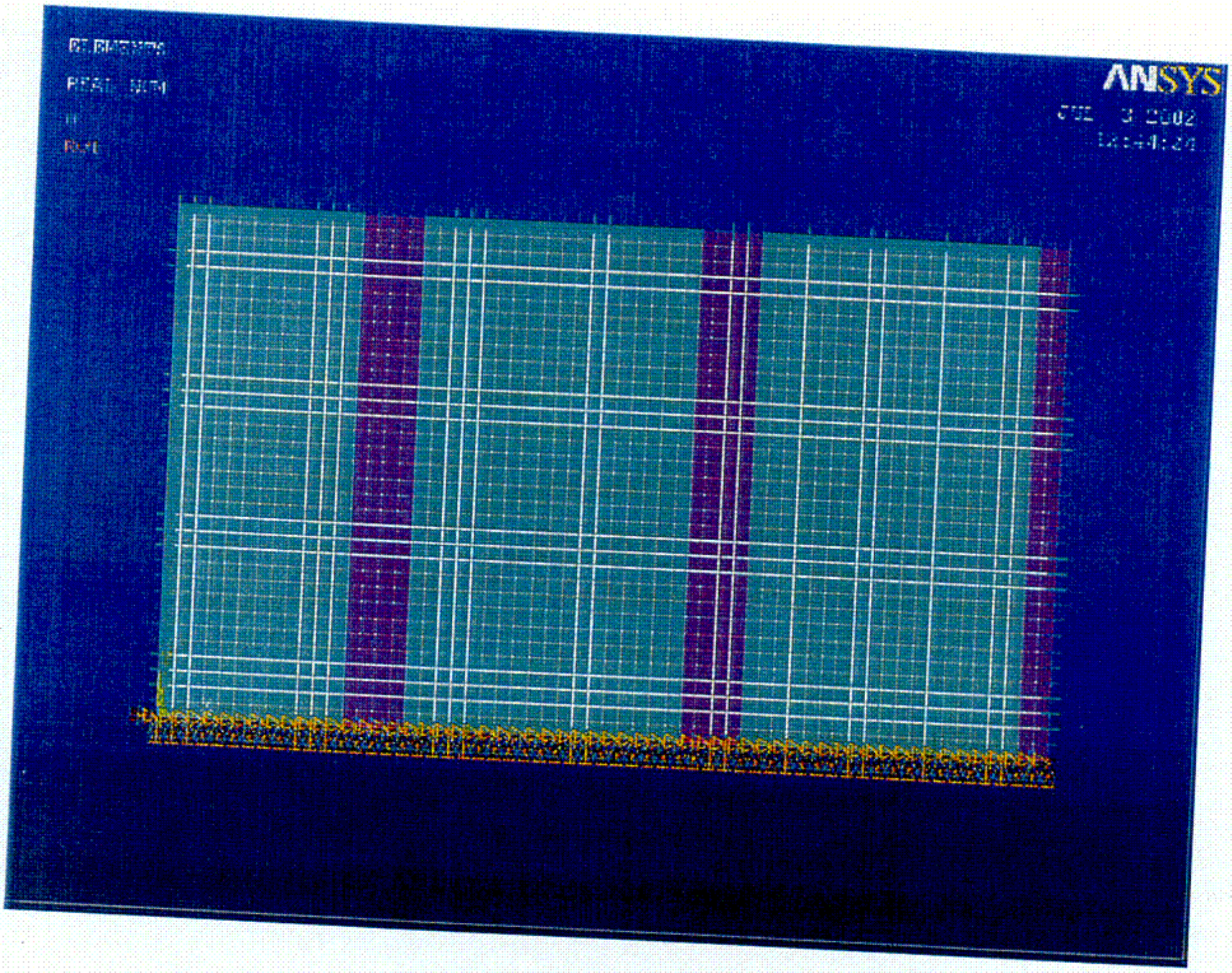


Figure 8.2.5 East Wall Above El. 62' (Between Column Lines 2FH2 and 2FH5) Finite Element Grid and Boundary Conditions

C08

9.0 RADIOLOGICAL EVALUATION

9.1 Fuel Handling Accident

The installation of a fuel storage rack (module) in the cask pit of St. Lucie Unit 1 or St. Lucie Unit 2 will not result in a change in the previously-analyzed fuel handling accident or its consequences. The new rack installed in each unit will simply provide increased fuel storage capacity for that unit.

9.2 Solid Radwaste

The necessity for resin replacement is determined primarily by the requirement for water clarity, and the resin is normally changed about once a year. No significant increase in the volume of solid radioactive waste from either unit is expected to result from the expanded fuel storage capacities in the units.

9.3 Gaseous Releases

Gaseous releases from the fuel storage area in each unit are combined with other exhausts from that unit. Normally, the contributions from the fuel storage areas are negligible compared to the other releases and no significant increases are expected in either unit as a result of the expanded storage capacity.

9.4 Personnel Exposures

Personnel exposures in the vicinity of the fuel storage facility at each unit result principally from radionuclides in the pool water and from fuel in transit. The radionuclides in the water derive generally from: 1) the mixing of primary system water with the pool water and 2) the spalling of crud deposits from the spent fuel assemblies as they are moved in the storage pool during refueling operations. Although the overall capacity of each pool is being increased, the movement of fuel during refueling is independent of storage capacity. Similarly, the dose rate from fuel in transit does not increase with increased storage capacity. However, the use of the cask pit rack will require fuel transits in the vicinity of the northeast corner of each spent fuel pool, similar to transit paths that would be used during cask loading. These transit paths will not increase the dose rate beyond that already experienced at either the north or east walls during placement of fuel into racks adjacent to those walls. Similarly, the dose rate from fuel stored in the cask pit racks is expected to be comparable to the dose rate from fuel stored in the spent fuel pool racks adjacent to the north and east walls, because the exterior wall thickness surrounding the cask pit is the same as the wall thickness surrounding the pool.

Operating experience has shown that there have been negligible concentrations of airborne radioactivity, and no increases are expected as a result of the expanded storage capacities. However, area monitors for airborne radioactivity are available in the immediate vicinity of the fuel storage facility in each unit.

No increase in radiation exposure to operating personnel of either unit is expected; therefore, neither the current health physics programs nor the area monitoring systems need to be modified.

9.5 Anticipated Exposure During Rack Installation

All operations involved in installing a cask pit rack in Unit 1 and a cask pit rack in Unit 2 will utilize detailed procedures prepared with full consideration of ALARA principles. Similar (but more complex) operations have been performed in a number of facilities in the past, and there is every reason to believe that the relatively-simple task of installing these single rack modules in locations not previously occupied by other rack modules can be accomplished with minimum radiation exposure to personnel. Diving operations are not expected to be required based on a physical survey of the existing Cask Pit configuration.

The occupational exposure for installing the rack in Unit 1 and the rack in Unit 2 is estimated to be a total of approximately 0.3 person-rem. This estimated dose is based on the following.

OPERATION	NUMBER OF PERSONNEL	HOURS EACH	ESTIMATED PERSON-REM EXPOSURE
Clean and Vacuum Pits	4	8	0.1
Install New Racks	4	16	0.2

For the cleaning and vacuuming operations, a conservative dose rate of approximately 2.5 mrem/hr is estimated, while the rack installation operations are based on the radiation-zone maximum dose rate of 2.5 mrem/hr. The cleaning and vacuuming exposure is rounded down, while the installation exposure is rounded up in the preceding table.

The existing radiation protection programs at Units 1 and 2 are adequate for the rack-installation operations. Radiation Work Permit(s) will govern activities, and personnel monitoring equipment will be issued to each individual. As a minimum, this will include thermoluminescent dosimeters and pocket dosimeters. Work, personnel traffic, and the movement of equipment will be monitored and controlled to assure that exposures are maintained ALARA.

9.6 Rack Removal and Storage during Cask Handling Operations

The cask pit racks must be unloaded and removed from their respective cask pit in preparation for future dry cask storage loading operations. Based on projected storage improvements for St. Lucie (i.e., Unit 2 reracking) and DOE performance by 2015, FPL expects to perform this rack removal process only once or twice in the next 20 years. Thereafter, the storage rack may be disposed, stored for temporary use, or permanently stored until decommissioning.

Based on Holtec experience with rack module removal and decontamination projects, the removal and storage process will not create significant radiological waste or personnel exposure. The removal and decontamination process should not result in more than 200 mrem based on a pool surface dose rate of 2.5 mrem/hr, an estimated rack contact surface dose rate of 20 mrem/hr and a job estimate of 80 manhours. Typically, the surfaces of a rack module can be decontaminated to a level that would allow free release; however, the inaccessible areas of the rack may prohibit storage as such. Accordingly, appropriate radiologically-controlled storage on-site will be provided as required.

Rack contamination and the risk of environmental release during removal and storage will be minimized by the following practices:

1. Prior to cask pit rack platform installation, the cask pit will be vacuumed and visually inspected for debris.
2. During rack installation, the cask pit rack will be wetted with deionized water.
3. During storage operations, only select non-failed fuel will be stored in the racks
4. Prior to removal from the cask pit, the racks will be visually inspected to ensure fuel and all debris are removed.
5. During rack removal (over the cask pit), the racks will be rinsed with deionized water, leaving most loose contamination in the spent fuel pool
6. During rack removal (over the cask pit), the racks will be drained of pool water and rinsed with water through holes in each cell
7. During rack removal (over the cask pit), after the racks are drained and drip-dried, the external surfaces will be wiped down
8. Prior to removal from the Fuel Handling Building, a "diaper" and plastic liner will be attached to absorb any subsequent liquid
9. After removal from the Fuel Handling Building, the racks will be placed in a [good integrity container] capable of protecting the rack from the elements and containing any reasonably-postulated leakage.
10. The storage container will be radiologically-controlled and stored in a secure building or otherwise secured within the protected area, similar to practices used for high-integrity containers (HICs) and other temporary radiological storage containers.
12. During storage, the storage facility will be routinely monitored for leakage.
13. FPL ALARA practices will be applied to every step of removal and storage.

Rack contamination and activation will be minimized by a fuel-loading process, which is careful to select non-failed spent fuel with good inspection records and operating history. Furthermore, the Unit 1 cask pit rack contamination will be minimized because that rack will be dedicated to temporary storage of fresh, unburned fuel and once-burned fuel.

10.0 INSTALLATION

10.1 Introduction

The installation phase of the St. Lucie Cask Pit Area fuel storage rack project will be executed by Holtec International's Field Services Division. Holtec, serving as the installer, is responsible for performance of specialized services, such as underwater diving and welding operations, as necessary. All installation work at St. Lucie is performed in compliance with NUREG-0612 (refer to Section 3.0), Holtec Quality Assurance Procedure 19.2, St. Lucie project specific procedures, and applicable St. Lucie procedures.

Crane and fuel bridge operators are trained in the operation of overhead cranes per the requirements of ANSI/ASME B30.2, and the plant's specific training program. Consistent with the installer's past practices, a videotape aided training session is presented to the installation team, all of whom are required to successfully complete a written examination prior to the commencement of work. Fuel handling bridge operations are performed by St. Lucie personnel, who are trained in accordance with St. Lucie procedures.

A rack lifting device is required. This lifting device is designed to engage and disengage on lift points at the bottom of the racks. The lifting device complies with the provisions of ANSI N14.6-1978 and NUREG-0612, including compliance with the design stress criteria, load testing at a multiplier of maximum working load, and nondestructive examination of critical welds.

A surveillance and inspection program shall be maintained as part of the installation of the racks. A set of inspection points, which have been proven to eliminate any incidence of rework or erroneous installation in previous rack projects, is implemented by the installer.

Underwater diving operations are not required for this project.

Holtec International developed procedures, to be used in conjunction with the St. Lucie procedures, which cover the scope of activities for the rack installation effort. Similar procedures have been utilized and successfully implemented by Holtec on previous rack installation projects. These procedures are written to include ALARA practices and provide requirements to assure equipment, personnel, and plant safety. These procedures are reviewed and approved in accordance with St. Lucie administrative procedures prior to use on site. The following is a list of the Holtec procedures, used in addition to the St. Lucie procedures to implement the installation phase of the project.

A. Installation/Handling Procedure:

This procedure provides direction for the handling/installation of the new storage rack modules in the Cask Pit. This procedure delineates the steps necessary to receive the new maximum density racks on site, the proper method for unloading and uprighting the racks, staging the racks prior to installation, and installation of the racks. The procedure provides for the installation of cask support platforms, adjustment of the rack pedestals and verification of the as-built field configuration to ensure compliance with design documents.

B. Receipt Inspection Procedure:

This procedure delineates the steps necessary to perform a thorough receipt inspection of a new rack module after its arrival on site. The receipt inspection includes dimensional measurements, cleanliness inspection, visual weld examination, and verticality measurements.

C. Cleaning Procedure:

This procedure provides for the cleaning of a new rack module, if required. The modules are to meet the requirements of ANSI N45.2.1, Level B, prior to placement in the Cask Pit. Methods and limitations on cleaning materials to be utilized are provided.

D. Pre- and Post-Installation Drag Test Procedure:

These two procedures stipulate the requirements for performing a functional test on a new rack module prior to and following installation. The procedures provide direction for inserting and withdrawing an insertion gage into designated cell locations, and establishes an acceptance criteria in terms of maximum drag force.

E. ALARA Procedure:

Consistent with Holtec International's ALARA Program, this procedure provides guidance to minimize the total man-rem received during the rack installation project, by accounting for time, distance, and shielding. This procedure will be used in conjunction with the St. Lucie ALARA program.

F. Liner Inspection Procedure:

In the event that a visual inspection of any submerged portion of the pool liner is deemed necessary, this procedure describes the method to perform such an inspection using an underwater camera and describes the requirements for documenting any observations.

G. Leak Detection Procedure:

This procedure describes the method to test the pool liner for potential leakage using a vacuum box. This procedure may be applied to any suspect area of the liner.

H. Liner Repair and Underwater Welding Procedure:

In the event of a positive leak test result, underwater welding procedures may be implemented which provide for a weld repair, or placement of a stainless steel repair patch, over the area in question. The procedures contain appropriate qualification records documenting relevant variables, parameters, and limiting conditions. The weld procedure is qualified in accordance with ASME Section XI , or may be qualified to an alternate code accepted by Florida Power & Light and Holtec International.

10.2 Rack Arrangement

The rack installation process will not require any fuel shuffling. The final rack arrangement allows for an 11 by 13 cell Region I style rack installed in the Unit 1 Cask Pit Area and a 15 by 15 cell region II style storage rack installed in the Unit 2 Cask Pit Area. Schematic plan views depicting Cask Pit Area storage rack configurations are shown in Figures 1.1.1 and 1.1.2.

10.3 Rack Interferences

A survey was conducted to identify any objects which would interfere with rack installation or prevent usage of any storage locations. This section discusses existing pool items that would physically interfere with placing the racks into the SFP, present interferences subsequent to reracking, or were considered during the design of the racks. There are no permanently installed components interfering with the installation of the racks in the Cask Pit Areas. Existing miscellaneous equipment that is temporarily stored within these areas will be removed followed by vacuuming prior to installation of the racks.

10.4 SFP Cooling

The pool cooling system shall be operated in order to maintain the pool water temperature at an acceptable level. It is anticipated that activities, such as rack platform placement, may require the temporary shutdown of the Spent Fuel Pool cooling system.

Prior to any shutdown of the Spent Fuel Pool cooling system, the estimated time after shutdown to increase the pool bulk coolant temperature to a selected value of ≤120 °F will be determined. A temperature of ≤ 120 °F is chosen with enough margin such that cooling may be restored to ensure the pool bulk temperature will not exceed 150 °F.

10.5 Installation of New Racks

Installation of the new high density racks, supplied by Holtec International, involves the following activities. The racks are delivered in the horizontal position. A new rack module is removed from the shipping trailer using a suitably rated crane, while maintaining the horizontal configuration. The rack is placed on the up-ender and secured. Using two independent overhead hooks, or a single overhead hook and a spreader beam, the module is up-righted into a vertical position.

The new rack lifting device is engaged in the lift points at the bottom of the rack. The rack is then transported to a pre-leveled surface where, after leveling the rack, the appropriate quality control receipt inspection is performed. (See 10.1B & D.)

The Cask Pit Area floor is inspected and any debris, which may inhibit the installation of platforms, is removed. New rack platforms are lowered by the Cask Handling Crane into position on the floor and leveled before the rack module is lowered into the Cask Pit Area. The new rack module is lifted with the Cask Handling Crane and transported along the pre-established safe load path. The rack module is carefully lowered into the Cask Pit Area.

Elevation readings are taken to confirm that the module is level. In addition, rack-to-wall off-set distances are also measured. Adjustments are made as necessary to ensure compliance with design documents. The lifting device is then disengaged and removed from the Cask Pit Area under Health Physics direction. As directed by procedure, post-installation free path verification is performed using an inspection gage.

10.6 Safety, Health Physics, and ALARA Methods

10.6.1 Safety

During the installation phase of the Cask Pit Area fuel storage rack project, personnel safety is of paramount importance. All work shall be carried out in compliance with applicable approved procedures.

10.6.2 Health Physics

Health Physics is carried out per the requirements of the St. Lucie Radiation Protection Program.

10.6.3 ALARA

The key factors in maintaining project dose As Low As Reasonably Achievable (ALARA) are time, distance, and shielding. These factors are addressed by utilizing many mechanisms with respect to project planning and execution.

Time

Each member of the project team is trained and provided appropriate education and understanding of critical evolutions. Additionally, daily pre-job briefings are employed to acquaint each team member with the scope of work to be performed and the proper means of executing such tasks. Such pre-planning devices reduce worker time within the radiological controlled area and, therefore, project dose.

Distance

Remote tooling such as lift fixtures, pneumatic grippers, a support leveling device and a lift rod disengagement device have been developed to execute numerous activities from the SFP surface, where dose rates are relatively low.

Shielding

During the course of the Cask Pit Area fuel storage rack project, primary shielding is provided by the water in the Spent Fuel Pool. The amount of water between an individual at the surface (or a diver in the pool) and an irradiated fuel assembly is an essential shield that reduces dose. Additionally, other shielding may be employed to mitigate dose when work is performed around high dose rate sources. If necessary, additional shielding may be utilized to meet ALARA principles.

10.7 Radwaste Material Control

Radioactive waste generated from the rack installation will be controlled in accordance with established St. Lucie procedures.

11.0 ENVIRONMENTAL COST / BENEFIT ASSESSMENT

11.1 Introduction

Article V of the USNRC OT Position Paper [11.1] requires the submittal of a cost/benefit analysis for a fuel storage capacity enhancement. This section provides justification for selecting installation of additional racks in the St. Lucie Cask Pit Area as the most cost effective alternative.

11.2 Imperative for Additional Spent Fuel Storage Capacity

The specific need to increase the limited existing storage capacity of the St. Lucie Spent Fuel Pool is based on the continually increasing inventory in the pool, the prudent requirement to maintain full-core offload capability, and a lack of viable economic alternatives.

St. Lucie Unit 1 is projected to lose full core reserve (FCR) in its Spent Fuel Pool (SFP) following Cycle 19, which ends in 2005. St. Lucie Unit 2 is projected to lose full core reserve (FCR) in its Spent Fuel Pool (SFP) following Cycle 17, which ends in 2007. The projected loss of storage capacity in the pool would affect the owner's ability to operate the reactor.

11.3 Appraisal of Alternative Options

Adding fuel storage space to the St. Lucie SFP is the most viable option for increasing spent fuel storage capacity.

The key considerations in evaluating the alternative options included:

- Safety: Minimize the risk to the public.
- Economy: Minimize capital and O&M expenditures.
- Security: Protection from potential saboteurs, natural phenomena.
- Non-intrusiveness: Minimize required modifications to existing plant systems.

- Maturity: Extent of industry experience with the technology.
- ALARA: Minimize cumulative dose.
- Schedule: Minimize time to implement a plan which will maintain full-core offload capability for the distant future.
- Risk Management: Maximize probability of completing the expansion to support fuel storage needs.

Rod Consolidation Option

Rod consolidation has been shown to be a potentially feasible technology. Rod consolidation involves disassembly of a fuel assembly and the disposal of the fuel assembly skeleton outside of the pool (this is considered a 2:1 compaction ratio). The rods are stored in a stainless steel can that has the outer dimensions of a fuel assembly. The can is stored in the spent fuel racks. The top of the can has an end fixture that matches up with the spent fuel handling tool. This permits moving the cans in an easy fashion.

Rod consolidation pilot project campaigns in the past have consisted of underwater tooling that is manipulated by an overhead crane and operated by a maintenance worker. This is a very slow and repetitive process.

The industry experience with rod consolidation has been mixed thus far. The principal advantages of this technology are: the ability to modularize, moderate cost, no need of additional land and no additional required surveillance. The disadvantages are: potential gap activity release due to rod breakage, potential for increased fuel cladding corrosion due to some of the protective oxide layer being scraped off, potential interference of the (prolonged) consolidation activity which might interfere with ongoing plant operation, and lack of sufficient industry experience. The drawbacks associated with consolidation are expected to diminish in time. However, it is FPL's view that rod consolidation technology has not matured sufficiently to make this a viable option for the present St. Lucie SFP limitations.

On-Site Dry Cask Storage Option

Dry cask storage is a method of storing spent nuclear fuel in a high capacity container. The cask provides radiation shielding and passive heat dissipation. Typical capacities for PWR fuel range from 21 to 37 assemblies that have been removed from the reactor for at least five years. The casks, once loaded, dried, and sealed are then stored outdoors on a seismically qualified concrete pad.

The casks, as presently licensed, are limited to 20-year storage service life. Once the 20 years has expired the cask manufacturer or the utility must recertify the cask or the utility must remove the spent fuel from the container. In the interim, the U.S. DOE has embraced the concept of multi-purpose canisters obsolescing all existing licensed cask designs. Work is also continuing by several companies, including Holtec International, to provide an MPC system that will be capable of long storage, transport, and final disposal in a repository. It is noted that a cask system makes substantial demands on the resources of a plant. For example, the plant must provide for a decontamination facility where the outgoing cask can be decontaminated for release.

Several plant modifications may be required to support cask use, including: (1) tap-ins must be made to the gaseous waste system, (2) chilled water to support vacuum drying of the spent fuel, and (3) piping must be installed to return cask water back to the Spent Fuel Pool/Cask Loading Pit. A seismic concrete pad would be needed to store the loaded casks. This pad would require a security fence, surveillance protection, a diesel generator for emergency power and video surveillance for the duration of fuel storage, which may extend beyond the life of the adjacent plant.

Other Storage Options

Other options such as Modular Vault Dry Storage and a new Fuel Storage Pool are overly expensive as compared to placing new racks in the Cask Pit. Due to the complexity of implementation, these options could not meet the required schedule for extending full-core offload capability.

11.3.1 Alternative Option Cost Summary

An estimate of relative costs in 2001 dollars for the aforementioned options is provided in the following:

Cask Pit Area Rack Installation:	$3-4 million
Rod consolidation:	$25 million
Dry Storage Horizontal Silo:	$35-45 million
Dry Storage Modular vault:	$56 million
Dry Storage Metal cask (MPC):	$68-100 million
New fuel pool:	$150 million

The above estimates are consistent with estimates by EPRI and others [11.2, 11.3].

To summarize, based on the required short time schedule, the status of the dry spent fuel storage industry, and the storage expansion costs, the most acceptable alternative for increasing the on-site spent fuel storage capacity at St. Lucie is expansion of the wet storage capacity. First, there are no commercial independent spent fuel storage facilities operating in the United States. Second, the adoption of the Nuclear Waste Policy Act (NWPA) created a de facto nuclear fuel cycle requiring disposal. Since the cost of spent fuel reprocessing is not offset by the salvage value of the residual uranium, reprocessing represents an added cost for the nuclear fuel cycle which already includes the NWPA Nuclear Waste Fund fees. In any event, there are no domestic reprocessing facilities. Third, at over $½ million per day replacement power cost, shutting down St. Lucie is many times more expensive than addition of high density racks to the existing Cask Pit.

11.4 Cost Estimate

The plant modification proposed for the St. Lucie fuel storage expansion utilizes a freestanding, high density, poisoned spent fuel rack in the Cask Pit for each Unit.

The total capital cost is estimated to be approximately $3 ½ million as detailed below.

Engineering, design, project management:	$1-1/4 million
Rack fabrication:	$2 million
Rack installation:	$½ million

As described in the preceding section, other fuel storage expansion technologies were evaluated prior to deciding on the use of SFP racks. Storage rack capacity expansion provides a cost advantage over other technologies.

11.5 Resource Commitment

The expansion of the St. Lucie spent fuel storage capacity via augmentation of the racks in the SFP is expected to require the following primary resources per Unit:

Stainless steel:	20 tons
Boral neutron absorber:	2 tons, of which 1 ton is Boron Carbide powder and 1.5 tons are aluminum.

The requirements for stainless steel and aluminum represent a small fraction of total world output of these metals (less than 0.001%). Although the fraction of world production of Boron Carbide required for the fabrication is somewhat higher than that of stainless steel or aluminum, it is unlikely that the commitment of Boron Carbide to this project will affect other alternatives. Experience has shown that the production of Boron Carbide is highly variable, depends upon need, and can easily be expanded to accommodate worldwide needs.

11.6 Environmental Considerations

The proposed rack installation results in an additional heat load burden to the Spent Fuel Pool Cooling and Cleanup System due to increased spent fuel pool inventory, as discussed in Section 5.0. The maximum bulk pool temperature will be limited to less than 150°F under normal refueling scenarios.

peak heat load from the spent fuel pool is less than 40 million Btu/hr, which is a minuscule fraction of the total operating plant heat loss to the environment and is well within the capability of the SFP cooling system. Consequently, the short duration of increased heat loading during an outage is not expected to have any significant impact on the environment.

The increased peak bulk pool temperature during a refueling results in a slightly higher increased pool water evaporation rate for a short period of time. This increase is within the Fuel Handling Building HVAC system capacity and does not necessitate any hardware modifications for the HVAC system. Therefore, the environmental impact resulting from the increased heat loss and water vapor generation at the pool surface is negligible.

11.7 References

[11.1] OT Position Paper for Review and Acceptance of Spent Fuel Storage and Handling Applications, USNRC (April 1978).

[11.2] Electric Power Research Institute, Report No. NF-3580, May 1984.

[11.3] "Spent Fuel Storage Options: A Critical Appraisal", Power Generation Technology, Sterling Publishers, pp. 137-140, U.K. (November 1990).