OYSTER CREEK NUCLEAR GENERATING STATION
ADDITIONAL STRESS INFORMATION FOR THE DRYWELL SHIELD WALL FROM THE STRUCTURAL EVALUATION OF THE SPENT FUEL POOL

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Objectives

The objective of the structural evaluation of the Spent Fuel Pool (SFP) at the Oyster Creek Nuclear Generating System (OCNGS), initiated under GPUN Contract No. PC-082008, was to evaluate the SFP concrete structure for consolidated and unconsolidated fuel loads with other design basis loads. The general technical requirements for this evaluation are defined in GPUN Specification SP-1302-53-047, Revision 1, [Ref. 8].

The analysis considers the effects of dead load, live load, thermal gradients, seismic load and cask drop accident using prescribed loads and load combinations. The specific evaluation of section capacities and stresses are performed in accordance with ACI-349 [Ref. 6]. A detailed finite element model of the SFP concrete structure including all connecting and supporting members, was generated to consider the effects of internal force redistribution and to obtain forces on the Reactor Building structural elements. The results and conclusions of the analyses are reported in ABB Impell report no. 03-0370-1341, Revision 0, [Ref. 1].

GPUN has requested, under contract no. PC-0443867, [Ref. 7], numerical values of stresses in the concrete and reinforcing steel in the OCNGS drywell shield wall above elevation 95 ft. These stresses are to be provided for load combinations 3.3.2c and 3.3.2d as contained on page 39 of ABB Impell report no. 03-0370-1341, revision 0, [Ref. 1]. Additionally, GPUN requested that the stresses be evaluated per ACI 349, [Ref. 6].

This report provides a summary of the stresses in the drywell shield wall above elevation 95 ft., and demonstrates that the stresses in the concrete and the reinforcing steel are within allowables.

1.2 Scope

The scope of work for this project is as follows:

1.2.1 Retrieve backup files for SFP analysis

The backup tapes for the Spent Fuel Pool Analysis are obtained from storage. The ANSYS postprocessing files for iteration 4S, Analysis Case C, load combinations 3.3.2c and 3.3.2d from the previous analysis are reloaded on to the computer. This iteration

is chosen because it represents the most realistic estimation of the present stiffness of the Reactor Building.

1.2.2 Verification of retrieved data

The results for load combinations c and d are examined closely to ensure that the appropriate load combinations are loaded. This is accomplished by comparing stress results to those reported in the SFP Report and Calculations.

1.2.3 Generate color contour stress plots and tables

These postprocessing files are then used to produce plots and lists of the vertical and hoop stress levels in the drywell shield wall above elevation 95 feet for load combinations 3.3.2c and 3.3.2d. Both the outer and inner surfaces of the drywell shield wall are examined. The load capacities of the concrete and reinforcing steel at the highest stressed area in this region are determined and reported.

1.3 Brief Summary of Results

The results of the review of stresses in the drywell shield wall above elevation 95 ft., demonstrate that all sections meet the requirements of ACI 349, [Ref. 6], for load combinations 3.3.2c and 3.3.2d.

2.0 METHODS OF ANALYSIS

The following two load combinations are loaded to obtain stresses in the concrete shield wall:

c. $0.75 (1.4D + 1.7L + 1.4T_o \pm 1.9E)$
d. $D + L + T_o \pm E'$

Where:

D = dead load as specified in Section 3.1.1 of [Ref. 1], Rack Conditions 2 and 3

L = design live load as specified in Section 3.1.2 of [Ref. 1]

T_o = thermal load due to temperature differential across the slab or wall. Two critical cases were considered as specified in Section 3.1.4 of [Ref. 1]

E = OBE seismic load as specified in Section 3.1.3 of [Ref. 1]

E' = SSE seismic load as specified in Section 3.1.3 of [Ref. 1]

C = Cask drop load as specified in Section 3.1.5 of [Ref. 1]

Verification that appropriate load combinations are loaded is contained in ABB Impell Calculation no. 0037-00196-C002, revision 0, [Ref. 3]. Contour stress plots and numerical values of stresses in the drywell shield wall above elevation 95 ft., are provided for the above load combinations. An ACI evaluation is also performed to demonstrate that the drywell shield wall and reinforcing steel are within allowables. These are documented in ABB Impell Calculation no. 0037-00196-C003, revision 0, [Ref. 4].

3.0 SUMMARY OF RESULTS

Figure 3.0-1 shows a view of the drywell shield wall for which stresses are extracted, (i.e. above elevation 95 ft.). Figures 3.0-2, 3.0-3 and 3.0-4 show the vertical stress (S_z) levels in the drywell shield wall above elevation 95 feet for load combination c, viewed in the Southwest, Southeast and North directions. Figures 3.0-5, 3.0-6 and 3.0-7 show the circumferential (hoop) stress (S_y) levels in the drywell shield wall above elevation 95 feet for load combination c, viewed in the Southwest, Southeast and North directions.

Figures 3.0-8, 3.0 9 and 3.0-10 show the vertical stress (S_z) levels in the drywell shield wall above elevation 95 feet for load combination d; viewed in the Southwest, Southeast and North directions. Figures 3.0-11, 3.0-12 and 3.0-13 show the circumferential (hoop) stress (S_y) levels in the drywell shield wall above elevation 95 feet for load combination d, viewed in the Southwest, Southeast and North directions.

These figures show that the highest stress levels in the shield wall and SFP occur in the SFP south wall at the fuel transfer opening. This location is a natural stress riser due to the stress concentrations around the slot. Figures 3.0-5 and 3.0-6, indicate a stress riser in the east and west shield wall a few feet below elevation 119 ft. However, the stress levels here are lower than those around the fuel transfer opening and this area of the wall contains similar reinforcing steel patterns as in the area around the fuel transfer opening, [Ref.9]. Therefore, the critical section is the area around the fuel transfer opening for all stresses and hence an ACI evaluation of this area is performed to demonstrate that the drywell shield satisfies the requirements of ACI 349, [Ref. 6].

Table 3.0-1 shows linearized hoop (S_y) stresses around the fuel transfer opening, for locations see Figure 3.0-14. See Section 5.2.4 of [Ref. 1], for further discussion on linearized stresses. The results shown in Table 3.0-1 indicate that circumferential tensile stresses rapidly decay away from the bottom of the fuel transfer opening. At a vertical distance of 90 inches away from the bottom of the fuel transfer opening, the tensile stress is shown to have decreased to 41% of the maximum tensile stress at the corner of the fuel transfer opening.

Table 3.0-2 shows linearized vertical (S_z) stresses around the fuel transfer opening, for locations see Figure 3.0-14. The results shown in Table 3.0-2 indicate that vertical tensile stresses rapidly decay away from the bottom of the fuel transfer opening. At a horizontal distance of 79 inches away from the bottom of the fuel transfer opening, the vertical tensile stress is shown to have decreased to 22% - 42% of the maximum tensile stress at the side of the fuel transfer opening.

In evaluating the capacity of the shield wall, two types of sections are examined. Figure 3.0-15 shows a typical section representing the bending stress acting in the circumferential direction , which corresponds to the section A-A shown in Figure 3.0-14. The depth of beam is taken to be the thickness of the shield wall below elevation 95 ft., and above the bottom of the spent fuel pool (i.e., 90 inches). The stresses from Table 3.0-1 are averaged and the corresponding moment and axial forces are evaluated considering moment-axial force interaction for ACI 349, [Ref. 6]. See Section 5.2.4 of [Ref. 1] for further discussion on computing moments and axial forces from averaged linearized stresses using RCBEAM.

For the vertical stresses (parallel to the side of the fuel transfer opening), the representative beam cross section is shown in Figure 3.0-16. For this cross section, the depth of the beam is taken to be 60 inches which corresponds to the thickness of the shield wall above elevation 95 ft. Two sections (Section A-B and section C-C as shown in Figure 3.0-14) are used to determine two sets of averaged stresses and associated moments and axial forces acting on the typical beam cross section shown in Figure 3.0-16. The resulting moments and axial forces are evaluated in the same fashion as for Section A-A.

The results of the ACI evaluation are presented in Table 3.0-3 which demonstrates that the concrete around the fuel transfer opening is within allowables and in compliance with ACI 349, [Ref. 6]. Table 3.0-4 demonstrates the maximum tensile stresses (S_t) in the reinforcing steel around the fuel transfer opening, as shown in Figure 3.0-14, are within allowables.

Figure 3.0-1: <u>Model of drywell shield wall above elevation 95 ft.</u>

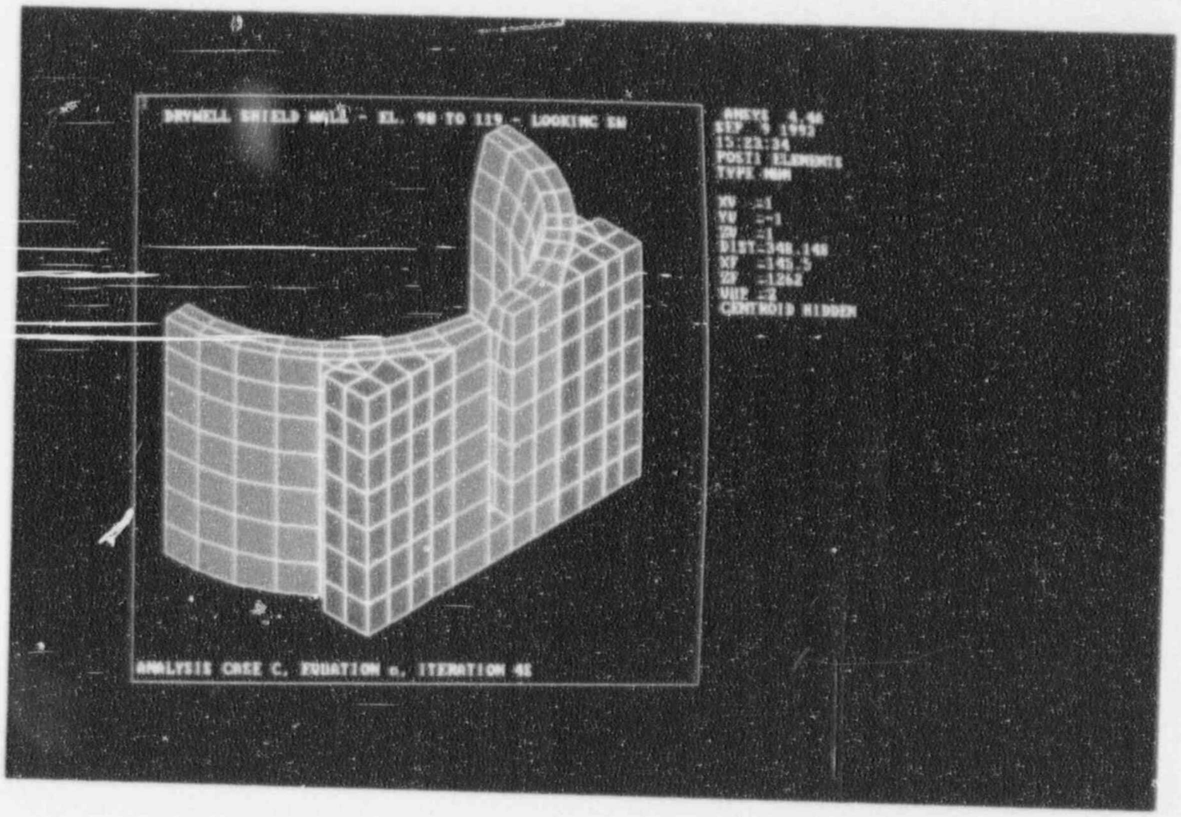


Figure 3.0-2: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking Southwest - Load combination c

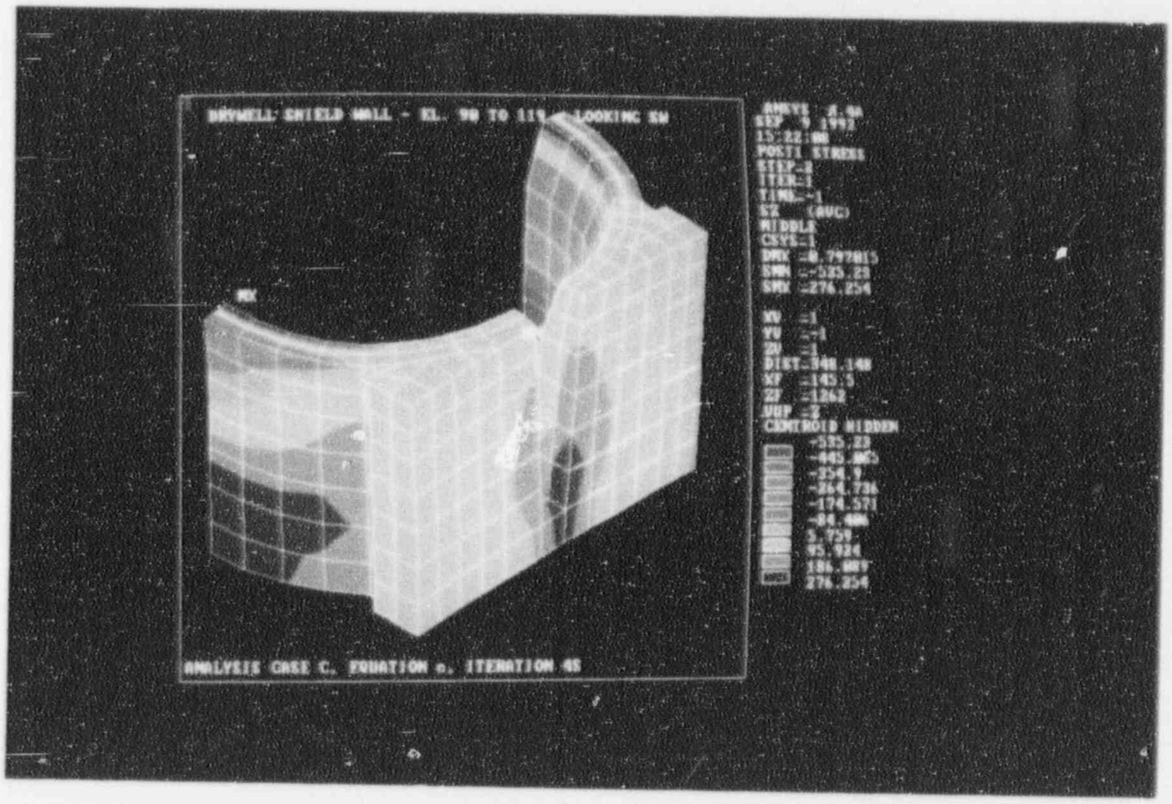


Figure 3.0-3: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking Southeast - Load combination c

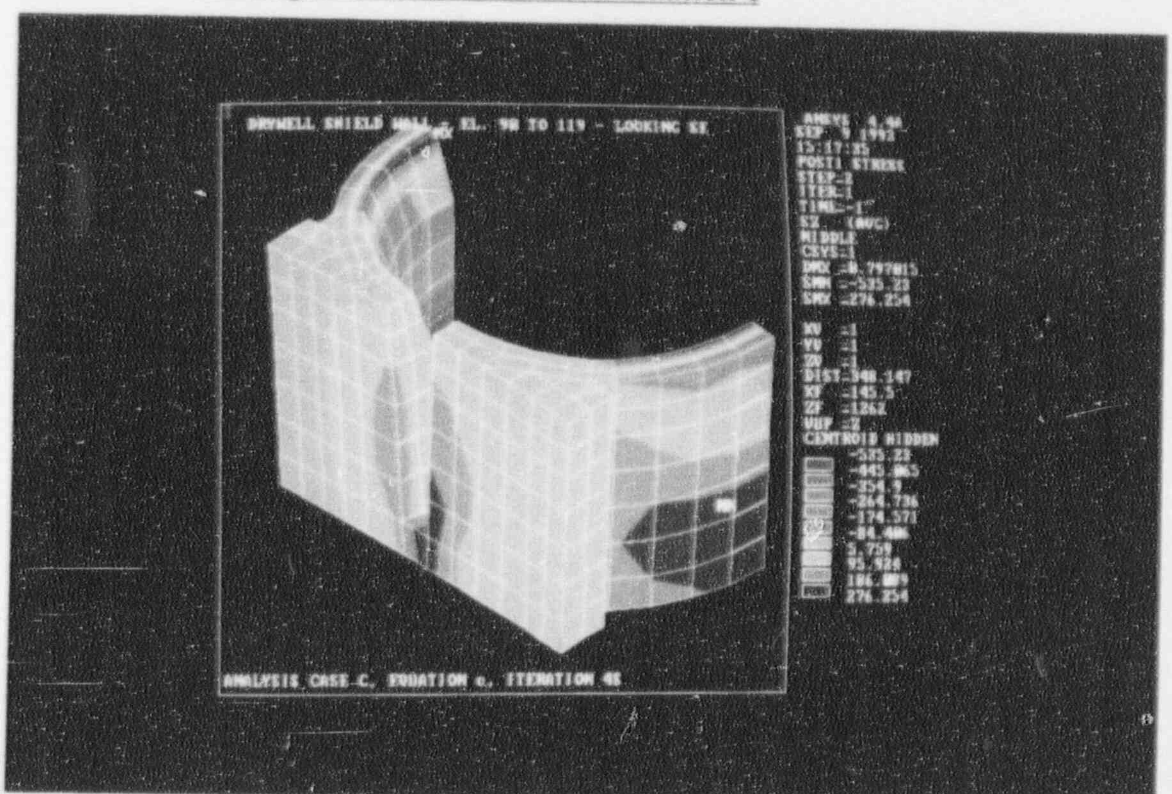


Figure 3.0-4: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking North - Load combination c

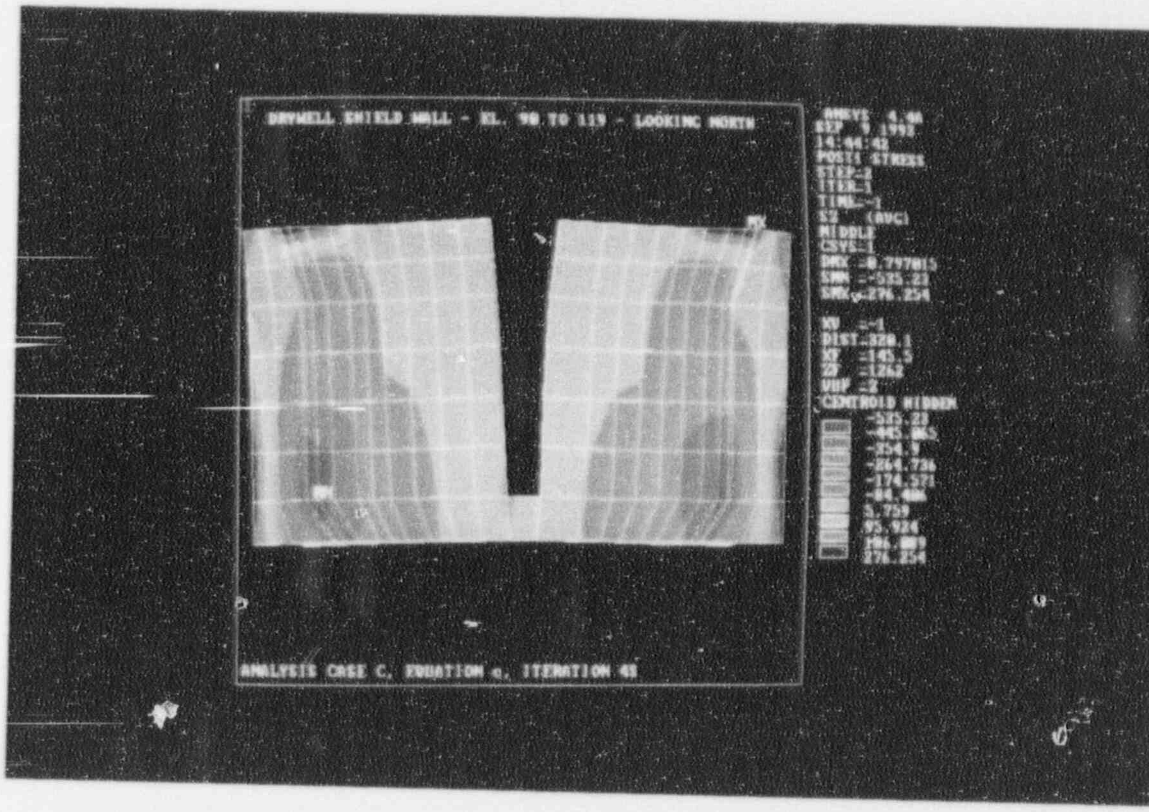


Figure 3.0-5: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking Southwest - Load combination c

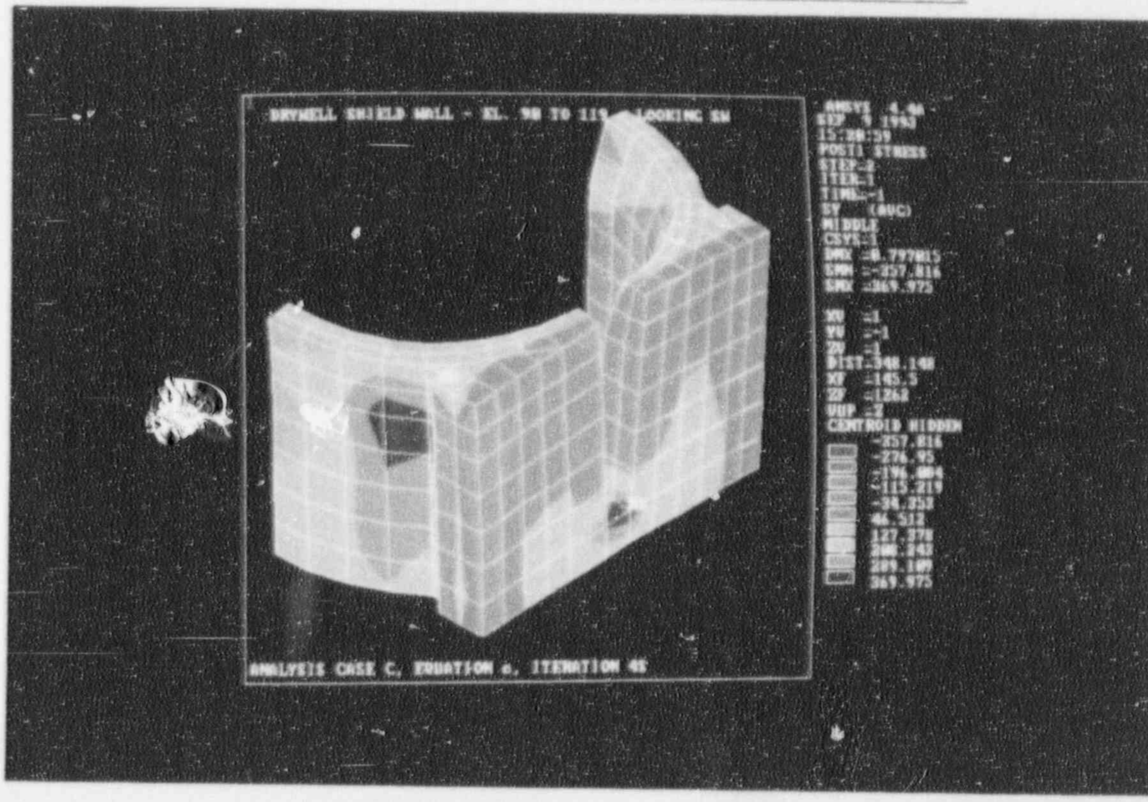


Figure 3.0-6: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking Southeast - Load combination c

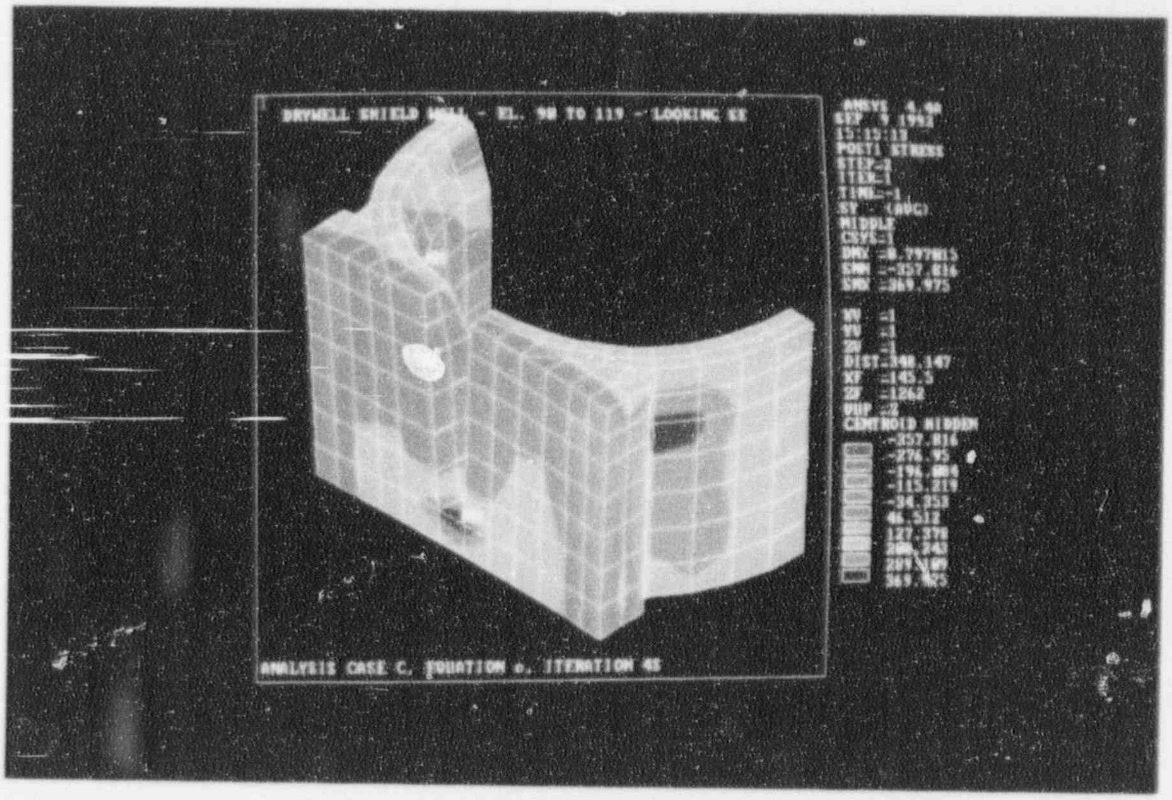


Figure 3.0-7: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking North - Load combination c

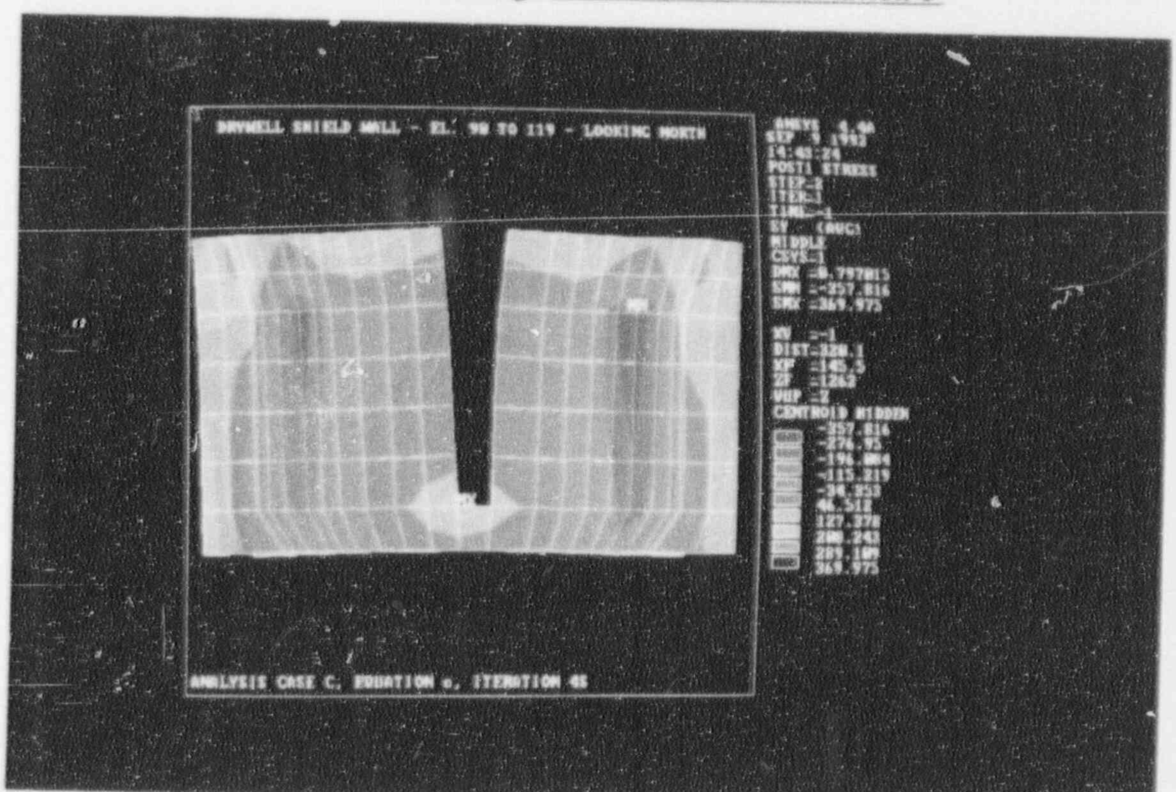


Figure 3.0-8: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking Southwest - Load combination d

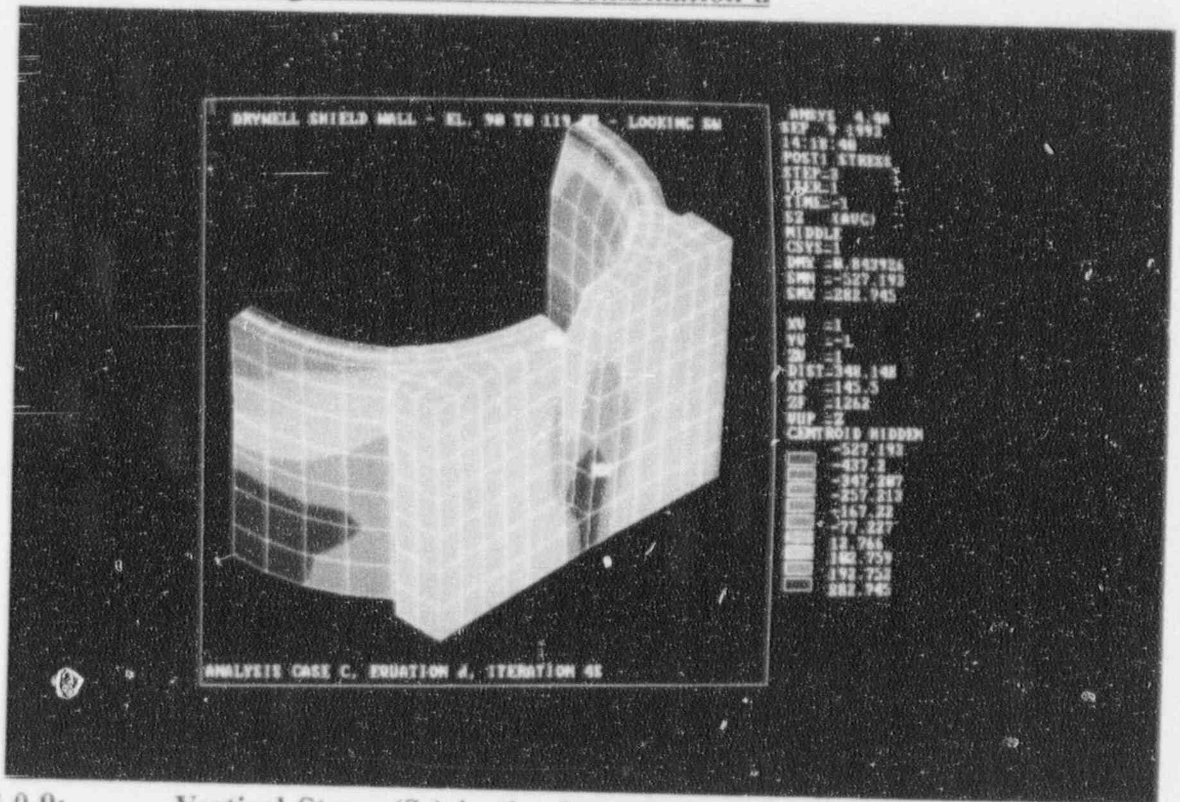


Figure 3.0-9: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking Southeast - Load combination d

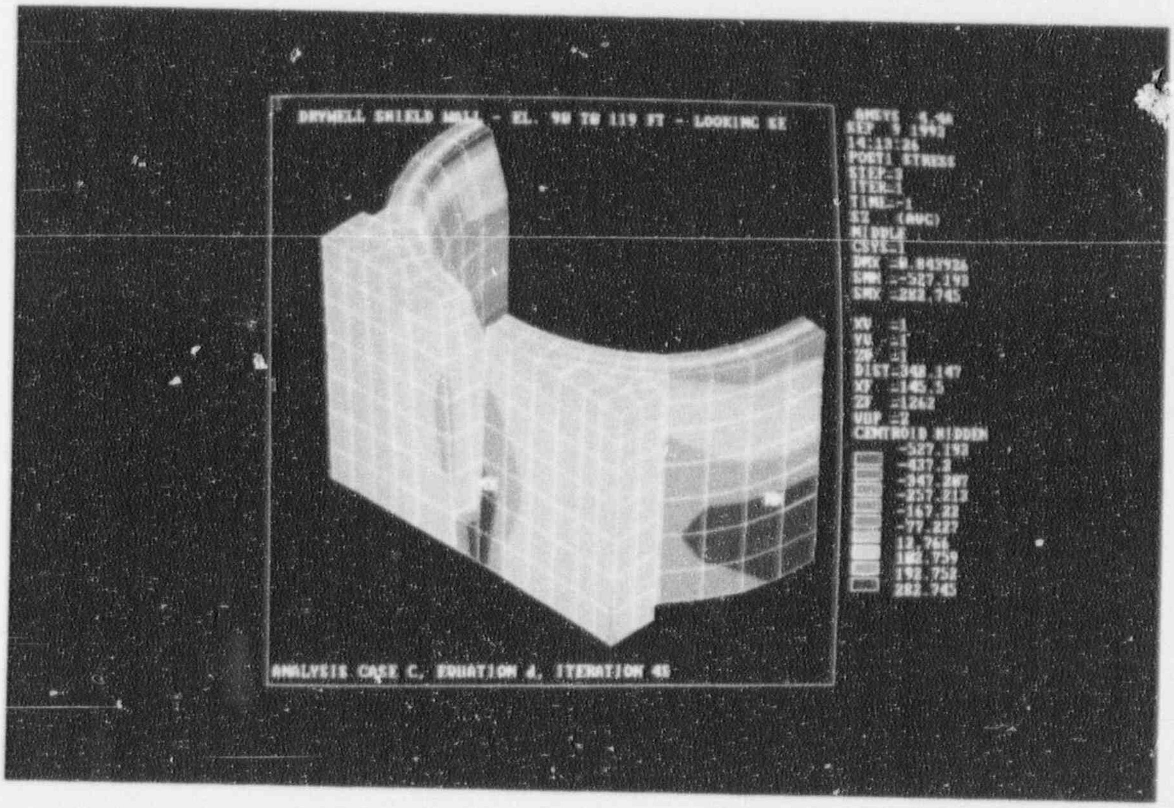


Figure 3.0-10: Vertical Stress (Sz) in the drywell shield wall above elevation 95 ft. Looking North - Load combination d

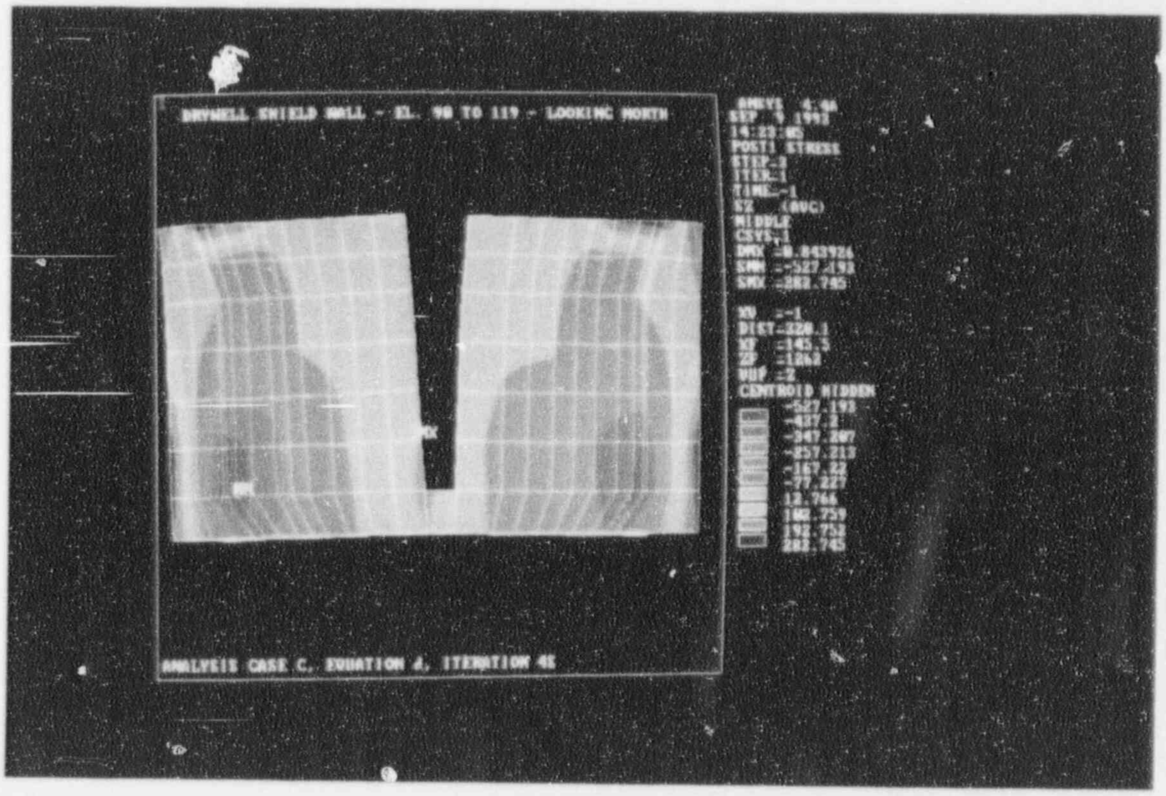


Figure 3.0-11: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking Southwest - Load combination d

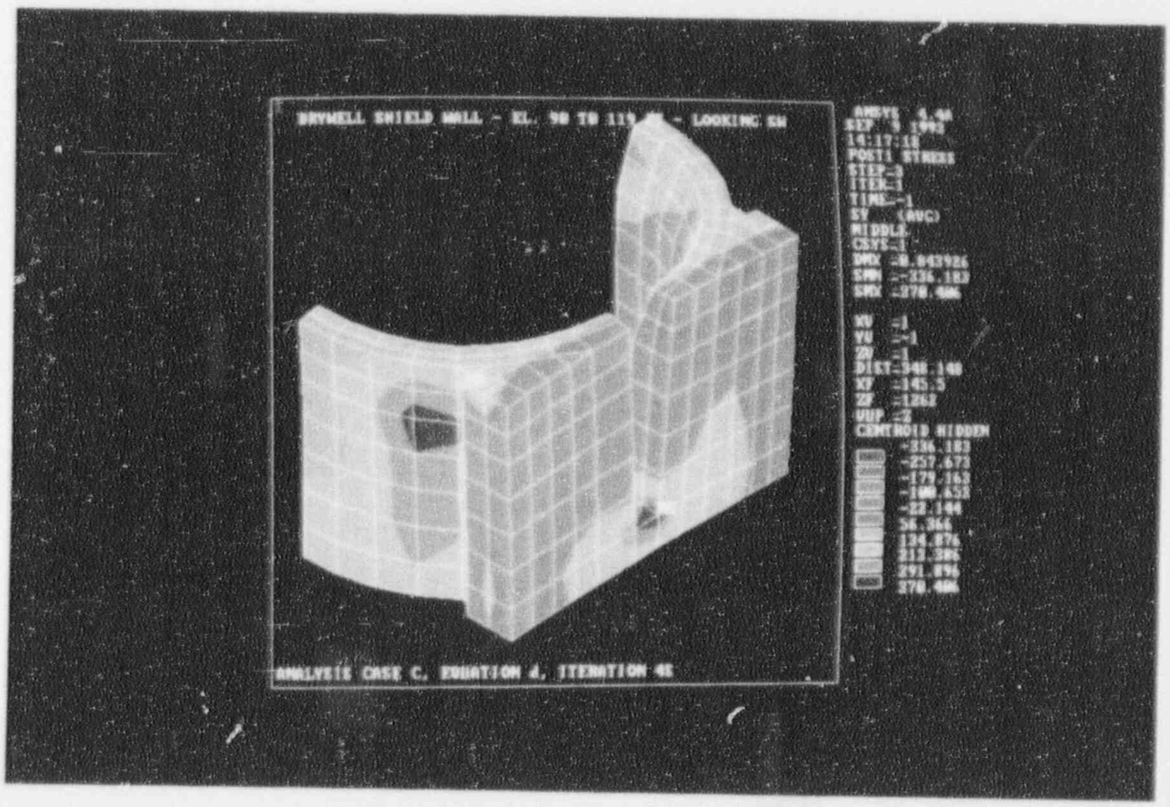


Figure 3.0-12: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking Southeast - Load combination d

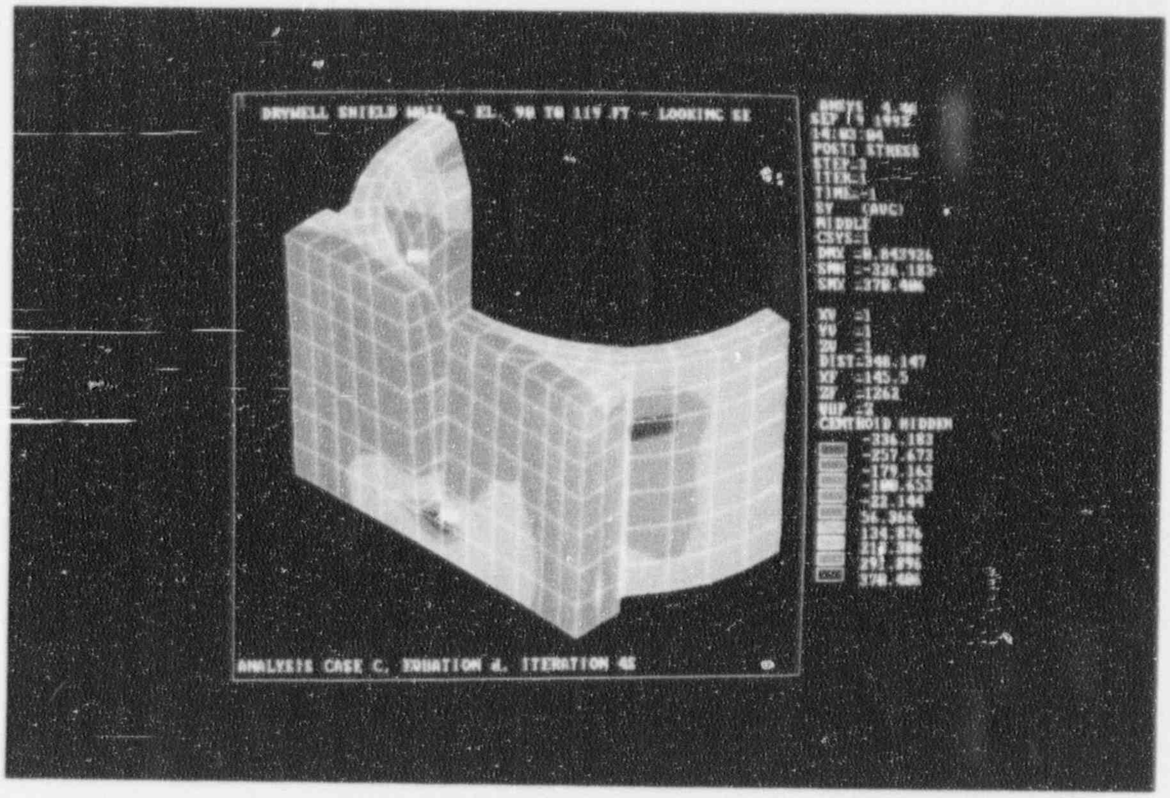


Figure 3.0-13: Circumferential (hoop) Stress (Sy) in the drywell shield wall above elevation 95 ft. Looking North - Load combination d

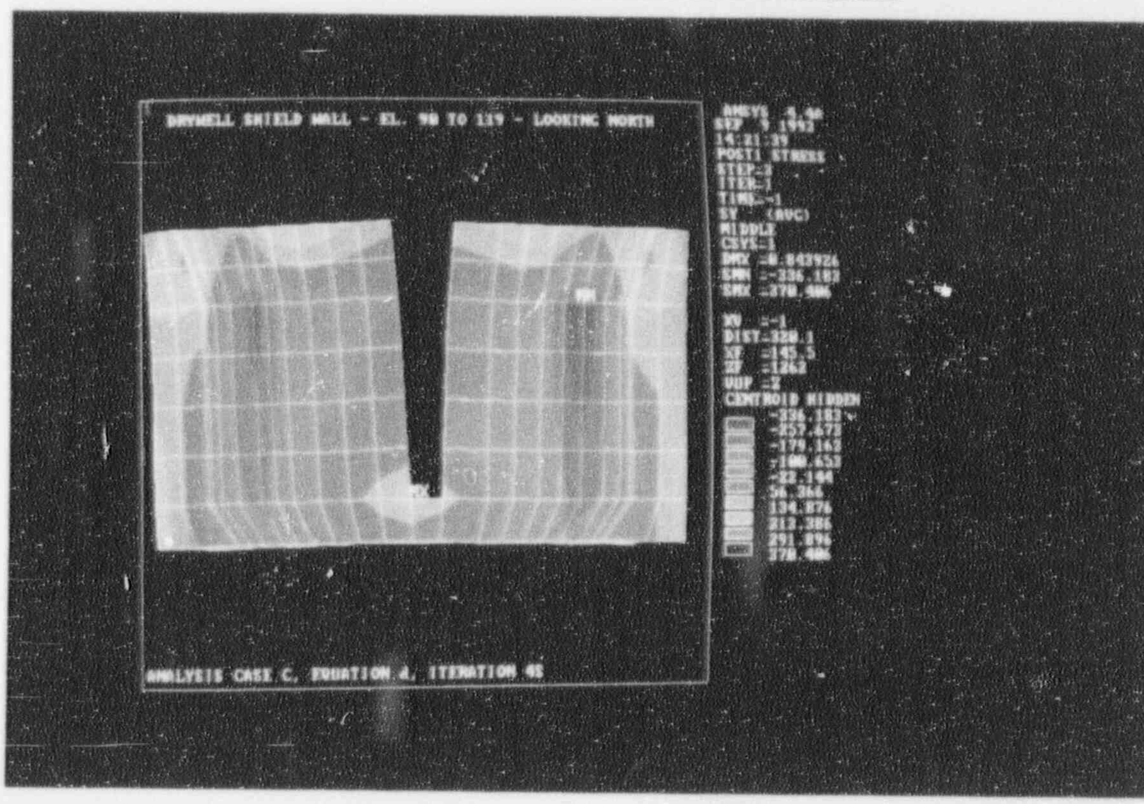


Figure 3.0-14: Location of sections used to evaluate the capacity of the drywell shield wall above elevation 95 ft.

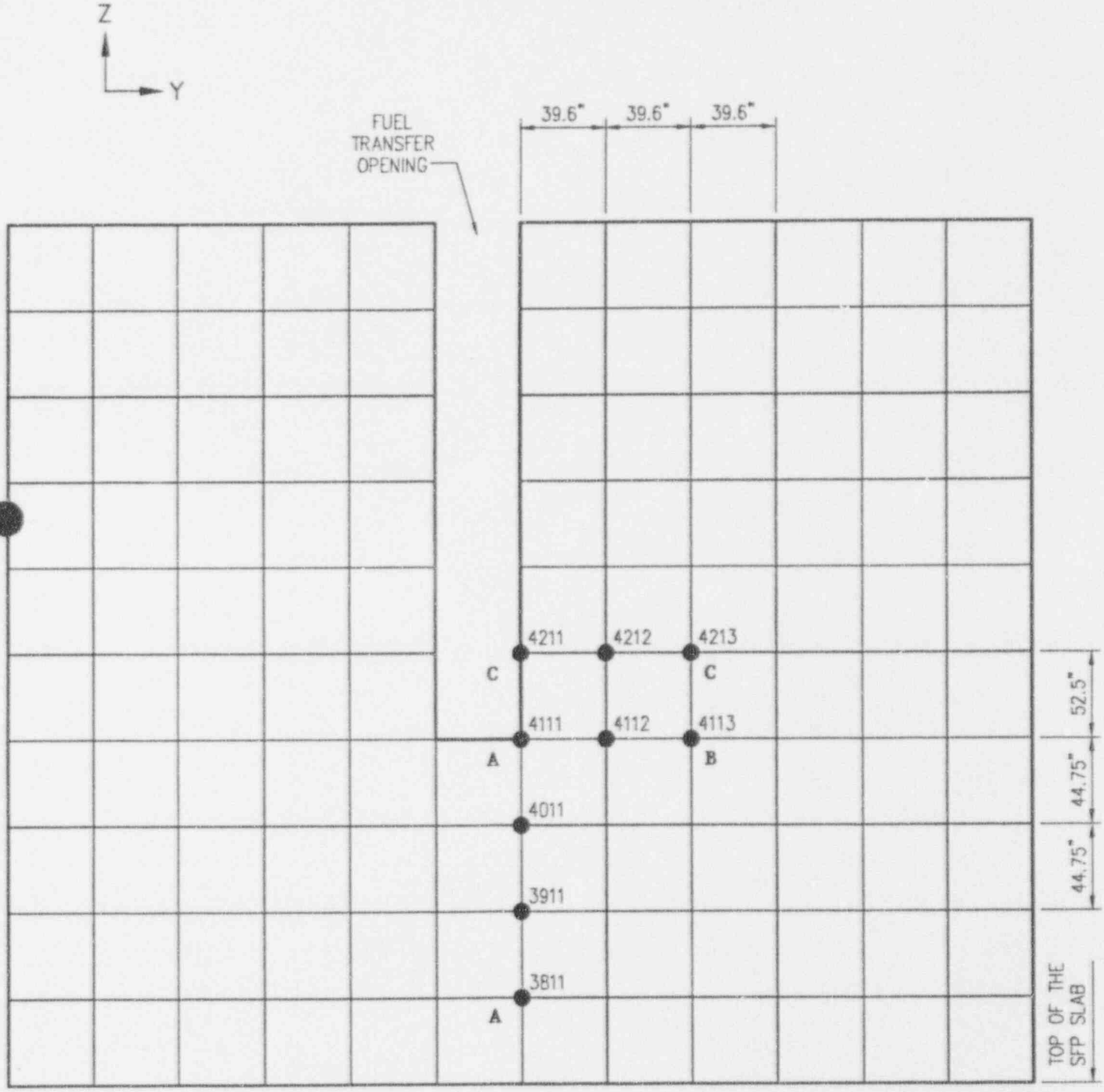
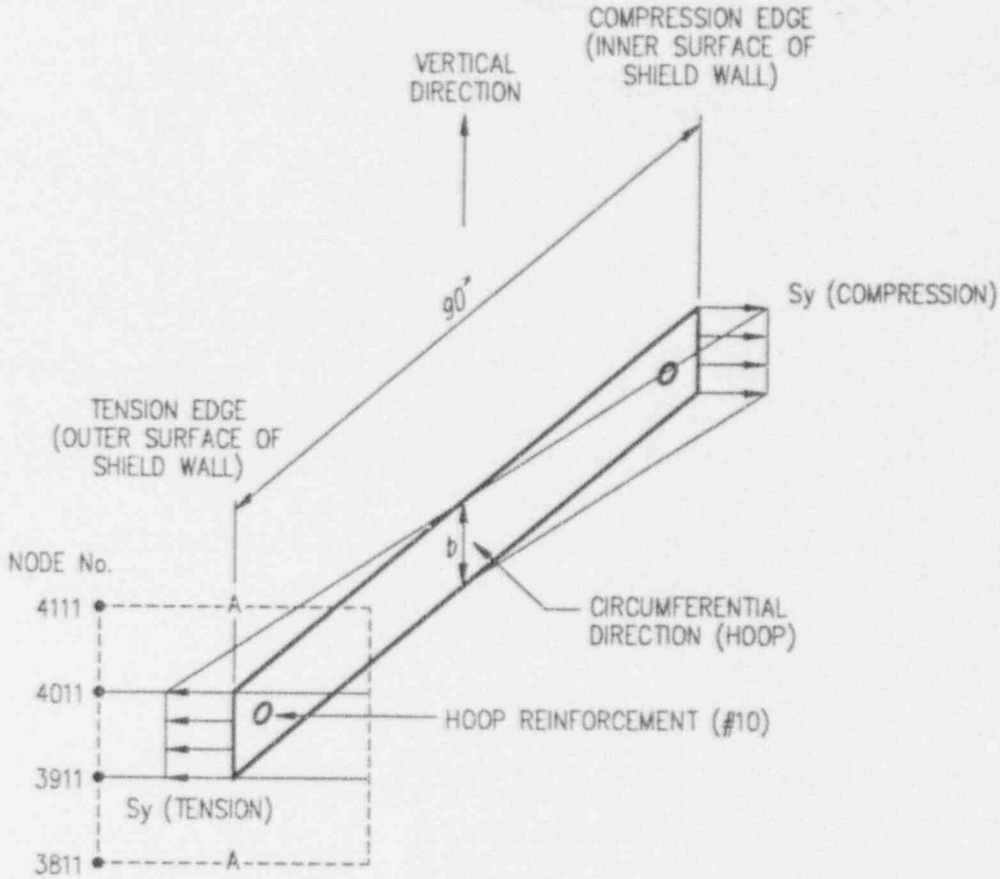


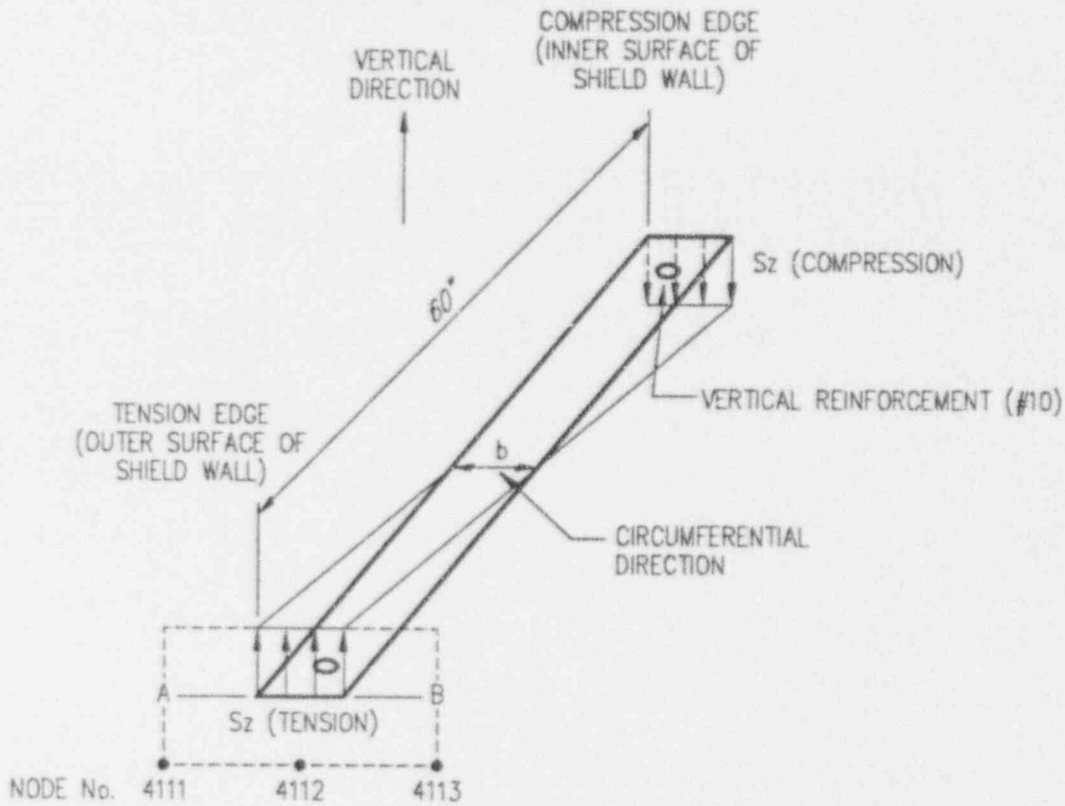
Figure 3.0-15: <u>Representation of a typical beam cross section corresponding to the average stress on RCBeam Section A-A</u>



NOTES:

1. DEPTH OF BEAM SECTION: 90"
2. THE HOOP STRESS (Sy) SHOWN ABOVE WAS OBTAINED BY AVERAGING THE HOOP STRESSES FROM THE LINEARIZED STRESSES AT 4111, 4011, 3911, 3811 SHOWN ON FIGURE 3.0-14.
3. RCBEAM SECTION A-A IS IDENTIFIED ON FIGURE 3.0-14.

Figure 3.0-16: Representation of a typical beam cross section corresponding to the average stress on RCBeam Section A-B and C-C



NOTES:

1. DEPTH OF BEAM SECTION: 60"
2. THE VERTICAL STRESS (Sz) SHOWN ABOVE WAS OBTAINED BY AVERAGING THE VERTICAL STRESSES FROM THE LINEARIZED STRESSES SHOWN ON FIGURE 3.0-14.

   FOR RCBEAM SECTION A-B, RESULTS FOR NODES 4111, 4112, 4113 WERE USED TO COMPUTE THE AVERAGE Sz FOR RCBEAM.

   FOR RCBEAM SECTION C-C, RESULTS FOR NODES 4211, 4212, 4213 WERE USED TO COMPUTE THE AVERAGE Sz FOR RCBEAM.

Table 3.0-1: Linearized Hoop Stresses S_y (psi) in the South Wall of the Spent Fuel Pool for Load Combination c and Load Combination d. [1] **[Ref. 2]**

RCBEAM SECTION: A-A [2]

Nodal ID[3]	Load Combination c		Load Combination d	
	Outer Surface	Inner Surface	Outer Surface	Inner Surface
4111	331	22	332	21
4011	157	-112	154	-122
3911	137	-110	136	-115
3811	116	-113	114	-117

Notes:

(1) The stress S_y corresponds to the stress in the circumferential direction in the shield wall.

(2) The sections employed in RCBEAM to determine the capacity of the concrete and the tension in the reinforcing steel are identified in Figures 3.0-14, 3.0-15 and 3.0-16.

(3) A series of linearized stresses were computed to determine the average stress acting on the section for which RCBEAM was used to perform the ACI evaluation. The node number indicated in this column corresponds to the node on the outer surface of the south wall of the spent fuel pool model of the pair of nodes used to determine the linearized stresses at this location. Figures 3.0-14, 3.0-15 and 3.0-16 show the location of the nodes shown in this table.

Table 3.0-2: Linearized Vertical Stresses S_z (psi) in the South Wall of the Spent Fuel Pool for Load Combination c and Load Combination d.[1] [Ref. 2]

RCBEAM SECTION: A-B [2]

Nodal ID[3]	Load Combination c		Load Combination d	
	Outer Surface	Inner Surface	Outer Surface	Inner Surface
4111	261	123	216	96
4112	111	-12	108	-14
4113	57	-70	74	-61

RCBEAM SECTION: C-C

Nodal ID[3]	Load Combination c		Load Combination d	
	Outer Surface	Inner Surface	Outer Surface	Inner Surface
4211	232	9	282	108
4212	147	-45	154	8
4213	98	-79	74	-58

Notes:

(1) The stress Sz corresponds to the stress in the vertical or axial direction in the shield wall.

(2) The sections employed in RCBEAM to determine the capacity of the concrete and the tension in the reinforcing steel are identified in Figures 3.0-14, 3.0-15 and 3.0-16.

(3) A series of linearized stresses were computed to determine the average stress acting on the section for which RCBEAM was used to perform the ACI evaluation. The node number indicated in this column corresponds to the node on the outer surface of the south wall of the spent fuel pool model of the pair of nodes used to determine the linearized stresses at this location. Figures 3.0-14, 3.0-15 and 3.0-16 show the location of the nodes shown in this table.

TABLE 3.0-3: Moment Capacity Margin in the SFP/Drywell Shield wall Analysis Case C, [Ref. 2]

ITER.	EQ.	SECTION OF WALL	AXIAL FORCE(1) (kips)	MOMENT M_u (ft-kips)	MOMENT CAPACITY(2) M_n (ft-kips)	MARGIN %
		South-Wall(3)				
4S	c	A-A	-38	173	192	10
4S	d	A-A	-35	176	206	15
4S	c	C-C	-48	47	105	55
4S	d	C-C	-54	44	91	52

Notes:

(1) A negative axial force produces a tensile axial stress on the slab cross section. The moment capacity is based on the same axial force.

(2) Axial Force, Moment, and Moment Capacity are for a 12" wide section of wall.

(3) The sections employed in RCBEAM to determine the capacity of the concrete section are identified in Figures 3.0-14, 3.0-15 and 3.0-16.

Table 3.0-4: Maximum Tensile Stresses (S_t) in the Reinforcement in the South Wall of the Spent Fuel Pool for Load Combination c and Load Combination d, [Ref. 4]

RCBEAM Section[1]	Load Combination c		Load Combination d	
	S_t (ksi)	S_{yield}(ksi)	S_t (ksi)	S_{yield}(ksi)
A-A	32.8	40	31.4	40
A-B	22.7	40	24.1	40
C-C	27.5	40	30.0	40

Notes:

(1) The sections used to determine the average stresses on a typical beam cross section are identified in Figure 3.0-14, 3.0-15 and 3.0-16.

4.0 CONCLUSIONS

The review of the stresses in the drywell shield wall above elevation 95 ft. indicates that both the concrete and reinforcing steel are within allowables and in compliance with ACI 349, [Ref.6].

5.0 REFERENCES

[1] ABB Impell, "OCNGS Structural Evaluation of the Spent Fuel Pool", Report No. 03-0370-1341, revision 0.

[2] ABB Impell Calculation No. 0370-187-007, "GPUN SFP Analysis Case C Using Cracked Transformed Properties.", Revision 0.

[3] ABB Impell Calculation No. 0037-00196-C002, "GPUN SFP Analysis - Verification of Retrieved Data", Revision 0.

[4] ABB Impell Calculation No. 00037-00196-C003, "GPUN SFP Analysis Case C Additional Stress Information for the Drywell Shield Wall", Revision 0.

[5] ANSYS, Version 4.4, Swanson Analysis Systems, Inc.

[6] ACI 349 - "Code Requirements for Nuclear Safety Related Concrete Structures," 1980.

[7] GPUN Contract No PC-0443867, "Engineering Services for the Oyster Creek Drywell Shield Wall", August 30, 1993.

[8] GPUN, "Specification for Oyster Creek Nuclear Generating Station Spent Fuel Pool Structure Qualification for Consolidated Spent Fuel Storage," SP-1302-53-047, Revision 1.

[9] Burns & Roe Drawing, 4066-3 (As-Built), Revision 3, Reactor Building Cross Section Details.