

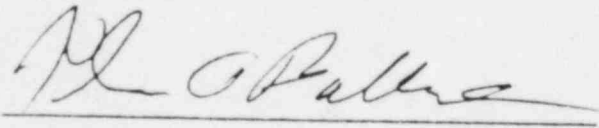
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APL-02-013
November 24, 1982

STRUCTURAL EVALUATION
OF THE ARKANSAS NUCLEAR ONE-UNIT 2
SPENT FUEL STORAGE FACILITY
FOR CONSOLIDATED FUEL STORAGE

Prepared by
Structural Dynamics Technology, Inc.
for
Arkansas Power and Light Company

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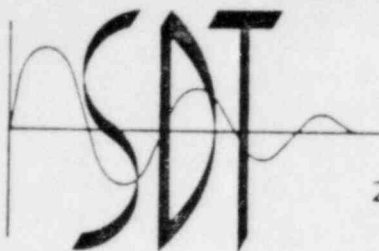


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REPORT NUMBER: APL-02-013, November 24, 1982

SUBJECT: Structural Evaluation of the Arkansas Nuclear One -
Unit 2 Spent Fuel Storage Facility for Consolidated
Fuel Storage

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EXECUTIVE SUMMARY

The purpose of this report is to present the results of the structural evaluation of the Arkansas Nuclear One-Unit 2 spent fuel storage facility for high density fuel storage. This activity was undertaken to determine whether it is possible to increase the fuel storage capacity of the existing spent fuel pool in the Unit 2 plant through utilization of high density fuel storage racks. This report discusses loading conditions, structural response to the critical loading conditions, definition of appropriate load combinations, and evaluation of the structural adequacy in accordance with the applicable criteria.

The evaluation utilized a detailed finite element model of the spent fuel pool to accurately quantify the structural response to various loading conditions. Computer techniques permitted assessment of all appropriate postulated load combinations, and a thorough comparison of forces and moments throughout the structure to allowable values established by the governing ACI Code.

As a result of this evaluation, it is concluded that the Arkansas Nuclear One-Unit 2 spent fuel pool has adequate capacity to resist all load combinations defined in the NRC Standard Review Plan (NUREG-0800). In addition, the margin between actual force and moment values and ACI Code allowable values may be adequate to permit future additional increase in the fuel storage capacity of the ANO Unit 2 spent fuel pool through fuel consolidation.

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1.0 INTRODUCTION

This report is divided into various sections that address different aspects of the evaluation process, and an Appendix is provided for drawings which document the computer model of the spent fuel pool.

Section 2.0 discusses the finite element model utilized for this evaluation, including a detailed description of the representation of the component parts of the pool, boundary conditions applied to this model, and representation of shear walls and floor diaphragms that frame into the pool at various elevations and locations. Section 3.0 discusses the load development, including a description of each of the individual load cases, with references to applicable data for their derivation. Section 4.0 discusses the results for the controlling individual load case. Section 5.0 is a discussion of the post-processing that was carried out to transform the basic analysis results into the form required for evaluation in accordance with the specified design criteria, and Section 6.0 presents the results of the design criteria evaluation. Section 7.0 discusses miscellaneous loading conditions that were not explicitly addressed in the computer analysis, and addresses other structural considerations, such as the pool liner plate. Section 8.0 presents the conclusion of this evaluation, and Section 9.0 identifies the reference documents that were utilized.

To provide non-ambiguous quality assurance traceability, and facilitate discussion of the analysis results, SDT has assigned a unique acronym identifier to each individual computer analysis run. Tabulation of the results will reference these unique computer run identifiers, which will be defined where necessary. Microfiche of the computer

output and data tapes for each of these computer analysis run will be transmitted to Arkansas Power and Light Company for archival purposes, along with full quality assurance documentation of each of these computer analysis runs. In addition, the calculations that were prepared in conjunction with the finite element model generation, load development and criteria check will also be provided to Arkansas Power and Light for archival purposes.

1.1 Evaluation Criteria

The criteria utilized for this evaluation are contained in Reference 1 (ANO-Unit 2 Design Criteria) and 4 (NRC Standard Review Plan). The original pool was designed in accordance with ACI 318-63 Code Criteria and load combinations, as specified in Reference 1. However in the interest of obtaining a more comprehensive evaluation, Arkansas Power and Light Company has elected to use NRC Standard Review Plan (Reference 4) load combinations, and take guidance from ACI 349 (Reference 2) in the reinforced concrete evaluation. All other criteria specified in Reference 1 were applied to this evaluation, with operating specifications utilized to define applicable analysis parameters. Free standing fuel rack loads on the pool structure were obtained from the fuel rack vendor (Reference 9).

1.2 Analysis Methodology

Due to the complexity of loadings and structural configuration, the finite element method was selected for the calculation of pool structural response. Since transverse shear is a relatively important concrete cross-section force component in this evaluation,

it was decided to utilize solid elements rather than thin shell elements that typically have less than adequate transverse shear formulation. The STARDYNE computer program (Reference 11) which has a long history of successful usage in the nuclear industry, and which has good quality control procedures, was used to perform the analysis.

Postprocessing was performed using a verified SDT postprocessor that performs load combinations and ACI code criteria checking for the combined effect of axial load and bending moment. Additional ACI criteria checks were carried out by hand calculations utilizing postprocessor results where appropriate.

2.0 SPENT FUEL POOL FINITE ELEMENT MODEL DEVELOPMENT

This section documents the finite element model utilized to carry out the spent fuel pool evaluation for Arkansas Nuclear One Unit 2. Included in this section is a discussion of the extent of the model, the structural boundary conditions, and the development of stiffnesses for shear walls and floor diaphragms that interact with the spent fuel pool. A set of detailed computer-generated geometry plots that fully defines the node numbers and element connectivity for the model is also provided in an Appendix. These plots serve to verify the geometry of the computer model as well as providing Arkansas Power and Light Company Engineering personnel with a means of potentially further utilizing the computer model or the detailed microfiche results.

2.1 Spent Fuel Pool Geometry

The finite element model is comprised of an assemblage of eight node, three-dimensional solid elements and four node membrane elements. The model includes the pool floor and walls, the fuel transfer canal floor and walls, and the cask laydown area floor and walls. Also included are the supporting foundation walls beneath the pool. The pool walls and floor slab are modeled with two layers of three-dimensional eight node solid elements. The reason for this detail is that, in order to apply a thermal gradient to the walls and floor, it is necessary to define that gradient has a uniform temperature of differing magnitude at each brick centroid through the wall thickness. In addition to these solid elements, membranes of negligible thickness are added to the inside, outside and middle planes of the walls and floor, in order to permit to stress recovery at these locations, in addition to the centroids of each solid element. In this manner, stresses are computed at

five locations through the wall thickness, and these stresses are integrated to determine the section resultant forces and moments for the criteria check phase. The north and west walls of the fuel transfer canal area, and the south and west walls of the cask laydown area are modeled with one layer of solid elements. These walls are included in the model only for the purpose of properly modeling the stiffness contribution of these components to the overall pool structure. Also, membrane elements have not been modeled for the exterior walls of the cask laydown area and fuel transfer canal area. The foundation walls below the pool floor are modeled with a single layer of solid elements since the thermal gradient defined for this region is relatively small or nonexistent. In the case where a small gradient exists, the uncracked section is assumed to resist the full thermal moment developed by this gradient. The foundation walls do include membrane elements on their inside and outside surfaces for the purpose of section force and moment derivation.

The spent fuel pool liner plate is not modeled explicitly, since this component is not meant to provide additional strength to the floors and walls. Liner plate strains, however, can be recovered from the inside membrane elements of the walls and floor to permit a structural assessment of the liner plate. The portion of the foundation beneath the cask laydown area floor is modeled for approximately six feet below the floor slab elevation. This region is extremely stiff, has no thermal gradients defined, and is considered rigid, relative to the rest of the structure. Figures 1 and 2 of the Appendix show the extent of the spent fuel pool model as discussed herein. Figures 3 through 15 fully describe the finite element model node and element numbering scheme.

The fuel transfer canal area contains two pipe struts that span the opening between the wall separating the spent fuel pool and the fuel transfer canal, and the fuel transfer canal outside wall. These two struts are located at the elevation of the lower portion of the fuel transfer canal gate, and are modeled as beam elements.

2.2 Finite Element Model Boundary Conditions

The objective in applying boundary conditions to the finite element model is to correctly represent the interaction of the pool structure with adjacent auxiliary building floors and walls, and only impose rigidity assumptions at locations that are sufficiently remote, such that analysis results are not incorrectly influenced by assumed boundary conditions.

Several floor diaphragms and shear walls frame into the pool at various elevations and locations. These floors and walls are included in the finite element model as stiffness matrix additions, which economically represent the effect of these restraining structures without the expense of explicit modelling. The matrix elements are defined such that shear is transferred between adjacent nodes in the plane of these walls or floor diaphragms. The stiffness of these diaphragms is derived based on the shear stiffness of a concrete panel of the same dimensions as the component being considered, assuming that, due to cracking, one-half of this panel stiffness is available. Other boundary conditions applied to this model consist of restraining all degrees of freedom of the nodes at the bottom of the entire pool foundation, which is very remote from the pool structural areas of interest.

Table 2-1 documents the material properties utilized for the spent fuel pool finite element analysis, which were reviewed by AP & L Engineering prior to incorporation into the analysis. These properties are based on standard accepted values or the original design criteria specification for the plant. The modulus of elasticity for the pool structure is a composite value, determined based on a ratio of steel modulus to concrete modulus of nine.

Table 2-1

Arkansas Power and Light Company
ANO-2 Spent Fuel Pool Evaluation
Summary of Material Properties

<u>Item</u>	<u>Value</u>		<u>Reference</u>
Concrete Compressive Strength	3,000	lb/in ²	1
Reinforcing Yield Strength	60,000	lb/in ²	1
Reinforcing Elastic Modulus	29.0×10^6	lb/in ²	2
Concrete Elastic Modulus	3.22×10^6	lb/in ²	(Note 1)
Concrete Poisson Ratio	0.17		3
Concrete Thermal Expansion Coefficient	5.5×10^{-6}	in/in/°F	2
Concrete Weight Density	8.68×10^{-2}	lb/in ³	3
	(150	lb/ft ³)	

Note: 1) Concrete composite elastic modulus based on a ratio of the elastic modulus of steel to concrete equal to 9.0

3.0 LOAD DEVELOPMENT

This section discusses the development and verification of the loads applied to the Arkansas Nuclear One-Unit 2 Spent Fuel Pool finite element model. A summary of the individual loads is presented in Table 3-1.

3.1 Development of Individual Load Cases

To provide flexibility in forming load combinations, as discussed in Section 5.0, the analysis was performed for primary, uncombined loads on an individual basis. These loads consist of dead weight of the concrete, hydrostatic pressure, accident flood load, normal operating and accident thermal loads, a nominal 1.0 g east/west seismic acceleration, a 1.0g north/south seismic acceleration, fuel rack submerged deadweight load, and fuel rack seismic reaction loads. These loads are developed on an individual basis so that they may be combined after the analysis is complete, in any required manner to represent different magnitudes and directions of the various applied loadings. The loading due to the fuel handling crane is excluded from this evaluation, since it is concluded that this effect on the overall pool structure is beneficial when considering this in combination with other loadings. This conclusion is based upon the observation that the upper portion of the pool walls are subjected to a relatively small vertical axial load when the crane load is excluded. For shear as well as axial load-moment interaction, compressive axial load is beneficial, in terms of the section's capacity to resist these forces. Therefore, excluding the crane load in combination with other live loads is conservative.

Table 3-2 identifies the parameters utilized in defining the loads discussed herein. This table, along with the indicated references, documents the assumptions utilized for load development.

Deadweight of the concrete structure is defined as a 1.0g vertical acceleration. This 1.0g vertical acceleration results in a downward vertical force at each node of the finite element model, equal to the tributary weight assigned to each node, and a total downward force equal to the weight of the reinforced concrete structure. The unit weight of reinforced concrete is defined in Table 2-1.

The pool water level is defined as 39.5 feet above the top of the pool floor slab, and water density is defined as 62.4 pounds per cubic foot. The concentrated nodal forces due to hydrostatic pressure are derived by multiplying the hydrostatic pressure at the elevation of the finite element node being considered by the tributary surface area for that node. The tributary surface area of a node is calculated as one-fourth of the surface areas of the membrane elements surrounding the node point. This total pressure force is transformed into global forces based on the direction cosines of the vector normal to the surface of the membrane elements surrounding the node being considered. This load was verified by generating a summation of the nodal forces and comparing the resulting force with manual calculations for the volume of the pool times the water density.

Accident flood load is defined as a hydrostatic pressure on the outside of the east wall of the pool structure from elevation 335 to elevation 361, and was generated in a manner similar to that described above.

Accident and operating thermal loads are defined based on the temperatures of each compartment, as shown in Table 3-2. This load is developed as a uniform thermal load on each membrane and brick element in the model, based on linear interpolation between the compartment temperatures. This is a conservative definition of thermal loads since conduction through the concrete for a true steady state condition will result in temperatures on the outside surface of each wall significantly higher than the gross air temperature in the respective compartment. Thermal gradients may not necessarily develop in a linear manner prior to the steady state condition; however, the local effect of a gradient which decays more rapidly within the concrete will not result in a more significant gross structural response than that resulting from a pure linear gradient defined based on compartment air temperature and the pool water temperature. The one exception to this assumption is the stress in the liner plate due to the thermal loads at the beginning of the transient. This is considered, however, separate from the basic finite element analysis and discussed in Section 7.1.

The operating basis earthquake (OBE) is defined utilizing six separate individual loads in order to properly account for the various possible seismic motion directions and variation in fuel rack loadings. Reference 8 defines the response spectra from which the earthquake loads discussed herein were defined.

It is not necessary to treat the vertical earthquake loadings associated with acceleration of the pool water mass and concrete mass as separate primary load cases since these loadings can be formulated in a post-processing step, utilizing the static

deadweight of concrete and hydrostatic load cases with the appropriate factor to account for dynamic amplification of the seismic motion.

The horizontal earthquake acceleration is defined by calculating the average spectral acceleration, reported in Reference 8, over the height of the pool, and applying this as an acceleration load in one horizontal direction and then in the orthogonal horizontal direction. Earthquake response of the pool water is defined based on the methodology outlined in Reference 5, Appendix F. The hydrodynamic loads are calculated as pressure profiles over the pool wetted surface and distributed to each node based on nodal tributary area. The resulting nodal forces were summed to determine the net resulting hydrodynamic forces in orthogonal directions, and these force resultants were verified using additional methodology in Reference 5, which defines the integrated pressure resultants. For simplicity, the combined east/west and north/south earthquake loadings are normalized to a 1.0g earthquake, and are combined with the appropriate g factor in a post-processing phase.

Reference 9 defines the fuel rack loads utilized in this analysis. They consist of a submerged deadweight loading, and a vertical and horizontal reaction loading due to the operating basis earthquake. These reaction loads are distributed to the pool floor node points based on the proximity of each pad to the surrounding nodes. The earthquake loads are distributed in the same proportion as the deadweight loads, with the total force equal to that specified in Reference 9. These loads were not normalized to 1.0g as was done for the pool water and concrete mass effects.

The preload which exists in each of the fuel transfer canal struts was represented by applying a uniform temperature load to these members in two separate load cases, and in a post-processing mode, the correct factors for these temperature loads was determined, to account for the actual preload in these members.

Table 3-1
Arkansas Nuclear One-Unit 2
Spent Fuel Storage Facility Structural Evaluation
Individual Load Case Description Table

Load Case No.	Notation	Description
1	D_c	Dead weight of the concrete.
2	H	Hydrostatic pressure due to water in the pool.
3	F	Accident flood load.
4	$T_o^{(1)}$	Normal operating thermal load.
5	$T_a^{(1)}$	Accident thermal load.
6	$E_{ew}^{(2)}$	Load generated by east-west 1.0g earthquake.
7	$E_{ns}^{(2)}$	Load generated by north-south 1.0g earthquake.
8	D_{fr}	Fuel rack dead weight load.
9	FR_v	Reaction load of fuel racks during 0.067g vertical earthquake.
10	FR_{ew}	Reaction load of fuel racks during 0.1g east-west earthquake.
11	FR_{ns}	Reaction load of fuel racks during 0.1g north-south earthquake.
12	PL_1	Preload (20°F temp drop) in east strut
13	PL_2	Preload (20°F temp drop) in west strut

NOTE: (1) Includes effects of thermal moment on the east foundation wall due to 28° thermal gradient.

(2) Includes effect of pool hydrodynamic load, and pool wall horizontal inertial forces.

Table 3-2

Arkansas Power and Light Company
ANO-2 Spent Fuel Pool Evaluation
Summary of Load Definition Parameters

<u>Item</u>	<u>Description</u>	<u>Reference</u>
Pool Properties:		
Pool Water Elevation	401'-6"	6
Pool Normal Operating Temperature	150°F	6
Pool Accident Temperature	212°F	4
Pool Hydrodynamic Forces	TID 7024, App F	5
Auxiliary Building Compartment Temperatures:		
Adjacent Pool North, East and South Walls	60°F	7
Adjacent Pool West Wall	32°F	7
Inside Foundation Walls	60°F	7
Inside Cask Laydown Area	60°F	7
Inside Fuel Transfer Canal Area	60°F	7
Outside East Foundation Wall	32°F	7
Thermal Stress Free Temperature	60°F	7
Operating Conditions		
Fuel Transfer Canal	Dry	
Cask Laydown Area	Dry	
Accident Flood Conditions	EL 335' to 361'	7
Seismic Ground Accelerations		
OBE Horizontal	0.10g	1
OBE Vertical	0.067g	1
SSE Horizontal	0.20g	1
SSE Vertical	0.133g	1

4.0 FINITE ELEMENT ANALYSIS RESULTS

This section discusses the finite element analysis results; in particular, results for the controlling load case.

Section 4.1 Verification of Results

The results of the finite element analysis were examined to insure that realistic deflections and stresses existed for each load case. Also, stresses and deflections in the base slab are examined for several load cases and compared to classical solutions. In addition, the finite element results were compared to results from several other analytical models presented in Reference 7 with very good agreement. The conclusion of this process is that the finite element model is behaving in a reasonable manner.

Section 4.2 Controlling Load Case Results

Based upon examination of the results for the individual primary load cases described in the previous section, one load case was determined to be controlling, and is described further in this section. The accident thermal load, defined as 212°F inside the pool, 60°F in all other compartments except the west wall, from elevation 356 to elevation 404, and the east wall from elevation 335 to elevation 356. This load results in a gradient across the pool walls and floor equal to 152°F , with the exception of the west wall which has a gradient of 180°F .

Figure 4-1 and 4-2 are deformed geometry plots at the top of the pool and the pool floor elevation, respectively. These deformed geometry plots show the restraining effects that various parts of the structure have on the components that are being heated by the pool water. Based upon thorough investigation of the results, it is concluded that the accident thermal gradient is, by far, the controlling load case. This thermal gradient causes significant bending moments about horizontal and vertical axes, resulting in significant transverse and in-plane shear forces at several locations.

The fuel transfer canal separation wall responds to the thermal gradient by deflecting outward at the upper west corner. This response causes significant transverse shear forces at the upper east corner and the lower west corner at the bottom of the gate opening. Also, the overall temperature increase on this wall causes significant in-plane shears at the bottom of the gate opening, as a result of the restraining effect that the lower portion of the wall has on the upper portion, which is free to expand because of the gate opening.

The west wall of the pool expands outward due to the flexible nature of the north end at the fuel transfer canal gate opening. The south portion of this wall is restrained by the south wall of the pool, resulting in significant transverse shears, especially at the top south end of the west wall, and significant tensile forces in the south wall. The east and south walls respond in a similar manner, with the overall effect being significant transverse shears in the upper corners where adjacent walls restrain these components.

In general, the entire upper portion of all of the four walls except for the fuel transfer canal separation wall, experience in-plane tensile forces. This is a secondary effect,

because, if these sections yield, much of the force that has developed will be relieved, and the remaining forces and moments will be redistributed.

The base slab grows uniformly in all directions as a result of the overall temperature increase. This response results in significant in-plane horizontal tensile forces in all of the foundation walls. These foundation walls, however, are provided to primarily carry vertical load, and the fact that the sections are subjected to horizontal in-plane tensile forces is of secondary concern for the integrity of the pool. Significant transverse shears are also observed at the intersection of the foundation walls with the base mat.

Figure 4-1
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Deformed Structure Plot
Top of Pool Plan View for Controlling Load Case

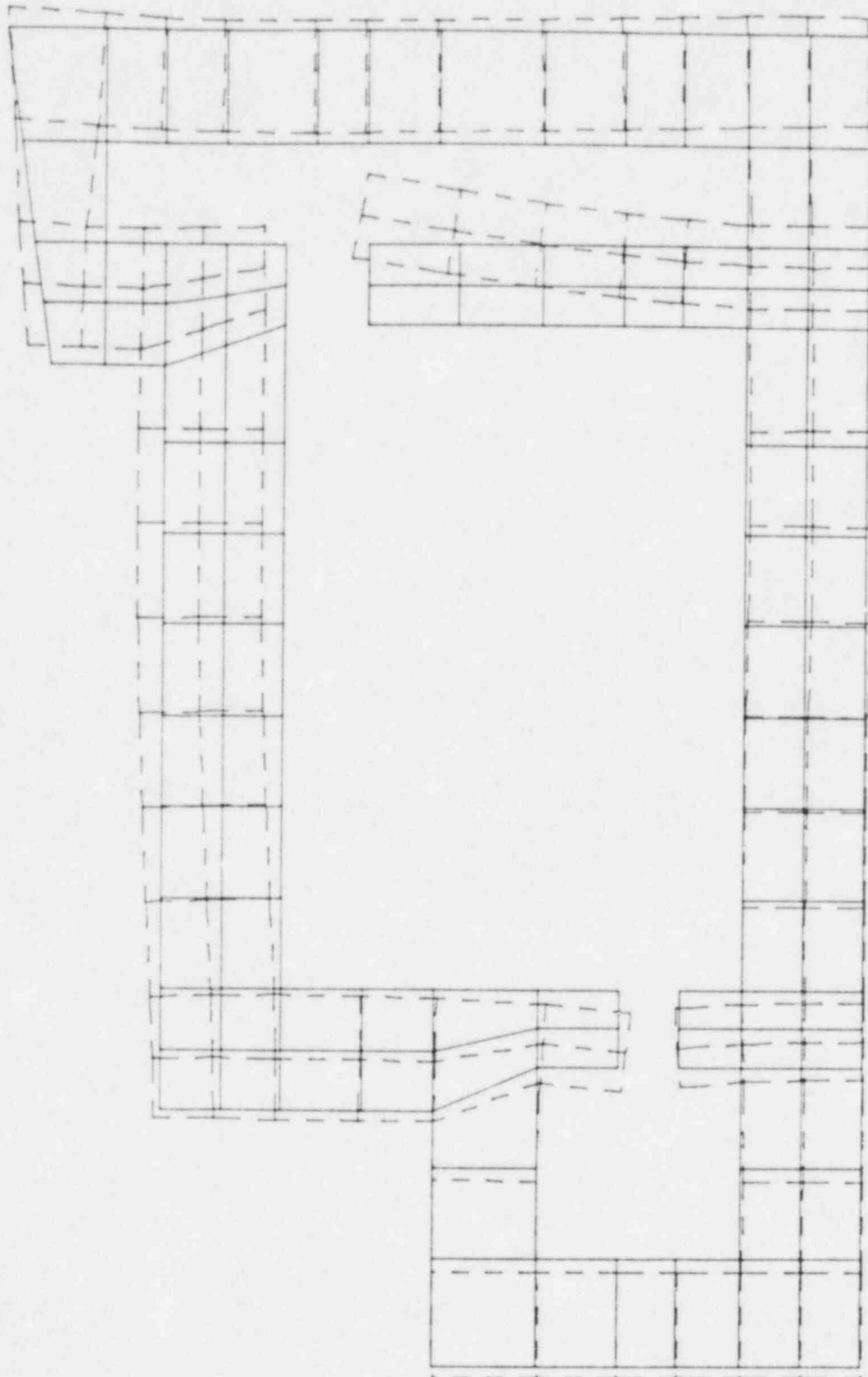
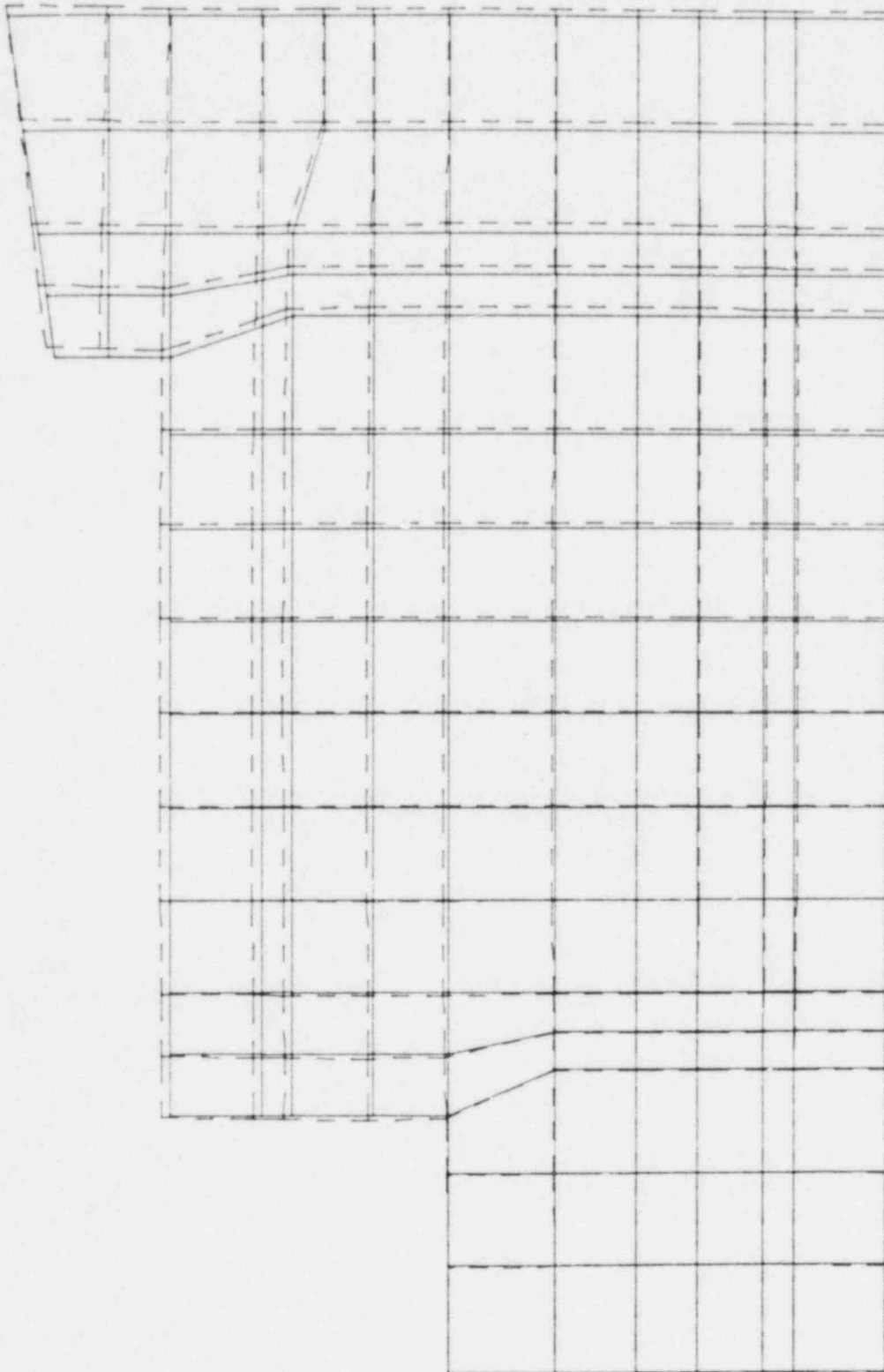


Figure 4.2

Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Deformed Structure Plot
Plan View of Pool Floor for Controlling Load Case



5.0 INITIAL POST-PROCESSING AND LOAD COMBINATION FORMULATION

This section discusses the process whereby the results of the finite element analysis are transformed as required for Code evaluation, and combined in various ways to arrive at the final load combinations specified in Reference 4.

5.1 Derivation of Section Resultant Forces And Moments

The results of the finite element analysis are in the form of normal stresses and shear stresses on the three orthogonal planes of the three-dimensional solid elements. Since the ACI Code is set up more directly to utilize section resultant forces and moments, the stresses resulting from the finite element analysis must be integrated to obtain these quantities. The areas of the pool considered in the evaluation include the pool foundation walls, the pool floor slab, and the four walls of the pool structure. Excluded from further evaluation are the outer walls of the fuel transfer canal area and the outer walls of the cask laydown area.

From the finite element analysis, the floor and walls of the pool structure have stresses defined at five locations through their thickness. These five points of stresses are integrated assuming a linear variation between points in order to produce the section resultant forces and moments for Code evaluation purposes. These resulting forces and moments include two normal forces in a plane for each integrated element, an in-plane shear force, two transverse shear force components, two bending moment components and one twisting moment component. These forces and moments are defined utilizing conventional shell theory, and are specified on a per-unit-length basis.

5.2 Composite Load Formulation

Following the finite element analysis, the first post-processing step necessitated combination of the individual primary load cases into composite loads, such that the final load combinations could be performed simply by applying the factor specified in Reference 4 to the appropriate composite case. These composite load cases are defined as deadload (including strut preload), live load, operating thermal load, accident thermal load, loads generated by 1.0g operating basis earthquake, and flood load. Table 5-1 shows the individual load cases along with the appropriate factors necessary to formulate these composite loads.

The composite deadload is obtained by combining the deadweight of concrete with the hydrostatic pressure loads, and adding to this the 80 kip compressive preload in the fuel transfer canal struts (which was obtained by applying an appropriate factor to the strut pseudo-thermal load). Live load consists of the submerged weight of the fuel racks, including their fuel complement. It would be logical to include only the fuel as live load, however, the loading is presented in Reference 9 as a total load, and as such, must conservatively be considered entirely as live load. Operating thermal, accident thermal and flood load are considered as their respective individual loads.

Reference 4 specifies that earthquake directions shall be combined by taking the square root of the sum of the squares (SRSS) of individual directional responses. Since this, by definition, does not consider the sign of the load, and since reinforced concrete must be evaluated based on the force and moment interaction for a particular section, it was not considered logical to proceed based on this simplifying specification of the Standard

Review Plan. An alternative to this is to formulate earthquake response by adding the effects of the three orthogonal directions in various permutations to produce the same results as an SRSS methodology, but maintaining the algebraic signs associated with the forces and moments. Table 5-1 indicates the factors applied to each of the individual loads to arrive at four composite earthquake loads. Four other composite earthquake loads are derived in a similar manner.

5.3 Final Load Combination Formulation

Reference 4 specifies the load combinations required to be evaluated for this class of structure. Table 5-2 shows the seven load cases that result by elimination of load combinations that are not applicable to this structure. Out of these seven load cases, load case seven has been determined to be the controlling combination. The basic reason for this conclusion is that the thermal accident load is by far the controlling load on this structure and, as such, results in the maximum load combination.

Load case seven is evaluated by including the effects of the SSE earthquake considering the eight possible seismic motion direction combinations as previously discussed. In accordance with the requirements of References 2 and 4, where it is determined that live load cancels out or reduces the effect of a particular earthquake load, live load is excluded from that combination. Also, when it is determined that deadweight, including hydrostatic, reduces or cancels out an earthquake load, deadweight is reduced by ten percent. SSE response is defined as 2.0 times OBE response. For the fuel rack reaction loads, this is a conservative assumption since Reference 9 specifies a value less than 2.0 times OBE for the SSE reaction forces.

Table 5-1
Arkansas Nuclear One-Unit 2
Spent Fuel Storage Facility Structural Evaluation
Summary of Composite Loads

Composite Loads	Load Factors										Description	
	D_c	H	F	T_o	T_a	E_{ew}	F_{ns}	D_{fr}	FR_v	FR_{ew}		FR_{ns}
$D^{(1)}$	1.0	1.0	-	-	-	-	-	-	-	-	-	Dead Load
L	-	-	-	-	-	-	-	1.0	-	-	-	Live Load
T_o	-	-	-	1.0	-	-	-	-	-	-	-	Operating Thermal Load
T_a	-	-	-	-	1.0	-	-	-	-	-	-	Accident Thermal Load
E_1	0.067	0.067	-	-	-	0.1	0.1	-	1.0	1.0	1.0	Loads Generated by
E_2	0.067	0.067	-	-	-	0.1	-0.1	-	1.0	1.0	-1.0	1.0g Operating
E_3	-0.067	-0.067	-	-	-	0.1	0.1	-	-	1.0	1.0	Basis Earthquake
E_4	-0.067	-0.067	-	-	-	0.1	-0.1	-	-	1.0	-1.0	
F	-	-	1.0	-	-	-	-	-	-	-	-	Flood Load

1) Dead Load Includes Addition of Strut Preload (Pseudo-Thermal Load) Cases with Appropriate Factors to Define an 80 kip Compressive Preload in Each Strut.

Table 5-2
Arkansas Nuclear One-Unit 2
Spent Fuel Storage Facility Structural Evaluation
Load Combination Summary Table

<u>No.</u>	<u>Load Combination</u>	<u>Reference⁽¹⁾</u>
1	$1.4D + 1.7L + 1.9E$	Load Case 2
2	$.75(1.4D + 1.7L + 1.7T_o)$	Load Case 4
3	$.75(1.4D + 1.7L + 1.7T_o + 1.9E)$	Load Case 5
4	$D + L + T_o + E'$	Load Case a
5	$D + L + T_o + F$	Load Case b
6	$D + L + T_a$	Load Case c
7	$D + L + T_a + 1.25E'$	Load Case d

Notes: (1) Reference 4 Section 3.8.4.

(2) E' Represents a load generated by .20g safe shutdown earthquake (SSE). For simplicity, this is taken conservatively as $2.0E$.

6.0 AGI CRITERIA POST-PROCESSING

This section discusses the methodology utilized to carry out the ACI Code evaluation of the spent fuel pool facility. Included in this section is a discussion of the post-processing carried out to account for the change in the moment due to thermal loading as reinforced concrete sections experience normal tensile cracking. In addition, the methods utilized to determine the acceptability of the structure relative to in-plane shear, transverse shear, and twisting moments are discussed.

6.1 Flexure and Axial Loads

Chapter 10 of Reference 2 (ACI 349-80) is the basis for qualifying the structure for combined effects of axial force and bending moment. Capacity reduction factors are taken as .9 and .7 for axial tension and compression, respectively. The restrained thermal moments from the linear structural analysis are processed to account for changes in the thermal moment magnitude as the section cracks, such that the section's curvature and static equilibrium are maintained. The relieved thermal moment is then defined as the moment required to maintain that static equilibrium and curvature for the cracked concrete section. For a given section, subjected to the combined effect of axial load and bending moment, following accepted ACI techniques, for the given magnitude of axial force, the allowable magnitude of bending moment is calculated. Table 6-1 presents the results of this evaluation for the controlling load combination for the spent fuel pool. This table identifies the critical sections for each pool and foundation component, along with the allowable bending moment associated with the section axial force, and the ratio of the actual relieved section moment to the allowable section

moment for the applied section axial force. Redistribution of force and moment was considered in regions near the top of the pool walls. This is considered logical since, if the section yields, not only will the forces and moments be redistributed, but much of the thermally-induced force and moment will be relieved. As seen from Table 6-1, all of the locations shown have significant margin relative to their ultimate strength.

Creep effects are not considered to be important since the loads associated with the normal service life of the spent fuel pool constitute a very small percentage of the ultimate strength of the concrete sections. Accident thermal and seismic loads are considered to be short duration loads and thus do not cause appreciable creep.

Figures 6-1 through 6-6 present contour plots of the bending moments and concrete and reinforcing stresses resulting from the controlling load combination. These results were obtained by relaxation of the thermal bending moment maintaining section equilibrium and curvature. These plots indicate the restraining effect that the portion of the floor slab in the fuel transfer canal has on the pool floor slab. This is due to the ambient condition in the fuel transfer canal versus accident thermal temperatures in the pool floor slab. Also, the slab below the cask lay down area causes a similar concentration of stresses near this region for the same reason. Since the pool walls and foundation do not provide as high a degree of restraint on the pool floor slab, the bending moments along the east and west walls tend to be lower than elsewhere in the floor slab. Concrete and reinforcing stresses follow the same pattern of stress distribution as their associated bending moments with the top of the slab in compression and the bottom in tension.

6.2 Evaluation for Shear and Torsion

Section 11 of Reference 2 (ACI 349-80) presents the Code requirements for evaluation for concrete structures subjected to shear and torsion. Within this Reference, it is specified that walls and slabs shall be evaluated by calculation of the section force extending in a plane across the entire width or height, and located at a distance from the face of the reaction area equal to the distance from the compressive face of the section to the centroid of the tensile steel. This section of the Code allows an averaging approach to be taken when evaluating wall and slab-type structures. Tables 6-2 and 6-3 present the results for the transverse shear force and in-plane shear force evaluation, respectively. Torsion effects are considered in the evaluation for transverse shear forces.

As seen in Table 6-2, several areas of the structure are close to their allowable values. Specifically, regions of the pool walls near the corners have high transverse shear. The east and west walls of the pool have been designed with a heavily-reinforced area at the top. One function of this embedded beam is to carry the offset crane loads, however, the shear reinforcing provided in this area also serves to carry the transverse shears, and provides a significant margin.

Table 6-3 shows the results of the in-plane shear evaluation. In accordance with ACI methodology, sections for in-plane shear evaluation are defined at locations that are not closer to the base of the walls than one-half the wall height or length. The only region that is close to the Code capacity is the section of the fuel transfer canal wall just above the bottom of the gate opening. This is due primarily to the restraining effect that the

lower portion of the wall has on the free edge of the upper portion at the gate opening when subjected to thermal expansion.

TABLE 6-1
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment(2,4)	Section Allowable Moment(3)	Moment Code Ratio
Pool Floor Slab: (AFPSTA2A2-11)				
East - West Section at 1/3 span (Element 330)	-49.67	893.5	1646.	0.54
North - South Section at Mid-span (Element 320)	-29.67	810.5	1670.	0.49
Pool Foundation: (AFPSTA2A2-12)				
North Wall, Horizontal Section at Top (Element 1367)	-13.40	-165.4	-904.5	0.18
East Wall, Horizontal Section at Top (Element 2878)	-7.222	181.1	599.2	0.30
West Wall, Horizontal Section at Top (Element 2857)	-27.69	315.4	869.7	0.36

Units: Kips/Inch, Kip-inches/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
 2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 3) Allowable moment is based on strength design method per ACI 349/80.
 4) T_a moments are relieved, maintaining equilibrium and curvature of section.

Table 6-1 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment(2,4)	Section Allowable Moment(3)	Moment Code Ratio
West Pool Wall: (AFPSTA2A2-10)				
Vertical Section at Bottom Mid-span (Element 2305)	-20.80	849.6	1771.	0.48
Horizontal Section near Bottom North End (Element 2808)	-32.17	922.6	1935.	0.48
Vertical Section at Top Mid-span (Average Elements 6304,5804 5304,4804 - AFPSTA2A2-14)	13.88	206.8	879.7	0.24

Units: Kips/Inch, Kip-inches/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
3) Allowable moment is based on strength design method per ACI 349/80.
4) T_a moments are relieved, maintaining equilibrium and curvature of section.

Table 6-1 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment(2,4)	Section Allowable Moment(3)	Moment Code Ratio
East Pool Wall: (AFPSTA2A2-07)				
Vertical Section at Bottom Mid-span (Element 2327)	-44.48	901.5	1750.	0.52
Horizontal Section at Bottom South Corner (Element 2329)	-32.00	902.4	1711.	0.53
Vertical Section at Top Center Span (Average Elements 6326, 5826, 5326, 4826 - AFPSTA2A2-14)	14.18	234.2	875.2	0.27

Units: Kips/Inch, Kip-inches/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
3) Allowable moment is based on strength design method per ACI 349/80.
4) T_a moments are relieved, maintaining equilibrium and curvature of section.

Table 6-1 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment(2,4)	Section Allowable Moment(3)	Moment Code Ratio
Fuel Transfer Canal Separation Wall: (AFPSTA2A2-09)				
Vertical Section Below Elevation of Bottom of Gate Opening (Element 3313)	-40.95	518.4	768.3	0.68
Horizontal Section at Bottom of Wall (Element 2813)	-23.83	403.9	758.3	0.56
Vertical Section at West End of Wall Above Elevation of Bottom of Gate Opening (Element 3818)	-11.63	267.8	447.7	0.60
Horizontal Section at West End of Wall Above Elevation of Bottom of Gate Opening (Element 3818)	-26.31	379.2	680.7	0.56

Units: Kips/Inch, Kip-inches/Inch

- Notes:
- 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
 - 2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 - 3) Allowable moment is based on strength design method per ACI 349/80.
 - 4) T_a moments are relieved, maintaining equilibrium and curvature of section.

Table 6-1 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment ^(2,4)	Section Allowable Moment ⁽³⁾	Moment Code Ratio
Cask Laydown Separation Wall: (AFPSTA2A2-08)				
Vertical Section Below Elevation of Bottom of Gate Opening (Element 3335)	-36.39	469.1	653.9	0.72
Horizontal Section at Bottom Mid-span (Element 2335)	-35.86	405.7	689.7	0.59
Vertical Section at East End of Wall Above Elevation Of Bottom of Gate Opening (Element 3834)	-13.99	205.3	392.2	0.52

Units: Kips/Inch, Kip-inches/Inch

- Notes:
- 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
 - 2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 - 3) Allowable moment is based on strength design method per ACI 349/80.
 - 4) T_a moments are relieved, maintaining equilibrium and curvature of section.

Table 6-1 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Controlling Section Resultant Moments (1)

Location	Section Axial Force	Section Resultant Moment(2,4)	Section Allowable Moment(3)	Moment Code Ratio
Pool South Wall: (AFPSTA2A2-13)				
Vertical Section at Bottom East Corner (Element 2338)	-15.77	745.8	1787.	0.42
Horizontal Section at Bottom East Corner (Element 2338)	-31.36	837.8	1703.	0.49
Vertical Section at Top West End (Average Elements 6339,5839,5339,4839 - AFPSTA2A2-15)	6.866	127.7	1543.	0.08

Units: Kips/Inch, Kip-inches/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
3) Allowable moment is based on strength design method per ACI 349/80.
4) T_a moments are relieved, maintaining equilibrium and curvature of section.

TABLE 6-2
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant Transverse Shear Forces (1)

Location	Section Shear ⁽²⁾	Allowable Section Shear ⁽³⁾	Code Shear Ratio
Pool Floor Slab: (AFPSTA2A2-06)			
North-South Section at West Edge (Average Elements 300 thru 306)	-2.083	-5.627	0.37
East-West Section at South Edge (Average Elements 300,307,314,321, 328,335)	4.346	15.89	0.27
Pool Foundation: (AFPSTA2A2-06)			
North Foundation Wall, Horizontal Section at Top (Average Elements 2367 thru 2371)	3.455	11.88	0.29
East Foundation Wall, Horizontal Section at Top (Average Elements 2374 thru 2381)	1.631	6.251	0.26

Units: Kips/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Shear forces are linearly interpolated to a distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel.
3) Allowable shear is based on strength design method per ACI 349/80.

TABLE 6-2 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant Transverse Shear Forces (1)

Location	Section Shear(2)	Allowable Section Shear(3)	Code Shear Ratio
Pool Foundation: (AFPSTA2A2-06)			
West Foundation Wall, Horizontal Section at Top (Average Elements 2350 thru 2361)	3.073	10.63	0.29
West Pool Wall: (AFPSTA2A2-06)			
Vertical Section at Top North Corner (Element 6308)	7.271	52.16	0.14
Horizontal Section at Mid-Height (Average Elements 3802 thru 3808)	-2.915	-6.116	0.48
Horizontal Section at Top (Average Elements 5802 thru 5808)	-5.802	-6.366	0.91

Units: Kips/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Shear forces are linearly interpolated to a distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel.
3) Allowable shear is based on strength design method per ACI 349/80.

TABLE 6-2 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant Transverse Shear Forces (1)

Location	Section Shear ⁽²⁾	Allowable Section Shear ⁽³⁾	Code Shear Ratio
East Pool Wall: (AFPSTA2A2-06)			
Vertical Section at Top Mid-Length (Element 6326)	10.56	33.15	0.32
Horizontal Section Near Top (Average Elements 5823 thru 5829)	-6.295	-7.324	0.86
Fuel Transfer Canal Separation Wall: (AFPSTA2A2-06)			
Vertical Section at West End Below Bottom of Gate Opening (Element 3313)	-5.263	-10.76 ⁽⁴⁾	0.49
Horizontal Section at Bottom of of Wall (Average Elements 2313 thru 2318)	2.362	13.50	0.18

Units: Kips/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Shear forces are linearly interpolated to a distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel.
3) Allowable shear is based on strength design method per ACI 349/80.
4) Through bolts not utilized to increase shear capacity.

TABLE 6-2 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant Transverse Shear Forces (1)

Location	Section Shear ⁽²⁾	Allowable Section Shear ⁽³⁾	Code Shear Ratio
Fuel Transfer Canal Separation Wall: (AFPSTA2A2-06)			
Vertical Section at Top East Corner (Average Elements 6318 and 5818)	3.721 ⁽⁴⁾	4.660	0.80
Horizontal Section at West End Above Bottom of Gate Opening (Element 3814)	12.48 ⁽⁴⁾	21.23	0.59
East Strut Punching Shear	1.791	8.380	0.21

Units: Kips/Inch

- Notes:
- 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
 - 2) Shear forces are linearly interpolated to a distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel.
 - 3) Allowable shear is based on strength design method per ACI 349/80.
 - 4) Transverse shear adjusted based upon cracked section equilibrium moment gradient.

TABLE 6-2 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant Transverse Shear Forces (1)

Location	Section Shear ⁽²⁾	Allowable Section Shear ⁽³⁾	Code Shear Ratio
Cask Laydown Area Separation Wall: (AFPSTA2A2-06)			
Vertical Section Below Gate Opening (Average Elements 2335,2835,3335)	1.845	3.737	0.49
Horizontal Section at Bottom of Wall (Average Elements 2334,2335,2336)	2.041	10.75	0.19
Pool South Wall: (AFPSTA2A2-06)			
Vertical Section at Top of Wall (Average Elements 5839,6339)	2.885 ⁽⁴⁾	3.208	0.90

Units: Kips/Inch

- Notes: 1) NUREG-0800 Load Combination ($D + L + T_a + 1.25E'$)
2) Shear forces are linearly interpolated to a distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel.
3) Allowable shear is based on strength design method per ACI 349/80.
4) Transverse shear adjusted based upon cracked section equilibrium moment gradient.

TABLE 6-3
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant In-plane Shear Forces (1)

Location	Section Shear	Allowable Section Shear(2)	Code Shear Ratio
Pool Floor Slab: (AFPSTA2A2-06)			
North-South Section at Mid-length (Average Elements 314 thru 320)	5.671	26.76	0.21
East-West Section at Mid-length (Average Elements 303,310,317,324 331,338)	4.185	27.98	0.15
Pool Foundation: (AFPSTA2A2-06)			
North Wall Section Near Top (Average Elements 2367 thru 2371)	4.629	11.44	0.40
East Wall Section at Top (Average Elements 2874 thru 2881)	18.53	24.54	0.76
West Wall Section at Top (Average Elements 2850 thru 2861)	-8.096	-12.59	0.64
West Pool Wall: (AFPSTA2A2-06)			
Section Near Top (Average Elements 5302 thru 5308)	5.370	29.84	0.18

Units: Kips/Inch

Notes: 1) NUREG-0800 Load Combination (D + L + T_a + 1.25E')
2) Allowable shear is based on strength design method per ACI 349/80.

6.16

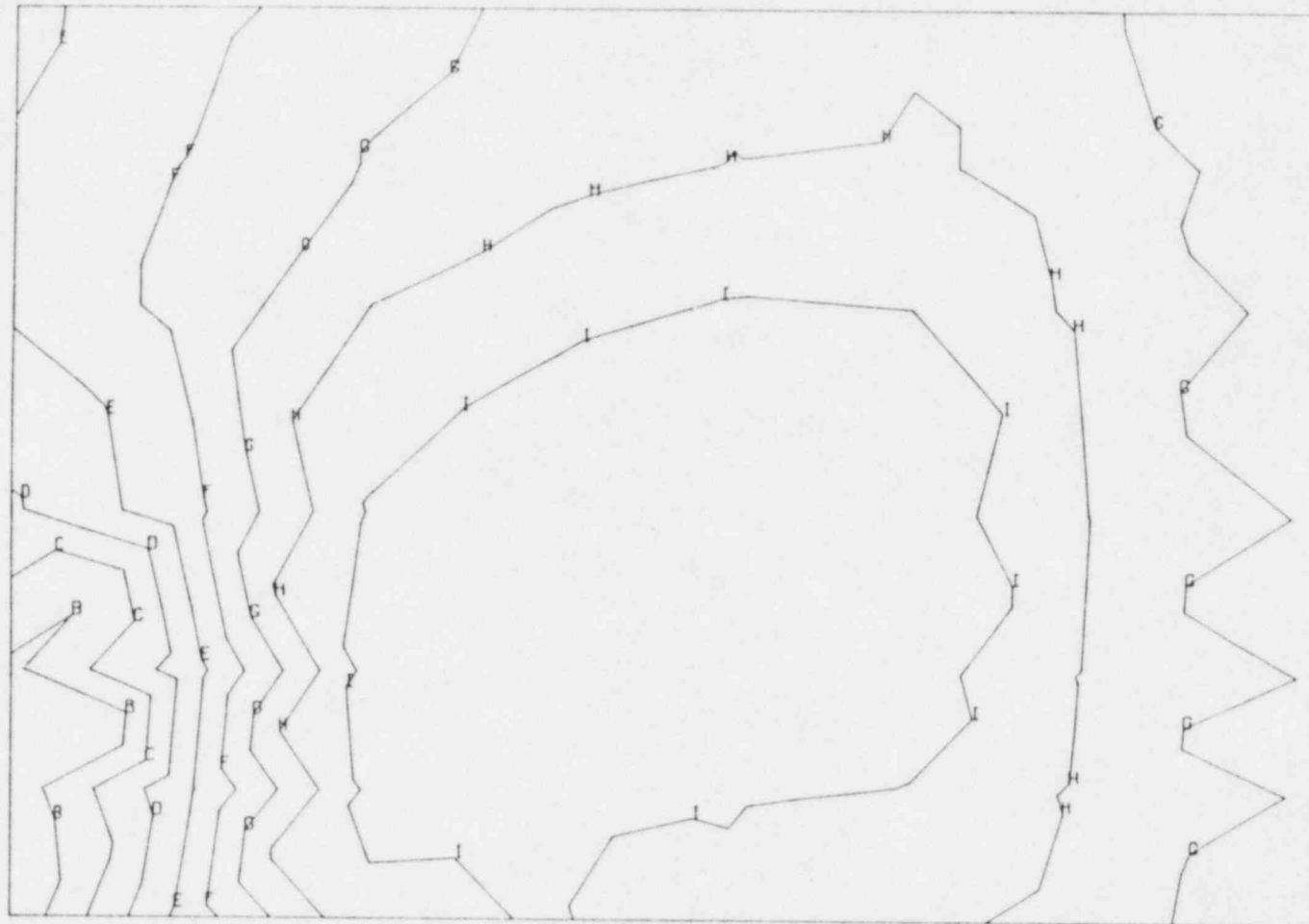
TABLE 6-3 (continued)
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Spent Fuel Storage Facility Evaluation
Tabulation of Resultant In-plane Shear Forces (1)

Location	Section Shear	Allowable Section Shear ⁽²⁾	Code Shear Ratio
East Pool Wall: (AFPSTA2A2-06)			
Section Near Top (Average Elements 5323 thru 5329)	0.707	24.54	0.03
Fuel Transfer Canal Separation Wall: (AFPSTA2A2-06)			
Lower Wall Below Bottom of Gate Opening (Average Elements 3313 thru 3318)	9.222	21.12	0.44
Upper Wall Above Bottom of Gate Opening (Average Elements 4314 thru 4318)	11.80	12.55	0.94
Cask Laydown Area Separation Wall: (AFPSTA2A2-06)			
Section Below Bottom of Gate Opening (Average Elements 3334 thru 3336)	3.706	18.04	0.21
Pool South Wall: (AFPSTA2A2-06)			
Section Near Top of Wall (Average Elements 5838, 5839)	9.319	29.85	0.31

Units: Kips/Inch

- Notes: 1) NUREG-0800 Load Combination $D + L + T_a + 1.25E'$
2) Allowable shear is based on strength design method per ACI 349/80.

FIGURE 6-1
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Bending Moments
Causing North-South Direction Stresses



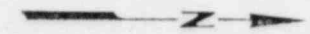
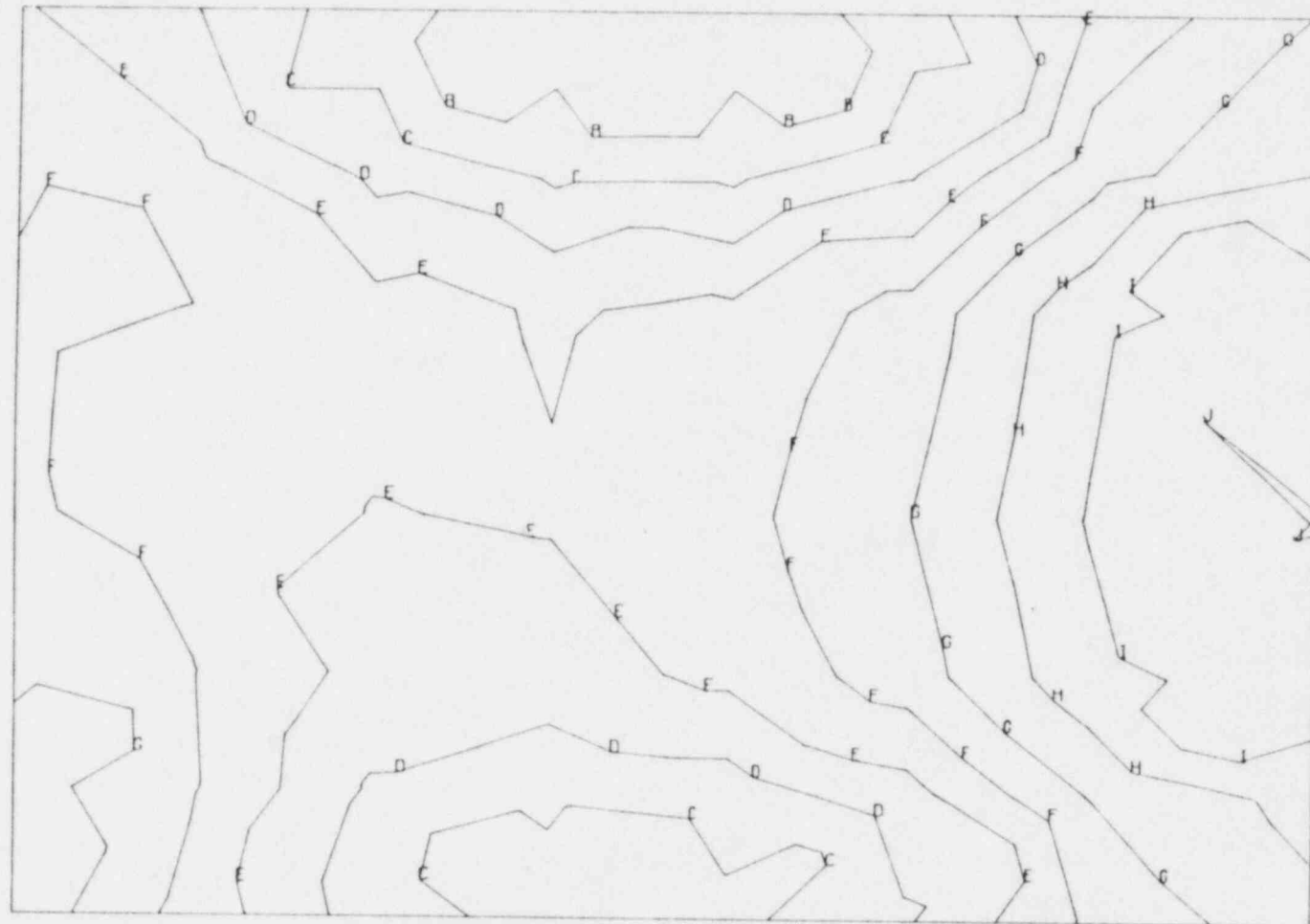
Units: in-lbs

CONTOUR LEVELS	
MIN	.64722E+06
A	.64722E+06
B	.67568E+06
C	.70414E+06
D	.73260E+06
E	.76106E+06
F	.78952E+06
G	.81798E+06
H	.84643E+06
I	.87489E+06
J	.90335E+06
MAX	.90335E+06

- Notes: 1) Positive moment causes tension on bottom of slab.
2) Data from AFPSTA2A2-11

APL-02-013
November 24, 1982

FIGURE 6-2
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Bending Moments
Causing East-West Direction Stresses



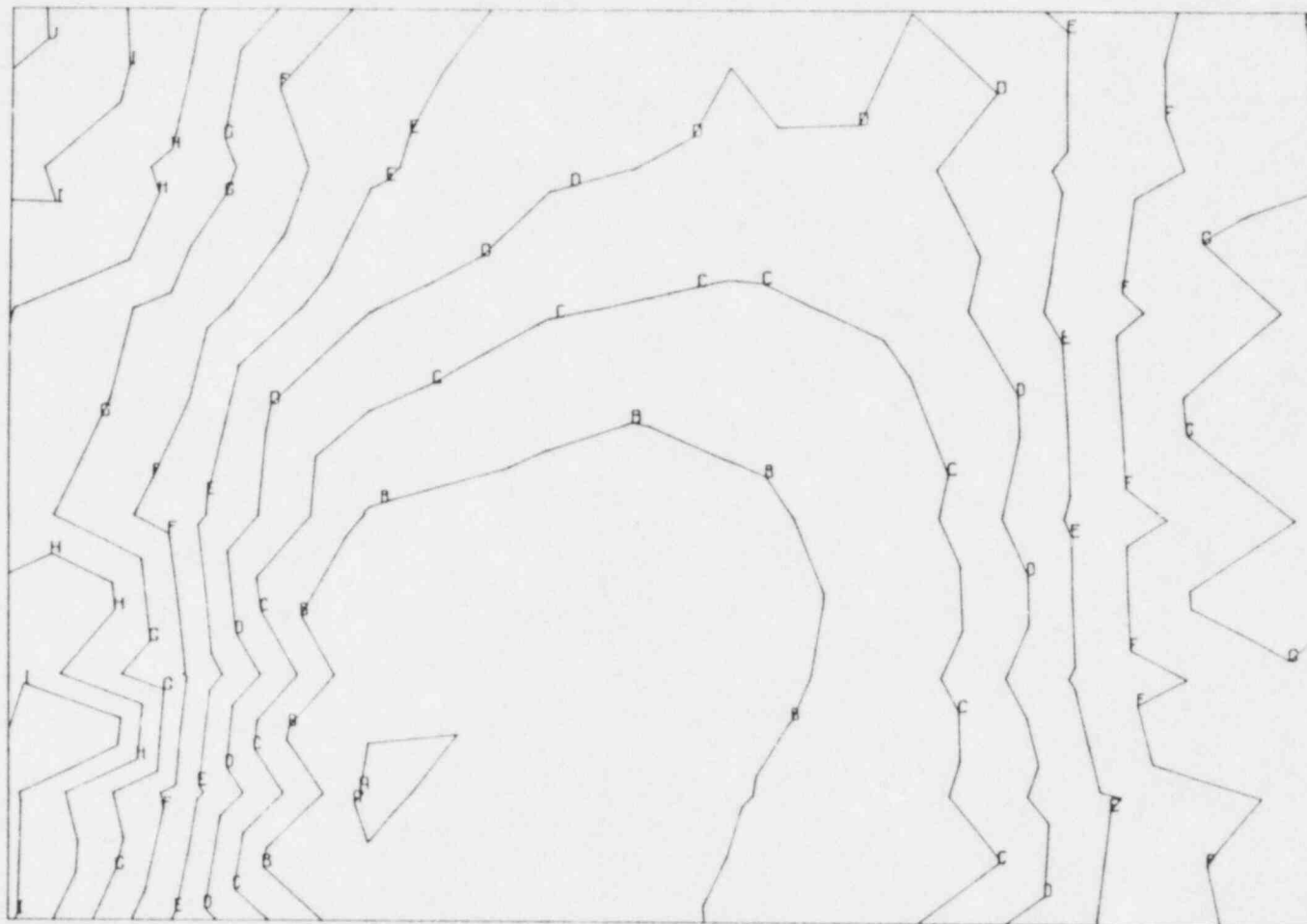
Units: in-lbs

CONTOUR LEVELS	
MIN	.48101E+06
A	.48101E+06
B	.51761E+06
C	.55422E+06
D	.59082E+06
E	.62743E+06
F	.66404E+06
G	.70064E+06
H	.73725E+06
I	.77386E+06
J	.81046E+06
MAX	.81046E+06

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- Notes: 1) Positive moment causes tension on bottom of slab.
2) Data from AFPSTA2A2-11

FIGURE 6-3
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Concrete Stresses
In North-South Direction on Top of Slab



Units:psi

CONTOUR LEVELS

MIN -1682.0

A -1682.0

B -1643.5

C -1604.9

D -1566.4

E -1527.9

F -1489.4

G -1450.9

H -1412.4

I -1373.9

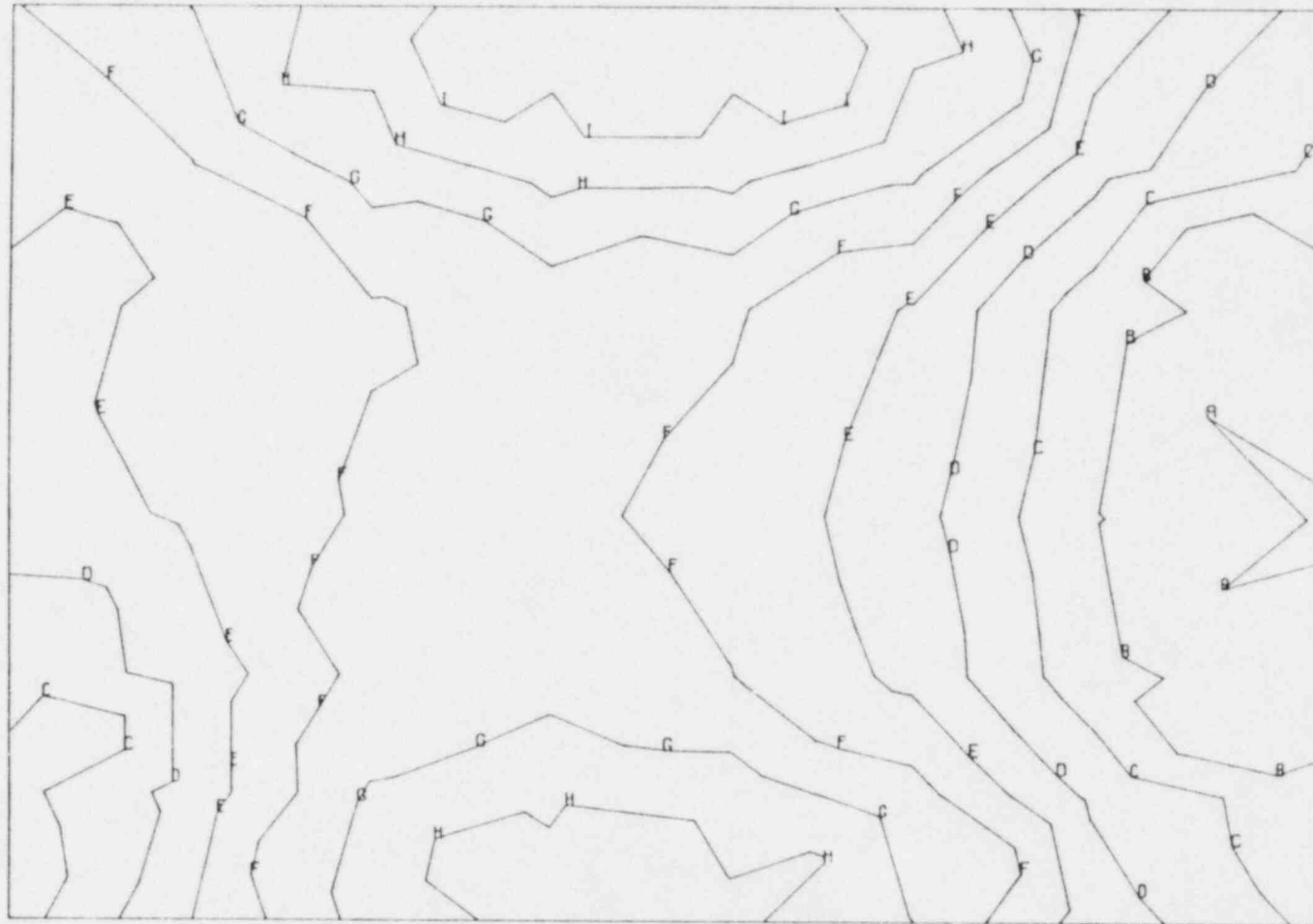
J -1335.4

MAX -1335.4

APL-02-013
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Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

FIGURE 6-4
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Concrete Stresses
In East-West Direction



Units:psi

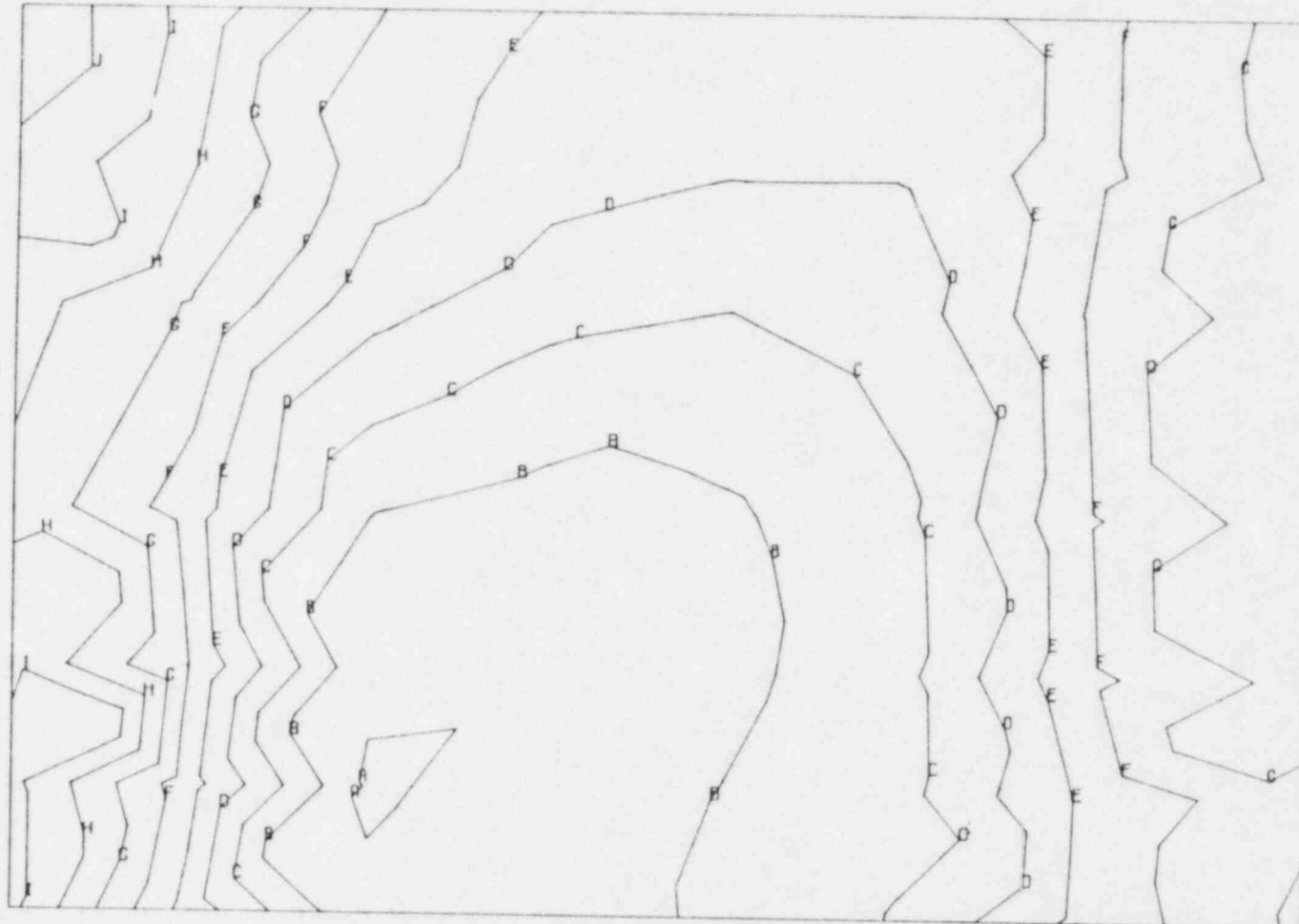
CONTOUR LEVELS

MIN	-1395.7
A	-1395.7
B	-1327.8
C	-1259.9
D	-1192.0
E	-1124.1
F	-1056.1
G	-988.22
H	-920.30
I	-852.38
J	-784.46
MAX	-784.46

APL-02-013
November 24, 1982

- Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

FIGURE 6-5
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Top North-South Reinforcing



Units:psi

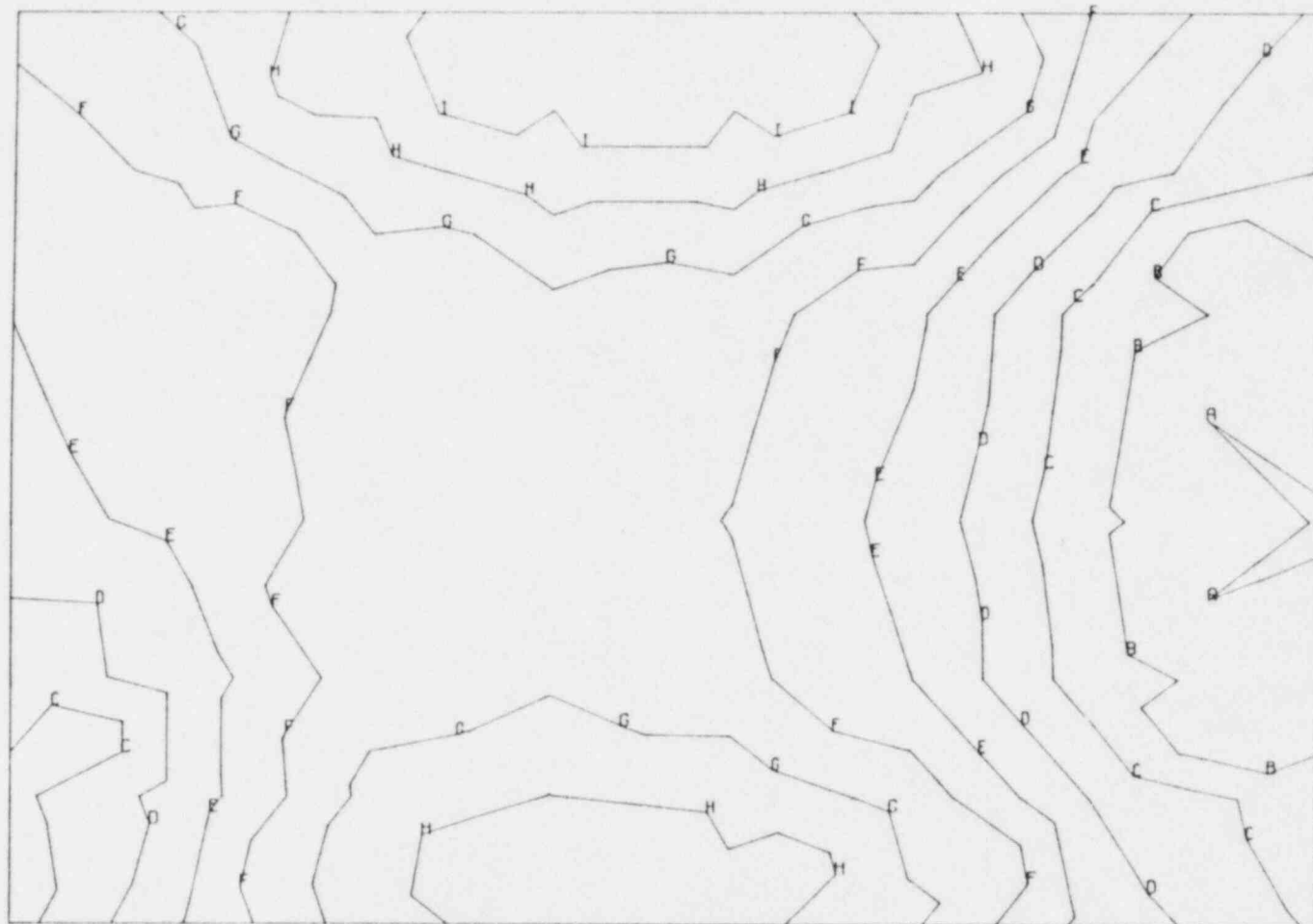
CONTOUR LEVELS

MIN	-23020.
A	-23020.
B	-22373.
C	-21727.
D	-21081.
E	-20435.
F	-19789.
G	-19143.
H	-18497.
I	-17851.
J	-17205.
MAX	-17205.

APL-02-013
November 24, 1982

- Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

FIGURE 6-6
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Top East-West Reinforcing

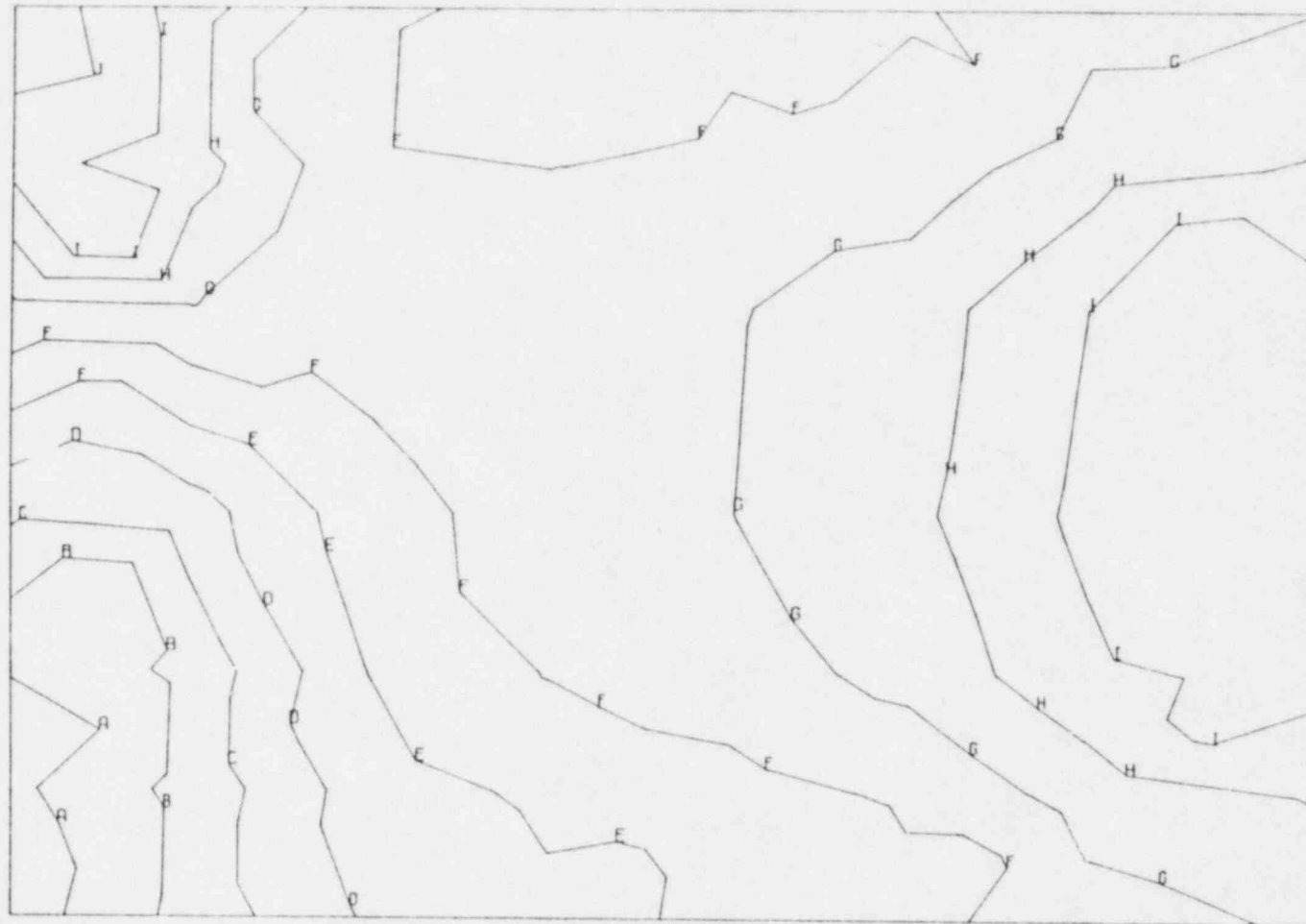


Units:psi
CONTOUR LEVELS
MIN -18367.
A -18367.
B -17352.
C -16337.
D -15322.
E -14307.
F -13292.
G -12277.
H -11262.
I -10247.
J -9232.3
MAX -9232.3

Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

APL-02-013
November 24, 1982

FIGURE 6-7
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Bottom North-South Reinforcing



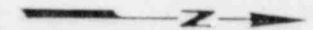
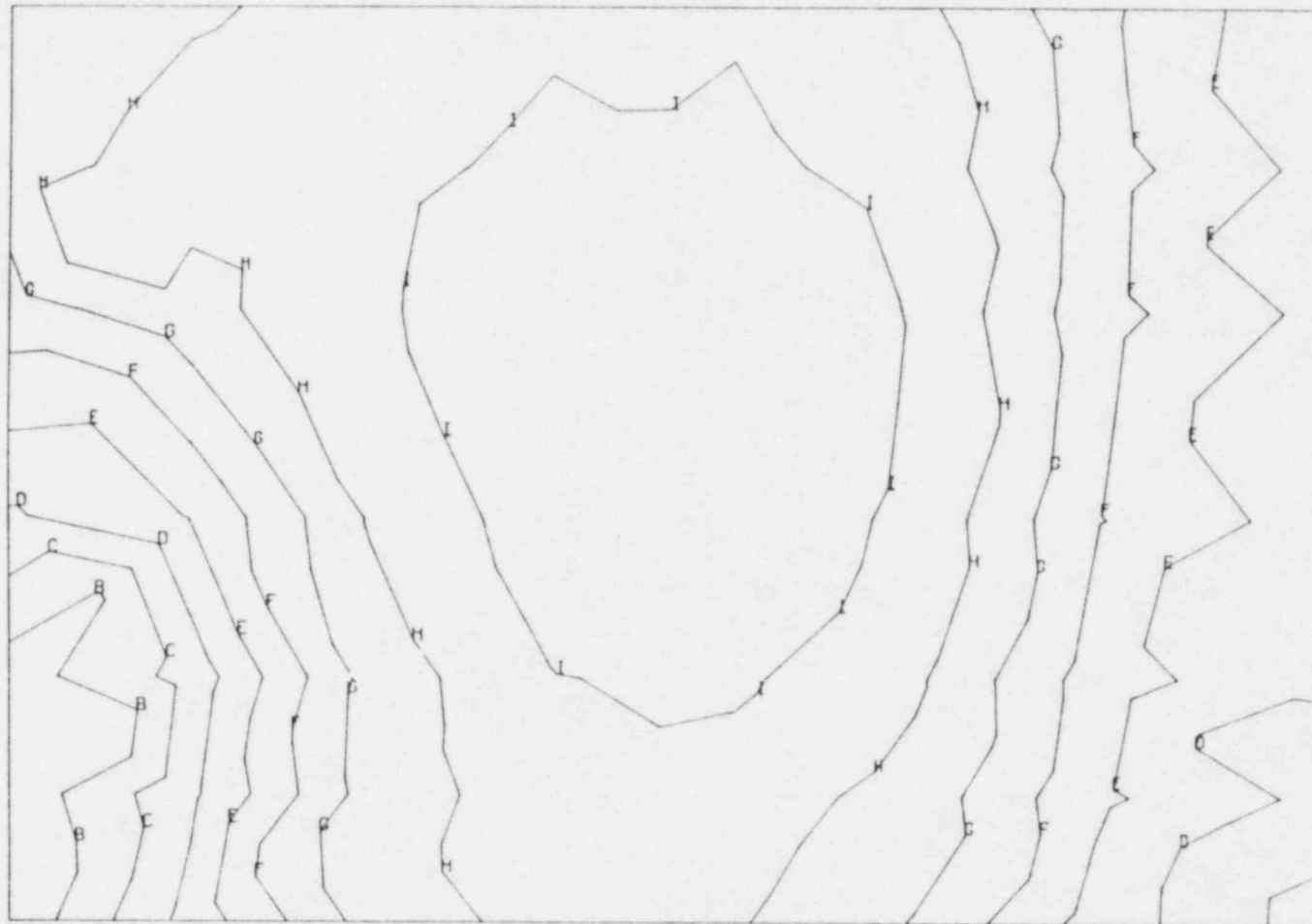
Units:psi

CONTOUR LEVELS	
MIN	1271.2
A	1271.2
B	1999.2
C	2727.3
D	3455.3
E	4183.4
F	4911.4
G	5639.4
H	6367.5
I	7095.5
J	7823.5
MAX	7823.5

APL-02-013
November 24, 1982

- Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

FIGURE 6-8
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Bottom East-West Reinforcing



Units:psi

CONTOUR LEVELS	
MIN	5111.4
A	5111.4
B	6180.9
C	7250.4
D	8319.8
E	9389.3
F	10459.
G	11528.
H	12598.
I	13667.
J	14737.
MAX	14737.

APL-02-013
November 24, 1982

- Notes: 1) Positive stresses denote tension.
2) Data from AFPSTA2A2-11

7.0 MISCELLANEOUS LOADINGS AND OTHER EFFECTS

This section discusses the evaluation of the pool liner plate and horizontal reinforcing in the pool walls, and addresses miscellaneous loading conditions.

7.1 Liner Plate Evaluation

Reference 7 discusses the calculations carried out to evaluate the adequacy of the liner plate. This evaluation considered the effect of differential coefficient of thermal expansion of the liner plate versus the concrete for the accident thermal load case. It has been shown by experience that this loading is, by far, the controlling load on the liner plate.

The evaluation in Reference 7 was carried out considering the load-deflection characteristics of the anchors, and the interaction between the stiffnesses of the liner plate panels and these anchors. This evaluation also addressed the possibility that there is a buckled liner plate in series with the unbuckled liner plates being evaluated. Based on the evaluation, it was determined that a factor of safety of 4.3 exists for the liner plate. Additional loads associated with the new horizontal fuel rack reactions are negligible when compared to the thermal effects, and in view of the substantial safety factor involved, are not of concern.

7.2 Wall Horizontal Reinforcing.

Reference 10 discusses the integrity test performed on the spent fuel pool to demonstrate that the horizontal reinforcing in the walls is adequate, even though the reinforcement development length was not as great as was desired. This test report verifies that the pool structure is satisfactory to carry loads associated with dead weight and hydrostatic load. Since the accident thermal load introduces a condition where the inside surface of the pool is in compression at the corners, whereas for the hydrostatic load, the outside surface at the corners is in compression, the conclusions from the structural integrity test report are unchanged by considering the accident thermal load. Since the increased slab load associated with addition of high-density racks does not affect the horizontal reinforcing of the walls, it is concluded that horizontal wall reinforcing remains adequate.

7.3 Miscellaneous Loads

Several loads have not been explicitly addressed in this report since they are not appropriate for this evaluation or since they have been eliminated by other licensing considerations. These loads include postulated cask drop, rack uplift, fuel drop, and heavy loads handling. The question of cask drop and heavy loads handling has been addressed previously by Arkansas Power and Light Company. Rack uplift and the associated impact loading have not been evaluated at this time since they are still under development by the fuel rack vendor, and fuel rod drop is to be evaluated by fuel rack vendor. However, in view of the significant reserve capacity of the pool floor to resist additional shear forces and bending moments, it is reasonable to assume that these

postulated loading conditions will not affect the conclusion that the structure is adequate to resist the applied loads.

8.0 CONCLUSIONS

Based on the results presented in Section 6, it is concluded that the spent fuel pool structure is adequate to carry the additional loadings associated with high density fuel storage racks. In addition, it is believed that the pool will be adequate for higher loads due to full fuel consolidation, however, this condition has not been formally evaluated. Since the primary effect of additional fuel is to increase the forces and moments in the base slab and foundation, and these components already have significant margin, as seen in the Section 6 tables and contour plots, SDT does not believe that additional loading due to full consolidation will present a problem.

9.0 REFERENCES

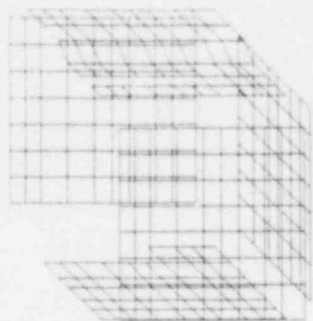
1. "Structural Design Criteria for the Arkansas Power and Light Company, Arkansas Nuclear One-Unit 2, Job 6600-2," Bechtel Power Corporation, Revision 2, January 28, 1976.
2. ACI Standard, "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-80)," American Concrete Institute, April 1981.
3. Troxel, Davis and Kelly, "Composition and Properties of Concrete," McGraw-Hill, 1968.
4. NUREG-0800, "Standard Review Plan for Review of Safety Analysis Reports for Nuclear Power Plants," Revision 1, U.S. Nuclear Regulatory Commission, July 1981.
5. TID-7024, "Nuclear Reactors and Earthquakes," U.S. Atomic Energy Commission, Washington D.C., August 1963.
6. Arkansas Nuclear One - Unit 2, Operating Procedure 2104.6, "Fuel Pool System Operation, Revision O, May 9, 1981.
7. Bechtel Calculations 2.4.6.2, Job 6600-2, "AP&L Auxiliary Building."
8. Specification AP&L-C-2502, "Technical Specifications for Earthquake Resistance Design of Equipment Located in the Auxiliary Building for the Arkansas Nuclear One Unit 2 Power Plant. "Arkansas Power and Light Company, Little Rock, Arkansas, Revision 1, 1982.
9. Westinghouse Electric Corporation Letter CPE-82-173. "AP&L Unit 2 Preliminary Static and Seismic Loads for Revised Poison Option," dated August 2, 1982.
10. Bechtel Report, "Arkansas Power 7 Light Company, Arkansas Nuclear One-Unit 2, Spent Fuel Pool Structural Integrity Test Report," November 1976.
11. STARDYNE User Information Manual, Control Data Corporation, Revision C, 1980.
12. American Institute of Steel Construction, "Manual of Steel Construction," Seventh Edition.

APL-02-013
November 24, 1982

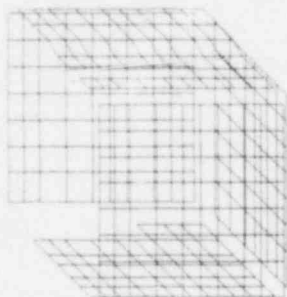
APPENDIX
ARKANSAS I NUCLEAR ONE - UNIT 2
SPENT FUEL POOL
FINITE ELEMENT MODEL

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

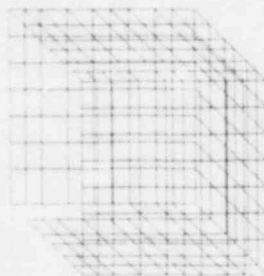
ISOMETRIC VIEWS OF SURFACE MEMBRANE ELEMENTS



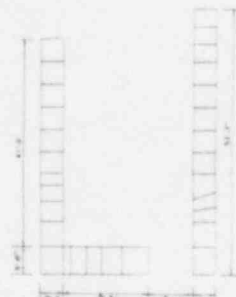
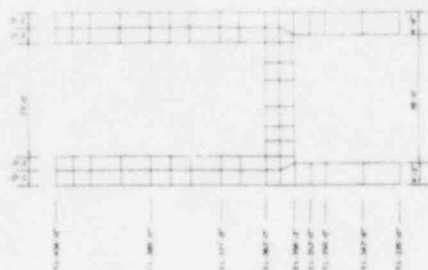
OUTER MEMBRANE



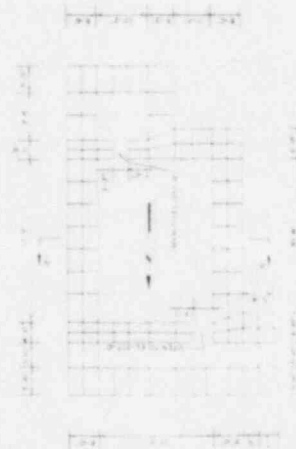
MIDDLE MEMBRANE



INNER MEMBRANE



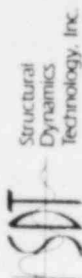
PLAN AT ELEVATION 335'-0"



PLAN AT ELEVATION 404'-0"

FIGURE 2

KEY DIAGRAMS AND DIMENSIONS



SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

NODE NUMBERS

1028	1028	1027	1026	1025	1024	1023
1018	1017	1016	1015	1014	1013	1012
1008	1007	1006	1005	1004	1003	1002
1001	1000	999	998	997	996	995
985	984	983	982	981	980	979
972	971	970	969	968	967	966
959	958	957	956	955	954	953
946	945	944	943	942	941	940
933	932	931	930	929	928	927
910	909	908	907	906	905	904
897	896	895	894	893	892	891
874	873	872	871	870	869	868
861	860	859	858	857	856	855
848	847	846	845	844	843	842
835	834	833	832	831	830	829
822	821	820	819	818	817	816
809	808	807	806	805	804	803
796	795	794	793	792	791	790
783	782	781	780	779	778	777
770	769	768	767	766	765	764
757	756	755	754	753	752	751
744	743	742	741	740	739	738
731	730	729	728	727	726	725
718	717	716	715	714	713	712
705	704	703	702	701	700	699
686	685	684	683	682	681	680
673	672	671	670	669	668	667
660	659	658	657	656	655	654
647	646	645	644	643	642	641
634	633	632	631	630	629	628
621	620	619	618	617	616	615
608	607	606	605	604	603	602
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98	97	96	95	94	93	92
85	84	83	82	81	80	79
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46	45	44	43	42	41	40
33	32	31	30	29	28	27
20	19	18	17	16	15	14
7	6	5	4	3	2	1

INSIDE SURFACE

1028	1028	1027	1026	1025	1024	1023
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1008	1007	1006	1005	1004	1003	1002
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46	45	44	43	42	41	40
33	32	31	30	29	28	27
20	19	18	17	16	15	14
7	6	5	4	3	2	1

MIDDLE SURFACE

1028	1027	1026	1025	1024	1023	1022
1018	1017	1016	1015	1014	1013	1012
1008	1007	1006	1005	1004	1003	1002
1001	1000	999	998	997	996	995
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972	971	970	969	968	967	966
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98	97	96	95	94	93	92
79	78	77	76	75	74	73
66	65	64	63	62	61	60
47	46	45	44	43	42	41
34	33	32	31	30	29	28
21	20	19	18	17	16	15
8	7	6	5	4	3	2
1	0	0	0	0	0	0

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

CURE ELEMENTS

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

MIDDLE LAYER

101	102	103	104	105	106	107	108	109	110
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121	122	123	124	125	126	127	128	129	130
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161	162	163	164	165	166	167	168	169	170
171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190
191	192	193	194	195	196	197	198	199	200

OUTER LAYER

SURFACE MEMBRANE ELEMENTS

101	102	103	104	105	106	107
108	109	110	111	112	113	114
115	116	117	118	119	120	121
122	123	124	125	126	127	128
129	130	131	132	133	134	135
136	137	138	139	140	141	142
143	144	145	146	147	148	149
150	151	152	153	154	155	156
157	158	159	160	161	162	163
164	165	166	167	168	169	170

MIDDLE SURFACE

171	172	173	174	175	176	177
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192	193	194	195	196	197	198
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220	221	222	223	224	225	226
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234	235	236	237	238	239	240

MIDDLE SURFACE

241	242	243	244	245	246	247
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255	256	257	258	259	260	261
262	263	264	265	266	267	268
269	270	271	272	273	274	275
276	277	278	279	280	281	282
283	284	285	286	287	288	289
290	291	292	293	294	295	296
297	298	299	300	301	302	303
304	305	306	307	308	309	310

OUTER SURFACE

FIGURE 4
EAST WALL ELEMENT NUMBERS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

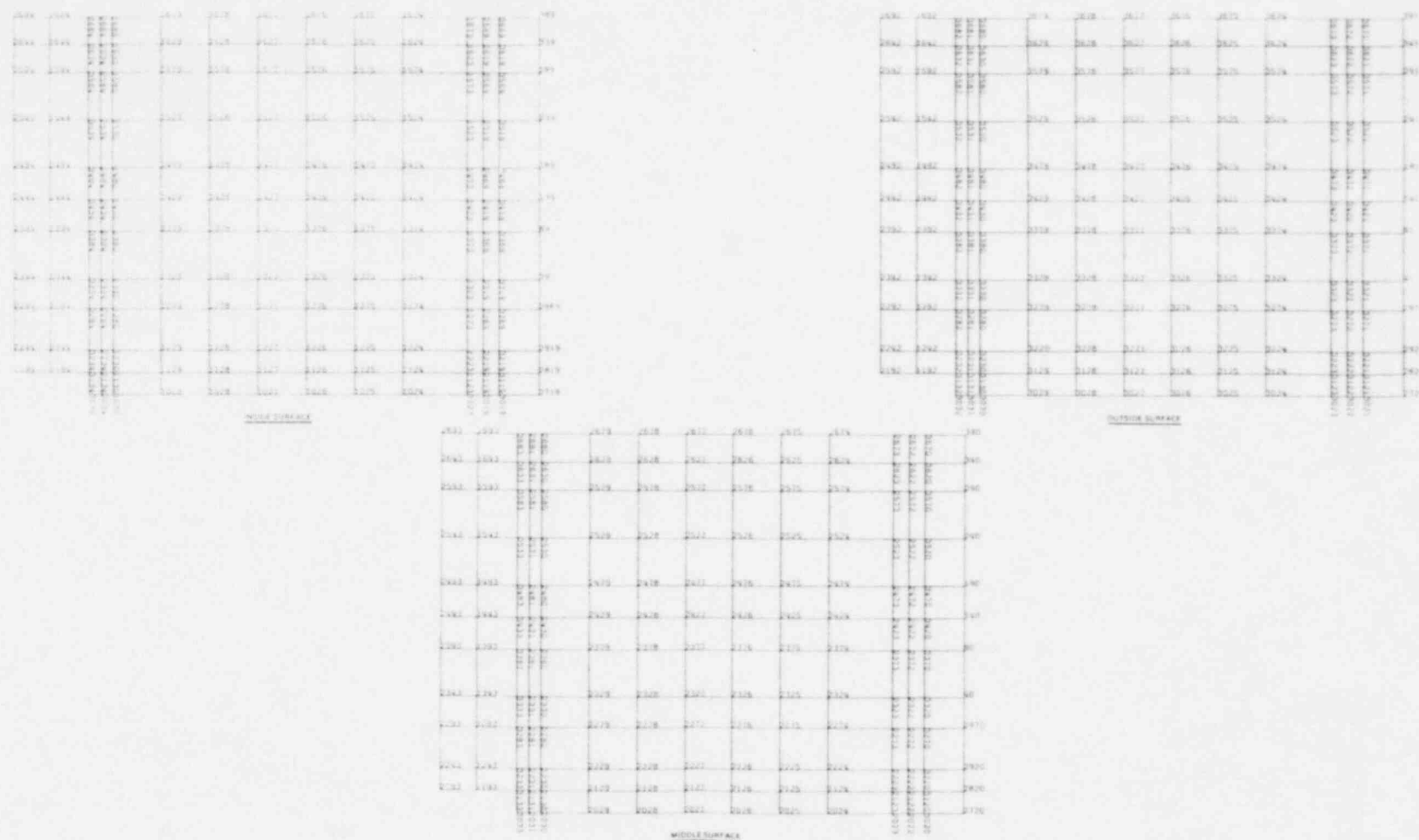


FIGURE 5

EAST WALL NODE NUMBERS

[illegible]

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54-55-56-57	54-57	54-58	54-59	54-60	54-61	54-62	54-63	54-64
54-65-66	54-67	54-68	54-69	54-70	54-71	54-72	54-73	54-74
54-75-76	54-77	54-78	54-79	54-80	54-81	54-82	54-83	54-84
54-85-86	54-87	54-88	54-89	54-90	54-91	54-92	54-93	54-94
54-95-96	54-97	54-98	54-99	54-100	54-101	54-102	54-103	54-104
54-105-106	54-107	54-108	54-109	54-110	54-111	54-112	54-113	54-114
54-115-116	54-117	54-118	54-119	54-120	54-121	54-122	54-123	54-124
54-125-126	54-127	54-128	54-129	54-130	54-131	54-132	54-133	54-134
54-135-136	54-137	54-138	54-139	54-140	54-141	54-142	54-143	54-144
54-145-146	54-147	54-148	54-149	54-150	54-151	54-152	54-153	54-154
54-155-156	54-157	54-158	54-159	54-160	54-161	54-162	54-163	54-164
54-165-166	54-167	54-168	54-169	54-170	54-171	54-172	54-173	54-174
54-175-176	54-177	54-178	54-179	54-180	54-181	54-182	54-183	54-184
54-185-186	54-187	54-188	54-189	54-190	54-191	54-192	54-193	54-194
54-195-196	54-197	54-198	54-199	54-200	54-201	54-202	54-203	54-204
54-205-206	54-207	54-208	54-209	54-210	54-211	54-212	54-213	54-214
54-215-216	54-217	54-218	54-219	54-220	54-221	54-222	54-223	54-224
54-225-226	54-227	54-228	54-229	54-230	54-231	54-232	54-233	54-234
54-235-236	54-237	54-238	54-239	54-240	54-241	54-242	54-243	54-244
54-245-246	54-247	54-248	54-249	54-250	54-251	54-252	54-253	54-254
54-255-256	54-257	54-258	54-259	54-260	54-261	54-262	54-263	54-264
54-265-266	54-267	54-268	54-269	54-270	54-271	54-272	54-273	54-274
54-275-276	54-277	54-278	54-279	54-280	54-281	54-282	54-283	54-284
54-285-286	54-287	54-288	54-289	54-290	54-291	54-292	54-293	54-294
54-295-296	54-297	54-298	54-299	54-300	54-301	54-302	54-303	54-304
54-305-306	54-307	54-308	54-309	54-310	54-311	54-312	54-313	54-314
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54-335-336	54-337	54-338	54-339	54-340	54-341	54-342	54-343	54-344
54-345-346	54-347	54-348	54-349	54-350	54-351	54-352	54-353	54-354
54-355-356	54-357	54-358	54-359	54-360	54-361	54-362	54-363	54-364
54-365-366	54-367	54-368	54-369	54-370	54-371	54-372	54-373	54-374
54-375-376	54-377	54-378	54-379	54-380	54-381	54-382	54-383	54-384
54-385-386	54-387	54-388	54-389	54-390	54-391	54-392	54-393	54-394
54-395-396	54-397	54-398	54-399	54-400	54-401	54-40		

OUTSIDE LAYER


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5.300	5.301	5.306	5.305	5.304	5.303	5.302
5.000	5.001	5.016	5.005	5.004	5.003	5.002
5.300	5.301	5.306	5.305	5.304	5.303	5.302
4.800	4.801	4.816	4.805	4.804	4.803	4.802
4.300	4.301	4.306	4.305	4.304	4.303	4.302
3.800	3.801	3.806	3.805	3.804	3.803	3.802
3.300	3.301	3.306	3.305	3.304	3.303	3.302
2.800	2.801	2.806	2.805	2.804	2.803	2.802
2.300	2.301	2.306	2.305	2.304	2.303	2.302

MANUSCRIPT NO. 114 1890-1891

4500	4501	4506	4507	4509	4513	4520
4600	4607	4608	4609	4609	4607	4600
5500	5503	5506	5509	5504	5503	5500
6000	6007	6006	6007	6004	6003	6000
6500	6507	6506	6507	6509	6513	6500
7000	7007	7006	7007	7004	7003	7000
7500	7507	7506	7507	7509	7513	7500
8000	8007	8006	8007	8004	8003	8000
8500	8507	8506	8507	8509	8513	8500
9000	9007	9006	9007	9004	9003	9000
9500	9507	9506	9507	9509	9513	9500

OUTSIDE SURFACE



Structural
Dynamics
Technology, Inc.

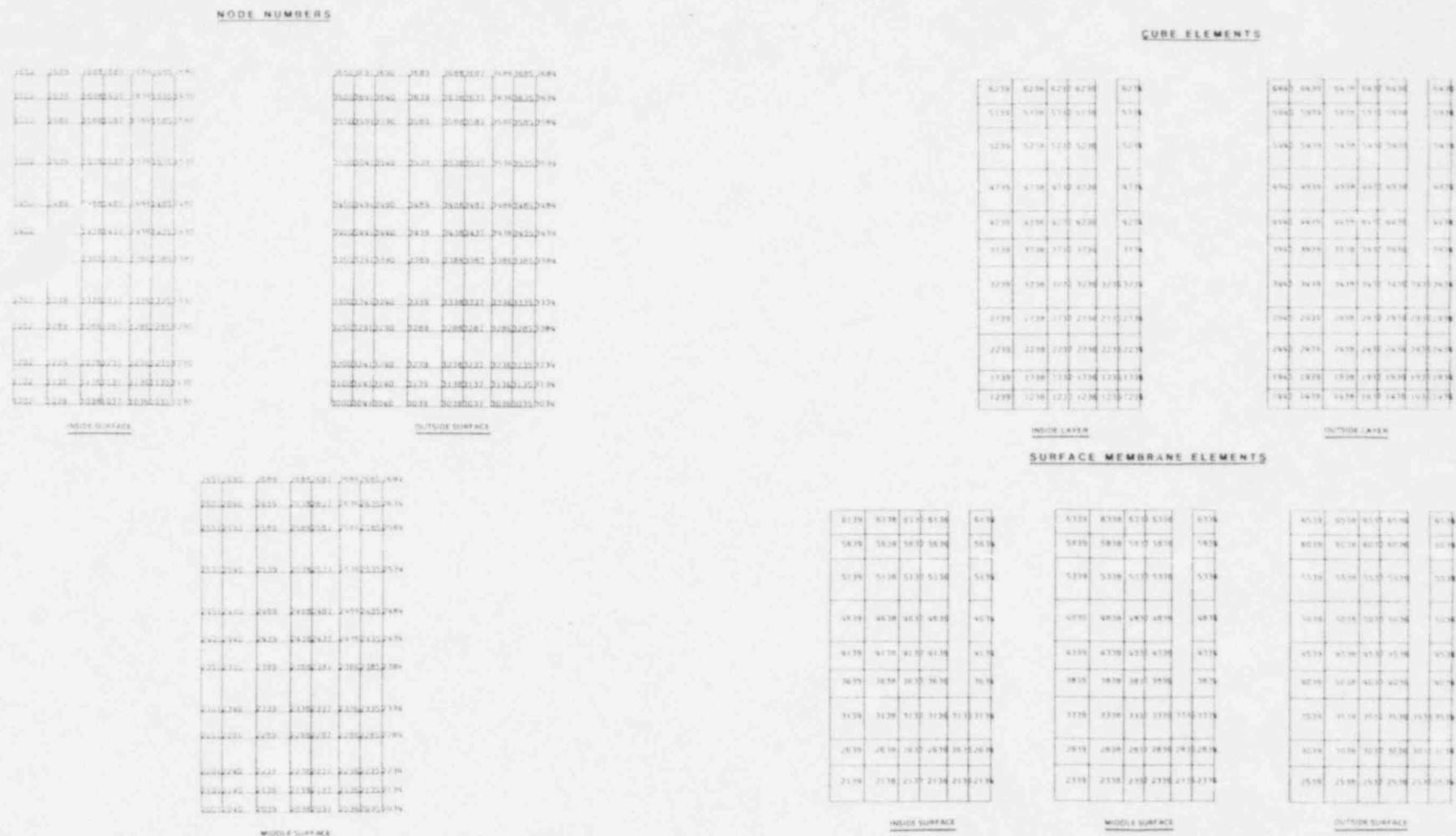
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

APL-02-013
November 24, 1982
Attachment

1801	1808	1815	1822	1829	1836	1843	1850
1848	1855	1862	1869	1876	1883	1890	1897
1904	1911	1918	1925	1932	1939	1946	1953
1960	1967	1974	1981	1988	1995	2002	2009
2016	2023	2030	2037	2044	2051	2058	2065
2079	2086	2093	2100	2107	2114	2121	2128
2142	2149	2156	2163	2170	2177	2184	2191
2205	2212	2219	2226	2233	2240	2247	2254
2268	2275	2282	2289	2296	2303	2310	2317
2328	2335	2342	2349	2356	2363	2370	2377
2384	2391	2398	2405	2412	2419	2426	2433
2440	2447	2454	2461	2468	2475	2482	2489
2500	2507	2514	2521	2528	2535	2542	2549
2560	2567	2574	2581	2588	2595	2602	2609
2620	2627	2634	2641	2648	2655	2662	2669
2680	2687	2694	2701	2708	2715	2722	2729
2740	2747	2754	2761	2768	2775	2782	2789
2800	2807	2814	2821	2828	2835	2842	2849
2860	2867	2874	2881	2888	2895	2902	2909
2920	2927	2934	2941	2948	2955	2962	2969
2980	2987	2994	3001	3008	3015	3022	3029
3040	3047	3054	3061	3068	3075	3082	3089
3100	3107	3114	3121	3128	3135	3142	3149
3160	3167	3174	3181	3188	3195	3202	3209
3220	3227	3234	3241	3248	3255	3262	3269
3280	3287	3294	3301	3308	3315	3322	3329
3340	3347	3354	3361	3368	3375	3382	3389
3400	3407	3414	3421	3428	3435	3442	3449
3460	3467	3474	3481	3488	3495	3502	3509
3520	3527	3534	3541	3548	3555	3562	3569
3580	3587	3594	3601	3608	3615	3622	3629
3640	3647	3654	3661	3668	3675	3682	3689
3700	3707	3714	3721	3728	3735	3742	3749
3760	3767	3774	3781	3788	3795	3802	3809
3820	3827	3834	3841	3848	3855	3862	3869
3880	3887	3894	3901	3908	3915	3922	3929
3940	3947	3954	3961	3968	3975	3982	3989
4000	4007	4014	4021	4028	4035	4042	4049
4060	4067	4074	4081	4088	4095	4102	4109
4120	4127	4134	4141	4148	4155	4162	4169
4180	4187	4194	4201	4208	4215	4222	4229
4240	4247	4254	4261	4268	4275	4282	4289
4300	4307	4314	4321	4328	4335	4342	4349
4360	4367	4374	4381	4388	4395	4402	4409
4420	4427	4434	4441	4448	4455	4462	4469
4480	4487	4494	4501	4508	4515	4522	4529
4540	4547	4554	4561	4568	4575	4582	4589
4600	4607	4614	4621	4628	4635	4642	4649
4660	4667	4674	4681	4688	4695	4702	4709
4720	4727	4734	4741	4748	4755	4762	4769
4780	4787	4794	4801	4808	4815	4822	4829
4840	4847	4854	4861	4868	4875	4882	4889
4900	4907	4914	4921	4928	4935	4942	4949
4960	4967	4974	4981	4988	4995	5002	5009
5020	5027	5034	5041	5048	5055	5062	5069
5080	5087	5094	5101	5108	5115	5122	5129
5140	5147	5154	5161	5168	5175	5182	5189
5200	5207	5214	5221	5228	5235	5242	5249
5260	5267	5274	5281	5288	5295	5302	5309
5320	5327	5334	5341	5348	5355	5362	5369
5380	5387	5394	5401	5408	5415	5422	5429
5440	5447	5454	5461	5468	5475	5482	5489
5500	5507	5514	5521	5528	5535	5542	5549
5560	5567	5574	5581	5588	5595	5602	5609
5620	5627	5634	5641	5648	5655	5662	5669
5680	5687	5694	5701	5708	5715	5722	5729
5740	5747	5754	5761	5768	5775	5782	5789
5800	5807	5814	5821	5828	5835	5842	5849
5860	5867	5874	5881	5888	5895	5902	5909
5920	5927	5934	5941	5948	5955	5962	5969
5980	5987	5994	6001	6008	6015	6022	6029
6040	6047	6054	6061	6068	6075	6082	6089
6100	6107	6114	6121	6128	6135	6142	6149
6160	6167	6174	6181	6188	6195	6202	6209
6220	6227	6234	6241	6248	6255	6262	6269
6280	6287	6294	6301	6308	6315	6322	6329
6340	6347	6354	6361	6368	6375	6382	6389
6400	6407	6414	6421	6428	6435	6442	6449
6460	6467	6474	6481	6488	6495	6502	6509
6520	6527	6534	6541	6548	6555	6562	6569
6580	6587	6594	6601	6608	6615	6622	6629
6640	6647	6654	6661	6668	6675	6682	6689
6700	6707	6714	6721	6728	6735	6742	6749
6760	6767	6774	6781	6788	6795	6802	6809
6820	6827	6834	6841	6848	6855	6862	6869
6880	6887	6894	6901	6908	6915	6922	6929
6940	6947	6954	6961	6968	6975	6982	6989
7000	7007	7014	7021	7028	7035	7042	7049
7060	7067	7074	7081	7088	7095	7102	7109
7120	7127	7134	7141	7148	7155	7162	7169
7180	7187	7194	7201	7208	7215	7222	7229
7240	7247	7254	7261	7268	7275	7282	7289
7300	7307	7314	7321	7328	7335	7342	7349
7360	7367	7374	7381	7388	7395	7402	7409
7420	7427	7434	7441	7448	7455	7462	7469
7480	7487	7494	7501	7508	7515	7522	7529
7540	7547	7554	7561	7568	7575	7582	7589
7600	7607	7614	7621	7628	7635	7642	7649
7660	7667	7674	7681	7688	7695	7702	7709
7720	7727	7734	7741	7748	7755	7762	7769
7780	7787	7794	7801	7808	7815	7822	7829
7840	7847	7854	7861	7868	7875	7882	7889
7900	7907	7914	7921	7928	7935	7942	7949
7960	7967	7974	7981	7988	7995	8002	8009
8020	8027	8034	8041	8048	8055	8062	8069
8080	8087	8094	8101	8108	8115	8122	8129
8140	8147	8154	8161	8168	8175	8182	8189
8200	8207	8214	8221	8228	8235	8242	8249
8260	8267	8274	8281	8288	8295	8302	8309
8320	8327	8334	8341	8348	8355	8362	8369
8380	8387	8394	8401	8408	8415	8422	8429
8440	8447	8454	8461	8468	8475	8482	8489
8500	8507	8514	8521	8528	8535	8542	8549
8560	8567	8574	8581	8588	8595	8602	8609
8620	8627	8634	8641	8648	8655	8662	8669
8680	8687	8694	8701	8708	8715	8722	8729
8740	8747	8754	8761	8768	8775	8782	8789
8800	8807	8814	8821	8828	8835	8842	8849
8860	8867	8874	8881	8888	8895	8902	8909
8920	8927	8934	8941	8948	8955	8962	8969
8980	8987	8994	9001	9008	9015	9022	9029
9040	9047	9054	9061	9068	9075	9082	9089
9100	9107	9114	9121	9128	9135	9142	9149
9160	9167	9174	9181	9188	9195	9202	9209
9220	9227	9234	9241	9248	9255	9262	9269
9280	9287	9294	9301	9308	9315	9322	9329
9340	9347	9354	9361	9368	9375	9382	9389
9400	9407	9414	9421	9428	9435	9442	9449
9460	9467	9474	9481	9488	9495	9502	9509
9520	9527	9534	9541	9548	9555	9562	9569
9580	9587	9594	9601	9608	9615	9622	9629
9640	9647	9654	9661	9668	9675	9682	9689
9700	9707	9714	9721	9728	9735	9742	9749
9760	9767	9774	9781	9788	9795	9802	9809
9820	9827	9834	9841	9848	9855	9862	9869
9880	9887	9894	9901	9908	9915	9922	9929
9940	9947	9954	9961	9968	9975	9982	9989
10000	10007	10014	10021	10028	10035	10042	10049

FIGURE 7
WEST WALL NODE NUMBERS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL



CUBE ELEMENTS

[illegible]

1995-1996-1997-1998-1999-2000-2001-2002-2003-2004-2005-2006-2007-2008-2009-2010-2011-2012-2013-2014-2015-2016-2017-2018-2019-2020-2021-2022-2023-2024-2025-2026-2027-2028-2029-2030-2031-2032-2033-2034-2035-2036-2037-2038-2039-2040-2041-2042-2043-2044-2045-2046-2047-2048-2049-2050-2051-2052-2053-2054-2055-2056-2057-2058-2059-2060-2061-2062-2063-2064-2065-2066-2067-2068-2069-2070-2071-2072-2073-2074-2075-2076-2077-2078-2079-2080-2081-2082-2083-2084-2085-2086-2087-2088-2089-2090-2091-2092-2093-2094-2095-2096-2097-2098-2099-2100-2101-2102-2103-2104-2105-2106-2107-2108-2109-2110-2111-2112-2113-2114-2115-2116-2117-2118-2119-2120-2121-2122-2123-2124-2125-2126-2127-2128-2129-2130-2131-2132-2133-2134-2135-2136-2137-2138-2139-2140-2141-2142-2143-2144-2145-2146-2147-2148-2149-2150-2151-2152-2153-2154-2155-2156-2157-2158-2159-2160-2161-2162-2163-2164-2165-2166-2167-2168-2169-2170-2171-2172-2173-2174-2175-2176-2177-2178-2179-2180-2181-2182-2183-2184-2185-2186-2187-2188-2189-2190-2191-2192-2193-2194-2195-2196-2197-2198-2199-2200-2201-2202-2203-2204-2205-2206-2207-2208-2209-2210-2211-2212-2213-2214-2215-2216-2217-2218-2219-2220-2221-2222-2223-2224-2225-2226-2227-2228-2229-2230-2231-2232-2233-2234-2235-2236-2237-2238-2239-2240-2241-2242-2243-2244-2245-2246-2247-2248-2249-2250-2251-2252-2253-2254-2255-2256-2257-2258-2259-2260-2261-2262-2263-2264-2265-2266-2267-2268-2269-2270-2271-2272-2273-2274-2275-2276-2277-2278-2279-2280-2281-2282-2283-2284-2285-2286-2287-2288-2289-2290-2291-2292-2293-2294-2295-2296-2297-2298-2299-2300-2301-2302-2303-2304-2305-2306-2307-2308-2309-2310-2311-2312-2313-2314-2315-2316-2317-2318-2319-2320-2321-2322-2323-2324-2325-2326-2327-2328-2329-2330-2331-2332-2333-2334-2335-2336-2337-2338-2339-2340-2341-2342-2343-2344-2345-2346-2347-2348-2349-2350-2351-2352-2353-2354-2355-2356-2357-2358-2359-2360-2361-2362-2363-2364-2365-2366-2367-2368-2369-2370-2371-2372-2373-2374-2375-2376-2377-2378-2379-2380-2381-2382-2383-2384-2385-2386-2387-2388-2389-2390-2391-2392-2393-2394-2395-2396-2397-2398-2399-2400-2401-2402-2403-2404-2405-2406-2407-2408-2409-2410-2411-2412-2413-2414-2415-2416-2417-2418-2419-2420-2421-2422-2423-2424-2425-2426-2427-2428-2429-2430-2431-2432-2433-2434-2435-2436-2437-2438-2439-2440-2441-2442-2443-2444-2445-2446-2447-2448-2449-2450-2451-2452-2453-2454-2455-2456-2457-2458-2459-2460-2461-2462-2463-2464-2465-2466-2467-2468-2469-2470-2471-2472-2473-2474-2475-2476-2477-2478-2479-2480-2481-2482-2483-2484-2485-2486-2487-2488-2489-2490-2491-2492-2493-2494-2495-2496-2497-2498-2499-2500-2501-2502-2503-2504-2505-2506-2507-2508-2509-2510-2511-2512-2513-2514-2515-2516-2517-2518-2519-2520-2521-2522-2523-2524-2525-2526-2527-2528-2529-2530-2531-2532-2533-2534-2535-2536-2537-2538-2539-2540-2541-2542-2543-2544-2545-2546-2547-2548-2549-2550-2551-2552-2553-2554-2555-2556-2557-2558-2559-2560-2561-2562-2563-2564-2565-2566-2567-2568-2569-2570-2571-2572-2573-2574-2575-2576-2577-2578-2579-2580-2581-2582-2583-2584-2585-2586-2587-2588-2589-2590-2591-2592-2593-2594-2595-2596-2597-2598-2599-2600-2601-2602-2603-2604-2605-2606-2607-2608-2609-2610-2611-2612-2613-2614-2615-2616-2617-2618-2619-2620-2621-2622-2623-2624-2625-2626-2627-2628-2629-2630-2631-2632-2633-2634-2635-2636-2637-2638-2639-2640-2641-2642-2643-2644-2645-2646-2647-2648-2649-2650-2651-2652-2653-2654-2655-2656-2657-2658-2659-2660-2661-2662-2663-2664-2665-2666-2667-2668-2669-2670-2671-2672-2673-2674-2675-2676-2677-2678-2679-2680-2681-2682-2683-2684-2685-2686-2687-2688-2689-2690-2691-2692-2693-2694-2695-2696-2697-2698-2699-2700-2701-2702-2703-2704-2705-2706-2707-2708-2709-2710-2711-2712-2713-2714-2715-2716-2717-2718-2719-2720-2721-2722-2723-2724-2725-2726-2727-2728-2729-2730-2731-2732-2733-2734-2735-2736-2737-2738-2739-2740-2741-2742-2743-2744-2745-2746-2747-2748-2749-2750-2751-2752-2753-2754-2755-2756-2757-2758-2759-2760-2761-2762-2763-2764-2765-2766-2767-2768-2769-2770-2771-2772-2773-2774-2775-2776-2777-2778-2779-2780-2781-2782-2783-2784-2785-2786-2787-2788-2789-2790-2791-2792-2793-2794-2795-2796-2797-2798-2799-2800-2801-2802-2803-2804-2805-2806-2807-2808-2809-2810-2811-2812-2813

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281321281412	28132885	2813	28132881413
281321281413	28132885	2813	28132881414
281321281414	28132885	2813	28132881415
281321281415	28132885	2813	28132881416
281321281416	28132885	2813	28132881417
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281321281419	28132885	2813	28132881420
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281321281422	28132885	2813	28132881423
281321281423	28132885	2813	28132881424
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281321281428	28132885	2813	28132881429
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281321281430	28132885	2813	28132881431
281321281431	28132885	2813	28132881432
281321281432	28132885	2813	28132881433
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281321281434	28132885	2813	28132881435
281321281435	28132885	2813	28132881436
281321281436	28132885	2813	28132881437
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281321281438	28132885	2813	28132881439
281321281439	28132885	2813	28132881440
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281321281442	28132885	2813	28132881443
281321281443	28132885	2813	28132881444
281321281444	28132885	2813	28132881445
281321281445	28132885	2813	28132881446
281321281446	28132885	2813	28132881447
281321281447	28132885	2813	28132881448
281321281448	28132885	2813	28132881449

CONTEMPORARY DESIGN AND ART

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62106218	62106219	62106220	62106221
62106222	62106223	62106224	62106225
62106226	62106227	62106228	62106229
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62106354	62106355	62106356	62106357
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62106362	62106363	62106364	62106365
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62106394	62106395	62106396	62106397
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62106458	62106459	62106460	62106461
62106462	62106463	62106464	62106465
62106466	62106467	62106468	62106469

INSIDE LAYER

[illegible]

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SURFACE MEMBRANE ELEMENTS

611061	7	51	0	61	6110
561060	2	56	0	76	5610
5110512	5	11	0	51	5110
051040	7	05	0	05	0510
011001	7	01	0	01	0110
161000	7	16	0	00	1610
311031	3	31	0	31	3110
261020	7	26	0	20	2610
211021	7	21	0	21	2110

INSIDE SURFACE

6.310	6.311	6.312	6.313	6.314
5.810	5.811	5.812	5.813	5.814
5.310	5.311	5.312	5.313	5.314
4.810	4.811	4.812	4.813	4.814
4.310	4.311	4.312	4.313	4.314
3.810	3.811	3.812	3.813	3.814
3.310	3.311	3.312	3.313	3.314
2.810	2.811	2.812	2.813	2.814
2.310	2.311	2.312	2.313	2.314
1.810	1.811	1.812	1.813	1.814
1.310	1.311	1.312	1.313	1.314
0.810	0.811	0.812	0.813	0.814
0.310	0.311	0.312	0.313	0.314

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45100512	45100513	45100514	45100515
45100516	45100517	45100518	45100519
45100520	45100521	45100522	45100523
45100524	45100525	45100526	45100527
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45100544	45100545	45100546	45100547
45100548	45100549	45100550	45100551
45100552	45100553	45100554	45100555
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45100560	45100561	45100562	45100563
45100564	45100565	45100566	45100567
45100568	45100569	45100570	45100571
45100572	45100573	45100574	45100575
45100576	45100577	45100578	45100579
45100580	45100581	45100582	45100583
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45100592	45100593	45100594	45100595
45100596	45100597	45100598	45100599
45100600	45100601	45100602	45100603
45100604	45100605	45100606	45100607
45100608	45100609	45100610	45100611
45100612	45100613	45100614	45100615
45100616	45100617	45100618	45100619
45100620	45100621	45100622	45100623
45100624	45100625	45100626	45100627
45100628	45100629	45100630	45100631
45100632	45100633	45100634	45100635
45100636	45100637	45100638	45100639
45100640	45100641	45100642	45100643
45100644	45100645	45100646	45100647
45100648	45100649	45100650	45100651
45100652	45100653	45100654	45100655
45100656	45100657	45100658	45100659
45100660	45100661	45100662	45100663
45100664	45100665	45100666	45100667
45100668	45100669	45100670	45100671
45100672	45100673	45100674	45100675
45100676	45100677	45100678	45100679
45100680	45100681	45100682	45100683
45100684	45100685	45100686	45100687
45100688	45100689	45100690	45100691
45100692	45100693	45100694	45100695
45100696	45100697	45100698	45100699
45100700	45100701	45100702	45100703
45100704	45100705	45100706	45100707
45100708	45100709	45100710	45100711
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45100736	45100737	45100738	45100739
45100740	45100741	45100742	45100743
45100744	45100745	45100746	45100747
45100748	45100749	45100750	45100751
45100752	45100753	45100754	45100755
45100756	45100757	45100758	45100759
45100760	45100761	45100762	45100763
45100764	45100765	45100766	45100767
45100768	45100769	45100770	45100771

OUTSIDE SURFACE

FIGURE 9

FUEL TRANSFER CANAL INSIDE WALL ELEMENT AND NODE NUMBERS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

API-02-013
November 24, 1982
Attachment

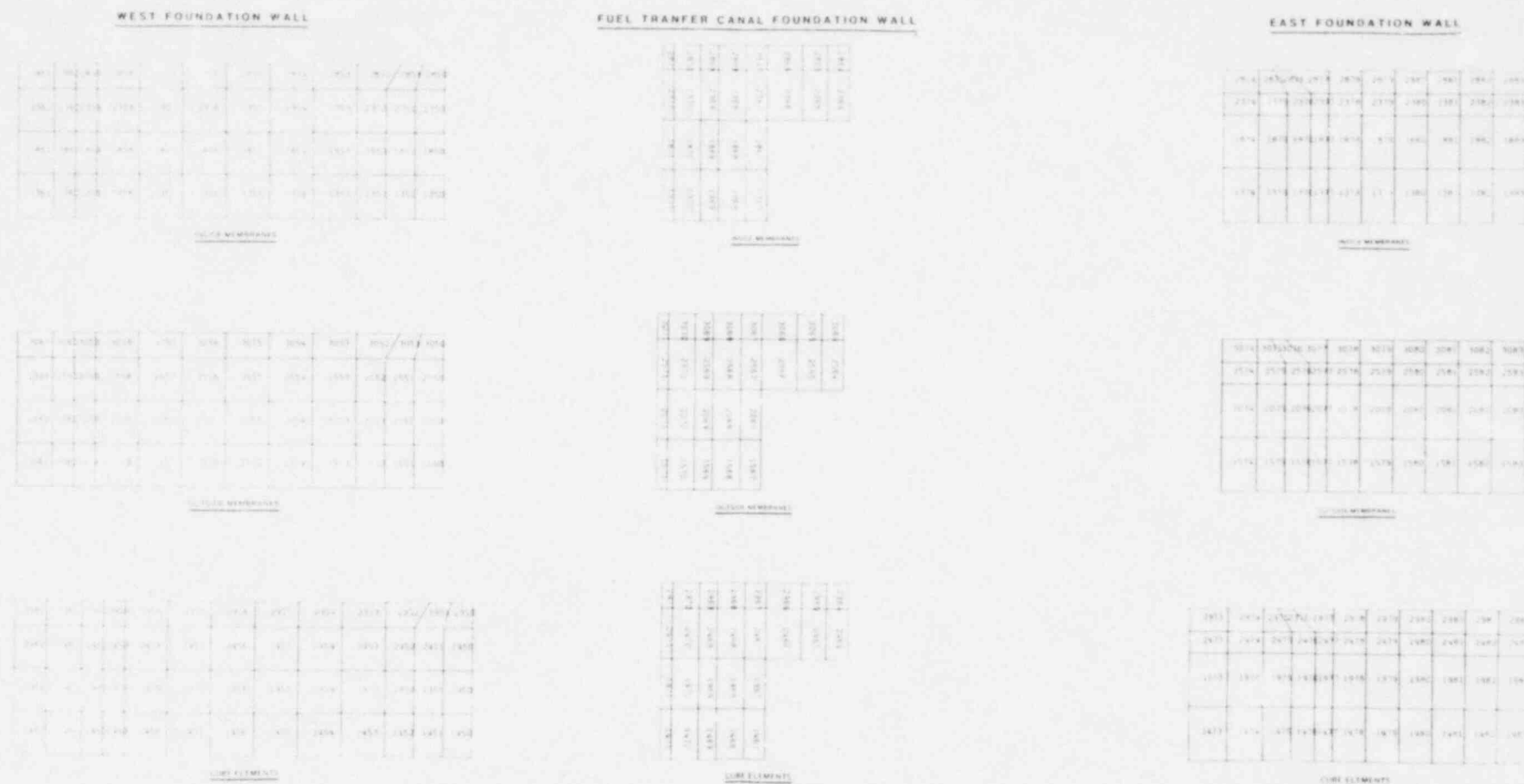


FIGURE 10

FOUNDATION WALLS ELEMENT NUMBERS

SDT Structural Dynamics Technology, Inc.



SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

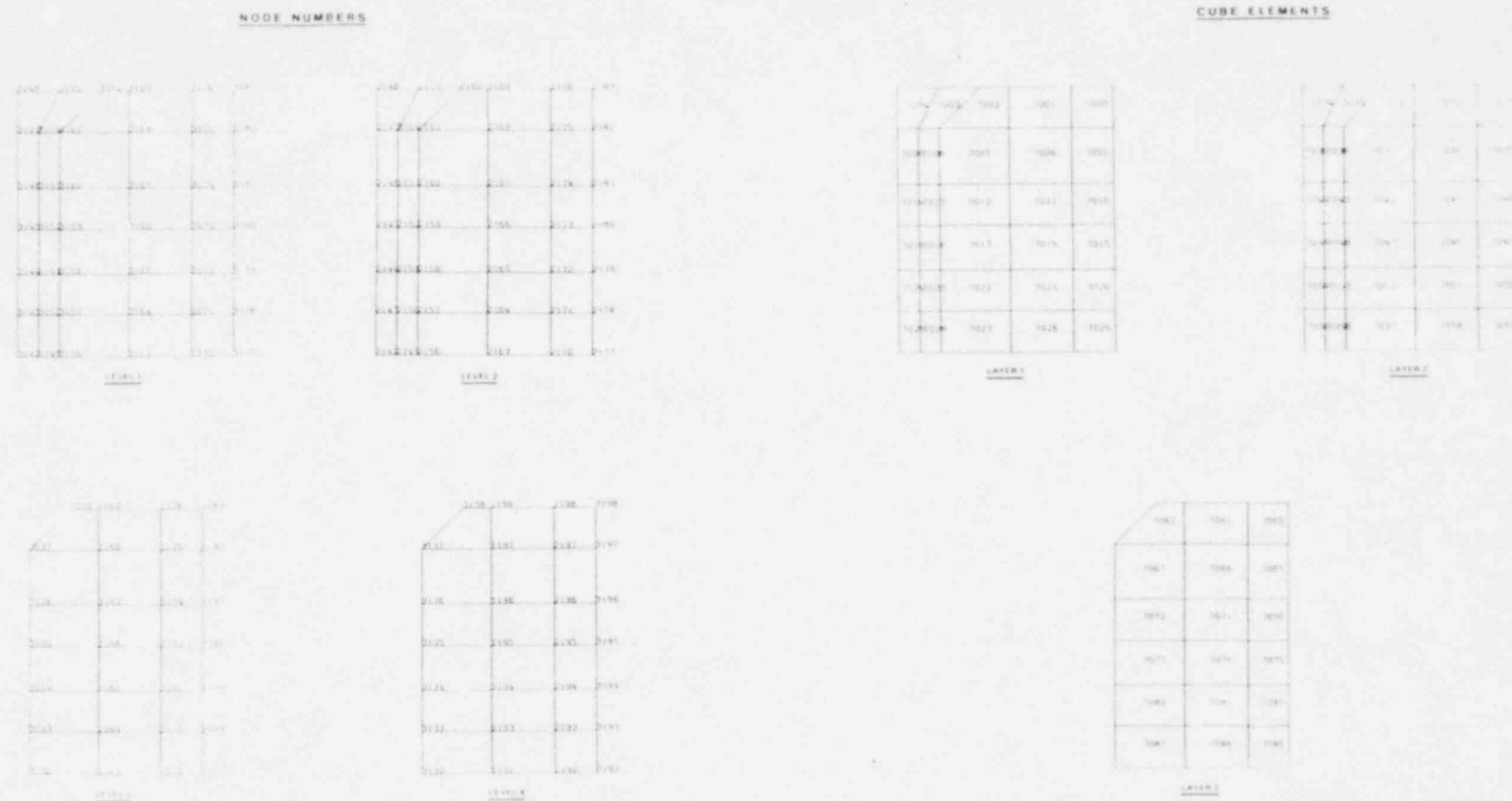


FIGURE 12

CASK LAYDOWN AREA FLOOR ELEMENT AND NODE NUMBERS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

