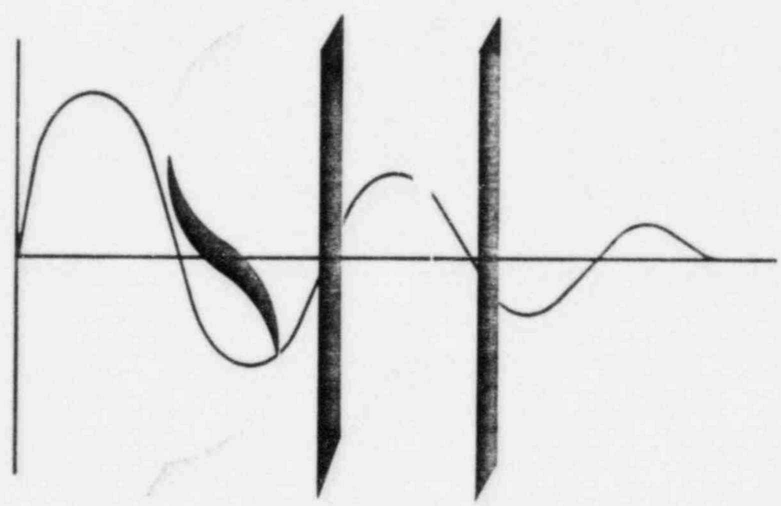

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APL-02-013
November 24, 1982

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

Prepared by

Structural Dynamics Technology, Inc.

for

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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 neglible 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

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five locations through the wall thickness, and these stresses are integrated to determine the section resultant forces and moments for the critera 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 diaphrams 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

Item	Value		Reference
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 Poison Ratio	0.17		3
Concrete Thermal Expansion Coefficient	5.5×10^{-6}	$in/in/^oF$	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 assoclatated 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

Item	Description	Reference
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

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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.

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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 cuse. 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.

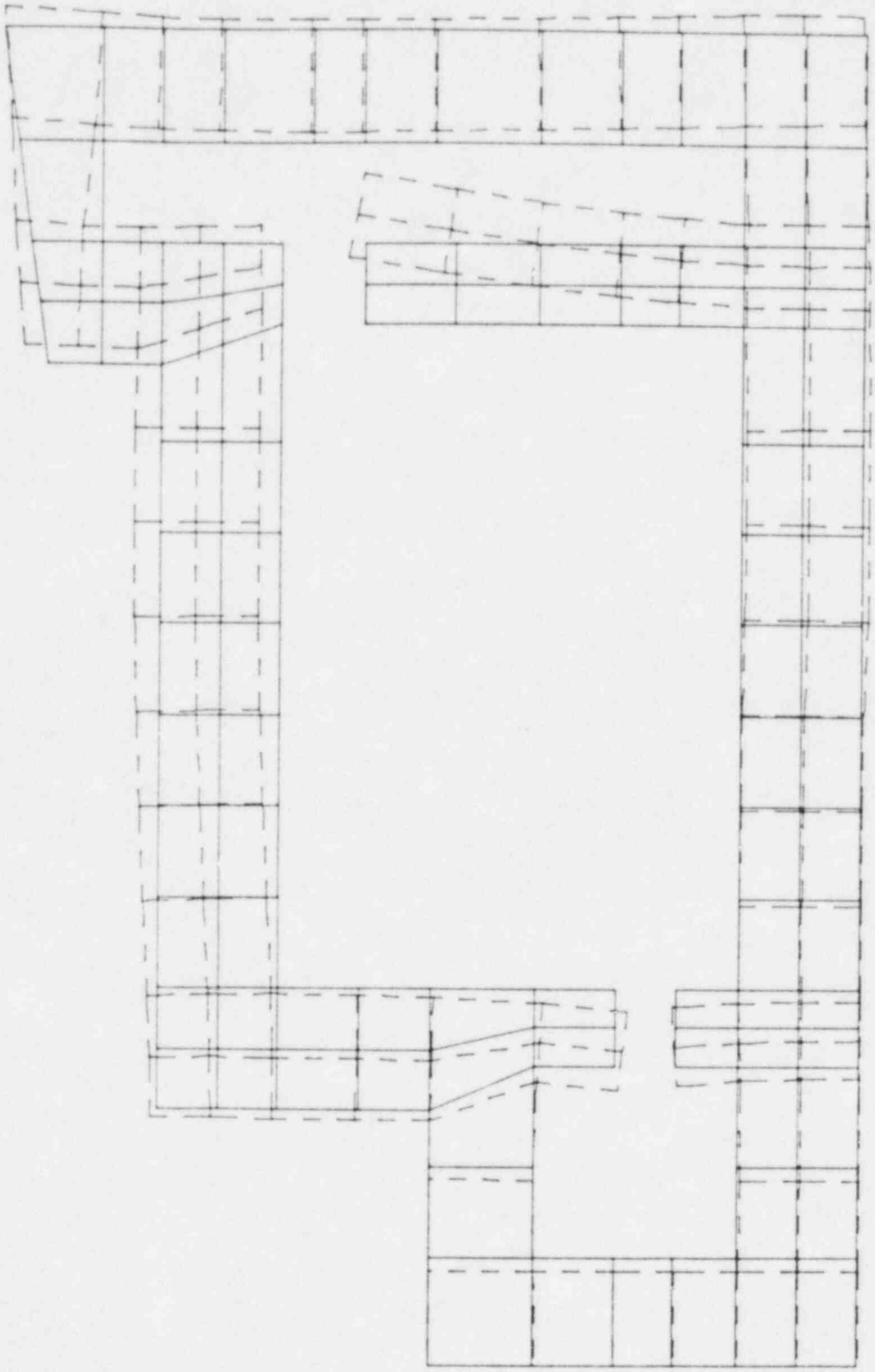
In general, the entire upper portion of all of the four walls except for the fuel transfer canal separation wall, experience in-plane tensile forces. This is a secondary effect,

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



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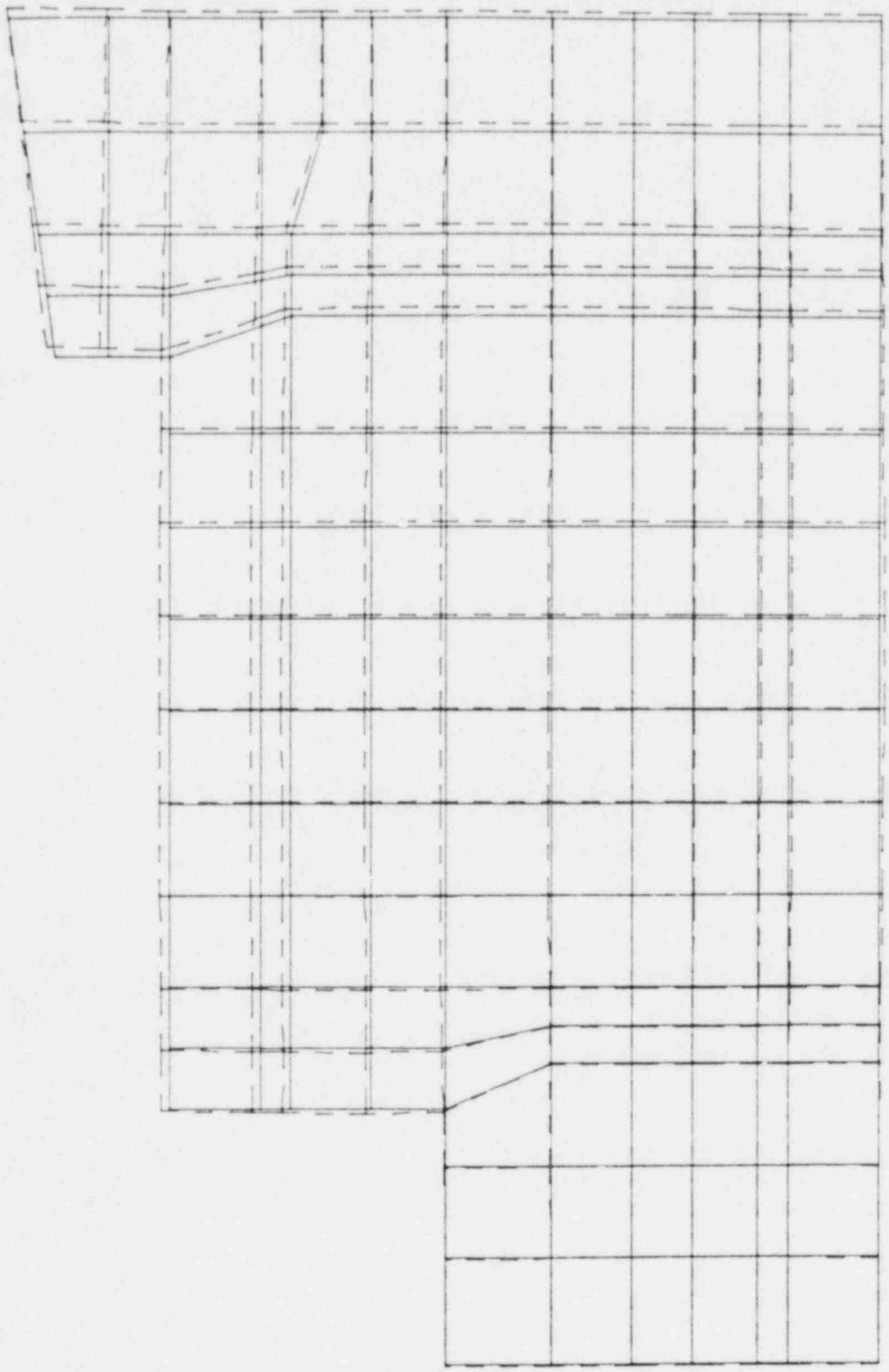

Figure 4-2

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

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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}	E_{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	.1g 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.

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Table 5-2

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

No.	Load Combination	Reference[(1)]
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.

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6.0 ACI 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 evaluaton are defined at locatons 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.

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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) Positiv. moment causes tension on outside surface of walls and lower surface of f'oor 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.

Structural Dynamics Technology

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.

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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.

Structural Dynamics Technology

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.

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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.

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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.

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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.

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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.

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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.

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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.

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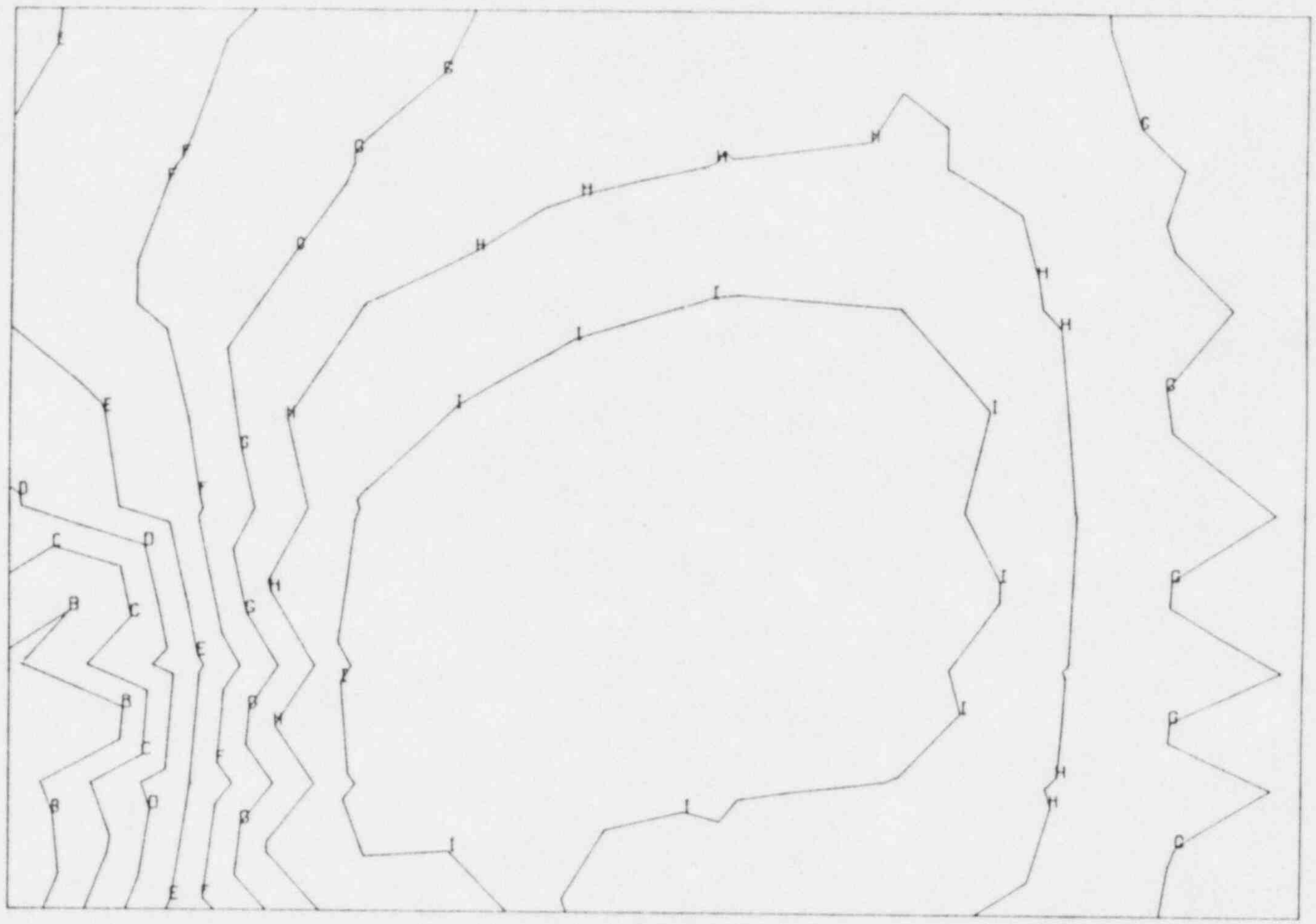
FIGURE 6-1
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Bending Moments
Causing North-South Direction Stresses



N

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

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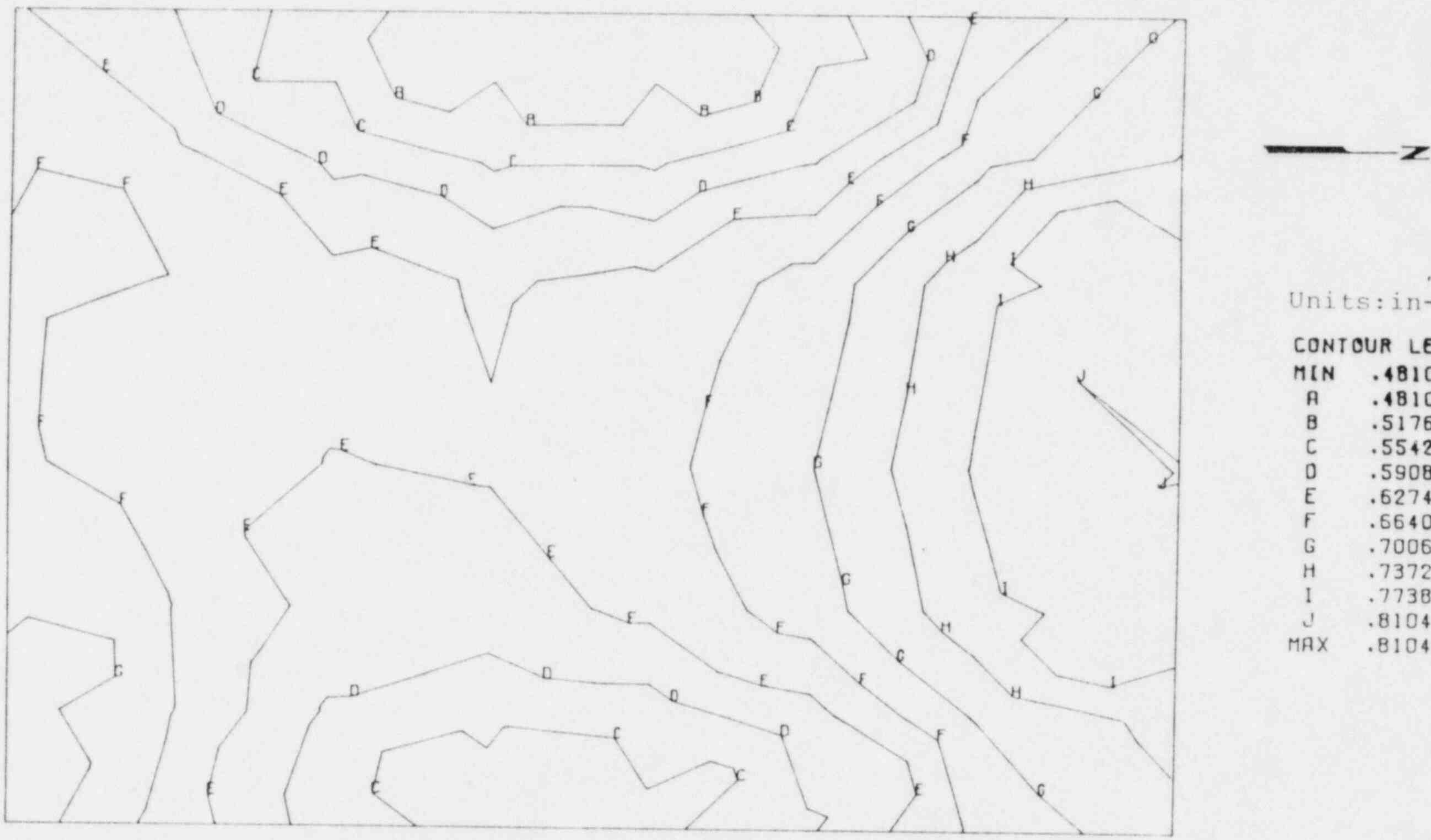
FIGURE 6-2
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Bending Moments
Causing East-West Direction Stresses



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

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

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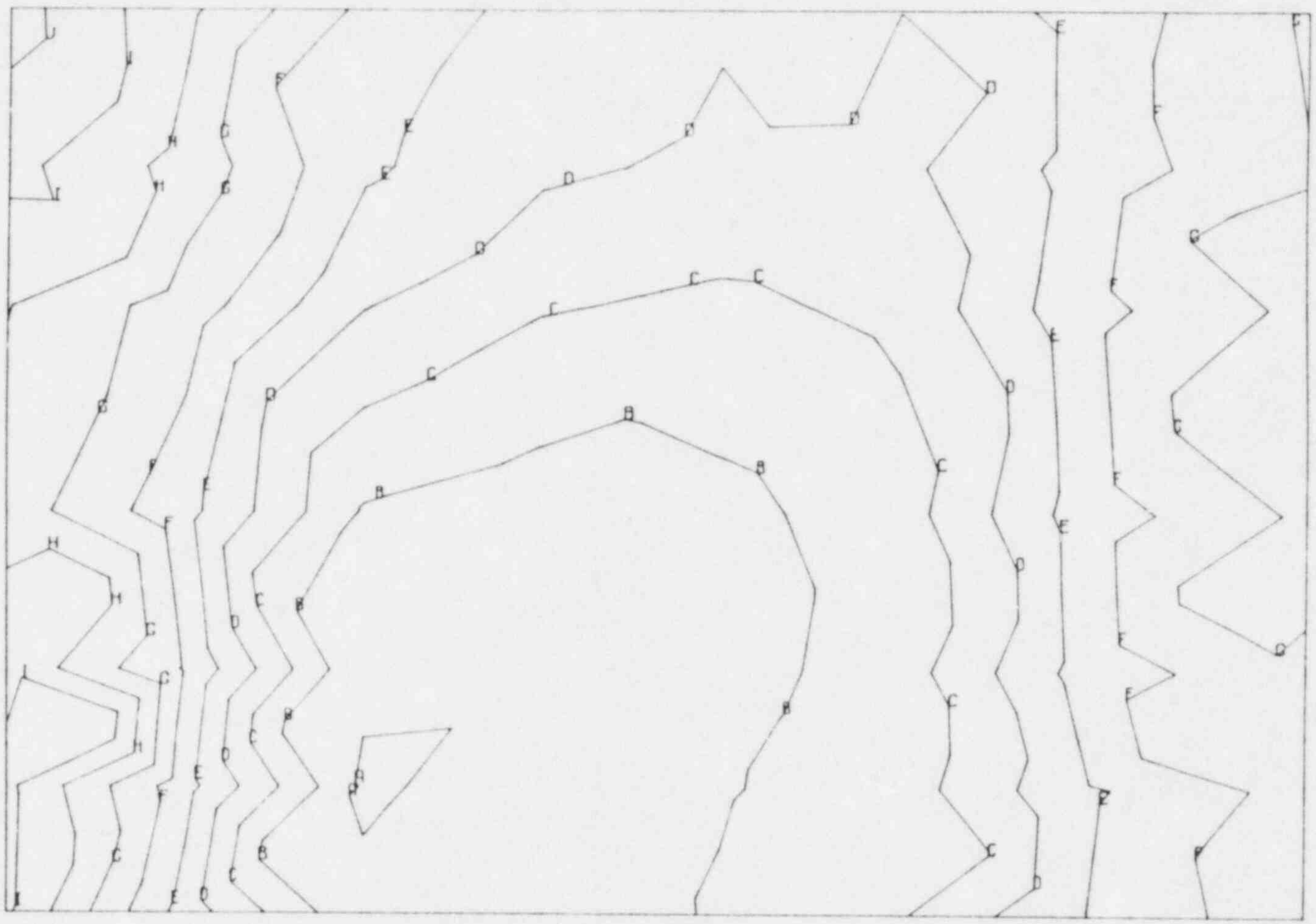
FIGURE 6-3
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Concrete Stresses
In North-South Direction on Top of Slab



N

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

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

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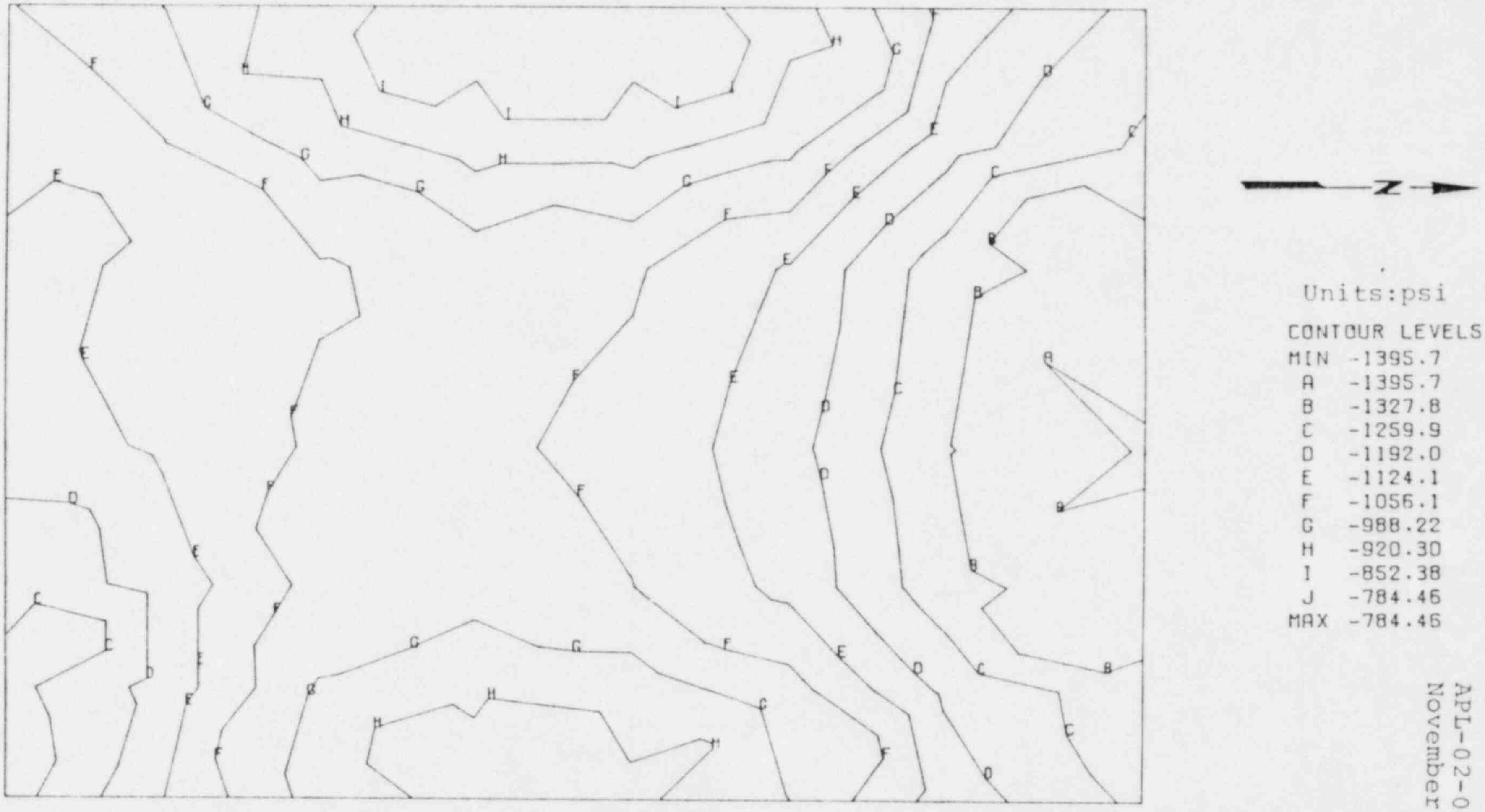
FIGURE 6-4
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Concrete Stresses
In East-West Direction



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

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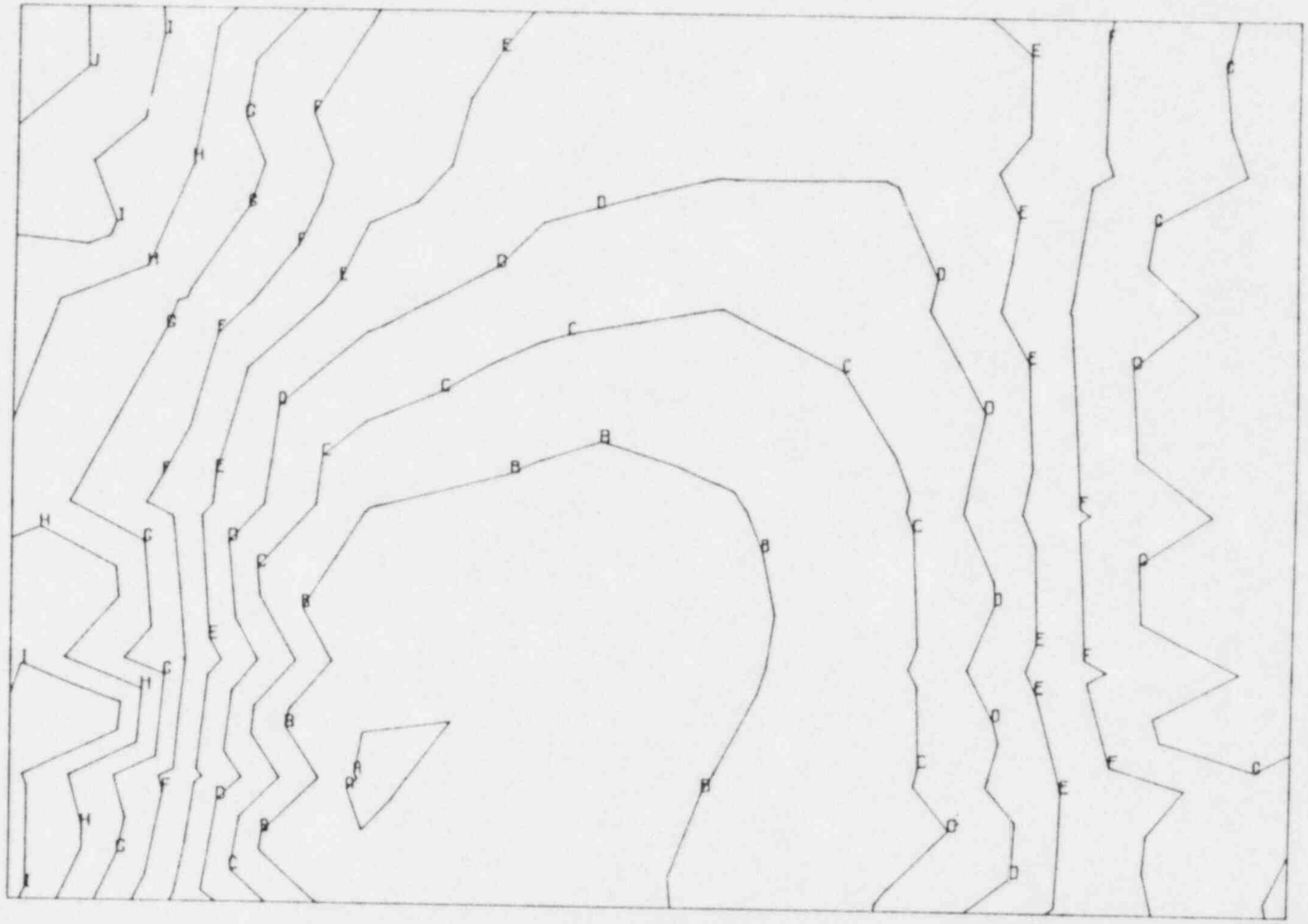
FIGURE 6-5
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Top North-South Reinforcing



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.

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

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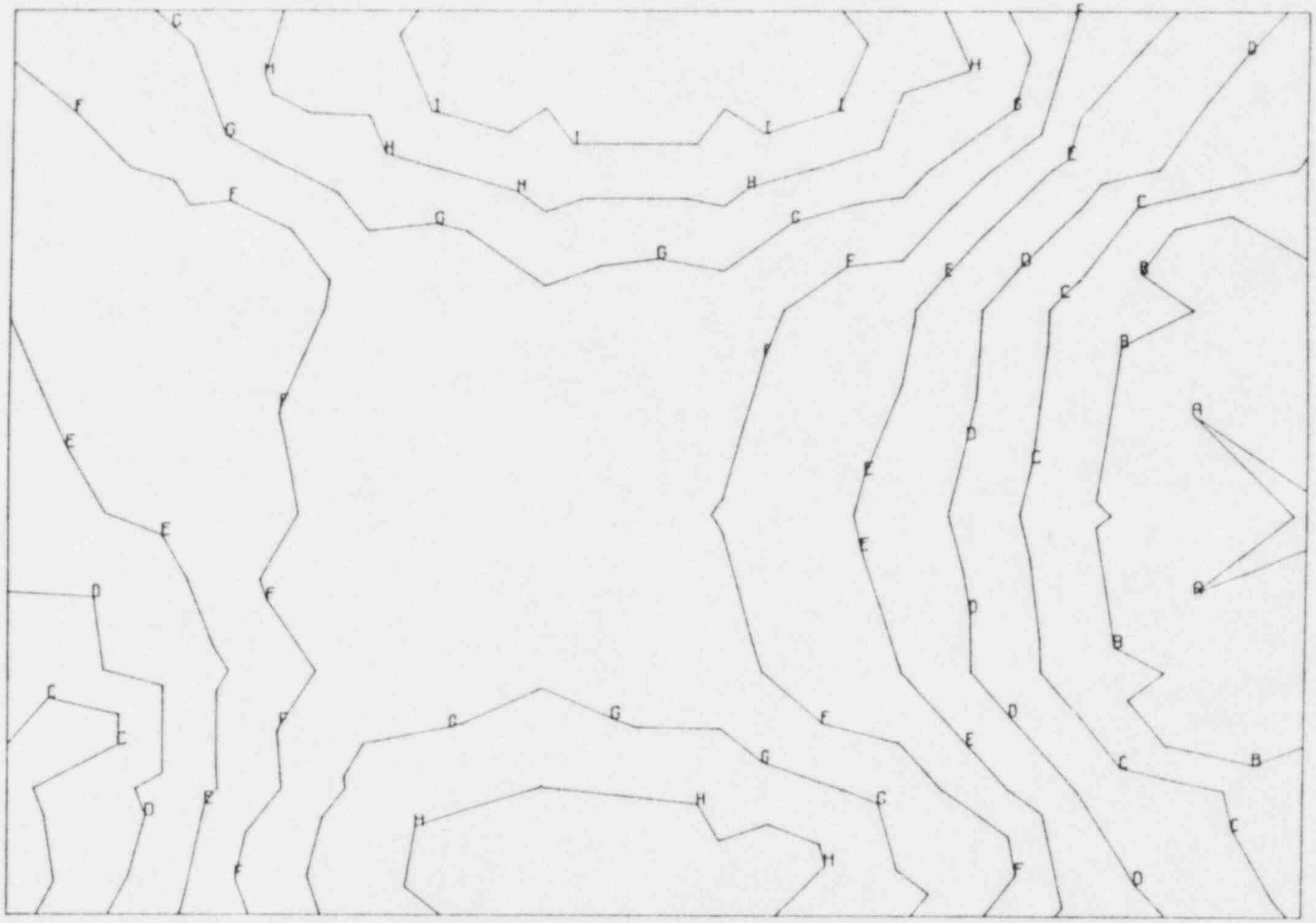
FIGURE 6-6
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Top East-West Reinforcing



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

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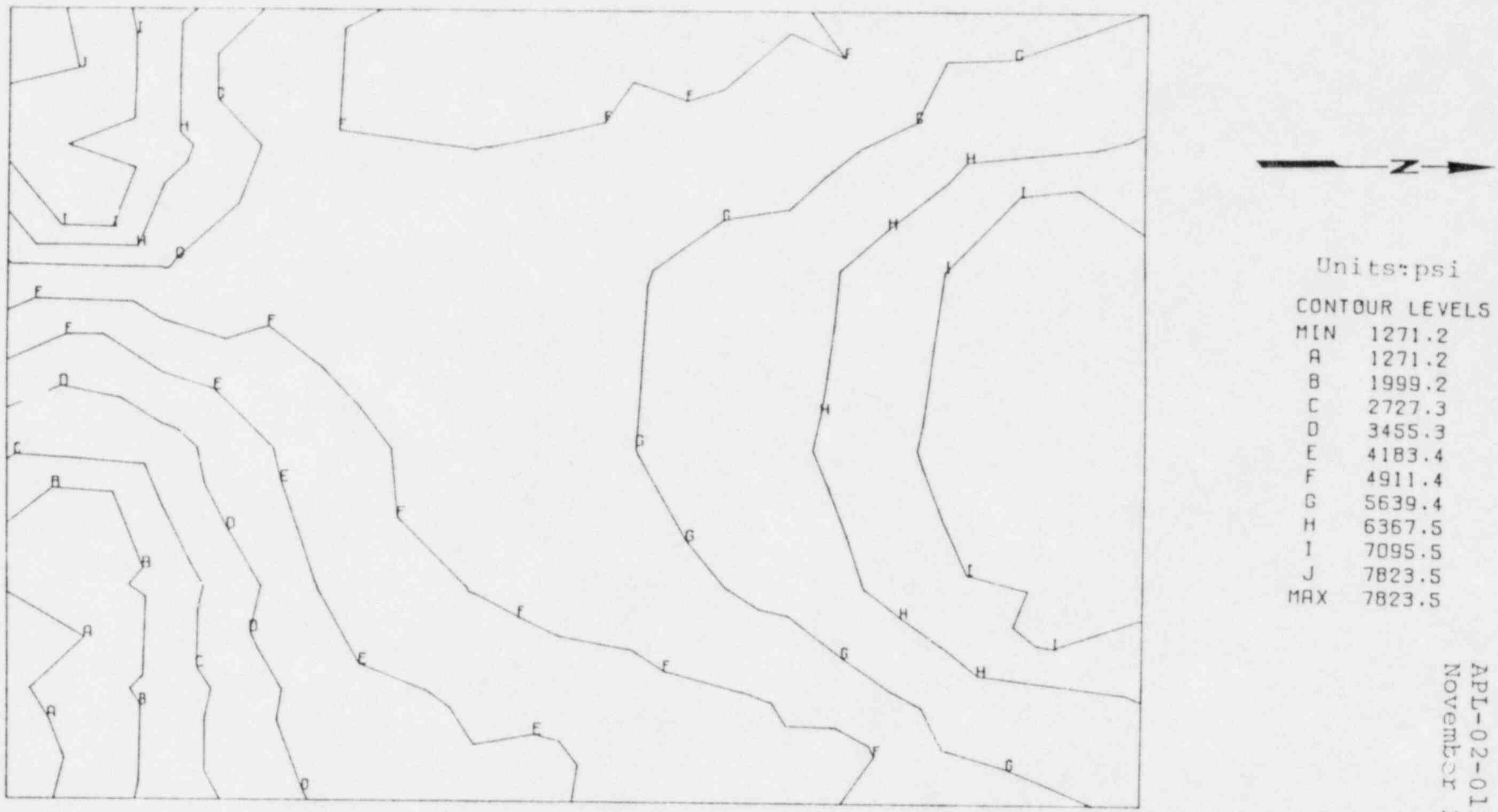
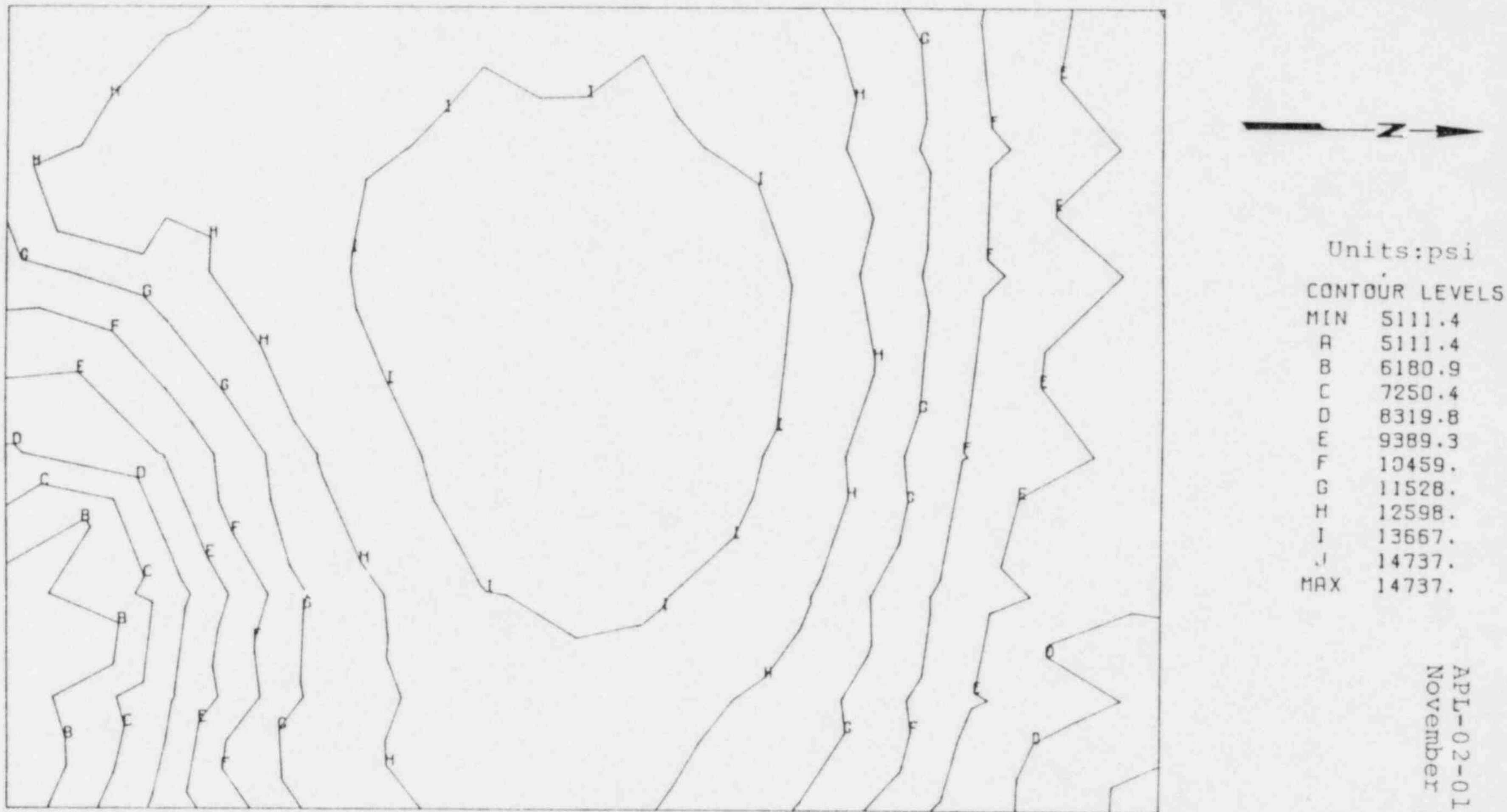
FIGURE 6-7
Arkansas Power and Light Company
Arkansas Nuclear One - Unit 2
Floor Slab Reinforcing Steel Stresses
For Bottom North-South Reinforcing



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



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

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November 24, 1982

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
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APPENDIX

ARKANSAS I NUCLEAR ONE - UNIT 2

SPENT FUEL POOL

FINITE ELEMENT MODEL

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

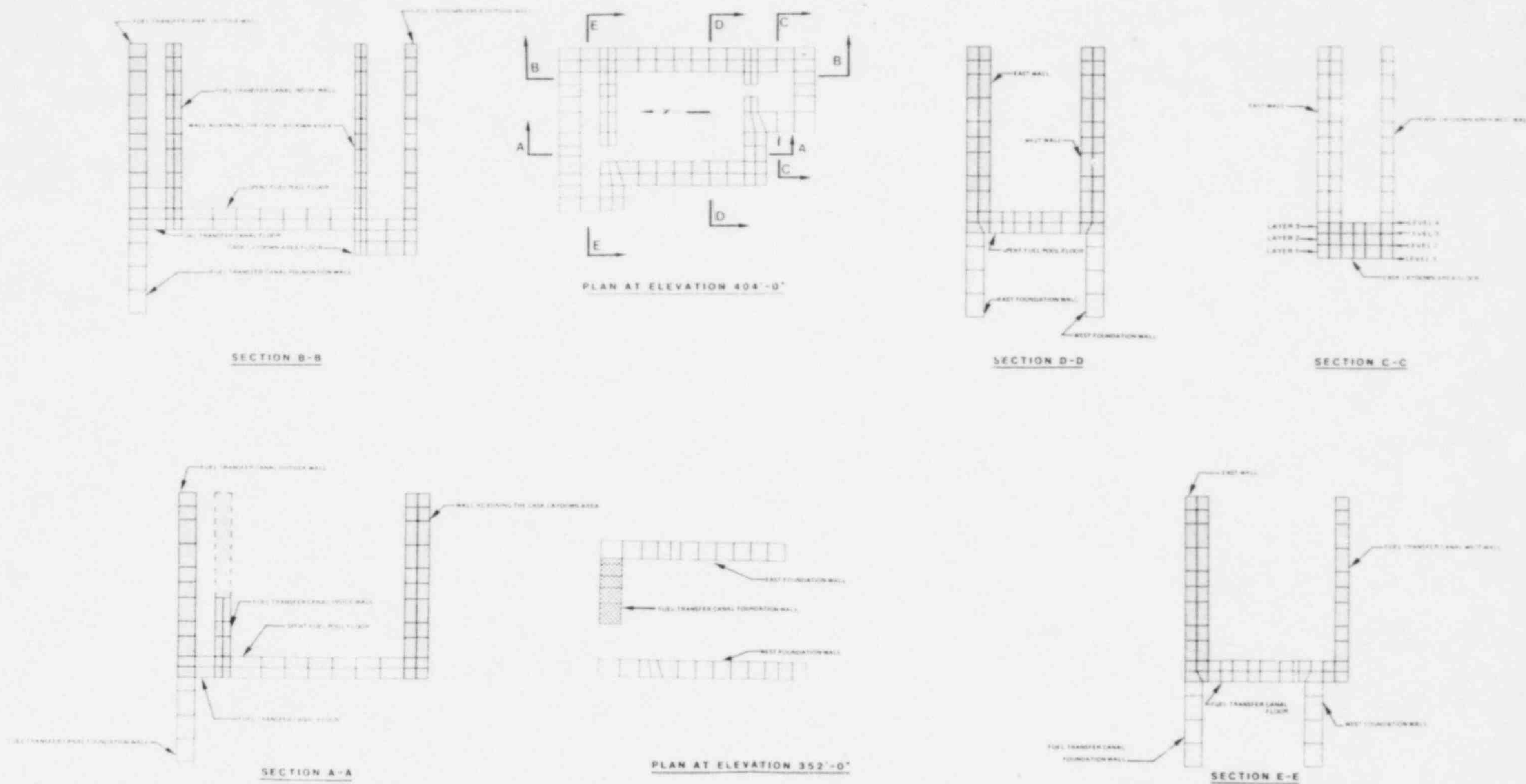


FIGURE 1

PLANS AND SECTIONS

Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

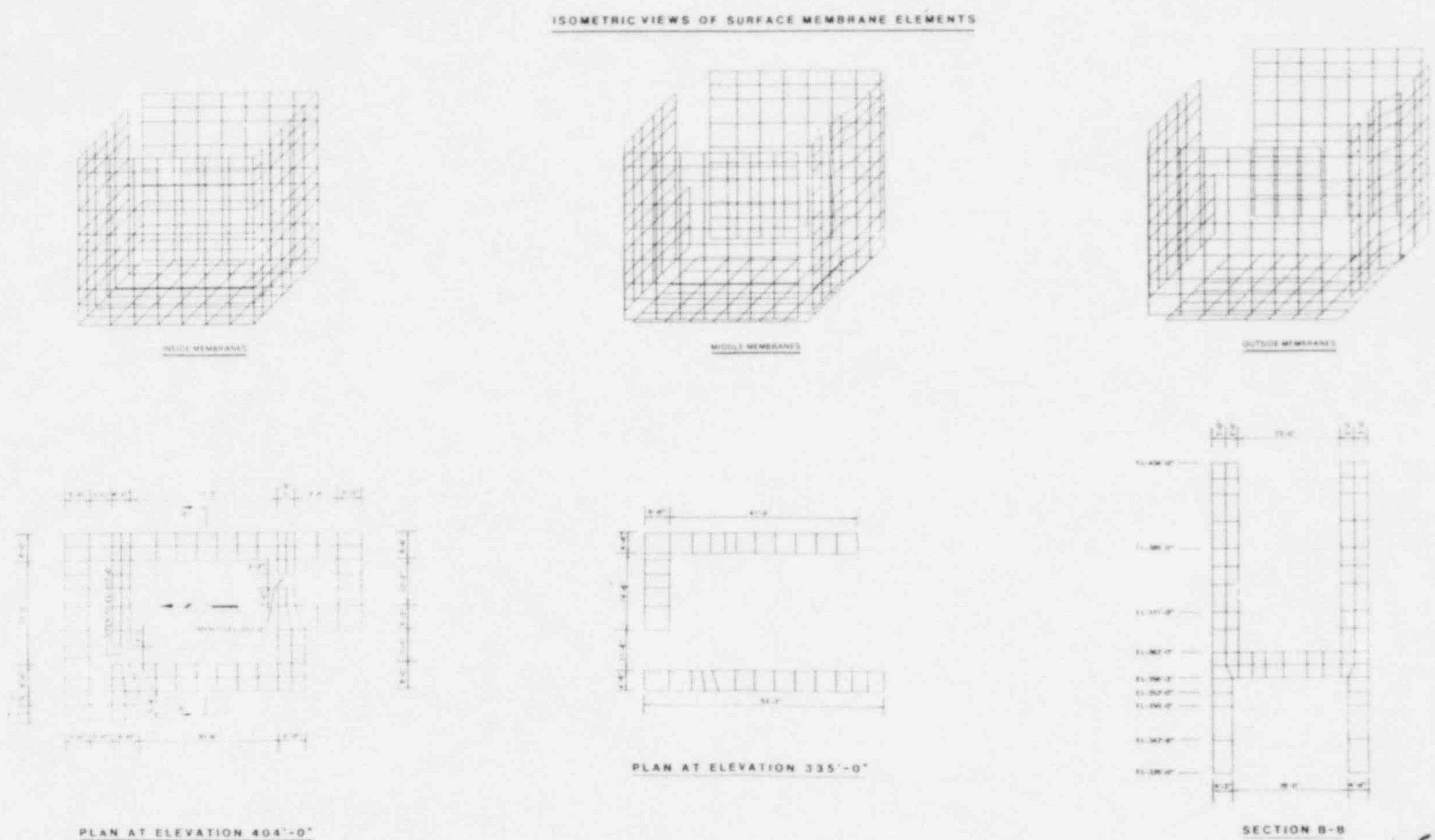


FIGURE 2

KEY DIAGRAMS AND DIMENSIONS

Structural
Dynamics
Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

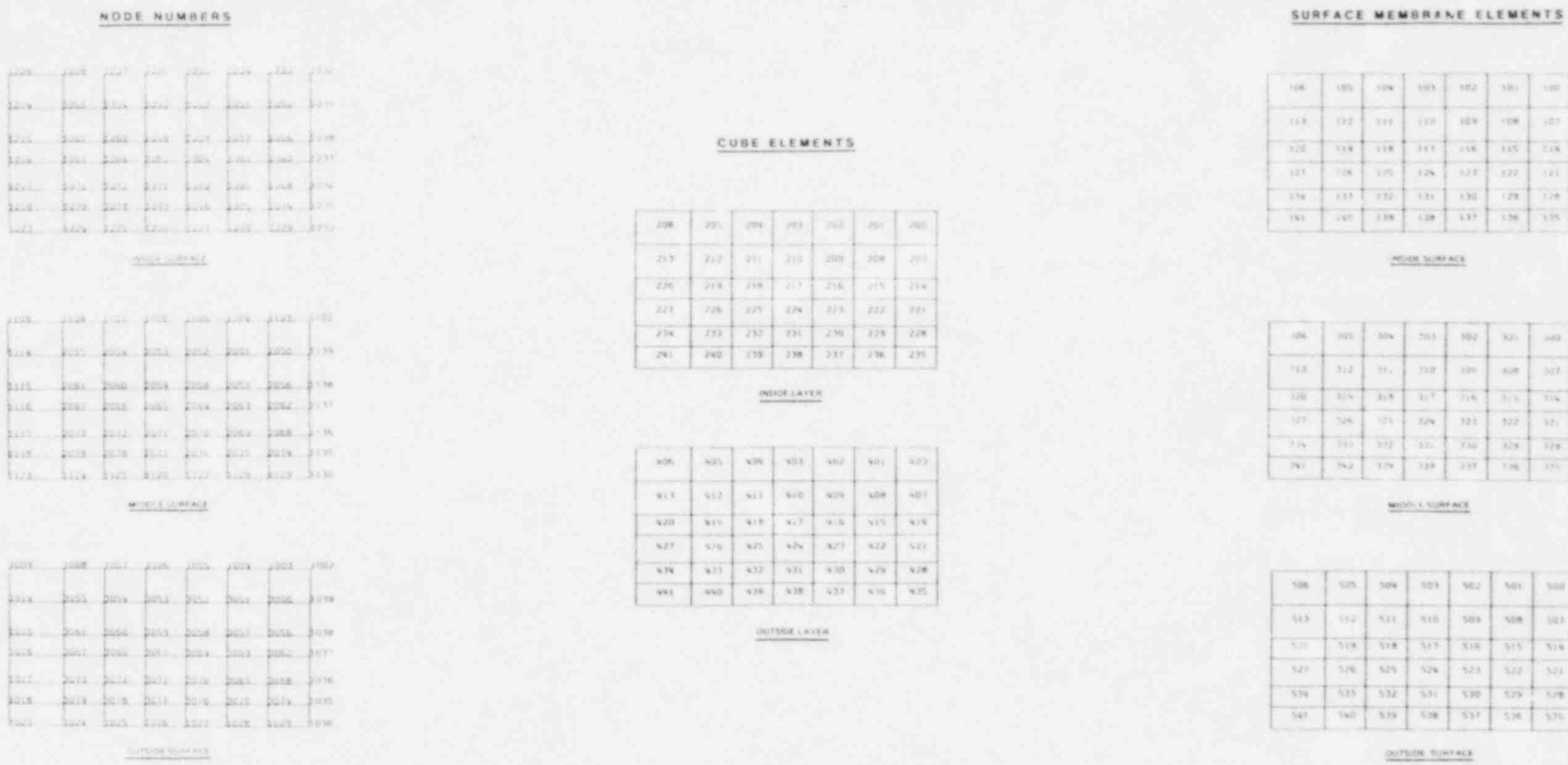


FIGURE 3

FLOOR ELEMENT AND NODE NUMBERS

Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

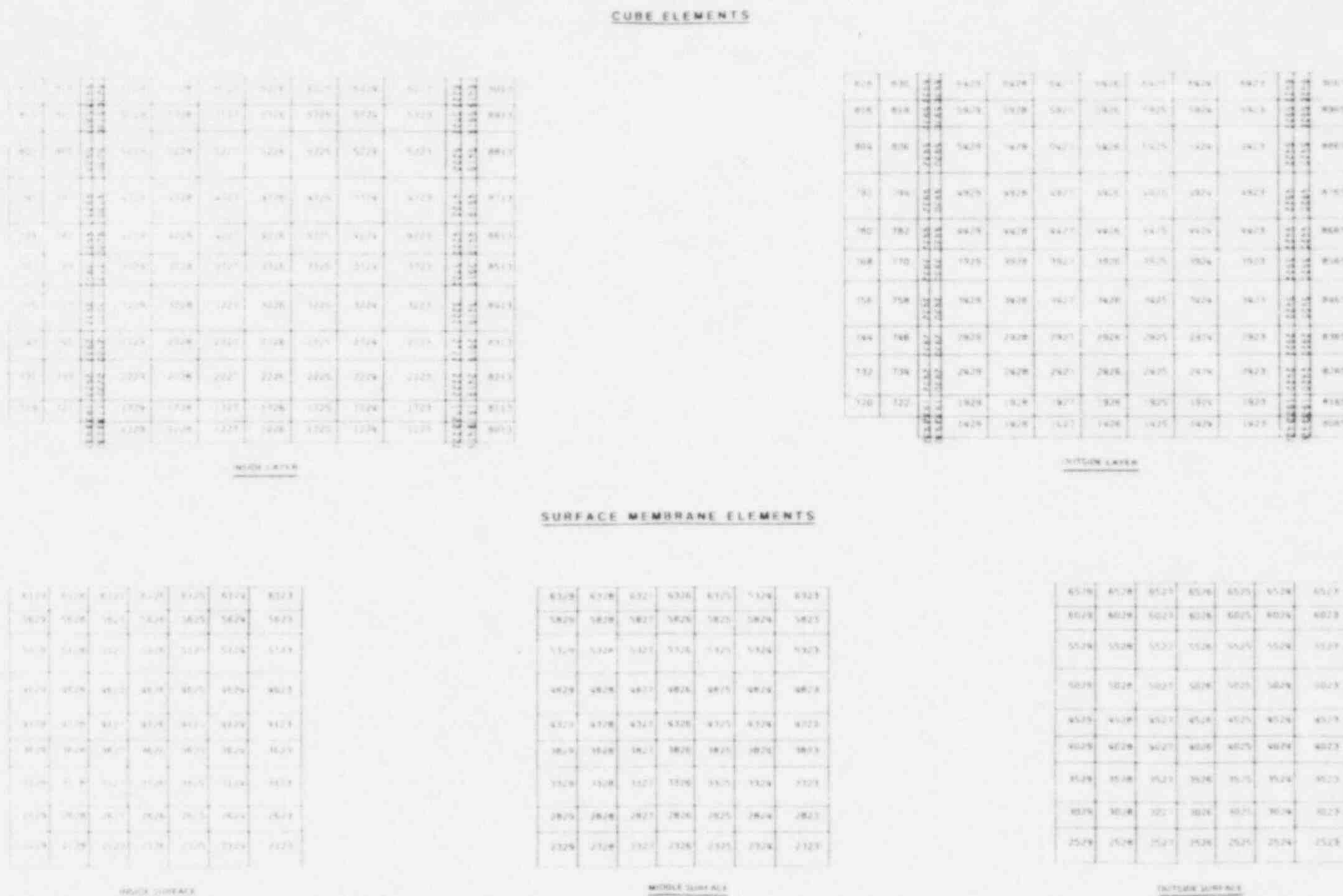


FIGURE 4

EAST WALL ELEMENT NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

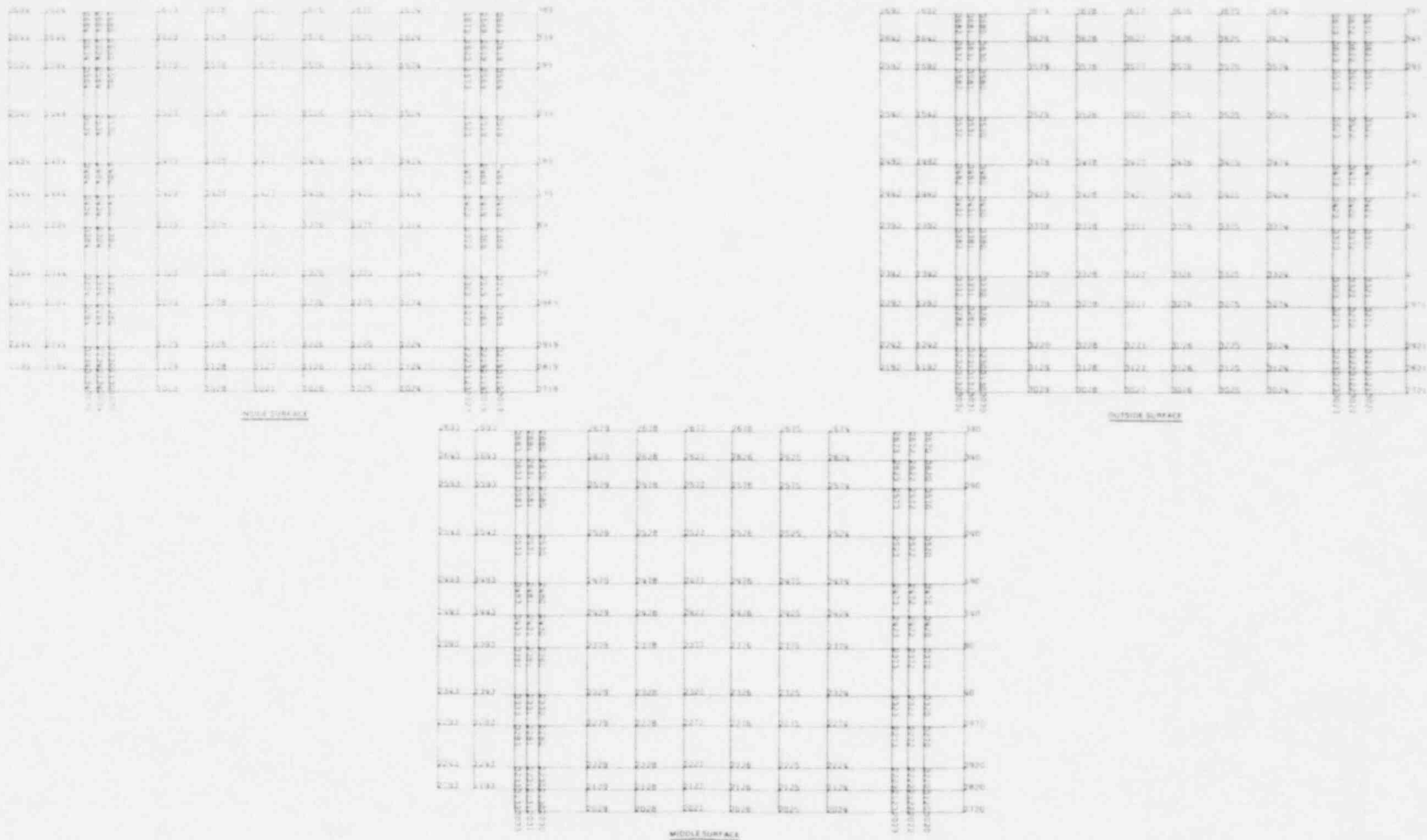


FIGURE 5

EAST WALL NODE NUMBERS

Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

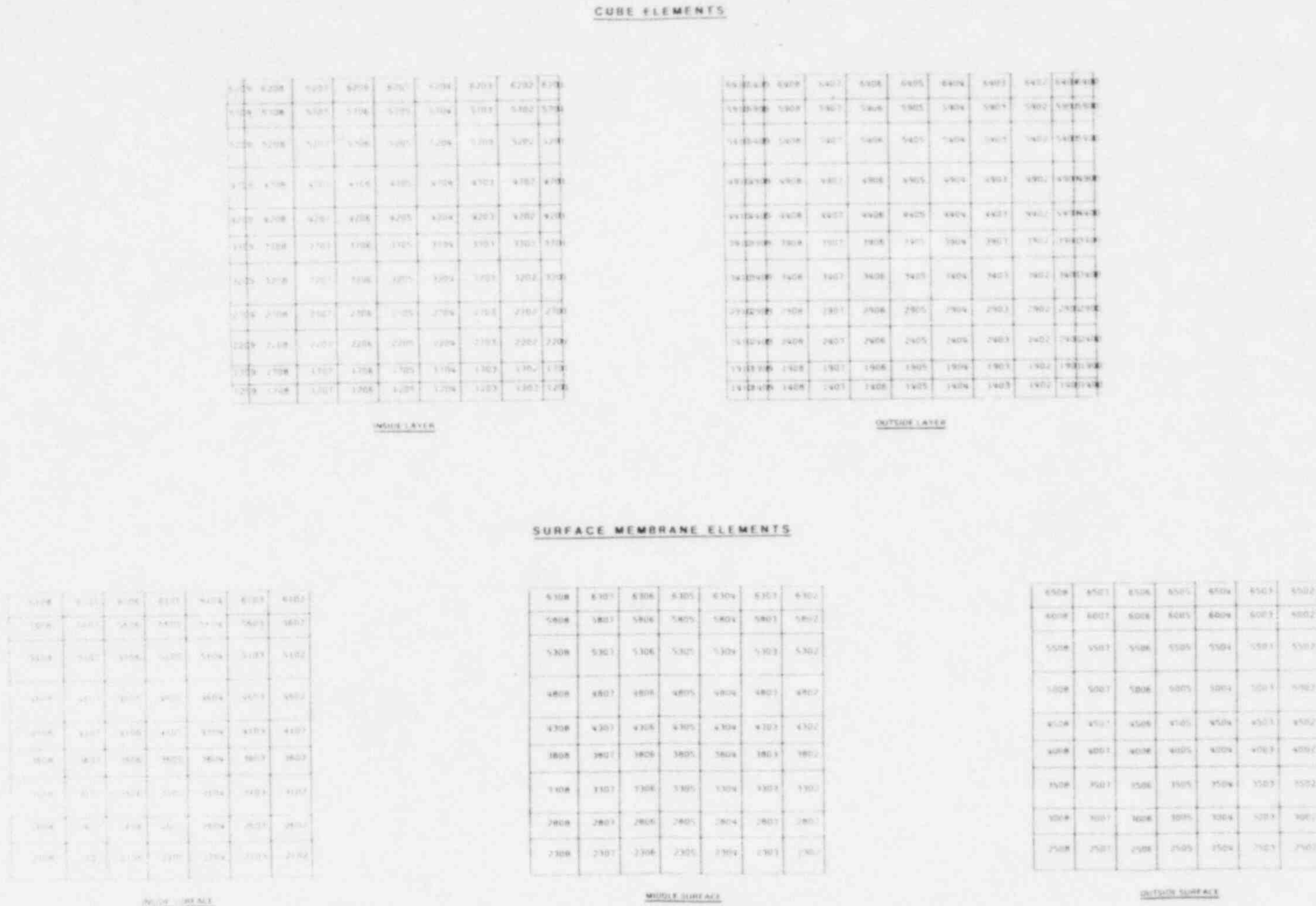


FIGURE 6

WEST WALL ELEMENT NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

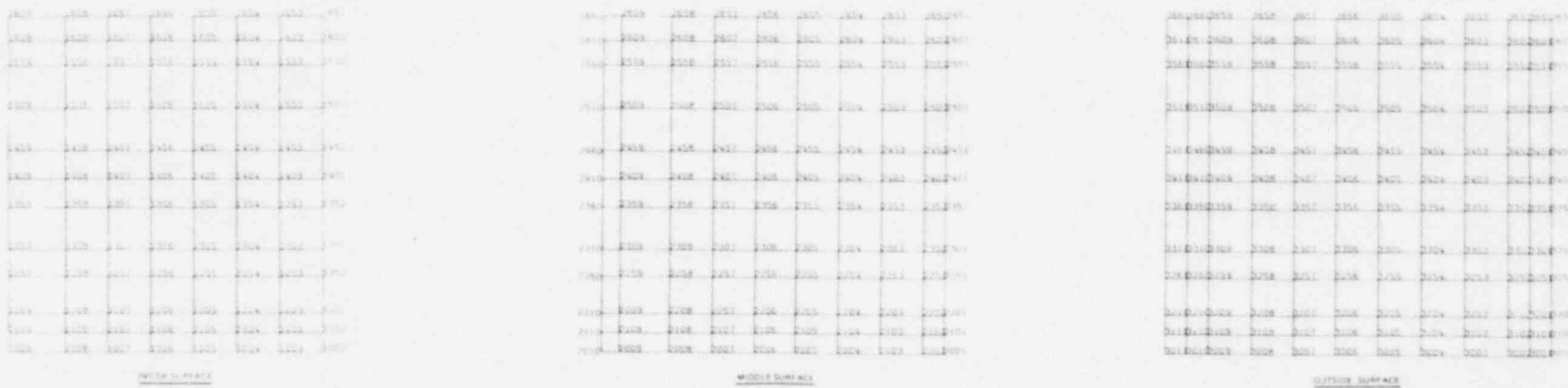


FIGURE 7

WEST WALL NODE NUMBERS

Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

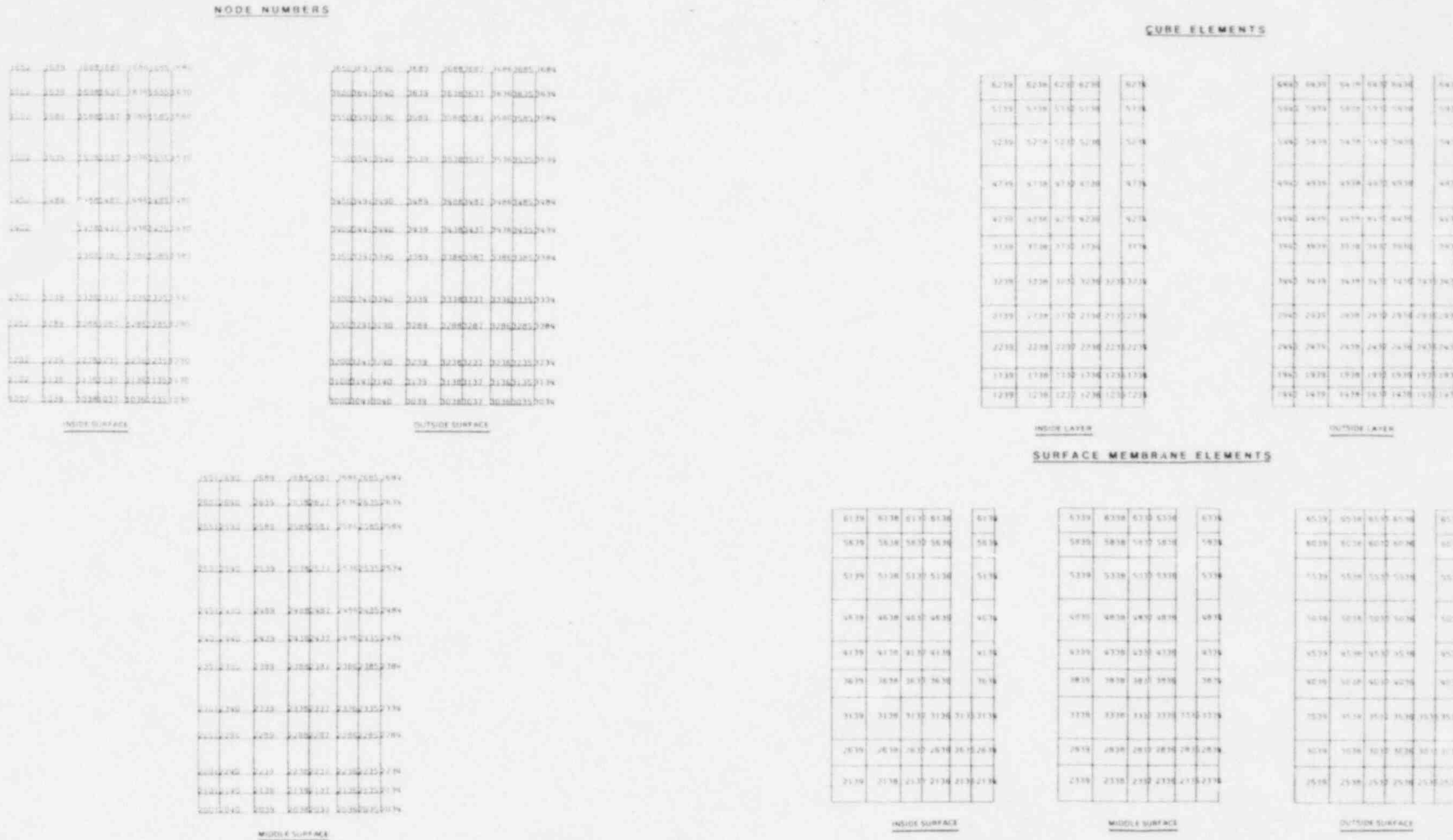


FIGURE 8

POOL WALL ADJOINING THE CASK LAYDOWN AREA ELEMENT AND NODE NUMBERS

Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

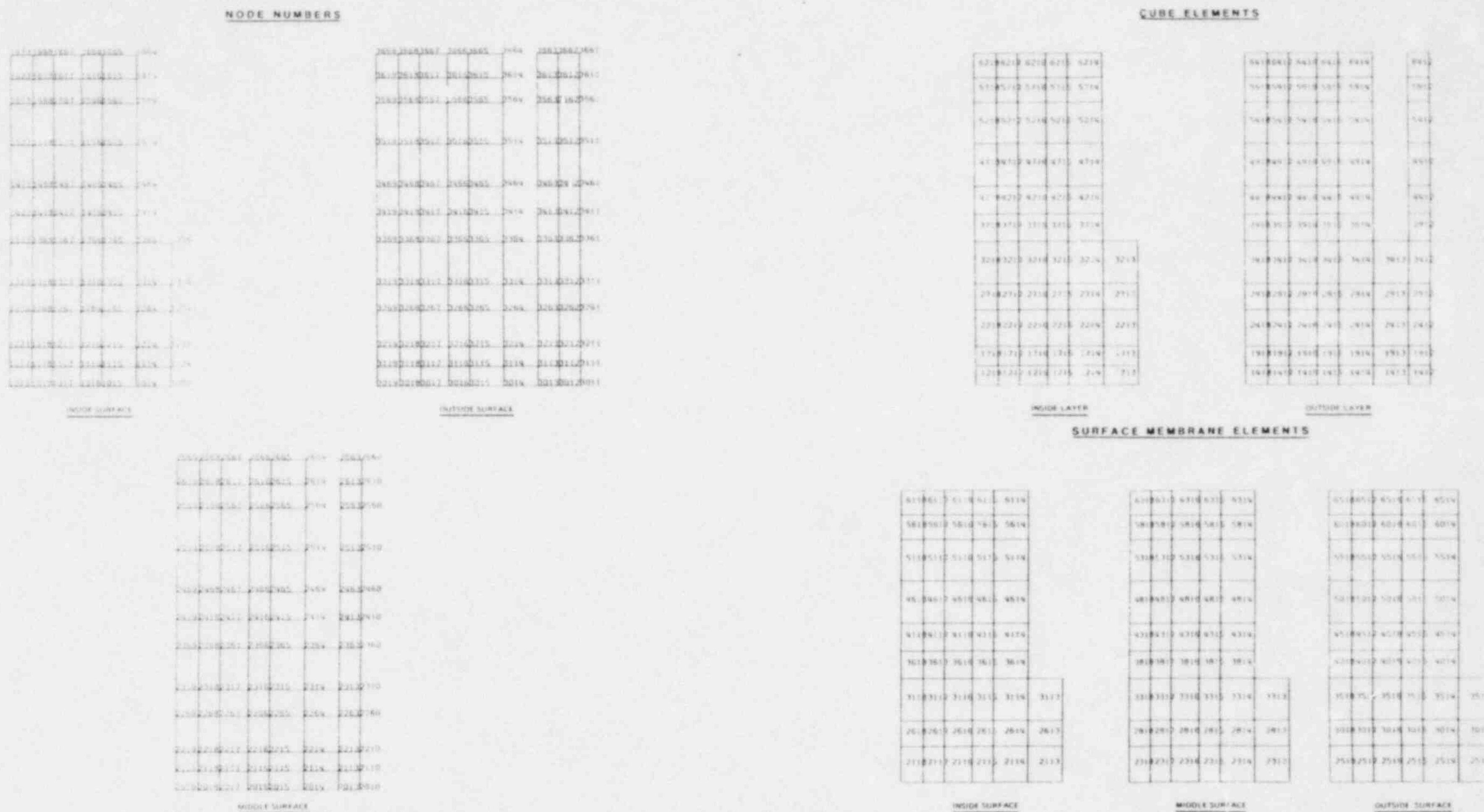


FIGURE 9

FUEL TRANSFER CANAL INSIDE WALL ELEMENT AND NODE NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

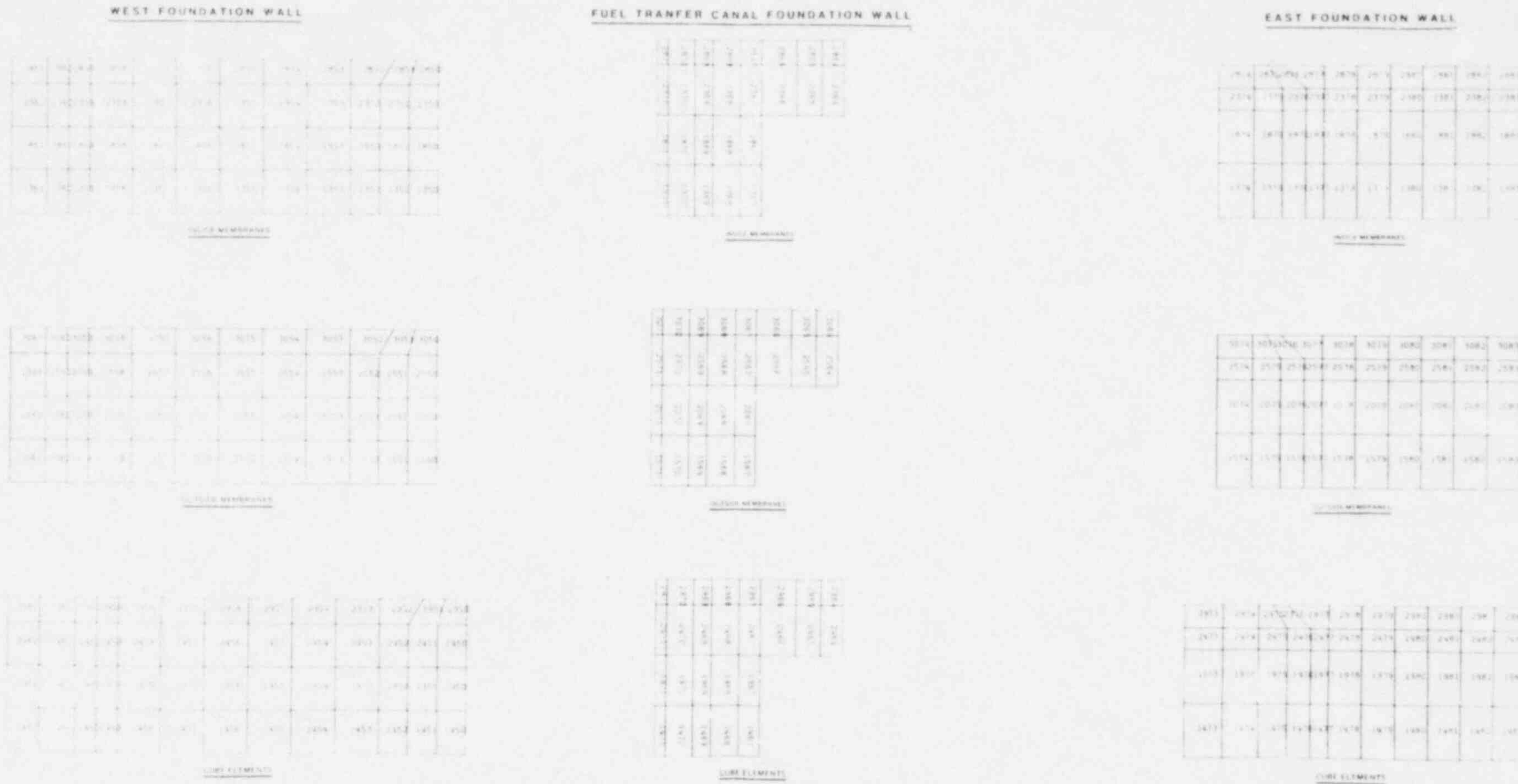


FIGURE 10

FOUNDATION WALLS ELEMENT NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

FIGURE 11

FOUNDATION WALLS NODE NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

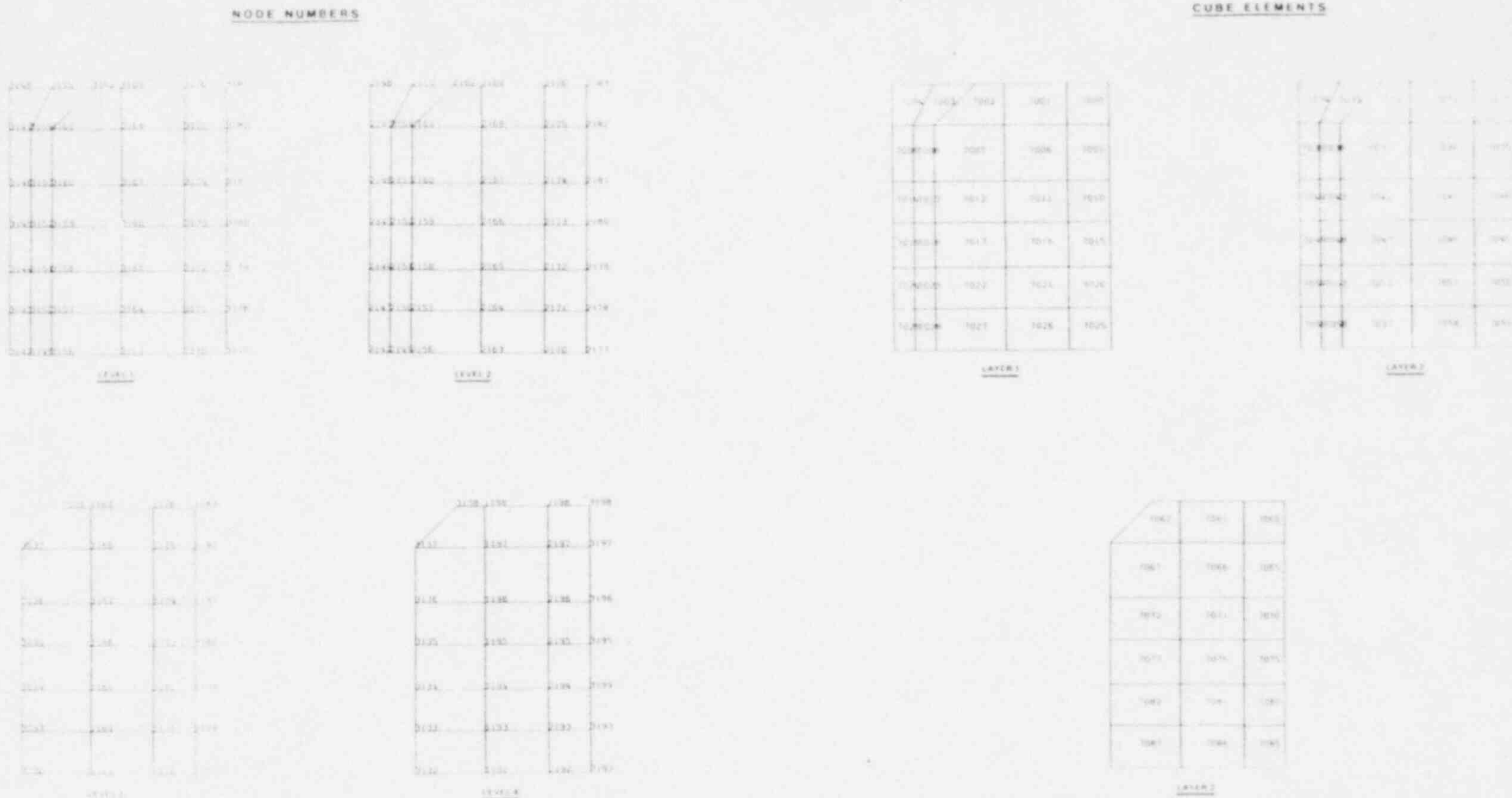


FIGURE 12

CASK LAYDOWN AREA FLOOR ELEMENT AND NODE NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

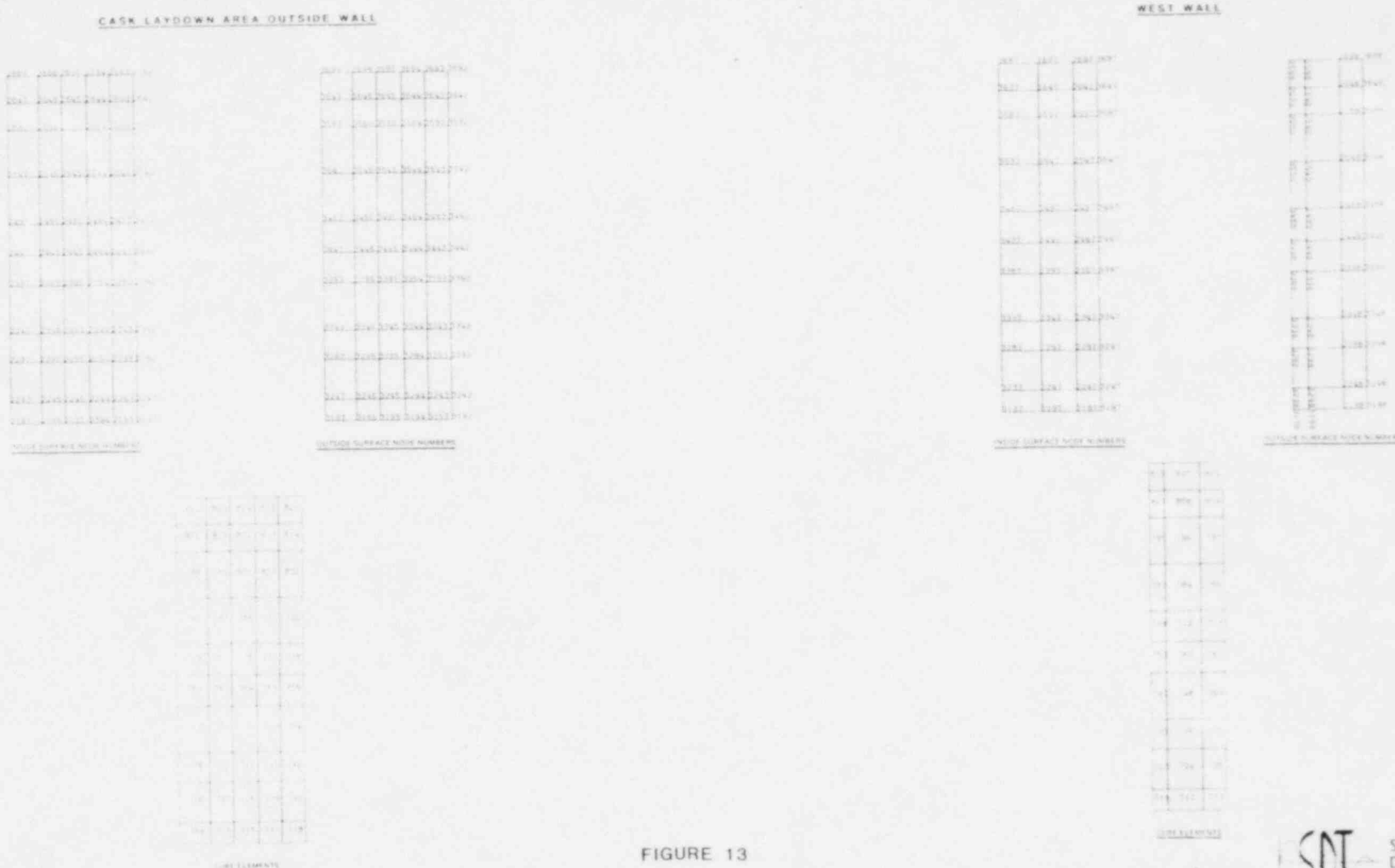


FIGURE 13

CASK LAYDOWN AREA WALLS ELEMENT AND NODE NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

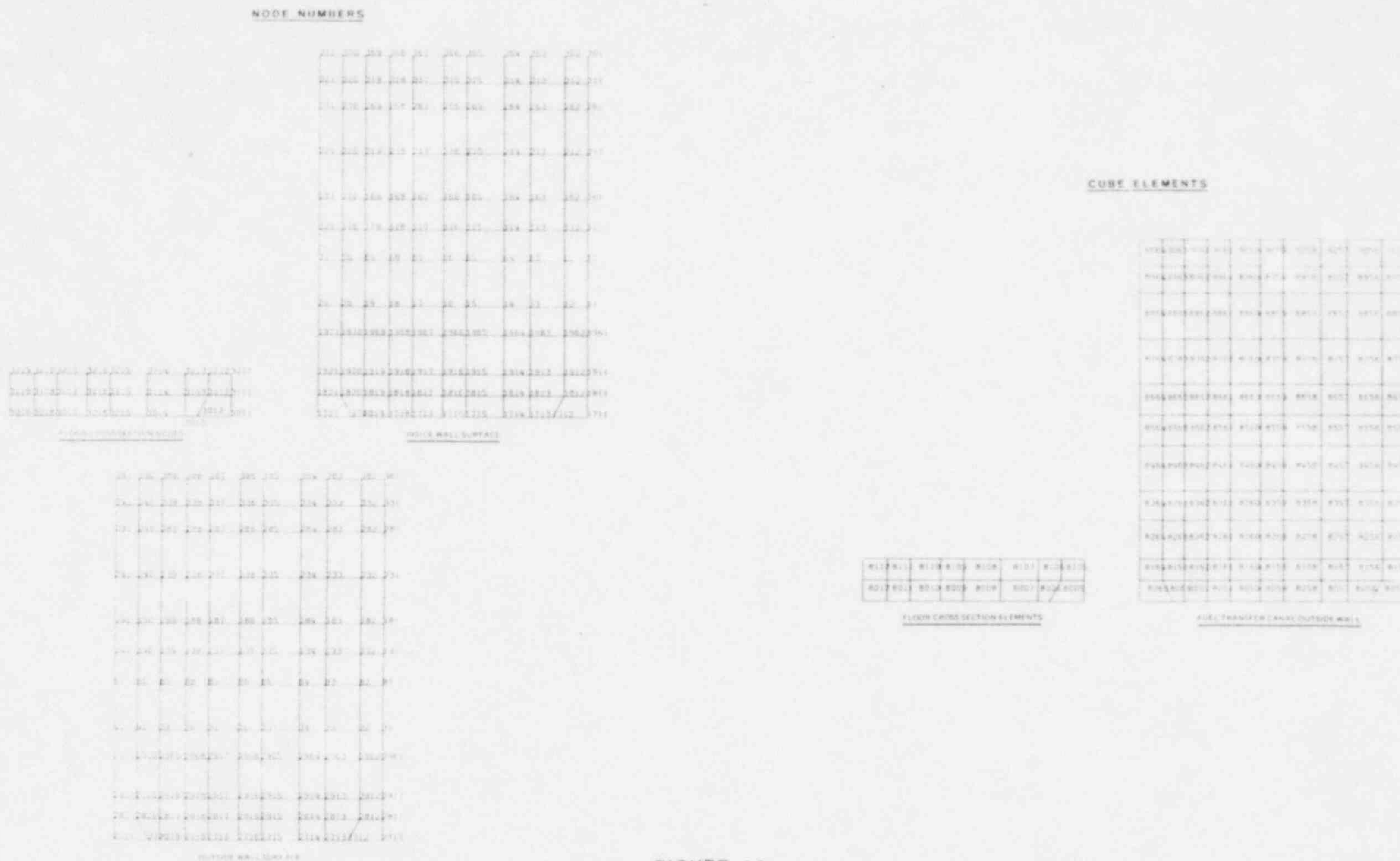
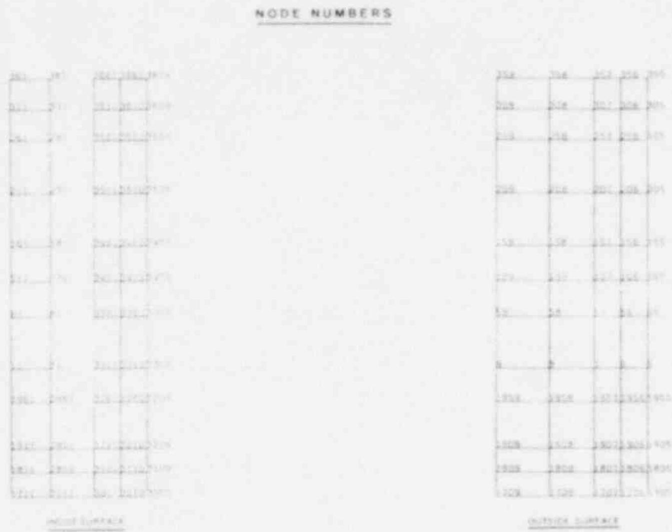


FIGURE 14

FUEL TRANSFER CANAL OUTSIDE WALL AND FLOOR
ELEMENT AND NODE NUMBERS

SDT Structural Dynamics Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL



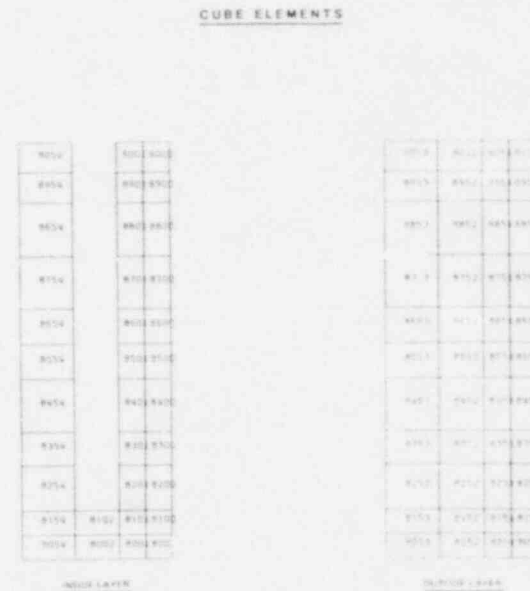


FIGURE 15

FUEL TRANSFER CANAL AREA
WEST WALL ELEMENT AND NODE NUMBERS

SDT Structural Dynamics Technology, Inc.