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MILSTONE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

General Offices • Seiden Street, Berlin, Connecticut

P.O. BOX 270
HARTFORD, CONNECTICUT 06141-0270
(203) 665-5000

October 28, 1985

Docket No. 50-336
B11827

Director of Nuclear Reactor Regulation
Attn: Mr. Edward J. Butcher, Chief
Operating Reactors Branch No. 3
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Millstone Nuclear Power Station, Unit No. 2
Reply to Request for Additional Information on Spent Fuel Storage Capacity

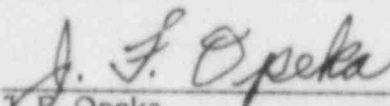
In October, 1985⁽¹⁾ the Staff requested additional information concerning a Northeast Nuclear Energy Company (NNECO) request⁽²⁾ to modify the Technical Specifications concerning the spent fuel storage capacity at Millstone Unit No. 2.

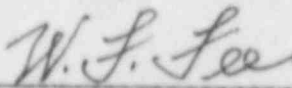
Attachment No. 1 to this letter provides the response, in a question and answer format, to the eleven (11) questions contained in the Staff's request for additional information.

We trust that the information provided is sufficient, and we remain ready to address any further questions as they arise to support expeditious processing of our pending amendment request.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY


J. F. Opeka
Senior Vice President


W. F. Fee
Executive Vice President

- (1) E. J. Butcher letter to J. F. Opeka, "Request for Additional Information on Spent Fuel Storage Capacity Expansion for Millstone Unit No. 2," dated October 3, 1985.
- (2) J. F. Opeka letter to E. J. Butcher, "Millstone Nuclear Power Station, Unit No. 2, Proposed Change to Technical Specification Modifications to Spent Fuel Storage Pool," dated July 24, 1985.

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Docket No. 50-336
B11827

Attachment No. 1

Millstone Nuclear Power Station, Unit No. 2
Response to Request for Additional Information on
Spent Fuel Storage Capacity

October, 1985

1. With respect to seismic loadings on the spent fuel rack modules:

a. Identify which modules were analyzed.

The following rack modules were analyzed:

- i) Region I 8 x 10 module
- ii) Region II 7 x 8 module
- iii) Region II 7 x 9 module
- iv) Region II modified 7 x 9 module

b. Provide a description of how the horizontal earthquake acceleration (time history) was oriented relative to the long and short cross-sectional dimensions of the rack modules in the non-linear displacement analysis.

The pool layout was arranged so that the rack modules were placed in specific locations and orientations within the spent fuel pool. Acceleration time histories were available for both the north-south and east-west directions. The acceleration time histories were applied to the rack module models in a manner consistent with their actual in-pool orientations.

c. Describe what constitutes the worst case (identifying the factors by which the worst case was identified) and how it was considered.

The worst case for shear load was a Region II 7 x 9 module, fully loaded and excited by the north-south seismic component.

The most significant factor in identifying possible worst cases is the relationship between the model natural frequencies and the acceleration response spectra for the appropriate spent fuel pool acceleration time histories. For a given response spectrum, potential worst cases may be identified by selecting cases where the model natural frequencies are near the peak of the response spectrum. There are a number of other factors, however, that have an effect on the model frequency characteristics and consequently the response loads, among these are; the natural frequency of the rack module in air, the type of fuel storage, the hydrodynamic effects between the fuel and the rack module and between the rack module and the pool structure.

Because a number of factors affect the identification of a "worst case", a number of analyses are performed, which correspond to different regions of the pool, different size modules, different earthquake directions and types of fuel storage.

2. Reference 4-2 was cited on page 22 of the Licensee's report in lieu of any description of the non-linear model:
 - a. Provide the relationship of this reference to the analysis performed for the Licensee's report.

The cited reference describes the general methodology used to develop a nonlinear seismic analysis model of a spent fuel rack module. The reference stresses the importance of modeling fuel assemblies as discrete structural elements and the non-linear impacting behavior between the rack module and the stored fuel. Beyond these general themes there is no specific relationship between the cited reference and the analysis performed for the Millstone 2 spent fuel racks.

SEISMIC ANALYSIS OF SPENT FUEL RACKS

R. LONGO


D. F. BAISLEY

Nuclear Power Systems
Combustion Engineering, Inc.
Windsor, Connecticut

Presented at

AMERICAN NUCLEAR SOCIETY
TOPICAL MEETING ON
OPTIONS FOR SPENT FUEL STORAGE

September 26-29, 1982
Savannah, Georgia

 POWER
SYSTEMS

ABSTRACT

The paper describes the nonlinear time history seismic analysis method used by C-E for the design and licensing of spent fuel racks. The method is applied to spent fuel racks that store both standard and consolidated fuel assemblies. The analysis is based upon a direct numerical integration of the coupled equations of motion for the fuel and the rack. The equations of motion account for the gaps, hydrodynamic coupling and impacting between the structures of the fuel and fuel rack system. A summary of representative results from nonlinear time history analyses covering a wide range of designs and seismic excitations is presented. A comparison of these results with those obtained through the use of the response spectrum analysis method is presented to demonstrate that the response spectrum method—which is unable to account for interaction effects—may lead to incorrect results. The importance of modeling the fuel as a separate structural element is established. Examples of how the fuel responds to seismic excitation at its own natural frequencies—not at that of the rack structure—are presented. The applicability of the seismic analysis method to a consolidated fuel and fuel rack design is discussed.

Additional copies of this technical paper may be obtained by writing Communications, Dept. 7021-1904, Windsor. Please refer to the number (TIS-7308) that appears in the lower right corner of the front cover.

SEISMIC ANALYSIS OF SPENT FUEL RACKS

INTRODUCTION

C-E led the industry in performing nonlinear time history seismic analyses of spent fuel racks in 1975. Since then, C-E has applied the methodology to nine spent fuel rack applications covering a wide range of designs and reactor sites. This experience is supplemented with many parameter studies using the nonlinear time-history method.

The nonlinear time-history analysis method employed by C-E is based upon a direct numerical integration of the equations of motion for the fuel and the rack. It utilizes multi-degree-of-freedom spring and lumped mass models of the fuel and the rack, and accounts for the effects of gaps and submergence in water directly in the equations of motion defined by the model. It uses the seismic excitation time-history corresponding to the spent fuel pool elevation in the auxiliary building. Figure 1 provides an example of a typical

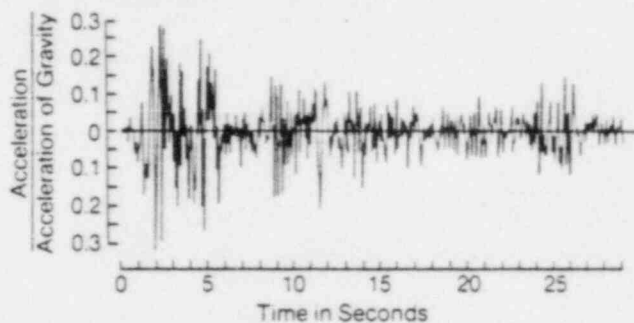


Figure 1: Example of Seismic Excitation Time History 1940 El Centro Earthquake

seismic excitation used for nonlinear time-history analysis—the acceleration time-history for the 1940 El Centro earthquake. The response of the fuel and rack, together with the seismic loads, is obtained directly from the analysis. The analysis is performed by means of the computer program CESHOCK.

To allow insertion and withdrawal of fuel, each spent fuel rack cell has a gap between the cell walls and the fuel. During seismic excitation, the fuel moves freely through the available gap and impacts the cell walls. The fuel responds to excitation at its own natural frequencies—not at that of the rack structure—since it is a separate structure and not attached to the rack. As the fuel moves within the rack and as the rack moves relative to the pool, the water between these structures is moved by them. The acceleration of the water introduces hydraulic loads on the structures which results in a lowering of natural frequencies of fuel and rack. These hydrodynamic effects are accentuated when the

interacting submerged structures are in close proximity (small gaps).

The nonlinear time-history method was developed by C-E for use in spent fuel rack analyses because the linear response spectrum method does not properly characterize the fuel-to-fuel rack-to-pool interaction and, as demonstrated later in this paper, it may yield incorrect results.

THEORY

To aid in understanding the analysis method requirements corresponding to the physical problem, consider the following simplified analog of the spent fuel rack problem (see Figure 2). The three concentric cylinders represent the pool (P), the rack (R), and the fuel (F). There is water between the fuel and the rack, and between the rack and the pool. The connection (spring K_G) between the fuel and the rack represents the gap between these structures as well as the impact stiffness with which the fuel spacer grids interact

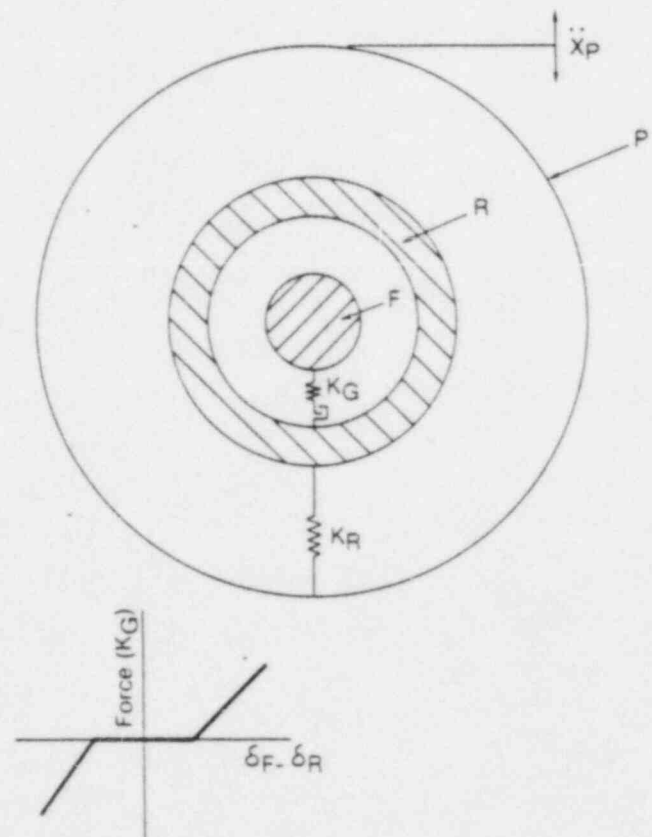


Figure 2: Simplified Analog of Spent Fuel Rack Physical Problem

with the rack when in contact. The connection (spring K_R) between the rack and the pool represents the manner in which the rack is supported by the pool. Nomenclature is as follows:

- \ddot{X}_p = seismic excitation (acceleration time-history) at spent fuel pool elevation
 $\ddot{\delta}_R$ = acceleration of rack (relative to pool)
 $\ddot{\delta}_F$ = acceleration of fuel (relative to pool)
 δ_R = displacement of rack (relative to pool)
 δ_F = displacement of fuel (relative to pool)
 M_R = mass of rack
 M_{R_0} = mass of water displaced by rack
 M_{R_C} = mass of water contained within rack
 M_F = mass of fuel
 M_{F_0} = mass of water displaced by fuel
 $F_{R_{IN}}$ = fluid force on inner boundary of rack
 $F_{R_{OUT}}$ = fluid force on outer boundary of rack
 $F_{F_{OUT}}$ = fluid force on outer boundary of fuel
 K_R, K_G = as defined above
 $\alpha_1, \alpha_2, \beta, \gamma$ = factors describing the effect of geometric proximity of hydrodynamics

With reference to the above nomenclature and Figure 2, and neglecting damping terms for purposes of simplifying discussion, the following equations of motion can be developed:

$$M_R(\ddot{X}_p + \ddot{\delta}_R) = -K_R(\delta_R) + K_G(\delta_F - \delta_R) + F_{R_{IN}} + F_{R_{OUT}}$$

$$M_F(\ddot{X}_p + \ddot{\delta}_F) = -K_G(\delta_F - \delta_R) + F_{F_{OUT}}$$

The fluid forces are given by:

$$F_{R_{OUT}} = M_{R_0}(\ddot{X}_p - \alpha_1 \ddot{\delta}_R)$$

$$F_{R_{IN}} = M_{R_C}(-\ddot{X}_p + 2\ddot{\delta}_F - \alpha_2 \ddot{\delta}_R)$$

$$F_{F_{OUT}} = M_{F_0}(\ddot{X}_p + 2\ddot{\delta}_R - \alpha_2 \ddot{\delta}_F)$$

Substitution of these expressions for fluid forces into the two equations of motion and simplification of terms yields the required coupled equations corresponding to the physical problem:

$$\begin{aligned}
 (M_R + \alpha_1 M_{R_0} + \alpha_2 M_{R_C})\ddot{\delta}_R - (2\beta M_{R_C})\ddot{\delta}_F + (K_R + K_G)\delta_R - K_G\delta_F = -(M_R + M_{R_C} - M_{R_0})\ddot{X}_p \\
 -(2\gamma M_{F_0})\ddot{\delta}_R + (M_F + \alpha_2 M_{F_0})\ddot{\delta}_F - K_G\delta_R + K_G\delta_F = -(M_F - M_{F_0})\ddot{X}_p
 \end{aligned}$$

The equations account for the gap between the fuel and the rack, the hydrodynamic coupling between the submerged structures and impacting between structures. The complete equations of motion (including damping) corresponding to the physical situation are modeled and solved

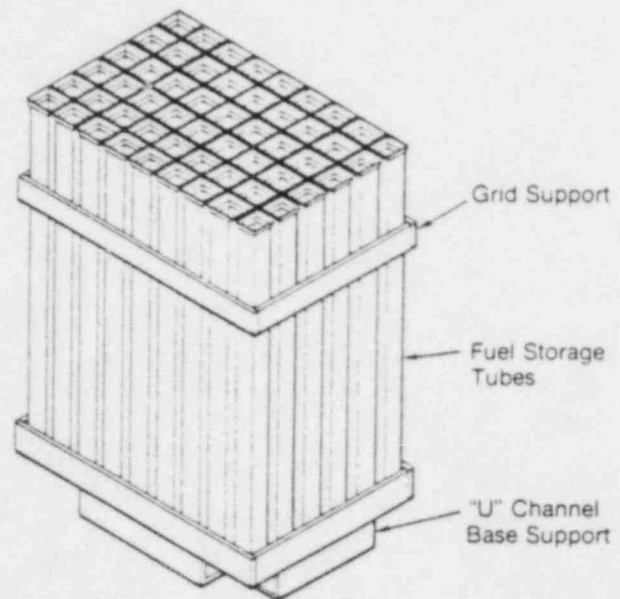


Figure 3: C-E HI-CAP Spent Fuel Rack Module

through the use of CESHOCK. In contrast to the above, the response spectrum method can accommodate only a single uncoupled equation for the response of a one-degree-of-freedom system. Modifying the response spectrum method to include an approximation of the effect of water on frequency, the analogous equation of motion for the system of Figure 3 that corresponds to the response spectrum method of analysis:

$$(M + M_C + M_0)\ddot{\delta} + K\delta = -(M + M_C)\ddot{X}_p$$

Here the representation of the system is clearly incomplete, with all sorts of approximations (of unknown effect) required to select the single values of mass, stiffness (linear only), etc., allowed. Comparison with the two equations above demonstrates the point that the response spectrum method does not model the real, physical situation. For example, it does not account for the gap between the fuel and the rack, which causes the system to have different natural frequencies (and to respond to different frequencies of excitation) and allows fuel to rack impacting to occur. Also, it does not account for the hydrodynamic coupling between the fuel and rack, with the introduction of interactive fluid forces.

RESULTS

A number of spent fuel rack seismic analyses have been performed by C-E, covering a wide range of rack designs and seismic excitations. The two basic types of spent fuel racks offered by C-E are shown in Figures 3 and 4. The High Capacity (HI-CAP) design in Figure 3 is composed of square storage cavities fabricated from stainless steel plate with each cavity capable of accepting one fuel assembly. The storage cavities are structurally connected to form modules from the use of channels, plates and chevron beams which provide the load-carrying frame and maintain spacing be-

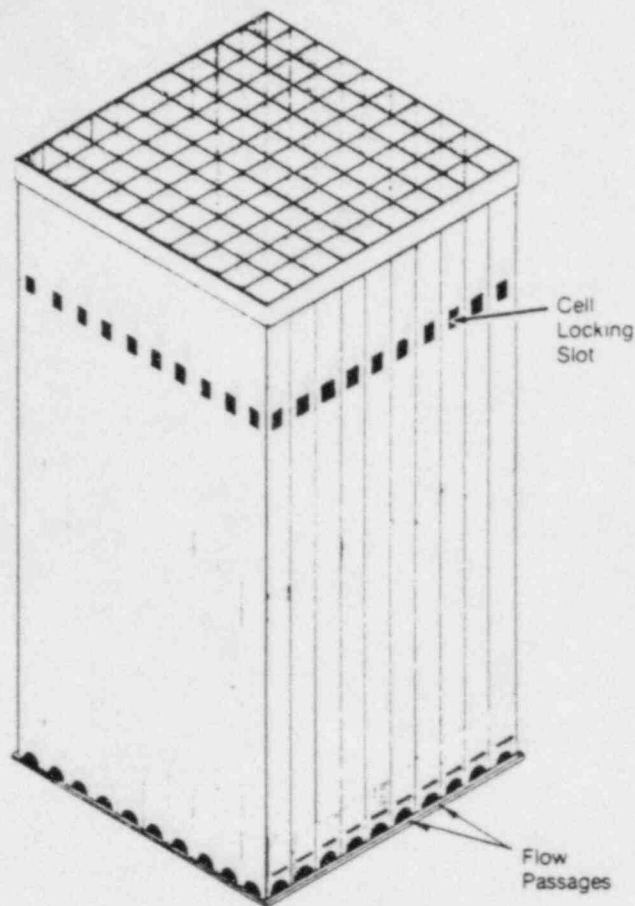


Figure 4: C-E Super HI-CAP Spent Fuel Storage Module

tween storage cavities. The C-E standard Super HI-CAP spent fuel storage rack shown in Figure 4 is a stainless steel monolithic honeycomb structure with square fuel storage locations. The fuel assembly storage cells are welded together to permit the assembled modules to be load-bearing structures as well as the storage cell enclosures. Each individual cell is a structural member and serves as a guide and retainer for a Neutron Poison Insert or a Consolidated Fuel Box. Following is a summary of representative results from nonlinear time-history analyses (utilizing CESHOCK), compared with corresponding response spectrum method analysis results.

Figure 5 shows several different seismic excitations used in obtaining the results. The response spectra are shown only to illustrate the differences in the excitations corresponding to seven sites; time-histories for these sites were used in the CESHOCK analyses.

Figures 6 and 7 represent two typical CESHOCK models. Model A corresponds to a freestanding HI-CAP design and Model B represents a freestanding Super HI-CAP design. For Model A, the fuel is modeled by masses 1 through 7 and springs K_{F1} through K_{F6} ; the rack is modeled by masses 8 through 14 and springs K_{R1} through K_{R6} ; the hydrodynamic coupling between the rack and the fuel and the rack and pool is represented by the couplings $-H$; the fuel-to-rack gaps and fuel-to-rack impact characteristics are modeled by the

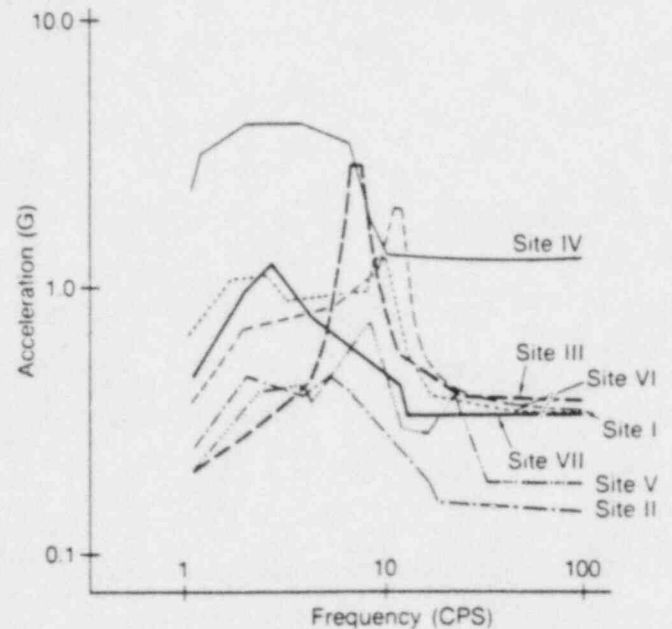


Figure 5: Spent Fuel Pools Seismic Response Spectra

nonlinear springs K_{G1} through K_{G6} ; the frictional restraint between the fuel and the rack and that between the rack and the pool are represented by the friction couplings F_{F-R} and F_{R-P} , respectively. The corresponding parameters for Model B are shown in Figure 7.

Figure 8 is a brief segment of typical displacement responses (Model A) to the seismic excitation corresponding

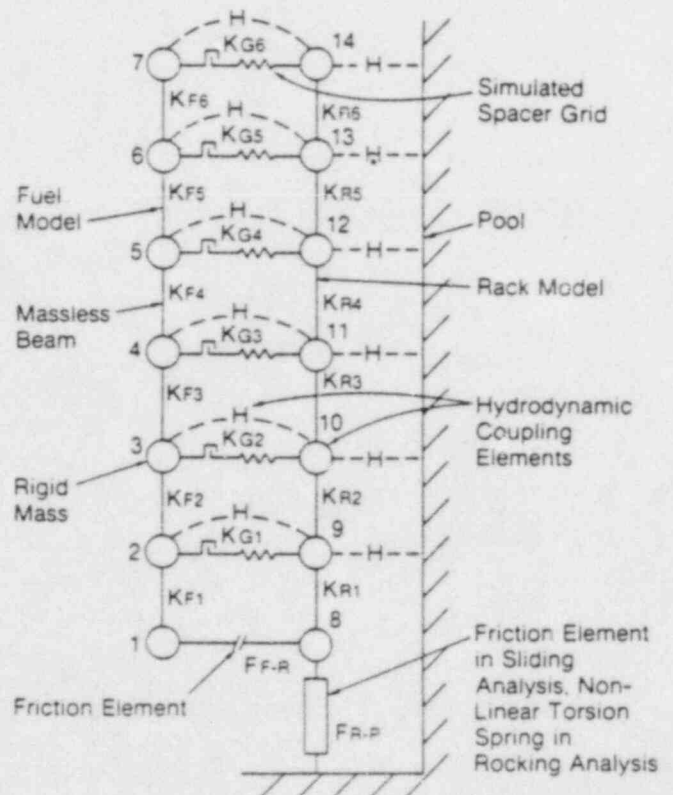


Figure 6: HI-CAP Fuel Rack Nonlinear CESHOCK Model

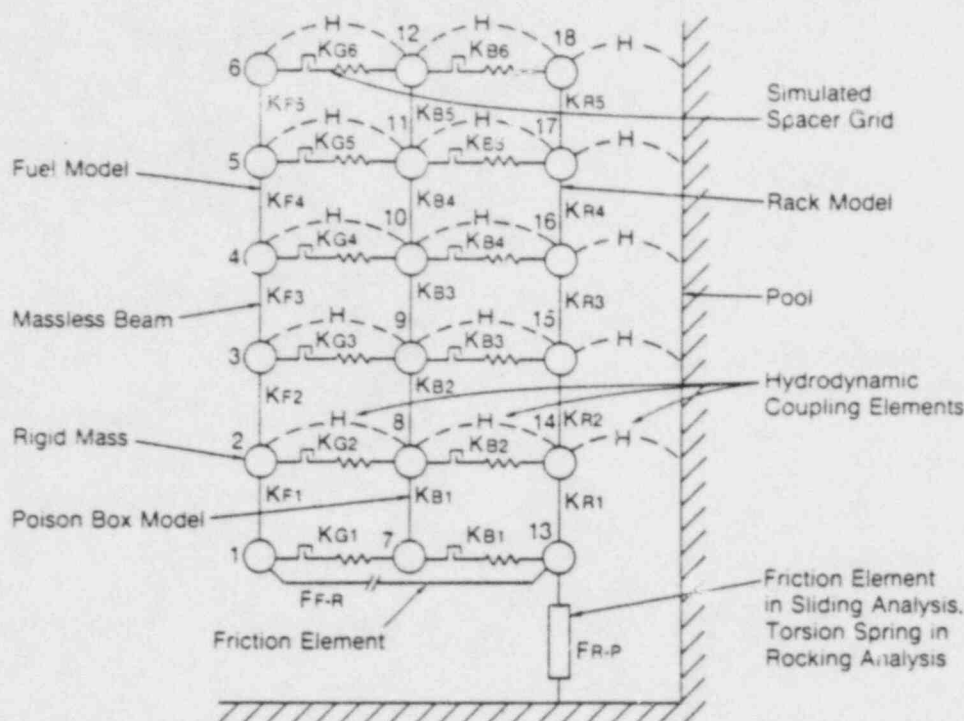


Figure 7: Super HI-CAP Fuel Rack Nonlinear CESHOCK Model

to a HI-CAP design for site III. Figure 9 provides a similar response for a Super HI-CAP design (Model B) for site VII. Note the low-amplitude, high-frequency response of the rack portion of the model in contrast to the high-amplitude, low-frequency response of the fuel. Typical fuel impact load pulses and their effect on peak base shear are seen by comparing the response quantities shown also on Figure 9. The peak base shears occurs just after the time of peak fuel impact loads.

Table I presents a tabulation of seismic loads developed within the rack and transmitted to the pool for a number of designs and the sites of Figure 5. The load values have been normalized. The first column identifies the site and the rack design. Four variations of a HI-CAP design (A – D) and 3 variations of a Super HI-CAP design (E – G) are presented. Four variations of HI-CAP design D are shown; the original version, a second version in which dynamic analysis parameters were changed by 10% (e.g., fuel stiffness), a third version with one-fourth the original fuel-to-rack gap, and a fourth version with an impact spring stiffness ten times that of the original. Four variations of Super HI-CAP design F are presented which include variation in gaps, impact stiffness and hydrodynamic mass representation. Design G shows results for both a stiff and a soft rack support structure. The second column presents the seismic loads obtained from the CESHOCK analyses. The third column presents the corresponding seismic loads obtained, for comparative purposes, by means of response spectrum method analyses. The last column gives the ratios of loads obtained by the two methods.

Comparison of results from nonlinear time-history analyses (fuel to rack interaction analyses) with those from re-

sponse spectrum analyses (refer to Table I) shows that the response spectrum method may give incorrect results. The results demonstrate the importance of the interaction between fuel and racks. The interaction is caused by the relative motion between the fuel and rack, through the water-filled gaps, and impacting of the fuel and rack.

TABLE I

IDENTIFIER SITE/DESIGN	NORMALIZED REACTION LOAD PER CELL		
	(1)	(2)	RATIO (1)/(2)
	TIME-HISTORY NONLINEAR ANALYSIS	RESPONSE SPECTRUM METHOD	
I DESIGN A (HI-CAP)	5.92	7.42	0.79
I DESIGN B (HI-CAP)	8.17	15.66	0.52
I DESIGN C (HI-CAP)	4.21	4.08	1.03
II DESIGN A	1.99	1.79	1.11
II	3.00	1.00	3.00
III DESIGN D (HI-CAP)	2.73	2.56	1.07
IV	17.08	8.74	1.95
II DESIGN D	ORIG.	3.00	3.00
	Δ 10%	2.83	2.83
	1/4 GAP	7.08	2.08
	10xK _G	4.27	4.27
V DESIGN E (SUPER HI-CAP)	3.84	2.72	1.41
VI DESIGN F (SUPER HI-CAP)	ORIG.	9.26	4.06
	GAP BOX/RACK	11.83	4.06
	GAP BOX/RACK	6.85	4.06
	DIFF HYDRO	7.93	4.06
	GAP BOX/RACK DIFF HYDRO 8 FUEL GAP 25 K _G (BOX)	7.93	4.06
VII DESIGN G	STIFF BASE	9.26	3.40
	SOFT BASE (SUPER HI-CAP)	4.19	5.31

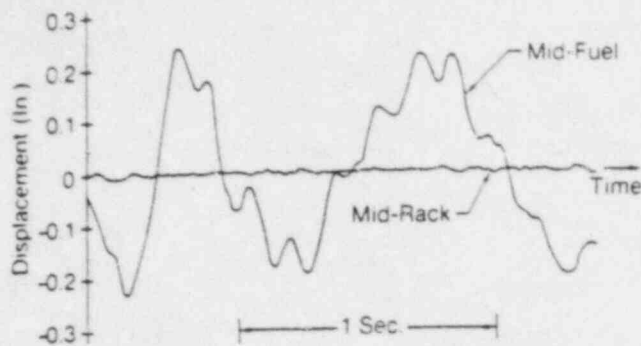


Figure 8: CESHOCK Displacement Response For HI-CAP Fuel Rack

FUEL CONSOLIDATION

Nonlinear time-history analysis is also used by C-E to analyze consolidated fuel rack designs. The consolidated fuel racks consist of the Super HI-CAP design with consolidated fuel rods in each cell. A typical consolidated fuel arrangement is shown in Figure 10. A consolidated fuel canister with a closely compacted array of fuel rods contained within it exhibits nonlinear characteristics similar to stan-

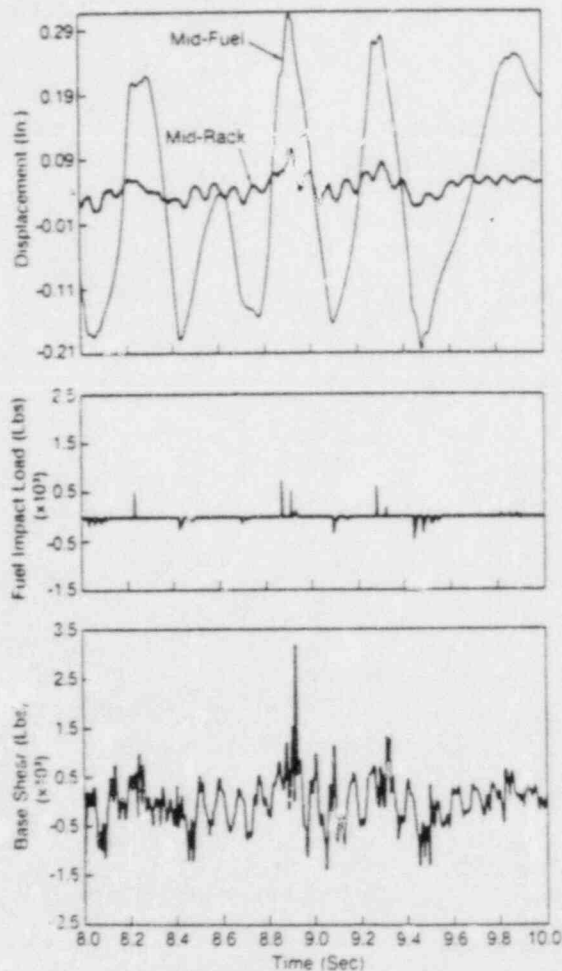


Figure 9: CESHOCK Response Parameters For Super HI-CAP Fuel Rack

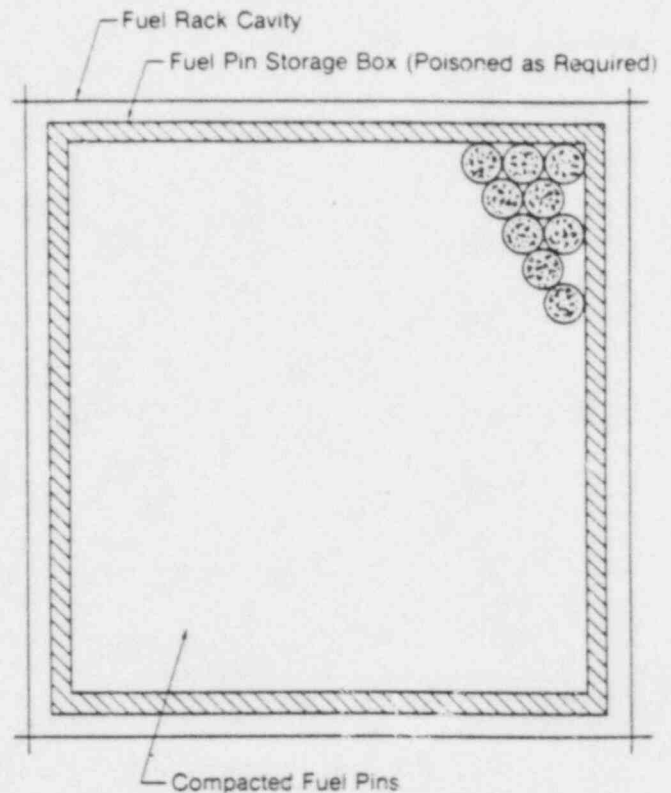


Figure 10: Consolidated Fuel Pin Arrangement

dard fuel assemblies. Separate models must be developed to represent different degrees of compaction and, for cases of less than complete compaction, fuel rod impacting must be accounted for. The hydrodynamic effects on fuel canister natural frequency and damping are also incorporated into the model. Basic modeling information concerning the dynamic interaction between the consolidated fuel and the can is provided only by testing. Because the interaction between consolidated fuel and the can is similar to standard fuel, the nonlinear time-history method is used to analyze consolidated fuel rack designs. The use of the response spectrum method for consolidated fuel rack designs may lead to incorrect results.

With consolidation factors of 2 or greater under consideration by many utilities, it is the job of the analyst to minimize storage pool design loads due to earthquakes. Because most pools were not designed for consolidation, they cannot readily accept higher loads. To minimize modifications to strengthen pools or to show that modifications are unnecessary, there are a number of steps the analyst can take. Some of the methods offered by C-E to obtain margin for consolidation designs are listed below:

1. Re-analyze the Auxiliary Building with Soil Structure Interaction.
2. Perform Finite Element Analysis of the Pool.
3. Couple the Fuel Rack Model to the Auxiliary Building Model.
4. Detune the Consolidated Fuel Racks from the Earthquake.

- b. Describe how the analysis for the Licensee's report differed from that presented in the referenced technical paper.

The analysis for the Licensee's report differed from that presented in the referenced paper in several respects. Most importantly, the analysis for the Licensee's report was done using models based on the Millstone 2 rack module designs and pool layout and site specific acceleration time history data. The actual Millstone 2 site specific model is described in the response to question #3.

- c. Provide a copy of the reference to expedite the review.

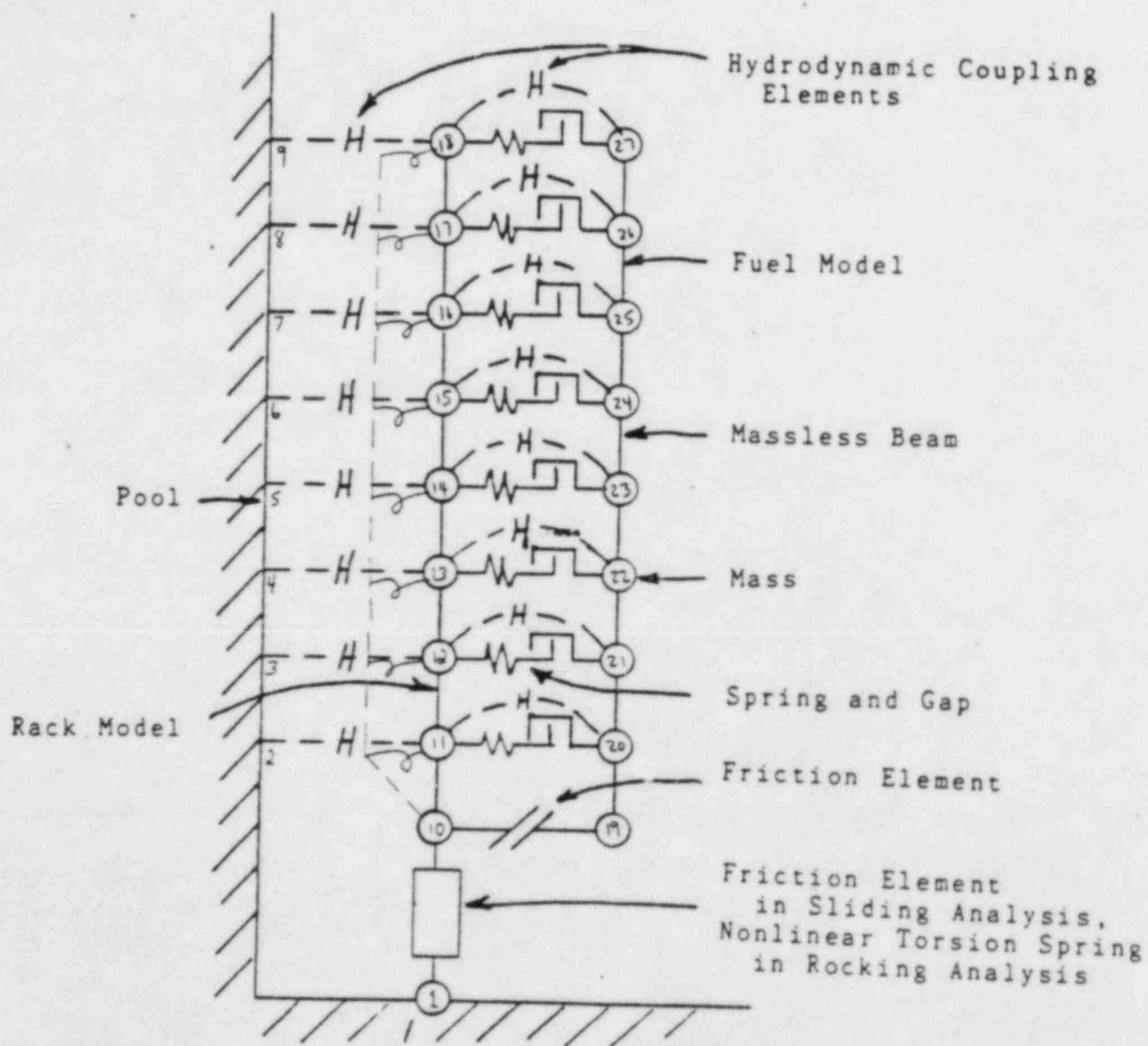
A copy of the referenced paper is attached.

3. Provide a full description of the mathematical model used for the non-linear rack module analysis.

A schematic description of the mathematical model used for the non-linear rack module analysis is shown in Figure 1. The model is two-dimensional, with each mass having a translational and a rotational degree-of-freedom. Mass nodes 1 through 18 were used to represent the fuel rack module. These mass nodes were linked by massless flexible elements. Similarly, mass nodes 19 through 27 were used to represent the fuel. Hydrodynamic couplings, designated by element H, are included between the rack module nodes and the pool structure nodes, and between the fuel nodes and the rack module nodes. Nonlinear gap-spring elements were used to represent the possibility of impacting between the fuel and the rack module. The fuel was coupled to the base of the rack module by a "slip-stick" friction element. An element at the interface of the module base and the pool liner represented a "slip-stick" friction element in the sliding analysis and a nonlinear torsion spring in the shear and rocking analyses.

FIGURE 1

CESHOCK Model of Millstone 2 Region II
7 X 9 Spent Fuel Rack Module



4. In addition to not providing the mathematical model for the non-linear dynamic displacement analysis, the Licensee did not indicate the relationship of the rack module analyzed to its adjacent rack modules.

The following information is required:

- a. Describe and justify how in-phase and/or out-of-phase motion with adjacent rack modules was considered and implemented

An in-phase mode of vibration was conservatively considered in assessing the hydrodynamic coupling effects between adjacent rack modules. Because of the character of the site specific Millstone 2 seismic excitation, the higher rack module frequencies resulting from the in-phase mode analysis were conservative because they were closer to the frequencies of the response spectra peaks. An out-of-phase mode of vibration would have resulted in the lower frequencies farther away from the response spectra peaks. The lower frequencies result from high hydrodynamic masses produced by out-of-phase motion.

- b. Describe fully how hydro dynamic coupling to adjacent rack modules was considered and justify the use of the theoretical basis employed.

In the nonlinear analysis models, hydrodynamic coupling is specified between the rack module and the pool, and between the fuel and the rack module. Potential theory (incompressible inviscid theory) is employed, using simple two-dimensional models of the structures coupled by the fluid, to estimate the hydrodynamic virtual mass terms based on the model configuration. Three-dimensional end effects were then accounted for by modifying the calculated hydrodynamic mass terms.

For the rack module-to-pool hydrodynamic element, the rack modules were assumed to move in-phase and the potential theory model consisted of two bodies: the fuel rack module array within the spent fuel pool structure.

To determine the resulting hydrodynamic mass terms, a finite element analysis using a computer code based on two-dimensional potential flow, was used. The ADDMASS computer code, C-E proprietary, was used to calculate the hydrodynamic masses of two dimensional bodies with arbitrary cross-sectional shapes with fluid finite elements between the bodies. ADDMASS is based principally on the following work: Yang, C.I., "A Finite - Element Code for Computing Added Mass Coefficients," Argonne National Laboratory Report No. ANL-LT-78-49, September 1978.

- c. Describe how the gap between adjacent rack modules was apportioned to each rack module and list the values for the racks analyzed.

A procedure of apportioning gaps between adjacent rack modules was not employed in the analysis.

- d. Provide numerical comparisons of rack displacements (at the top of the rack if that is the point of maximum displacement) to the apportioned clearance.

No method of apportioning intermodule clearances was used. The peak intermodule clearances was used. The peak intermodule relative displacement, however, was determined to be 1.776 inches. This is less than the actual clearance between modules.

- e. Where frequencies may be cited, please provide a copy of each reference with the response to expedite the review.

The cited references are attached.

5. With respect to the modeling of impact between the fuel assembly and a rack cell in the non-linear dynamic analysis:

- a. Provide the data and structural premise upon which impact stiffness was based.

C-E uses a gap-spring element to model the impact between the fuel assembly and the rack cell in a nonlinear dynamic analysis. The spring represents the spacer grid one-sided impact stiffness with the appropriate gap. C-E determines fuel assembly one-sided impact stiffnesses using full-scale fuel assembly pluck impact tests and model-test correlations of the test data with analytical results. The value of the spacer grid impact stiffness for the Westinghouse fuel assemblies that was provided to C-E by Northeast Utilities was greater than that for a C-E fuel assembly and was conservatively used in the nonlinear dynamic analysis.

- b. Provide the value of impact damping used, if greater than the nominal structural damping used in the analysis, and provide documentation justifying that damping value.

Impact damping was conservatively not used in the analysis.

6. The Licensee did not indicate what range of friction coefficient values was used in the non-linear displacement analysis between the rack mounting feet and the pool floor liner:

- a. Provide the range of friction coefficient used and describe the procedures used to determine the friction coefficient that produces the maximum rack displacement.

Friction between the pool liner and the module mounting feet is addressed in two ways. In the first approach, the rack module is not permitted to slide relative to the pool. In this case, the coefficient of friction is assumed to be extremely high to model the possibility of adhesion between the rack module and the pool which could occur

over the design life of the modules due to one of several mechanisms. This fixed-base model provides conservative shear loads to both the module and the pool liner.

The second approach uses a sliding-base model in which a friction element connects the rack module base to the pool liner. The friction element used is a slip-stick friction element with a velocity dependent coefficient of friction. Realistic values for the coefficient of friction are used in this sliding base model. A static coefficient of friction of 0.55 was used. The coefficient of friction decreases linearly with increasing relative velocity of the module base with respect to the pool liner until a minimum dynamic coefficient of friction of 0.28 is reached at a relative velocity of the module base with respect to the pool liner until a minimum dynamic coefficient of friction of 0.28 is reached at a relative velocity of 2.5 in/sec. For relative velocities above 2.5 in/sec., the minimum dynamic coefficient of friction applies.

- b. Justify and document the validity of the range of friction coefficient used.

The friction values used are based on the following sources:

- i) data from Combustion Engineering laboratory tests,
- ii) data obtained through a technical exchange agreement with Kraftwerk Union (KWU) of West Germany.

Final Report of a Theoretical and Experimental Study for Further Development of Light Water Pressurized Water Reactors, "Wear Behavior of Friction Materials and Protective Layers With Regard to their Application Possibilities in Water Cooled Nuclear Reactors", written by P. Hoffman, Metallic Materials RT41, Fordervagsvorhaben BMFT-Inv. Reakt. 72/S11 Kraftwerk Union, August 1973., and

- iii) textbook Friction and Wear of Materials, Ernest Rabinowicz.

Justification for the use of the stated values of friction coefficient lies in the basis of their selection being results of experimental studies. The values used in the analysis are values that have been derived from laboratory testing.

Question #7a - The Licensee did not indicate how the results from the non-linear displacement analysis was introduced to the stress analysis model.

- b - Provide full description of the load selection process and how the vertical and lateral dynamic loads on each rack mounting foot, as well as rack dead weight, are considered during rack lift-off in the stress analysis model.

Answer #7a - The results of the non-linear time history analyses, performed in both horizontal directions, and the linear response spectrum analysis, performed for the vertical direction, provide a set of load multiplication factors to be applied to the three-dimensional SAP IV stress model. The horizontal load factor is defined as the ratio of the maximum horizontal shear load derived from the CESHOCK model non-linear time history analysis to the horizontal empty rack (modal) weight from the SAP IV model. Likewise, the vertical load factor is defined as the ratio of the maximum vertical load determined from the response spectrum analysis to the vertical empty rack (modal) weight from the SAP IV model. The load factors are applied to the component stresses obtained from the SAP IV model. These stresses were obtained by applying a one-G response spectrum load to each of the three orthogonal directions. Maximum Base shears and load factors are tabulated below:

<u>Base Shears</u>	<u>Region I Rack</u>	<u>Region II Rack</u>
Maximum Horizontal:		
SSE	880#/Cell	977 #/Cell
OBE	Not Applicable	603 #/Cell

<u>Base Shears</u>	<u>Region I Rack</u>	<u>Region II Rack</u>
Maximum Vertical:		
SSE	3721 #/Cell	3423 #/Cell
OBE	SSE values for maximum vertical base shears were used.	

<u>Typical Load Factors</u>	<u>Region I Rack</u>	<u>Region II Rack</u>
Horizontal (X-direction)	10.10	12.70
Horizontal (Y-direction)	9.39	11.59
Vertical (Z-direction)	26.02	26.82
(Factors shown are based on 8 X 10 and 7 X 9 Racks.)		

- b. The analysis to determine the structural adequacy of the fuel storage module under tipping was conducted using the following technique: 1) Two loading conditions were applied to the SAP IV model these are: a 1-G horizontal load placed in the direction the module tips, and a 1-G vertical downward load. 2) Using the principal of superposition the vertical load is adjusted until the compression and tension in the feet which lift is reduced to zero, thereby creating a load state that approximates the module at the instant the module lifts off.

The actual horizontal seismic load, at the point of lift off, is determined in a similar fashion as described above using a non-linear time history analysis. The 1-G horizontal and the adjusted 1-G vertical load can now be factored. This factor will be the seismic load due to the loaded module divided by the 1-G horizontal load of an empty module.

8. Non-linear analyses, especially those involving impact of bodies as occurs between the fuel assemblies and the rack module, and between the rack mounting feet and the pool floor during lift-off, generally require additional procedures such as repeated solutions using a range of integration time steps to assure that the solution is both stable and fully converged. This is important because integration procedures that have yielded a valid solution do not necessarily remain stable for all solutions. The Licensee made no mention of this important point.
- a. Provide a description of the methods used to assure that a valid solution of the non-linear analysis was reached for all cases investigated.

The CESHOCK code numerically integrates the equations of motion using a Runge-Kutta-Gill technique. The initial integration timestep, calculated by CESHOCK, is one-twentieth of the period of the highest individual mass-spring frequency in the model. The timestep is continually checked and adjusted by the code as a function of the rate of change of the linear and angular accelerations. The timestep is held within the bounds of one-fifth times the initial timestep to two times the initial timestep. With this procedure for selecting the integration timestep, the CESHOCK numerical solution has been shown to be stable and convergent.

This approach can determine the stress state of the module due to module tipping under seismic effects. This approach is only valid for lift off of a few mils. The results of the non-linear analysis indicates such a situation does exist.

TYPICAL MULTIPLICATION FACTORS FOR SEISMIC EFFECT

Horizontal 1-G Factor = 6.895

Vertical 1-G Factor = 20.82

(Factors shown are based on 7 X 9 rack.)

Question #9 - At the bottom of page 22 of the Licensee's report, the Licensee stated that "The component stress on each element resulting from the application of each directional load is combined by the square root sum of the squares method". No computed stresses or allowable stresses were provided.

Answer #9a - Final Stress combinations are derived from R.S.S. method of each component stresses magnitude regardless of the direction. (E.G.: A typical element may be comprised of both tension and compression stress combined together.) The component stresses assumes a three directional earthquake having their peaks occurring simultaneously.

b. The loads and load combinations used in the structural analysis of the spent fuel racks are listed below and are consistent with NRC guidance in "Review an Acceptance of Spent Fuel Storage and Handling Applications".

<u>Load Combination</u> <u>(Elastic Analysis)</u>	<u>Acceptance Limit</u>
D + L	Normal limits of NF 3231.1a
D + L + E	Normal limits of NF 3231.1a
D + L + To	Lesser of 2Sy or Su stress range
D + L + To + E	Lesser of 2Sy or Su stress range
D + L + Ta + E	Lesser of 2Sy or Su stress range
D + L + Ta + E ¹	Faulted Condition Limits of NF 3231. 1c

The abbreviations in the table above are those used in Section 3.8.4 of the Standard Review Plan where each term is defined except for Ta which is defined as the highest temperature associated with the postulated abnormal design conditions.

- c. The maximum stress values associated with the analyses performed for the Millstone II spent fuel racks are provided below. These values are based upon the SSE load condition. Except for the adjustment screw, the stresses associated with the SSE load condition are lower than the OBE allowable stress limits and therefore are acceptable for both the OBE and SSE conditions. The stress values for the adjustment screw and their allowable stress limits are provided for both OBE and SSE condition. The design margin is defined as $\frac{\text{allowable} - 1}{\text{actual}} \times 100\%$.

NOTE: In most cases the maximum stress is associated with SSE load condition, while the allowable stress is for the OBE condition.

Maximum Stress

Stresses do not necessarily
occur at the same location.

A.	<u>Monolith</u>	<u>Maximum Stress</u>	<u>Allowable Stress</u>	<u>OBE</u>	<u>Design</u> <u>Margin</u>
----	-----------------	-----------------------	-------------------------	------------	--------------------------------

Membrane stress	=	17,560 psi	18,300 psi		4.2%
Membrane plus bending	=	21,760 psi	27,450 psi		26.2%
Primary plus thermal	=	28,511 psi	55,000 psi		92.9%

B. Support Bars

Bending stress	=	5,454 psi	16,500 psi		202.3%
Shear stress	=	526 psi	11,000 psi		1991.3%

C. Adjustable Foot

1. Block

Shear Stress	=	2,918 psi	11,000 psi		277.0%
Axial plus bending	=				
OBE	=	13,665 psi	16,500 psi		20.8%
SSE	=	19,290 psi	33,000 psi		71.1%

2. Adjustment Screw

<u>OBE Condition</u>	<u>Maximum Stress</u>	<u>OBE Allowable Stress</u>	<u>Design</u> <u>Margin</u>
Axial stress	= 11,810 psi	49,360 psi	317.9%
Shear stress	= 18,230 psi	33,500 psi	83.8%
Bending stress	= 24,980 psi	50,250 psi	101. %
Combined axial compress. plus bending	= $\frac{f_a}{F_a} + \frac{f_b}{F_b} = .736$	1	20.8%

<u>SSE Condition</u>	<u>Maximum Stress</u>	<u>SSE Allowable Stress</u>	<u>Design Margin</u>
Axial stress	= 14,773 psi	91,000 psi	516%
Shear stress	= 29,400 psi	54,600 psi	85.7%
Bending stress	= 60,554 psi	91,000 psi	50.28%
Combined axial compress. plus bending	= $\frac{f_a + f_b}{F_a F_b} = .828$	1	20.8%

<u>SSE Condition</u>	<u>Maximum Stress</u>	<u>SSE Allowable Stress</u>	
Thread shear	= 6,710 psi	11,000 psi	63.9%

Question #10 - With respect to fuel handling accidents as addressed by the Licensee on page 23 of the report:

- a. Provide analysis and justification as to why a spent fuel assembly falling through a rack cell and impacting the bottom of the cell "will not affect the primary function of the racks".
- b. Provide the approach, the assumptions, the data employed, and the results of analysis performed to assure that a fuel assembly dropped through a rack storage cell will not penetrate the bottom of the rack module, or, if it does penetrate the bottom of the rack module that it will not damage the pool liner.
- c. For the case of a crane uplift accident, provide the method of analysis employed, and the criteria by which the results were judged to be acceptable, including identification and documentation of the allowable stresses.

Answer #10a

The fuel drop accident was evaluated to determine the effect of the dropped assembly on the functional and structural integrity of the racks. The analysis indicated that the impact of the fuel assembly on the support bars caused plastic deformation of the support bars and the fuel cell wall supporting the bars. For conservatism it was assumed that further displacement of the bars occurs, resulting in the fuel and support bars resting on the pool floor. No functional or structural integrity of the racks was impaired.

- b. A fuel bundle drop vertically through the rack to the fuel support has resulted in the side walls of the rack shearing however, the bundle and support bars did not impact the floor, resulting in no damage to the pool liner. (The active fuel length of the bundle will remain contained within the storage rack.
- c. An analysis of a typical fuel rack indicated that the force required to deform an individual canister or to overcome the dead weight of the rack is significantly greater than the load which the spent fuel handling machine can impart.

QUESTION

11.a. Provide sketches and drawings of the portions of the pool and auxiliary building structures to be modeled.

Response

This section provides the finite element plots of the spent fuel pool, pool liner, and associated auxiliary building components covered by the analyses.

The models were derived based upon information supplied on the following NUSCO-Millstone Unit No. 2 drawings: 25203-11090 through 11099, 11104, 11106, 11107, 11112, 11126, 11127, 27016, 27018, 27019, 270122, 51044, 51045.

The spent fuel pool and associated auxiliary building components model contain over 9,600 degrees of freedom. Sketches are also provided of the floor liner plate model used in the analyses.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

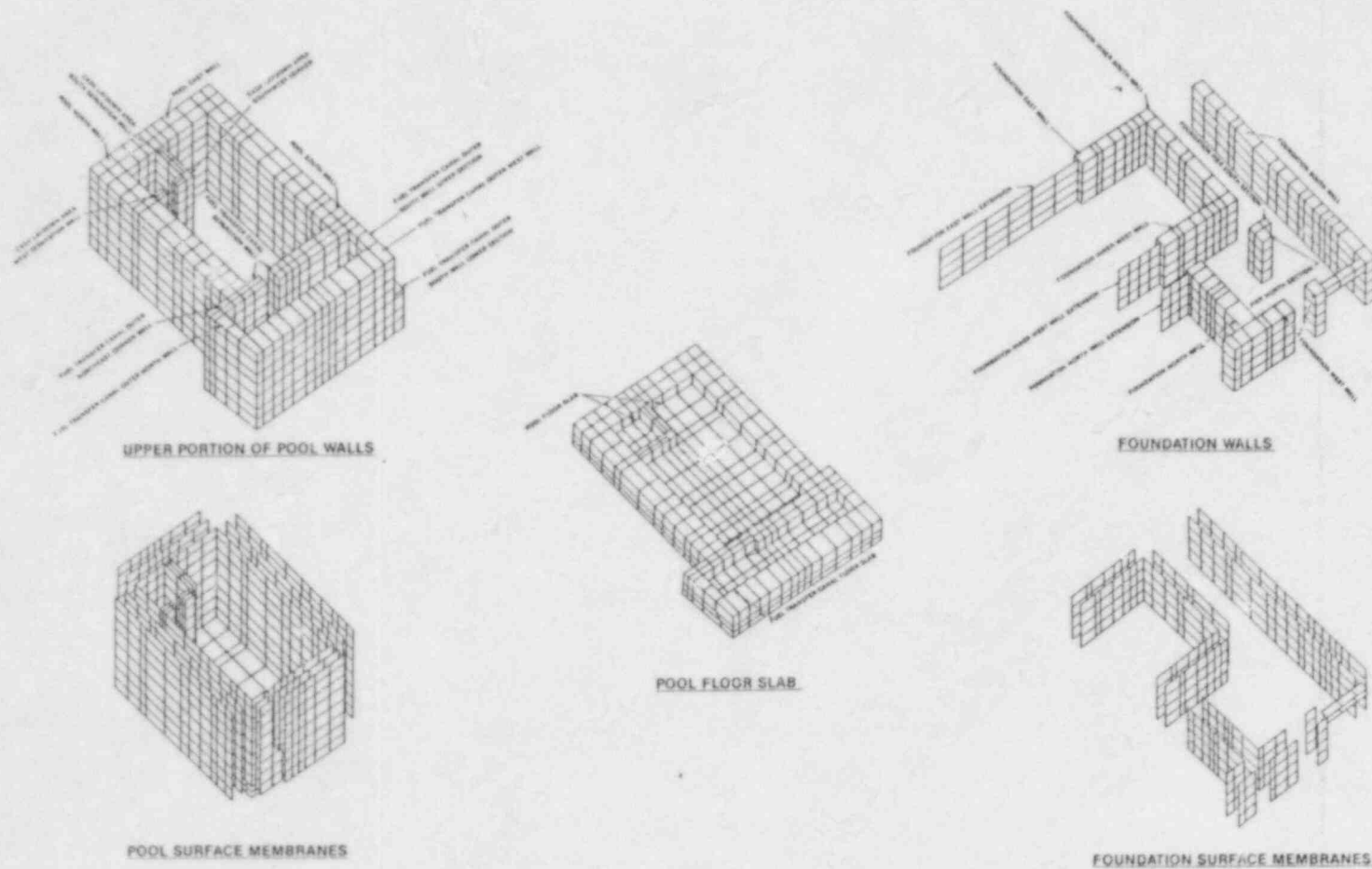


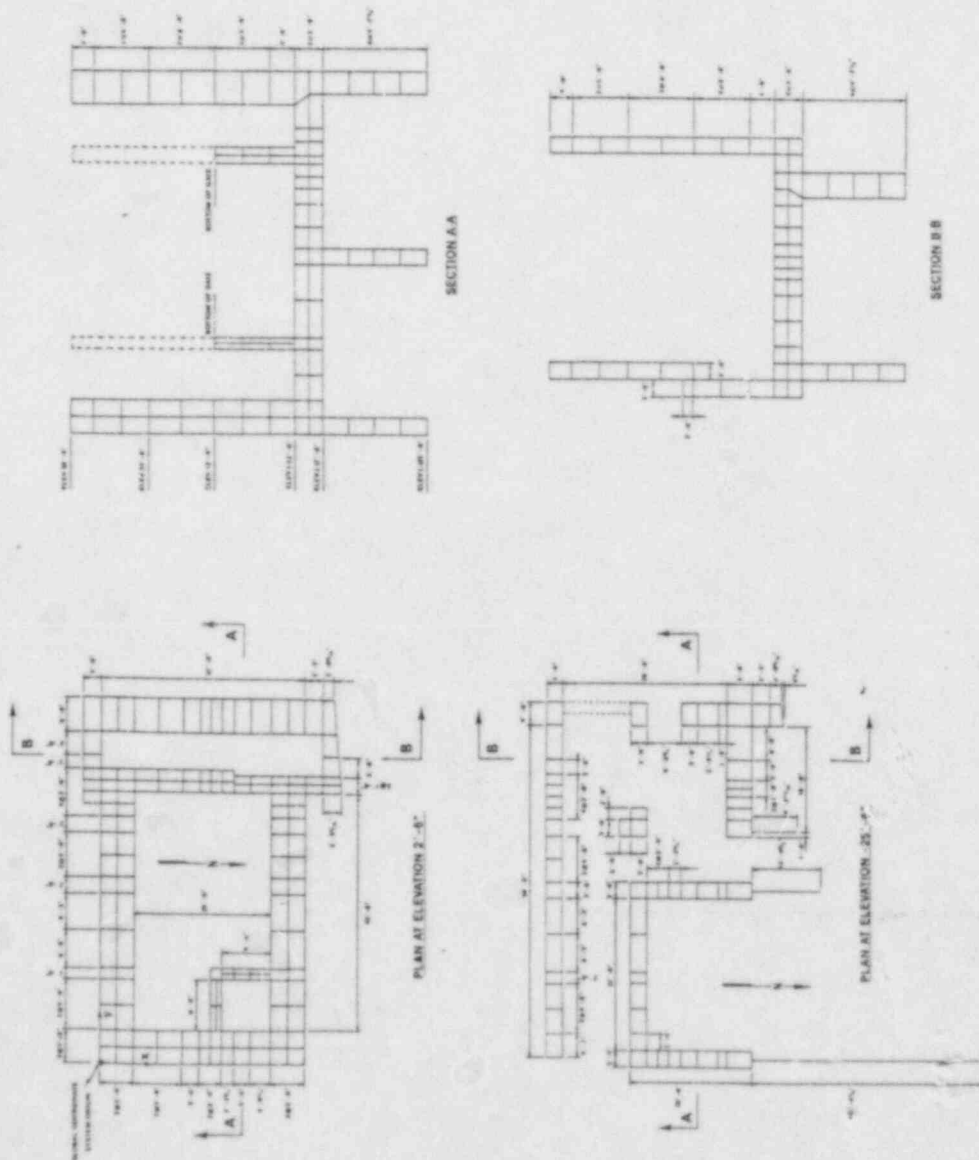
FIGURE 1
ISOMETRIC VIEWS AND KEY DIAGRAMS

NUS-01-015, REV 1
JULY 25, 1983
ENCLOSURE

ASDT Structural
Dynamics
Technology, Inc.

MILLSTONE POINT - UNIT 2 SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

11.a.3



GENERAL NOTES

- 1) Reference Drawings: "Millstone Nuclear Power Station, Unit No. 2", 2505 11090 thru 11099, 11104, 11106, 11107, 11112, 11126, 11127, 27016, 27018, 27019, 27022.
- 2) The following deviations from the reference drawings were made in areas not considered important to model behavior:
 - * The position of the lower south wall of the fuel transfer canal area was moved 3" north.
 - * The length of the lower south wall of the fuel transfer canal area was reduced to provide alignment with existing vaults.
 - * The curvature in the outside face of the north wall of the fuel transfer canal area was eliminated.
 - * The opening in the west foundation wall was adjusted to provide alignment with existing vaults.
- 3) Coordinate systems:
 - * Global coordinate system origin is located at the southeast outside corner of the pool at elevation 0' - 0".
 - * Local membrane element coordinate systems for pool and foundation walls are defined such that the positive local x axis vector points toward the positive global x axis and the positive local y axis vector points toward the positive global y axis. Local membrane element coordinate systems for the foundation wall are defined such that the positive local x axis vector points down with the positive local y axis vector parallel to the positive global x axis.
- 4) Membrane elements are provided on the surfaces of the walls that are to be modeled. The thickness of the walls is defined by the element thickness and the thickness of the walls is not provided additional information. The thickness of the walls is obtained from three membranes are used along with stresses obtained from the solid elements to calculate resultant section forces and moments.
- 5) Shear stiffness of auxiliary building floors and walls that frame into pool and foundation walls are represented as general matrix elements.
- 6) Foundation wall extensions are modeled as membrane elements with their actual thickness specified.
- 7) All solid elements are defined using eight nodes. Where intersections of components are made with a discontinuity of nodes, such as, the intersection of the east laydown separation walls with the pool walls, the non-continuous node is restrained to adjacent nodes such that the plane section through the non-continuous component remains plane.
- 8) The east laydown area gate opening is centered in east separation wall by relocating nodes from elevation 12' - 6" to top of pool as shown in Figure 8.
- 9) Section 1 to Figures 1, 2 and 11 are for the opening in the west foundation wall. Section 1 to Figure 7 shows the section heading for the north and south sections of the fuel transfer canal separation wall.

SOLID ELEMENTS

[illegible]

INSIDE LAYER.

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Population (millions)	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25
GDP (billions of dollars)	100	105	110	115	120	125	130	135	140	145	150
Per capita GDP (dollars)	87	90	94	97	101	104	108	110	114	117	120
Unemployment (%)	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0
Life expectancy (years)	70	71	72	73	74	75	76	77	78	79	80
Health expenditure (billions of dollars)	10	12	14	16	18	20	22	24	26	28	30
Health expenditure (% of GDP)	10	11	12	14	15	16	17	18	19	20	20
Health expenditure per capita (dollars)	8.7	10.4	12.0	13.6	15.1	16.7	18.2	19.5	21.0	22.6	24.0
Health expenditure per capita (% of GDP)	8.7	9.0	9.4	9.7	10.1	10.4	10.8	11.0	11.4	11.7	12.0
Health expenditure per capita (constant 1970 dollars)	8.7	9.0	9.4	9.7	10.1	10.4	10.8	11.0	11.4	11.7	12.0
Health expenditure per capita (constant 1970 dollars, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	120
Health expenditure per capita (constant 1970 dollars, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100, 1970=100)	100	102	104	106	108	110	112	114	116	118	12

OUTSIDE LAY-ON

8.73	8.85	8.95	9.08	9.17	9.28	9.38	9.52
9.77	9.83	9.94	10.03	10.18	10.27	10.38	10.54
10.75	10.82	10.93	11.06	11.15	11.26	11.37	11.58
12.75	12.81	12.92	13.03	13.18	13.25	13.38	13.57
14.55	14.60	14.70	14.82	14.93	15.08	15.18	15.38
16.68	16.78	16.90	17.01	17.12	17.23	17.38	17.53
18.87	18.97	19.08	19.20	19.31	19.42	19.53	19.68
20.85	20.97	21.08	21.20	21.32	21.43	21.53	21.68
22.85	22.98	23.10	23.22	23.32	23.43	23.53	23.68
24.85	24.98	25.10	25.22	25.32	25.43	25.53	25.68
26.85	26.98	27.10	27.22	27.32	27.43	27.53	27.68
28.85	28.98	29.10	29.22	29.32	29.43	29.53	29.68
30.85	30.98	31.10	31.22	31.32	31.43	31.53	31.68
32.85	32.98	33.10	33.22	33.32	33.43	33.53	33.68
34.85	34.98	35.10	35.22	35.32	35.43	35.53	35.68
36.85	36.98	37.10	37.22	37.32	37.43	37.53	37.68
38.85	38.98	39.10	39.22	39.32	39.43	39.53	39.68
40.85	40.98	41.10	41.22	41.32	41.43	41.53	41.68
42.85	42.98	43.10	43.22	43.32	43.43	43.53	43.68
44.85	44.98	45.10	45.22	45.32	45.43	45.53	45.68
46.85	46.98	47.10	47.22	47.32	47.43	47.53	47.68
48.85	48.98	49.10	49.22	49.32	49.43	49.53	49.68
50.85	50.98	51.10	51.22	51.32	51.43	51.53	51.68
52.85	52.98	53.10	53.22	53.32	53.43	53.53	53.68
54.85	54.98	55.10	55.22	55.32	55.43	55.53	55.68
56.85	56.98	57.10	57.22	57.32	57.43	57.53	57.68
58.85	58.98	59.10	59.22	59.32	59.43	59.53	59.68
60.85	60.98	61.10	61.22	61.32	61.43	61.53	61.68
62.85	62.98	63.10	63.22	63.32	63.43	63.53	63.68
64.85	64.98	65.10	65.22	65.32	65.43	65.53	65.68
66.85	66.98	67.10	67.22	67.32	67.43	67.53	67.68
68.85	68.98	69.10	69.22	69.32	69.43	69.53	69.68
70.85	70.98	71.10	71.22	71.32	71.43	71.53	71.68
72.85	72.98	73.10	73.22	73.32	73.43	73.53	73.68
74.85	74.98	75.10	75.22	75.32	75.43	75.53	75.68
76.85	76.98	77.10	77.22	77.32	77.43	77.53	77.68
78.85	78.98	79.10	79.22	79.32	79.43	79.53	79.68
80.85	80.98	81.10	81.22	81.32	81.43	81.53	81.68
82.85	82.98	83.10	83.22	83.32	83.43	83.53	83.68
84.85	84.98	85.10	85.22	85.32	85.43	85.53	85.68
86.85	86.98	87.10	87.22	87.32	87.43	87.53	87.68
88.85	88.98	89.10	89.22	89.32	89.43	89.53	89.68
90.85	90.98	91.10	91.22	91.32	91.43	91.53	91.68
92.85	92.98	93.10	93.22	93.32	93.43	93.53	93.68
94.85	94.98	95.10	95.22	95.32	95.43	95.53	95.68
96.85	96.98	97.10	97.22	97.32	97.43	97.53	97.68
98.85	98.98	99.10	99.22	99.32	99.43	99.53	99.68
100.85	100.98	101.10	101.22	101.32			

INSIDE SURFACE

0.872	0.858	0.845	0.828	0.817	0.828	0.732	0.702
0.872	0.852	0.836	0.822	0.816	0.822	0.736	0.706
0.871	0.851	0.835	0.821	0.815	0.821	0.735	0.705
0.870	0.850	0.832	0.819	0.818	0.825	0.736	0.705
0.869	0.849	0.831	0.818	0.817	0.824	0.735	0.704
0.868	0.848	0.830	0.817	0.816	0.823	0.734	0.703
0.867	0.847	0.829	0.816	0.815	0.822	0.733	0.702
0.866	0.846	0.828	0.815	0.814	0.821	0.732	0.701
0.865	0.845	0.827	0.814	0.813	0.820	0.731	0.700
0.864	0.844	0.826	0.813	0.812	0.819	0.730	0.699
0.863	0.843	0.825	0.812	0.811	0.818	0.729	0.698
0.862	0.842	0.824	0.811	0.810	0.817	0.728	0.697
0.861	0.841	0.823	0.810	0.809	0.816	0.727	0.696
0.860	0.840	0.822	0.809	0.808	0.815	0.726	0.695
0.859	0.839	0.821	0.808	0.807	0.814	0.725	0.694
0.858	0.838	0.820	0.807	0.806	0.813	0.724	0.693
0.857	0.837	0.819	0.806	0.805	0.812	0.723	0.692
0.856	0.836	0.818	0.805	0.804	0.811	0.722	0.691
0.855	0.835	0.817	0.804	0.803	0.810	0.721	0.690
0.854	0.834	0.816	0.803	0.802	0.809	0.720	0.689
0.853	0.833	0.815	0.802	0.801	0.808	0.719	0.688
0.852	0.832	0.814	0.801	0.800	0.807	0.718	0.687
0.851	0.831	0.813	0.800	0.799	0.806	0.717	0.686
0.850	0.830	0.812	0.799	0.798	0.805	0.716	0.685
0.849	0.829	0.811	0.798	0.797	0.804	0.715	0.684
0.848	0.828	0.810	0.797	0.796	0.803	0.714	0.683
0.847	0.827	0.809	0.796	0.795	0.802	0.713	0.682
0.846	0.826	0.808	0.795	0.794	0.801	0.712	0.681
0.845	0.825	0.807	0.794	0.793	0.800	0.711	0.680
0.844	0.824	0.806	0.793	0.792	0.799	0.710	0.679
0.843	0.823	0.805	0.792	0.791	0.798	0.709	0.678
0.842	0.822	0.804	0.791	0.790	0.797	0.708	0.677
0.841	0.821	0.803	0.790	0.789	0.796	0.707	0.676
0.840	0.820	0.802	0.789	0.788	0.795	0.706	0.675
0.839	0.819	0.801	0.788	0.787	0.794	0.705	0.674
0.838	0.818	0.800	0.787	0.786	0.793	0.704	0.673
0.837	0.817	0.799	0.786	0.785	0.792	0.703	0.672
0.836	0.816	0.798	0.785	0.784	0.791	0.702	0.671
0.835	0.815	0.797	0.784	0.783	0.790	0.701	0.670
0.834	0.814	0.796	0.783	0.782	0.789	0.700	0.669
0.833	0.813	0.795	0.782	0.781	0.788	0.699	0.668
0.832	0.812	0.794	0.781	0.780	0.787	0.698	0.667
0.831	0.811	0.793	0.780	0.779	0.786	0.697	0.666
0.830	0.810	0.792	0.779	0.778	0.785	0.696	0.665
0.829	0.809	0.791	0.778	0.777	0.784	0.695	0.664
0.828	0.808	0.790	0.777	0.776	0.783	0.694	0.663
0.827	0.807	0.789	0.776	0.775	0.782	0.693	0.662
0.826	0.806	0.788	0.775	0.774	0.781	0.692	0.661
0.825	0.805	0.787	0.774	0.773	0.780	0.691	0.660
0.824	0.804	0.786	0.773	0.772	0.779	0.690	0.659
0.823	0.803	0.785	0.772	0.771	0.778	0.689	0.658
0.822	0.802	0.784	0.771	0.770	0.777	0.688	0.657
0.821	0.801	0.783	0.770	0.769	0.776	0.687	0.656
0.820	0.800	0.782	0.769	0.768	0.775	0.686	0.655
0.819	0.799	0.781	0.768	0.767	0.774	0.685	0.654
0.818	0.798	0.780	0.767	0.766	0.773	0.684	0.653
0.817	0.797	0.779	0.766	0.765	0.772	0.683	0.652
0.816	0.796	0.778	0.765	0.764	0.771	0.682	0.651
0.815	0.795	0.777	0.764	0.763	0.770	0.681	0.650
0.814	0.794	0.776	0.763	0.762	0.769	0.680	0.649
0.813	0.793	0.775	0.762	0.761	0.768	0.679	0.648
0.812	0.792	0.774	0.761	0.760	0.767	0.678	0.647
0.811	0.791	0.773	0.760	0.759	0.766	0.677	0.646
0.810	0.790	0.772	0.759	0.758	0.765	0.676	0.645
0.809	0.789	0.771	0.758	0.757	0.764	0.675	0.644
0.808	0.788	0.770	0.757	0.756	0.763	0.674	0.643
0.807	0.787	0.769	0.756	0.755	0.762	0.673	0.642
0.806	0.786	0.768	0.755	0.754	0.761	0.672	0.641
0.805	0.785	0.767	0.754	0.753	0.760	0.671	0.640
0.804	0.784	0.766	0.753	0.752	0.759	0.670	0.639
0.803	0.783	0.765	0.752	0.751	0.758	0.669	0.638
0.802	0.782	0.764	0.751	0.750	0.757	0.668	0.637
0.801	0.781	0.763	0.750	0.749	0.756	0.667	0.636
0.800	0.780	0.762	0.749	0.748	0.755	0.666	0.635
0.799	0.779	0.761	0.748	0.747	0.754	0.665	0.634
0.798	0.778	0.760	0.747	0.746	0.753	0.664	0.633
0.797	0.777	0.759	0.746	0.745	0.752	0.663	0.632
0.796	0.776	0.758	0.745	0.744	0.751	0.662	0.631
0.795	0.775	0.757	0.744	0.743	0.750	0.661	0.630
0.794	0.774	0.756	0.743	0.742	0.749	0.660	0.629
0.793	0.773	0.755	0.742	0.741	0.748	0.659	0.628
0.792	0.772	0.754	0.741	0.740	0.747	0.658	0.627
0.791	0.771	0.753	0.740	0.739	0.746	0.657	0.626
0.790	0.770	0.752	0.739	0.738	0.745	0.656	0.625
0.789	0.769	0.751	0.738	0.737	0.744	0.655	0.624
0.788	0.768	0.750	0.737	0.736	0.743	0.654	0.623
0.787	0.767	0.749	0.736	0.735	0.742	0.653	0.622
0.786	0.766	0.748	0.735	0.734	0.741	0.652	0.621
0.785	0.765	0.747	0.734	0.733	0.740	0.651	0.620
0.784	0.764	0.746	0.733	0.732	0.739	0.650	0.619
0.783	0.763	0.745	0.732	0.731	0.738	0.649	0.618
0.782	0.762	0.744	0.731	0.730	0.737	0.648	0.617
0.781	0.761	0.743	0.730	0.729	0.736	0.647	0.616
0.780	0.760	0.742	0.729	0.728	0.735	0.646	0.615
0.779	0.759	0.741	0.728	0.727	0.734	0.645	0.614
0.778	0.758	0.740	0.727	0.726	0.733	0.644	0.613
0.777	0.757	0.739	0.726	0.725	0.732	0.643	0.612
0.776	0.756	0.738	0.725	0.724	0.731	0.642	0.611
0.775	0.755	0.737	0.724	0.723	0.730	0.641	0.610
0.774	0.754	0.736	0.723	0.722	0.729	0.640	0.609
0.773	0.753	0.735	0.722	0.721	0.728	0.639	0.608
0.772	0.752	0.734	0.721	0.720	0.727	0.638	0.607
0.771	0.751	0.733	0.720	0.719	0.726	0.637	0.606
0.770	0.750	0.732	0.719	0.718	0.725	0.636	0.605
0.769	0.749	0.731	0.718	0.717	0.724	0.635	0.604
0.768	0.748	0.730	0.717	0.716	0.723	0.634	0.603
0.767	0.747	0.729	0.716	0.715	0.722	0.633	0.602
0.766	0.746	0.728	0.715	0.714	0.721	0.632	0.601
0.765	0.745	0.727	0.714	0.713	0.720	0.631	0.600
0.764	0.744	0.726	0.713	0.712	0.719	0.630	0.599
0.763	0.743	0.725	0.712	0.711	0.718	0.629	0.598
0.762	0.742	0.724	0.711	0.710	0.717	0.628	0.597
0.761	0.741	0.723	0.710	0.709	0.716	0.627	0.596
0.760	0.740	0.722	0.709	0.708	0.715	0.626	0.595
0.759	0.739	0.721	0.708	0.707	0.714	0.625	0.594
0.758	0.738	0.720	0.707	0.706	0.713	0.624	0.593
0.757	0.737	0.719	0.706	0.705	0.712	0.623	0.592
0.756	0.736	0.718	0.705	0.704	0.711	0.622	0.591
0.755	0.735	0.717	0.704	0.703	0.710	0.621	0.590
0.754	0.734	0.716	0.703	0.702	0.709	0.620	0.589
0.753	0.733	0.715	0.702	0.701	0.708	0.619	0.588
0.752	0.732	0.714	0.701	0.700	0.707	0.618	0.587
0.751	0.731	0.713	0.700	0.699	0.706	0.617	0.586
0.750	0.730	0.712	0.699	0.698	0.705	0.616	0.585
0.749	0.729	0.711	0.698	0.697	0.704	0.615	0.584
0.748	0.728	0.710	0.697	0.696	0.703	0.614	0.583
0.747	0.727	0.709	0.696	0.695	0.702	0.613	0.582
0.746	0.726	0.708	0.695	0.694	0.701	0.612	0.581
0.745	0.725	0.707	0.694	0.693	0.700	0.611	0.580
0.744	0.724	0.706	0.693	0.692	0.699	0.610	0.579
0.743	0.723	0.705	0.692	0.691	0.698	0.609	0.578
0.742	0.722	0.704	0.691	0.690	0.697	0.608	0.577
0.741	0.721	0.703	0.690	0.689	0.696	0.607	0.576
0.740	0.720	0.702	0.689	0.688	0.695	0.606	0.575
0.739	0.719	0.701	0.688	0.687	0.694	0.605	0.574
0.738	0.718	0.700	0.687	0.686	0.693	0.604	0.573
0.737	0.717	0.699	0.686	0.685	0.692	0.603	0.572
0.736	0.716	0.698	0.685	0.684	0.691	0.602	0.571
0.735	0.715	0.697	0.684	0.683	0.690	0.601	0.570
0.734	0.714	0.696	0.683	0.682	0.689	0.600	0.569
0.733	0.713	0.695	0.682	0.681	0.688	0.599	0.568
0.732	0.712	0.694	0.681	0.680	0.687	0.598	0.567
0.731	0.711	0.693	0.680	0.679	0.686	0.597	0.566
0.730	0.710	0.692	0.679	0.678	0.685	0.596	0.565
0.729	0.709	0.691	0.678	0.677	0.684	0.595	0.564
0.728	0.708	0.690	0.677	0.676	0.683	0.594	0.563
0.727	0.707	0.689	0.676	0.675	0.682	0.593	0.562
0.726	0.706	0.688					

RODOLFO E. GUERRA JR.

0.672	0.674	0.675	0.708	0.717	0.728	0.738	0.750
0.672	0.683	0.686	0.705	0.716	0.727	0.738	0.749
0.671	0.682	0.683	0.704	0.715	0.726	0.737	0.748
0.680	0.681	0.682	0.703	0.714	0.725	0.736	0.747
0.680	0.680	0.681	0.702	0.713	0.724	0.735	0.746
0.680	0.679	0.680	0.701	0.712	0.723	0.734	0.745
0.687	0.688	0.689	0.700	0.711	0.722	0.733	0.744
0.686	0.677	0.680	0.698	0.710	0.721	0.732	0.743
0.682	0.675	0.687	0.698	0.709	0.720	0.731	0.742
0.684	0.676	0.687	0.697	0.708	0.719	0.730	0.741

OUTSIDE SURFACE

FIGURE 3
POOL SOUTH WALL ELEMENTS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

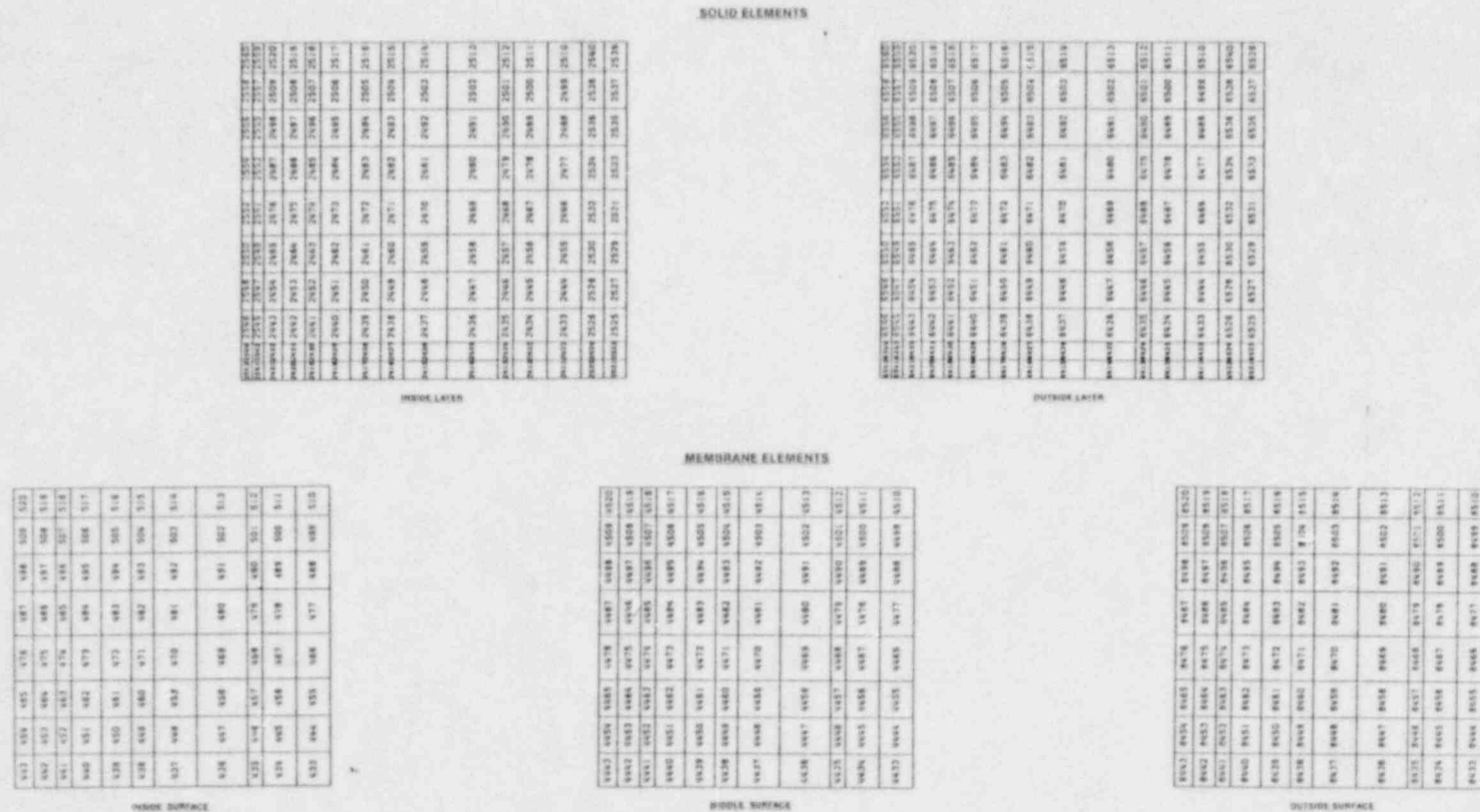


FIGURE 4

POOL NORTH WALL ELEMENTS

NUS-01-015
MARCH 25, 1983
ENCLOSURE

MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

SOUTH WALL

1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545	1546	1547	1548	1549	1550	1551	1552	1553	1554	1555	1556	1557	1558	1559	1560	1561	1562	1563	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573	1574	1575	1576	1577	1578	1579	1580	1581	1582	1583	1584	1585	1586	1587	1588	1589	1590	1591	1592	1593	1594	1595	1596	1597	1598	1599	1600	1601	1602	1603	1604	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	1615	1616	1617	1618	1619	1620	1621	1622	1623	1624	1625	1626	1627	1628	1629	1630	1631	1632	1633	1634	1635	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1661	1662	1663	1664	1665	1666	1667	1668	1669	1670	1671	1672	1673	1674	1675	1676	1677	1678	1679	1680	1681	1682	1683	1684	1685	1686	1687	1688	1689	1690	1691	1692	1693	1694	1695	1696	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	1738	1739	1740	1741	1742	1743	1744	1745	1746	1747	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	1758	1759	1760	1761	1762	1763	1764	1765	1766	1767	1768	1769	1770	1771	1772	1773	1774	1775	1776	1777	1778	1779	1780	1781	1782	1783	1784	1785	1786	1787	1788	1789	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	1820	1821	1822	1823	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	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	2
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SOLID ELEMENTS

Population (millions)	5.52	5.60	5.68	5.76	5.84	5.92	6.00	6.08	6.16	6.24	6.32	6.40	6.48	6.56	6.64	6.72	6.80	6.88	6.96	7.04	7.12	7.20	7.28	7.36	7.44	7.52	7.60	7.68	7.76	7.84	7.92	8.00	8.08	8.16	8.24	8.32	8.40	8.48	8.56	8.64	8.72	8.80	8.88	8.96	9.04	9.12	9.20	9.28	9.36	9.44	9.52	9.60	9.68	9.76	9.84	9.92	10.00	10.08	10.16	10.24	10.32	10.40	10.48	10.56	10.64	10.72	10.80	10.88	10.96	11.04	11.12	11.20	11.28	11.36	11.44	11.52	11.60	11.68	11.76	11.84	11.92	12.00	12.08	12.16	12.24	12.32	12.40	12.48	12.56	12.64	12.72	12.80	12.88	12.96	13.04	13.12	13.20	13.28	13.36	13.44	13.52	13.60	13.68	13.76	13.84	13.92	14.00	14.08	14.16	14.24	14.32	14.40	14.48	14.56	14.64	14.72	14.80	14.88	14.96	15.04	15.12	15.20	15.28	15.36	15.44	15.52	15.60	15.68	15.76	15.84	15.92	16.00	16.08	16.16	16.24	16.32	16.40	16.48	16.56	16.64	16.72	16.80	16.88	16.96	17.04	17.12	17.20	17.28	17.36	17.44	17.52	17.60	17.68	17.76	17.84	17.92	18.00	18.08	18.16	18.24	18.32	18.40	18.48	18.56	18.64	18.72	18.80	18.88	18.96	19.04	19.12	19.20	19.28	19.36	19.44	19.52	19.60	19.68	19.76	19.84	19.92	20.00	20.08	20.16	20.24	20.32	20.40	20.48	20.56	20.64	20.72	20.80	20.88	20.96	21.04	21.12	21.20	21.28	21.36	21.44	21.52	21.60	21.68	21.76	21.84	21.92	22.00	22.08	22.16	22.24	22.32	22.40	22.48	22.56	22.64	22.72	22.80	22.88	22.96	23.04	23.12	23.20	23.28	23.36	23.44	23.52	23.60	23.68	23.76	23.84	23.92	24.00	24.08	24.16	24.24	24.32	24.40	24.48	24.56	24.64	24.72	24.80	24.88	24.96	25.04	25.12	25.20	25.28	25.36	25.44	25.52	25.60	25.68	25.76	25.84	25.92	26.00	26.08	26.16	26.24	26.32	26.40	26.48	26.56	26.64	26.72	26.80	26.88	26.96	27.04	27.12	27.20	27.28	27.36	27.44	27.52	27.60	27.68	27.76	27.84	27.92	28.00	28.08	28.16	28.24	28.32	28.40	28.48	28.56	28.64	28.72	28.80	28.88	28.96	29.04	29.12	29.20	29.28	29.36	29.44	29.52	29.60	29.68	29.76	29.84	29.92	30.00	30.08	30.16	30.24	30.32	30.40	30.48	30.56	30.64	30.72	30.80	30.88	30.96	31.04	31.12	31.20	31.28	31.36	31.44	31.52	31.60	31.68	31.76	31.84	31.92	32.00	32.08	32.16	32.24	32.32	32.40	32.48	32.56	32.64	32.72	32.80	32.88	32.96	33.04	33.12	33.20	33.28	33.36	33.44	33.52	33.60	33.68	33.76	33.84	33.92	34.00	34.08	34.16	34.24	34.32	34.40	34.48	34.56	34.64	34.72	34.80	34.88	34.96	35.04	35.12	35.20	35.28	35.36	35.44	35.52	35.60	35.68	35.76	35.84	35.92	36.00	36.08	36.16	36.24	36.32	36.40	36.48	36.56	36.64	36.72	36.80	36.88	36.96	37.04	37.12	37.20	37.28	37.36	37.44	37.52	37.60	37.68	37.76	37.84	37.92	38.00	38.08	38.16	38.24	38.32	38.40	38.48	38.56	38.64	38.72	38.80	38.88	38.96	39.04	39.12	39.20	39.28	39.36	39.44	39.52	39.60	39.68	39.76	39.84	39.92	40.00	40.08	40.16	40.24	40.32	40.40	40.48	40.56	40.64	40.72	40.80	40.88	40.96	41.04	41.12	41.20	41.28	41.36	41.44	41.52	41.60	41.68	41.76	41.84	41.92	42.00	42.08	42.16	42.24	42.32	42.40	42.48	42.56	42.64	42.72	42.80	42.88	42.96	43.04	43.12	43.20	43.28	43.36	43.44	43.52	43.60	43.68	43.76	43.84	43.92	44.00	44.08	44.16	44.24	44.32	44.40	44.48	44.56	44.64	44.72	44.80	44.88	44.96	45.04	45.12	45.20	45.28	45.36	45.44	45.52	45.60	45.68	45.76	45.84	45.92	46.00	46.08	46.16	46.24	46.32	46.40	46.48	46.56	46.64	46.72	46.80	46.88	46.96	47.04	47.12	47.20	47.28	47.36	47.44	47.52	47.60	47.68	47.76	47.84	47.92	48.00	48.08	48.16	48.24	48.32	48.40	48.48	48.56	48.64	48.72	48.80	48.88	48.96	49.04	49.12	49.20	49.28	49.36	49.44	49.52	49.60	49.68	49.76	49.84	49.92	50.00	50.08	50.16	50.24	50.32	50.40	50.48	50.56	50.64	50.72	50.80	50.88	50.96	51.04	51.12	51.20	51.28	51.36	51.44	51.52	51.60	51.68	51.76	51.84	51.92	52.00	52.08	52.16	52.24	52.32	52.40	52.48	52.56	52.64	52.72	52.80	52.88	52.96	53.04	53.12	53.20	53.28	53.36	53.44	53.52	53.60	53.68	53.76	53.84	53.92	54.00	54.08	54.16	54.24	54.32	54.40	54.48	54.56	54.64	54.72	54.80	54.88	54.96	55.04	55.12	55.20	55.28	55.36	55.44	55.52	55.60	55.68	55.76	55.84	55.92	56.00	56.08	56.16	56.24	56.32	56.40	56.48	56.56	56.64	56.72	56.80	56.88	56.96	57.04	57.12	57.20	57.28	57.36	57.44	57.52	57.60	57.68	57.76	57.84	57.92	58.00	58.08	58.16	58.24	58.32	58.40	58.48	58.56	58.64	58.72	58.80	58.88	58.96	59.04	59.12	59.20	59.28	59.36	59.44	59.52	59.60	59.68	59.76	59.84	59.92	60.00	60.08	60.16	60.24	60.32	60.40	60.48	60.56	60.64	60.72	60.80	60.88	60.96	61.04	61.12	61.20	61.28	61.36	61.44	61.52	61.60	61.68	61.76	61.84	61.92	62.00	62.08	62.16	62.24	62.32	62.40	62.48	62.56	62.64	62.72	62.80	62.88	62.96	63.04	63.12	63.20	63.28	63.36	63.44	63.52	63.60	63.68	63.76	63.84	63.92	64.00	64.08	64.16	64.24	64.32	64.40	64.48	64.56	64.64	64.72	64.80	64.88	64.96	65.04	65.12	65.20	65.28	65.36	65.44	65.52	65.60	65.68	65.76	65.84	65.92	66.00	66.08	66.16	66.24	66.32	66.40	66.48	66.56	66.64	66.72	66.80	66.88	66.96	67.04	67.12	67.20	67.28	67.36	67.44	67.52	67.60	67.68	67.76	67.84	67.92	68.00	68.08	68.16	68.24	68.32	68.40	68.48	68.56	68.64	68.72	68.80	68.88	68.96	69.04	69.12	69.20	69.28	69.36	69.44	69.52	69.60	69.68	69.76	69.84	69.92	70.00	70.08	70.16	70.24	70.32	70.40	70.48	70.56	70.64	70.72	70.80	70.88	70.96	71.04	71.12	71.20	71.28	71.36	71.44	71.52	71.60	71.68	71.76	71.84	71.92	72.00	72.08	72.16	72.24	72.32	72.40	72.48	72.56	72.64	72.72	72.80	72.88	72.96	73.04	73.12	73.20	73.28	73.36	73.44	73.52	73.60	73.68	73.76	73.84	73.92	74.00	74.08	74.16	74.24	74.32	74.40	74.48	74.56	74.64	74.72	74.80	74.88	74.96	75.04	75.12	75.20	75.28	75.36	75.44	75.52	75.60	75.68	75.76	75.84	75.92	76.00	76.08	76.16	76.24	76.32	76.40	76.48	76.56	76.64	76.72	76.80	76.88	76.96	77.04	77.12	77.20	77.28	77.36	77.44	77.52	77.60	77.68	77.76	77.84	77.92	78.00	78.08	78.16	78.24	78.32	78.40	78.48	78.56	78.64	78.72	78.80	78.88	78.96	79.04	79.12	79.20	79.28	79.36	79.44	79.52	79.60	79.68	79.76	79.84	79.92	80.00	80.08	80.16	80.24	80.32	80.40	80.48	80.56	80.64	80.72	80.80	80.88	80.96	81.04	81.12	81.20	81.28	81.36	81.44	81.52	81.60	81.68	81.76	81.84	81.92	82.00	82.08	82.16	82.24	82.32	82.40	82.48	82.56	82.64	82.72	82.80	82.88	82.96	83.04	83.12	83.20	83.28	83.36	83.44	83.52	83.60	83.68	83.76	83.84	83.92	84.00	84.08	84.16	84.24	84.32	84.40	84.48	84.56	84.64	84.72	84.80	84.88	84.96	85.04	85.12	85.20	85.28	85.36	85.44	85.52	85.60	85.68	85.76	85.84	85.92	86.00	86.08	86.16	86.24	86.32	86.40	86.48	86.56	86.64	86.72	86.80	86.88	86.96	87.04	87.12	87.20	87.28	87.36	87.44	87.52	87.60	87.68	87.76	87.84	87.92	88.00	88.08	88.16	88.24	88.32	88.40	88.48	88.56	88.64	88.72	88.80	88.88	88.96	89.04	89.12	89.20	89.28	89.36	89.44	89.52	89.60	89.68	89.76	89.84	89.92	90.00	90.08	90.16	90.24	90.32	90.40	90.48	90.56	90.64	90.72	90.80	90.88	90.96	91.04	91.12	91.20	91.28	91.36	91.44	91.52	91.60	91.68	91.76	91.84	91.92	92.00	92.08	92.16	92.24	92.32	92.40	92.48	92.56	92.64	92.72	92.80	92.88	92.96	93.04	93.12	93.20	93.28	93.36	93.44	93.52	93.60	93.68	93.76	93.84	93.92	94.00	94.08	94.16	94.24	94.32	94.40	94.48	94.56	94.64	94.72	94.80	94.88	94.96	95.04	95.12	95.20	95.28	95.36	95.44	95.52	95.60	95.68	95.76	95.84	95.92	96.00	96.08	96.16	96.24	96.32	96.40	96.48	96.56	96.64	96.72	96.80	96.88	96.96	97.04	97.12	97.20	97.28	97.36	97.44	97.52	97.60	97.68	97.76	97.84	97.92	98.00	98.08	98.16	98.24	98.32	98.40	98.48	98.56	98.64	98.72	98.80	98.88	98.96	99.04	99.12	99.20	99.28	99.36	99.44	99.52	99.60	99.68	99.76	99.84	99.92	100.00	100.08	100.16	100.24	100.32	100.40	100.48	100.56	100.64	100.72	100.80	100.88	100.96	101.04	101.12	101.20	101.28	101.36	101.44	101.52	101.60	101.68	101.76	101.84	101.92	102.00	102.08	102.16	102.24	102.32	102.40	102.48	102.56	102.64	102.72	102.80	102.88	102.96	103.04	103.12	103.20	103.28	103.36	103.44	103.52	103.60	103.68	103.76	103.84	103.92	104.00	104.08	104.16	104.24	104.32	104.40
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INSIDE LATER

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OUTSIDE LAYER

907007	107	108	2054	2124	2044	2444	2084	2108	2324
907008	109	181	2051	2121	2045	2403	2085	2107	2309
907009	110	182	2050	2126	2044	2404	2086	2106	2310
907010	111	2053	2123	2043	2405	2087	2105	2311	
907011	112	2052	2124	2042	2406	2088	2104	2312	
907012	113	2051	2125	2041	2407	2089	2103	2313	
907013	114	2050	2126	2040	2408	2090	2102	2314	
907014	115	2049	2127	2039	2409	2091	2101	2315	
907015	116	2048	2128	2038	2410	2092	2100	2316	
907016	117	2047	2129	2037	2411	2093	2099	2317	
907017	118	2046	2130	2036	2412	2094	2098	2318	
907018	119	2045	2131	2035	2413	2095	2097	2319	
907019	120	2044	2132	2034	2414	2096	2096	2320	
907020	121	2043	2133	2033	2415	2097	2095	2321	
907021	122	2042	2134	2032	2416	2098	2094	2322	
907022	123	2041	2135	2031	2417	2099	2093	2323	
907023	124	2040	2136	2030	2418	2100	2092	2324	
907024	125	2039	2137	2029	2419	2101	2091	2325	
907025	126	2038	2138	2028	2420	2102	2090	2326	
907026	127	2037	2139	2027	2421	2103	2089	2327	
907027	128	2036	2140	2026	2422	2104	2088	2328	
907028	129	2035	2141	2025	2423	2105	2087	2329	
907029	130	2034	2142	2024	2424	2106	2086	2330	
907030	131	2033	2143	2023	2425	2107	2085	2331	
907031	132	2032	2144	2022	2426	2108	2084	2332	
907032	133	2031	2145	2021	2427	2109	2083	2333	
907033	134	2030	2146	2020	2428	2110	2082	2334	
907034	135	2029	2147	2019	2429	2111	2081	2335	
907035	136	2028	2148	2018	2430	2112	2080	2336	
907036	137	2027	2149	2017	2431	2113	2079	2337	
907037	138	2026	2150	2016	2432	2114	2078	2338	
907038	139	2025	2151	2015	2433	2115	2077	2339	
907039	140	2024	2152	2014	2434	2116	2076	2340	
907040	141	2023	2153	2013	2435	2117	2075	2341	
907041	142	2022	2154	2012	2436	2118	2074	2342	
907042	143	2021	2155	2011	2437	2119	2073	2343	
907043	144	2020	2156	2010	2438	2120	2072	2344	
907044	145	2019	2157	2009	2439	2121	2071	2345	
907045	146	2018	2158	2008	2440	2122	2070	2346	
907046	147	2017	2159	2007	2441	2123	2069	2347	
907047	148	2016	2160	2006	2442	2124	2068	2348	
907048	149	2015	2161	2005	2443	2125	2067	2349	
907049	150	2014	2162	2004	2444	2126	2066	2350	
907050	151	2013	2163	2003	2445	2127	2065	2351	
907051	152	2012	2164	2002	2446	2128	2064	2352	
907052	153	2011	2165	2001	2447	2129	2063	2353	
907053	154	2010	2166	2000	2448	2130	2062	2354	
907054	155	2009	2167	1999	2449	2131	2061	2355	
907055	156	2008	2168	1998	2450	2132	2060	2356	
907056	157	2007	2169	1997	2451	2133	2059	2357	
907057	158	2006	2170	1996	2452	2134	2058	2358	
907058	159	2005	2171	1995	2453	2135	2057	2359	
907059	160	2004	2172	1994	2454	2136	2056	2360	
907060	161	2003	2173	1993	2455	2137	2055	2361	
907061	162	2002	2174	1992	2456	2138	2054	2362	
907062	163	2001	2175	1991	2457	2139	2053	2363	
907063	164	2000	2176	1990	2458	2140	2052	2364	
907064	165	1999	2177	1989	2459	2141	2051	2365	
907065	166	1998	2178	1988	2460	2142	2050	2366	
907066	167	1997	2179	1987	2461	2143	2049	2367	
907067	168	1996	2180	1986	2462	2144	2048	2368	
907068	169	1995	2181	1985	2463	2145	2047	2369	
907069	170	1994	2182	1984	2464	2146	2046	2370	
907070	171	1993	2183	1983	2465	2147	2045	2371	
907071	172	1992	2184	1982	2466	2148	2044	2372	
907072	173	1991	2185	1981	2467	2149	2043	2373	
907073	174	1990	2186	1980	2468	2150	2042	2374	
907074	175	1989	2187	1979	2469	2151	2041	2375	
907075	176	1988	2188	1978	2470	2152	2040	2376	
907076	177	1987	2189	1977	2471	2153	2039	2377	
907077	178	1986	2190	1976	2472	2154	2038	2378	
907078	179	1985	2191	1975	2473	2155	2037	2379	
907079	180	1984	2192	1974	2474	2156	2036	2380	
907080	181	1983	2193	1973	2475	2157	2035	2381	
907081	182	1982	2194	1972	2476	2158	2034	2382	
907082	183	1981	2195	1971	2477	2159	2033	2383	
907083	184	1980	2196	1970	2478	2160	2032	2384	
907084	185	1979	2197	1969	2479	2161	2031	2385	
907085	186	1978	2198	1968	2480	2162	2030	2386	
907086	187	1977	2199	1967	2481	2163	2029	2387	
907087	188	1976	2200	1966	2482	2164	2028	2388	
907088	189	1975	2201	1965	2483	2165	2027	2389	
907089	190	1974	2202	1964	2484	2166	2026	2390	
907090	191	1973	2203	1963	2485	2167	2025	2391	
907091	192	1972	2204	1962	2486	2168	2024	2392	
907092	193	1971	2205	1961	2487	2169	2023	2393	
907093	194	1970	2206	1960	2488	2170	2022	2394	
907094	195	1969	2207	1959	2489	2171	2021	2395	
907095	196	1968	2208	1958	2490	2172	2020	2396	
907096	197	1967	2209	1957	2491	2173	2019	2397	
907097	198	1966	2210	1956	2492	2174	2018	2398	
907098	199	1965	2211	1955	2493	2175	2017	2399	
907099	200	1964	2212	1954	2494	2176	2016	2400	
907100	201	1963	2213	1953	2495	2177	2015	2401	
907101	202	1962	2214	1952	2496	2178	2014	2402	
907102	203	1961	2215	1951	2497	2179	2013	2403	
907103	204	1960	2216	1950	2498	2180	2012	2404	
907104	205	1959	2217	1949	2499	2181	2011	2405	
907105	206	1958	2218	1948	2500	2182	2010	2406	
907106	207	1957	2219	1947	2501	2183	2009	2407	
907107	208	1956	2220	1946	2502	2184	2008	2408	
907108	209	1955	2221	1945	2503	2185	2007	2409	
907109	210	1954	2222	1944	2504	2186	2006	2410	
907110	211	1953	2223	1943	2505	2187	2005	2411	
907111	212	1952	2224	1942	2506	2188	2004	2412	
907112	213	1951	2225	1941	2507	2189	2003	2413	
907113	214	1950	2226	1940	2508	2190	2002	2414	
907114	215	1949	2227	1939	2509	2191	2001	2415	
907115	216	1948	2228	1938	2510	2192	2000	2416	
907116	217	1947	2229	1937	2511	2193	1999	2417	
907117	218	1946	2230	1936	2512	2194	1998	2418	
907118	219	1945	2231	1935	2513	2195	1997	2419	
907119	220	1944	2232	1934	2514	2196	1996	2420	
907120	221	1943	2233	1933	2515	2197	1995	2421	
907121	222	1942	2234	1932	2516	2198	1994	2422	
907122	223	1941	2235	1931	2517	2199	1993	2423	
907123	224	1940	2236	1930	2518	2200	1992	2424	
907124	225	1939	2237	1929	2519	2201	1991	2425	
907125	226	1938	2238	1928	2520	2202	1990	2426	
907126	227	1937	2239	1927	2521	2203	1989	2427	
907127	228	1936	2240	1926	2522	2204	1988	2428	
907128	229	1935	2241	1925	2523	2205	1987	2429	
907129	230	1934	2242	1924	2524	2206	1986	2430	
907130	231	1933	2243	1923	2525	2207	1985	2431	
907131	232	1932	2244	1922	2526	2208	1984	2432	
907132	233	1931	2245	1921	2527	2209	1983	2433	
907133	234	1930	2246	1920	2528	2210	1982	2434	
907134	235	1929	2247	1919	2529	2211	1981	2435	
907135	236	1928	2248	1918	2530	2212	1980	2436	
907136	237	1927	2249	1917	2531	2213	1979	2437	
907137	238	1926	2250	1916	2532	2214	1978	2438	
907138	239	1925	2251	1915	2533	2215	1977	2439	
907139	240	1924	2252	1914	2534	2216	1976	2440	
907140	241	1923	2253	1913	2535	2217	1975	2441	
907141	242	1922	2254	1912	2536	2218	1974	2442	
907142	243	1921	2255	1911	2537	2219	1973	2443	
907143	244	1920	2256	1910	2538	2220	1972	2444	
907144	245	1919	2257						

SPINNING SURFACE

5884	5882	5856	5858	5828	5832	5830
5893	5891	5886	5887	5838	5822	5831
5882	5880	5848	5848	5814	5822	5830
5881	5881	5847	5825	5812	5829	5827
5860	5848	5836	5806	5812	5826	5828
5878	5867	5832	5823	5811	5819	5827
5868	5866	5846	5822	5812	5818	5826
5865	5865	5832	5821	5806	5817	5825

INSIDE SURFACE

PLANT ELEMENTS

[illegible]

BANDS SURFACE

95.96	95.92	96.06	96.18	96.28	96.50
96.02	96.01	96.09	96.15	96.23	96.38
96.42	96.50	96.68	96.78	96.92	96.98
96.81	96.89	96.97	97.05	97.13	97.29
97.40	97.48	97.56	97.64	97.72	97.88
97.95	98.07	98.13	98.19	98.27	98.35
98.39	98.47	98.55	98.63	98.71	98.79
98.87	98.95	99.03	99.11	99.19	99.27
99.35	99.43	99.51	99.59	99.67	99.75
99.83	99.91	99.99	100.07	100.15	100.23

OUTSIDE SURFACE

NODES

900	284	1192	1384	2212	2422	2482	2502	2682	2702
910	285	1202	1394	2222	2432	2492	2512	2692	2712
920	286	1212	1404	2232	2442	2502	2522	2702	2722
930	287	1222	1414	2242	2452	2512	2532	2712	2732
940	288	1232	1424	2252	2462	2522	2542	2722	2742
950	289	1242	1434	2262	2472	2532	2552	2732	2752
960	290	1252	1444	2272	2482	2542	2562	2742	2762
970	291	1262	1454	2282	2492	2552	2572	2752	2772
980	292	1272	1464	2292	2502	2562	2582	2762	2782
990	293	1282	1474	2302	2512	2572	2592	2772	2792

ANDREW A. SUMNER AND S.

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	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
1975	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	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

OUTSIDE SURFACE

FIGURE 6

MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

SOUTH SECTION

SOLID ELEMENTS

Year	1990	1991	1992	1993	1994	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
1990	1990	1991	1992	1993	1994	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

THESE LATTER

1990-1991	0.016	0.022	0.020	0.046	0.036	0.032	0.020
1991-1992	0.013	0.021	0.020	0.037	0.040	0.033	0.030
1992-1993	0.012	0.020	0.020	0.030	0.036	0.032	0.028
1993-1994	0.011	0.019	0.020	0.025	0.032	0.030	0.027
1994-1995	0.010	0.018	0.020	0.022	0.030	0.028	0.026
1995-1996	0.010	0.017	0.019	0.020	0.029	0.027	0.025

OUTSIDE LAYER

0.19	0.22	0.20	0.16	0.08	0.04	0.02
0.12	0.20	0.18	0.14	0.07	0.04	0.03
0.11	0.18	0.17	0.13	0.06	0.03	0.03
0.10	0.16	0.15	0.11	0.05	0.02	0.02
0.09	0.14	0.13	0.09	0.04	0.02	0.02
0.08	0.12	0.11	0.07	0.03	0.01	0.01
0.07	0.10	0.09	0.06	0.02	0.01	0.01
0.06	0.08	0.07	0.04	0.01	0.01	0.01
0.05	0.06	0.05	0.03	0.01	0.01	0.01
0.04	0.04	0.03	0.02	0.01	0.01	0.01
0.03	0.02	0.02	0.01	0.01	0.01	0.01
0.02	0.01	0.01	0.01	0.01	0.01	0.01
0.01	0.01	0.01	0.01	0.01	0.01	0.01

INSIDE SURFACE

MEMBRANE ELEMENTS

0.0174	0.0122	0.0200	0.0139	0.0054	0.0079	0.0042	0.0070
0.0013	0.0021	0.0039	0.0031	0.0043	-0.0043	0.0051	0.0046
0.0017	0.0020	0.0026	0.0030	0.0039	0.0042	0.0050	0.0048
0.0017	0.0019	0.0027	0.0031	0.0043	0.0051	0.0056	0.0067
0.0010	0.0016	0.0024	0.0034	0.0042	0.0050	0.0058	0.0068
0.0002	0.0017	0.0025	0.0032	0.0041	0.0049	0.0057	0.0066

MIDDLE SURFACE

880114	880222	880336	880404	880514	880622	880730
880119	880226	880331	880404	880513	880620	880628
880122	880228	880336	880404	880512	880620	880628
880121	880227	880335	880403	880511	880618	880627
880121	880226	880329	880402	880510	880618	880626
880120	880225	880328	880401	880509	880617	880625

OUTSIDE SURFACE.

NORTH SECTION

SOLID ELEMENTS

1990-1991	2000-01	2001-02	2002-03	2003-04	2004-05
2000-01	2001-02	2002-03	2003-04	2004-05	2005-06

INQUIRY LAYERS

0.000000	0.000	0.000	0.000	0.000
0.000000	0.000	0.000	0.000	0.000

OUTSIDE LAYER

MEMBRANE ELEMENTS

第(一)组	第(二)组	第(三)组	第(四)组	第(五)组	第(六)组
100	100	100	100	100	100

INSIDE SURFACE

0.00	0.15	0.20
0.05	0.15	0.25
0.10	0.20	0.30
0.15	0.25	0.35

MIDDLE SURFACE

00000	00010	00020
00030	00040	00050
00060	00070	00080
00090	00100	00110

OUTSIDE SURFACE

NODES

[illegible]

INSIDE SURFING

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
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MIDDLE SURFACE

[illegible]

OUTSIDE SURFACE

NODES

[illegible]

INSIDE SURFACE

800	100	1.50	1.55	20.55	2.200
807	100	0.55	1.855	22.70	2.200
808	100	0.55	1.855	22.70	2.200
809	100	0.55	1.855	22.70	2.200
810	100	0.55	1.855	22.70	2.200
811	100	0.55	1.855	22.70	2.200
812	100	0.55	1.855	22.70	2.200
813	100	0.55	1.855	22.70	2.200
814	100	0.55	1.855	22.70	2.200
815	100	0.55	1.855	22.70	2.200
816	100	0.55	1.855	22.70	2.200
817	100	0.55	1.855	22.70	2.200
818	100	0.55	1.855	22.70	2.200
819	100	0.55	1.855	22.70	2.200
820	100	0.55	1.855	22.70	2.200
821	100	0.55	1.855	22.70	2.200
822	100	0.55	1.855	22.70	2.200
823	100	0.55	1.855	22.70	2.200
824	100	0.55	1.855	22.70	2.200
825	100	0.55	1.855	22.70	2.200
826	100	0.55	1.855	22.70	2.200
827	100	0.55	1.855	22.70	2.200
828	100	0.55	1.855	22.70	2.200
829	100	0.55	1.855	22.70	2.200
830	100	0.55	1.855	22.70	2.200
831	100	0.55	1.855	22.70	2.200
832	100	0.55	1.855	22.70	2.200
833	100	0.55	1.855	22.70	2.200
834	100	0.55	1.855	22.70	2.200
835	100	0.55	1.855	22.70	2.200
836	100	0.55	1.855	22.70	2.200
837	100	0.55	1.855	22.70	2.200
838	100	0.55	1.855	22.70	2.200
839	100	0.55	1.855	22.70	2.200
840	100	0.55	1.855	22.70	2.200
841	100	0.55	1.855	22.70	2.200
842	100	0.55	1.855	22.70	2.200
843	100	0.55	1.855	22.70	2.200
844	100	0.55	1.855	22.70	2.200
845	100	0.55	1.855	22.70	2.200
846	100	0.55	1.855	22.70	2.200
847	100	0.55	1.855	22.70	2.200
848	100	0.55	1.855	22.70	2.200
849	100	0.55	1.855	22.70	2.200
850	100	0.55	1.855	22.70	2.200
851	100	0.55	1.855	22.70	2.200
852	100	0.55	1.855	22.70	2.200
853	100	0.55	1.855	22.70	2.200
854	100	0.55	1.855	22.70	2.200
855	100	0.55	1.855	22.70	2.200
856	100	0.55	1.855	22.70	2.200
857	100	0.55	1.855	22.70	2.200
858	100	0.55	1.855	22.70	2.200
859	100	0.55	1.855	22.70	2.200
860	100	0.55	1.855	22.70	2.200
861	100	0.55	1.855	22.70	2.200
862	100	0.55	1.855	22.70	2.200
863	100	0.55	1.855	22.70	2.200
864	100	0.55	1.855	22.70	2.200
865	100	0.55	1.855	22.70	2.200
866	100	0.55	1.855	22.70	2.200
867	100	0.55	1.855	22.70	2.200
868	100	0.55	1.855	22.70	2.200
869	100	0.55	1.855	22.70	2.200
870	100	0.55	1.855	22.70	2.200
871	100	0.55	1.855	22.70	2.200
872	100	0.55	1.855	22.70	2.200
873	100	0.55	1.855	22.70	2.200
874	100	0.55	1.855	22.70	2.200
875	100	0.55	1.855	22.70	2.200
876	100	0.55	1.855	22.70	2.200
877	100	0.55	1.855	22.70	2.200
878	100	0.55	1.855	22.70	2.200
879	100	0.55	1.855	22.70	2.200
880	100	0.55	1.855	22.70	2.200
881	100	0.55	1.855	22.70	2.200
882	100	0.55	1.855	22.70	2.200
883	100	0.55	1.855	22.70	2.200
884	100	0.55	1.855	22.70	2.200
885	100	0.55	1.855	22.70	2.200
886	100	0.55	1.855	22.70	2.200
887	100	0.55	1.855	22.70	2.200
888	100	0.55	1.855	22.70	2.200
889	100	0.55	1.855	22.70	2.200
890	100	0.55	1.855	22.70	2.200
891	100	0.55	1.855	22.70	2.200
892	100	0.55	1.855	22.70	2.200
893	100	0.55	1.855	22.70	2.200
894	100	0.55	1.855	22.70	2.200
895	100	0.55	1.855	22.70	2.200
896	100	0.55	1.855	22.70	2.200
897	100	0.55	1.855	22.70	2.200
898	100	0.55	1.855	22.70	2.200
899	100	0.55	1.855	22.70	2.200

MIDDLE SURFACE

805 83062 8335	78625	70045	72465
805 79068 8335	76615	70045	72465
805 73373 8335	78379	70045	72465
805 73373 8335	78379	70045	72465

OUTSIDE SURFACE

FIGURE 7

FUEL TRANSFER CANAL SEPARATION WALL

MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

SOUTH SEPARATION WALL

SOLID ELEMENTS

2853	2855	2857	2858	2811	2813	2815	2817
2859	2858	2858	2810	2812	2815	2818	2818

INSIDE LAYER

4852	4855	4857	4858	4811	4813	4815	4817
4859	4858	4858	4810	4812	4815	4818	4818

OUTSIDE LAYER

MEMBRANE ELEMENTS

805	808	808	810	812	815	818	818
-----	-----	-----	-----	-----	-----	-----	-----

INSIDE SURFACE

4852	4855	4857	4858	4811	4813	4815	4817
4859	4858	4858	4810	4812	4815	4818	4818

MIDDLE SURFACE

805	808	808	810	812	815	818	818
-----	-----	-----	-----	-----	-----	-----	-----

OUTSIDE SURFACE

NODES

1232	1243	1243	1243	1243	1243	1243	1243
1243	1243	1243	1243	1243	1243	1243	1243

INSIDE SURFACE

1243	1243	1243	1243	1243	1243	1243	1243
1243	1243	1243	1243	1243	1243	1243	1243

MIDDLE SURFACE

1243	1243	1243	1243	1243	1243	1243	1243
1243	1243	1243	1243	1243	1243	1243	1243

OUTSIDE SURFACE

WEST SEPARATION WALL

SOLID ELEMENTS

4871	4874	4877	4880	4843	4845	4847	4847
4872	4875	4878	4881	4844	4846	4848	4848

INSIDE LAYER

4871	4874	4877	4880	4843	4845	4847	4847
4872	4875	4878	4881	4844	4846	4848	4848

OUTSIDE LAYER

MEMBRANE ELEMENTS

871	874	877	880	843	845	847	847
872	875	878	881	844	846	848	848

INSIDE SURFACE

4871	4874	4877	4880	4843	4845	4847	4847
4872	4875	4878	4881	4844	4846	4848	4848

MIDDLE SURFACE

871	874	877	880	843	845	847	847
872	875	878	881	844	846	848	848

OUTSIDE SURFACE

NODES

1255	1256	1256	1256	1256	1256	1256	1256
1256	1256	1256	1256	1256	1256	1256	1256

INSIDE SURFACE

1255	1256	1256	1256	1256	1256	1256	1256
1256	1256	1256	1256	1256	1256	1256	1256

MIDDLE SURFACE

1255	1256	1256	1256	1256	1256	1256	1256
1256	1256	1256	1256	1256	1256	1256	1256

OUTSIDE SURFACE

SOUTHWEST CORNER

SOLID ELEMENTS

2853	2855	2857	2858	2811	2813	2815	2817
------	------	------	------	------	------	------	------

NODES

1255	1256	1256	1256	1256	1256	1256	1256
1256	1256	1256	1256	1256	1256	1256	1256

INSIDE SURFACE

NUS-01-015
MARCH 25, 1983
ENCLOSURE

FIGURE 8
CASK LAYDOWN AREA SEPARATION WALLS

ASDT Structural Dynamics Technology, Inc.

MILLSTONE POINT - UNIT 2

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

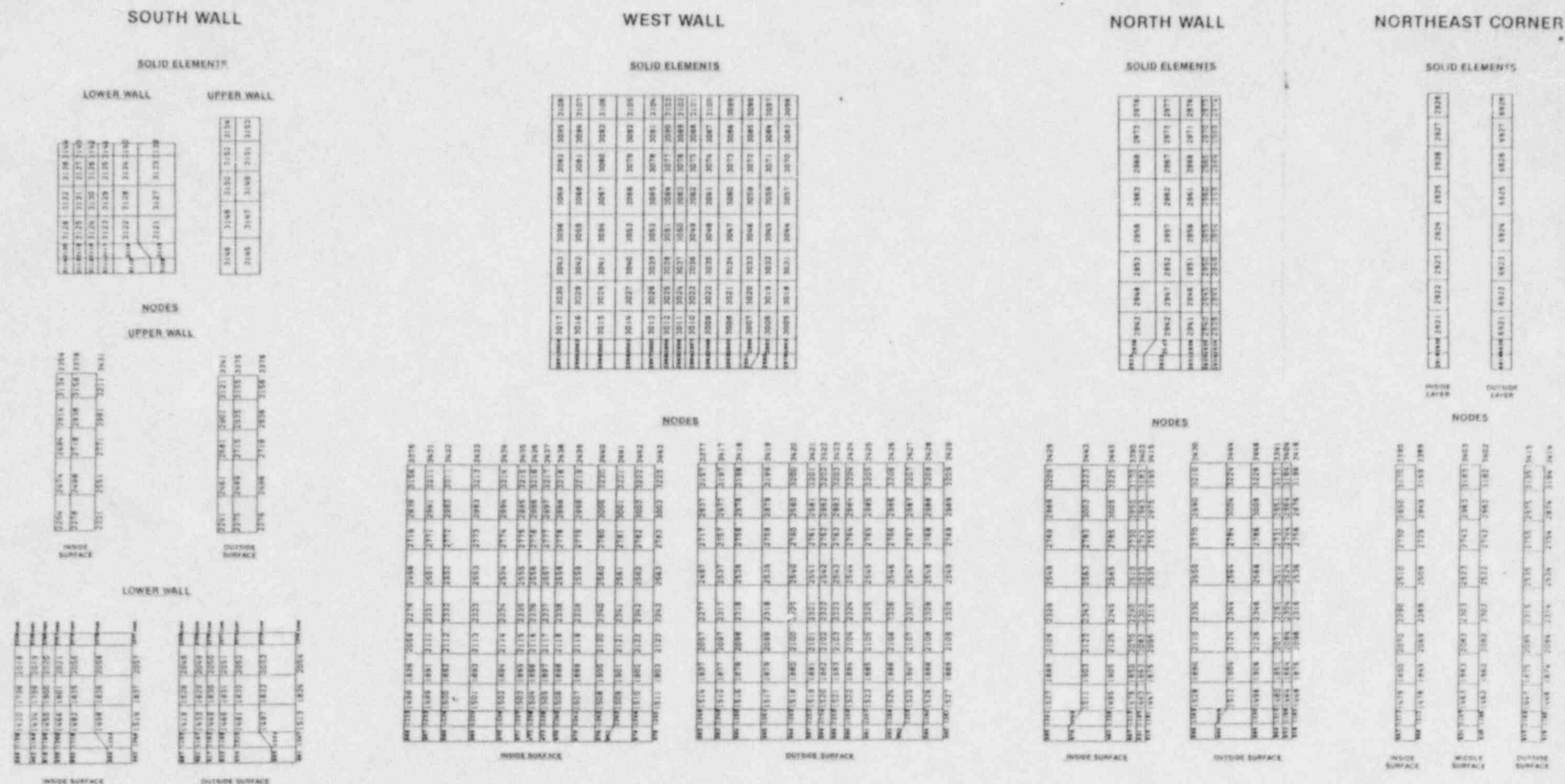


FIGURE 9

FUEL TRANSFER CANAL OUTER WALLS

NUS-01-015
MARCH 25, 1983
ENCLOSURE

SDT Structural Dynamics Technology, Inc.

MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

SOUTH WALL

SOLID ELEMENTS

8001	8017	8033	8049
8002	8018	8034	8050
8003	8019	8035	8051
8004	8020	8036	8052
8005	8021	8037	8053
8006	8022	8038	8054
8007	8023	8039	8055
8008	8024	8040	8056
8009	8025	8041	8057
8010	8026	8042	8058
8011	8027	8043	8059
8012	8028	8044	8060
8013	8029	8045	8061
8014	8030	8046	8062
8015	8031	8047	8063
8016	8032	8048	8064
8017	8033	8049	8065

MEMBRANE ELEMENTS

1	17	33	49
2	18	34	50
3	19	35	51
4	20	36	52
5	21	37	53
6	22	38	54
7	23	39	55
8	24	40	56
9	25	41	57
10	26	42	58
11	27	43	59
12	28	44	60
13	29	45	61
14	30	46	62
15	31	47	63
16	32	48	64

INSIDE SURFACE

8001	8017	8033	8049
8002	8018	8034	8050
8003	8019	8035	8051
8004	8020	8036	8052
8005	8021	8037	8053
8006	8022	8038	8054
8007	8023	8039	8055
8008	8024	8040	8056
8009	8025	8041	8057
8010	8026	8042	8058
8011	8027	8043	8059
8012	8028	8044	8060
8013	8029	8045	8061
8014	8030	8046	8062
8015	8031	8047	8063
8016	8032	8048	8064

OUTSIDE SURFACE

NODES

25	168	312	456
26	169	313	457
27	170	314	458
28	171	315	459
29	172	316	460
30	173	317	461
31	174	318	462
32	175	319	463
33	176	320	464
34	177	321	465
35	178	322	466
36	179	323	467
37	180	324	468
38	181	325	469
39	182	326	470
40	183	327	471
41	184	328	472
42	185	329	473

INSIDE SURFACE

1	17	33	49
2	18	34	50
3	19	35	51
4	20	36	52
5	21	37	53
6	22	38	54
7	23	39	55
8	24	40	56
9	25	41	57
10	26	42	58
11	27	43	59
12	28	44	60
13	29	45	61
14	30	46	62
15	31	47	63
16	32	48	64

OUTSIDE SURFACE

WEST WALL

SOLID ELEMENTS

8065	8081	8097	8113
8066	8082	8098	8114
8067	8083	8099	8115
8068	8084	8100	8116
8069	8085	8101	8117
8070	8086	8102	8118
8071	8087	8103	8119
8072	8088	8104	8120
8073	8089	8105	8121
8074	8090	8106	8122
8075	8091	8107	8123
8076	8092	8108	8124
8077	8093	8109	8125
8078	8094	8110	8126
8079	8095	8111	8127
8080	8096	8112	8128

MEMBRANE ELEMENTS

BEAM TOP SURFACE

80 100 120

BEAM BOTTOM SURFACE

800 1000 1200

72	82	92	102
----	----	----	-----

72	82	92	102
74	84	94	104
76	86	96	106

72	82	92	102
74	84	94	104
76	86	96	106

8072	8082	8092	8102
------	------	------	------

8072	8082	8092	8102
8074	8084	8094	8104
8076	8086	8096	8106

8072	8082	8092	8102
8074	8084	8094	8104
8076	8086	8096	8106

INSIDE SURFACE

OUTSIDE SURFACE

NODES

433	437	441	445
434	438	442	446
435	439	443	447
436	440	444	448
437	441	445	449
438	442	446	450
439	443	447	451
440	444	448	452
441	445	449	453
442	446	450	454
443	447	451	455
444	448	452	456
445	449	453	457
446	450	454	458
447	451	455	459
448	452	456	460

INSIDE SURFACE

OUTSIDE SURFACE

NUS-01-015, REV 1
JULY 25, 1983
ENCLOSURE

FIGURE 11

FOUNDATION SOUTH WALL AND WEST WALL

ASDT
Structural
Dynamics
Technology, Inc.

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

NORTH WALL

SOLID ELEMENTS

8108	8115	8121	8127
8110	8116	8122	8128
8111	8117	8123	8129
8112	8118	8124	8130
8113	8119	8125	8131
8114	8120	8126	8132
8115	8121	8127	8133

MEMBRANE ELEMENTS

108	115	121	127
110	116	122	128
111	117	123	129
112	118	124	130
113	119	125	131
114	120	126	132
115	121	127	133

INSIDE SURFACE

8108	8115	8121	8127
8110	8116	8122	8128
8111	8117	8123	8129
8112	8118	8124	8130
8113	8119	8125	8131
8114	8120	8126	8132
8115	8121	8127	8133

OUTSIDE SURFACE

NODES

81	121	249	335	817
82	122	250	336	818
83	123	251	337	819
84	124	252	338	820
85	125	253	339	821
86	126	254	340	822
87	127	255	341	823
88	128	256	342	824

INSIDE SURFACE

81	121	249	335	817
82	122	250	336	818
83	123	251	337	819
84	124	252	338	820
85	125	253	339	821
86	126	254	340	822
87	127	255	341	823
88	128	256	342	824

OUTSIDE SURFACE

EAST WALL

SOLID ELEMENTS

8217	8224	8231	8237
8218	8225	8232	8238
8219	8226	8233	8239
8220	8227	8234	8240
8221	8228	8235	8241
8222	8229	8236	8242
8223	8230	8237	8243

MEMBRANE ELEMENTS

217	224	231	238
218	225	232	239
219	226	233	240
220	227	234	241
221	228	235	242
222	229	236	243
223	230	237	244

INSIDE SURFACE

8217	8224	8231	8237
8218	8225	8232	8238
8219	8226	8233	8239
8220	8227	8234	8240
8221	8228	8235	8241
8222	8229	8236	8242
8223	8230	8237	8243

OUTSIDE SURFACE

NODES

119	244	310	358	738
120	245	311	359	739
121	246	312	360	740
122	247	313	361	741
123	248	314	362	742
124	249	315	363	743
125	250	316	364	744
126	251	317	365	745

INSIDE SURFACE

119	244	310	358	738
120	245	311	359	739
121	246	312	360	740
122	247	313	361	741
123	248	314	362	742
124	249	315	363	743
125	250	316	364	744
126	251	317	365	745

OUTSIDE SURFACE

SOUTH INNER WALL

SOLID ELEMENTS

8277	8278	8279	8280
8281	8282	8283	8284
8285	8286	8287	8288
8289	8290	8291	8292
8293	8294	8295	8296
8297	8298	8299	8300
8301	8302	8303	8304

MEMBRANE ELEMENTS

182	188	205	212
184	190	206	214
185	191	207	215
186	192	208	216
187	193	209	217
188	194	210	218
189	195	211	219

INSIDE SURFACE

8183	8189	8205	8211
8184	8206	8208	8212
8185	8207	8209	8213
8186	8210	8208	8214
8187	8203	8205	8215
8188	8204	8210	8216
8189	8205	8211	8217

OUTSIDE SURFACE

NODES

171	287	362	368	839
172	288	363	369	840
173	289	364	370	841
174	290	365	371	842
175	291	366	372	843
176	292	367	373	844
177	293	368	374	845
178	294	369	375	846

INSIDE SURFACE

171	287	362	368	839
172	288	363	369	840
173	289	364	370	841
174	290	365	371	842
175	291	366	372	843
176	292	367	373	844
177	293	368	374	845
178	294	369	375	846

OUTSIDE SURFACE

WEST INNER WALL

SOLID ELEMENTS

8189	8172	8178	8184
8180	8173	8179	8185
8181	8174	8180	8186
8182	8175	8181	8187
8183	8176	8182	8188
8184	8177	8183	8189
8185	8178	8184	8190

MEMBRANE ELEMENTS

185	172	178	184
186	173	179	185
187	174	180	186
188	175	181	187
189	176	182	188
190	177	183	189
191	178	184	190

INSIDE SURFACE

8189	8172	8178	8184
8180	8173	8179	8185
8181	8174	8180	8186
8182	8175	8181	8187
8183	8176	8182	8188
8184	8177	8183	8189
8185	8178	8184	8190

OUTSIDE SURFACE

NODES

183	248	335	341	847
184	249	336	342	848
185	250	337	343	849
186	251	338	344	850
187	252	339	345	851
188	253	340	346	852
189	254	341	347	853
190	255	342	348	854

INSIDE SURFACE

183	248	335	341	847
184	249	336	342	848
185	250	337	343	849
186	251	338	344	850
187	252	339	345	851
188	253	340	346	852
189	254	341	347	853
190	255	342	348	854

OUTSIDE SURFACE

NUS 01-015
MARCH 25, 1983
ENCLOSURE

FIGURE 12

FOUNDATION NORTH WALL, EAST WALL AND INNER WALLS

SDT Structural Dynamics Technology, Inc.

MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

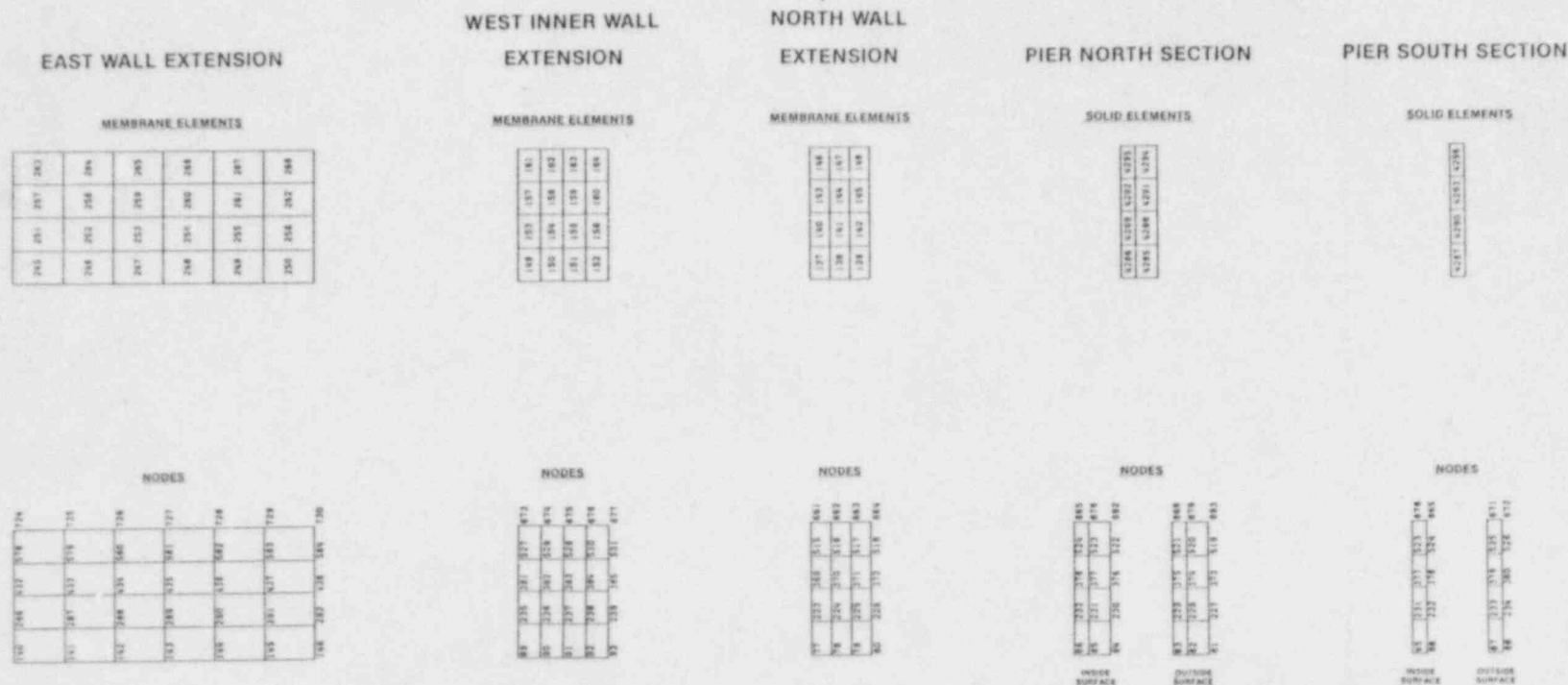
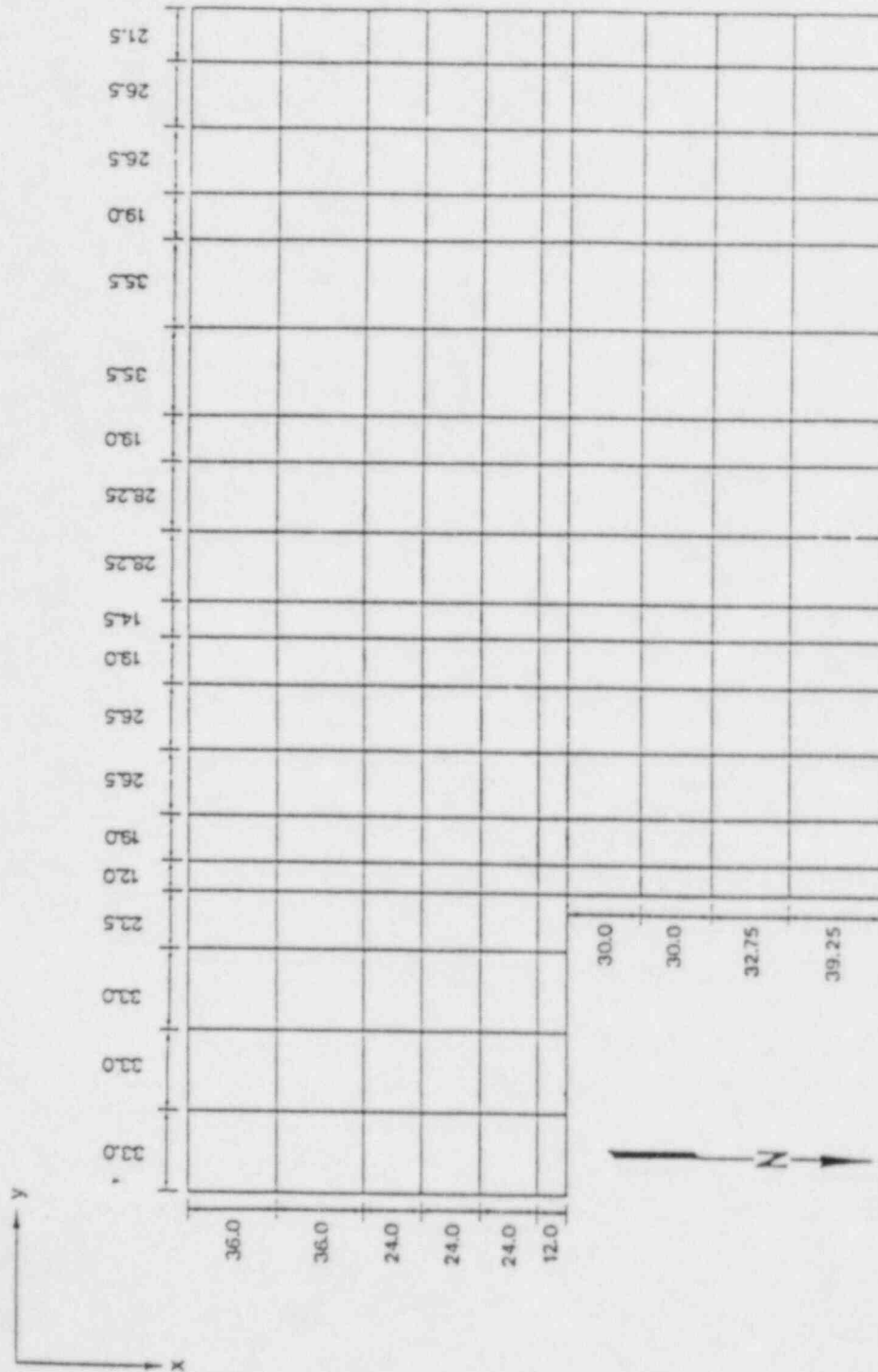


FIGURE 13
FOUNDATION PIER AND MISCELLANEOUS WALLS

NUS-01-015
MARCH 25, 1983
ENCLOSURE

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Floor Liner Plate Geometry



Notes: 1. Dimensions are in inches.

2. Global and local coordinate systems are coincident with the SAP6 model pool floor slab surface membranes.

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Floor Liner Plate Model Node Numbers

1	8	15	22	29	36	43	50	57	64	71	78	85	92	99	106
2	9	16	23	30	37	44	51	58	65	72	79	86	93	100	107
3	10	17	24	31	38	45	52	59	66	73	80	87	94	101	108

4	11	18	25	32	39	46	53	60	67	74	81	88	95	102	109
5	12	19	26	33	40	47	54	61	68	75	82	89	96	103	110
6	13	20	27	34	41	48	55	62	69	76	83	90	97	104	111
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112

15	22	29	36	43	50	57	64	71	78	85	92	99	106	113	120
16	23	30	37	44	51	58	65	72	79	86	93	100	107	114	121
17	24	31	38	45	52	59	66	73	80	87	94	101	108	115	122
18	25	32	39	46	53	60	67	74	81	88	95	102	109	116	123
19	26	33	40	47	54	61	68	75	82	89	96	103	110	117	124
20	27	34	41	48	55	62	69	76	83	90	97	104	111	118	125
21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126

95	106	117	128	139	150	161	172	183	194	205	216	227	238	249	260
96	107	118	129	140	151	162	173	184	195	206	217	228	239	250	261
97	108	119	130	141	152	163	174	185	196	207	218	229	240	251	262
98	109	120	131	142	153	164	175	186	197	208	219	230	241	252	263
99	110	121	132	143	154	165	176	187	198	209	220	231	242	253	264
100	111	122	133	144	155	166	177	188	199	210	221	232	243	254	265

100	111	122	133	144	155	166	177	188	199	210	221	232	243	254	265
101	112	123	134	145	156	167	178	189	200	211	222	233	244	255	266
102	113	124	135	146	157	168	179	190	201	212	223	234	245	256	267
103	114	125	136	147	158	169	180	191	202	213	224	235	246	257	268
104	115	126	137	148	159	170	181	192	203	214	225	236	247	258	269
105	116	127	138	149	160	171	182	193	204	215	226	237	248	259	270

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Floor Liner Plate Model Element Numbers

1	7	12	18	25	35	45	55	65	75
2	8	14	20	26	36	46	56	66	76

3	9	15	21	27	37	47	57	67	77
4	10	16	22	28	38	48	58	68	78
5	11	17	23	29	39	49	59	69	79
6	12	18	24	30	40	50	60	70	80

31	41	51	61	71	81
32	42	52	62	72	82
33	43	53	63	73	83
34	44	54	64	74	84

85	95	105	115	125	135	145	155	165
86	96	106	116	126	136	146	156	166
87	97	107	117	127	137	147	157	167
88	98	108	118	128	138	148	158	168
89	99	109	119	129	139	149	159	169

90	100	110	120	130	140	150	160	170
91	101	111	121	131	141	151	161	171
92	102	112	122	132	142	152	162	172
93	103	113	123	133	143	153	163	173
94	104	114	124	134	144	154	164	174

QUESTION

- 11.b Provide a description of the mathematical model employed, including assumptions and limitations of the model.

Response

This section includes a detailed description of the finite element model used in the spent fuel pool storage facility structural evaluation along with justification of modeling assumptions which were considered important in predicting the response of the structure.

The extent of the structural model includes the pool walls, cask laydown and fuel transfer canal area walls (excluding the gates), pool floor slab and fuel transfer canal floor slab and the foundation walls directly beneath this portion of the auxiliary building. All walls directly adjacent the pool (including the fuel transfer canal inside wall and cask laydown area walls) and the pool floor slab are modeled with two layers of eight node solid elements to permit proper application of thermal gradients and to provide good definition of stress variations through the wall thickness. Four node membrane elements of negligible thickness were used on the inside, middle, and outside surfaces of the wall or floor to obtain stress values at the solid elements faces as well as at the solid element centroids. In this manner, five integration points through the walls and floors were obtained. The outer walls and floor slab of the fuel transfer canal area were modeled with a single layer of solid elements since these components were only included for their stiffness properties and were not evaluated according to stress criteria. The portions of the foundation which were modeled include the south, west, north, inner west, inner south and east foundation walls. These components were modeled with only one layer of solid elements with membrane elements on the inside and outside surfaces since there is no thermal gradient through the walls of the compartments at this elevation. The other structural components modeled in the foundation were the pier (solid elements) and the extensions of the inner west and east foundation walls (which were modeled with membrane elements to represent their in-plane stiffness).

Since rotations at the node points of the three-dimensional solid elements are not defined, all rotational degrees of freedom in the model were restrained. Stiffnesses of the walls and floors framing into the pool model were represented using direct matrix additions. The matrix coupling terms were computed assuming that, due to cracking, one-half of the wall or floor panel stiffness is available. The nodes at the base of the foundation which are remote from the structural areas of interest in the pool were completely restrained.

The liner plate was modeled such that all weld seams and anchor locations were coincident with node lines or node locations. Global and local coordinate systems were specified such that they were coincident with the pool floor slab elements in the SAP6 finite element model. All rotations and displacements normal to the plate were restrained. Lateral degrees of freedom are unrestrained for all nodes except weld seams and anchor locations, which were identified as boundary degrees of freedom at which displacements can be either specified or restrained.

The results of the finite element model were examined to insure that realistic deflections and stresses existed for each individual load case. Classical solutions were also prepared for selected components for comparison to the finite element model results. Gross force and moment reactions were calculated and resulting stresses were compared to those in the computer model. The general behavior of the model under the loads was determined to be reasonable by viewing deformed geometry plots and screening stresses at key locations.

The material properties used in the mathematical model were obtained from design criteria specifications or by NUSCO Engineering.

Concrete Material Properties

Concrete Compressive Strength	3,000	lb/in ²
Reinforcing Yield Strength	60,000	lb/in ²
Reinforcing Elastic Modulus	29.0×10^6	lb/in ²
Concrete Elastic Modulus	3.15×10^6	lb/in ²
Concrete Poisson Ratio	0.17	
Concrete Thermal Expansion Coefficient	5.5×10^{-6}	in/in/°F
Concrete Weight Density	8.68×10^{-2} (150 lb/ft ³)	lb/in ³

Liner Plate Material and Anchor Properties

Plate Material	304 Stainless Steel
Plate Thickness	0.25 inches
Plate Thickness Tolerance	16%
Poissons Ratio	0.24
Coefficient of Thermal Expansion	8.82×10^{-6} in/in°F
Yield Strength	30 ksi
Weld Electrode	E308-16
Electrode Tensile Strength	90 ksi

QUESTION

11.c Describe and list the load cases used as well as the justification for these load cases.

Response

This section discusses the development and application of the loads which were applied to the finite element model. To provide flexibility for formulation of the load combinations, a static analysis was performed for the loads described in this section with the appropriate factors and permutations applied to these loads for formulation of the SRP load combinations. It should be stated that the loads applied to the mathematical model of the spent fuel pool and liner were derived based on a 2:1 consolidated fuel load. The conservatism of this are described later in this section.

Structural Individual Load Cases

The twelve individual loads applied to the finite element model are described in Table 3.2-2. Loads which were excluded from this evaluation include fuel cask drop, crane load, rack impact and accident flood load. Fuel cask drop has been previously addressed and therefore is not considered in this analysis. The loads from the fuel handling crane were excluded since the effect on the overall pool structure was considered beneficial when considered in combination with other loads. This assumption is based upon the fact that the relatively small compressive vertical load exerted on the pool walls, due to the crane weight, aids the concrete section's ability to carry shear forces as well as other axial and moment loadings. Impacting of the rack pads due to tipping was considered a local effect and was addressed as a separate item. Accident flood load has also been eliminated from consideration since the flood gates protect the auxiliary building to the maximum probable flood height.

Dead weight of the pool structure was defined as a 1.0g vertical acceleration. Hydrostatic loading of the structure was analyzed for a pool water depth of 38'-6". The hydrostatic forces are applied to the wetted surface of the pool by computing nodal forces in the three directions as the product of the pressure at the nodal elevations by an area vector (A_x , A_y , A_z) which is computed from adjacent element areas. Membrane elements (only for the purpose of load application) were used to represent the gates in the fuel transfer canal and cask laydown areas so that the hydrostatic forces on the gates were accounted for. A resultant force was computed for this load verifying application of the load and additionally, confirming correct orientation of the elements since the nodal area vectors are based on the local coordinate systems of the membrane elements.

Individual load cases 3, 4, and 9 through 12 are nominal 1,000 pounds per square foot loads applied to the pool floor slab in the negative global z (vertical), x and y directions. These unit load cases were used to later formulate vertical (z) rack loads and lateral (X-y) loads. Application of the load in each direction was subdivided into two load cases to provide for the differential fuel rack configurations in regions 1 and 2 of the pool.

Load cases 5 and 6 are operating and accident thermal loads, corresponding to pool water temperatures of 150°F and 212°F, respectively. The ambient (or stress free) temperature for all compartments outside the pool (including the cask laydown and fuel transfer canal areas) was defined as 55°F. These loads were applied by defining nodal temperatures for all nodes in the model based on linear interpolation of temperatures between adjacent compartments. The accident pool temperature of 212°F is justified since the pool water free surface is at atmospheric pressure. The pool bulk temperature will also be fairly uniform as a result of convection currents caused by heating of the water at lower elevations resulting in the movement of this lower density water toward the top of the pool.

Building seismic effects and the associated hydrodynamic forces due to lateral earthquake loads are included in load cases 7 and 8. The horizontal earthquake acceleration applied for these loads was calculated by taking the average of the floor zero period accelerations, determined from the auxiliary building seismic analysis for the various levels over the pool height, and applying this acceleration to the structural mass of the model. All g levels used in this analysis were taken from the "Seismic Analysis-Auxiliary Building," Millstone Nuclear Power Station, Unit No. 2, Bechtel Power Corporation, Job No. 7604-01, Revision 3, July 31, 1972.

Using the peak acceleration value from the various floor elevations over the pool height, the average peak horizontal acceleration value was found to be 0.21 g's for the 0.09 g (OBE) building base excitation. To facilitate load combinations, this seismic acceleration was expressed in terms of a nominal 1.0 g building base excitation to give a nominal 2.34 g peak acceleration at the spent fuel pool elevation. This nominal 1.0 g base excitation and resulting 2.34 g fuel pool acceleration is indicated in Table 3.2-2 for individual load cases 7 and 8.

Earthquake response of the pool water was based on the methodology outlined in TID-7024, "Nuclear Reactors and Earthquakes," which provided a basis for computing pool wall and floor pressures which result from earthquake-induced pool fluid motion. Hydrodynamic forces were calculated as the product of the pressure profiles over the wetted surfaces of the pool and their associated area vectors, similar to the application of the hydrostatic forces described previously. Gross hydrodynamic forces and moments were computed from these nodal forces, with

verification by comparison to forces and moments calculated from formulas in TID-7024. These hydrodynamic responses were also normalized to a 1.0 g earthquake to facilitate load combinations.

Vertical earthquake loads were not included as individual load cases, since acceleration of the pool water mass and concrete mass are equivalent to applying appropriate load factors to their respective static load cases to account for dynamic amplification of the seismic motion.

Table 3.2-3 summarizes the load definition parameters used in evaluating the concrete structure.

Composite Load Cases

The twelve individual loads just described were combined to formulate the composite load cases applicable to this evaluation. The composite loads are shown in Table 3.2-4 and include dead load (D), live load (L), operating and accident thermal (T_o and T_a), and SSE and OBE earthquake (E and E'). Table 3.2-4 also defines the relationship between individual loads and composite loads. The Standard Review Plan load combinations which are described later in this section are formulated from these composite load cases.

Dead Loads

Dead load includes dead weight of the concrete structure, hydrostatic pressure and weight of the fuel rack modules excluding their fuel complements. The fuel module dead weight was 365 pounds per cell. Since the individual load cases for rack loads were based on nominal 1,000 psf vertical loads over Regions 1 and 2 of the pool floor slab, individual load cases 3 and 4 are factored by 0.374 and 0.607.

Live Loads

Live load consisted entirely of the submerged weight of the consolidated fuel and storage box. The weight of these two items is 2,500 pounds per cell. Based on this value, the floor slab vertical loads were computed as 2,561 pounds per square foot over Region 1 and 4,155 pounds per square foot over Region 2.

These values are based on all cells in the pool having 2:1 consolidated fuel placed in them. The actual live load for reracking in Region 1 will be 1,528 pounds per square foot or 40 percent less than analyzed for. Similarly, actual live load in Region 2 is 1,332 pounds per square foot or 68 percent less than analyzed for.

Thermal Loads

Operating and accident thermal composite loads were taken directly as their individual load cases with factors of 1.0.

Earthquake Loads

Operating basis earthquake (E) was specified as 0.09 g horizontal and 0.06 g vertical ZPA levels measured at the base of the foundation. Since amplification of the base motion acceleration levels was accounted for in the individual load cases, a coefficient of 0.09 was applied to the horizontal response loads (load cases 7 and 8). Similarly, the response to vertical earthquake is constant over the pool height as specified in the plant design manual, so a factor of 0.06 on the dead weight load was used for this load case. SSE horizontal and vertical reactions for the submerged racks were specified in as 3,500 pounds per cell and 1,000 pounds per cell, respectively. OBE loads are calculated as 56 percent of the SSE loads. Based on these cell reactions, the OBE vertical loads are 569 psf over Region 1 and 923 psf over Region 2. The resulting OBE horizontal loads are 1,992 psf over Region 1 and 3,232 psf over Region 2.

As required by the Standard Review Plan, the three directions (X, Y, Z) of earthquake were applied such that all permutations of the signs were considered. Table 3.2-4 shows four of the OBE composite loads. Four additional cases not shown in Table 3.2-4 were developed by multiplying those shown in the table (E1 through E4) by -1.0. Similarly, SSE loads were formulated by multiplying the eight OBE cases by 1.8.

The service and factored load combinations were formulated according to Section 3.8.4, paragraph 3.6 of the Standard Review Plan (Reference 7). Table 3.2-5 presents the eight service load combinations and five factored load combinations from the Standard Review Plan. Eight of the SRP composite load components were not applicable to this structure and were not considered in the evaluation. These composite load components include R_o (normal operating pipe reactions), W (design wind), W_t (design tornado), R_b (pipe break reactions), P (accident pressure) and Y_i, Y_j, Y_k (impact and impulse from pipe break and impact). Excluding^m these loads, the final loads considered reduce to those shown in Table 3.2-6.

Examination of Table 3.2-6 shows load cases i.b.1 and i.b.3 to be identical, as are i.b.4 and i.b.6. Since live load is always present, the response of the structure to i.b.7 is bounded by i.b.2. Similarly, load case i.b.1 bounds i.b.8. This results in four service load combinations considered, two of which contain OBE, which has eight sub-load cases, resulting in a total of eighteen service load combinations.

The response of the structure to T_o is similar to T_a , with T_a controlling. Therefore, load case ii.b was eliminated in lieu of ii.c. For the same reason, load cases ii.a and ii.e are bounded by ii.a. This leaves two factored cases, one containing SSE, which has eight subcases, resulting in a total of nine factored load combinations.

Table 3.2-7 summarizes the coefficients applied to the composite loads for formulation of the service and factored loads previously described. Since the effect of the dead and live portions of a load combination are reduced during earthquake motion in the negative global direction, the factors on these composite loads are reduced by 10 percent. The final loads were formulated for all areas of the pool which were considered in this evaluation. Analysis was then performed for each particular concrete wall or floor for the two or three controlling load combinations.

Liner Plate Load Combination Formulation

The individual and composite load cases used for evaluation of the liner plate are identical to those presented in Tables 3.2-2 and 3.2-4, respectively, with one exception. During the liner plate evaluation, SSE horizontal rack reaction loads specified by the fuel rack vendor were reduced from 3,500 pounds per cell to 2,500 pounds per cell. This resulted in a corresponding reduction in the coefficients for individual load cases 9 through 12. The liner plate composite load cases are shown in Table 3.2-8.

The service and factored loads specified by the Standard Review Plan for plastic design methods are shown in Table 3.2-9. The same eight components for composite loads that were not considered for the liner plate analysis: including R_o (pipe break reactions), P (accident pressure), and Y_i , Y_o , Y_m (impact and impulse from pipe break and missile impact). Excluding these loads, the loads considered were reduced to those shown in Table 3.2-10.

From Table 3.2-10, it is evident that load cases i.b.1 and i.b.3 are identical, as are i.b.4 and i.b.6. Application of OBE in all possible locations resulted in load combination i.b.1 being bounded by i.b.2. The number of service load combinations considered was reduced to three, two of which contained OBE, which has eight subcases, resulting in seventeen possible service load combinations.

The response of structure to T_o was bounded by T_a , which resulted in elimination of ii.b.2 in lieu of ii.b.3. Similarly, load case ii.b.1 was bounded by ii.b.5. Structural response due to SSE (which is OBE factored by 1.8) results in elimination of ii.b.4 in lieu of ii.b.5. A load case of $(D + L + E')$ was considered separately to address the effects of earthquake without thermal

loads. Three factored load combinations remain, two containing SSE which (considering earthquake permutations) results in a total of 17 factored load combinations.

The final composite load case coefficients are summarized in Table 3.2.11, for the service and factored load cases previously described. Applied displacements and strains due to cracking and curvature effects were applied for the load combinations described. Concentrated loads representing the rack pad forces were not applied directly to the liner plate model at the individual load case level. It can be shown that the coefficient of friction between the rack pads and liner plate (steel-to-steel interface) is less than that between the liner plate and concrete slab. Consequently, the racks will slide before the load will be taken by the liner plate. If the rack pads stick (corresponding to a coefficient of friction of 1.0), the force provided by the cell's vertical reaction and the concrete liner plate friction is greater than the cell's horizontal reaction. In either case, the load is transmitted directly to the concrete slab which was qualified for the design loads.

11.c.7
Table 3.2-2

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Individual Load Case Description

<u>SAP6 Load Case Number</u>	<u>Description</u>
1	1 g vertical acceleration for dead weight of concrete
2	Hydrostatic forces
3	1000 lb/ft ² vertical slab load over Region 1
4	1000 lb/ft ² vertical slab load over Region 2
5	Operating thermal (pool water at 150°F)
6	Accident thermal (pool water at 212°F)
7	1 g ZPA north earthquake. 2.34 g peak pool wall acceleration plus hydrodynamic forces (+X acceleration)
8	1 g ZPA west earthquake. 2.34 g peak pool wall acceleration plus hydrodynamic forces (+Y acceleration)
9	-1000 lb/ft ² horizontal slab load over Region 1 in X direction (+X acceleration)
10	-1000 lb/ft ² horizontal slab load over Region 2 in X direction (+X acceleration)
11	-1000 lb/ft ² horizontal slab load over Region 1 in Y direction (+Y acceleration)
12	-1000 lb/ft ² horizontal slab load over Region 2 in Y direction (+Y acceleration)

Table 3.2-3

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Summary of Load Definition Parameters

<u>Item</u>	<u>Description</u>
Pool Properties:	
Pool Water Depth	38'-6"
Pool Normal Operating Temperature	150°F
Pool Accident Temperature	212°F
Pool Hydrodynamic Forces	TID 7024, App F
Auxiliary Building Compartment Temperatures:	
All Compartments	55°F
Thermal Stress - Free Temperature	55°F
Operating Conditions:	
Fuel Transfer Canal	Dry
Cask Laydown Area	Dry
Seismic Ground Accelerations:	
OBE Horizontal	0.09 g
OBE Vertical	0.06 g
SSE Horizontal & Vertical	1.8 (OBE)

Table 3.2-4

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Composite Load Case Description

Individual Load Case Number:	1	2	3	4	5	6	7	8	9	10	11	12
Composite Load Case												
1 D - Dead Load	1.00	1.00	.374	.607								
2 L - Live Load			2.56	4.16								
3 T ^o - Operating Thermal					1.00							
4 T ^a - Accident Thermal						1.00						
5 E1 - OBE	0.06	0.06	0.57	0.92			0.09	0.09	1.99	3.23	1.99	3.23
6 E2 - OBE	0.06	0.06	0.57	0.92			-0.09	0.09	-1.99	-3.23	1.99	3.23
7 E3 - OBE	0.06	0.06	0.57	0.92			-0.09	-0.09	-1.99	-3.23	-1.99	-3.23
8 E _q - OBE	0.06	0.06	0.57	0.92			0.09	-0.09	1.99	3.23	-1.99	-3.23

NOTES: 1) Four additional OBE cases are defined as -1.0 times E₁ through E₄, respectively.

2) SSE is taken as 1.8 times OBE.

11.c.9

Table 3.2-5

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Standard Review Plan Load Combination Summary

Load
 Combination
 Number

Description

SERVICE LOAD COMBINATIONS

i.b.1	$1.4D + 1.7L$
i.b.2	$1.4D + 1.7L + 1.9E$
i.b.3	$1.4D + 1.7L + 1.7W$
i.b.4	$.75 (1.4D + 1.7L + 1.7T_o + 1.7 R_o)$
i.b.5	$.75 (1.4D + 1.7L + 1.9E + 1.7T_o + 1.7R_o)$
i.b.6	$.75 (1.4D + 1.7L + 1.7W + 1.7T_o + 1.7 R_o)$
i.b.7	$1.2D + 1.9E$ or $.9 (1.4D) + 1.9E$
i.b.8	$1.2D + 1.7W$ or $.9 (1.4D) + 1.7W$

FACTORED LOAD COMBINATIONS

ii.a	$D + L + T_o + E'$
ii.b	$D + L + T_o + R_o + W_t$
ii.c	$D + L + T_o + R_o + 1.5 P_o$
ii.d	$D + L + T_o + R_o + 1.25 P_o + 1.0 Y_r + Y_j + Y_m + 1.25 E'$
ii.e	$D + L + T_o + R_o + 1.0 P_o + 1.0 (Y_r + Y_j + Y_m) + 1.0 E'$

Table 3.2-6

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Applicable Standard Review Plan Load Combinations

<u>Load Combination Number</u>	<u>Description</u>	
SERVICE LOAD COMBINATIONS		
i.b.1	$1.4D + 1.7L$	
i.b.2	$1.4D + 1.7L + 1.9E$	
i.b.3	$1.4D + 1.7L$	(Identical to i.b.1)
i.b.4	$.75 (1.4D + 1.7L + 1.7T_o)$	
i.b.5	$.75 (1.4D + 1.7L + 1.9E + 1.7T_o)$	
i.b.6	$.75 (1.4D + 1.7L + 1.7T_o)$	(Identical to i.b.4)
i.b.7	$1.2D + 1.9E$ or $.9 (1.4D) + 1.9E$	(Bounded by i.b.2)
i.b.8	$1.2D$ or $.9 (1.4D)$	(Bounded by i.b.1)

FACTORED LOAD COMBINATIONS

ii.a	$D + L + T_o + E'$	(Bounded by ii.d)
ii.b	$D + L + T_o$	(Bounded by ii.c)
ii.c	$D + L + T_a$	
ii.d	$D + L + T_o + 1.25E'$	
ii.e	$D + L + T_a + 1.0E'$	(Bounded by ii.d)

Table 3.2-7

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Final Load Combination Coefficients

Composite Load Cases	D	L	T _o	T _a	E ₁	E ₂	E ₃	E ₄
LOAD COMBINATION IDENTIFIER								
i.b.1	1.40	1.70						
i.b.2.1	1.40	1.70			1.90			
i.b.2.2	1.40	1.70				1.90		
i.b.2.3	1.40	1.70					1.90	
i.b.2.4	1.40	1.70						-1.80
i.b.2.5	1.26	1.53			-1.90			
i.b.2.6	1.26	1.53				-1.90		
i.b.2.7	1.26	1.53					-1.90	
i.b.2.8	1.26	1.53						1.90
i.b.4	1.05	1.28	1.28					
i.b.5.1	1.05	1.28	1.28		1.43			
i.b.5.2	1.05	1.28	1.28			1.43		
i.b.5.3	1.05	1.28	1.28				1.43	
i.b.5.4	1.05	1.28	1.28					1.43
i.b.5.5	0.95	1.15	1.28		-1.43			
i.b.5.6	0.95	1.15	1.28			-1.43		
i.b.5.7	0.95	1.15	1.28				-1.43	
i.b.5.8	0.95	1.15	1.28					-1.43
ii.c	1.00	1.00	1.00					
ii.d.1	1.00	1.00		1.00	2.25			
ii.d.2	1.00	1.00		1.00		2.25		
ii.d.3	1.00	1.00		1.00			2.25	
ii.d.4	1.00	1.00		1.00			2.25	
ii.d.5	0.90	0.90		1.00	-2.25			
ii.d.6	0.90	0.90		1.00		-2.25		
ii.d.7	0.90	0.90		1.00			-2.25	
ii.d.8	0.90	0.90		1.00				2.25

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Composite Load Case Descriptions

Individual Load Case Number:		1	2	3	4	5	6	7	8	9	10	11	12
Liner Plate													
Composite Load Case													
1	D - Dead Load	1.00	1.00	.306	.544								
2	L - Live Load			2.49	4.42								
3	T _o - Operating Thermal					1.00							
4	T _a - Accident Thermal						1.00						
5	E ₁ - OBE	0.06	0.06	0.51	0.91			0.09	0.09	0.55	0.97	0.55	0.97
6	E ₂ - OBE	0.06	0.06	0.51	0.91			-0.09	0.09	-0.55	-0.97	0.55	0.97
7	E ₃ - OBE	0.06	-0.06	0.51	0.91			-0.09	-0.09	-0.55	-0.97	-0.55	-0.97
8	E ₄ - OBE	0.06	0.06	0.51	0.91			0.09	-0.09	0.55	0.97	-0.55	-0.97

11.0.13

- NOTES: 1) Four additional OBE cases are defined as -1.0 times E₁ through E₄, respectively.
2) SSE is taken as 1.8 times OBE.

Table 3.2-9

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Liner Plate Standard Review Plan Load Combination Summary

<u>Load Combination Number</u>	<u>Description</u>
SERVICE LOAD COMBINATIONS - LINER PLATE	
i.b.1	$1.7D + 1.7L$
i.b.2	$1.7D + 1.7L + 1.7E$
i.b.3	$1.7D + 1.7L + 1.7W$
i.b.4	$1.3 (D + L + T_o + R_o)$
i.b.5	$1.3 (D + L + E + T_o + R_o)$
i.b.6	$1.3 (D + L + W + T_o + R_o)$
FACTORED LOAD COMBINATIONS - LINER PLATE	
ii.b.1	$D + L + T_o + R_o + E'$
ii.b.2	$D + L + T_o + R_o + W_t$
ii.b.3	$D + L + T_o + R_o + 1.5 P_o$
ii.b.4	$D + L + T_o + R_o + 1.25 P_o + 1.0 (Y_r + Y_j + Y_m) + 1.25 E$
ii.b.5	$D + L + T_o + R_o + 1.0 P_o + 1.0 (Y_r + Y_j + Y_m) + E'$

Table 3.2-10

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Applicable Liner Plate Standard Review Plan Load Combinations

<u>Load Combination Number</u>	<u>Description</u>	
SERVICE LOAD COMBINATIONS - LINER PLATE		
i.b.1	$1.7D + 1.7L$	(Bounded by i.b.2)
i.b.2	$1.7D + 1.7L + 1.7E$	
i.b.3	$1.7D + 1.7L$	(Identical to i.b.1)
i.b.4	$1.3(D + L + T_o)$	
i.b.5	$1.3(D + L + E + T_o)$	
i.b.6	$1.3(D + L + T_o)$	(Identical to i.b.4)
FACTORED LOAD COMBINATIONS - LINER PLATE		
ii.b.1	$D + L + T_o + E'$	(Bounded by ii.b.5)
ii.b.2	$D + L + T_o$	(Bounded by ii.b.3)
ii.b.3	$D + L + T_o$	
ii.b.4	$D + L + T_o + 1.25E$	(Bounded by ii.b.5)
ii.b.5	$D + L + T_o + E'$	

Table 3.2-11

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Final Load Combination Coefficients

Service Composite Load Cases - Liner Plate

D L T_o T_a E_1 E_2 E_3 E_4

LOAD COMBINATION IDENTIFIER

i.b.2.1	1.70	1.70			1.70			
i.b.2.2	1.70	1.70				1.70		
i.b.2.3	1.70	1.70					1.70	
i.b.2.4	1.70	1.70						1.70
i.b.2.5	1.53	1.53			-1.70			
i.b.2.6	1.53	1.53				-1.70		
i.b.2.7	1.53	1.53					-1.70	
i.b.2.8	1.53	1.53						-1.70
i.b.4	1.30	1.30	1.30					
i.b.5.1	1.30	1.30	1.30		1.30			
i.b.5.2	1.30	1.30	1.30			1.30		
i.b.5.3	1.30	1.30	1.30				1.30	
i.b.5.4	1.30	1.30	1.30					1.30
i.b.5.5	1.17	1.17	1.30		-1.30			
i.b.5.6	1.17	1.17	1.30			-1.30		
i.b.5.7	1.17	1.17	1.30				-1.30	
i.b.5.8	1.17	1.17	1.30					-1.30

Table 3.2-11 (continued)

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Final Load Combination Coefficients

Factored Composite Load Cases - Liner Plate	D	L	T _o	T _a	E ₁	E ₂	E ₃	E ₄
LOAD COMBINATION IDENTIFIER								
ii.b.1.1	1.00	1.00			1.80			
ii.b.1.2	1.00	1.00				1.80		
ii.b.1.3	1.00	1.00					1.80	
ii.b.1.4	1.00	1.00						1.80
ii.b.1.5	0.90	0.90			-1.80			
ii.b.1.6	0.90	0.90				-1.80		
ii.b.1.7	0.90	0.90					-1.80	
ii.b.1.8	0.90	0.90						-1.80
ii.b.3	1.00	1.00		1.00				
ii.b.5.1	1.00	1.00		1.00	1.80			
ii.b.5.2	1.00	1.00				1.80		
ii.b.5.3	1.00	1.00					1.80	
ii.b.5.4	1.00	1.00						1.80
ii.b.5.5	0.90	0.90		1.00	-1.80			
ii.b.5.6	0.90	0.90		1.00		-1.80		
ii.b.5.7	0.90	0.90		1.00			-1.80	
ii.b.5.8	0.90	0.90		1.00				-1.80

- 11d. Describe how the dynamic interaction between the pool structure and the rack modules was considered, including the value of any associated dynamic amplification factors. Include all assumptions made regarding the summation and phase of all rack loads.

The dynamic interaction between the pool structure and the rack modules was accounted for by considering the mass of fully loaded rack modules in the dynamic analysis model of the auxiliary building. Motions of the spent fuel pool from a time-history analysis of the auxiliary building were then used as input for a nonlinear seismic time-history analysis of the spent fuel rack modules. The nonlinear time-history analysis of the rack modules produced seismic loads which are transmitted to the pool floor. These seismic loads consisted of horizontal shear loads and vertical loads including impacting of the rack module on the pool floor.

The total horizontal loads on the pool floor are obtained by combining the loads due to the North-South & East-West earthquake directions in accordance with Reg. Guide 1.92. The total vertical loads are obtained by combining the vertical seismic load and the tipping impact load in accordance with Reg. Guide 1.92 and adding the deadweight load. The evaluation of the local loading under the rack feet and the total pool load should be provided by Northeast Utilities. As far as phasing of racks, the nonlinear seismic analysis of the racks assumes all the rack modules move in phase. CE recommends that loads be applied to the pool floor in accordance with this assumption.

QUESTION

11.e Provide analysis of the adequacy of the pool floor and liner under the local maximum rack module dynamic mounting foot loads.

Response

An analysis was performed which investigated the local effects on the pool floor slab due to rack module impact loads. The analysis considered two adjacent rack mounting feet impacting the slab simultaneously. The concrete being impacted was considered to be fully cracked. Therefore, only the residual reinforcing bar strength was accounted for. The controlling load combination for this analysis was 1.7 (D + L + E). It was determined that the residual shear strength for the section is 3,565 kips. The required residual shear strength capacity is 239.4 kips.

The analysis therefore shows that the structural integrity of the pool floor is maintained when subjected to the local maximum rack module dynamic mounting foot loads.

QUESTION

- 11.f Provide identification of the most critical regions of the pool structure. List the stresses and their comparison to allowable values, where the source and justification of their use of that allowable is also documented.

Response

The spent fuel pool was evaluated according to the criteria in the Millstone Point Unit 2 Design Criteria NRC Standard Review Plan. The original design was performed according to ACI-318-63 code criteria. For this evaluation Northeast Utilities has chosen to utilize load combinations specified in the NRC Standard Review Plan followed by evaluation of the reinforced concrete sections according to ACI 349-80. The pool wall and floor liner plate were evaluated according to the strain criteria specified by the ASME Code. A plate thickness tolerance of 16% was used, along with the weld offset, for computing membrane plus bending strains. Pool floor liner plate weld stresses were compared to AISC criteria. As shown in Table 3.1-1, a stress allowable criteria is used in evaluating the anchors for nonthermal loads versus a displacement criteria for thermal load combinations.

The following tables identifies the critical spent fuel pool and liner stresses and their comparison to allowable values based upon the previously described criteria. As described previously, these stresses are based on fully consolidated fuel loads.

By review of these tables, it can be shown that all stresses/strains remain within the stated code allowables.

Table 3.1-1

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Liner Plate Criteria Summary

Liner Plate Allowables⁽¹⁾

Membrane Strains

$$sc = .005 \text{ in/in}$$

$$st = .003 \text{ in/in}$$

Membrane Plus Bending Strains

$$sc = 0.014 \text{ in/in}$$

$$st = 0.010 \text{ in/in}$$

Liner Anchor Allowables⁽²⁾

Load Combinations Without Thermal

$$\text{Non-Factored Load Combinations } Fa = 0.5 F_u$$

$$\text{Factored Load Combinations } Fa = 0.85 F_u$$

Load Combinations with Thermal

$$a = 0.5 \quad u$$

F_u and u are based on an ultimate displacement of 0.2 inches.



Notes:

- 1) These allowables are consistent with those specified by ASME Section II, Subsection CC for containment liner plate when ultimate strength is the basis, i.e., factored load combinations.
- 2) These allowables are consistent with AISC, Specification for Steel Structures, Part 2; ASME Section III Subsection CC for containment liner anchors and formulas from References 13 and 14.

Table 4.1-1

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Tabulation of Controlling Section Resultant Moments

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Pool North Wall					
Horizontal Section Lower Portion of Wall - East End Elements 444-445-446-447 (MFPSTAIAI-05B)	$(D+L+T_a+1.25E3')$	6.686	76.97	388.2	0.20
Vertical Section Lower Portion of Wall Mid-Span Element 437 (MFPSTAIAI-05)	$(D'+L'+T_a-1.25E3')$	-22.11	710.9	1325.0	0.54
Horizontal Section Upper Portion of Wall - East End Elements 477-478-479-480 (MFPSTAIAI-05B)	$(D+L+T_a+1.25E3')$	1.794	44.35	545.8	0.08
Vertical Section Upper Portion, Mid-Span Elements 482-493-504-515 (MFPSTAIAI-05A)	$(D+L+T_a+1.25E3')$	10.42	272.5	598.6	0.46
Pool South Wall					
Horizontal Section Lower Portion, West End of Pool Element 625 (MFPSTAIAI-06)	$(D'+L'+T_a-1.25E4')$	-30.32	810.1	1367.0	0.59

Units: Forces are in kips/in.
Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
2) T_a moments are relieved, maintaining equilibrium and curvature of section.
3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Pool South Wall (Continued)					
Vertical Section Lower Portion, Mid-Span Element 668 (MFPSTAIAI-06)	$(D'+L'+T_a-1.25E4')$	-33.12	813.1	1516.0	0.54
Horizontal Section Upper Portion, West End of Pool Element 707 (MFPSTAIAI-06)	$(D'+L'+T_a-1.25E4')$	-23.27	685.6	1142.0	0.60
Vertical Section Upper Portion, Mid-Span Elements 712-723-734-745 (MFPSTAIAI-06A)	$(D+L+T_a+1.25E4')$	11.99	177.3	545.7	0.32
Pool East Wall					
Horizontal Section Bottom of Wall Elements 577-578-579-580-581-582-583-584 (MFPSTAIAI-07B)	$(D'+L'+T_a-1.25E2')$	7.807	109.3	339.1	0.32
Vertical Section Lower Portion of Wall - South End Element 578 (MFPSTAIAI-07)	$(D'+L'+T_a-1.25E3')$	-18.52	669.0	1332.0	0.50

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_a moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Tabulation of Controlling Section Resultant Moments
(Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Pool East Wall (Continued)					
Horizontal Section Upper Portion of Wall Elements 609-610-611-612-613-614-615-616 (MFPSTAI-07B)	(D'+L'+T _a -1.25E3')	-0.821	133.0	612.8	0.22
Vertical Section Top of Wall - South End Elements 609-617-625-633 (MFPSTAI-07A)	(D'+L'+T _a -1.25E3')	7.527	19.77	695.6	0.03
Fuel Transfer Canal Separation Wall					
South (4 ft.) Portion of Wall (MFPSTAI-08)					
Horizontal Section Mid-Span (Element 844)	(D'+L'+T _a -1.25E3')	15.30	58.27	60.56	0.96
Vertical Section South End of Wall Lower Portion (Element 829)	(D'+L'+T _a -1.25E4')	-15.82	366.4	749.0	0.49
Horizontal Section South End of Wall Lower Portion (Element 829)	(D'+L'+T _a -1.25E4')	-18.12	345.6	640.0	0.54

Units: Forces are in kips/in.
Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
2) T_a moments are relieved, maintaining equilibrium and curvature of section.
3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Fuel Transfer Canal Separation Wall (Continued)					
Vertical Section Mid-Span (Element 843)	$(D'+L'+T_a - 1.25E4')$	-8.915	268.1	684.5	0.39
North (3 ft.) Portion of Wall (MFPSTAIAI-08)					
Vertical Section Below Elevation of Bottom of Gate Opening (Element 823)	$(D'+L'+T_a - 1.25E4')$	-23.64	363.6	581.5	0.63
Horizontal Section Below Elevation of Bottom of Gate Opening (Element 823)	$(D'+L'+T_a - 1.25E3')$	-14.47	304.6	591.9	0.51
Vertical Section Above Elevation of Bottom of Gate Opening (Element 839)	$(D+L+T_a + 1.25E4')$	-11.11	196.1	473.9	0.41
Horizontal Section Above Elevation of Bottom of Gate Opening (Element 839)	$(D'+L'+T_a - 1.25E4')$	-7.476	192.5	332.1	0.58

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_a moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Cask Laydown Area West Separation Wall (MFPSTAI-10)					
Vertical Section Below Elevation of Bottom of Gate (Element 874)	(D'+L'+T _a -1.25E2')	-10.26	-134.7	-232.3	0.58
Horizontal Section at Bottom of Wall (Element 872)	(D'+L'+T _a -1.25E1')	-7.759	-91.34	-184.4	0.50
Vertical Section Above Elevation of Bottom of Gate Opening (Element 880)	(D'+L'+T _a -1.25E2')	-5.537	-84.16	-351.2	0.24
Horizontal Section Above Elevation of Bottom of Gate Opening (Element 880)	(D'+L'+T _a -1.25E2')	-10.92	-91.31	-203.6	0.45

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_a moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Cask Laydown Area South Separation Wall (MFPSTAIAI-10)					
Vertical Section Below Elevation of Bottom of Gate Opening (Element 906)	$(D'+L'+T_a-1.25E2')$	-5.087	-104.0	-203.6	0.51
Horizontal Section at Bottom of Wall (Element 903)	$(D'+L'+T_a-1.25E2')$	-7.573	-88.94	-183.2	0.49
Vertical Section Above Elevation of Bottom of Gate Opening (Element 910)	$(D'+L'+T_a-1.25E2')$	1.031	-118.2	-355.4	0.33
Horizontal Section Above Elevation of Bottom of Gate Opening (Element 910)	$(D'+L'+T_a-1.25E1')$	-9.703	-85.72	-196.6	0.44
Pool Floor Slab (MFPSTAIAI-09)					
North-South Section at South End of Pool Mid-Span (Element 338)	$(D+L+T_a+1.25E4')$	-0.417	537.5	759.8	0.71

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_a moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Tabulation of Controlling Section Resultant Moments
(Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Pool Floor Slab (Continued)					
East-West Section at South End of Pool Mid-Span (Element 346)	(D+L+T ₀ +1.25E4')	-25.36	644.0	1121.	0.57
North-South Section in Cask Laydown Area Elements 302-303-304 (MFPSTAIAI-09B)	(D+L+T ₀ +1.25E1')	17.01	-33.76	-259.3	0.13
East-West Section in Cask Laydown Area Elements 303-311-319-327 (MFPSTAIAI-09A)	(D+L+T ₀ +1.25E1')	3.843	129.0	646.6	0.20
Foundation West Wall Beam					
Horizontal Section at South End of Beam Element 99 (MFPSTAIAI-17)	(D+L+T ₀ +1.25E3')	-1.283	-39.59	-237.6	0.17

Units: Forces are in kips/in.
Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
2) T₀ moments are relieved, maintaining equilibrium and curvature of section.
3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Foundation West Wall Column					
Horizontal Section at Top of Column Element 102 (MFPSTAI1-18)	$(D+L+T_o+1.25E4')$	-28.12	277.0	865.3	0.32
South Foundation Wall					
Vertical Section East Portion East End of Wall at Bottom Elements 1-2-3-4-5 (MFPSTAI1-11B-1)	$(D'+L'+T_o-1.25E2')$	-3.954	-102.5	-312.6	0.33
Vertical Section West Portion West End of Wall at Bottom Elements 10-11-12-13-14-15-16 (MFPSTAI1-11B)	$(D'+L'+T_o-1.25E4')$	10.22	54.0	54.92	0.98
Inner West Foundation Wall					
Vertical Section at Bottom Elements 165-166-167-168-169-170-171 (MFPSTAI1-15B)	$(D'+L'+T_o-1.25E2')$	-0.994	58.02	289.7	0.20

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_o moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-1

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Controlling Section Resultant Moments
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section Axial Force</u>	<u>Section⁽²⁾ Resultant Moment</u>	<u>Section⁽³⁾ Allowable Moment</u>	<u>Section Code Ratio</u>
Inner South Foundation Wall					
Vertical Section at Bottom Elements 193-194-195-196 (MFPSTAIAI-13B)	(D'+L'+T _a -1.25E4')	1.553	-89.81	-128.8	0.70

Units: Forces are in kips/in.
 Moments are in kip in/in.

- Notes: 1) Positive moment causes tension on outside surface of walls and lower surface of floor slab.
 2) T_a moments are relieved, maintaining equilibrium and curvature of section.
 3) Allowable moment is based on strength design method per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Pool North Wall				
Vertical Section at West End of Wall Elements 443-454-465- 476-487-498-509	(D+L+T _o +1.25E3')	3.062	6.377	0.48
Vertical Section at West End of Wall at Top Element 520	(D+L+T _o +1.25E3')	8.881	27.77	0.32
Vertical Section at Intersection with Cask Laydown Area West Wall at Top Element 512	(D'+L'+T _o -1.25E4')	14.50	28.93	0.50
Vertical Section at Intersection with Cask Laydown Area West Wall Elements 435-446-457- 468-479-501	(D'+L'+T _o -1.25E4')	11.27	31.21	0.36
Horizontal Section at Bottom of Wall Elements 433-434-435-436- 437-438-439-440-441-442-443	(D+L+T _o +1.25E3')	1.805	6.167	0.29

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAIAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Pool South Wall				
Vertical Section at West End at Top of Wall Element 740	$(D+L+T_a+1.25E4')$	10.18	25.89	0.39
Vertical Section at West End of Wall Elements 663-674-685- 696-707-718-729	$(D+L+T_a+1.25E4')$	1.087	6.234	0.17
Horizontal Section at Top of Wall Elements 740-741-742- 743-744-745-746-747- 748-749-750	$(D'+L'+T_a-1.25E4')$	5.397	7.827	0.69
Pool East Wall				
Vertical Section at South End of Wall at Top Element 633	$(D+L+T_a+1.25E3')$	3.876	25.88	0.15
Vertical Section at South End of Wall Elements 577-585-593- 601-609-617-625	$(D+L+T_a+1.25E3')$	3.018	6.362	0.47

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAIAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Pool East Wall (Continued)				
Vertical Section at Intersection with Cask Laydown Area South Wall at Top Element 637	(D+L+T ₀ +1.25E2')	8.720	26.26	0.33
Vertical Section at Intersection with Cask Laydown Area South Wall Elements 581-589-597- 605-613-621-629	(D+L+T ₀ +1.25E2')	14.55	31.18	0.47
Horizontal Section at Top of Wall Elements 625-626-627- 628-629-630-631-632	(D'+L'+T ₀ +1.25E2')	5.573	5.922	0.94
Fuel Transfer Canal Separation Wall				
Vertical Section at South End of Wall (4 ft. portion) at Top Element 870	(D+L+T ₀ +1.25E3')	11.73	19.05	0.62

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAIAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Fuel Transfer Canal Separation Wall (Continued)				
Vertical Section at South End of Wall (4 ft. portion) Elements 814-822-830- 838-846-854-862	(D+L+T _a +1.25E3')	1.849	4.837	0.38
Horizontal Section at Mid Height of South (4 ft.) Portion Elements 833-834-835- 836-837-838	(D+L+T _a +1.25E3')	4.130	4.346	0.95
Vertical Section Below Gate Opening North (3 ft.) Portion Elements 808-816-824	(D+L+T _a +1.25E3')	0.718	3.307	0.22
Horizontal Section at Bottom of Wall Elements 807-808-809- 810-811-812-813-814	(D+L+T _a +1.25E3')	2.910	4.041	0.72

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Cask Laydown Area South Separation Wall				
Vertical Section at Intersection with Pool East Wall Elements 903-905-907- 909-911-913-915-917	$(D+L+T_a+1.25E4')$	2.533	3.325	0.76
Horizontal Section at Bottom of Wall Elements 903-904	$(D'+L'+T_a-1.25E3')$	1.594 ⁽⁴⁾	2.084	0.76
Cask Laydown Area West Separation Wall				
Vertical Section at Intersection with Cask Laydown Area South Wall Elements 873-876-879- 882-885-888-891-894	$(D'+L'+T_a-1.25E2')$	1.887	4.079	0.46
Horizontal Section at Bottom of Wall Elements 871-872-873	$(D'+L'+T_a-1.25E1')$	1.691	1.943	0.87

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.
 - 4) Transverse shear adjusted based upon cracked section equilibrium moment gradient.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Pool Floor Slab				
East-West Section at Mid-Span Elements 301-309- 317-325-333-341-349 357-365-373-381	$(D'+L'+T_a-1.25EI')$	4.323	5.622	0.77
North-South Section Beneath Cask Laydown Area West Separation Wall Elements 313-314-315- 316-317-318-319-320	$(D+L+T_a+1.25EI')$	11.23	13.07	0.86
North-South Section at Mid-Span Elements 321-322-323- 324-325-326-327-328	$(D+L+T_a+1.25EI')$	2.996	8.491	0.35
Foundation South Wall				
West Portion Horizontal Section at Top Elements 58-59-60-61-62-63-64	$(D'+L'+T_a-1.25EI')$	2.141	7.581	0.28
East Portion Horizontal Section at Top Elements 49-50-51-52-53- 54-55-56-57	$(D+L+T_a+1.25EI')$	2.446	7.064	0.35

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAIAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Tabulation of Resultant Transverse Shear Forces
(Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Foundation East Wall				
Horizontal Section at Top Elements 238-239-240- 241-242-243-244	$(D+L+T_a+1.25E1')$	2.976	6.949	0.43
Foundation Inner South Wall				
Horizontal Section at Bottom Elements 193-194-195-196-197-198	$(D'+L'+T_a-1.25E4')$	1.848	3.316	0.56
Foundation Inner West Wall				
Horizontal Section at Bottom Elements 165-166-167-168- 169-170-171	$(D'+L'+T_a-1.25E3')$	1.848	2.920	0.63
Foundation North Wall				
Horizontal Section at Bottom Elements 109-110-111- 112-113-114	$(D+L+T_a+1.25E2')$	5.803	10.46	0.55
Foundation West Wall				
North Portion Horizontal Section at Bottom Elements 77-78	$(D+L+T_a+1.25E4')$	3.001	11.79	0.25

Units: Kips/inch

- Notes:
- 1) Data from MFPSTAI-04
 - 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 - 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-2

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant Transverse Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽²⁾ Shear</u>	<u>Allowable⁽³⁾ Section Shear</u>	<u>Code Shear Ratio</u>
Foundation West Wall				
South Portion Horizontal Section at Bottom Elements 83-84-85	(D+L+T _o +1.25E3')	6.140	12.91	0.48

- Notes: 1) Data from MFPSTAI-04
 2) Shear forces are linearly interpolated to the distance from the face of the effective support equal to the distance from the section compressive face to the centroid of the tensile steel where applicable.
 3) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-3

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant In-Plane Shear Forces

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section⁽¹⁾ Shear</u>	<u>Allowable Section Shear</u>	<u>Code Shear Ratio</u>
Pool North Wall				
Horizontal Section at Top of Wall Elements 510-511-512-513- 514-515-516-517-518-519-520	$(D'+L'+T_g-1.25E3')$	0.774	25.4	0.03
Pool South Wall				
Horizontal Section at Bottom of Wall Elements 663-664-665- 666-667-668-669-670- 671-672-673	$(D+L+T_g-1.25E3')$	3.032	25.4	0.12
Pool East Wall				
Horizontal Section at Bottom of Wall Elements 577-578-579- 580-581-582-583-584	$(D+L+T_g+1.25E2')$	9.206	26.58	0.35
Fuel Transfer Canal Separation Wall				
South (4 ft.) Portion Horizontal Section at Bottom of Wall Elements 817-818-819- 820-821-822	$(D+L+T_g+1.25E3')$	8.670	24.79	0.35

Units: Kips/inch

Notes: 1) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-3

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Tabulation of Resultant In-Plane Shear Forces
 (Continued)

<u>Location</u>	<u>Controlling Load Case</u>	<u>Section (1) Shear</u>	<u>Allowable Section Shear</u>	<u>Code Shear Ratio</u>
Fuel Transfer Canal Separation Wall (Continued)				
Horizontal Section at Bottom of North (3 ft.) Portion Elements 807-808	(D+L+T ₀ +1.25E3')	14.29	23.90	0.60
Cask Laydown Area South Separation Wall				
Horizontal Section in Upper Portion of Wall Elements 913-914	(D+L+T ₀ +1.25E2')	5.566	30.35	0.18
Cask Laydown Area West Separation Wall				
Horizontal Section at Bottom of Wall Elements 871-872-873	(D+L+T ₀ +1.25E3')	6.770	12.80	0.53
Pool Floor Slab				
North-South Section Near East End of Pool Elements 313-314-315- 316-317-318-319-320	(D+L+T ₀ +1.25E1')	14.14	24.87	0.57

Units: Kips/inch

Notes: 1) Allowable shear is based on strength design per ACI 349/80.

Table 4.1-4

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Pool Floor Liner Plate Analysis Summary

Controlling Non-Thermal Load Combination 1.7 (D + L + E2) i.b.2.2

	<u>Element</u>	<u>Strain (in/in)$\times 10^{-3}$ s</u>	<u>Allowable Strain (in/in)$\times 10^{-3}$ a</u>	<u>Ratio s/a</u>
Membrane Strains				
Tensile	31	0.201	3.0	0.07
Compressive	45	-0.051	-5.0	0.01
Membrane plus Bending Strains				
Tensile	84	0.444	10.0	0.04
	<u>Node(s)</u>	<u>Weld Stress s</u>	<u>Allowable Stress(ksi) a</u>	<u>Ratio s/a</u>
Weld Stress	105	2.69	20.4	0.13

Data from MFPSTA2A1-12

Controlling Thermal Load Combination (D + L + Ta + E2') ii.b.5.2

	<u>Element</u>	<u>Strain (in/in)$\times 10^{-3}$ s</u>	<u>Allowable Strain (in/in)$\times 10^{-3}$ a</u>	<u>Ratio s/a</u>
Membrane Strains				
Compressive	6	-0.639	-5.0	0.13
Membrane plus Bending Strains				
Compressive	6	-2.83	-14.0	0.20
	<u>Node(s)</u>	<u>Weld Stress (ksi) s</u>	<u>Allowable Stress (ksi) a</u>	<u>Ratio s/a</u>
Weld Stress	195-198 by 1	20.2	20.4	0.99

Data from MFPSTA2A1-12

Table 4.1-4

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Pool Floor Liner Plate Analysis Summary
 (Continued)

Controlling Non-Thermal Load Combination 1.7 (D + L + E2) i.b.2.2

<u>Node (Anchor Location)</u>	<u>Displacement (inches)</u>	<u>Allowable Displacement (inches)</u>	<u>(Ratio)</u>
204	0.074	0.10	0.74

Data from MFPSTA2A1-09

Controlling Thermal Load Combination (D + L + Ta + E2') i.b.5.2

<u>Node (Anchor Location)</u>	<u>Displacement (inches)</u>	<u>Allowable Displacement (inches)</u>	<u>(Ratio)</u>
22	0.013	0.10	0.10

Seam Embedded Angle

<u>Node-DOF</u>	<u>Shear Stress-F_s (ksi)</u>	<u>Allowable Stress - F_{sa} (ksi)</u>	<u>F_s/F_{sa} (Ratio)</u>
68	5.192	16.5	0.31

Data from MFPSTA2A1-10

Table 4.1-5

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Wall Liner Plate Strains
 Membrane Tensile Strains

Location - Description (Analysis Identifier)		Load Combination	Nominal Strain (in/in) $\times 10^{-3}$	Allowable Strain (in/in) $\times 10^{-3}$	Ratio E_s/E_a
North & South Walls (MFPSTA1A2-11)	Element 518 - X Section North Wall at Top	$(D'+L'+T - 1.25E'4)$ I.B.5.8	1.118	3.0	0.37
East Wall (MFPSTA1A2-12)	Element 601 - X Section Mid-Height of Wall	$1.7(D'+L'+E2)$ I.B.2.2	0.438	3.0	0.15
Fuel Transfer Canal Wall 3 Foot Portion (MFPSTA1A2-13)	Element 863 - X Section at Top of Wall	$1.7(D+L+E4)$ I.B.2.4	0.820	3.0	0.27
Fuel Transfer Canal Wall 4 Foot Portion (MFPSTA1A2-13)	Element 844 - Y Section Mid-Height of Wall	$(D'+L'+T - 1.25E'4)$ I.B.5.8	0.694	3.0	0.23
Cask Laydown Area South Wall (MFPSTA1A2-14)	Element 871 - Y Section West Separation Wall at Bottom	$1.7(D+L+E2)$ I.B.2.2	0.197	3.0	0.07

11.E.25

Table 4.1-5 (Continued)

Northeast Utilities Service Company
Millstone Point Unit 2 Spent Fuel Pool Evaluation
Wall Liner Plate Strains
Membrane Compressive Strains

Location - Description (Analysis Identifier)		Load Combination	Nominal Strain (in/in) $\times 10^{-3}$	Allowable Strain (in/in) $\times 10^{-3}$	Ratio E_s/E_a
North & South Walls (MFPSTAIA2-11)	Element 668 - X Section South Wall at Bottom	(D'+L'+T _g -1.25E4') II.B.5.8	-0.623	-5.0	0.12
East Wall (MFPSTAIA2-12)	Element 612 - Y Section Mid-Span of Wall	(D'+L'+T _g -1.25E3') II.B.5.7	-0.597	-5.0	0.12
Fuel Transfer Canal Wall 3 Foot Thick Portion (MFPSTAIA2-13)	Element 823- X Section Mid-Height of Wall	(D'+L'+T _g -1.25E4') II.B.5.8	-0.949	-5.0	0.19
Fuel Transfer Canal Wall 4 Foot Thick Portion (MFPSTAIA2-13)	Element 822 - X Section South End at Bottom	(D'+L'+T _g -1.25E4') II.B.5.8	-0.587	-5.0	0.12
Cask Laydown Area Walls (MFPSTAIA2-14)	Element 878 - X Section West Separation Wall Below Gate	(D'+L'+T _g -1.25E2') II.B.5.6	-0.911	-5.0	0.18

Table 4.1-5 (Continued)

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Wall Liner Plate Strains
 Membrane + Bending Tensile Strains

Location - Description (Analysis Identifier)		Load Combination	Nominal Strain (in/in) $\times 10^{-3}$	Membrane Bending Strain (in/in) $\times 10^{-3}$	Allowable Strain (in/in) $\times 10^{-3}$	Ratio E_s/E_a
North and South Walls (MFPSTAIA2-11)	Element 512 - X Section North Wall at Top	(D'+L'+T ₀ -1.25E4') II.B.5.8	1.111	4.444	10.0	0.44
East Wall (MFPSTAIA2-12)	Element 601 - X Section North Wall Adjacent CLA South Wall	(D'+L'+T ₀ -1.25E3') II.B.5.7	0.438	1.751	10.0	0.18
Fuel Transfer Canal Wall 3 Foot Thick Portion (MFPSTAIA2-13)	Element 863 - X Section Top of Wall	1.7(D+L+E4) I.B.2.4	0.820	3.280	10.0	0.33
Fuel Transfer Canal Wall 4 Foot Thick Portion (MFPSTAIA2-13)	Element 870 - X Section Top at South End of Wall	(D'+L'+T ₀ -1.25E4') II.B.5.8	0.571	2.284	10.0	0.23
Cask Laydown Area Walls (MFPSTAIA2-14)	Element 871 - Y Section West Separation Wall at Bottom	1.7(D+L+E2) I.B.2.2	0.197	0.768	10.0	0.79

11.E.27

Table 4.1-5 (Continued)

Northeast Utilities Service Company
 Millstone Point Unit 2 Spent Fuel Pool Evaluation
 Wall Liner Plate Strains
 Membrane + Bending Compressive Strains

Location - Description (Analysis Identifier)		Load Combination	Nominal Strain (in/in) $\times 10^{-3}$	Membrane Bending Strain (in/in) $\times 10^{-3}$	Allowable Strain (in/in) $\times 10^{-3}$	Ratio E_s/E_a
North and South Walls (MFPSTA1A2-11)	North Wall - Element 443 Y Section, Bottom at West End of Wall	(D'+L'+T ₀ -1.25E4') II.B.5.8	-0.544	-2.176	-14.0	0.16
East Wall (MFPSTA1A2-13)	Element 580 - Y Section Bottom of Wall at Mid-Span	(D'+L'+T ₀ -1.25E3') II.B.5.7	-0.561	-2.245	-14.0	0.16
Fuel Transfer Canal Wall 3 Foot Thick Portion (MFPSTA1A2-13)	Element 823 - X Section Mid-Height of Wall	(D'+L'+T ₀ -1.25E4') II.B.5.8	-0.949	-3.796	-14.0	0.27
Fuel Transfer Canal Wall 4 Foot Thick Portion (MFPSTA1A2-13)	Element 822 - X Section South End at Bottom	(D'+L'+T ₀ -1.25E4') II.B.5.8	-0.587	-2.348	-14.0	0.17
Cask Laydown Area Walls (MFPSTA1A2-14)	Element 877 - X Section West Separation Wall Below Gate	(D'+L'+T ₀ -1.25E2') II.B.5.6	-0.762	-3.050	-14.0	0.22

11.F.28