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WESTERN MASSACHUSETTS ELECTRIC COMPANY
MILLSTONE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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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

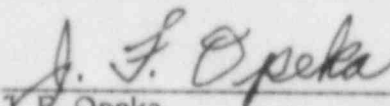
In October, 1985⁽¹⁾ the Staff requested additional information concerning a Northeast Nuclear Energy Company (NNECO) request⁽²⁾ to modify the Technical Specifications concerning the spent fuel storage capacity at Millstone Unit No. 2.

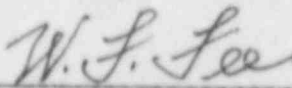
Attachment No. 1 to this letter provides the response, in a question and answer format, to the eleven (11) questions contained in the Staff's request for additional information.

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

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D. F. BAISLEY

Nuclear Power Systems
Combustion Engineering, Inc.
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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

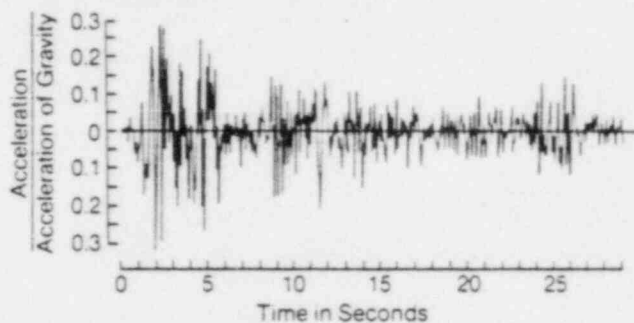


Figure 1: Example of Seismic Excitation Time History 1940 El Centro Earthquake

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

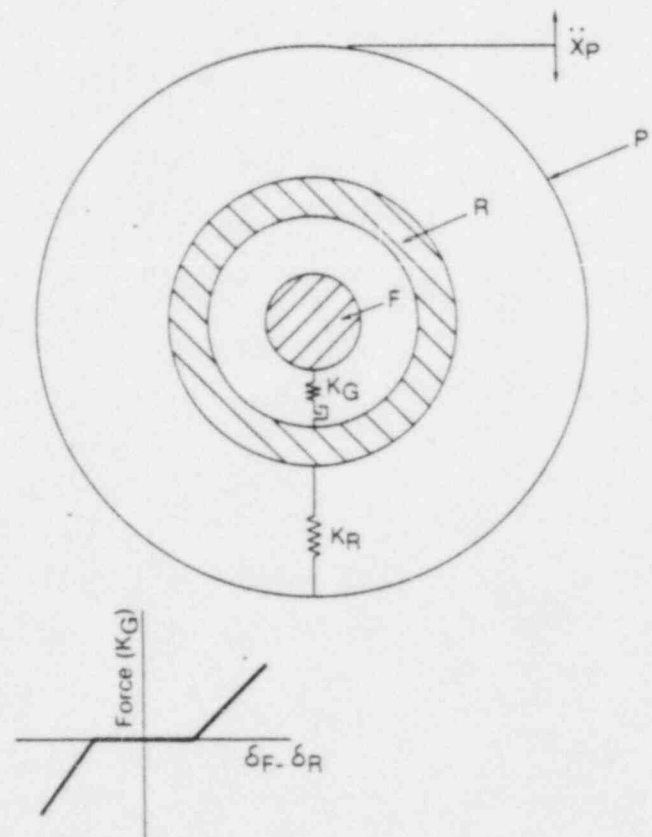


Figure 2: Simplified Analog of Spent Fuel Rack Physical Problem

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

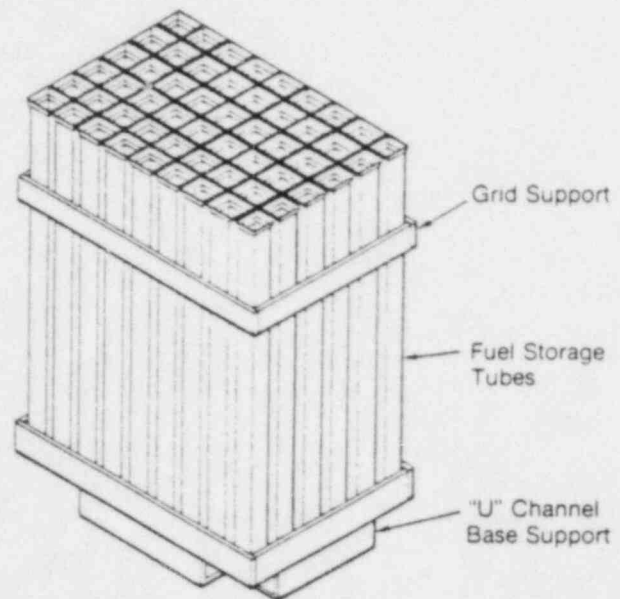


Figure 3: C-E HI-CAP Spent Fuel Rack Module

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-

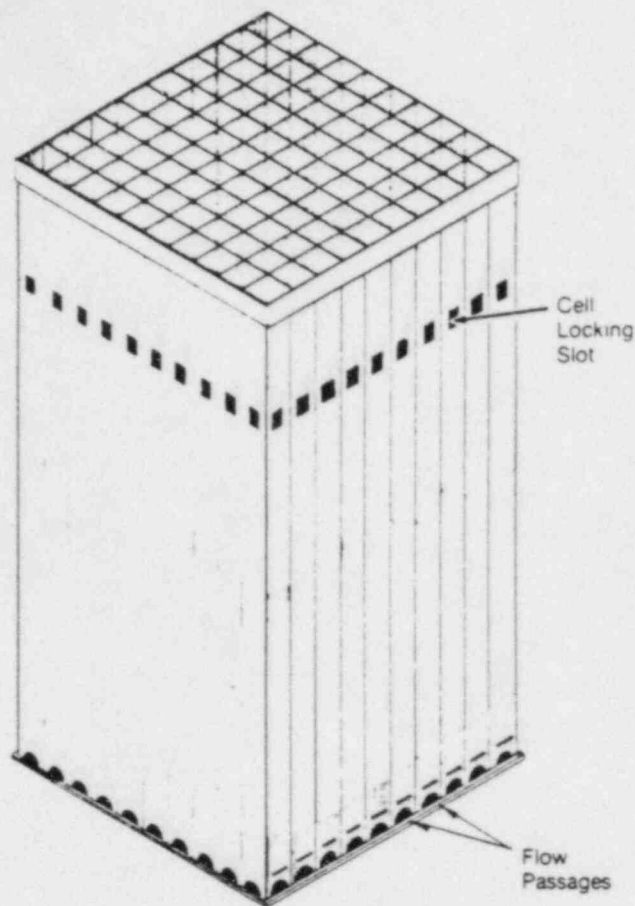


Figure 4: C-E Super HI-CAP Spent Fuel Storage Module

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

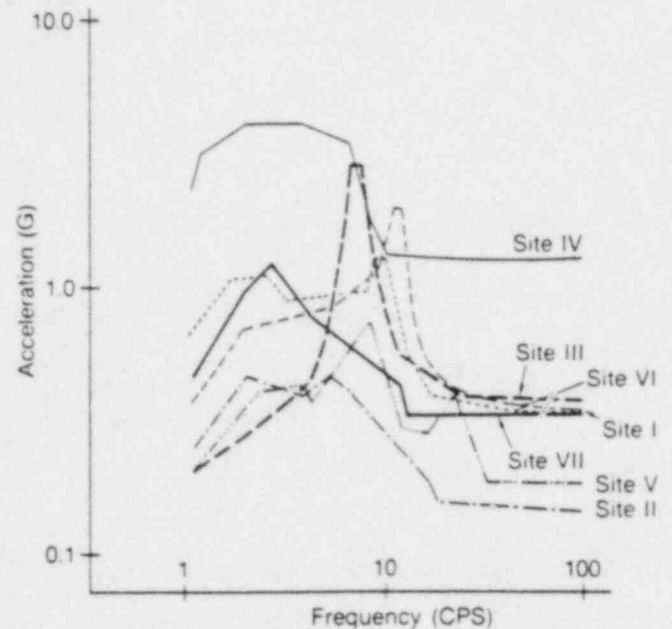


Figure 5: Spent Fuel Pools Seismic Response Spectra

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

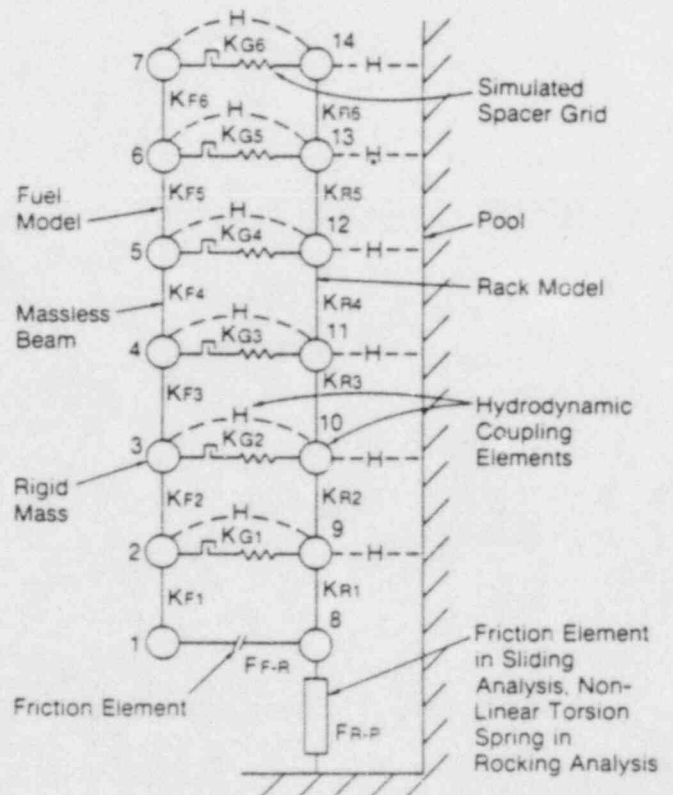


Figure 6: HI-CAP Fuel Rack Nonlinear CESHOCK Model

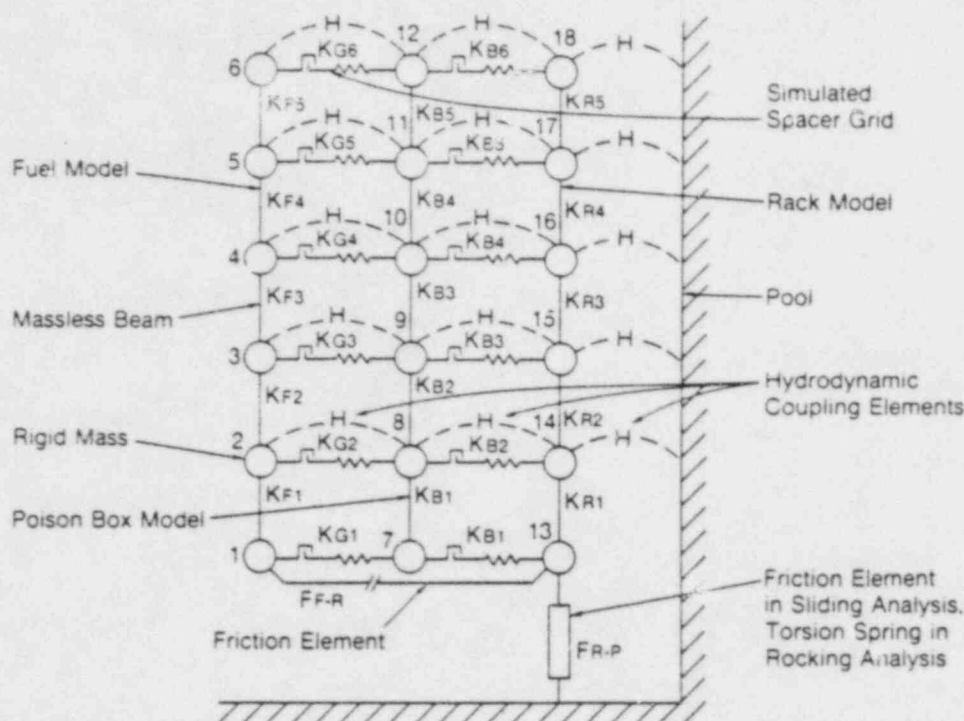


Figure 7: Super HI-CAP Fuel Rack Nonlinear CESHOCK Model

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 occur 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	3.00	1.00	3.00
II DESIGN D	2.83	1.00	2.83
II DESIGN D	7.08	1.00	2.08
II DESIGN D	4.27	1.00	4.27
V DESIGN E (SUPER HI-CAP)	3.84	2.72	1.41
V	9.26	4.06	2.28
V	11.83	4.06	2.91
VI DESIGN F (SUPER HI-CAP)	6.85	4.06	1.69
VI DESIGN F (SUPER HI-CAP)	7.93	4.06	1.95
VI DESIGN F (SUPER HI-CAP)	7.93	4.06	1.95
VI DESIGN F (SUPER HI-CAP)	7.93	4.06	1.95
VII DESIGN G	9.26	3.40	2.72
VII DESIGN G	4.19	5.31	.79

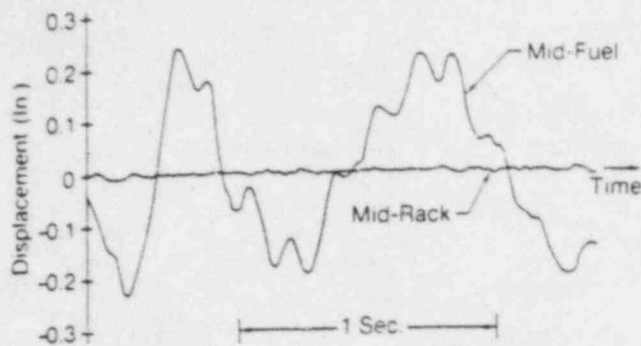


Figure 8: CESHOCK Displacement Response For HI-CAP Fuel Rack

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-

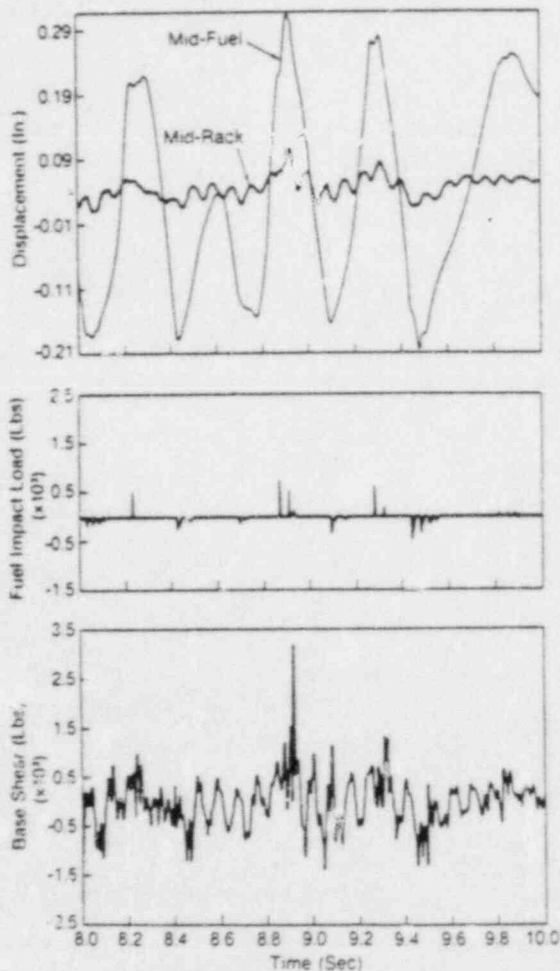


Figure 9: CESHOCK Response Parameters For Super HI-CAP Fuel Rack

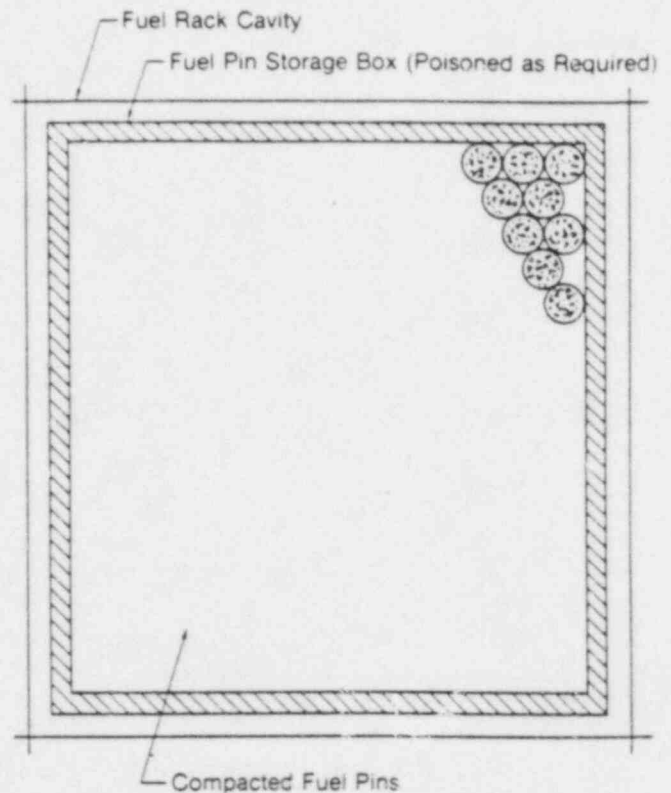


Figure 10: Consolidated Fuel Pin Arrangement

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.

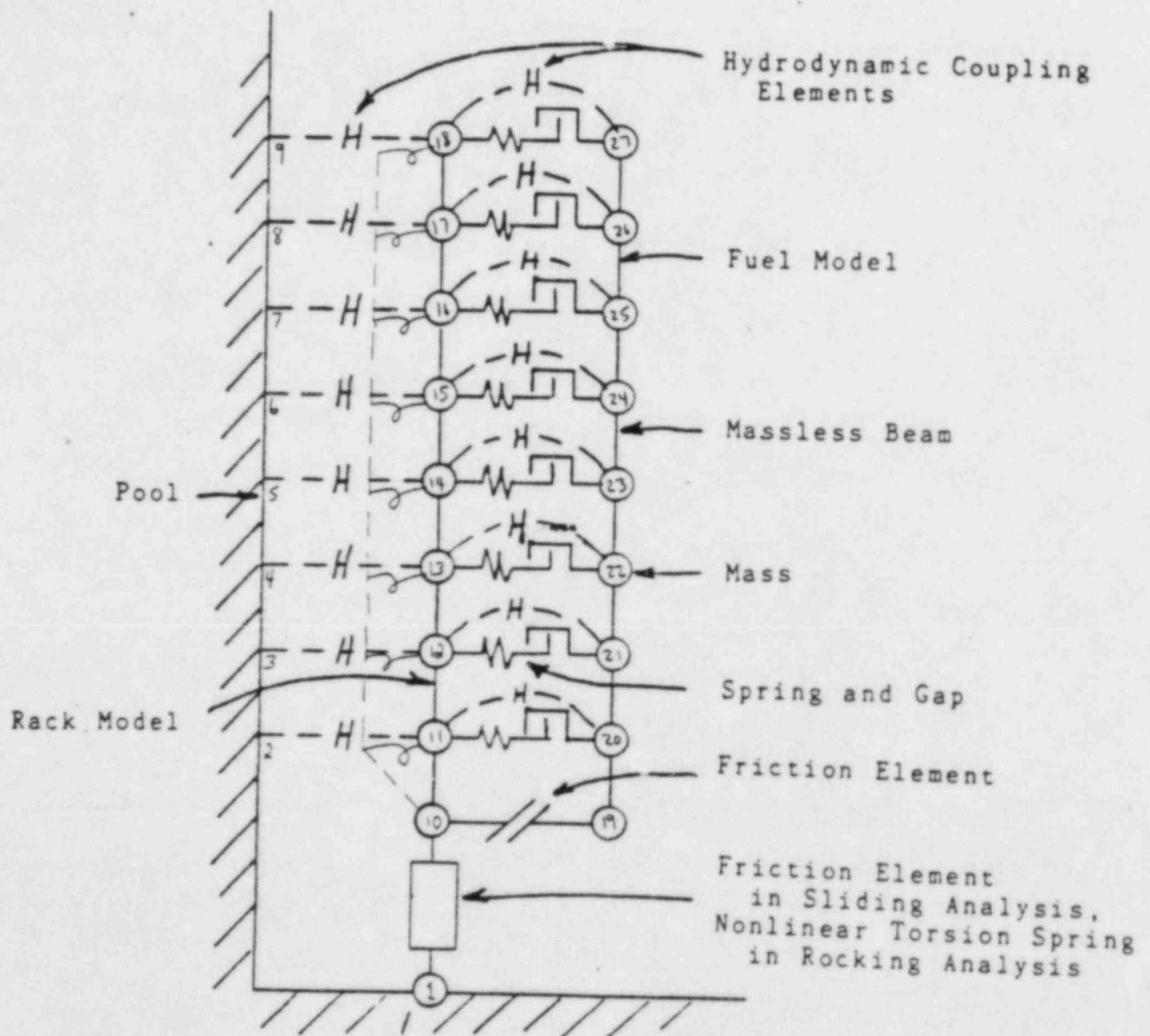
- c. Provide a copy of the reference to expedite the review.

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.

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

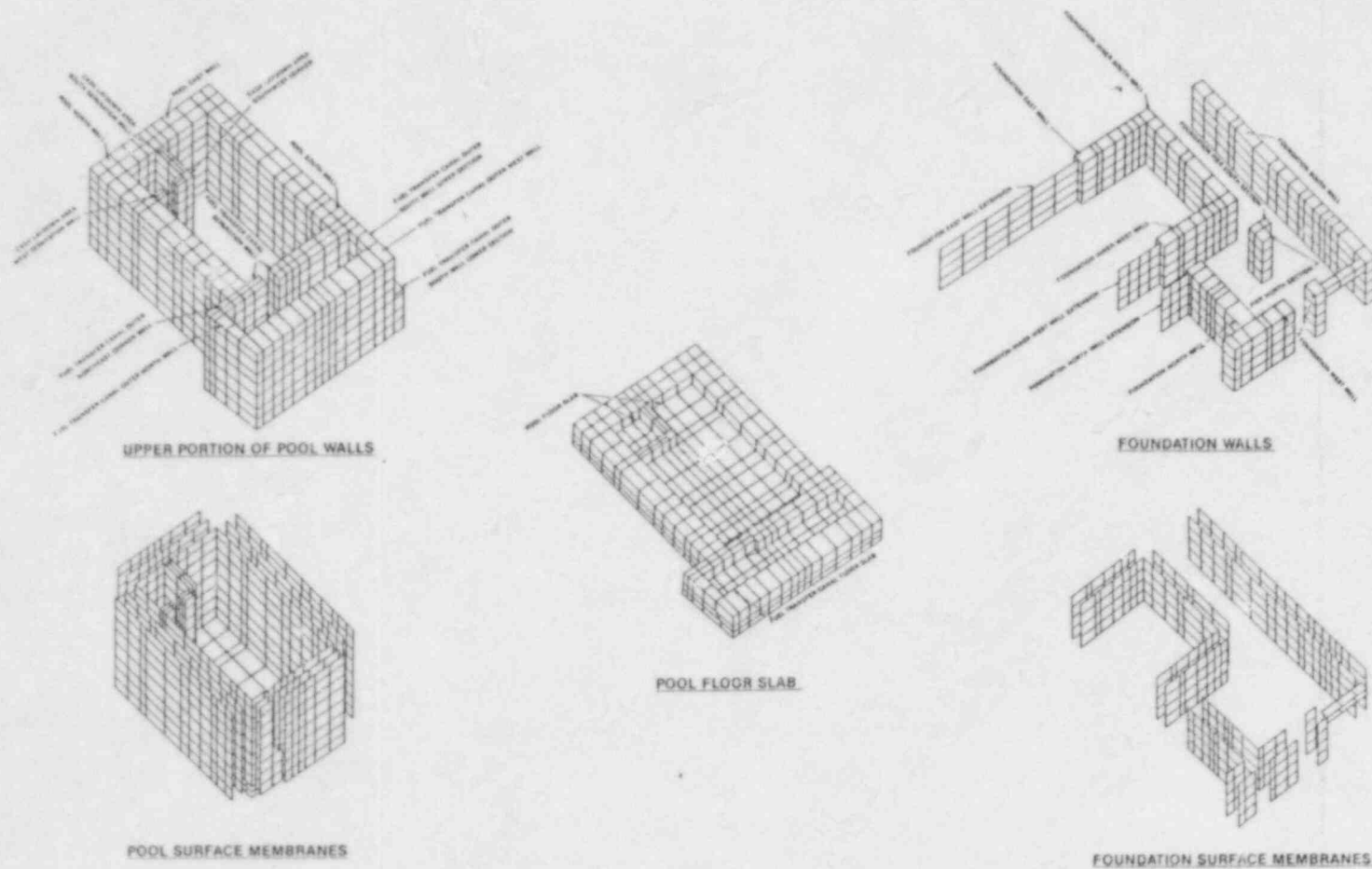
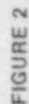


FIGURE 1
ISOMETRIC VIEWS AND KEY DIAGRAMS

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

ASDT Structural
Dynamics
Technology, Inc.

11.8.3



References Drawings: "Millstone Indian Power Station, Unit No. 2," 25205 11080 Rev. 11089, 11104, 11105, 11107, 11112, 11126, 11177, 27018, 27019, 27019, 27022

The following deviations from the reference drawings were made in accordance with the design of the Millstone Indian Power Station, Unit No. 2, and are 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 nodes.
- The curvature in the outside face of the north wall of the fuel transfer canal area was eliminated.
- The spring in the west foundation wall was adjusted to coincide alignment with existing nodes.

3) Coordinate systems

- * Global coordinate system origin located at the southeast's outside corner of the pool at elevation $0' - 0''$.
- * Local membrane element coordinate systems for pool and foundation walls are defined by the wall's centerline. The pool's wall is projected up toward the outside of the walls, and the foundation's wall is projected up toward the inside of the walls.
- * Local membrane element coordinate systems for the pool floor 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.
- * Membrane elements are provided on the surfaces of the walls that are to be evaluated to code criteria. These membranes are assigned negligible thickness and therefore do not provide additional stiffness. Stiffness obtained from these membranes are used along with stiffeners obtained from solid elements to calculate resultant section forces and moments.
- * Shear stiffness of auxiliary building floors and walls that frame into pool and foundation walls are represented as general in-plane elements.
- * Foundation wall extensions are modeled as membrane elements with their actual thickness specified.
- * All solid elements are defined using eight nodes. Where intersections of the cast in-place concrete walls occur, the intersection of the cast in-place concrete walls with the pool walls, the main continuous node is re-positioned to adjacent nodes such that the plane section through the non-continuous component remains plane.
- * The cast in-place concrete cap spanning is contained in vertical co-ordinates and is represented by a single node. The cap is modeled as shown in Figure 8.
- * Section 1 to Figures 1, 2 and 11 are for the opening in the west foundation wall. Section 1 to Figure 7 refers to the section heading for the north and east foundations.

SOLID ELEMENTS

[illegible]

INSIDE LAYER.

[illegible]

OUTSIDE LAY-ON

8.73	8.85	8.95	9.08	9.13	9.28	9.38	9.52
8.75	8.85	8.94	9.03	9.18	9.27	9.38	9.51
8.75	8.82	8.93	9.06	9.15	9.26	9.37	9.48
8.75	8.81	8.92	9.03	9.18	9.25	9.38	9.57
8.85	8.90	8.93	9.02	9.12	9.28	9.35	9.48
8.88	8.98	8.90	9.01	9.12	9.22	9.28	9.35
8.87	8.95	8.98	9.00	9.11	9.22	9.32	9.35
8.95	8.97	8.98	8.99	9.10	9.23	9.33	9.42
8.95	8.98	8.97	8.98	9.09	9.20	9.31	9.42
8.95	8.98	8.98	8.97	9.08	9.18	9.30	9.41
8.95	8.98	8.98	8.98	9.07	9.18	9.30	9.41
8.95	8.98	8.98	8.98	9.07	9.18	9.30	9.41

INSIDE SURFACE

0.872	0.858	0.845	0.828	0.817	0.828	0.733	0.702
0.873	0.853	0.836	0.823	0.816	0.829	0.736	0.706
0.871	0.861	0.843	0.826	0.813	0.826	0.737	0.707
0.870	0.861	0.842	0.823	0.818	0.826	0.736	0.707
0.869	0.860	0.841	0.822	0.813	0.828	0.739	0.709
0.868	0.859	0.840	0.821	0.812	0.823	0.736	0.706
0.867	0.858	0.839	0.820	0.811	0.822	0.732	0.706
0.866	0.857	0.838	0.819	0.810	0.821	0.731	0.705
0.865	0.856	0.837	0.818	0.809	0.820	0.730	0.704
0.864	0.855	0.836	0.817	0.808	0.819	0.729	0.703

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	0.693	0.704	0.715	0.726	0.737	0.748
0.665	0.681	0.692	0.703	0.714	0.725	0.736	0.747
0.660	0.680	0.691	0.702	0.713	0.724	0.735	0.746
0.650	0.670	0.680	0.691	0.702	0.713	0.724	0.735
0.647	0.668	0.678	0.690	0.701	0.712	0.723	0.734
0.647	0.667	0.678	0.689	0.700	0.711	0.722	0.733
0.646	0.667	0.678	0.689	0.700	0.711	0.722	0.733
0.645	0.666	0.687	0.698	0.709	0.720	0.731	0.742
0.644	0.665	0.687	0.698	0.709	0.720	0.731	0.742
0.644	0.665	0.687	0.698	0.709	0.720	0.731	0.742

OUTSIDE SURFACE

FIGURE 3
POOL SOUTH WALL ELEMENTS

SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

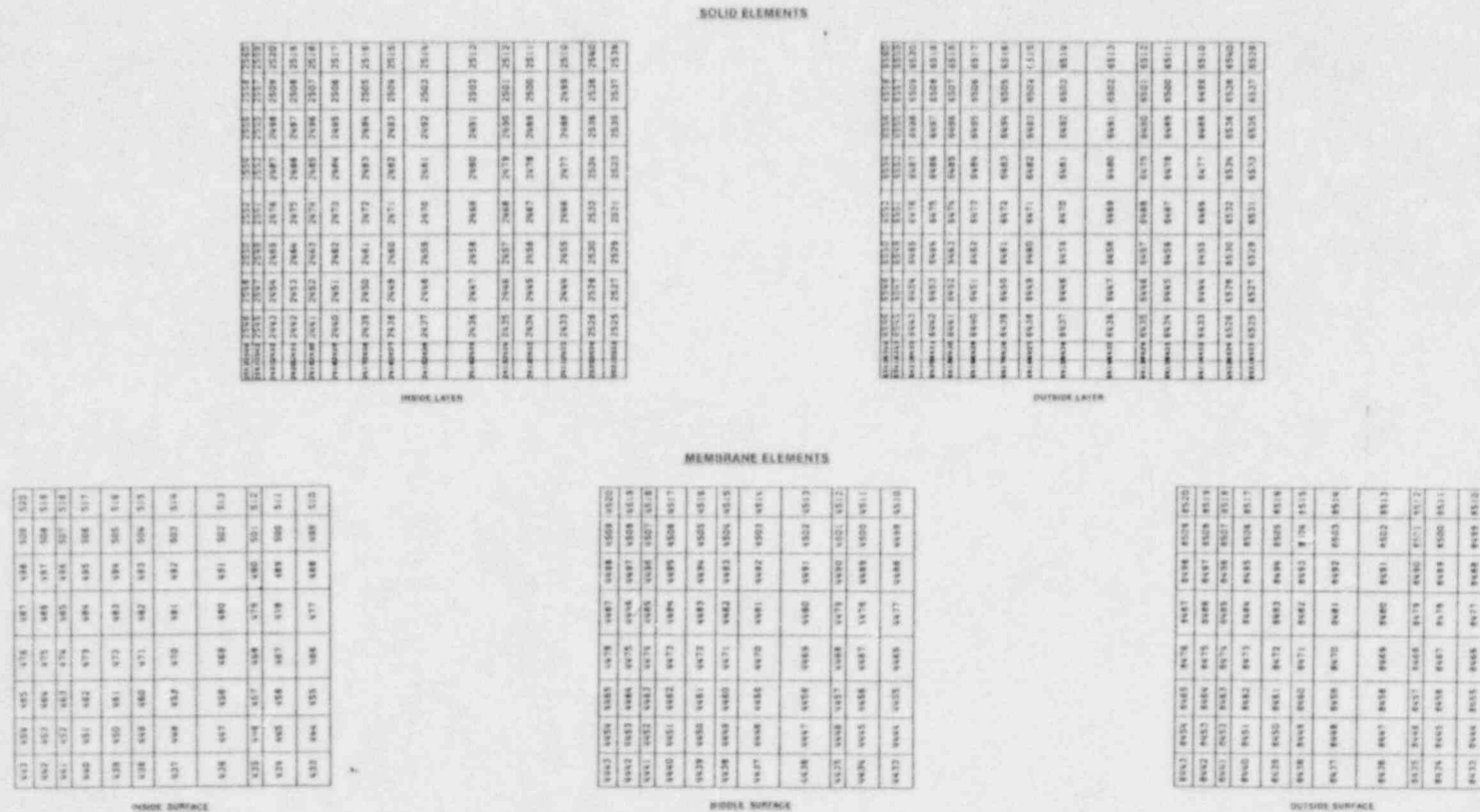


FIGURE 4

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)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1
Population (millions)	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1																																																																																																																																																																																														

INSTRUMENTATION

[illegible]

OUTSIDE LAYER

2007-2008	138	138	2654	2226	2654	2444	2088	2138	2328
2008-2009	141	141	2621	2121	2621	2403	2085	2145	2105
2009-2010	134	134	2574	2074	2574	2344	2046	2126	2124
2010-2011	134	134	2574	2074	2574	2344	2046	2126	2124
2011-2012	134	134	2574	2074	2574	2344	2046	2126	2124
2012-2013	134	134	2574	2074	2574	2344	2046	2126	2124
2013-2014	134	134	2574	2074	2574	2344	2046	2126	2124
2014-2015	134	134	2574	2074	2574	2344	2046	2126	2124
2015-2016	134	134	2574	2074	2574	2344	2046	2126	2124
2016-2017	134	134	2574	2074	2574	2344	2046	2126	2124
2017-2018	134	134	2574	2074	2574	2344	2046	2126	2124
2018-2019	134	134	2574	2074	2574	2344	2046	2126	2124
2019-2020	134	134	2574	2074	2574	2344	2046	2126	2124
2020-2021	134	134	2574	2074	2574	2344	2046	2126	2124
2021-2022	134	134	2574	2074	2574	2344	2046	2126	2124
2022-2023	134	134	2574	2074	2574	2344	2046	2126	2124
2023-2024	134	134	2574	2074	2574	2344	2046	2126	2124
2024-2025	134	134	2574	2074	2574	2344	2046	2126	2124
2025-2026	134	134	2574	2074	2574	2344	2046	2126	2124
2026-2027	134	134	2574	2074	2574	2344	2046	2126	2124
2027-2028	134	134	2574	2074	2574	2344	2046	2126	2124
2028-2029	134	134	2574	2074	2574	2344	2046	2126	2124
2029-2030	134	134	2574	2074	2574	2344	2046	2126	2124
2030-2031	134	134	2574	2074	2574	2344	2046	2126	2124
2031-2032	134	134	2574	2074	2574	2344	2046	2126	2124
2032-2033	134	134	2574	2074	2574	2344	2046	2126	2124
2033-2034	134	134	2574	2074	2574	2344	2046	2126	2124
2034-2035	134	134	2574	2074	2574	2344	2046	2126	2124
2035-2036	134	134	2574	2074	2574	2344	2046	2126	2124
2036-2037	134	134	2574	2074	2574	2344	2046	2126	2124
2037-2038	134	134	2574	2074	2574	2344	2046	2126	2124
2038-2039	134	134	2574	2074	2574	2344	2046	2126	2124
2039-2040	134	134	2574	2074	2574	2344	2046	2126	2124
2040-2041	134	134	2574	2074	2574	2344	2046	2126	2124
2041-2042	134	134	2574	2074	2574	2344	2046	2126	2124
2042-2043	134	134	2574	2074	2574	2344	2046	2126	2124
2043-2044	134	134	2574	2074	2574	2344	2046	2126	2124
2044-2045	134	134	2574	2074	2574	2344	2046	2126	2124
2045-2046	134	134	2574	2074	2574	2344	2046	2126	2124
2046-2047	134	134	2574	2074	2574	2344	2046	2126	2124
2047-2048	134	134	2574	2074	2574	2344	2046	2126	2124
2048-2049	134	134	2574	2074	2574	2344	2046	2126	2124
2049-2050	134	134	2574	2074	2574	2344	2046	2126	2124
2050-2051	134	134	2574	2074	2574	2344	2046	2126	2124
2051-2052	134	134	2574	2074	2574	2344	2046	2126	2124
2052-2053	134	134	2574	2074	2574	2344	2046	2126	2124
2053-2054	134	134	2574	2074	2574	2344	2046	2126	2124
2054-2055	134	134	2574	2074	2574	2344	2046	2126	2124
2055-2056	134	134	2574	2074	2574	2344	2046	2126	2124
2056-2057	134	134	2574	2074	2574	2344	2046	2126	2124
2057-2058	134	134	2574	2074	2574	2344	2046	2126	2124
2058-2059	134	134	2574	2074	2574	2344	2046	2126	2124
2059-2060	134	134	2574	2074	2574	2344	2046	2126	2124
2060-2061	134	134	2574	2074	2574	2344	2046	2126	2124
2061-2062	134	134	2574	2074	2574	2344	2046	2126	2124
2062-2063	134	134	2574	2074	2574	2344	2046	2126	2124
2063-2064	134	134	2574	2074	2574	2344	2046	2126	2124
2064-2065	134	134	2574	2074	2574	2344	2046	2126	2124
2065-2066	134	134	2574	2074	2574	2344	2046	2126	2124
2066-2067	134	134	2574	2074	2574	2344	2046	2126	2124
2067-2068	134	134	2574	2074	2574	2344	2046	2126	2124
2068-2069	134	134	2574	2074	2574	2344	2046	2126	2124
2069-2070	134	134	2574	2074	2574	2344	2046	2126	2124
2070-2071	134	134	2574	2074	2574	2344	2046	2126	2124
2071-2072	134	134	2574	2074	2574	2344	2046	2126	2124
2072-2073	134	134	2574	2074	2574	2344	2046	2126	2124
2073-2074	134	134	2574	2074	2574	2344	2046	2126	2124
2074-2075	134	134	2574	2074	2574	2344	2046	2126	2124
2075-2076	134	134	2574	2074	2574	2344	2046	2126	2124
2076-2077	134	134	2574	2074	2574	2344	2046	2126	2124
2077-2078	134	134	2574	2074	2574	2344	2046	2126	2124
2078-2079	134	134	2574	2074	2574	2344	2046	2126	2124
2079-2080	134	134	2574	2074	2574	2344	2046	2126	2124
2080-2081	134	134	2574	2074	2574	2344	2046	2126	2124
2081-2082	134	134	2574	2074	2574	2344	2046	2126	2124
2082-2083	134	134	2574	2074	2574	2344	2046	2126	2124
2083-2084	134	134	2574	2074	2574	2344	2046	2126	2124
2084-2085	134	134	2574	2074	2574	2344	2046	2126	2124
2085-2086	134	134	2574	2074	2574	2344	2046	2126	2124
2086-2087	134	134	2574	2074	2574	2344	2046	2126	2124
2087-2088	134	134	2574	2074	2574	2344	2046	2126	2124
2088-2089	134	134	2574	2074	2574	2344	2046	2126	2124
2089-2090	134	134	2574	2074	2574	2344	2046	2126	2124
2090-2091	134	134	2574	2074	2574	2344	2046	2126	2124
2091-2092	134	134	2574	2074	2574	2344	2046	2126	2124
2092-2093	134	134	2574	2074	2574	2344	2046	2126	2124
2093-2094	134	134	2574	2074	2574	2344	2046	2126	2124
2094-2095	134	134	2574	2074	2574	2344	2046	2126	2124
2095-2096	134	134	2574	2074	2574	2344	2046	2126	2124
2096-2097	134	134	2574	2074	2574	2344	2046	2126	2124
2097-2098	134	134	2574	2074	2574	2344	2046	2126	2124
2098-2099	134	134	2574	2074	2574	2344	2046	2126	2124
2099-2100	134	134	2574	2074	2574	2344	2046	2126	2124
2100-2101	134	134	2574	2074	2574	2344	2046	2126	2124
2101-2102	134	134	2574	2074	2574	2344	2046	2126	2124
2102-2103	134	134	2574	2074	2574	2344	2046	2126	2124
2103-2104	134	134	2574	2074	2574	2344	2046	2126	2124
2104-2105	134	134	2574	2074	2574	2344	2046	2126	2124
2105-2106	134	134	2574	2074	2574	2344	2046	2126	2124
2106-2107	134	134	2574	2074	2574	2344	2046	2126	2124
2107-2108	134	134	2574	2074	2574	2344	2046	2126	2124
2108-2109	134	134	2574	2074	2574	2344	2046	2126	2124
2109-2110	134	134	2574	2074	2574	2344	2046	2126	2124
2110-2111	134	134	2574	2074	2574	2344	2046	2126	2124
2111-2112	134	134	2574	2074	2574	2344	2046	2126	2124
2112-2113	134	134	2574	2074	2574	2344	2046	2126	2124
2113-2114	134	134	2574	2074	2574	2344	2046	2126	2124
2114-2115	134	134	2574	2074	2574	2344	2046	2126	2124
2115-2116	134	134	2574	2074	2574	2344	2046	2126	2124
2116-2117	134	134	2574	2074	2574	2344	2046	2126	2124
2117-2118	134	134	2574	2074	2574	2344	2046	2126	2124
2118-2119	134	134	2574	2074	2574	2344	2046	2126	2124
2119-2120	134	134	2574	2074	2574	2344	2046	2126	2124
2120-2121	134	134	2574	2074	2574	2344	2046	2126	2124
2121-2122	134	134	2574	2074	2574	2344	2046	2126	2124
2122-2123	134	134	2574	2074	2574	2344	2046	2126	2124
2123-2124	134	134	2574	2074	2574	2344	2046	2126	2124
2124-2125	134	134	2574	2074	2574	2344	2046	2126	2124
2125-2126	134	134	2574	2074	2574	2344	2046	2126	2124
2126-2127	134	134	2574	2074	2574	2344	2046	2126	2124
2127-2128	134	134	2574	2074	2574	2344	2046	2126	2124
2128-2129	134	134	2574	2074	2574	2344	2046	2126	2124
2129-2130	134	134	2574	2074	2574	2344	2046	2126	2124
2130-2131	134	134	2574	2074	2574	2344	2046	2126	2124
2131-2132	134	134	2574	2074	2574	2344	2046	2126	2124
2132-2133	134	134	2574	2074	2574	2344	2046	2126	2124
2133-2134	134	134	2574	2074	2574	2344	2046	2126	2124
2134-2135	134	134	2574	2074	2574	23			

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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	5828	5826
5865	5865	5832	5821	5808	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	96.07	96.15	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	98.38
98.59	98.66	98.72	98.78	98.88	98.98
99.02	99.10	99.18	99.24	99.32	99.38
99.42	99.50	99.58	99.64	99.72	99.78
99.81	99.89	99.97	100.05	100.13	100.29
100.40	100.48	100.56	100.64	100.72	100.88
100.95	101.07	101.13	101.19	101.27	101.38
101.59	101.66	101.72	101.78	101.88	101.98
102.02	102.10	102.18	102.24	102.32	102.38
102.42	102.50	102.58	102.64	102.72	102.78
102.81	102.89	102.97	103.05	103.13	103.29
103.40	103.48	103.56	103.64	103.72	103.88
103.95	104.07	104.13	104.19	104.27	104.38
104.59	104.66	104.72	104.78	104.88	104.98
105.02	105.10	105.18	105.24	105.32	105.38
105.42	105.50	105.58	105.64	105.72	105.78
105.81	105.89	105.97	106.05	106.13	106.29
106.40	106.48	106.56	106.64	106.72	106.88
106.95	107.07	107.13	107.19	107.27	107.38
107.59	107.66	107.72	107.78	107.88	107.98
108.02	108.10	108.18	108.24	108.32	108.38
108.42	108.50	108.58	108.64	108.72	108.78
108.81	108.89	108.97	109.05	109.13	109.29
109.40	109.48	109.56	109.64	109.72	109.88
109.95	110.07	110.13	110.19	110.27	110.38
110.59	110.66	110.72	110.78	110.88	110.98
111.02	111.10	111.18	111.24	111.32	111.38
111.42	111.50	111.58	111.64	111.72	111.78
111.81	111.89	111.97	112.05	112.13	112.29
112.40	112.48	112.56	112.64	112.72	112.88
112.95	113.07	113.13	113.19	113.27	113.38
113.59	113.66	113.72	113.78	113.88	113.98
114.02	114.10	114.18	114.24	114.32	114.38
114.42	114.50	114.58	114.64	114.72	114.78
114.81	114.89	114.97	115.05	115.13	115.29
115.40	115.48	115.56	115.64	115.72	115.88
115.95	116.07	116.13	116.19	116.27	116.38
116.59	116.66	116.72	116.78	116.88	116.98
117.02	117.10	117.18	117.24	117.32	117.38
117.42	117.50	117.58	117.64	117.72	117.78
117.81	117.89	117.97	118.05	118.13	118.29
118.40	118.48	118.56	118.64	118.72	118.88
118.95	119.07	119.13	119.19	119.27	119.38
119.59	119.66	119.72	119.78	119.88	119.98
120.02	120.10	120.18	120.24	120.32	120.38
120.42	120.50	120.58	120.64	120.72	120.78
120.81	120.89	120.97	121.05	121.13	121.29
121.40	121.48	121.56	121.64	121.72	121.88
121.95	122.07	122.13	122.19	122.27	122.38
122.59	122.66	122.72	122.78	122.88	122.98
123.02	123.10	123.18	123.24	123.32	123.38
123.42	123.50	123.58	123.64	123.72	123.78
123.81	123.89	123.97	124.0		

OUTSIDE SURFACE

POOL EAST WALL

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

SOUTH SECTION

SOLID ELEMENTS

[illegible]

MUSQUEL LÄRM

[illegible]

OUTSIDE LAYER

0.18	0.22	0.26	0.30	0.40	0.50	0.62	0.70
0.12	0.20	0.28	0.38	0.48	0.52	0.60	0.68
0.11	0.19	0.27	0.35	0.43	0.51	0.59	0.67
0.10	0.18	0.26	0.34	0.42	0.50	0.58	0.66
0.09	0.17	0.25	0.33	0.41	0.49	0.57	0.65

INSIDE, SURFACE

MEMBRANE ELEMENTS

0.0116	0.022	0.020	0.038	0.053	0.062	0.070
0.013	0.021	0.020	0.037	0.051	0.061	0.068
0.012	0.020	0.020	0.036	0.050	0.060	0.068
0.011	0.019	0.019	0.035	0.049	0.059	0.067
0.010	0.018	0.018	0.034	0.048	0.058	0.066
0.009	0.017	0.017	0.033	0.047	0.057	0.065
0.008	0.016	0.016	0.032	0.046	0.056	0.064
0.007	0.015	0.015	0.031	0.045	0.055	0.063
0.006	0.014	0.014	0.030	0.044	0.054	0.062
0.005	0.013	0.013	0.029	0.043	0.053	0.061
0.004	0.012	0.012	0.028	0.042	0.052	0.060
0.003	0.011	0.011	0.027	0.041	0.051	0.059
0.002	0.010	0.010	0.026	0.040	0.050	0.058
0.001	0.009	0.009	0.025	0.039	0.049	0.057

MIDDLE SURFACE

00114	00222	00200	00330	00554	00662	00770
00119	00226	00234	00342	00557	00665	00773
00122	00230	00238	00346	00560	00668	00776
00127	00235	00243	00351	00565	00673	00781
00132	00240	00248	00356	00570	00678	00786
00137	00245	00253	00361	00575	00683	00791
00142	00250	00258	00366	00580	00688	00796
00147	00255	00263	00371	00585	00693	00801
00152	00260	00268	00376	00590	00698	00806
00157	00265	00273	00381	00595	00703	00811
00162	00270	00278	00386	00600	00708	00816
00167	00275	00283	00391	00605	00713	00821
00172	00280	00288	00396	00610	00718	00826
00177	00285	00293	00401	00615	00723	00831
00182	00290	00298	00406	00620	00728	00836
00187	00295	00303	00411	00625	00733	00841
00192	00300	00308	00416	00630	00738	00846
00197	00305	00313	00421	00635	00743	00851
00202	00310	00318	00426	00640	00748	00856
00207	00315	00323	00431	00645	00753	00861
00212	00320	00328	00436	00650	00758	00866
00217	00325	00333	00441	00655	00763	00871
00222	00330	00338	00446	00660	00768	00876
00227	00335	00343	00451	00665	00773	00881
00232	00340	00348	00456	00670	00778	00886
00237	00345	00353	00461	00675	00783	00891
00242	00350	00358	00466	00680	00788	00896
00247	00355	00363	00471	00685	00793	00901
00252	00360	00368	00476	00690	00798	00906
00257	00365	00373	00481	00695	00803	00911
00262	00370	00378	00486	00700	00808	00916
00267	00375	00383	00491	00705	00813	00921
00272	00380	00388	00496	00710	00818	00926
00277	00385	00393	00501	00715	00823	00931
00282	00390	00398	00506	00720	00828	00936
00287	00395	00403	00511	00725	00833	00941
00292	00400	00408	00516	00730	00838	00946
00297	00405	00413	00521	00735	00843	00951
00302	00410	00418	00526	00740	00848	00956
00307	00415	00423	00531	00745	00853	00961
00312	00420	00428	00536	00750	00858	00966
00317	00425	00433	00541	00755	00863	00971
00322	00430	00438	00546	00760	00868	00976
00327	00435	00443	00551	00765	00873	00981
00332	00440	00448	00556	00770	00878	00986
00337	00445	00453	00561	00775	00883	00991
00342	00450	00458	00566	00780	00888	00996
00347	00455	00463	00571	00785	00893	01001
00352	00460	00468	00576	00790		

OUTSIDE SURFACE

SOLID ELEMENTS

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

INFLUENCE LAYERS

2.4. 2000	0.5. 0	0.0. 200	0.0. 7	0.0. 53	0.0. 3
2.4. 2000	0.5. 0	0.0. 200	0.0. 7	0.0. 53	0.0. 3

OUTSIDE LAYER

NORTH SECTION

MEMBRANE ELEMENTS

Year	1990	1991	1992	1993	1994	1995	1996
Population (millions)	1.1	1.2	1.3	1.4	1.5	1.6	1.7
GDP (billions of dollars)	100	120	140	160	180	200	220
Per capita GDP (dollars)	90.9	100.0	107.7	114.3	120.0	125.0	129.4

INSIDE SURFACE

[illegible]

MIDDLE SURFACE

0.020	0.018	0.026
0.027	0.015	0.022
		0.031
		0.026
		0.047
		0.015
		0.053

OUTSIDE SURFACE

NODES

[illegible]

INSIDE SURFACE

1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
10,300	11,315	12,421	13,527	14,633	15,739	16,845	17,951	19,057	20,163	21,269

WINDY SURFACE

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	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000
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OUTSIDE SURFACE

NODES

885798	022	1845	2080	2310
885799	023	1871	2081	2311
885800	024	1897	2082	2312
885801	025	1923	2083	2313
885802	026	1949	2084	2314
885803	027	1975	2085	2315
885804	028	2001	2086	2316
885805	029	2027	2087	2317
885806	030	2053	2088	2318
885807	031	2079	2089	2319
885808	032	2105	2090	2320
885809	033	2131	2091	2321
885810	034	2157	2092	2322
885811	035	2183	2093	2323
885812	036	2209	2094	2324
885813	037	2235	2095	2325
885814	038	2261	2096	2326
885815	039	2287	2097	2327
885816	040	2313	2098	2328
885817	041	2339	2099	2329
885818	042	2365	2100	2330
885819	043	2391	2101	2331
885820	044	2417	2102	2332
885821	045	2443	2103	2333
885822	046	2469	2104	2334
885823	047	2495	2105	2335
885824	048	2521	2106	2336
885825	049	2547	2107	2337
885826	050	2573	2108	2338
885827	051	2599	2109	2339
885828	052	2625	2110	2340
885829	053	2651	2111	2341
885830	054	2677	2112	2342
885831	055	2703	2113	2343
885832	056	2729	2114	2344
885833	057	2755	2115	2345
885834	058	2781	2116	2346
885835	059	2807	2117	2347
885836	060	2833	2118	2348
885837	061	2859	2119	2349
885838	062	2885	2120	2350
885839	063	2911	2121	2351
885840	064	2937	2122	2352
885841	065	2963	2123	2353
885842	066	2989	2124	2354
885843	067	3015	2125	2355
885844	068	3041	2126	2356
885845	069	3067	2127	2357
885846	070	3093	2128	2358
885847	071	3119	2129	2359
885848	072	3145	2130	2360
885849	073	3171	2131	2361
885850	074	3197	2132	2362
885851	075	3223	2133	2363
885852	076	3249	2134	2364
885853	077	3275	2135	2365
885854	078	3301	2136	2366
885855	079	3327	2137	2367
885856	080	3353	2138	2368
885857	081	3379	2139	2369
885858	082	3405	2140	2370
885859	083	3431	2141	2371
885860	084	3457	2142	2372
885861	085	3483	2143	2373
885862	086	3509	2144	2374
885863	087	3535	2145	2375
885864	088	3561	2146	2376
885865	089	3587	2147	2377
885866	090	3613	2148	2378
885867	091	3639	2149	2379
885868	092	3665	2150	2380
885869	093	3691	2151	2381
885870	094	3717	2152	2382
885871	095	3743	2153	2383
885872	096	3769	2154	2384
885873	097	3795	2155	2385
885874	098	3821	2156	2386
885875	099	3847	2157	2387
885876	100	3873	2158	2388

INSIDE SURFACE

2000	1000	500	250	125	62.5	31.25	15.625	7.8125	3.90625	1.953125	0.9765625	0.48828125	0.244140625	0.1220703125	0.06103515625	0.030517578125	0.0152587890625	0.00762939453125	0.003814697265625	0.0019073486328125	0.00095367431640625	0.000476837158203125	0.0002384185791015625	0.00011920928955078125	0.000059604644775390625	0.0000298023223876953125	0.00001490116119384765625	0.000007450580596923828125	0.0000037252902984619140625	0.00000186264514923095703125	0.000000931322574615478515625	0.0000004656612873077392578125	0.00000023283064365386962890625	0.000000116415321826934814453125	0.000000582076609134674072265625	0.0000002910383045673370361328125	0.00000014551915228366851806640625	0.000000072759576141834259033203125	0.0000000363797880709171295166015625	0.00000001818989403545856475830078125	0.000000009094947017729282379150390625	0.0000000045474735088646411895751953125	0.00000000227373675443232059478759765625	0.000000001136868377216160297393798828125	0.0000000005684341886080801486968994140625	0.00000000028421709430404007434844970703125	0.000000000142108547152020037174224853515625	0.0000000000710542735760100185871124267578125	0.00000000003552713678800500929355621337890625	0.000000000017763568394002504646778106689453125	0.0000000000088817841970012523233890533447265625	0.00000000000444089209850062616169452667236328125	0.000000000002220446049250313080847263336181640625	0.0000000000011102230246251565404236316680908203125	0.00000000000055511151231257827021181583340541015625	0.000000000000277555756156289135105907916702705078125	0.0000000000001387778780781445675529539583513525390625	0.00000000000006938893903907228377647697917567626953125	0.000000000000034694469519536141888238489587838134765625	0.0000000000000173472347597680709441192447939190673828125	0.0000000000000086736173798840354720596223969595369140625	0.00000000000000433680868994201773602981119847976845703125	0.0000000000000021684043449710088680149055992398928265625	0.000000000000001084202172485504434007452799619946412890625	0.0000000000000005421010862427522170037263998099732064453125	0.00000000000000027105054312137610850186319990498660322265625	0.000000000000000135525271560688054250931599952493301611328125	0.0000000000000000677626357803440271254657999762466508056640625	0.00000000000000003388131789017201356273289998812332540283203125	0.000000000000000016940658945086006781366449994406162701416015625	0.00000000000000000847032947254300339068322499720308135070578125	0.000000000000000004235164736271501695341612498601540675352890625	0.0000000000000000021175823681357508476708062493007703376764453125	0.00000000000000000105879118406787542383540312465038516883822265625	0.000000000000000000529395592033937711917701562325192584419111328125	0.0000000000000000002646977960169688559588507811629629222095556640625	0.00000000000000000013234889800848442797942539058148146110477783203125	0.000000000000000000066174449004242213989712695290740730552388916015625	0.0000000000000000000330872245021211069948563476453703652761944580078125	0.00000000000000000001654361225106055349742817382268518263809722900390625	0.000000000000000000008271806125530276748714086911342591319048614501953125	0.0000000000000000000041359030627651383743570434556712956595243072509765625	0.00000000000000000000206795153138256918717852172783564782976215362548828125	0.000000000000000000001033975765691284593589260863917823914881076812744140625	0.0000000000000000000005169878828456422967946304319589119574403840613720703125	0.00000000000000000000025849394142282114839731521597945597872019203068603515625	0.000000000000000000000129246970711410574198657607989727989360096015343017578125	0.00000000000000000000006
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MIDDLE SURFACE

[illegible]

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	2867	2858	2811	2813	2815	2817
2856	2858	2868	2810	2812	2815	2818	2818

INSIDE LAYER

4852	4855	4867	4856	4811	4813	4815	4817
4858	4858	4868	4810	4812	4815	4818	4818

OUTSIDE LAYER

MEMBRANE ELEMENTS

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

INSIDE SURFACE

4852	4855	4867	4856	4811	4813	4815	4817
4858	4858	4868	4810	4812	4815	4818	4818

MIDDLE SURFACE

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

OUTSIDE SURFACE

NODES

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

INSIDE SURFACE

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

MIDDLE SURFACE

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

OUTSIDE SURFACE

WEST SEPARATION WALL

SOLID ELEMENTS

4871	4874	4877	4880	4882	4885	4887	4890
4872	4875	4878	4881	4884	4887	4890	4893

INSIDE LAYER

4871	4874	4877	4880	4882	4885	4887	4890
4872	4875	4878	4881	4884	4887	4890	4893

OUTSIDE LAYER

MEMBRANE ELEMENTS

871	874	877	880	882	885	887	890
872	875	878	881	884	887	890	893

INSIDE SURFACE

4871	4874	4877	4880	4882	4885	4887	4890
4872	4875	4878	4881	4884	4887	4890	4893

MIDDLE SURFACE

871	874	877	880	882	885	887	890
872	875	878	881	884	887	890	893

OUTSIDE SURFACE

NODES

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

INSIDE SURFACE

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

MIDDLE SURFACE

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

OUTSIDE SURFACE

SOUTHWEST CORNER

SOLID ELEMENTS

2853	2855	2867	2858	2811	2813	2815	2817
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INSIDE LAYER

NODES

1232	1243	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260

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

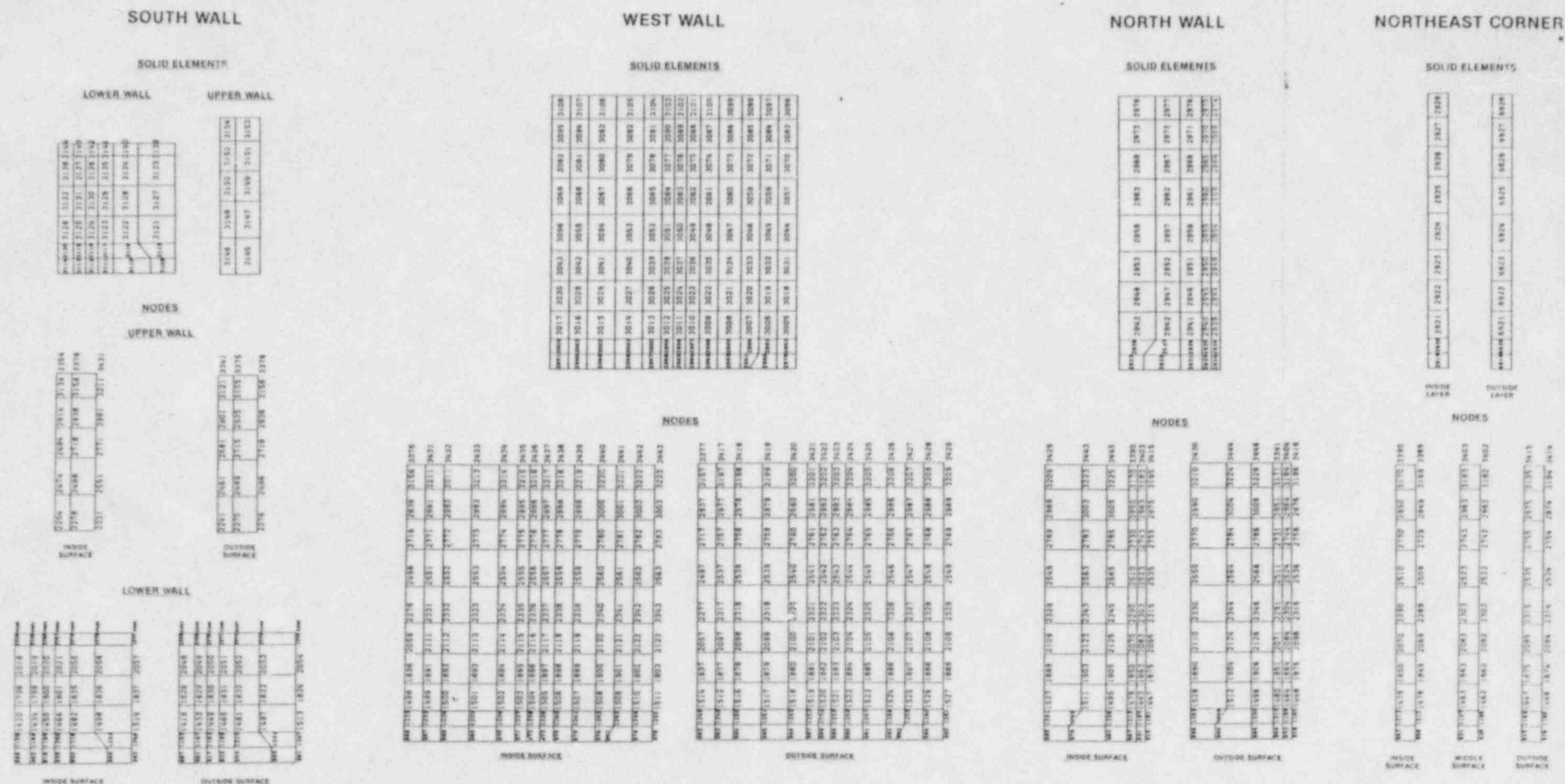


FIGURE 9

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

MEMBRANE ELEMENTS

1000	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	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MILLSTONE POINT - UNIT 2
SPENT FUEL STORAGE FACILITY FINITE ELEMENT MODEL

SOUTH WALL

SOLID ELEMENTS

6001	6017	6033	6049
6002	6018	6034	6050
6003	6019	6035	6051
6004	6020	6036	6052
6005	6021	6037	6053
6006	6022	6038	6054
6007	6023	6039	6055
6008	6024	6040	6056
6009	6025	6041	6057
6010	6026	6042	6058
6011	6027	6043	6059
6012	6028	6044	6060
6013	6029	6045	6061
6014	6030	6046	6062
6015	6031	6047	6063
6016	6032	6048	6064
6017	6033	6049	6065

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

6001	6017	6033	6049
6002	6018	6034	6050
6003	6019	6035	6051
6004	6020	6036	6052
6005	6021	6037	6053
6006	6022	6038	6054
6007	6023	6039	6055
6008	6024	6040	6056
6009	6025	6041	6057
6010	6026	6042	6058
6011	6027	6043	6059
6012	6028	6044	6060
6013	6029	6045	6061
6014	6030	6046	6062
6015	6031	6047	6063
6016	6032	6048	6064

OUTSIDE SURFACE

NODES

25	168	312	456
27	187	331	475
29	206	350	494
31	225	369	513
33	244	388	532
35	263	407	551
37	282	426	570
39	301	445	589
41	320	464	608
43	339	483	627
45	358	502	646
47	377	521	665
49	396	540	684
51	415	559	703
53	434	578	722
55	453	597	741
57	472	616	760
59	491	635	779
61	510	654	798
63	529	673	817
65	548	692	836
67	567	711	855
69	586	730	874
71	605	749	893

INSIDE SURFACE

OUTSIDE SURFACE

WEST WALL

SOLID ELEMENTS

6066	6100	6134	6168
6067	6101	6135	6169
6068	6102	6136	6170
6069	6103	6137	6171
6070	6104	6138	6172
6071	6105	6139	6173
6072	6106	6140	6174
6073	6107	6141	6175
6074	6108	6142	6176
6075	6109	6143	6177
6076	6110	6144	6178
6077	6111	6145	6179
6078	6112	6146	6180
6079	6113	6147	6181
6080	6114	6148	6182

MEMBRANE ELEMENTS

BEAM TOP SURFACE

60 100 101

BEAM BOTTOM SURFACE

600 100 101

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

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

77	87	97	107
78	88	98	108

6072	6082	6092	6102
------	------	------	------

6073	6083	6093	6103
6074	6084	6094	6104
6075	6085	6095	6105

6076	6086	6096	6106
6077	6087	6097	6107
6078	6088	6098	6108

INSIDE SURFACE

OUTSIDE SURFACE

NODES

61	167	311	455
63	186	330	474
65	205	349	493
67	224	368	512
69	243	387	531
71	262	406	550
73	281	425	569
75	300	444	588
77	319	463	607
79	338	482	626
81	357	501	645
83	376	520	664
85	395	539	683
87	414	558	702
89	433	577	721
91	452	596	740
93	471	615	759
95	490	634	778
97	509	653	797
99	528	672	816
101	547	691	835
103	566	710	854
105	585	729	873
107	604	748	892
109	623	767	911
111	642	786	930
113	661	805	949
115	680	824	968
117	699	843	987
119	718	862	1006
121	737	881	1025
123	756	900	1044
125	775	919	1063
127	794	938	1082
129	813	957	1101
131	832	976	1120
133	851	995	1139
135	870	1014	1158
137	889	1033	1177
139	908	1052	1196
141	927	1071	1215
143	946	1090	1234
145	965	1109	1253
147	984	1128	1272
149	1003	1147	1291
151	1022	1166	1310
153	1041	1185	1329
155	1060	1204	1348
157	1079	1223	1367
159	1098	1242	1386
161	1117	1261	1405
163	1136	1280	1424
165	1155	1299	1443
167	1174	1318	1462
169	1193	1337	1481
171	1212	1356	1500
173	1231	1375	1519
175	1250	1394	1538
177	1269	1413	1557
179	1288	1432	1576
181	1307	1451	1595
183	1326	1470	1614
185	1345	1489	1633
187	1364	1508	1652
189	1383	1527	1671
191	1402	1546	1690
193	1421	1565	1709
195	1440	1584	1728
197	1459	1603	1747
199	1478	1622	1766
201	1497	1641	1785
203	1516	1660	1804
205	1535	1679	1823
207	1554	1698	1842
209	1573	1717	1861
211	1592	1736	1880
213	1611	1755	1899
215	1630	1774	1918
217	1649	1793	1937
219	1668	1812	1956
221	1687	1831	1975
223	1706	1850	1994
225	1725	1869	2013
227	1744	1888	2032
229	1763	1907	2051
231	1782	1926	2070
233	1801	1945	2089
235	1820	1964	2108
237	1839	1983	2127
239	1858	2002	2146
241	1877	2021	2165
243	1896	2040	2184
245	1915	2059	2203
247	1934	2078	2222
249	1953	2097	2241
251	1972	2116	2260
253	1991	2135	2279
255	2010	2154	2298
257	2029	2173	2317
259	2048	2192	2336
261	2067	2211	2355
263	2086	2230	2374
265	2105	2249	2393
267	2124	2268	2412
269	2143	2287	2431
271	2162	2306	2450
273	2181	2325	2469
275	2200	2344	2488
277	2219	2363	2507
279	2238	2382	2526
281	2257	2401	2545
283	2276	2420	2564
285	2295	2439	2583
287	2314	2458	2602
289	2333	2477	2621
291	2352	2496	2640
293	2371	2515	2659
295	2390	2534	2678
297	2409	2553	2697
299	2428	2572	2716
301	2447	2591	2735
303	2466	2610	2754
305	2485	2629	2773
307	2504	2648	2792
309	2523	2667	2811
311	2542	2686	2830
313	2561	2705	2849
315	2580	2724	2868
317	2599	2743	2887
319	2618	2762	2906
321	2637	2781	2925
323	2656	2800	2944
325	2675	2819	2963
327	2694	2838	2982
329	2713	2857	3001
331	2732	2876	3020
333	2751	2895	3039
335	2770	2914	3058
337	2789	2933	3077
339	2808	2952	3096
341	2827	2971	3115
343	2846	2990	3134
345	2865	3009	3153
347	2884	3028	3172
349	2903	3047	3191
351	2922	3066	3210
353	2941	3085	3229
355	2960	3104	3248
357	2979	3123	3267
359	2998	3142	3286
361	3017	3161	3305
363	3036	3180	3324
365	3055	3199	3343
367	3074	3218	3362
369	3093	3237	3381
371	3112	3256	3400
373	3131	3275	3419
375	3150	3294	3438
377	3169	3313	3457
379	3188	3332	3476
381	3207	3351	3495
383	3226	3370	3514
385	3245	3389	3533
387	3264	3408	3552
389	3283	3427	3571
391	3302	3446	3590
393	3321	3465	3609
395	3340	3484	3628
397	3359	3503	3647
399	3378	3522	3666
401	3397	3541	3685
403	3416	3560	3704
405	3435	3579	3723
407	3454	3598	3742
409	3473	3617	3761
411	3492	3636	3780
413	3511	3655	3799
415	3530	3674	3818
417	3549	3693	3837
419	3568	3712	3856
421	3587	3731	3875
423	3606	3750	3894
425	3625	3769	3913
427	3644	3788	3932
429	3663	3807	3951
431	3682	3826	3970
433	3701	3845	3989
435	372		

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

88	256	342	348	824
89	257	343	349	825
90	258	344	350	826
91	259	345	351	827
92	260	346	352	828
93	261	347	353	829
94	262	348	354	830
95	263	349	355	831
96	264	350	356	832

OUTSIDE SURFACE

EAST WALL

SOLID ELEMENTS

8217	8226	8231	8239
8218	8227	8232	8240
8219	8228	8233	8241
8220	8229	8234	8242
8221	8230	8235	8243
8222	8231	8236	8244
8223	8232	8237	8245

MEMBRANE ELEMENTS

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

INSIDE SURFACE

8217	8226	8231	8239
8218	8227	8232	8240
8219	8228	8233	8241
8220	8229	8234	8242
8221	8230	8235	8243
8222	8231	8236	8244
8223	8232	8237	8245

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
127	252	318	366	746

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
127	252	318	366	746

OUTSIDE SURFACE

SOUTH INNER WALL

SOLID ELEMENTS

8277	8278	8279	8280
8278	8279	8280	8281
8279	8280	8281	8282
8280	8281	8282	8283
8281	8282	8283	8284
8282	8283	8284	8285
8283	8284	8285	8286

MEMBRANE ELEMENTS

182	188	205	212
184	200	208	214
185	201	207	215
186	202	209	216
187	203	210	217
188	204	211	218

INSIDE SURFACE

8182	8188	8205	8212
8184	8200	8208	8214
8185	8201	8207	8215
8186	8202	8209	8216
8187	8203	8210	8217
8188	8204	8211	8218

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
179	295	370	376	847

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
179	295	370	376	847

OUTSIDE SURFACE

WEST INNER WALL

SOLID ELEMENTS

8189	8192	8198	8199
8190	8193	8199	8200
8191	8194	8200	8201
8192	8195	8201	8202
8193	8196	8202	8203
8194	8197	8203	8204
8195	8198	8204	8205

MEMBRANE ELEMENTS

185	192	198	199
186	193	199	200
187	194	200	201
188	195	201	202
189	196	202	203
190	197	203	204
191	198	204	205

INSIDE SURFACE

8189	8192	8198	8199
8190	8193	8199	8200
8191	8194	8200	8201
8192	8195	8201	8202
8193	8196	8202	8203
8194	8197	8203	8204
8195	8198	8204	8205

OUTSIDE SURFACE

NODES

185	192	198	199	847
186	193	199	200	848
187	194	200	201	849
188	195	201	202	850
189	196	202	203	851
190	197	203	204	852
191	198	204	205	853
192	199	205	206	854
193	200	206	207	855

INSIDE SURFACE

185	192	198	199	847
186	193	199	200	848
187	194	200	201	849
188	195	201	202	850
189	196	202	203	851
190	197	203	204	852
191	198	204	205	853
192	199	205	206	854
193	200	206	207	855

OUTSIDE SURFACE

NUS 01-015
MARCH 25, 1983
ENCLOSURE

FIGURE 12

FOUNDATION NORTH WALL, EAST WALL AND INNER WALLS

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

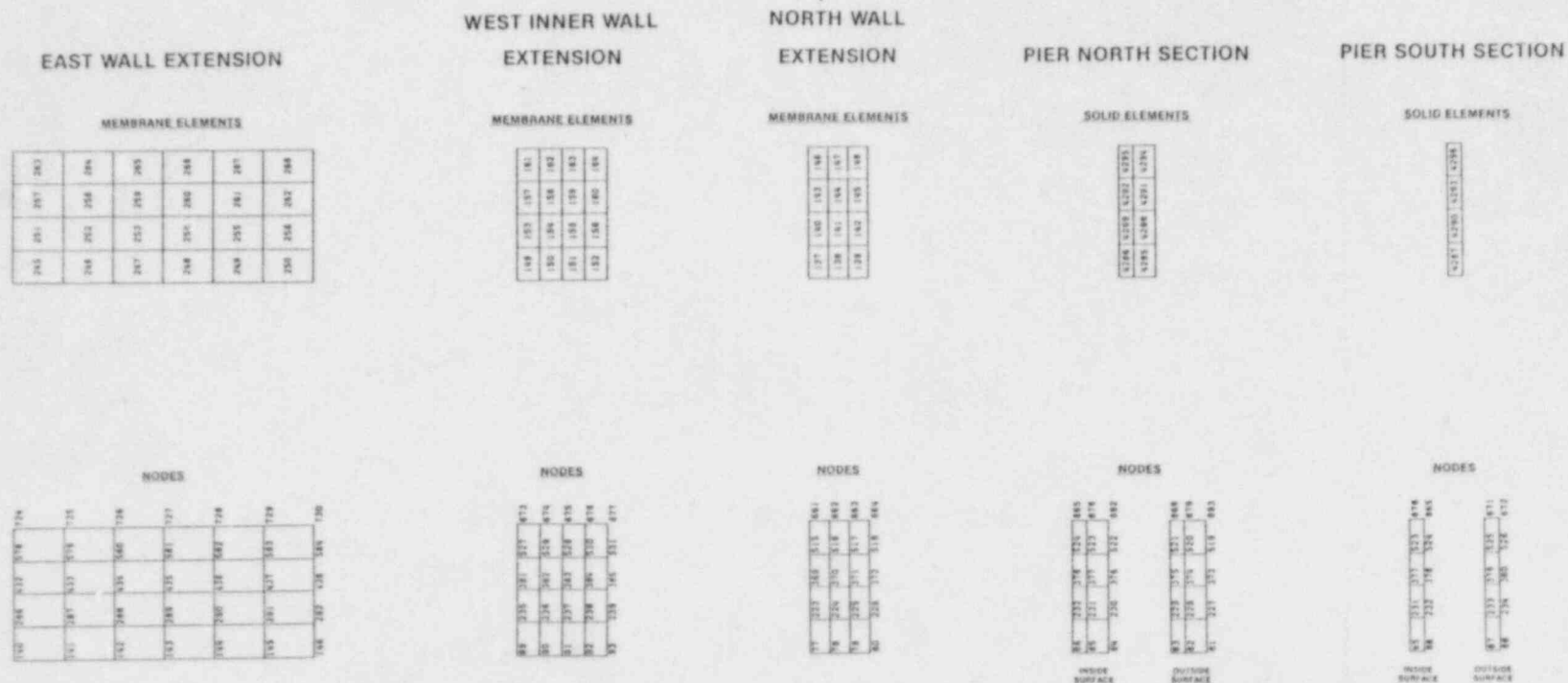


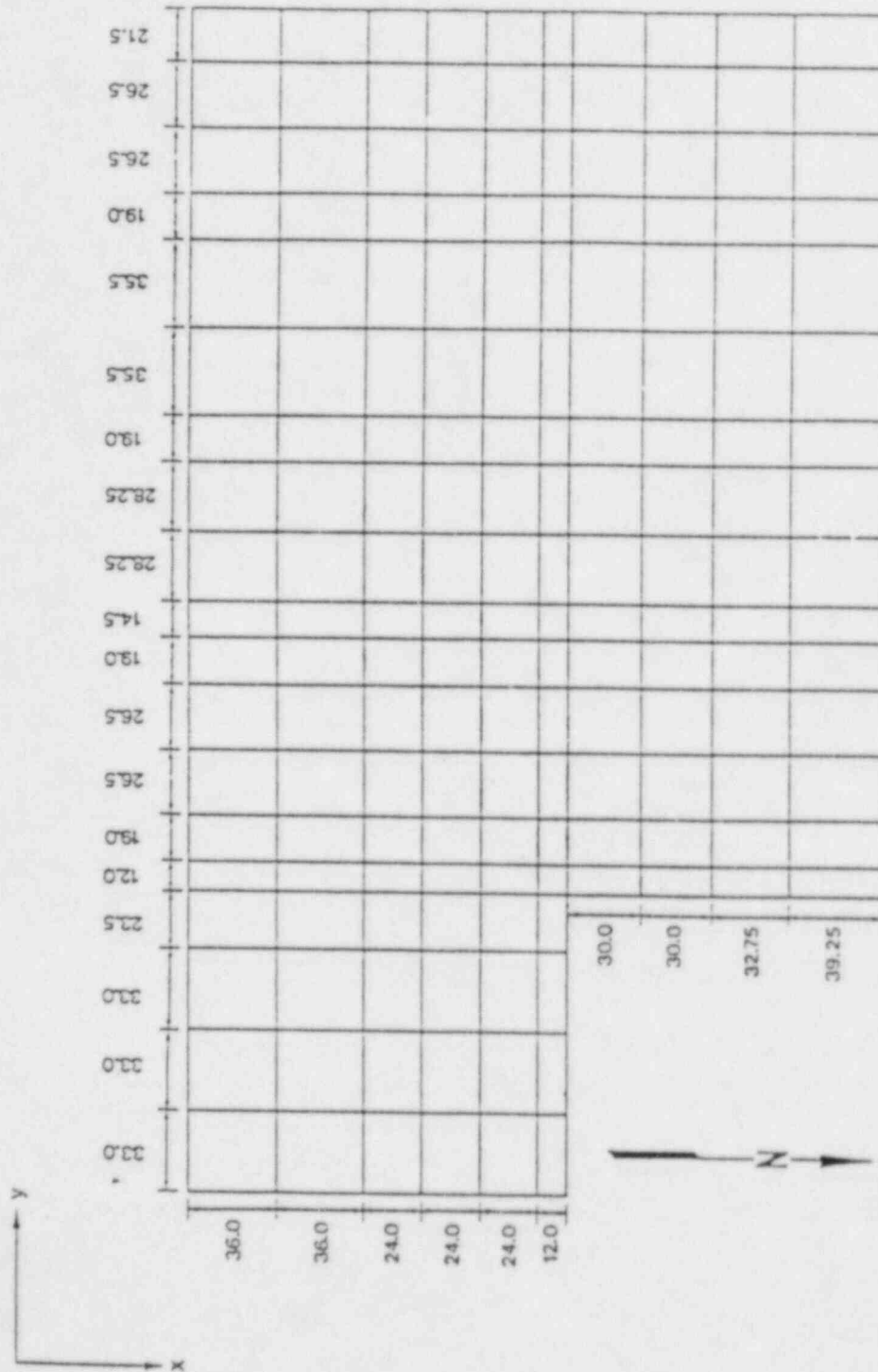
FIGURE 13

FOUNDATION PIER AND MISCELLANEOUS WALLS

NUS-01-015
MARCH 25, 1983
ENCLOSURE

SDT
Structural
Dynamics
Technology, Inc.

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

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_a (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_0 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_p (pipe break reactions), P_a (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_0 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 E ₁ - OBE	0.06	0.06	0.57	0.92			0.09	0.09	1.99	3.23	1.99	3.23
6 E ₂ - OBE	0.06	0.06	0.57	0.92			-0.09	0.09	-1.99	-3.23	1.99	3.23
7 E ₃ - OBE	0.06	0.06	0.57	0.92			-0.09	-0.09	-1.99	-3.23	-1.99	-3.23
8 E ₄ - 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 (MFPSTAI-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 (MFPSTAI-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 (MFPSTAI-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 (MFPSTAI-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 (MFPSTAI-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 (MFPSTAI-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 (MFPSTAI-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 ₀ +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