APPENDIX F

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REPORT TO AEC REGULATORY STAFF

ADEQUACY OF THE STRUCTURAL CRITERIA FOR THE MAINE YANKEE ATOMIC POWER STATION

MAINE YANKEE ATOMIC POWER COMPANY

(AEC DOCKET NO. 50-309)

by

N. M. Newmark and W. J. Hall

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OF THE STRUCTURAL CRITERIA FOR THE MAINE YANKEE ATOMIC POWER STATION

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INTRODUCTION

This report is concerned with the adequacy of the [redacted]s for the Maine Yankee Atomic Power Station for which application for a construction permit has been made to the U. S. Atomic Energy Commission by the Maine Yankee Atomic Power Company. The facility is located on the west shore of Back River, 3.9 miles south of Wiscasset, Maine.

Specifically this report is concerned with the design criteria that determine the ability of the containment system and [redacted] as well as Class II structures and equipment, to withstand an Operating Basis Earthquake of 0.05g maximum transient horizontal ground acceleration simultaneously with other applicable loads forming the basis of design. The facility is also to be designed to withstand a Design Basis Earthquake of 0.10g maximum horizontal ground acceleration to the extent of insuring safe shutdown and containment.

This report is based on information and criteria set forth in the Preliminary Safety Analysis Report (PSAR) and the amendments thereto as listed at the end of this report. Also, we have participated in discussions with the applicant, and the AEC Regulatory Staff concerning the design of this unit.

DESCRIPTION OF FACILITY

The Maine Yankee Atomic Power Station is described in the PSAR as consisting of a pressurized-water type reactor employing three closed cooling loops connected in parallel to the reactor vessel. Each reactor coolant loop is connected to a steam generator. The nuclear steam supply system will be furnished by Combustion Engineering, Inc., and the turbine generator is to be supplied by the Westinghouse Electric Corporation. The plant is to be designed for a power level of about 2440 MWt (827 MWe).

The containment structure is a reinforced concrete right cylindrical structure with a hemispherical dome and an essentially flat base. The cylinder has an internal diameter of 135 ft.-0 in. with a 4 ft.-6 in. minimum wall thickness. The springline of the dome is 102 ft. above the inside surface of the foundation mat. The dome will have an inside radius of 67 ft.-6 in. and a thickness of 2 ft.-6 in. The designers propose to make the containment wall construction for the Maine Yankee plant adequate to accommodate operating, incident and earthquake loadings through the use of vertical and hoop reinforcement with appropriate shear reinforcement, but without using diagonal reinforcing steel.

The inside surface of the concrete containment vessel is lined with a steel plate and below grade portions of the liner are treated with corrosion protective coating on the outside.

The steel reinforcing used for the reactor containment structure will conform to ASTM Specifications A15 or A408. With minor exceptions the liner plate will conform to Specification ASTM-A516, Grade 60.

the area of the site where the facility buildings are to be located, overburden consists of medium soft to medium stiff silty clays with occasional sandy lenses and pebbly sands. This overburden varies from 15 to 20 ft. in thickness and overlies bedrock of Silurian-Devonian age. The bedrock is sound and will provide good foundation support for structures and equipment. The major structures are to be founded directly on the hard, crystalline bedrock, and minor structures are to be founded either on rock or compacted granular fill above the rock. The seismic survey at the site shows the average compressional wave velocity to be about 13,000 to 15,000 fps. No major faulting has been reported in the area.

SOURCES OF STRESSES IN CONTAINMENT STRUCTURE AND TYPE I COMPONENTS

The containment vessel is to be designed for the following conditions: deadload, including the effects of hydrostatic pressure, ice and snow loads; design accident pressure of 55 psig; thermal loads corresponding to an internal design temperature of 280°F; an air test pressure 115 percent of the design pressure; and interior pressure below the outside atmosphere (it is noted in the PSAR that the containment will withstand a negative pressure approximately 7.5 psi below the outside atmosphere); a wind load corresponding to 35 psf on rectangular buildings 30 ft. above ground; and tornado winds of 300 mph tangential velocity and 60 mph forward velocity concurrent with a negative pressure drop of 3 psi, with associated missiles.

The containment liner is shielded from impact from such objects of missiles which could conceivably have enough energy to penetrate it. Most

pressurized equipment and pipelines are contained within the loop compartments and are surrounded by reinforced concrete walls. A 2 ft. thick reinforced concrete shield is placed over the control rod drive mechanisms to provide such protection.

The seismic design is to be made for an Operating Basis Earthquake based upon a 0.05g maximum horizontal ground acceleration and a Design Basis Earthquake based on a maximum horizontal ground acceleration of 0.10g.

[redacted]

COMMENTS ON ADEQUACY OF DESIGN

Foundations

The major structures are to be founded directly on hard, crystalline bedrock and minor structures are to be founded either on this same rock base, or compacted granular fill above the rock. On the basis of the information presented in the PSAR and in Amendment No. 4, the foundation conditions appear acceptable to us.

Seismic Design Criteria

We agree with the approach involving a basic design for an Operating Basis Earthquake of 0.05g maximum horizontal ground acceleration, with the provision that safe shutdown can be achieved for a Design Basis Earthquake of 0.10g. These earthquake design values are in agreement with those given by the U. S. Coast and Geodetic Survey (Reference 4).

The response spectra for the Operating Basis Earthquake and Design Basis Earthquake to be employed in the design are presented as Figs. 2.5-6 and 2.5-7 in the PSAR. These spectra are scaled after spectra presented in earlier publications by Dr. G. W. Housner and we are in agreement with the spectra to be employed.

The earthquake analyses will include the effects of vertical ground acceleration, which is to be taken as 2/3 of the horizontal ground acceleration. We are in agreement with this criterion.

It is indicated in answer to Question 5.13 of Amendment No. 10 that the earthquake loadings will be added linearly and directly as appropriate to the deadload, liveload, operating and accident loadings. We are in agreement with this criterion.

The method of dynamic analysis to be employed for Class I structures and components is described generally on page 2.5-6 of the PSAR and for the containment structure in more detail in the answer to Question 5.4 of Amendment 10. The applicant advises us that his study showed that the rocking and translational response was not significant. The general procedure described for the containment structure design appears acceptable to us.

The damping values to be employed in the design are listed in Table 2.5-1 and we are in agreement with the values given there.

The loading expressions given in Table 5.1.2-1, with amended load factors as noted in the answer to Question 5.22, appear acceptable to us for use in the design of the containment structure.

The allowable stresses to be used with the Design Basis Earthquake loading and under conditions of safe shutdown and containment, are stated at various places in the PSAR and amendments as being limited to 90 percent of the yield stress. The criterion is acceptable to us.

With regard to the liner, it is noted in the answer to Question 5.8 that the liner participation is not relied upon to provide assistance to lateral shear arising from the earthquake. Moreover, in the answer to Question 5.6 of Amendment 9, it is noted that the liner will not be stressed above yield under any of the loading conditions. These criteria are acceptable to us. However, we find no discussion of the buckling criteria for design of the liner except under operating conditions as described on page 5.1-10 of the PSAR. We have been advised by the applicant that the general statement concerning the design of the liner as given in the answer to Question 5.6 includes consideration of the possibility of buckling at all design stages and, in view of this assurance, we are in agreement with the general design procedure.

The matter of carrying the lateral shear in the structure arising from earthquake and accident loadings, through the use of orthogonally spaced reinforcing steel (i.e., without diagonal steel), has been reviewed in detail in meetings with the applicant and individually in studies by ourselves. In the present case, with the low seismic risk, and on the basis of information currently available, it is our belief that this approach to the design for this particular plant is acceptable. Additional studies on this matter are underway at various places in the United States.

With regard to the major penetrations, the general design approach with regard to reinforcement, etc., is described on page 5.1-5 of the PSAR. The applicant advises that the method of analysis does account for equilibrium and compatibility of deformation in the vicinity of the penetrations. On this basis we believe the general design procedure is acceptable.

The design of Class II structures is discussed in the answer to Question A5.15 of Amendment 10. It is our recommendation that if the design of Class II structures is made to the Uniform Building Code that a factor of 0.31 be applied to the coefficients for Seismic Zone 3, which corresponds to about 1.25 times those applicable to Seismic Zone 1. If UBC's approach is not employed, the method used should provide an equivalent margin of safety.

Piping, Reactor Internals and Vessels

[redacted] Although the general criteria put forth there appear generally acceptable, it would be our recommendation that there be a restriction of the maximum allowable deformation for the design of the various classes of piping for the design criteria involving safe shutdown. The applicant advises us that the strain limits will not exceed 20% of the uniform strain corresponding to the maximum stress for piping, reactor internals and vessels. This criterion is acceptable to us.

The design criteria for reactor internals as described in the answer to Question 3.11 of Amendment 9 appear generally acceptable since it appears

that there is about a 50 percent margin of safety for deformations that would lead to failure.

[redacted] Although the method involving the use of the [redacted] to the appropriate damping factor is generally acceptable, as noted in item 4 in the listing on page 2.5-6 of the PSAR, it would be our recommendation that this should be demonstrated for certain of the critical piping systems by comparison with that of a rigorous dynamic analysis. The applicant has advised us that such comparisons have been made on critical systems for another similar nuclear facility. The applicant states that the comparisons confirmed the adequacy of the approach that is to be used in the Maine Yankee design and these comparisons are available for review.

With regard to the design criteria for instrumentation, controls, batteries and battery supports which are critical for safe shutdown and containment, little detailed information is noted in the PSAR or amendments concerning the seismic design. We recommended that careful attention be given to this aspect of the plant during the design phase.

The general design criteria provided for the crane as described in Amendment 6 are acceptable to us.

CONCLUSION COMMENT

On the basis of information presented in the PSAR and amendments and in keeping with the design goal of providing serviceable structures and components with a reserve of strength and ductility, we believe that the design outline for the containment and other Class I structures and equipment, and Class II structures and components can provide an adequate margin of safety for seismic resistance. However, in arriving at this conclusion we have made comments in the report concerning the design of the penetrations, piping, Class II structures, and instrumentation and batteries.

N. M. Newmark

REFERENCES

1. "Preliminary Safety Analysis Report -- Volumes I and II," Maine Yankee Power Station, Maine Yankee Atomic Power Company, 1967.

2. "Preliminary Safety Analysis Report -- Amendments 1, 2, 3, 4, 5, 6, 7, 9, 10," Maine Yankee Atomic Power Station, Maine Yankee Atomic Power Company, 1968.

3. "Thermal Shock Analysis on Reactor Vessels Due to Emergency Core Cooling System Operation," by W. H. Tuppeny, Jr., W. F. Siddall, L. C. Hsu, Combustion Engineering, Inc., Report A-68-9-1, March 15, 1968.

4. "Report on the Seismicity of the Maine Yankee Power Station Site," U. S. Coast and Geodetic Survey, Rockville, Maryland, June 7, 1968.

B.2 STONE & WEBSTER EQUIPMENT

B.2.1 Analyses and Design Criteria of Seismic Class I and Seismic Class II Piping

B.2.1.1 General analytical procedure

Analyses of Seismic Class I and some seismic Class II piping systems are performed by the modal analysis response spectra method. Each piping system is idealized mathematically as an elastically coupled dynamic structural model in three-dimensional space. Inertial characteristics of the piping system are simulated by discrete masses of piping components, including all eccentric masses, such as valves, valve operators, etc., lumped at selected nodes. The stiffness matrix of the piping system is calculated by Stone & Webster computer program PIPESTRESS, based on formulations presented in Reference 1. Modal seismic responses at each node of the piping system, due to amplified response spectra excitation applied at its support points, are calculated by Stone & Webster computer program SHØCK2. The modal analysis technique used in SHØCK2 computer program computes the peak inertial responses for all significant participating modes, which are then combined by the method of square root of sum of square (SRSS) at each mass node. Normal Mode, linear elastic, and small displacement theory are incorporated in SHØCK2 and PIPESTRESS computer programs.

Structural response spectra, consisting of peak responses of a family of seismic loadings for the piping systems, are amplified response spectra, obtained for discrete locations in the structure where the piping system is supported. The development of the amplified response spectra is covered in Section B.1.5 entitled, "Amplification of Ground Response Spectra for Seismic Design of Equipment and Piping." Damping factors used for vital piping and components are 0.5 percent for Operating Basis Earthquake (OBE) and one percent for Design Basis Earthquake (DBE).

The uncertainties in the calculated values of fundamental structural frequencies due to reasonable variations in subgrade and structural material properites are taken into account. The peak resonant period value(s) in the amplified response spectrum developed as described in Section B.1.5.2 are subject to variations of ±25 percent for this plant and site.

Accordingly, piping systems designed using those amplified response spectra having modal periods within ±25 percent of the peak resonant period(s) are assigned the peak response value(s). Beyond this range, the amplified response spectra are utilized exactly as shown.

Where a piping system is subjected to more than one amplified response spectrum as when support points are located in different parts of the structure, the amplified response spectrum which is

closest to and higher in elevation than the center of mass of the piping system is applied to this system.

Relative seismic structural displacements between the piping supports and anchor points, that is, between floor penetrations and equipment supports at different elevations within a building and between the buildings, are used as inputs of equivalent static boundary displacement conditions in the computations. Relative seismic displacements between the pipe support points at different buildings are always considered to be out of phase in order to obtain the most conservative piping responses.

Internal forces/moments and displacements in all Seismic Class I and some Seismic Class II piping systems, due to relative seismic displacements between piping supports, are computed at each mass node by the PIPESTRESS computer program. Seismic responses due to anchor displacements are due to all three superimposed with moments or displacements due to inertial effects to become the total seismic response in each global coordinate direction of the piping system. The total seismic responses of the piping system are then combined with responses from deadweight, pressure, thermal, and all other mechanical loads to complete stress analysis of the Seismic Class I and some Seismic Class II piping. Maximum stresses are computed by Stone & Webster computer program MØMENTCØMBINER, based on formulations specified in ANSI-B31.1 (Reference 1). Wherever the analysis indicates that a stress is in excess of the allowable stress, the system is redesigned and then recalculated to verify that the stresses satisfy the criteria. The design loading combinations and stress limits for Seismic Class I piping systems are defined in Table B.2-1. The following are the basic steps and equations used in the analytical procedure:

B.2.1.2 Flexibility/stiffness influence coefficient matrix

The flexibility influence coefficient matrix [q], as defined here, gives the deflections in the structure due to unit loads at each static degree of freedom. This matrix is related to the stiffness matrix by the following:

$$[\sigma][K] = [I] \qquad (1)$$

Where [k] is the square stiffness matrix of all mass nodes of the piping system obtained by combining the stiffness of individual piping elements, and [I] is a unit matrix. The flexibility matrix of each beam element includes the coupled axial, bending, shear, and torsional flexibilities. The size of the stiffness matrix for each piping structural element is 12 x 12, since six forces/moments and six deflections/rotations are considered by the piping flexibility program in each of the two nodes of an element.

The unrestrained general stiffness matrix [k] of a dynamic structural model is condensed to a reduced stiffness matrix [k] to exclude rigid constraints and to condense rotational stiffness coordinates as dependent coordinates of linear displacement stiffness matrix by formulations presented in Reference 3.

B.2.1.3 Normal mode frequencies and mode shapes

After development of stiffness and mass matrices, natural frequencies and their associated mode shapes are determined by solution of the following equations:

$$[[k] - w_i{}^2[m]]\ [Q_i] = 0 \tag{2}$$

Where [k] = square reduced stiffness matrix

[m] = mass matrix

w_i = natural frequencies of system

$[Q_i]$ = mode shape vector associated with the i-th mode

Through the use of S&W computer program SHØCK2, the w values and [Q] matrix for each of the n modes are computed (i = 1, 2...n, n = degrees of freedom of piping system dynamic structural model).

B.2.1.4 Modal response quantities

For the acceleration response spectrum method of analysis, the maximum displacements in global coordinates can be shown as:

$$\{y_{max}\}_n = [Q]\ \{q_{max}\} \tag{3}$$

where

$$\{q_{max}\} = [M_n]^{-1}\ [Q]^T\ [m]\ \{D\}\ [W_n^2\ ]^{-1}\ \{S_a\} \tag{4}$$

and

$[M_n\ ]$ = generalized mass = $[Q]^T [m] [Q]$

[Q] = square matrix containing eigenvector vector for each mode

$\{S_a\}$ = spectral acceleration values

{D} = direction vector

Equation (4) may be written as:

$$\{y_{max}\} = [Q] \{\Gamma\}_n [W_n^2]^{-1} \{S_a\} \tag{5}$$

defining the quantity of $[M_n]^{-1}$ $[Q]^T [m]$ $\{D\}$ in Eq. (4) as the participation factor $\{r\}_n$ of the system.

Let: d = number of modes considered
Inerteria forces for each mass point may then be calculated from Eq. (6).

$$\{F_{max}\}_n = [m]_d [w_n^2]_d \{y_{max}\}_n \tag{6}$$

B.2.1.5 Piping Stress Limits

Seismic Class I piping systems are analyzed using Stone & Webster computer program MØMENTCØMBINER, based on formulations specified in Reference 1. The seismic stresses are governed by the following allowables:

Pressure stress (S_{LP}) + dead load stress (S_{DL}) $\leq S_h$ (7)

Pressure stress + dead load stress + Operating Basis Earthquake stress/ $\leq$ 1.2 S_h (8)

Pressure stress + dead load stress + Design Basis Earthquake stress/ $\leq$ 1.8 S_h (9)

Thermal stress $\leq (1.25\, S_c + 0.25\, S_h)\, f + (S_h - /S_{LP} + S_{DL}/)\, f$ (10)

where:

S_h = allowable stress of material at hot temperature, Tables A-1 and A-2 of ANSI-B31.

S_c = allowable stress of material at cold temperature, Tables A-1 and A-2 of ANSI-B31.1.

f = stress range reduction factor for cyclic condition, Table 102.3.2(c), ANSI-B31.1.

Dynamic force loadings, resulting from sudden closure of isolating valve system or turbine throttle valve on the piping system (for example, transient loading on steamline due to turbine trip) are to be included as occasional mechanical loads in piping analysis. Constraints or hydraulic snubbers will be

used as required to control excessive displacements or moments due to these transients loadings.

Field location of seismic supports and constraints for Seismic Class I piping system, including snubbers and dampers will be installed in accordance with seismically designed piping shown on approved construction drawings. Inspections will be conducted at the jobsite to verify that these seismic restraints are fabricated and located in accordance with approved documentations and drawings.

B.2.1.6 Buried seismic Class I piping

Responses of buried Seismic Class I piping to differential ground motion, due to particle motions caused by seismic wave propagations, are calculated by a method developed by N. M. Newmark in Reference 4.

Reactions and bending moments of buried seismic Class I piping, due to differential motion at structural penetrations, are calculated by considering buried pipe as a semi-infinite beam on elastic soil foundation with full restraint at structural penetrations. Using the maximum expected seismic displacements at structural penetration and the modulus of soil foundation, the stress thus calculated is superimposed with axial tension-compression stress meet the requirements defined in ANSI-B31.1 Code for Pressure Piping. If these stresses are found to be excessive, a seismic design of the underground piping within concrete or steel conduits (unattached to structure) combined with or without expansion joints is incorporated in the system.

B.2.1.7 Seismically induced effects of seismic Class II piping on seismic Class I piping

Seismic Class II piping systems are designed to be isolated from the seismic Class I piping systems by either a constraint/barrier, or remotely removed from seismic Class I piping systems -- if failure of seismic Class II piping can propagate failure of seismic Class I piping systems. If it is not feasible or practical to isolate the seismic Class I piping system from the seismic Class II piping system to prevent any adversely induced seismic effects, then adjacent seismic Class II piping will be seismically designed according to the criteria described in this section, applicable for the seismic Class I piping system.

B.2.1.8 Pressure relief devices

The design criteria for all safety/relief valves are in accordance with the rules in paragraph 122.6 of ANSI-B.31.1. Maximum stresses on each valve nozzle is calculated based upon its full discharge loads (i.e., thrust and bending) and internal design pressure. Maximum stress intensity in the run pipe or header under full discharge loads (thrust, bending and torsion) and

internal design pressure is also computed by Stone & Webster "PITRUST" computer program. "PITRUST" computer program is based upon Bijlaard's method of calculating local stresses and experimental results developed in Reference 5.

In the event where the safety/relief valves are mounted on a common header and a full discharging occurs concurrently, the additional stresses induced in the header will be combined together with the computed local and primary membrane stresses to obtain the maximum stress intensity.

B.2.1.1.9 Simplified seismic analysis of small size seismic Class I piping

Piping systems designed to ANSI-B31.1 pressure piping code with diameters of 6 in. NPS and below, are subjected to analyses using acceleration values from the amplified response spectra. The length of span between supports is selected such that the fundamental frequency is removed from the resonant band of the amplified response spectra as specified in Section B.1.5.

The basic approach to the design of small-size seismic Class I piping is to make the system relatively rigid whenever engineering design criteria dictate.

The spacing between pipe constraints is determined so that fundamental frequency fp of piping section will always be greater than 1.5 f where f = peak resonant frequency of structure, as determined from applicable amplified response spectrum. Inertial loads ("g" factor), from OBE and DBE, are conservatively set at one-half peak acceleration of OBE and DBE respectively, using this predetermined span. The deadweight stresses are multiplied by the applicable "g" factor in X, Y, and Z directions as specified, which is set at one-half peak acceleration or 0.5 G minimum; this produces seismic stress induced by OBE and DBE respectively, in all three directions. The seismic stress calculation is based upon equations in paragraph 119.6.4 of Reference 1. The "g" factor for the X, Y, and Z directions is specified explicitly for each problem. Pressure stress is calculated as $Pd^2/(do^2-d^2)$, as per paragraph 102.3.2(d) of Reference 1. Thermal stresses based on paragraph 102.3.2 of Reference 1 of the piping sections can be calculated under applicable boundary conditions.

The approach is to perform stress calculations for small-size pipes in a sectionalized "between supports" manner without using computer analyses. This is justifiable because a rigid system with sufficient pipe supports represents many one-dimensional, straight-beam problems, wherein the coupling effects of the three-dimensional piping systems are eliminated by placing constraints near all elbows, tees, and concentrated masses, such as valves, etc. These calculations of maximum combined stresses provide sufficient and conservative data to satisfy the

Question 3.23

Submit a list of computer programs that will be used in dynamic and static analyses to determine mechanical loads and deformations of Seismic Category I structures, components and equipment and the analysis to determine stresses in ASME Code Class 1 components. In each program, include a brief description of the theoretical basis, the assumptions and references used, and the extent of its application.

Response

The following computer programs will be used in dynamic and stress analyses of Stone and Webster supplied seismic piping systems:

Class I

1. "PSTRESS" - Piping flexibility, thermal stress, and dead load stress program

2. "SHØCK 2" - Piping dynamic analysis program

3. "PITRUST" - Trunnion-supported piping stress analysis program

4. "PILUG" - Lug-supported piping stress analysis program

5. "SAVAL" - Piping junction with safety/relief valve nozzle stress analysis program

All of the above computer programs are operational in the IBM 370/165 computer of the Stone & Webster Computer Division.

Description of each program follows.

PSTRESS

"PSTRESS" is a program for flexibility, thermal stress, and deadload stress analysis in accordance with ANSI-31.1.0 Power Pipe Code. This program accepts the complete geometric and physical description of the piping system, provides a complete error-check and coordinate check for the inputs; and computes responses for a variety of static loading cases including deadweight, thermal expansion, applied forces, applied displacements, uniform weight, and concentrated loads. The computed responses include internal forces and moments, support and equipment reactions, displacements, and stress levels.

This program applies the algorithm described in Reference 1 to calculate the flexibility matrices. The deflections at branch points and reactions of each branch, all referenced to the global origin, are calculated using the algorithm described in Reference 2. For each point within each branch, the program then computes deflection, combined stresses, and restraining reactions.

Program "PSTRESS" has been verified by comparing its solutions of a test problem (Figure Response 3.23-1), to the results obtained of the same problem by an independently written piping flexibility program, "MEL-40", in the public domain. The "MEL-40" piping flexibility program was developed by Mare Island Naval Shipyard and is presently used by the U.S. Navy Department and engineering companies. A comparison of results is tabulated in Table Response 3.23-1, 3.23-2, 3.23-3, and 3.23-4.

References

1. Supplement to The Design of Piping Systems - Second Edition, W. M. Kellog Company (John Wiley & Sons, 1965).

2. "Piping Flexibility and Analysis by Stiffness Matrix", L. H. Chen, Journal of Applied Mechanics; Paper No. 59-APM-24, 1959.

SHØCK2

"SHØCK 2" is a program for dynamic responses of piping systems under seismic loading conditions. "SHØCK 2", using geometry and physical inputs from direct "PSTRESS" access, calculates the modal and combined internal forces and moments due to dynamic responses of the piping system as characterized by input amplified response spectra for points of support of the system. Amplified seismic structural displacement responses are accepted statically at terminal points, and the piping responses are combined with dynamic responses to produce overall seismic responses. "SHØCK 2" provides direct access to "PSTRESS" for static solution of displacement responses. This program uses the Flexibility Matrix from "PSTRESS" which is inverted to form a Stiffness Matrix. By static condensation, the number of coordinates is reduced to translational coordinates only, and the frequency and mode shapes calculated.

[redacted]

PITRUST

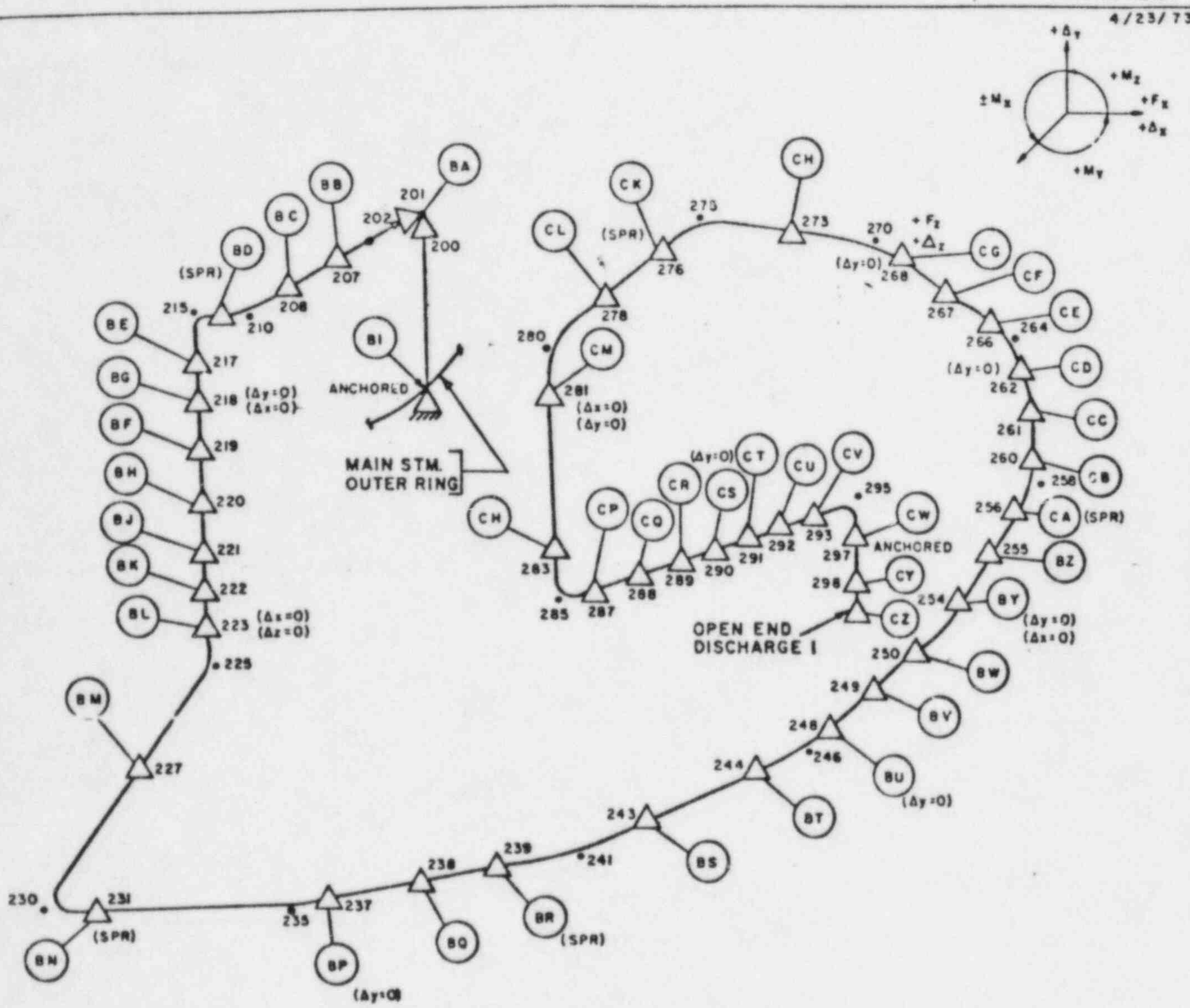
"PITRUST" is a program to calculate local stresses in the pipe caused by cylindrical welded attachments under external loadings. This program uses the Bijlaard method as published in Reference 1 to calculate local stresses in the pipe wall caused by cylindrical welded attachments under external loadings, including pressure, dead load, and combinations of maximum seismic reactions.

Program "PITRUST" has been verified by comparing its solution of a test problem to the solution of the same problem by an independently written piping local stress program, "CYLNOZ", in the public domain. The "CYLNOZ" piping local stress program was written by Franklin Institute (Philadelphia, Pa.), and is presently used by engineering companies. The test problem is of a 72.375" O.D. x .375" thick run pipe, reacting under an external loading condition of 1000 lbs. force (normal and shear) and 1000 in-lbs. bending and torsional moments transmitted by a 16" O.D. nozzle. A comparison of results is tabulated in Table Response 3.23-8 Program "PITRUST" has also been verified by comparing its solution of a test problem to the experimental results obtained in Reference 2. A comparison of these results is tabulated in Table Response 3.23-9.

References

1. "Local Stress in Spherical and Cylindrical Shells due to External Loading", Welding Research Council Bulletin, WRC-107, 1965.

2. "Experimental Elastic Stress Analysis of Cylinder to Cylinder Shell Models and Comparison with Theoretical Predictions", J. M. Corum and W. L. Greenstreet, First International Conference on Structural Mechanics in Reactor Technology (Berlin, Preprints Vol. 3, Part G, 1971).



NOTE:
PIPE SIZE - 10.75" O.D. x .365" THICKNESS
TEMPERATURE - 575°F
MATERIAL - CARBON STEEL ASTM-A106, GR. B

FIG. RESPONSE 3.23-1
TEST PROBLEM SCHEMATIC - "PSTRESS"
BEAVER VALLEY POWER STATION
FINAL SAFETY ANALYSIS REPORT

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TABLE RESPONSE 3.23-1

COMPARISON OF REACTIONS AND COMBINED STRESSES POINTS SELECTED AT RANDOM - THERMAL LOAD ONLY

		Internal Reactions (lb. and ft-lb)						
Point No.	Program	Fx	Fy	Fz	Mx	My	Mz	Combined Stress (PSI)
285	MEL-40	-535.	1614.	2092.	8587.	-11548.	3391.	14922.
	PSTRESS	-534.	1616.	2094.	8598.	-11591.	3386.	14957.
275	MEL-40	2261.	235.	2092.	-5013.	7996.	3281.	8765.
	PSTRESS	2289.	240.	2094.	-5048.	8123.	3306.	8897.
290	MEL-40	-535.	1614.	2092.	-2099.	-6625.	-3344.	3197.
	PSTRESS	-534.	1616.	2094.	-2896.	-6653.	-3357.	3208.
254	MEL-40	-3549.	833.	2092.	1626.	-21211.	-2787.	8609.
	PSTRESS	-3601.	843.	2094.	1765.	-21150.	-2845.	8593.
215	MEL-40	-227.	-203.	1234.	-834.	-11927.	-1320.	5059.
	PSTRESS	-234.	-260.	1327.	-832.	-12065.	-1494.	5161.

TABLE RESPONSE 3.23-2

COMPARISON OF DISPLACEMENTS

POINTS SELECTED AT RANDOM - THERMAL LOAD ONLY

Point No.	Program	Translation (inches) X	Y	Z	Rotation (radians) ØX	ØY	ØZ
285	MEL-40	.056	-0.255	1.55	-.00061	.00761	.00454
	PSTRESS	.0574	-0.2253	1.5529	-.000625	.00764	.004575
275	MEL-40	-.845	-.092	.739	-.00258	.01439	.00159
	PSTRESS	-.8489	-.0925	.7398	-.00258	.014439	.001603
290	MEL-40	-.199	-0.	.495	.0012	.00238	.00396
	PSTRESS	-.1995	0.	.4955	.00119	.002393	.00393
254	MEL-40	0.	0.	.916	-.00017	.00018	.00270
	PSTRESS	0.	0.	.8955	-.000194	.000156	.002701
218	MEL-40	-.029	0.	0.	.00065	-.00564	-.00035
	PSTRESS	-.0281	0.	0.	.000544	-.00546	-.00032

TABLE RESPONSE 3.23-3

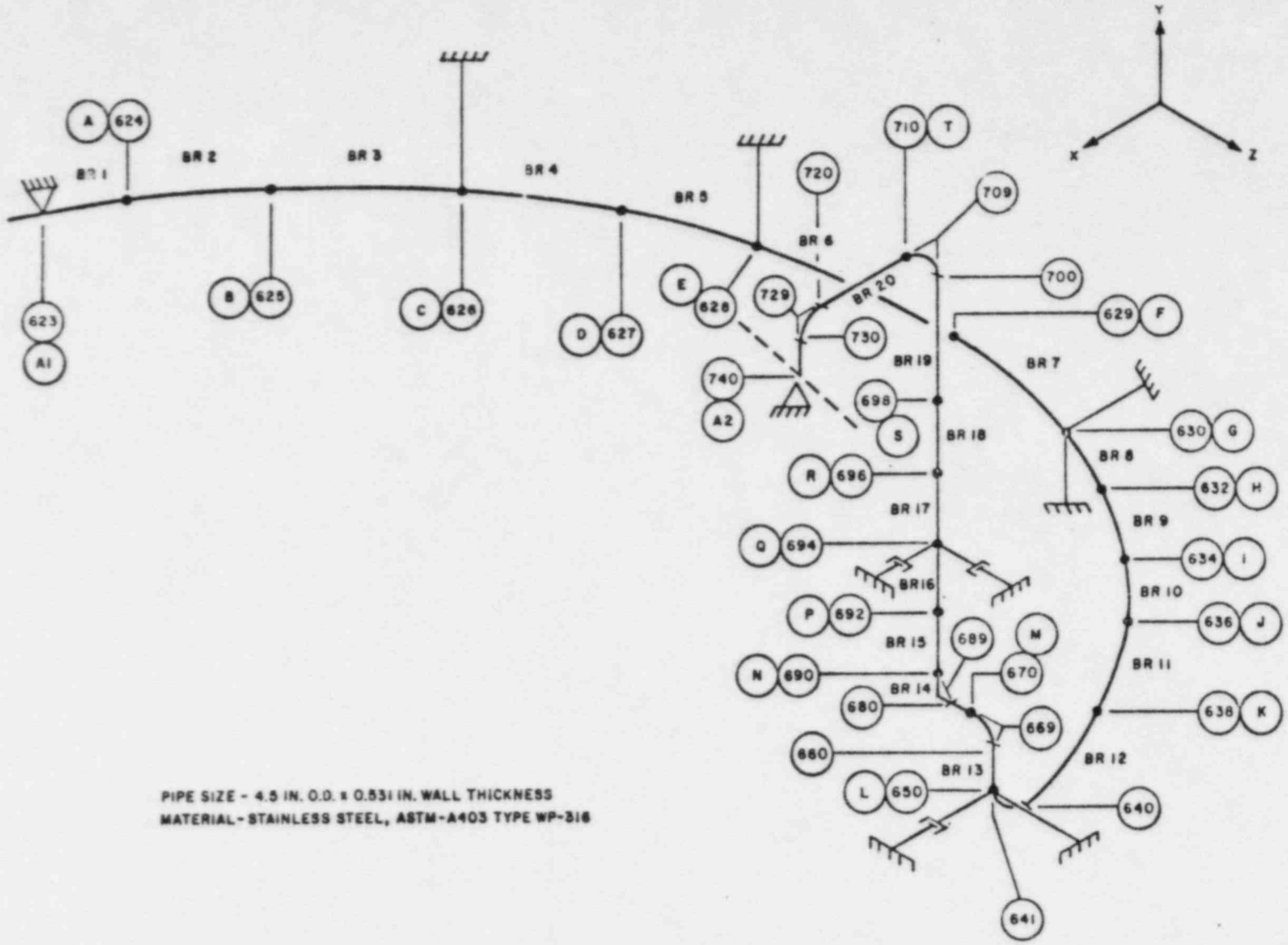
COMPARISON OF REACTIONS AND COMBINED STRESS
POINTS SELECTED AT RANDOM - DEAD LOAD ONLY

Point No.	Program	Fx	Fy	Fz	Mx	My	Mz	Combined Stress (PSI)
		Internal Reactions (lb and ft-lb)						
235	MEL-40	0.	-285.	-1.	-79.	3.	-17.	84.
	PSTRESS	1.	-286.	-2.	-84.	6.	-14.	88.
275	MEL-40	0.	132.	-1.	-11.	6.	-49.	52.
	PSTRESS	-2.	131.	-2.	-11.	-10.	-42.	46.
290	MEL-40	0.	439.	-1.	-3108.	4.	-525.	565.
	PSTRESS	1.	438.	-2.	-1308.	16.	-521.	565.
254	MEL-40	0.	200.	-1.	-167.	-13.	-19.	68.
	PSTRESS	2.	193.	-2.	-153.	4.	-21.	64.
218	MEL-40	0.	146.	-1.	51.	7.	-7.	21.
	PSTRESS	-1.	141.	-2.	40.	16.	-20.	19.

TABLE RESPONSE 3.23-4

COMPARISON OF REACTIONS AT SUPPORTS - DEAD LOAD ONLY
DEAD LOAD REACTIONS AT SUPPORTS (LB)

Node	PSTRESS Conc. Load	PSTRESS Uniform Load	MEL-40 Uniform Load
BD	-684	-577.	-576.
BG	-1142.	-1157.	-1161.
BN	-274.	-233.	-234.
BP	-169.	-175.	-176.
BR	-477.	-479.	-477.
BU	-517.	-518.	-523.
BY	-329.	-322.	-327.
CA	-401.	-407.	-421.
CD	-473.	-465.	-478.
CG	-419.	-421.	-417.
CK	-357.	-322.	-333.
CM	-610.	-581.	-580.
CS	-865.	-866.	-867.
CW	-632.	-643.	-603.



PIPE SIZE - 4.5 IN. O.D. x 0.531 IN. WALL THICKNESS
MATERIAL - STAINLESS STEEL, ASTM-A403 TYPE WP-316

FIG. RESPONSE 3.23-2
TEST PROBLEM SCHEMATIC-"SHOCK 2"
BEAVER VALLEY POWER STATION
FINAL SAFETY ANALYSIS REPORT

TABLE RESPONSE 3.23-5

COMPARISON OF NATURAL FREQUENCIES

Mode No.	SHOCK 2 Calculated Frequency (CPS)	ADLPIPE Calculated Frequency (CPS)
1	2.768	2.768
2	5.016	5.015
3	7.999	7.999
4	10.034	10.028
5	11.214	11.155
6	12.346	12.050
7	14.852	14.787

TABLE RESPONSE 3.23-6

COMPARISON OF MODAL INTERNAL FORCES AND MOMENTS POINTS SELECTED AT RANDOM [redacted]

Mode No.	Point No.		Forces in Pounds Fx	Fy	Fz	Moments in Foot-Pounds Mx	My	Mz
1	630	ADLPIPE	-22	6	-163	0	-76	94
		SHOCK 2	-22	6	-164	0	-76	98
	696	ADLPIPE	-2	-1	-25	-166	209	53
		SHOCK 2	-2	-2	-25	-171	211	53
2	638	ADLPIPE	-10	179	-48	-285	136	266
		SHOCK 2	-12	191	-53	-305	146	278
	710	ADLPIPE	15	325	20	28	-61	23
		SHOCK 2	17	345	21	28	-65	27
3	634	ADLPIPE	-2	-1	-2	-10	2	10
		SHOCK 2	-2	1	-2	-10	2	10
	698	ADLPIPE	0	-14	-3	22	-2	2
		SHOCK 2	0	-14	-3	22	-2	2

TABLE RESPONSE 3.23-6

COMPARISON OF MODAL INTERNAL FORCES AND MOMENTS
POINTS SELECTED AT RANDOM [redacted]

			Forces in Pounds			Moments in Foot-Pounds		
Mode No.	Point No.		Fx	Fy	Fz	Mx	My	Mz
1	630	ADLPIPE	-22	6	-163	0	-76	94
		SHOCK 2	-22	6	-164	0	-76	98
	696	ADLPIPE	-2	-1	-25	-166	209	53
		SHOCK 2	-2	-2	-25	-171	211	53
2	638	ADLPIPE	-10	179	-48	-285	136	266
		SHOCK 2	-12	191	-53	-305	146	278
	710	ADLPIPE	15	325	20	28	-61	23
		SHOCK 2	17	345	21	28	-65	27
3	634	ADLPIPE	-2	-1	-2	-10	2	10
		SHOCK 2	-2	1	-2	-10	2	10
	698	ADLPIPE	0	-14	-3	22	-2	2
		SHOCK 2	0	-14	-3	22	-2	2

TABLE RESPONSE 3.23-7

COMPARISON OF MODAL DEFLECTIONS
POINTS SELECTED AT RANDOM - X EARTHQUAKE

Mode No.	Point No.		Deflections in Inches X	Y	Z
1	630	ADLPIPE	.298	0	0
		SHOCK 2	.300	0	0
	696	ADLPIPE	.011	-.004	.012
		SHOCK 2	.011	-.004	.012
2	638	ADLPIPE	-.017	-.198	.046
		SHOCK 2	-.019	-.212	.049
	710	ADLPIPE	-.004	-.032	-.010
		SHOCK 2	-.004	-.033	-.010
3	634	ADLPIPE	0	-.002	.001
		SHOCK 2	0	-.002	.0007
	698	ADLPIPE	0	.003	-.001
		SHOCK 2	0	.0027	-.001

MAINE YANKEE FSAR

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FSAR

Maine Yankee FSAR

The ultimate load capacity of the [redacted] as modified by the safety provisions of ACI-318-63, Section 1504, is not less than that required to satisfy the following structural loading criteria:

1. (1.0 ± 0.05) D + 1.5P + 1.0 (T + TL)

2. (1.0 ± 0.05) D + 1.25P + 1.0 (T + $\overline{TL}$) + 1.25E

3. (1.0 ± 0.05) D + 1.0T + 1.0C

4. (1.0 ± 0.05) D + 1.0P + 1.0 (T + $\underline{TL}$) + 1.0E'

D - Dead load of structure, including effect of any hydrostatic pressure, ice and snow loads, when their effect increases the resultant stresses and equipment and operating loads.

P - Design incident pressure load.

T - Effect of temperature gradient through the concrete shell and mat.

TL - Load exerted by the exposed liner, based upon temperature associated with 1.5 times design incident pressure. The sidewall liner is insulated to a height of approximately 30 ft above the top of the mat.

$\overline{TL}$ - Load exerted by the exposed liner, based upon temperature associated with 1.25 times design incident pressure.

$\underline{TL}$ - Load exerted by the exposed liner, based upon temperature associated with 1.0 times design incident pressure.

E - Load due to acceleration from the design earthquake. OBE

E' - Load due to acceleration from the hypothetical earthquake. DBE [redacted] When the equivalent effect of a wind load on the structure of 35 psf on rectangular buildings 30 ft above ground exceeds the earthquake effects, the wind load will replace E or E'. It is assumed that maximum forces due to wind and those due to earthquakes do not act at the same time. This wind pressure agrees with that recommended by American National Standards Institute A58.1 for Minimum Design Loads in Buildings and Other Structures for round or elliptical structures in this area.

what about amplification & damping effects in earthquake

7

M.Y. PSAR A5.13-..
5/68
Maine Yankee

5.13 QUESTION

The method of seismic analysis for Class I structures and components is described generally on page 2.5-6 of the PSAR. [redacted] The explanation as to how the earthquake effects are to be combined with the stresses arising from other operating and accident loads is not precisely clear and we should like confirmation that the earthquake loadings will be added linearly and directly as appropriate to the dead load, live load, operating and accident loadings.

ANSWER

The earthquake loadings will be added linearly and directly as appropriate to the dead load, live load, operating and accident loadings.

7B

~~CONTAINMENT STRUCTURE LOADING CRITERIA~~

LOADING COMBINATIONS

1. 1.0D + 1.5P + 1.0(T+TL)
2. 1.0D + 1.0P + 1.0(T+<u>TL</u>) + 1.5E
3. 1.0D + 1.0T + 1.0C
4. 1.0D + 1.0P + 1.0(T+<u>TL</u>) + 2.0E

D - Dead load of structure, including effect of any hydrostatic pressure, ice and snow loads, when their effect increases the resultant stresses and equipment and operating loads.

P - Design pressure load.

T - Load due to maximum temperature gradient through the concrete shell and mat.

TL - Load exerted by the exposed liner, based upon temperature associated with 1.5 times design incident pressure.

<u>TL</u> - Load exerted by the exposed liner, based upon temperature associated with 1.0 times design pressure.

E - [redacted]

When the equivalent effect of a wind load on the structure of 35 psf on rectangular buildings 30 feet above ground exceeds the earthquake effects, the wind load will replace E. It is assumed that maximum forces due to wind and those due to earthquakes do not act at the same time. This wind pressure agrees with that recommended by American Standard Building Code Requirements Standard A58.1 for Minimum Design Loads in Buildings and Other Structures of the USAI for round or elliptical structures in this area.

C - Load due to negative pressure of 3 psi associated with assumed tornado and load due to 300 mph horizontal wind velocity associated with the assumed tornado.

The response spectrum is the envelope of response of simple structures with variable damping to the accelerations measured in a number of earthquakes. This analysis is applied for all structures and components in this class and groups thereof whose responses may be interdependent, considering their natural period and using appropriate damping factors as list. in Table 2.5-1.

Class 1 structures and components are designed in the following general manner:

1. An analysis is made to determine the natural periods of vibration of the structure using equivalent lump mass systems or distributed mass systems as is considered appropriate. In these analyses, periods and mode shapes are determined for each lumped mass mode. These data then define participation factors for each structure. Where structures are supported on their own foundations, foundation displacements are considered in determining natural periods and participation factors. It should be noted, however, that Class 1 structures at this site are founded on granite gneiss. Accordingly foundation yielding will be very small and may in many cases be neglected without introducing significant error.

2. The earthquake design acceleration value for the specific natural period of the structure or component being considered is determined from Figure 2.5-6 using appropriate damping factors. [redacted]

3. Design of the reactor containment is performed in accordance with the criteria as established in Section 5.2.

4. For some structures, and especially for vibratory systems of a highly complex nature, [redacted].

5. A tabulation of typical damping factors which are used for various vibratory systems important to nuclear safety is presented in Table 2.5-1. Conservative values are shown for various materials, methods of construction, and location with respect to the ground.