GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

February 9, 1993

Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: **Submittal Supporting Accelerated ABWR Review Schedule**

Dear Chet:

Enclosed are (1) markups for proposed changes to Sections 3.7 and 3.9, (2) results of GE's analysis of BNL (NUREG/CR-1677) Piping Benchmark Problem No. 2 using PISYS, and (3) results of GE's previous analyses of BNL (NUREG/CR-1677) Piping Benchmark Problems using SAP for all four problems and PISYS for Problem No. 1. This submittal is for resolution of the open and confirmatory piping DFSER items listed in Attachment 1, which also includes the previously closed items for information.

Please provide copies of this transmittal to Dave Terao, Jim Brammer, and Shou Hou.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Son Ninh (NRC-NRR) w/o Enclosure
Giuliano DeGrassi (BNL) w/Enclosure
Norman Fletcher (DOE) w/o Enclosure
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JF93-24

See attached list

ZZ22
1/1

ATTACHMENT 1

**LIST OF OPEN OR CONFIRMATORY
PIPING DFSER ITEMS
ADDRESSED BY FEBRUARY 9, 1993 TRANSMITTAL**

OPEN

14.1.3.3.3.6-1 ITAAC-structural design of small bore piping
(Same as 3.9.2.2-5)

14.1.3.3.4.1-1 ITAAC-confirmatory analys on computer model adequacy
(Not in 3.9)

14.1.3.3.4.3-1 ITAAC-piping benchmark program
(Same as 3.9.1-2)

14.1.3.3.5.7-1 ITAAC-environmental effects in fatique design, Cl. 1 Piping
(Same as 3.9.3.1-1, 14.1.3.3.5.7-2, 14.1.3.3.5.8-1 and 14.1.3.3.9.1-1)

14.1.3.3.5.7-2 ITAAC-method of including environ effects of fatigue
(Same as 14.1.3.3.5.7-1 and 14.1.3.3.9.1-1)

14.1.3.3.5.8-1 ITAAC-environmental effect in fatigue design, Cl. 2
(Same as 3.9.3.1-1, 14.1.3.3.5.7-1, 14.1.3.3.5.7-2 and 14.1.3.3.9.1-1)

14.1.3.3.5.10-1 ITAAC-methodology to address thermal striping
(Same as 3.9.3.1-2)

14.1.3.3.5.15-1 ITAAC-OBE as a design load
(Same as 3.1-1)

14.1.3.3.5.18-1 ITAAC-minimum temperature for thermal analyses
(Same as 3.9.3.1-3)

14.1.3.3.6-1 ITAAC-pipe support criteria (8 items)
(Same as 3.9.3.3-1 (1) thru (6) and 3.9.3.3-2)

14.1.3.3.9.1-1 ITAAC-fatigue cumulative usage factor of 1.0
(Same as 3.9.3.1-1, 14.1.3.3.5.7-1, and 14.1.3.3.5.8-1)

- Continued -

ATTACHMENT 1 (Continued)

LIST OF OPEN OR CONFIRMATORY PIPING DFSER ITEMS ADDRESSED BY FEBRUARY 9, 1993 TRANSMITTAL

CONFIRM

14.1.3.3.3.8-1 ITAAC-Dynamic seismic analyses of MS piping
(Not in 3.9) See new Section 3.2.5.3

14.1.3.3.3.8-2 ITAAC-verification of seismic/nonseismic
(Same as 3.9.2.1 :: and) See Item 14.1.3.3.3.8-1 above

14.1.3.3.4.2-2 ITAAC-Pipe flexibility between node points
(Same as 3.9.2.2-2)

14.1.3.3.4.2-3 ITAAC-Effects of equipment attached to piping
(Same as 3.9.2.2-3)

14.1.3.3.5.4-2 ITAAC-Use of Code case N-411 and N-420
(Not in 3.9)

14.1.3.3.5.6-1 ITAAC-High frequency mode analysis
(Not in 3.9)

PREVIOUSLY CLOSED PIPING DFSER ITEMS
(For information only)

CLOSED

14.1.3.3.3.9-1 ITAAC-Buried piping design
(Same as 3.9.2.2-7) See Amendment 23
14.1.3.3.4.4-1 ITAAC-Small bore piping decoupling criteria
(Same as 3.9.2.2-4) See Amendment 23
14.1.3.3.5.2-1 ITAAC-60 year life cycle factor of 1.5
(Same as 3.9.1-1) See Amendment 23 and 1/30/93 transmittal
14.1.3.3.4.2-1 ITAC-Mass point in dynamic piping model
(Same as 3.9.2.2-2) SSAR Section 3.7.3.3.1.2 is accetable
14.1.3.3.5.4-1 ITAAC-Code case N-411 damping values
(Not in 3.9) See Amendment 23
14.1.3.3.5.13-1 ITAAC-Inertial and seismic motion effects
(Not in 3.9) See markups of Sections 3.7 and 3.9 in 1/28/93 and 1/30/93 transmittals
14.1.3.3.5.17-1 ITAAC-modal damping for composite structures
(Same as 3.9.2.2-6) See Amendment 23

(2/9/93)

MARKUPS OF

SECTIONS 3.7 AND 3.9
FOR
PIPING DFSER ITEMS

(I)

branch line connection to the pipe run and the elevation of the branch line anchors and restraints.

(2) The response spectra will not be less than the envelope of the response spectra used in the dynamic analysis of the run pipe.

(3) ~~Amplification by the run pipe must be accounted for. However,~~ If the location of branch connection to the run pipe is more than three run pipe diameters from the nearest run pipe seismic restraint, amplification by the run pipe will be accounted for.

When the equivalent static analysis method is used, the horizontal and vertical load coefficients C_h and C_v applied to the response spectra accelerations will conform with Subsection 3.7.3.8.1.5.

The relative anchor motions to be used in either static or dynamic analysis of the decoupled branch pipe shall be as follows:

(1) The internal displacements only, as determined from analysis of the run pipe, may be applied to the branch pipe if the relative differential building movements of the large pipe supports and the branch pipe supports are less than 1/16 inch.

(2) If the relative differential building movements of the large pipe supports and the branch pipe supports are more than 1/16 inch, motion of the restraints and anchors of the branch pipe must be considered in addition to the inertial displacement of the run pipe.

3.7.3.3.1.5 Selection of Input Time-Histories

In selecting the acceleration time-history to be used for dynamic analysis of a piping system, the time-history chosen is one which most closely describes the accelerations existing at the piping support attachment points. For a piping system supported at more than two points located at different elevations in the building, the time-history analysis is performed using the independent support motion method where acceleration time histories are input at all of the piping structural attachment points.

3.7.3.3.1.6 Modeling of Piping Supports

Snubbers are modeled with an equivalent stiffness which is based on dynamic tests performed on prototype snubber assemblies or on data provided by the vendor. Struts are modeled with a stiffness calculated based on their length and cross-sectional properties. The stiffness of the supporting structure for snubbers and struts is included in the piping analysis model, unless the supporting structure can be considered rigid relative to the piping. The supporting structure can be considered as rigid relative to the piping as long as the criteria specified in Subsection 3.7.3.3.4 are met.

Insert Att. 3a

Anchors at equipment such as tanks, pumps and heat exchangers are modeled with calculated stiffness properties. Frame type pipe supports are modeled as described in Subsection 3.7.3.3.4.

3.7.3.3.1.7 Modeling of Special Engineered Pipe Supports

Modifications to the normal linear-elastic piping analysis methodology used with conventional pipe supports are required to calculate the loads acting on the supports and on the piping components when the special engineered supports, described in Subsection 3.9.3.4.1(6), are used. These modifications are needed to account for greater damping of the energy absorbers and the non-linear behavior of the limit stops. If these special devices are used, the modeling and analytical methodology will be in accordance with methodology accepted by the regulatory agency at the time of certification or at the time of application, per the discretion of the applicant.

In addition, the information required by Regulatory Guide 1.84 will be provided to the regulatory agency.

Item No. 14.1.3.3.6-1 comment 1.

3.7.3.3.1.8 Insert Att. 3b

3.7.3.3.2 Modeling of Equipment

For dynamic analysis, Seismic Category I equipment is represented by lumped-mass systems which consist of discrete masses connected by weightless springs. The criteria used to lump masses are:

(1) The number of modes of a dynamic system is controlled by the number of masses used; therefore, the number of masses is chosen so that all significant modes are included

Attachment 3a

Mass effects will be included for equipment which have a fundamental frequency of less than 60 hz. A simplified model of the equipment is included in the piping system model.

(Item No. 14.1.3.3.4.2-3)

Attachment 3b

3.7.3.3.1.8 Response Spectra Amplification at Support Attachment Points

The response spectra provided to the Piping Analyst will include amplification factors due to the flexibility of building local structures, such as steel platforms used for supporting piping and other equipment. Alternatively, the Civil/Structural engineer will specify the amplification factor to be applied to the building response spectra.

(Item No. 14.1.3.3.4.2-2)

(Item no. 14.1.3.3.6-1, comment 5) The following static coefficients of friction will be used in the analysis: 0.80 for steel on steel, and 0.15 for lubricated slide plates.

the number of degrees of freedom ~~are taken~~ more than twice the number of modes with frequencies less than 33 Hz.

(2) Mass is lumped at any point where a significant concentrated weight is located (e.g., the motor in the analysis of pump motor stand, the impeller in the analysis of pump shaft, etc).

(3) If the equipment has free-end overhang span with flexibility significant compared to the center span, a mass is lumped at the overhang span.

(4) When a mass is lumped between two supports, it is located at a point where the maximum displacement is expected to occur. This tends to lower the natural frequencies of the equipment because the equipment frequencies are in the higher spectral range of the response spectra. Similarly, in the case of live loads (mobile) and a variable support stiffness, the location of the load and the magnitude of support stiffness are chosen to yield the lowest frequency content for the system. This ensures conservative dynamic loads since the equipment frequencies are such that the floor spectra peak is in the lower frequency range. If not, the model is adjusted to give more conservative results.

3.7.3.3.3 Field Location of Supports and Restraints

The field location of seismic supports and restraints for Seismic Category I piping and piping systems components is selected to satisfy the following two conditions:

(1) the location selected must furnish the required response to control strain within allowable limits; and

(2) adequate building strength and stiffness for attachment of the component supports must be available.

The final location of seismic supports and restraints for Seismic Category I piping, piping system components, and equipment, including the placement of snubbers, is checked against the drawings and instructions issued by the engineer. An additional examination of these supports and restraining devices is made to assure that their location and characteristics are consistent with the dynamic and static analyses of the system.

3.7.3.3.4 Analysis of Frame Type Supports

The design loads on frame type pipe supports include (a) loads transmitted to the support by the piping response to thermal expansion, dead weight, and the inertia and anchor motion effects, (b) support internal loads caused by the weight, thermal and inertia effects of loads of the structure itself, and (c) friction loads caused by pipe sliding on the support. To calculate the frictional force acting on the support dynamic loads that are cyclic in nature need not be considered. ~~The coefficient of friction used will be static coefficients and will be substantiated by actual test data covering the range of materials, geometry and loading condition.~~ To determine the response of the support structure to applied dynamic loads, the equivalent static load method of analysis described in Subsection 3.7.3.8.1.5 may be used. The loads trasmitted to the support by the piping will be applied as static loads acting on the support.

As in the case of other supports, the forces the piping places on the frame-type support are obtained from an analysis of the piping. In the analysis of the piping the stiffness of the frame-type supports shall be included in the piping analysis model, unless the support can be shown to be rigid. The frame-type supports may be modeled as rigid restraints providing they are designed so the maximum service level D deflection in the direction of the applied load is less than ~~1/16~~ 1/8 (*) inch and providing the total gap or diametrical clearance between the pipe and frame support is between 1/16 inch and 3/16 inch when the pipe is in either the hot or cold condition. For a frame-type support to be considered rigid, it shall be at least ~~50~~ 200 times as stiff as the piping. The piping stiffness is calculated using the following equation:

$$Kp = \frac{EI}{L^3}$$

E = modules of elasticity of pipe

(Item no. 14.1.3.3.6-1 / comment 2) Nonlinear analysis methods to account for gaps between pipe and supports subjected to high frequency vibration loads, such as suppression pool loads will not be used.

An explanatory comment for information only – not to be included in the SSAR

* Per WRC Bulletin No. 353: the service level B deflection limit should be 1/16", therefore 1/8" is a reasonable service Level D limit

I = moment of inertia of pipe

L = ~~one-half~~ the suggested pipe support spacing in Table NF-3611-1 of ASME Code, Section III

3.7.3.4 Basis of Selection of Frequencies

Where practical, in order to avoid adverse resonance effects, equipment and components are designed/selected such that their fundamental frequencies are outside the range of one-half to twice the dominant frequency of the associated support structures. Moreover, in any case, the equipment is analyzed and/or tested to demonstrate that it is adequately designed for the applicable loads considering both its fundamental frequency and the forcing frequency of the applicable support structure.

All frequencies in the range of 0.25 to 33 Hz are considered in the analysis and testing of structures, systems, and components. These frequencies are excited under the seismic excitation.

If the fundamental frequency of a component is greater than or equal to 33 Hz, it is treated as seismically rigid and analyzed accordingly. Frequencies less than 0.25 Hz are not considered as they represent very flexible structures and are not encountered in this plant.

The frequency range between 0.25 Hz and 33 Hz covers the range of the broad band response spectrum used in the design.

3.7.3.5 Use of Equivalent Static Load Methods of Analysis

3.7.3.5.1 Subsystems Other Than NSSS

See Subsection 3.7.3.8.1.5 for equivalent static load analysis method.

3.7.3.5.2 NSSS Subsystems

When the natural frequency of a structure of component is unknown, it may be analyzed by applying a static force at the center of mass. In order to conservatively account for the possibility of more than one significant dynamic mode, the static force is calculated as 1.5 times the times the mass times the maximum spectral acceleration from the floor response spectra of the point of attachments of multispan structures. The factor of 1.5 is adequate for simple beam type structures, the factor used is justified.

3.7.3.6 Three Components of Earthquake Motion

The total seismic response is predicted by combining the response calculated from the two

horizontal and the vertical analysis.

When the response spectrum method or static coefficient method is used, the method for combining the responses due to the three orthogonal components of seismic excitation is given as follows:

$$R_i = \left[\sum_{j=1}^{3} R_{ij}^2 \right]^{1/2} \quad (3.7\text{-}14)$$

where

R_{ij} = maximum, coaxial seismic response of interest (e.g., displacement, moment, shear, stress, strain) in directions i due to earthquake excitation in direction j, (j = 1, 2, 3).

R_i = seismic response of interest in i direction for design (e.g., displacement, moment, shear, stress, strain) obtained by the SRSS rule to account for the nonsimultaneous occurrence of the R_{ij}'s.

When the time-history method of analysis is used and separate analyses are performed for each earthquake component, the total combined response for all three components shall be obtained using the SRSS method described above to combine the maximum codirectional responses from each earthquake component. The total response may alternatively be obtained, if the three component motions are mutually statistically independent, by algebraically adding the codirectional responses calculated separately for each component at each time step.

When the time-history analysis is performed by applying the three components motions simultaneously, the combined response is obtained directly by solution of the equations of motion. This method of combination is applicable only if the three component motions are mutually statistically independent.

3.7.3.7 Combination of Modal Response

3.7.3.7.1 Subsystems Other Than NSSS

insert Attachment 4

When the response spectrum method of modal analysis is used, contributions from all modes, except the closely spaced modes (i.e., the difference between any two natural frequencies is equal to or less than 10%) are combined by the square-root-of-the-sum-of-the-squares (SRSS) combination of modal responses. This is defined mathematically as:

$$R_i = \sqrt{\sum_{i=1}^{N} (R_i)^2} \quad (3.7\text{-}15)$$

where

R = combined response;

R_i = response to the i^{th} mode; and

N = number of modes considered in the analysis.

Closely spaced modes are combined by taking the absolute sum of the such modes.

An alternate to the absolute sum method presented in Regulatory Guide 1.92 is the following:

$$R = \left[\sum_{i=1}^{N} R_i^2 + 2\Sigma \left| R_l R_m \right| \right]^{1/2} \quad (3.7\text{-}16)$$

where the second summation is to be done on all l and m modes whose frequencies are closely spaced to each other.

3.7.3.7.2 NSSS Subsystems

In a response spectrum modal dynamic analysis, if the modes are not closely spaced (i.e., if the frequencies differ from each other by more than 10% of the lower frequency), the modal responses are combined by the square-root-of-the-sum-of- the-squares (SRSS) method as described in Subsection 3.7.3.7.1 and Regulatory Guide 1.92.

If some or all of the modes are closely spaced, a double sum method, as described in Subsection 3.7.3.7.2.2, is used to evaluate the

Attachment 4

"When the response spectrum method of analysis is used, the modal responses for modes below the cutoff frequency (specified in Section 3.7) are combined in accordance with the methods given in Subsections 3.7.3.7.1 and 3.7.3.7.2. The responses associated with higher frequency modes (above cutoff frequency) are calculated and combined with the low frequency modal responses according to the procedure described in Subsection 3.7.3.7.3. These methods and procedures are applicable for seismic loads as well as for loads with higher frequency input such as suppression pool dynamic loads."

(item no. 14.1.3.3.5.6-1 comment 1)

3.7.3.8.1.9 Design of Small Branch and Small Bore Piping

(1) Small branch lines are defined as those lines that can be decoupled from the analytical model used for the analysis of the main run piping to which the branch lines attach. As allowed by Subsection 3.7.3.3.1.3 branch lines can be decoupled when the ratio of run to branch pipe moment of inertia is 25 to 1, or greater. In addition to the moment of inertia criterion for acceptable decoupling, these small branch lines shall be designed with no concentrated masses, such as valves, in the first one-half span length from the main run pipe; and with sufficient flexibility to prevent restraint of movement of the main run pipe. The small branch line is considered to have adequate flexibility if its first anchor or restraint to movement is at least one-half pipe span in a direction perpendicular to the direction of relative movement between the pipe run and the first anchor or restraint of the branch piping. A pipe span is defined as the length tabulated in Table NF-3611-1, Suggested Piping Support Spacing, ASME B&PV Code, Section III, Subsection NF. For branches where the preceding criteria for sufficient flexibility cannot be met, the applicant will demonstrate acceptability by using an alternative criteria for sufficient flexibility, or by accounting for the effects of the branch piping in the analysis of the main run piping.

(2) For small bore piping defined as piping 2 inches and less nominal pipe size, and small branch lines 2 inches and less nominal pipe size, as defined in (1) above, it is acceptable to use small bore piping handbooks in lieu of performing a system flexibility analysis, using static and dynamic mathematical models, to obtain loads on the piping elements and using these loads to calculate stresses per equations in NB, NC, and ND3600 in Section III of ASME Code, whenever the following are met:

(a) The small bore piping handbook at the time of application is currently accepted by the regulatory agency for use on equivalent piping at other nuclear power plants.

(b) When the small bore piping handbook is serving the purpose of the Design Report it meets all of the ASME requirements for a piping design report. This includes the piping and its supports.

(c) Formal documentation exists showing piping designed and installed to the small bore piping handbook (1) is conservative in comparison to results from a detail stress analysis for all applied loads and load combinations ~~defined in the design specification,~~ using static and dynamic analysis methods defined in Section 3.7.3, (2) does not result in piping that is less reliable because of loss of flexibility or because of excessive number of supports, (3) satisfies required clearances around sensitive components.

[handwritten margin: Item No. 14.1.3.3.6-1 (Same as 3.9.2.2-5)]

The small bore piping handbook methodology will not be applied when specific information is needed on (a) magnitude of pipe and fittings stresses, (b) pipe and fitting cumulative usage factors, (c) accelerations of pipe mounted equipment, or locations of postulated breaks and leaks.

The small bore piping handbook methodology will not be applied to piping systems that are fully engineered and installed in accordance with the engineering drawings.

[handwritten insertion: Supports for ASME Code Section III instrumentation lines are analyzed in accordance with Subsection 3.7.2.2.1 3.7.3, and are designed in accordance with Subsection 3.9.3.4.] (7)

(Item No. 14.1.3.3.6-1, comment 7)

3.7.3.8.1.10 Multiply-Supported Equipment and Components with Distinct Inputs

For multi-supported systems (equipment and piping) analyzed by the response spectrum method for the determination of inertial responses, either of the following two input motions are acceptable:

(1) envelope response spectrum of all support points for each orthogonal direction of excitation, or

(2) independent support motion (ISM) response spectrum at each support for each orthogonal direction of excitation.

When the ISM response spectrum method of analysis is used, the following conditions should be met:

are applied to the subsystem model, and the modal forces, shears, moments, stresses, and deflections are determined.

(9) The modal forces, shears, moments, stresses, and deflections for a given direction are combined in accordance with Subsection 3.7.3.8.1.4.

(10) Steps (5) through (9) are performed for each of the three earthquake directions.

(11) The seismic force, shear, moment, and stress resulting from the simultaneous application of the three components of earthquake loading are obtained in the following manner:

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2} \qquad (3.7\text{-}24)$$

R = equivalent seismic response quantity (force, shear, moment, stress, etc.)

R_x R_y R_z = colinear response quantities due to earthquake motion in the x, y, and z directions, respectively.

3.7.3.8.1.7 Damping Ratio

The damping ratio percentage of critical damping of piping subsystems corresponds to Regulatory Guide 1.61 or 1.84 (ASME Code Case N-411-1). The damping ratio is specified in Table 3.7-1.

Strain energy weighted modal damping can also be used in the dynamic analysis. Strain energy weighting is used to obtain the modal damping coefficient due to the contributions of damping different elements of the piping system. The element damping values are specified in Table 3.7-1. Strain energy weighted modal damping is calculated as specified in Subsection 3.7.2.15.

In direct integration analysis, damping is input in the form of α and β damping constants, which give the percentage of critical damping, λ as a function of the circular frequency, ω.

$$\omega = \frac{\alpha}{2\omega} + \frac{\beta\omega}{2}$$

Item NO. 14.1.3.3.5.4-2

ASME Code Case N-411-1 damping can not be used for analyzing linear energy absorbing supports designed in accordance with ASME Code Case N-420.

3.7.3.8.1.8 Effect of Differential Building Movements

In most cases, piping subsystems are anchored and restrained to floors and walls of buildings that may have differential movements during a seismic event. The movements may range from insignificant differential displacements between rigid walls of a common building at low elevations to relatively large displacements between separate buildings at a high seismicity site.

Differential endpoint or restraint deflections cause forces and moments to be induced into the piping system. The stress thus produced is a secondary stress. It is justifiable to place this stress, which results from restraint of free-end displacement of the piping system, in the secondary stress category because the stresses are self-limiting and, when the stresses exceed yield strength, minor distortions or deformations within the piping system satisfy the condition which caused the stress to occur.

The earthquake thus produces a stress-exhibiting property much like a thermal expansion stress and a static analysis can be used to obtain actual stresses. The differential displacements are obtained from the dynamic analysis of the building. The displacements are applied to the piping anchors and restraints corresponding to the maximum differential displacements which could occur. The static analysis is made three times: once for one of the horizontal differential displacements, once for the other horizontal differential displacement, and once for the vertical.

The inertia (primary) and displacement (secondary) loads are dynamic in nature and their peak values are not expected to occur at the same time. Hence, combination of the peak values of inertia load and anchor displacement load is quite conservative. In addition, anchor movement effects are computed from static analyses in which the displacements are applied to produce the most conservative loads on the components. Therefore, the primary and secondary loads are combined by the SRSS method

The results of the data analyses, vibration amplitudes, natural frequencies, and mode shapes are then compared to those obtained from the theoretical analysis.

Such comparisons provide the analysts with added insight into the dynamic behavior of the reactor internals. The additional knowledge gained from previous vibration tests has been utilized in the generation of the dynamic models for seismic and loss of coolant accident (LOCA) analyses for this plant. The models used for this plant are similar to those used for the vibration analysis of earlier prototype BWR plants.

3.9.3 ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures

3.9.3.1 Loading Combinations, Design Transients, and Stress Limits

This section delineates the criteria for selection and definition of design limits and loading combination associated with normal operation, postulated accidents, and specified seismic and other reactor building vibration (RBV) events for the design of safety-related ASME Code components (except containment components which are discussed in Section 3.8).

This section discusses the ASME Class 1, 2, and 3 equipment and associated pressure retaining parts and identifies the applicable loadings, calculation methods, calculated stresses, and allowable stresses. A discussion of major equipment is included on a component-by-component basis to provide examples. Design transients and dynamic loading for ASME Class 1, 2, and 3 equipment are covered in Subsection 3.9.1.1. Seismic-related loads and dynamic analyses are discussed in Section 3.7. The suppression pool-related RBV loads are described in Appendix 3B. Table 3.9-2 presents the combinations of dynamic events to be considered for the design and analysis of all ABWR ASME Code Class 1, 2, and 3 components, component supports, core support structures and equipment. Specific loading combinations considered for evaluation of each specific equipment are derived from Table 3.9-2 and are contained in the design specifications and/or design reports of the respective equipment. See Subsection 3.9.7.4 for COL license information requirements.

Thermal stratification of fluids in a piping system is one of the specific operating conditions that is included in the loads and load combinations that are contained in the piping design specifications and design reports. It is known stratification can occur in the feedwater piping during plant startup and when the plant is in hot standby conditions following scram (see Subsection 3.9.2.1.3). If, during design or startup, evidence of thermal stratification is detected in any other piping system, then stratification will be evaluated. If it cannot be shown that the stresses in the pipe are low and that movement due to bowing is acceptable, then stratification will be treated as a design load. In general, if temperature differences between the top and bottom of the pipe are less than 50°F, it may be assumed design specification and stress reports need not be revised to include stratification.

The design life for the ABWR Standard Plant is 60 years. A 60 year design life is a requirement for all major plant components with reasonable expectation of meeting this design life. However, all plant operational components and equipment except the reactor vessel are designed to be replaceable, design life not withstanding. The design life requirement allows for refurbishment and repair, as appropriate, to assure the design life of the overall plant is achieved. In effect, essentially all piping systems, components and equipment are designed for a 60 year design life. Many of these components are classified as ASME Class 2 or 3 or Quality Group D. In the event any non-Class 1 components are subjected to cyclic loadings, including operating vibration loads and thermal transient effects, of a magnitude and/or duration so severe that the 60 year design life can be assured by required Code calculations. COL applicants will identify these components and either provide an appropriate analysis to demonstrate the required design life or provide designs to mitigate the magnitude or duration of the cyclic loads. Components excluded from this requirement are (1) tees where mixing of hot and cold fluids occurs and thermal sleeves have been provided in accordance with the P&IDs, ~~(2) components such as the quencher, for which a fatigue analysis has already been performed, providing the com-~~ e e

(item no. 14.1.3.3.5.7-1
14.1.3.3.5.8-1
14.1.3.3.9.1-1)

Attachment 2

New third para. in section 3.9.3.1

(Item No. 14.1.3.3.5.18-1)

Piping loads due to the thermal expansion of the piping and thermal anchor movements at supports are included in the piping load combinations. All operating modes are evaluated and the maximum moment ranges are included in the fatigue evaluation. Piping systems with maximum operating temperatures of less than or equal to 150°F are not required to be analyzed for thermal expansion loading.

New fourth para. in Section 3.9.3.1

(Item No. 14.1.3.3.5.19-1)

Low-pressure piping systems that interface with the reactor coolant pressure boundary will be designed with either a schedule 40 pipe wall thickness, or a pipe wall thickness calculated for a pressure equal to 0.4 times the reactor coolant system pressure.

SSAR page 3.9-18

and (2)
~~ponent is designed so as to not cause excessive localized stresses, or harmful thermal gradients in the pipe wall, (3)~~ feedwater piping outside containment that is designed so cyclic loadings and stresses are no more severe than experienced by Class 1 piping inside containment. ~~See Subsection 3.9.7.2 for COL license information requirements.~~

(item no. 14.1.3.3.5.7-1
14.1.3.3.5.8-1
14.1.3.3.9.1-1)

Insert Attachment 5

3.9.3.1.1 Plant Conditions

All events that the plant will or might credibly experience during a reactor year are evaluated to establish design basis for plant equipment. These events are divided into four plant conditions. The plant conditions described in the following paragraphs are based on event probability (i.e., frequency of occurrence as discussed in Subsection 3.9.3.1.1.5) and correlated to service levels for design limits defined in the ASME Boiler and Pressure Vessel Code Section III as shown in Tables 3.9-1 and 3.9-2.

3.9.3.1.1.1 Normal Condition

Normal conditions are any conditions in the course of system startup, operation in the design power range, normal hot standby (with condenser available), and system shutdown other than upset, emergency, faulted, or testing.

3.9.3.1.1.2 Upset Condition

An upset condition is any deviation from normal conditions anticipated to occur often enough that design should include a capability to withstand the conditions without operational impairment. The upset conditions include system operational transients (SOT) which result from any single operator error or control malfunction, from a fault in a system component requiring its isolation from the system, from a loss of load or power, or from an operating basis earthquake. Hot standby with the main condenser isolated is an upset condition.

ATTTACHMENT 5 FOR SECTION 3.9.3.1 (PAGE 3.9-18.1)

Severe thermal transients that will be evaluated for possible effect on plant life are temperature rate changes faster than 830°C/Hour, when the total fluid temperature change is greater than 38°C.

The Safety Relief Valve (SRV) discharge piping in the wetwell and the SRV Quenchers are subjected to severe thermal transients during SRV blowdown events. Therefore, the COL applicant will perform ASME Class 1 fatigue analyses of the ASME Class 3 SRV discharge piping in the wetwell and the SRV Quenchers. The purpose of these fatigue evaluations is to confirm that the fatigue cumulative usage factor is less than 1.0, and the fatigue stresses are less than their allowables. The fatigue evaluations will include the SRV blowdown thermal transient loads, thermohydraulic loads, Safe Shutdown earthquake loads and the Reactor Building vibration loads due to SRV blowdown. Environmental effects will be considered in the fatigue analysis in accordance with the requirements for ASME Section III Class 1 carbon steel piping specified in Subsection 3.9.3.1.1.7.

The SRV discharge piping in the wetwell will be analyzed for SRV blowdown thermal stresses due to a step change in temperature inside the pipe from 32°C to 166°C. In order to minimize piping thermal stresses, no shear lugs will be welded to the SRV discharge piping.

The fatigue analysis of the SRV Quencher will be performed in accordance with ASME Section III, Subsection NB-3200. The quencher will be analyzed for the heat transfer transient during SRV blowdown where there is a step change in temperature inside the quencher from 20°C to 166°C, and the outside of the quencher remains at 20°C. The fatigue evaluation will also include the SRV discharge pipe applied thermal loads, thermohydraulic transient loads, Safe Shutdown Earthquake loads and the SRV blowdown Reactor Building Vibration loads.

See Subsection 3.9.7.2 for COL license information requirements.

(item no. 14.1.3.3.5.7-1, 14.1.3.3.5.8-1, 14.1.3.3.9.1-1)

Insert Attachment 1

to accomplish its safety functions as required by any subsequent design condition event.

For active Class 2 and 3 pumps, specific stress criteria to meet the functional requirements are identified in a footnote to Table 3.9-2. For piping and valves there are no specific stress criteria for functional requirements. The ASME code allowable stresses are applied to assure functional capability under emergency and faulted design conditions.

→ 3.9.3.1.1.7

3.9.3.1.2 Reactor Pressure Vessel Assembly

The reactor vessel assembly consists of the reactor pressure vessel, vessel support skirt, and shroud support.

The reactor pressure vessel, vessel support skirt, and shroud support are constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III. The shroud support consists of the shroud support plate and the shroud support cylinder and its legs. The reactor pressure vessel assembly components are classified as an ASME Class 1. Complete stress reports on these components are prepared in accordance with ASME Code requirements. NUREG-0619 (Reference 5) is also considered for feedwater nozzle and other such RPV inlet nozzle design.

The stress analysis is performed on the reactor pressure vessel, vessel support skirt, and shroud support for various plant operating conditions (including faulted conditions) by using the elastic methods except as noted in Subsection 3.9.1.4.2. Loading conditions, design stress limits, and methods of stress analysis for the core support structures and other reactor internals are discussed in Subsection 3.9.5.

3.9.3.1.3 Main Steam (MS) System Piping

The piping systems extending from the reactor pressure vessel to and including the outboard main steam isolation valve are constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 1 criteria. Stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the ASME Code Section III.

The MS system piping extending from the outboard main steam isolation valve to the turbine stop valve is constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 2 Criteria.

Turbine stop valve (TSV) closure in the main steam (MS) piping system results in a transient that produces momentary unbalanced forces acting on the MS piping system. Upon closure of the TSV, a pressure wave is created and it travels at sonic velocity toward the reactor vessel through each MS line. Flow of steam into each MS line from the reactor vessel continues until the steam compression wave reaches the reactor vessel. Repeated reflection of the pressure wave at the reactor vessel and the TSV produce time varying pressures and velocities, throughout the MS lines.

The analysis of the MS piping TSV closure transient consists of a stepwise time-history solution of the steam flow equation to generate a time-history of the steam properties at numerous locations along the pipe. Reaction loads on the pipe are determined at each elbow. These loads are composed of pressure-times-area, momentum change and fluid-friction terms.

The time-history direct integration method of analysis is used to determine the response of the MS piping system to TSV closure. The forces are applied at locations on the piping system where steam flow changes direction thus causing momentary reactions. The resulting loads on the MS piping are combined with loads due to other effects as specified in Subsection 3.9.3.1.

3.9.3.1.4 Recirculation Motor Cooling (RMC) Subsystem

The RMC system piping loop between the recirculation motor casing and the heat exchanger is constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Subsection NB-3600. Stresses are calculated on an elastic basis and evaluated in accordance with NB-3600 of the ASME Code, Section III.

3.9.3.1.5 Recirculation Pump Motor Pressure Boundary

The motor casing of the recirculation internal pump is a part of and welded into an RPV

Attachment 1

3.9.3.1.1.7 Environmental Effects on Fatigue Evaluation of Carbon Steel Piping

Environmental effects on the fatigue design of ASME Section III Class 1 carbon steel piping will be evaluated in accordance with GE document, 408HA414 (Reference 9). Additional fatigue evaluations for environmental effects are not required for any of the following conditions: (a) Water temperature is below 245°C, (b) Fittings, such as elbows and tees, that are conservatively designed and analyzed using the ASME Section III stress indicies and (c) For transients having total cycle times of 10 seconds or less and no tensile hold time, provided that the oxygen content of the water does not exceed 0.3 ppm.

Environmental effects are considered by increasing the local peak stress through four factors used as multipliers to the stress indicies. The four factors are:(1) the notch factor, (2) the mean stress factor, (3) the environmental correction factor, and (4) the butt weld strength reduction factor.

(Item No. 14.1.3.3.5.7-2)

3.9.3.4 Component Supports

The design of bolts for component supports is specified in the ASME Code Section III, Subsection NF. Stress limits for bolts are given in NF-3225. The rules and stress limits which must be satisfied are those given in NF-3324.6 multiplied by the appropriate stress limit factor for the particular service loading level and stress category specified in Table NF-3225.2-1.

Moreover, on equipment which is to be, or may be, mounted on a concrete support, sufficient holes for anchor bolts are provided to limit the anchor bolt stress to less than 10,000 psi on the nominal bolt area in shear or tension.

Concrete anchor bolts (including under-cut type anchor bolts) which are used for pipe support base plates will be designed to the applicable factors of safety which are defined in I&E Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Revision 2 dated November 8, 1979.

3.9.3.4.1 Piping

Supports and their attachments for essential ASME Code Section III, Class 1,2, and 3 piping are designed in accordance with Subsection NF* up to the interface of the building structure, with jurisdictional boundaries as defined by Subsection NF. The loading combinations for the various operating conditions correspond to those used for design of the supported pipe. The component loading combinations are discussed in Subsection 3.9.3.1. The stress limits are per ASME III, Subsection NF and Appendix F. Supports are generally designed either by load rating method per paragraph NF-3260 or by the stress limits for linear supports per paragraph NF-3231. The critical buckling loads for the Class 1 piping supports subjected to faulted loads that are more severe than normal, upset and emergency loads, are determined by using the methods discussed in Appendices F and XVII of the Code. To avoid buckling in the piping supports, the allowable loads are limited to two thirds of the determined critical buckling loads.

Maximum calculated static and dynamic deflections at support locations are checked to confirm that the support has not rotated beyond the vendor's recommended cone of action or the recommended arc of loading.

Supports for ASME Code Section III instrumentation lines are designed and analyzed in accordance with ASME Code Section III, Subsection NF.

The design of all supports for non-nuclear piping satisfies the requirements of ANSI\ASME B31.1 Power Piping Code, Paragraphs 120 and 121.

For the major active valves identified in Subsection 3.9.3.2.4, the valve operators are not used as attachment points for piping supports.

The design criteria and dynamic testing requirements for the ASME III Subsection NF piping supports are as follows:

(1) Piping Supports - All piping supports are designed, fabricated, and assembled so that they cannot become disengaged by the movement of the supported pipe or equipment after they have been installed. All piping supports are designed in accordance with the rules of Subsection NF of the ASME Code up to the building structure interface as defined by the jurisdictional boundaries in Subsection NF.

(2) Spring Hangers - The operating load on spring hangers is the load caused by dead weight. The hangers are calibrated to ensure that they support the operating load at both their hot and cold load settings. Spring hangers provide a specified down travel and up travel in excess of the specified thermal movement. Deflections

(Item No 14.1.3.3.6-1, comment 7)

*Augmented by the following: (1) application of Code Case N-476, Supplement 89.1 which governs the design of single angle members of ASME Class 1,2,3 and MC linear component supports; and (2) when eccentric loads or other torsional loads are not accommodated by designing the load to act through the shear center or meet "Standard for Steel Support Design", analyses will be performed in accordance with torsional analysis methods such as: "Torsional Analysis of Steel Members, USS Steel Manual", Publication T114-2/83.

due to dynamic loads bottom out. are checked to confirm that they do not ~~fall outside the working range of the support and the variation in the support load does not induce unacceptable loads on other supports.~~

(item no. 14.1.3.3.6-1, comment 2)
(insert as new first paragraph)
Mechanical and hydraulic type snubbers will be used when required as shock arrestors for nuclear safety related piping systems. Snubbers are designed in accordance with ASME Section III, Subsection NF, Component standard supports. Snubbers consist of a velocity-limiting or acceleration-limiting cylinder pinned to a pipe clamp at the pipe end and pinned to a clevis attached to the building structure at the other end. Snubbers operate as structural supports during dynamic events such as earthquake, but during normal operation act as passive devices which accomodate normal expansions and contractions without resistance.

(3) Snubbers - The operating loads on snubbers are the loads caused by dynamic events (e.g., seismic, RBV due to LOCA and SRV discharge, discharge through a relief valve line or valve closure) during various operating conditions. Snubbers restrain piping against response to the vibratory excitation and to the associated differential movement of the piping system support anchor points. The criteria for locating snubbers and ensuring adequate load capacity, the structural and mechanical performance parameters used for snubbers and the installation and inspection considerations for the snubbers are as follows:

(a) Required Load Capacity and Snubber Location

The loads calculated in the piping dynamic analysis, described in Subsection 3.7.3.8, cannot exceed the snubber load capacity for design, normal, upset, emergency and faulted conditions.

For hydraulic snubbers with load ratings greater than 50 kips, dynamic cyclic load tests will be conducted to verify the performance of the control valve. These hydraulic snubbers will be subjected to dynamic cyclic load tests at loads greater than or equal to one-half the calculated safe shutdown earthquake load on the snubber.

November 1977. Also NEDO-24057-P, Amendment 1, December 1978, and NEDE-2-P 24057 Amendment 2, June 1979.

4. *General Electric Company, Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50, Appendix K.* NEDE-20566P, Proprietary Document, November 1975.

5. *BWR Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking,* NUREG-0619.

6. *General Electric Environmental Qualification Program,* NEDE-24326-1-P, Proprietary Document, January 1983.

7. *Functional Capability* ~~*Criteria for Essential Mark II Piping*, NEDO-21985, September 1978, prepared by Battelle Columbus Laboratories for General Electric Company.~~ of Piping Systems, U.S. Nuclear Regulatory Commission, NUREG-1367, November 1992

8. *Generic Criteria for High Frequency Cutoff of BWR Equipment,* NEDO-25250, Proprietary Document, January 1980.

9. General Electric Company, Plain Carbon Steels, 408HA414, Rev. 1

(2/9/93)

PYSIS RESULTS

BNL (NUREG CR-1677)
BENCHMARK PROBLEM NO. 2

GE-NE
ABWR PROGRAM

DATE: FEBRUARY 5, 1993

TO: N.PATEL

FROM: M.HERZOG M.Herzog

SUBJECT: ANALYSIS RESULTS FOR PIPING BENCHMARK PROBLEM NO. 2

REFERENCES:
1. "PISYS-Piping System Analysis Program", GE Document No. NEDE-24077
2. "Piping Benchmark Problems Dynamic Analysis Independent Support Motion Response Spectrum Method" NUREG/CR-1677, Volume II August 1985

1.0 PURPOSE

To present the results of the piping dynamic analysis performed using the PISYS-Piping Analysis Program (Reference 1). Benchmark Problem No. 2 provided in Reference 2 was analyzed.

2.0 DYNAMIC ANALYSIS METHODS

The dynamic analysis was performed using the following response spectrum methods:

1) Uniform Support Motion (USM) Method,
2) Independent Support Motion (ISM) Method with square root some of the squares (SRSS) combination of support group contributions.
3) ISM Method with absolute sum combination of support group contributions.

For all three solution methods, the SRSS modal combination was performed first, followed by the combination of support group contributions, followed by the SRSS interspatial combination.

The Benchmark results provided in Reference 2, were not calculated in the same order as described above. Instead, the support group contributions were combined first, followed by the interspatial combination, followed by the modal combination.

Due to this difference in how the final results are calculated, the PISYS results for Method 3 are up to 10% greater than the Reference 2 results.

3.0 DESCRIPTION OF ANALYSIS PERFORMED

Benchmark problem no. 2 is shown in Figure 1.

A complete listing of the piping model and dynamic loads input data is provided in Appendix 1.

The following output results are provided in Appendix 2:

- modal frequencies and participation factors
- displacements and calculated loads for the three analysis methods.

4.0 SUMMARY OF RESULTS

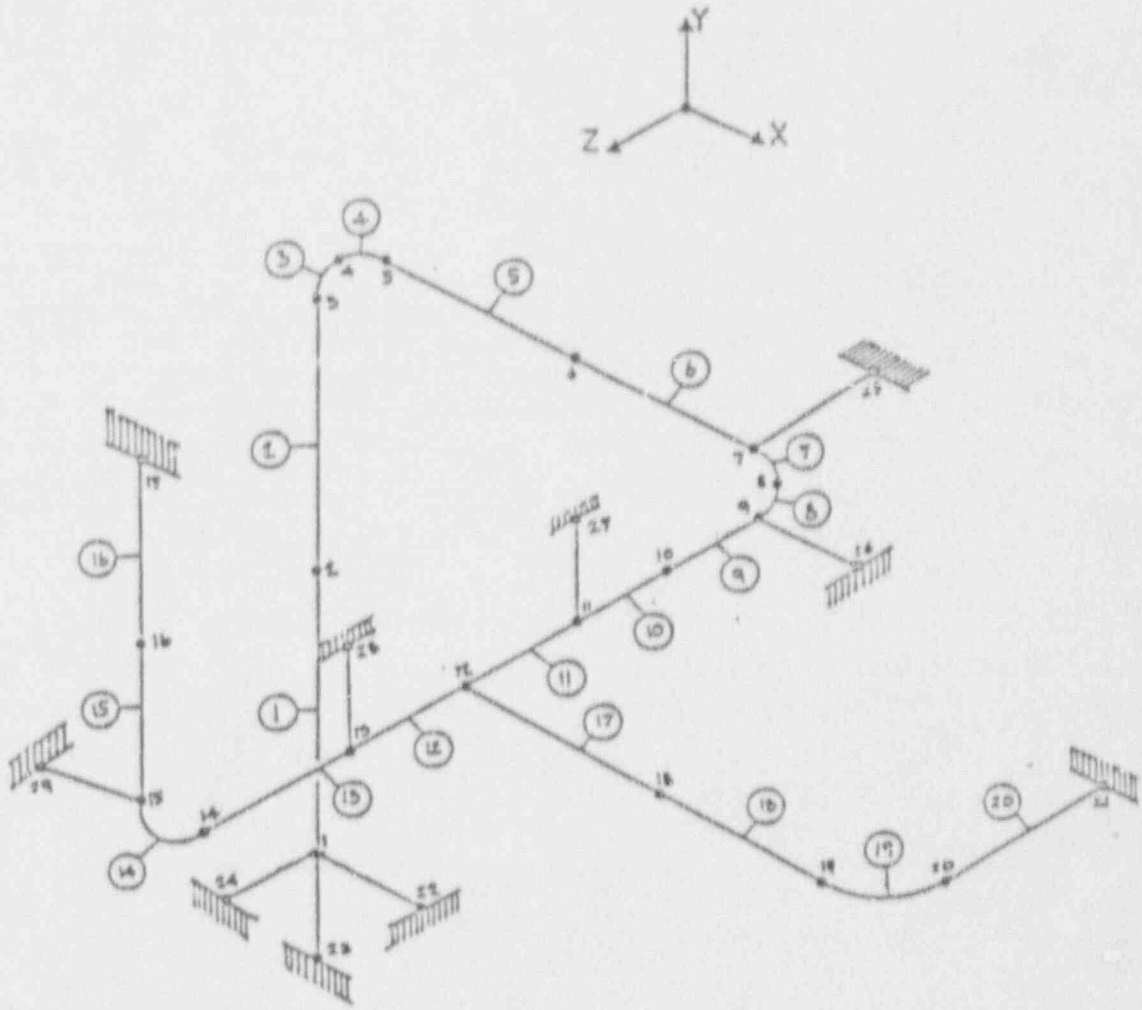
Tables 1 through 3 provide a comparison of the PISYS results with the Reference 2 results.

The analysis results for the USM method and for the ISM method with SRSS combination of group contributions are identical to the Reference 2 results.

The analysis results for the ISM method with absolute sum combination of group contributions are within 10% of the Reference 2 results. The difference in analysis results is because PISYS combines the final results in a different order than what was used in Reference 2. (See Section 2.0)

5.0 CONCLUSION

The PISYS computer program accurately calculates piping system dynamic loads and displacements due to Envelope Spectrum excitation and Independent Support excitation.



BENCHMARK PROBLEM № 2

Figure 1

TABLE 1 SUPPORT FORCES FOR ENVELOPE SPECTRA METHOD AND INDEPENDENT SUPPORT MOTION WITH SRSS OF GROUPS

Support No.	PISYS Envelope (Lb.)	NUREG 1677 Envelope (Lb.)	PISYS SRSS Group (Lb.)	NUREG 1677 SRSS Group (Lb.)
1	90	90	53	53
2	65	65	46	46
3	177	177	113	113
4	708	708	441	441
5	446	446	257	257
6	206	206	123	123
7	164	164	98	98
8	373	373	221	221
9	58	58	32	32
10	198	198	124	124
11	103	103	66	66
12	378	378	103	103
13	192	192	114	114
14	245	245	116	116

TABLE 2 SUPPORT FORCES FOR INDEPENDENT SUPPORT MOTION WITH ABSOLUTE SUM OF GROUP CONTRIBUTIONS

Support No.	PISYS (Lb.)	NUREG 1677 (Lb.)	Percent Difference
1	83	76	9.2
2	77	70	10.0
3	158	156	1.3
4	619	607	2.0
5	367	350	4.9
6	190	184	3.3
7	149	146	2.1
8	316	301	5.0
9	49	45	8.9
10	179	169	5.9
11	94	91	3.3
12	165	152	8.6
13	175	170	2.9
14	172	158	8.9

TABLE 3 PIPE MOMENTS AND DISPLACEMENTS COMPARISON

TYPE OF METHOD	MAXIMUM RESULTANT MOMENT (In-Lbs.)		MAXIMUM DISPLACEMENT (In.)	
	PISYS	NUREG 1677	PISYS	NUREG 1677
ENVELOPE	20828	20769	0.09	0.09
	Element 9		Node 4 (Z direction)	
ISM with SRSS Group	13067	13045	0.06	0.06
	Element 9		Node 4 (Z direction)	
ISM with ABS Group	18316	18176	0.08	0.08
	Element 9		Node 4 (Z direction)	

APPENDIX 1

APPENDIX 1

TABLE OF CONTENTS

N O D A L   M A T R I X   F O R   P I S Y S

NODE NO.	EQUATION NUMBER ASSIGNMENT X	Y	Z	RX	RY	RZ	JOINT IDEN.	STRESS FLAG	GLOBAL -- COORDINATES X	Y	Z	BRANCH POINT
1	1	2	3	4	5	6	001.	S	0.	0.	0.	
2	7	8	9	10	11	12	002.	S	0.	54.45	0.	
3	13	14	15	16	17	18	003.	S	0.	108.90	0.	
4	19	20	21	22	23	24	004.	S	10.63	134.57	0.	
5	25	26	27	28	29	30	005.	S	36.30	145.20	0.	
6	31	32	33	34	35	36	006.	S	54.15	145.20	0.	
7	37	38	39	40	41	42	007.	S	72.00	145.20	0.	
8	43	44	45	46	47	48	008.	S	97.67	145.20	10.63	
9	49	50	51	52	53	54	009.	S	108.30	145.20	36.30	
10	55	56	57	58	59	60	010.	S	108.30	145.20	56.80	
11	61	62	63	64	65	66	011.	S	108.30	145.20	77.30	
12	67	68	69	70	71	72	012.	S	108.30	145.20	97.80	
13	73	74	75	76	77	78	013.	S	108.30	145.20	118.30	
14	79	80	81	82	83	84	014.	S	108.30	145.20	188.80	
15	85	86	87	88	89	90	015.	S	108.30	181.50	225.10	
16	91	92	93	94	95	96	015.	S	10C.30	236.00	225.10	
17	97	98	99	100	101	102	017.	S	108.30	290.00	225.10	
18	103	104	105	106	107	108	018.	S	148.30	145.20	97.80	
19	109	110	111	112	113	114	019.	S	188.30	145.20	97.80	
20	115	116	117	118	119	120	020.	S	224.60	145.20	61.50	
21	121	122	123	124	125	126	021.	S	224.50	145.20	20.00	
22	9001	0	0	0	0	0	A001 X		1.00	0.	0.	
23	0	9002	0	0	0	0	A001 Y		0.	1.00	0.	
24	0	0	9003	0	0	0	A001 Z		0.	0.	1.00	
25	9004	0	0	0	0	0	A017 X		109.30	290.00	225.10	
26	0	9005	0	0	0	0	A017 Y		108.30	291.00	225.10	
27	0	0	9006	0	0	0	A017 Z		108.30	290.00	226.10	
28	9007	0	0	0	0	0	A021 X		225.60	145.20	20.00	
29	0	9008	0	0	0	0	A021 Y		224.60	146.20	20.00	
30	0	0	9009	0	0	0	A021 Z		224.60	145.20	21.00	
31	0	0	9010	0	0	0	STR07		-2.00	145.20	-1.00	
32	9011	0	0	0	0	0	STR09		109.30	145.20	36.30	
33	0	9012	0	0	0	0	STR11		108.30	146.20	77.30	
34	0	9013	0	0	0	0	STR13		108.30	146.20	118.30	
35	9014	9015	9016	0	0	0	STR15		107.80	182.00	225.80	

S E C T I O N P R O P E R T I E S T A B L E MODES

SEC. NO.	OUTSIDE DIAMETER	WALL THICKNESS	SHEAR FACTOR	WEIGHT/UNIT LENGTH	MASS/UNIT LENGTH	COMPONENT DESIG NO.	B 1	B 2	C 1	C 2	S 11
1	7.288	0.2410	1.9984	2.1790E 00	5.6451E-03	1	0	0	0	0	0

4182T 01 10-28-92 10.470 P I S Y S 0 6 NRC PROBLEM 2

S E C T I O N P R O P E R T I E S T A B L E MODES

P I P E I N P U T D A T A

MODES

ELE NO	LINE ID	ELEMENT TYPE	FROM JOINT	FROM NODE	OUTP FLAG	BR	TO JOINT	TO NODE	OUTP FLAG	BR	MAT	SEC	TEMP	PRESS	DIST WGT	TO-RELE/ RADIUS	3RD POINT COORDINATES X	Y	Z
1	PIPE	STRAIGHT	001.	1	S	0	002.	2	S	0	10	1	0.	350.	2.				
2	PIPE	STRAIGHT	002.	2	S	0	003.	3	S	0	10	1	0.	350.	2.				
3	PIPE	BEND-CC	003.	3	S	0	004.	4	S	0	10	1	0.	350.	2.	36.	36.36	108.96	0.
4	PIPE	BEND-CC	004.	4	S	0	005.	5	S	0	10	1	0.	350.	2.	36.	36.36	108.96	0.
5	PIPE	STRAIGHT	005.	5	S	0	006.	6	S	0	10	1	0.	350.	2.				
6	PIPE	STRAIGHT	006.	6	S	0	007.	7	S	0	10	1	0.	350.	2.				
7	PIPE	BEND-CC	007.	7	S	0	008.	8	S	0	10	1	0.	350.	2.	36.	72.00	145.20	36.36
8	PIPE	BEND-CC	008.	8	S	0	009.	9	S	0	10	1	0.	350.	2.	36.	72.00	145.20	36.36
9	PIPE	STRAIGHT	009.	9	S	0	010.	10	S	0	10	1	0.	350.	2.				
10	PIPE	STRAIGHT	010.	10	S	0	011.	11	S	0	10	1	0.	350.	2.				
11	PIPE	STRAIGHT	011.	11	S	0	012.	12	S	0	10	1	0.	350.	2.				
12	PIPE	STRAIGHT	012.	12	S	0	013.	13	S	0	10	1	0.	350.	2.				
13	PIPE	STRAIGHT	013.	13	S	0	014.	14	S	0	10	1	0.	350.	2.				
14	PIPE	BEND-CC	014.	14	S	0	315.	15	S	0	10	1	0.	350.	2.	36.	108.30	181.50	188.80
15	PIPE	STRAIGHT	015.	15	S	0	016.	16	S	0	10	1	0.	350.	2.				
16	PIPE	STRAIGHT	016.	16	S	0	017.	17	S	0	10	1	0.	350.	2.				
17	PIPE	STRAIGHT	012.	12	S	0	018.	18	S	0	10	1	0.	350.	2.				
18	PIPE	STRAIGHT	018.	18	S	0	019.	19	S	0	10	1	0.	35C.	2.				
19	PIPE	BEND-CC	015.	19	S	0	020.	20	S	0	10	1	0.	350.	2.	36.	188.30	145.20	61.50
20	PIPE	STRAIGHT	020.	20	S	0	021.	21	S	0	10	1	0.	350.	2.				

1182T 01 10-28-92 10.470 P I S Y S 0 6 NRC PROBLEM 2

I P E I N P U T D A T A

MODES

R E S T R A I N T E L E M E N T I N P U T D A T A MODES

ELEM NO.	PIPE JOINT	REST. IDENT	R E S T R A I N T TYPE	STIFFNESS COEFFICIENTS (LOCAL) TRANSLATION	/ ROTATION	*APPLIED DISPLACEMENTS AS INPUT* (GLOBAL) X / RX	Y / RY	Z / RZ	TABLE IND
1	001.	A001	X ANCHOR X	1.0000E 10		0.			4
			+ RX		1.0000E 13	0.			
2	001.	A001	Y ANCHOR Y	1.0000E 10			0.		4
			+ RY		1.0000E 13		0.		
3	001.	A001	Z ANCHOR Z	1.0000E 10				0.	4
			+ RZ		1.0000E 13			0.	
4	017.	A017	X ANCHOR X	1.0000E 10		0.			4
			+ RX		1.0000E 00	0.			
5	017.	A017	Y ANCHOR Y	1.0000E 10			0.		4
			+ RY		1.0000E 00		0.		
6	017.	A017	Z ANCHOR Z	1.0000E 10				0.	4
			+ RZ		1.0000E 00			0.	
7	021.	A021	X ANCHOR X	1.0000E 10		0.			4
			+ RX		1.0000E 13	0.			
8	021.	A021	Y ANCHOR Y	1.0000E 10			0.		4
			+ RY		1.0000E 13		0.		
9	021.	A021	Z ANCHOR Z	1.0000E 10				0.	4
			+ RZ		1.0000E 13			0.	
10	007.	STR07	STRUT	1.0000E 08		0.	0.	0.	5
						0.	0.	0.	
11	009.	STR09	STRUT	1.0000E 08		0.	0.	0.	5
						0.	0.	0.	
12	011.	STR11	STRUT	1.0000E 04		0.	0.	0.	5
						0.	0.	0.	
13	013.	STR13	STRUT	1.0000E 04		0.	0.	0.	5
						0.	0.	0.	
14	015.	STR15	STRUT	1.0000E 08		0.	0.	0.	5
						0.	0.	0.	

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R E S T R A I N T E L E M E N T I N P U T D A T A MODES

J O I N T L O A D I N P U T F O R D Y N A M I C A N L Y S I S MODES

1	MAS	018.	586.0000	586.0000	586.0000

J O I N T L O A D I N P U T F O R D Y N A M I C A N L Y S I S MODES

S P E C T R U M T A B L E S

```
SPECTRUM TABLE NUMBER =     1
NUMBER OF ENTRIES     =   16
SPECTRUM TYPE         = PEROOD/      ACC
SCALE FACTOR          =  386.0
DAMPING COEFFICIENT   =    2.000E-02
DESCRIPTION           = X SPECTRUM

SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

    1.0000E-03   /     6.5000E-01
    6.0600E-02   /     6.5000E-01
    6.6100E-02   /     7.7000E-01
    1.0100E-01   /     9.0000E-01
    1.5150E-01   /     1.7500E 00
    1.7480E-01   /     2.0500E 00
    2.1370E-01   /     2.0500E 00
    2.9240E-01   /     1.6000E 00
    3.6360E-01   /     1.4600E 00
    4.1320E-01   /     1.7000E 00
    5.8650E-01   /     2.4000E 00
    7.2730E-01   /     4.1500E 00
    8.8850E-01   /     4.1500E 00
    1.5500E 00   /     8.1000E-01
    1.5873E 00   /     8.1400E-01
    2.5000E 00   /     2.7000E-01

SPECTRUM TABLE NUMBER =     2
NUMBER OF ENTRIES     =   13
SPECTRUM TYPE         = PEROOD/      ACC
SCALE FACTOR          =  386.0
DAMPING COEFFICIENT   =    2.000E-02
DESCRIPTION           = Y SPECTRUM

SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

    1.0000E-03   /     3.7000E-01
    6.4500E-02   /     3.7000E-01
    9.8000E-02   /     5.5000E-01
    1.1360E-01   /     7.3000E-01
    1.5150E-01   /     1.3200E 00
    1.8520E-01   /     1.3200E 00
    2.8000E-01   /     8.7000E-01
    4.0410E-01   /     9.0000E-01
    5.6820E-01   /     1.5000E 00
```

```
     7.2730E-01   /     2.8700E 00
     8.8890E-01   /     2.8700E 00
     1.3500E 00   /     1.1500E 00
     2.5000E 00   /     3.4000E-01

 SPECTRUM TABLE NUMBER =      3
 NUMBER OF ENTRIES     =    13
 SPECTRUM TYPE         = PEROOO/      ACC
 SCALE FACTOR          =   386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = Z SPECTRUM

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     5.5000E-01
     5.7100E-02   /     5.5000E-01
     7.6500E-02   /     6.5000E-01
     1.2540E-01   /     1.0000E 00
     1.8380E-01   /     1.3000E 00
     1.8180E-01   /     1.[illegible]800E 00
     2.2220E-01   /     1.[illegible]E 00
     3.7040E-01   /     1.0800E 00
     5.6820E-01   /     1.9500E 00
     7.2730E-01   /     3.5500E 00
     8.8890E-01   /     3.5500E 00
     1.4500E 00   /     1.0600E 00
     2.5000E 00   /     3.4000E-01
```

S P E C T R U M   T A B L E S

```
SPECTRUM TABLE NUMBER =     1
NUMBER OF ENTRIES     =   17
 PECTRUM TYPE         = PER000/      ACC
SCALE FACTOR          =  386.0
DAMPING COEFFICIENT   =   2.000E-02
DESCRIPTION           = XGROUP1

SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /      2.2000E-01
     2.8600E-02   /      2.2000E-01
     3.0300E-02   /      2.5000E-01
     9.0900E-02   /      4.2000E-01
     1.1660E-01   /      8.5000E-01
     1.5150E-01   /      1.2900E 00
     1.7480E-01   /      1.4200E 00
     2.1370E-01   /      1.4200E 00
     2.8490E-01   /      1.1500E 00
     3.7040E-01   /      7.5000E-01
     4.5450E-01   /      6.3000E-01
     5.5550E-01   /      6.3000E-01
     7.4070E-01   /      3.8000E-01
     9.0910E-01   /      5.7000E-01
     1.1111E 00   /      5.7000E-01
     1.3889E 00   /      2.2000E-01
     2.5000E 00   /      1.3000E-01

SPECTRUM TABLE NUMBER =     2
NUMBER OF ENTRIES     =   18
SPECTRUM TYPE         = PER000/      ACC
SCALE FACTOR          =  386.0
DAMPING COEFFICIENT   =   2.000E-02
DESCRIPTION           = YGROUP1

SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /      1.9000E-01
     3.1300E-02   /      1.9000E-01
     3.5100E-02   /      2.0500E-01
     6.2500E-02   /      2.0500E-01
     6.4900E-02   /      2.2000E-01
     1.0690E-01   /      4.2000E-01
     1.1490E-01   /      6.8000E-01
     1.5150E-01   /      9.0000E-01
```

```
     1.8180E-01   /    9.9800E-01
     2.2220E-01   /    9.9800E-01
     2.8570E-01   /    7.7000E-01
     5.5550E-01   /    4.2000E-01
     6.0610E-01   /    3.5000E-01
     6.9930E-01   /    7.1500E-01
     9.0910E-01   /    9.9500E-01
     1.1111E 00   /    9.9500E-01
     1.5625E 00   /    1.8000E-01
     2.5000E 00   /    1.8000E-01

  SPECTRUM TABLE NUMBER =     3
  NUMBER OF ENTRIES     =   15
  SPECTRUM TYPE         = PERDOD/     ACC
  SCALE FACTOR          =  386.0
  DAMPING COEFFICIENT   =    2.000E-02
  DESCRIPTION           = ZGROUP1

  SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /    1.7000E-01
     3.8500E-02   /    1.7000E-01
     4.5500E-02   /    2.0000E-01
     6.9900E-02   /    2.4000E-01
     1.2420E-01   /    4.7000E-01
     1.8180E-01   /    6.3000E-01
     2.2220E-01   /    6.3000E-01
     2.7780E-01   /    5.1000E-01
     4.0000E-01   /    3.0000E-01
     4.5450E-01   /    3.0000E-01
     6.4940E-01   /    7.8000E-01
     7.2730E-01   /    1.6000E 00
     8.8890E-01   /    1.6000E 00
     1.6667E 00   /    1.7000E-01
     2.5000E 00   /    1.7000E-01

  SPECTRUM TABLE NUMBZR =     4
  NUMBER OF ENTRIES     =   11
  SPECTRUM TYPE         = PERDOD/     ACC
  SCALE FACTOR          =  386.0
  DAMPING COEFFICIENT   =    2.000E-02
  DESCRIPTION           = XGROUP2

  SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /    2.3000E-01
     4.5500E-02   /    2.3000E-01
     5.8800E-02   /    3.0000E-02
     3.0303E-01   /    3.8000E-01
```

```
     5.0000E-01   /     7.5000E-01
     6.0610E-01   /     1.0700E 00
     6.9930E-01   /     2.2500E 00
     8.5470E-01   /     2.2500E 00
     1.8519E 00   /     2.3000E-01
     2.0833E 00   /     1.7000E-01
     2.5000E 00   /     1.7000E-01

 SPECTRUM TABLE NUMBER =     5
 NUMBER OF ENTRIES     =    11
 SPECTRUM TYPE         = PER000/      ACC
 SCALE FACTOR          =  386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = YGROUP2

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     3.7000E-01
     6.4500E-02   /     3.7000E-01
     1.2500E-01   /     6.5000E-01
     1.8180E-01   /     8.5000E-01
     2.2220E-01   /     8.5000E-01
     4.0410E-01   /     9.0000E-01
     5.6820E-01   /     1.5000E 00
     7.2730E-01   /     2.8700E 00
     8.8890E-01   /     2.8700E 00
     1.6390E 00   /     3.0000E-01
     2.5000E 00   /     1.7000E-01

 SPECTRUM TABLE NUMBER =     6
 NUMBER OF ENTRIES     =    14
 SPECTRUM TYPE         = PER000/      ACC
 SCALE FACTOR          =  386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = ZGROUP2

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     5.5000E-01
     5.7100E-02   /     5.5000E-01
     7.6900E-02   /     6.5000E-01
     1.2540E-01   /     1.0000E 00
     1.5380E-01   /     1.3000E 00
     1.8180E-01   /     1.3800E 00
     2.2220E-01   /     1.3600E 00
     3.7040E-01   /     1.0800E 00
     5.6820E-01   /     1.9500E 00
     7.2730E-01   /     3.5500E 00
     8.8890E-01   /     3.5500E 00
```

```
     1.6667E 00   /     3.6200E-01
     2.0000E 00   /     2.0000E-01
     2.5000E 00   /     2.0000E-01

 SPECTRUM TABLE NUMBER =     7
 NUMBER OF ENTRIES     =    15
 SPECTRUM TYPE         = PEROOO/       ACC
 SCALE FACTOR          =  388.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = XGROUP3

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     6.5000E-01
     6.0600E-02   /     6.5000E-01
     6.6100E-02   /     7.7000E-01
     1.0100E-01   /     9.0000E-01
     1.5150E-01   /     1.7500E 00
     1.7480E-01   /     2.0500E 00
     2.1370E-01   /     2.0500E 00
     2.9240E-01   /     1.6000E 00
     3.6360E-01   /     1.4600E 00
     4.1320E-01   /     1.7000E 00
     5.8650E-01   /     2.4000E 00
     7.2730E-01   /     4.1500E 00
     8.8890E-01   /     4.1500E 00
     1.6611E 00   /     4.2000E-01
     2.5000E 00   /     1.8000E-01

 SPECTRUM TABLE NUMBER =     8
 NUMBER OF ENTRIES     =    14
 SPECTRUM TYPE         = PEROOO/       ACC
 SCALE FACTOR          =  386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = YGROUP3

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     2.3000E-01
     3.6400E-02   /     2.3000E-01
     4.0400E-02   /     2.5000E-01
     9.0900E-02   /     4.2000E-01
     1.1360E-01   /     7.3000E-01
     1.5150E-01   /     1.3200E 00
     1.8520E-01   /     1.3200E 00
     3.8310E-01   /     5.6000E-01
     5.5550E-01   /     5.3000E-01
     9.2590E-01   /     2.8000E-01
     1.1111E 00   /     1.7000E-01
```

```
     1.4204E 00   /     2.8000E-01
     1.7361E 00   /     2.8000E-01
     2.5000E 00   /     1.4000E-01

 SPECTRUM TABLE NUMBER =     9
 NUMBER OF ENTRIES     =    18
 SPECTRUM TYPE         = PEROOO/      ACC
 SCALE FACTOR          =  386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = ZGROUP3

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     1.1200E-01
     3.1300E-02   /     1.1200E-01
     3.4900E-02   /     1.2500E-01
     5.8800E-02   /     1.3P00E-01
     7.1300E-02   /     1.8000E-01
     1.1360E-01   /     3.4600E-01
     1.5150E-01   /     5.5000E-01
     1.8520E-01   /     5.5000E-01
     2.7780E-01   /     3.3000E-01
     3.7590E-01   /     2.1400E-01
     6.1730E-01   /     1.7000E-01
     7.0170E-01   /     1.2500E-01
     7.2730E-01   /     1.9500E-01
     9.0910E-01   /     2.5000E-01
     1.0695E 00   /     4.9800E-01
     1.3568E 00   /     5.3500E-01
     1.6584E 00   /     5.3500E-01
     2.5000E 00   /     2.2400E-01

 SPECTRUM TABLE NUMBER =    10
 NUMBER OF ENTRIES     =    13
 SPECTRUM TYPE         = PEROOO/      ACC
 SCALE FACTOR          =  386.0
 DAMPING COEFFICIENT   =    2.000E-02
 DESCRIPTION           = XGROUP4

 SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     1.2600E-01
     5.5500E-02   /     1.2600E-01
     6.7300E-02   /     1.4000E-01
     1.1360E-01   /     2.1500E-01
     1.5150E-01   /     3.1000E-01
     1.8520E-01   /     3.1000E-01
     3.7040E-01   /     2.6500E-01
     4.9140E-01   /     3.3500E-01
```

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M U L T I P L E   S U P P O R T   R E S P O N S E   S P E C T R U M   I N P U T   M-RSRSS

```
     7.5750E-01   /     5.3600E-01
     1.0695E 00   /     8.5000E-01
     1.3072E 00   /     8.5000E-01
     1.5873E 00   /     6.1400E-01
     2.5000E 00   /     2.7000E-01

  SPECTRUM TABLE NUMBER =    11
  NUMBER OF ENTRIES     =    15
  SPECTRUM TYPE         = PER000/      ACC
  SCALE FACTOR          =  386.0
  DAMPING COEFFICIENT   =    2.000E-02
  DESCRIPTION           = YGROUP4

  SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     2.1000E-01
     3.5700E-02   /     2.1000E-01
     5.4100E-02   /     2.6000E-01
     6.7300E-02   /     3.6000E-01
     1.0330E-01   /     4.2000E-01
     1.2120E-01   /     7.3000E-01
     1.5150E-01   /     1.0200E 00
     1.8520E-01   /     1.0200E 00
     2.3150E-01   /     8.5000E-01
     4.9140E-01   /     6.8000E-01
     6.0060E-01   /     6.8000E-01
     7.2730E-01   /     8.5000E-01
     1.0695E 00   /     1.2000E 00
     1.3072E 00   /     1.2000E 00
     2.5000E 00   /     3.4000E-01

  SPECTRUM TABLE NUMBER =    12
  NUMBER OF ENTRIES     =    15
  SPECTRUM TYPE         = PER000/      ACC
  SCALE FACTOR          =  386.0
  DAMPING COEFFICIENT   =    2.000E-02
  DESCRIPTION           = ZGROUP4

  SPECTRAL PERIOD   /   DISPLACEMENT-OR-ACCELERATION

     1.0000E-03   /     2.1000E-01
     3.5700E-02   /     2.1000E-01
     5.4100E-02   /     2.6000E-01
     6.7300E-02   /     3.6000E-01
     1.0330E-01   /     4.2000E-01
     1.2120E-01   /     7.3000E-01
     1.5150E-01   /     1.0200E 00
     1.8520E-01   /     1.0200E 00
     2.3150E-01   /     8.5000E-01
```

4.9140E-01	/	6.8000E-01
5.0060E-01	/	6.8000E-01
7.2730E-01	/	8.5000E-01
1.0695E 00	/	1.2000E 00
1.3072E 00	/	1.2000E 00
2.5000E 00	/	3.4000E-01

SUPPORT EXCITATION INPUT INFORMATION

RESTRAINT LABEL	S P E C T R U M M U L T I P L I E R S X TRANSLATIONAL	Y TRANSLATIONAL	Z TRANSLATIONAL	SPECTRUM NUMBER
A001	1.00000E 00	0.	0.	1
A001	0.	1.00000E 00	0.	2
A001	0.	0.	1.00000E 00	3
STR07	0.	0.	1.00000E 00	6
STR09	1.00000E 00	0.	0.	4
STR11	0.	1.00000E 00	0.	5
STR13	0.	1.00000E 00	0.	5
STR15	1.00000E 00	0.	0.	4
STR15	0.	1.00000E 00	0.	5
STR15	0.	0.	1.00000E 00	6
A017	1.00000E 00	0.	0.	7
A017	0.	1.00000E 00	0.	8
A017	0.	0.	1.00000E 00	9
A021	1.00000E 00	0.	0.	10
A021	0.	1.00000E 00	0.	11
A021	0.	0.	1.00000E 00	12

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ULTIPLE SUPPORT RESPONSE SPECTRUM INPUT M-RSRSS

APPENDIX 2

APPENDIX 2

TABLE OF CONTENTS

**** E I G E N V A L U E S U M M A R Y T A B L E ****

MODE LABEL	CIRCULAR FREQUENCY (RAD/TIME)	FREQUENCY (HERTZ)	PERIOD (TIME)	JOINT LABEL	DEG OF FREEDOM	MAXIMUM DISPLACEMT	JOINT LABEL	DEG OF FREEDOM	MAXIMUM ROTATION
1	5.8771E 01	9.3536E 00	1.0691E-01	004	3	6.1021E-01	004	5	1.2869E-02
2	7.9822E 01	1.2704E 01	7.8715E-02	019	2	6.2947E-01	019	6	7.1745E-03
3	9.6612E 01	1.5376E 01	6.5036E-02	013	1	5.9348E-01	013	5	1.1025E-02
4	1.1184E 02	1.7800E 01	5.6179E-02	008	2	1.3528E 00	008	6	1.8180E-02
5	1.3573E 02	2.1602E 01	4.6293E-02	003	3	1.0809E 00	003	5	1.9125E-02
6	1.5767E 02	2.5094E 01	3.9850E-02	003	3	7.3024E-01	003	5	1.3446E-02
7	2.0121E 02	3.2024E 01	3.1226E-02	014	1	7.8452E-01	014	6	2.0955E-02
8	2.3911E 02	3.8056E 01	2.6277E-02	019	2	7.7531E-01	019	6	2.0409E-02
9	2.5315E 02	4.0290E 01	2.4820E-02	014	1	7.6198E-01	014	6	1.9216E-02
10	3.0702E 02	4.8864E 01	2.0465E-02	002	1	9.1061E-01	002	6	2.6736E-02
11	3.6121E 02	5.7488E 01	1.7395E-02	016	3	1.3428E 00	016	4	3.7179E-02
12	3.8621E 02	6.1467E 01	1.6269E-02	002	3	8.5990E-01	002	4	3.4108E-02
13	3.9280E 02	6.2517E 01	1.5996E-02	002	3	9.4731E-01	002	4	3.1840E-02
14	4.3556E 02	6.9321E 01	1.4426E-02	016	1	7.5543E-01	016	5	3.7158E-02
15	4.8657E 02	7.7440E 01	1.2913E-02	006	2	8.3609E-01	006	6	3.7686E-02
16	4.9573E 02	7.8898E 01	1.2675E-02	002	1	8.0872E-01	002	6	2.6034E-02
17	6.3879E 02	1.0167E 02	9.8360E-03	019	3	1.2658E 00	019	5	1.9621E-02
18	6.5052E 02	1.0353E 02	9.6587E-03	020	2	1.3046E 00	020	4	4.6940E-02
19	6.7821E 02	1.0794E 02	9.2643E-03	008	2	8.6067E-01	008	4	5.1772E-02
20	7.2307E 02	1.1508E 02	8.6896E-03	005	3	1.4408E 00	005	4	5.6717E-02
21	8.4943E 02	1.3519E 02	7.3970E-03	014	2	9.6116E-01	014	4	3.1118E-02
22	9.7483E 02	1.5515E 02	6.4454E-03	013	1	1.3449E 00	013	5	4.7870E-02
23	1.0087E 03	1.6054E 02	6.2292E-03	013	1	1.0284E 00	013	6	4.7810E-02
24	1.2798E 03	2.0369E 02	4.9095E-03	020	1	1.2986E 00	020	5	2.7515E-02
25	1.3183E 03	2.0981E 02	4.7661E-03	009	2	1.0989E 00	009	4	6.4364E-02

R E S P O N S E S P E C T R U M A N A L Y S I S RESNCSM

M O D A L P A R T I C I P A T I O N F A C T O R S

MODE NUMBER	FREQUENCY (HERTZ)	X- DIRECTION	Y- DIRECTION	Z- DIRECTION
1	9.354	1.0040E 00	-6.9794E-02	9.7519E-01
2	12.704	2.5216E-01	1.8321E 00	-4.4622E-02
3	15.376	1.4277E 00	-2.0434E-01	-2.2613E-01
4	17.800	2.0214E-01	2.2855E-01	5.0213E-02
5	21.602	4.6496E-01	2.8298E-02	7.7561E-01
6	25.094	1.3198E-01	-8.3310E-02	1.3389E 00
7	32.024	-2.2480E-01	2.3648E-01	4.6862E-01
8	38.056	-1.0960E-01	-1.4137E-03	-1.0750E-01
9	40.290	-8.2179E-01	1.8467E-02	4.2084E-01
10	48.864	-4.5565E-01	-2.1821E-01	1.5989E-01
11	57.488	1.9309E-01	2.2510E-01	-4.1049E-01
12	61.467	-1.5095E-01	3.5732E-01	1.6070E-01
13	62.517	1.1043E-01	2.2197E-01	-1.1996E-01
14	69.321	3.3779E-01	-1.9063E-01	-1.0750E-01
15	77.440	-3.8745E-01	1.2930E-01	2.7940E-01
16	78.898	-3.0980E-01	-5.6993E-02	2.3320E-01
17	101.667	3.0705E-01	-5.0319E-03	-1.0332E-01
18	103.533	-5.1132E-02	-2.3501E-01	8.4793E-02
19	107.941	-3.1882E-03	-7.4042E-03	-2.2460E-01
20	115.080	[illegible]418E-02	1.1901E-01	-3.6387E-01
21	135.190	-3.1441E-01	3.9575E-01	4.2917E-01
22	155.149	1.2773E-01	-1.1478E-01	-5.5857E-02
23	160.535	1.0418E-01	1.8486E-01	4.4348E-02
24	203.687	-1.5102E-02	-4.0649E-02	-3.0817E-01
25	209.814	-2.0825E-03	-1.4549E-01	2.0993E-02

1182T 01 10-28-92 10.470 P I S Y S 0 6 NRC PROBLEM 2

I E S P O N S E S P E C T R U M A N A L Y S I S RESNCSM

UNIFORM SUPPORT MOTION RESULTS

R E S P O N S E   S P E C T R U M   M O D A L   R E P O R T   RESNCSM

C O M B I N E D   N O D E   D I S P L A C E M E N T S / R O T A T I O N S
C O M B I N A T I O N   M E T H O D   4 FOR MODAL SHAPES.   MODE # 1 TO 25

LOAD CASES # 1 TO 3 (FINAL)

JOINT LABEL	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
001.	9.05773E-09	6.48230E-09	1.77395E-08	1.63482E-09	5.12226E-10	7.00363E-10
002.	1.04915E-02	2.76706E-06	2.49826E-02	7.97324E-04	4.55612E-04	3.31906E-04
003.	3.21250E-02	5.48827E-06	7.71340E-02	1.02696E-03	9.11223E-04	4.39070E-04
004.	4.31493E-02	4.89838E-03	9.07842E-02	8.99298E-04	1.20343E-03	4.68367E-04
005.	4.75002E-02	1.89467E-02	8.31397E-02	7.38909E-04	1.63752E-03	4.77212E-04
006.	4.74958E-02	2.52022E-02	3.27249E-02	6.79389E-04	1.76944E-03	4.66675E-04
007.	4.74899E-02	3.31523E-02	7.08536E-06	6.20878E-04	1.89509E-03	4.45324E-04
008.	2.80692E-02	3.78711E-02	4.91928E-02	5.39262E-04	1.66033E-03	3.78868E-04
009.	4.46086E-06	3.10999E-02	6.31746E-02	4.15274E-04	6.02203E-04	3.55226E-04
010.	1.07516E-02	2.48824E-02	6.32872E-02	3.50443E-04	5.04223E-04	3.54534E-04
011.	2.00763E-02	2.06305E-02	6.33555E-02	2.63582E-04	5.41709E-04	3.66577E-04
012.	2.85234E-02	1.85714E-02	6.34398E-02	1.83187E-04	5.74299E-04	3.90177E-04
013.	3.74436E-02	1.64430E-02	6.34945E-02	1.77887E-04	7.00373E-04	3.84349E-04
014.	8.51208E-02	8.48633E-03	6.35509E-02	1.77923E-04	8.94720E-04	5.22038E-04
015.	8.94865E-02	1.67606E-04	6.38204E-02	2.79945E-04	8.67636E-04	7.25189E-04
016.	4.77781E-02	8.35832E-05	4.02436E-02	6.28254E-04	8.67636E-04	8.32875E-04
017.	5.84627E-09	1.98155E-08	1.03614E-08	7.99508 -04	8.67636E-04	9.09222E-04
018.	2.85870E-02	3.17777E-02	4.22348E-02	1.82986E-04	6.00222E-04	2.22504E-04
019.	2.85249E-02	3.29267E-02	1.81011E-02	3.37175E-04	6.43053E-04	1.22456E-04
020.	1.31238E-02	9.51383E-03	7.95275E-05	3.74366E-04	4.76766E-04	1.56790E-04
021.	3.77922E-08	1.51800E-08	2.45311E-08	1.11346E-09	1.65984E-09	2.31279E-10

MAXIMUM DISPLACEMENT, 9.07842E-02, OCCURED AT JOINT 004.
MAXIMUM ROTATION, 1.89509E-03, OCCURED AT JOINT 007.

1182T 01   10-28-92   10.470   P I S Y S 0 6   NRC PROBLEM 2

IESPONSE   S P E C T R U M   M O D A L   R E P O R T   RESNCSM

R E S P O N S E S P E C T R U M A N A L Y S I S --- S T R E S S R E P O R T PISYS PAGE 7
E L E M E N T T Y P E 1 --- 3-D S T R A I G H T O R C U R V E D P I P E E L E M E N T S

C O M B I N E D E L E M E N T F O R C E S A N D M O M E N T S
C O M B I N E D M E T H O D 4 L O A D C A S E 1 T O L O A D C A S E 3 --- F I N A L

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1T		001.	64.823	177.395	90.577	5122.262	7003.629	16348.197
		002.	64.823	177.395	90.577	5122.262	3189.710	7139.996
2T		002.	64.264	138.049	62.460	5122.262	3189.710	7139.996
		003.	64.264	138.049	62.460	5122.262	2236.067	1772.612
3B		003.	83.497	53.244	80.412	5122.996	1770.487	2236.067
		CENTER	64.941	51.473	80.412	4427.997	3354.643	2252.854
		304.	62.810	54.053	80.412	2763.704	5525.774	2229.505
4B		004.	72.695	49.324	83.557	2760.115	5527.567	2229.505
		CENTER	71.384	51.203	83.557	705.474	6330.975	2065.819
		005.	64.670	59.458	83.557	2199.999	6419.021	1948.719
5T		005.	85.039	47.695	100.574	2214.267	6414.112	1948.719
		006.	85.039	47.595	100.574	2214.267	6863.168	1964.124
6T		006.	104.365	35.260	108.889	2214.267	6863.168	1964.124
		007.	104.365	36.260	108.889	2214.267	7627.589	2105.901
7B		007.	131.633	691.843	26.231	2214.267	2105.901	7627.589
		CENTER	252.400	657.260	26.231	2782.192	1242.166	4747.613
		008.	466.473	527.352	26.231	2970.000	799.739	12046.584
8B		008.	446.278	518.867	32.491	2969.991	799.774	12046.584
		CENTER	597.395	333.924	32.491	2713.744	1461.925	17799.758
		009.	665.506	159.653	32.491	2027.247	2483.349	20580.371
9T		009.	638.511	53.588	392.119	2022.596	20580.371	2487.139
		010.	638.511	53.588	392.119	2022.596	14850.814	3046.132
10T		010.	616.324	72.299	384.763	2022.596	14850.814	3046.132
		011.	616.324	72.299	384.763	2022.596	11943.578	4072.522
11T		011.	594.637	131.067	368.994	2022.596	11943.578	4072.522
		012	594.637	131.067	368.994	2022.596	13332.107	3382.714

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT PISYS PAGE 8
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 4 LOAD CASE 1 TO LOAD CASE 3 --- FINAL

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
12T		012.	384.131	151.138	116.805	2862.954	7733.677	4791.522
		013.	384.131	151.138	116.805	2862.954	6413.350	2467.696
13T		013.	339.165	56.662	92.374	2862.954	6413.350	2467.696
		014.	339.165	56.662	92.374	2862.954	3383.554	3333.620
148		014.	287.359	62.955	93.211	2862.954	3383.554	3333.620
		CENTER	209.729	206.282	93.211	1660.606	2024.415	2048.118
		015.	62.955	287.359	93.211	0.001	2891.604	7919.476
15T		015.	197.424	56.848	39.078	0.001	2891.604	7919.476
		016.	197.424	56.848	39.078	0.001	3156.984	5595.141
16T		016.	198.155	103.614	58.463	0.001	3156.984	5595.141
		017.	198.155	103.614	58.463	0.001	0.001	0.001
17T		012.	244.890	249.534	274.735	3066.520	9736.197	2033.078
		018.	244.890	249.534	274.735	3066.520	6251.679	8422.200
18T		018.	286.423	114.270	234.655	3066.520	6251.679	8422.200
		019.	286.423	114.270	234.655	3066.520	4663.941	3968.614
198		019.	343.730	244.798	171.538	3066.520	3968.614	4663.941
		CENTER	403.108	124.820	171.538	1304.121	639.920	6677.586
		020.	244.798	343.730	171.538	2312.786	3266.971	3828.070
20T		020.	245.311	191.500	377.922	2312.786	3828.070	3266.971
		021.	245.311	191.500	377.922	2312.786	16598.383	11134.554

MAXIMUM AND/OR MINIMUM VALUES
CORRESPONDING ELEM/LOAD-CASE

	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
MAXIMUM TANG	638.511	249.535	392.119	5122.262	20580.372	16348.197
	9-	17-	9-	1-	9-	1-
MINIMUM	64.264	36.260	39.078	0.001	0.001	0.001

R E S P O N S E S P E C T R U M A N A L Y S I S --- S T R E S S R E P O R T
E L E M E N T T Y P E 2 --- R E S T R A I N T E L E M E N T

C O M B I N E D E L E M E N T F O R C E S A N D M O M E N T S
C O M B I N E D M E T H O D 4 L O A D C A S E 1 T O L O A D C A S E 3 --- F I N A L

ELEM NO	LOAD CASE	RESTRAINT TYPE	PIPE JOINT	STRUCT. POINT	RESTRAINT FORCE	RESTRAINT MOMENT
1		ANCHOR	001.	A001 X	9.058E 01	1.635E 04
2		ANCHOR	001.	A001 Y	6.492E 01	5.122E 03
3		ANCHOR	001.	A001 Z	1.774E 02	7.004E 03
4		ANCHOR	017.	A017 X	5.846E 01	7.995E-04
5		ANCHOR	017.	A017 Y	1.982E 02	8.676E-04
6		ANCHOR	017.	A017 Z	1.036E 02	9.092E-04
7		ANCHOR	021.	A021 X	3.770E 02	1.113E 04
8		ANCHOR	021.	A021 Y	1.915E 02	1.660E 04
9		ANCHOR	021.	A021 Z	2.453E 02	2.313E 03
10		STRUT	007.	STR07	7.085E 02	0.
11		STRUT	009.	STR09	4.461E 02	0.
12		STRUT	011.	STR11	2.063E 02	0.
13		STRUT	013.	STR13	1.644E 02	0.
14		STRUT	015.	STR15	3.735E 02	0.

RESULTS FOR INDEPENDENT SUPPORT MOTION METHOD
WITH SRSS OF GROUP CONTRIBUTIONS

COMBINED NODE DISPLACEMENTS/ROTATIONS
COMBINATION METHOD 4 FOR MODAL SHAPES, MODE # 1 TO 25

LOAD CASES # 1 TO 3 (FINAL)

JOINT LABEL	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
001.	5.30190E-09	4.59802E-09	1.12823E-08	1.03366E-09	3.23525E-10	4.20680E-10
002.	6.35719E-03	1.95564E-05	1.57892E-02	5.03864E-04	2.87767E-04	2.02653E-04
003.	1.97112E-02	3.89262E-08	4.87457E-02	6.49262E-04	5.75534E-04	2.73400E-04
004.	2.66698E-02	3.10368E-09	5.73824E-02	5.69213E-04	7.60137E-04	2.98941E-04
005.	2.94730E-02	1.06671E-02	3.99232E-02	4.68378E-04	1.03520E-03	3.07194E-04
006.	2.94707E-02	1.61948E-02	2.06975E-02	4.31281E-04	1.11879E-03	2.98815E-04
007.	2.94668E-02	2.12895E-02	4.41078E-06	3.95099E-04	1.19907E-03	2.82394E-04
008.	1.69875E-02	2.41274E-62	3.11272E-02	3.46665E-04	1.04554E-03	2.30135E-04
009.	2.57214E-06	1.93836E-02	3.98825E-02	2.74218E-04	2.56585E-04	2.10831E-04
010.	2.92336E-03	1.51746E-02	3.99429E-02	2.34351E-04	1.31398E-04	2.09186E-04
011.	5.12675E-03	1.23107E-02	4.00007E-02	1.78863E-04	2.64034E-04	2.17090E-04
012.	1.02998E-02	1.09979E-02	4.00560E-02	1.23406E-04	3.56976E-04	2.33575E-04
013.	1.77820E-02	9.82350E-03	4.00911E-02	1.09362E-04	4.43807E-04	2.32358E-04
014.	5.31151E-02	5.30365E-03	4.01919E-02	1.08140E-04	5.36826E-04	3.21238E-04
015.	5.66386E-02	1.04572E-04	4.03928E-02	1.74011E-04	4.83242E-04	4.56043E-04
016.	3.01609E-02	5.21681E-05	2.55088E-02	3.97791E-04	4.83242E-04	5.26917E-04
017.	3.20586E-0[illegible]	1.23678E-08	6.65033E-09	5.07043E-04	4.83242E-04	5.73184E-04
018.	1.03329E-02	1.87337E-02	2.67492E-02	1.21526E-04	3.64577E-04	1.37720E-04
019.	1.03351E-02	1.95036E-02	1.11548E-02	2.05452E-04	3.98450E-04	7.63850E-05
020.	3.28172E-03	5.66669E-03	3.74833E-05	2.23105E-04	1.29808E-04	9.22412E-05
021.	1.03240E-08	1.13949E-08	1.15621E-08	6.62934E-10	4.03266E-10	1.36063E-10

MAXIMUM DISPLACEMENT, 5.73824E-02, OCCURED AT JOINT 004.
MAXIMUM ROTATION, 1.19907E-03, OCCURED AT JOINT 007.

R E S P O N S E S P E C T R U M A N A L Y S I S --- S T R E S S R E P O R T
E L E M E N T T Y P E 1 --- 3-D S T R A I G H T O R C U R V E D P I P E E L E M E N T S

C O M B I N E D E L E M E N T F O R C E S A N D M O M E N T S
C O M B I N E D M E T H O D 4 L O A D C A S E 1 T O L O A D C A S E 3 --- F I N A L

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1T		001.	45.980	112.823	53.019	3235.255	4206.797	10336.547
		002.	45.980	112.823	53.019	3235.255	2003.763	4526.026
2T		002.	45.562	87.567	38.977	3235.255	2003.763	4526.026
		003.	45.562	87.567	38.977	3235.255	1403.728	1166.654
3B		003.	45.009	28.532	51.521	3235.713	1165.383	1403.728
		CENTER	45.491	27.758	51.521	2799.984	2134.696	1451.876
		004.	41.639	33.258	51.521	1757.694	3498.897	1396.847
4B		004.	44.669	27.691	53.878	1755.455	3500.021	1396.847
		CENTER	39.101	35.118	53.878	509.608	4012.220	1225.655
		005.	31.239	42.265	53.878	1420.376	4079.544	1119.868
5T		005.	43.206	33.513	64.258	1429.281	4076.433	1119.868
		006.	43.206	33.513	64.258	1429.281	4382.105	1207.336
6T		006.	55.028	24.288	69.293	1429.281	4382.105	1207.336
		007.	55.028	24.289	69.293	1429.281	4885.091	1387.517
7B		007.	71.710	430.164	14.956	1429.281	1387.517	4885.091
		CENTER	143.288	411.888	14.956	1760.552	958.429	2800.276
		008.	281.874	332.762	14.956	1883.645	763.291	7387.027
8B		008.	264.986	327.669	22.726	1883.649	763.281	7387.027
		CENTER	364.269	211.879	22.726	1749.034	978.190	11069.412
		009.	411.717	89.855	22.726	1348.199	1564.865	12903.079
9T		009.	392.192	36.780	195.000	1345.434	12903.079	1567.242
		010.	392.192	36.780	195.000	1345.434	9309.948	1936.918
10T		010.	375.873	48.527	194.339	1345.434	9309.948	1936.918
		011.	375.873	48.527	194.339	1345.434	6194.935	2634.640
11T		011.	359.659	77.617	191.212	1345.434	6194.935	2634.640
		012.	359.659	77.617	191.212	1345.434	4577.641	2284.000

R E S P O N S E S P E C T R U M A N A L Y S I S --- S T R E S S R E P O R T
E L E M E N T T Y P E 1 --- 3-D S T R A I G H T O R C U R V E D P I P E E L E M E N T S

C O M B I N E D E L E M E N T F O R C E S A N D M O M E N T S
C O M B I N E D M E T H O D 4 L O A D C A S E 1 T O L O A D C A S E 3 --- F I N A L

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
12T		012.	240.317	89.005	68.718	1728.574	4246.341	2980.309
		013.	240.317	89.005	68.718	1728.574	2975.171	1666.828
13T		013.	211.079	34.057	53.427	1728.574	2975.171	1666.828
		014.	211.079	34.057	53.427	1728.574	1339.507	2062.930
14B		014.	176.309	40.913	36.901	1728.574	1339.507	2062.[illegible]0
	CENTER		126.543	129.405	36.901	983.734	1222.287	1201.7[illegible]
		015.	40.913	176.309	36.901	0.000	1390.845	4989.986
15T		015.	123.132	37.129	23.854	0.000	1390.845	4989.986
		016.	123.132	37.129	23.854	0.000	1731.164	3591.175
16T		016.	123.678	66.503	32.059	0.000	1731.164	3591.175
		017.	123.678	66.503	32.059	0.000	0.001	0.001
17T		012.	135.274	147.479	154.878	1807.640	3396.281	1264.316
		018.	135.274	147.479	154.878	1807.640	3549.961	4972.630
18T		018.	91.121	67.723	99.037	1807.640	3549.961	4972.630
		019.	91.121	67.723	99.037	1807.640	1486.801	2370.063
19B		019.	95.852	115.405	101.402	1807.640	2370.063	1486.801
	CENTER		142.877	45.740	101.402	786.847	397.861	2835.987
		020.	115.405	95.852	101.402	1360.634	1959.671	2303.965
20T		020.	115.621	113.949	103.240	1360.634	2303.965	1959.671
		021.	115.621	113.949	103.240	1360.634	4032.[illegible]60	6629.338

M A X I M U M A N D / O R M I N I M U M V A L U E S
C O R R E S P O N D I N G E L E M / L O A D - C A S E

	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
MAXIMUM TANG	392.[illegible]	147.479	195.000	3235.255	12903.079	10336.647
	9-	17-	9-	1-	3-	1-
MINIMUM	43.206	24.288	23.854	0.000	0.001	0.001

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT
ELEMENT TYPE 2 --- RESTRAINT ELEMENT

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 4 LOAD CASE 1 TO LOAD CASE 3 ---FINAL

ELEM NO	LOAD CASE	RESTRAINT TYPE	PIPE JOINT	STRUCT. POINT	RESTRAINT FORCE	RESTRAINT MOMENT
1		ANCHOR	001.	A001 X	5.302E 01	1.034E 04
2		ANCHOR	001.	A001 Y	4.598E 01	3.235E 03
3		ANCHOR	001.	A001 Z	1.128E 02	4.207E 03
4		ANCHOR	017.	A017 X	3.206E 01	5.070E-04
5		ANCHOR	017.	A017 Y	1.237E 02	4.832E-04
6		ANCHOR	017.	A017 Z	6.650E 01	5.732E-04
7		ANCHOR	021.	A021 X	1.032E 02	6.629E 03
8		ANCHOR	021.	A021 Y	1.139E 02	4.033E 03
9		ANCHOR	021.	A021 Z	1.156E 02	1.361E 03
10		STRUT	007.	STR07	4.411E 02	0.
11		STRUT	009.	STR09	2.572E 02	0.
12		STRUT	011.	STR11	1.231E 02	0.
13		STRUT	013.	STR13	9.823E 01	0.
14		STRUT	015.	STR15	2.211E 02	0.

4182T 01 10-28-92 10.470 P I S Y S 0 6 NRC PROBLEM 2
MULTIPLE SUPPORT RESPONSE SPECTRUM STRESS REPORT M-RSRSS

RESULTS FOR INDEPENDENT SUPPORT MOTION METHOD
WITH ABS OF GROUP CONTRIBUTIONS

COMBINED NODE DISPLACEMENTS/ROTATIONS
COMBINATION METHOD 1 FOR MODAL SHAPES, MODE # 1 TO 25

LOAD CASE # 1 (FINAL)

JOINT LABEL	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
001.	3.49746E-09	2.61009E-08	4.14327E-09	3.50895E-10	1.07911E-10	1.91497E-10
002.	2.61394E-03	1.11013E-08	5.30699E-03	1.68439E-04	9.59839E-05	7.76568E-05
003.	7.28705E-03	2.20891E-08	1.62572E-02	2.15610E-04	1.91968E-04	9.55626E-05
004.	9.44917E-03	1.11018E-03	1.90774E-02	1.88379E-04	2.53595E-04	1.08766E-04
005.	1.02870E-02	3.97665E-03	1.32360E-02	1.57477E-04	3.44025E-04	1.14348E-04
006.	1.02858E-02	5.94297E-03	6.85370E-03	1.47151E-04	3.70956E-04	1.10431E-04
007.	1.02838E-02	7.79923E-03	1.61621E-06	1.37799E-04	3.96449E-04	1.02495E-04
008.	6.23919E-03	8.64205E-03	1.02931E-02	1.28992E-04	3.51297E-04	7.24415E-05
009.	1.17797E-06	6.40805E-03	1.32873E-02	1.12351E-04	1.37368E-04	5.49464E-05
010.	2.25598E-03	4.52358E-03	1.33054E-02	9.91556E-05	1.04034E-04	5.05784E-05
011.	4.12766E-03	3.15811E-03	1.3322[illegible]E-02	7.82684E-05	1.24067E-04	5.46006E-05
012.	5.22953E-03	2.59349E-03	1.3338[illegible]E-02	5.43318E-05	1.25315E-04	6.54953E-05
013.	8.53785E-03	2.50930E-03	1.33499E-02	4.19860E-05	1.47843E-04	6.93403E-05
014.	1.83051E-02	1.92315E-03	1.33812E-02	3.34910E-05	1.99939E-04	1.14968E-04
015.	1.87074E-02	4.34726E-05	1.33423E-02	6.45034E-05	2.00676E-04	1.56451E-04
016.	1.01389E-02	2.17259E-05	8.45986E-03	1.31299E-04	2.00676E-04	1.74414E-04
017.	2.05577E-09	5.15068E-09	2.50925E-09	1.68856E-04	2.00676E-04	1.94746E-04
018.	6.24498E-03	3.76135E-03	8.87003E-03	4.93581E-05	1.33263E-04	5.30729E-05
019.	6.23427E-03	4.50831E-03	3.99004E-03	6.14066E-05	1.39980E-04	3.23872E-05
020.	2.65790E-03	1.53883E-03	1.96957E-05	5.97247E-05	9.89856E-05	1.94342E-05
021.	8.05864E-09	3.38158E-09	6.07535E-09	1.82832E-10	3.41455E-10	2.86671E-11

MAXIMUM DISPLACEMENT, 1.90774E-02, OCCURED AT JOINT 004.
MAXIMUM ROTATION, 3.96449E-04, OCCURED AT JOINT 007.

C O M B I N E D N O D E D I S P L A C E M E N T S / R O T A T I O N S
C O M B I N A T I O N M E T H O D 1 FOR MODAL SHAPES, MODE # 1 TO 25

LOAD CASE # 2 (FINAL)

JOINT LABEL	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
001.	4.83631E-09	5.96294E-08	8.04735E-09	5.30809E-10	1.65299E-10	2.99419E-10
002.	4.15179E-03	2.53817E-05	8.04810E-03	2.55749E-04	1.47029E-04	1.22393E-04
003.	1.10436E-02	5.04544E-05	2.47082E-02	3.29736E-04	2.94057E-04	1.42204E-04
004.	1.35611E-02	2.27321E-03	2.90574E-02	2.98198E-04	3.87388E-04	2.53773E-04
005.	1.51011E-02	1.02520E-02	2.01985E-02	2.63955E-04	5.25082E-04	3.54232E-04
006.	1.50990E-02	1.66868E-02	1.04549E-02	2.57418E-04	5.66098E-04	3.63632E-04
007.	1.50961E-02	2.30974E-02	2.23076E-06	2.53090E-04	6.04257E-04	3.59159E-04
008.	8.86614E-03	2.93022E-02	1.88390E-02	2.59830E-04	5.28070E-04	3.20188E-04
009.	1.25006E-06	2.63626E-02	2.00997E-02	2.57132E-04	1.60947E-04	3.03906E-04
010.	2.30653E-03	2.17865E-02	2.01280E-02	2.34297E-04	1.04398E-04	3.05624E-04
011.	4.14349E-03	1.81165E-02	2.01550E-02	1.81780E-04	1.51093E-04	3.16715E-04
012.	6.89613E-03	1.61488E-02	2.01808E-02	1.30250E-04	1.83754E-04	3.35898E-04
013.	1.05558E-02	1.42210E-02	2.01972E-02	1.39448E-04	2.30304E-04	3.15174E-04
014.	2.83603E-02	5.67809E-03	2.02440E-02	1.51859E-04	2.80218E-04	2.74822E-04
015.	2.87664E-02	7.18895E-05	2.05086E-02	1.07273E-04	2.62285E-04	2.55800E-04
016.	1.51970E-02	3.58793E-05	1.34101E-02	2.04073E-04	2.62285E-04	2.66046E-04
017.	2.49958E-09	8.50610E-09	4.06027E-09	2.69171E-04	2.62285E-04	2.89768E-04
018.	6.91044E-03	2.78111E-02	1.35130E-02	1.52786E-04	1.89422E-04	1.91708E-04
019.	6.90119E-03	2.88919E-02	5.57447E-03	3.01597E-04	2.06252E-04	1.07773E-04
020.	2.78073E-03	8.33732E-03	2.20535E-05	3.28740E-04	1.03937E-04	1.36635E-04
021.	8.34016E-09	1.66111E-08	6.80266E-09	9.73809E-10	3.48634E-10	2.01547E-10

MAXIMUM DISPLACEMENT, 2.93022E-02, OCCURED AT JOINT 008.
MAXIMUM ROTATION, 6.04257E-04, OCCURED AT JOINT 007.

C O M B I N E D N O D E D I S P L A C E M E N T S / R O T A T I O N S
C O M B I N A T I O N M E T H O D 1 FOR MODAL SHAPES. MODE # 1 TO 25

LOAD CASE # 3 (FINAL)

JOINT LABEL	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
001.	5.80609E-09	4.08893E-09	1.40930E-08	1.30041E-09	4.07400E-10	5.13472E-10
002.	7.88861E-03	1.73911E-08	1.98819E-02	6.34833E-04	3.62372E-04	2.53955E-04
003.	2.48447E-02	3.46095E-08	8.14332E-02	8.18663E-04	7.24743E-04	3.45143E-04
004.	3.37585E-02	3.76399E-03	7.23454E-02	7.16809E-04	9.57363E-04	3.50345E-04
005.	3.72637E-02	1.22898E-02	5.03489E-02	5.87000E-04	1.30504E-03	3.09437E-04
006.	3.72658E-02	1.75941E-02	2.61068E-02	5.37862E-04	1.41095E-03	2.85391E-04
007.	3.72610E-02	2.23944E-02	6.53928E-06	4.89024E-04	1.51269E-03	2.53839E-04
008.	2.15394E-02	2.29549E-02	3.92760E-02	4.19022E-04	[illegible]1983E-03	1.57339E-04
009.	3.23746E-06	1.50527E-02	5.03354E-02	3.12602E-04	3.324[illegible]6E-04	9.80865E-05
010.	3.41467E-03	9.32580E-03	5.04115E-02	2.60504E-[illegible]4	1.4897[illegible]E-04	6.55907E-05
011.	5.68260E-03	4.97049E-03	5.04842E-02	1.97357E 04	3.41975[illegible]-04	7.26015E-05
012.	1.32785E-02	2.89246E-03	5.05537E-02	1.33505[illegible]-04	4.50878E 04	1.11234E-04
013.	2.30129E-02	3.66708E-03	5.05980E-02	9.5285[illegible]E-05	5.58527E-04	1.55975E-04
014.	6.69298E-02	5.13601E-03	5.07253E-02	6.2383[illegible]E-05	6.81652E-[illegible]4	3.70032E-04
015.	7.14195E-02	1.25548E-04	5.09352E-02	2.13674E-04	6.18617E-[illegible]4	5.71099E-04
016.	3.80439E-02	6.26030E-05	3.20690E-02	5.01276E 04	6.18617E-04	6.64636E-04
017.	3.66431E-09	1.48416E-08	8.09681E-09	6.36667E-04	6.18617E-0[illegible]	7.22799E-04
018.	1.33237E-02	3.99535E-03	3.37226E-02	1.14104E-04	4.62118E-04	8.84307E-05
019.	1.33305E-02	6.00567E-03	1.41182E-02	1.09705E-04	5.03310E-04	4.35732E-05
020.	3.45831E-03	2.10788E-03	4.72924E-05	8.36514E-05	1.51095E-04	[illegible].72900E-05
021.	1.16901E-08	4.33794E-09	1.45879E-08	2.45856E-10	3.97267E-10	2.[illegible]5042E-1[illegible]

MAXIMUM DISPLACEMENT, 7.23454E-02, OCCURED AT JOINT 004.
MAXIMUM ROTATION, 1.51269E-03, OCCURED AT JOINT 007.

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 1 MODE 1 TO MODE 25 --- FINAL

EL. NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1T	1	001.	26.101	41.433	34.975	1079.109	1914.973	3508.948
		002.	26.101	41.433	34.975	1079.109	851.347	1539.817
	2	001.	59.629	60.473	48.363	1652.986	2994.193	5308.093
		002.	59.629	60.473	48.363	1652.986	1078.969	2341.071
	3	001.	40.889	140.930	58.061	4074.000	5134.720	13004.126
		002.	40.889	140.930	58.061	4074.000	2487.081	5702.324
2T	1	002.	25.795	30.176	19.358	1079.109	851.347	1539.817
		003.	25.795	30.176	19.358	1079.109	797.457	485.724
	2	002.	59.037	45.504	38.822	1652.986	1078.969	2341.071
		003.	59.037	45.504	38.822	1652.986	2105.447	759.074
	3	002.	40.498	109.973	42.852	4074.000	2487.081	5702.324
		003.	40.498	109.973	42.852	4074.000	945.613	1367.740
3B	1	003.	25.343	21.407	18.143	1079.305	485.312	797.457
		CENTER	26.580	19.941	18.143	931.594	769.708	704.245
		004.	26.266	21.003	18.143	604.981	1191.382	653.330
	2	003.	58.348	29.926	27.022	1653.106	758.722	2105.447
		CENTER	62.723	18.590	27.022	1486.909	1226.839	2275.928
		004.	58.453	29.114	27.022	1080.715	1851.487	2148.931
	3	003.	39.969	27.279	64.321	4074.563	1366.070	945.613
		CENTER	36.687	31.689	64.321	3522.146	2651.923	842.315
		004.	31.442	36.863	64.321	2185.201	4400.420	843.847
4B	1	004.	29.477	22.865	18.046	604.308	1191.721	653.330
		CENTER	29.542	21.954	18.046	270.485	1332.286	583.223
		005.	27.455	23.682	18.046	539.090	1347.554	546.109
	2	004.	56.370	27.004	23.963	1079.870	1851.918	2148.931
		CENTER	44.654	43.599	23.963	675.501	2039.640	1752.478
		005.	28.201	55.754	23.963	1043.191	2025.719	1253.857
	3	004.	38.310	28.272	65.311	2182.302	4401.859	843.847
		CENTER	34.478	32.576	65.311	445.726	5059.952	863.577
		005.	29.443	36.942	65.311	1724.025	5138.962	1081.304
5T	1	005.	35.061	18.276	22.002	541.741	1346.517	546.109
		006.	35.061	18.276	22.002	541.741	1460.018	566.448

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 1 MODE 1 TO MODE 25 --- FINAL

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
	2	005.	32.789	45.198	29.560	1046.788	2024.137	1253.857
		006.	32.789	45.198	29.560	1046.788	2133.247	999.766
	3	005.	45.183	28.718	77.706	1735.696	5135.032	1081.304
		006.	45.183	28.718	77.706	1735.696	5488.746	1398.692
6T	1	006.	41.885	14.374	24.036	541.741	1460.018	566.448
		007.	41.885	14.374	24.036	541.741	1644.385	625.343
	2	006.	37.748	32.752	32.747	1046.788	2133.247	999.766
		007.	37.748	32.752	32.747	1046.788	2331.014	1084.947
	3	006.	60.305	20.633	83.902	1735.696	5488.746	1398.692
		007.	60.305	20.633	83.902	1735.696	6066.792	1645.820
7B	1	007.	51.372	156.116	13.577	541.741	625.343	1644.385
		CENTER	80.104	143.454	13.577	597.217	489.791	1142.573
		008.	119.805	112.507	13.577	541.658	431.683	2681.565
	2	007.	45.130	218.428	13.824	1046.788	1084.947	2331.014
		CENTER	85.735	205.531	13.824	1077.869	1038.527	1436.425
		008.	152.190	163.894	13.824	1123.066	1085.066	3762.272
	3	007.	81.216	542.061	14.118	1735.696	1645.820	6066.792
		CENTER	174.996	519.402	14.118	2185.724	1004.496	3518.424
		008.	352.891	419.455	14.118	2346.221	598.785	9356.351
8B	1	008.	119.145	110.824	15.090	641.677	431.676	2681.565
		CENTER	142.980	77.648	15.090	647.694	475.908	3844.388
		009.	149.909	63.161	15.090	578.974	607.966	4423.953
	2	008.	145.448	161.624	29.489	1123.105	1085.074	3762.272
		CENTER	191.171	105.953	29.489	1169.463	842.085	5510.577
		009.	210.304	52.811	29.489	1090.351	861.750	6419.646
	3	008.	331.238	412.871	18.740	2346.222	598.783	9356.351
		CENTER	[illegible]6.417	264.788	18.740	2152.355	1135.360	14006.742
		009.	519.236	102.745	18.740	1598.447	1951.683	16298.412
9T	1	009.	144.833	18.384	90.135	578.462	4423.953	608.372
		010.	144.833	18.384	90.135	578.462	3195.511	764.890
	2	009.	201.854	54.144	101.595	1089.542	6419.646	862.372
		010.	201.854	54.144	101.595	1089.542	4711.983	1486.894
	3	009.	494.907	26.209	252.185	1594.617	16298.412	1954.812

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT PISYS PAGE 3
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 1 MODE 1 TO MODE 25 --- FINAL

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
		010.	494.907	26.209	252.185	1594.617	11753.784	2311.439
10T	1	010.	140.809	22.877	88.650	578.462	3195.511	764.890
		011.	140.809	22.877	88.650	578.462	2802.712	1069.811
	2	010.	194.898	71.652	100.598	1089.542	4711.583	1486.894
		011.	194.898	71.652	100.598	1089.542	3377.721	2793.938
	3	010.	474.547	33.615	251.036	1594.617	11753.784	2311.439
		011.	474.547	33.615	251.036	1594.617	7980.072	2809.522
11T	1	011.	136.998	23.896	85.164	578.462	2802.712	1069.811
		012.	136.998	23.896	85.164	578.462	2951.449	1188.307
	2	011.	188.071	114.595	98.064	1089.542	3377.721	2793.938
		012.	188.071	114.595	98.064	1089.542	2756.159	2136.623
	3	011.	454.293	29.173	246.537	1594.617	7980.072	2809.522
		012.	454.293	29.173	246.537	1594.617	5810.746	2583.212
12T	1	012.	87.724	25.345	31.367	641.142	1945.020	1219.918
		013.	87.724	25.345	31.367	641.142	1586.376	862.143
	2	012.	124.894	128.591	42.088	1331.013	2408.996	3911.340
		013.	124.894	128.591	42.088	1331.013	1702.209	1636.081
	3	012.	301.120	43.207	84.914	2061.713	5379.589	2538.360
		013.	301.120	43.207	84.914	2061.713	3845.806	1848.760
13T	1	013.	77.655	16.855	25.129	641.142	1586.376	862.143
		014.	77.655	16.855	25.129	641.142	1015.317	888.506
	2	013.	110.871	21.190	30.950	1331.013	1702.209	1636.081
		014.	110.871	21.190	30.950	1331.013	950.210	1072.792
	3	013.	263.952	40.536	66.144	2061.713	3845.806	1848.760
		014.	263.952	40.536	66.144	2061.713	1590.855	2508.812
14B	1	014.	67.048	25.606	27.970	641.142	1015.317	888.506
		CENTER	53.998	47.942	27.970	388.080	453.356	515.068
		015.	26.606	67.048	27.970	0.000	812.559	1736.644
	2	014.	93.912	35.729	26.177	1331.013	950.210	1072.792
		CENTER	66.203	76.713	26.177	931.555	941.168	903.126
		015.	35.729	93.912	26.177	0.000	1432.411	3109.217
	3	014.	219.080	40.853	43.825	2061.713	1590.855	2508.812

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT PISYS PAGE 4
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 1 MODE 1 TO MODE 25 --- FINAL

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
		CENTER	155.991	159.272	43.825	1088.104	1457.851	1417.332
		015.	40.853	219.080	43.825	0.001	1451.813	6141.426
15T	1	015.	51.099	18.894	16.024	0.000	812.559	1736.644
		016.	51.099	18.894	16.024	0.000	1110.114	1354.994
	2	015.	84.617	28.642	21.887	0.000	1432.411	3109.217
		016.	84.617	28.642	21.887	0.000	1349.773	2192.545
	3	015.	147.899	41.839	24.393	0.001	1451.813	6141.426
		016.	147.859	41.839	24.393	0.001	1978.728	4372.278
16T	1	016.	51.507	25.092	20.558	0.000	1110.114	1354.994
		017.	51.507	25.092	20.558	0.000	0.000	0.000
	2	016.	85.061	40.603	24.996	0.000	1349.773	2192.545
		017.	85.061	40.603	24.996	0.000	0.000	0.000
	3	016.	148.416	60.968	36.643	0.001	1978.728	4372.278
		017.	148.416	60.968	36.643	0.001	0.001	0.001
17T	1	012.	60.194	40.856	74.269	432.950	2322.395	646.662
		018.	60.194	40.856	74.269	432.950	1640.911	1194.620
	2	012.	67.813	218.121	69.735	2628.692	2142.421	1628.157
		018.	67.813	218.121	69.735	2625.692	1810.107	7335.120
	3	012.	170.846	56.911	190.764	639.759	4147.418	1118.406
		018.	170.846	56.911	190.764	639.759	4341.322	1518.400
18T	1	018.	61.315	20.044	54.668	432.950	1640.911	1194.620
		019.	61.315	20.044	54.668	432.950	1052.957	668.873
	2	018.	69.629	99.508	63.027	2625.692	1810.107	7335.120
		019.	69.629	99.508	63.027	2625.692	1638.659	3459.579
	3	018.	110.609	20.147	125.349	639.759	4341.322	1518.400
		019.	110.609	20.147	125.349	639.759	1835.632	975.114
19B	1	019.	72.194	60.558	23.902	432.950	668.873	1052.957
		CENTER	91.190	29.421	23.902	228.332	179.912	1510.908
		020	60.558	72.194	23.902	286.671	527.008	878.092
	2	019	77.614	67.925	149.306	2625.692	3459.579	1038.659
		CENTER	99.824	28.132	149.306	1148.086	474.920	1819.798
		020	67.925	77.614	149.306	2015.474	2897.522	1156.259

RESPONSE SPECTRUM ANALYSIS --- STRESS REPORT
ELEMENT TYPE 1 --- 3-D STRAIGHT OR CURVED PIPE ELEMENTS

COMBINED ELEMENT FORCES AND MOMENTS
COMBINED METHOD 1 MODE 1 TO MODE 25 --- FINAL

ELEM NO	LOAD CASE	END	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
	3	019	110.100	145.486	31.451	639.759	975.114	1835.63[illegible]
		CENTER	177.998	57.898	31.451	425.845	323.940	3648.833
		020	145.486	110.100	31.451	255.042	848.764	2922.791
20T	1	020	60.754	33.816	80.586	286.671	878.092	527.008
		021	60.754	33.816	80.586	286.671	3414.555	1828.916
	2	020	68.027	166.111	83.402	2015.474	1156.259	2897.522
		021	68.027	166.111	83.402	2015.474	3486.342	9738.087
	3	020	145.879	43.379	116.901	255.042	2922.791	848.764
		021	145.879	43.379	116.901	255.042	3972.673	2458.559

MAXIMUM AND/OR MINIMUM VALUES
CORRESPONDING ELEM/LOAD-CASE

	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSION MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
MAXIMUM TANG	494.907	218.121	252.185	4074.000	16298.412	13004.126
	9- 3	17- 2	9- 3	1- 3	9- 3	1- 3
MINIMUM	25.795	14.374	16.024	0.000	0.000	0.000
	2- 1	6- 1	15- 1	15- 1	16- 1	16- 1
MAXIMUM BEND	519.236	542.061	149.306	4074.563	5138.962	16298.412
	[illegible]- 3	7- 3	19- 2	3- 3	4- 3	8- 3
MINIMUM	25.743	18.590	13.577	0.000	179.912	515.068
	2- 1	3- 2	7- 1	14- 1	19- 1	14- 1

R E S P O N S E S P E C T R U M A N A L Y S I S --- S T R E S S R E P O R T
E L E M E N T T Y P E 2 --- R E S T R A I N T E L E M E N T

C O M B I N E D E L E M E N T F O R C E S A N D M O M E N T S
C O M B I N E D M E T H O D 1 M O D E 1 T O M O D E 25 --- F I N A L

ELEM NO	LOAD CASE	RESTRAINT TYPE	PIPE JOINT	STRUCT. POINT	RESTRAINT FORCE	RESTRAINT MOMENT
1	1	ANCHOR	001.	A001 X	3.497E 01	3.509E 03
	2	ANCHOR	001.	A001 X	4.836E 01	5.308E 03
	3	ANCHOR	001.	A001 X	8.808E 01	1.300E 04
2	1	ANCHOR	001.	A001 Y	2.610E 01	1.079E 03
	2	ANCHOR	001.	A001 Y	5.963E 01	1.653E 03
	3	ANCHOR	001.	A001 Y	4.089E 01	4.074E 03
3	1	ANCHOR	001.	A001 Z	4.143E 01	1.915E 03
	2	ANCHOR	001.	A001 Z	6.047E 01	2.994E 03
	3	ANCHOR	001.	A001 Z	1.409E 02	5.135E 03
4	1	ANCHOR	017.	A017 X	2.056E 01	1.689E-04
	2	ANCHOR	017.	A017 X	2.500E 01	2.692E-04
	3	ANCHOR	017.	A017 X	3.664E 01	6.367E-04
5	1	ANCHOR	017.	A017 Y	5.151E 01	2.007E-04
	2	ANCHOR	017.	A017 Y	8.506E 01	2.623E-04
	3	ANCHOR	017.	A017 Y	1.484E 02	6.186E-04
6	1	ANCHOR	017.	A017 Z	2.909E 01	1.947E-04
	2	ANCHOR	017.	A017 Z	4.060E 01	2.898E-04
	3	ANCHOR	017.	A017 Z	8.097E 01	7.228E-04
7	1	ANCHOR	021.	A021 X	8.059E 01	1.829E 03
	2	ANCHOR	021.	A021 X	8.340E 01	9.738E 03
	3	ANCHOR	021.	A021 X	1.169E 02	2.459E 03
8	1	ANCHOR	021.	A021 Y	3.382E 01	3.415E 03
	2	ANCHOR	021.	A021 Y	1.661E 02	3.486E 03
	3	ANCHOR	021.	A021 Y	4.338E 01	3.973E 03
9	1	ANCHOR	021.	A021 Z	6.075E 01	2.867E 02
	2	ANCHOR	021.	A021 Z	6.803E 01	2.015E 03
	3	ANCHOR	021.	A021 Z	1.459E 02	2.860E 02

10	1	STRUT	007.	STR07	1.616E 02	0.
	2	STRUT	007.	STR07	2.231E 02	0.
	3	STRUT	007.	STR07	5.539E 02	0.
11	1	STRUT	009.	STR09	1.178E 02	0.
	2	STRUT	009.	STR09	1.250E 02	0.
	3	STRUT	009.	STR09	3.237E 02	0.
12	1	STRUT	011.	STR11	3.158E 01	0.
	2	STRUT	011.	STR11	1.812E 02	0.
	3	STRUT	011.	STR11	4.970E 01	0.
13	1	STRUT	013.	STR13	2.509E 01	0.
	2	STRUT	013.	STR13	1.422E 02	0.
	3	STRUT	013.	STR13	3.667E 01	0.
14	1	STRUT	015.	STR15	9.195E 01	0.
	2	STRUT	015.	STR15	1.284E 02	0.
	3	STRUT	015.	STR15	2.740E 02	0.

NORMAL TERMINATION OF P I S Y S

4182T 01 10-28-92 10.470 P I S Y S 0 6 NRC PROBLEM 2

M U L T I P L E S U P P O R T R E S P O N S E S P E C T R U M S T R E S S R E P O R T M-RABS

(2/9/93)

GE's 6/1987 COMPARISON

BNL (NUREG CR-1677) BENCHMARK PROBLEMS

III

GENERAL ELECTRIC COMPANY
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

PLANT PIPING ANALYSIS

DESIGN MEMO PDE-6-2087
DRF #A00-03074

BENCHMARK ANALYSIS OF SAP AND PISYS TO NUREG/CR-1677 PROBLEM

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Plant Piping Analysis

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Plant Design Engineering

JUNE 1987

GF8707/GAL87

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

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TABLE OF CONTENTS

1.0 ABSTRACT

A benchmark analysis of PISYS was performed in August of 1979 and documented in NEDO-24210, "PISYS ANALYSIS OF NRC BENCHMARK PROBLEMS". The analysis established that PISYS predicted dynamic responses consistent with the NRC benchmarks when applying the enveloped response spectra method of analysis. Although independent support motion analysis was employed in 1977, no benchmark problems existed. The purpose of this report is to document that the PISYS and SAP programs predict responses consistent with the 1985 NRC Benchmark when the independent support motion method of analysis is employed.

2.0 BACKGROUND

General Electric was the first to implement independent support motion dynamic analysis of piping in 1977 using the SAP program. The independent support motion method was developed by General Electric to eliminate the conservatism associated with applying the envelope of spectra at all pipe attachment points to the entire piping system. Subsequently the independent support motion method was incorporated into all major piping programs used by industry. In 1985, after the independent support motion method had been widely accepted for piping analysis, the United States Nuclear Regulatory Commission issued NUREG/CR-1677 for confirming the correctness of computer programs predicting responses by the independent support motion method. Since the analytical methods used in the NUREG/CR-1677 bench mark calculations are the same as those used by General Electric in 1977, the NRC bench marks provide official confirmation of the correctness of the original General Electric methodology.

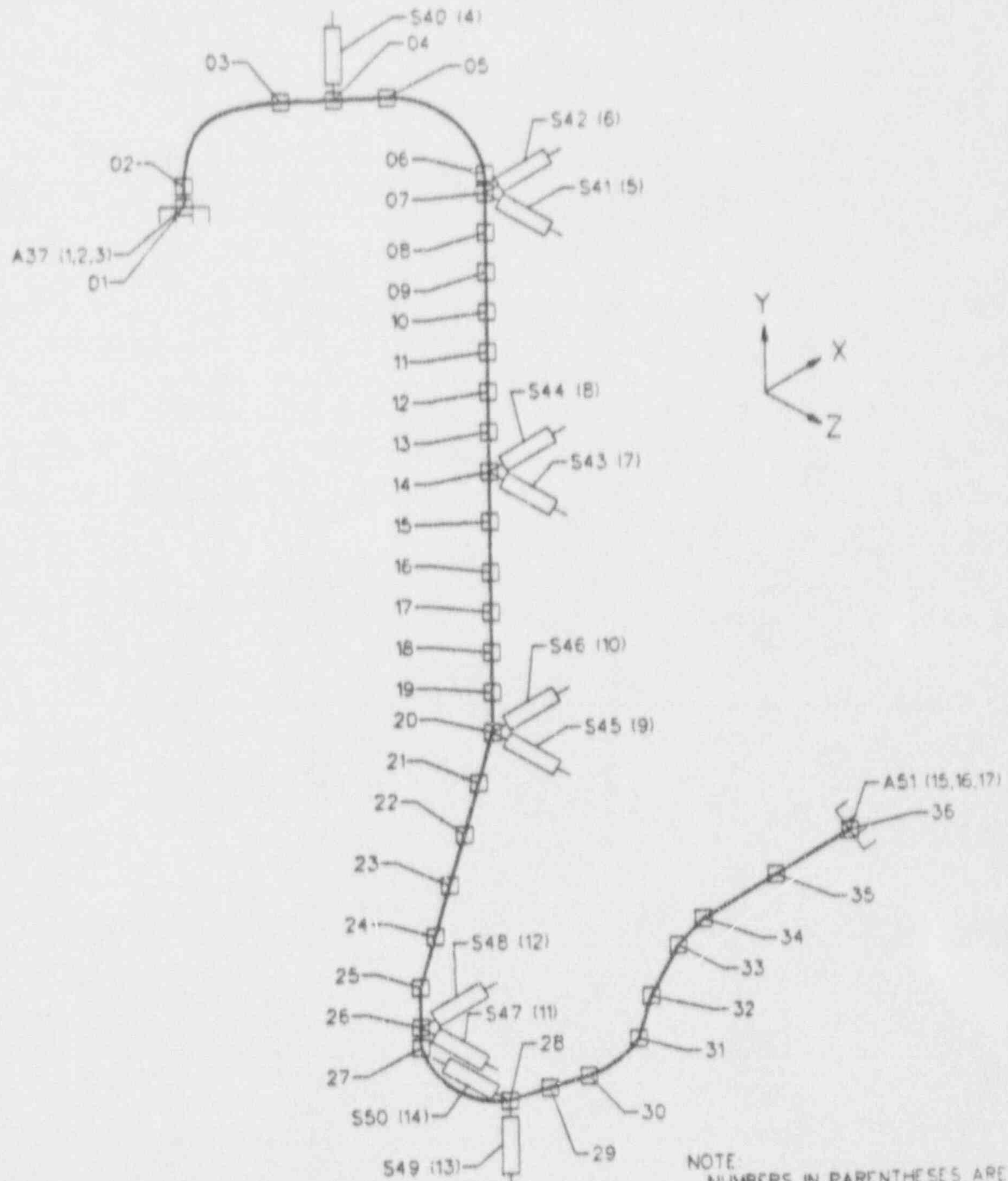
3.0 DESCRIPTION OF SAPGO4 AND PISYS

The SAP program was originally constructed from three earlier programs developed under the direction of Professor E. L. Wilson, Department of Civil Engineering, University of California at Berkeley. The element library and static analysis options were taken from the SOLID/SAP Program, the eigenvalue extraction algorithms were incorporated from coding that was originated by Dr. K. J. Bathe, and the forced vibration and response spectrum analyses were adapted from the original version of Professor Wilson's SAP Program. The capability for ASME Class 1, 2 or 3 piping analysis was developed by the Engineering/Analysis Corporation under a contract with the General Electric Company at San Jose. Later, the capability of the program was further developed and expanded within the General Electric Company at San Jose for independent support motion seismic and dynamic analysis and for fluid-mass-effect evaluations.

PISYS is a specialized development of SAP for use in the analysis of piping. The basic solution routines of SAP have been combined with an input language translator specialized for modeling piping. The SAP and PISYS programs have been benchmarked against one another to verify that the solution routines give consistent load predictions.

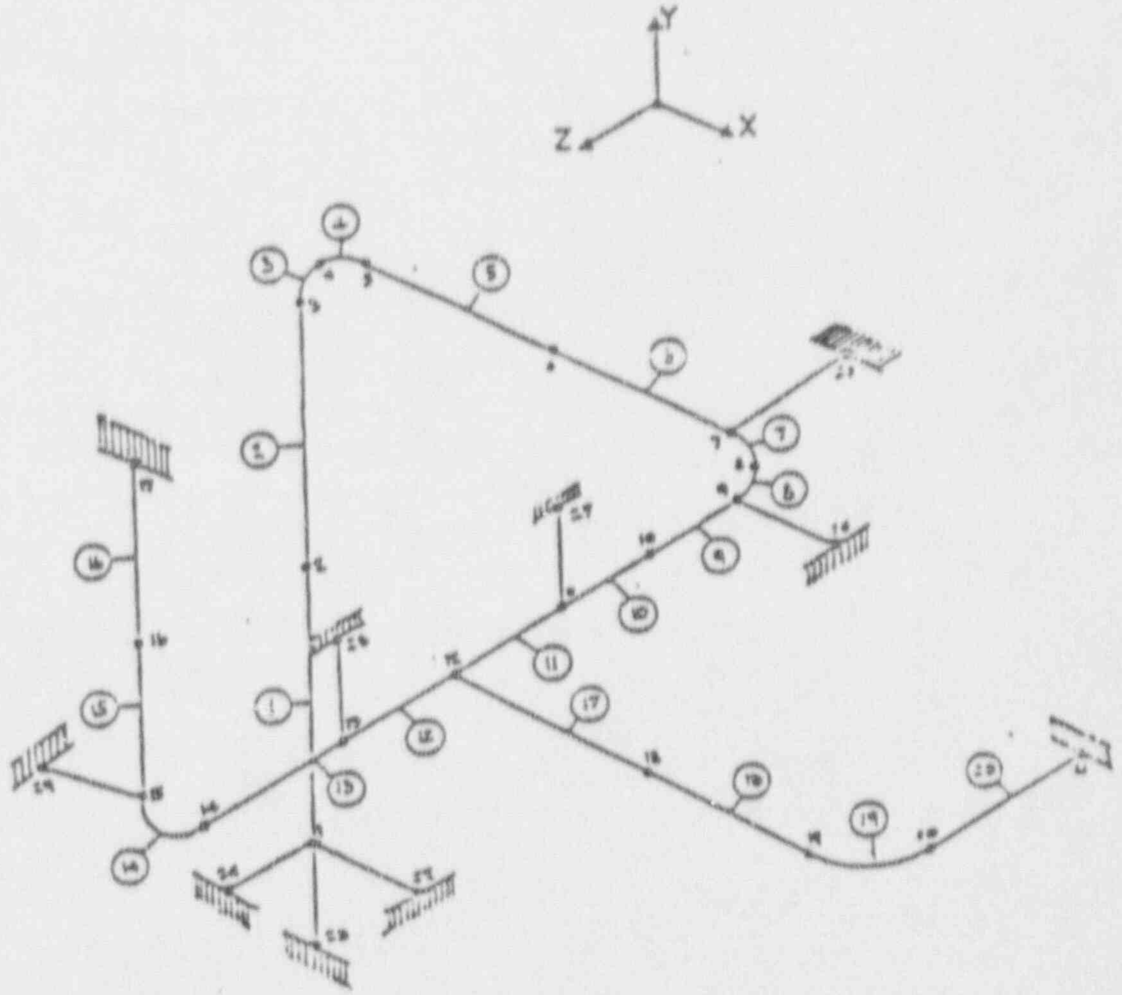
SAP was selected for the primary benchmark verification presented in this report because the input for the piping models could be directly applied. The predictions of PISYS are identical to SAP since they have the same solution routine; therefore the benchmark comparisons are equally valid for SAP and PISYS.

4. NRC BENCHMARK PROBLEMS

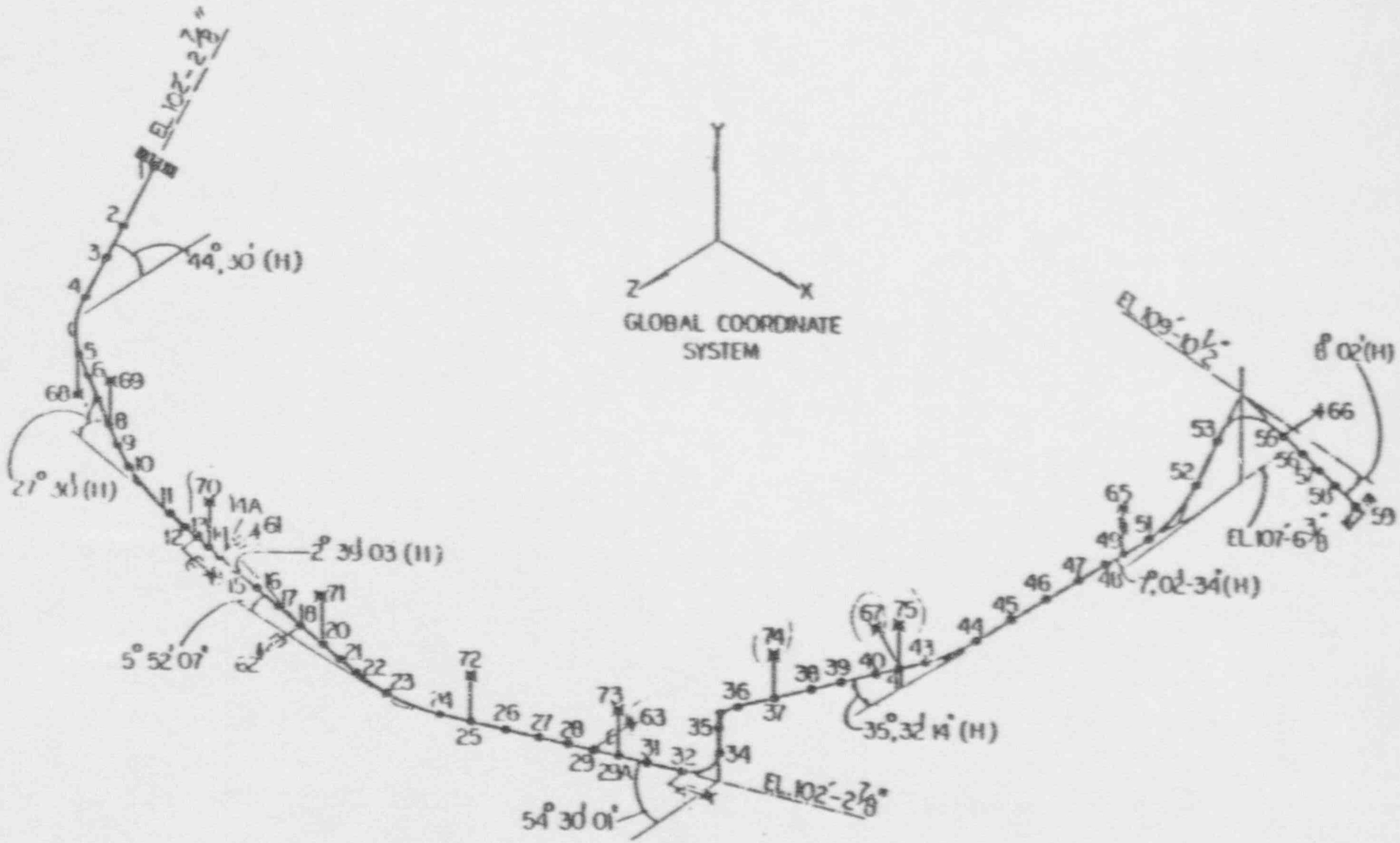


BENCHMARK PROBLEM

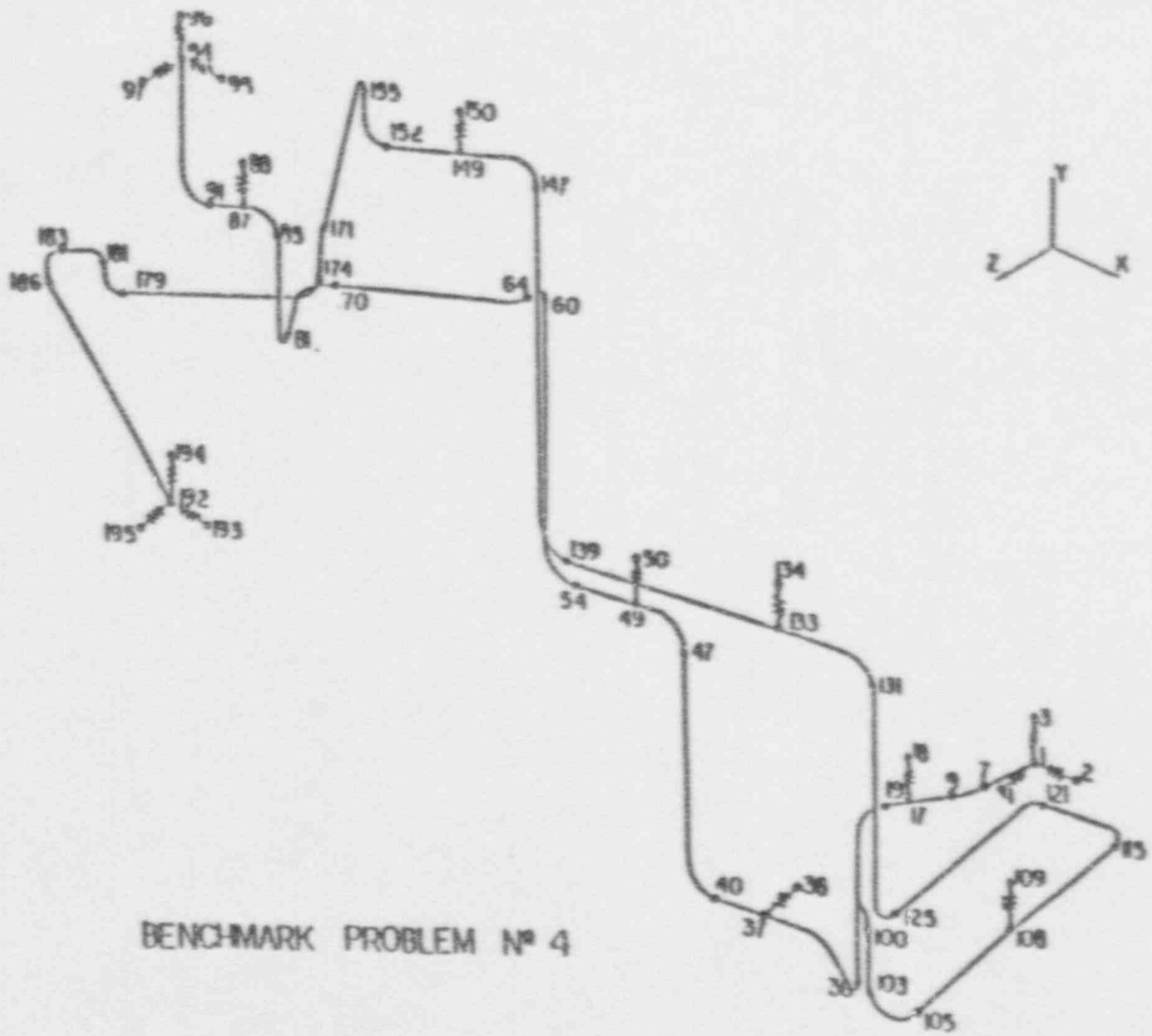
NO. 1



BENCHMARK PROBLEM Nº 2



BENCHMARK PROBLEM NO 3



BENCHMARK PROBLEM Nº 4

5. COMPARISON OF PISYS AND SAPC04 PREDICTION WITH BENCHMARK PROBLEM 1.

METHOD / SUPPORT ELEMENT	ENVELOPE		
	NU[illegible] 677	PISYS [LB]	SAP [LB]
1	93	93	93
2	107	107	106
3	89	89	88
4	234	234	234
5	84	84	84
6	100	100	100
7	39	39	39
8	78	78	78
9	28	28	28
10	78	78	78
11	59	59	59
12	185	185	185
13	221	221	220
14	89	89	89
15	120	120	120
16	57	57	57
17	56	56	56

COMPARISON OF PISYS AND SAPGO4 PREDICTION WITH BENCHMARK

PROBLEM 1.

(CONTINUED)

SUPPORT ELEMENT \ METHOD	SQUARE ROOT OF THE SUM OF SQUARES BY GROUP		
	NUREG 1677 [LB]	PISYS [LB]	SAP [LB]
1	86	86	86
2	93	94	92
3	81	81	80
4	202	204	200
5	74	73	72
6	84	83	81
7	34	33	32
8	55	45	45
9	26	26	25
10	57	38	38
11	53	52	51
12	136	126	126
13	152	146	145
14	95	97	94
15	84	84	83
16	67	68	66
17	74	75	73

COMPARISON OF PISYS AND SAPGO4 PREDICTION WITH BENCHMARK

PROBLEM 1.

(CONTINUED)

METHOD / SUPPORT ELEMENT	ABSOLUTE SUM BY GROUP		
	NUREG 1677 [LB]	PISYS [LB]	SAP [LB]
1	117	121	NA
2	128	133	NA
3	109	114	NA
4	278	289	NA
5	100	103	NA
6	113	117	NA
7	44	44	NA
8	65	63	NA
9	35	36	NA
10	63	62	NA
11	72	74	NA
12	185	176	NA
13	204	204	NA
14	131	137	NA
15	116	118	NA
16	92	96	NA
17	103	106	NA

NRC BENCHMARK COMPARISON

PROBLEM 2

SUPPORT ELEMENT	NUREG 1677 ENVELOPE [LB]	SAP ENVELOPE [LB]	NUREG 1677 SRSS GROUP [LB]	SAP SRSS GROUP [LB]
1	90	90	53	52
2	65	65	46	46
3	177	177	113	110
4	708	708	441	430
5	446	446	257	252
6	206	206	123	130
7	164	164	98	104
8	373	373	221	216
9	58	58	32	31
10	198	198	124	121
11	103	104	66	65
12	378	378	103	98
13	192	192	114	120
14	245	245	116	114

NRC BENCHMARK COMPARISON

PROBLEM 3

SUPPORT ELEMENT	NUREG 1677 ENVELOPE [LB]	SAP ENVELOPE [LB]	NUREG 1677 SRSS GROUP [LB]	SAP SRSS GROUP [LB]
1	11	11	4	4
2	7837	7824	6845	6790
3	4472	4470	3100	3064
4	8931	8928	2923	2905
5	359	361	524	404
6	729	732	1144	874
7	784	784	1068	817
8	1043	1043	1416	1284
9	1378	1378	1666	1591
10	3408	3404	2776	2684
11	1448	1444	1736	1699
12	1688	1624	3160	3152
13	87	81	2408	2397
14	1370	1368	2408	2397
15	9930	9943	12711	11240
16	58341	58290	77406	76930
17	10767	10760	12661	12350
18	3031	3029	2834	2800
19	15459	15850	4923	4910
20	896	894	803	793

NRC BENCHMARK COMPARISON

PROBLEM 3

(CONTINUED)

SUPPORT ELEMENT	NUREG 1677 ENVELOPE [LB]	SAP ENVELOPE [LB]	NUREG 1677 SRSS GROUP [LB]	SAP SRSS GROUP [LB]
21	169227	169100	89089	88830
22	34378	34330	28458	28020
23	1697062	1696000	599310	547200
24	6792	6786	4953	4885
25	801	800	831	813
26	303	303	312	308
27	7447	7443	4412	4371
28	11991	11980	5898	5820

<u>NRC BENCHMARK COMPARISON</u>

<u>PROBLEM 4</u>

<u>(CONTINUED)</u>

SUPPORT ELEMENT	NUREG 1677 ENVELOPE [LB]	SAP ENVELOPE [LB]	NUREG 1677 SRSS GROUP [LB]	SAP SRSS GROUP [LB]
1	3724	3722	2416	2415
2	2390	2412	1497	1502
3	2156	2154	1523	1521
4	42	42	24	25
5	2466	2478	1484	1489
6	4850	4850	2524	2523
7	4765	4769	3028	3031
8	3825	3822	2094	2081
9	3482	3481	2302	2300
10	2101	2191	1265	1307
11	61	60	34	34
12	6660	6659	5043	5038
13	2669	2670	1857	1856
14	6554	6553	5308	5304
15	109	109	84	84
16	5015	5013	3878	3871
17	3334	3334	2593	2590
18	4739	4738	3706	3700
19	861	867	681	682
20	64	64	36	36

NRC BENCHMARK COMPARISON

PROBLEM 4

(CONTINUED)

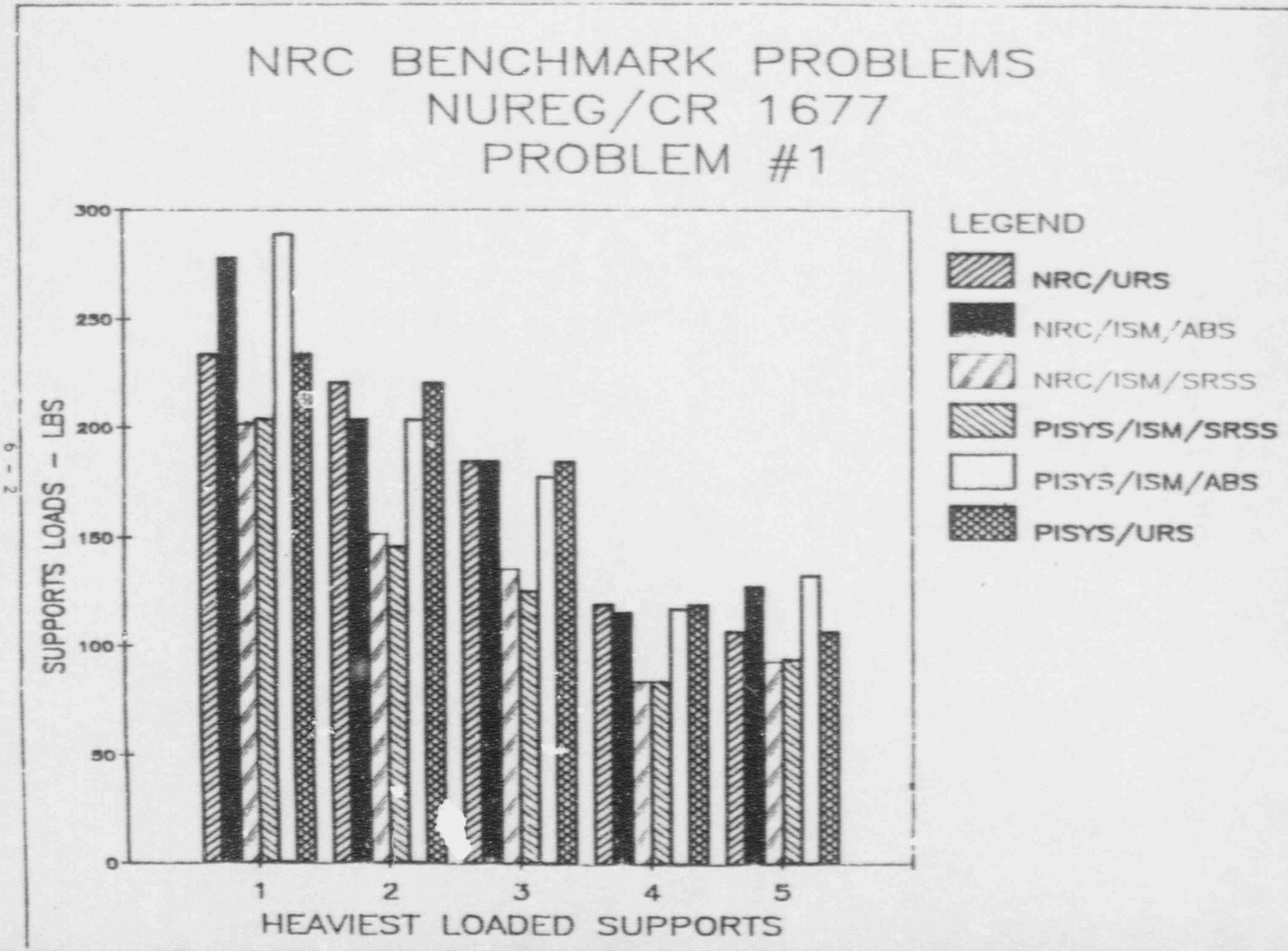
SUPPORT ELEMENT	NUREG 1677 ENVELOPE [LB]	SAP ENVELOPE [LB]	NUREG 1677 SRSS GROUP [LB]	SAP SRSS GROUP [LB]
21	2312	2313	1297	1298
22	2079	2078	1227	1227
23	1153	1151	655	655
24	1829	1815	863	860
25	883	879	531	531
26	869	850	437	436
27	1858	1860	988	989
28	2571	2563	1674	1665
29	1349	1339	1008	1004
30	106	108	68	69
31	4370	4369	3588	3590
32	1370	1357	905	906
33	1170	1148	589	558
34	970	982	685	692
35	749	729	347	318
36	2952	2947	1876	1807

MOMENTS AND DISPLACEMENTS COMPARISON

VARIABLES / PROBLEM #	TYPE OF THE METHOD	MOMENT [IN-LBS]			DISPLACEMENT [IN]		
		NUREG 1677	PISYS	SAP	NUREG 1677	PISYS	SAP
1	ENVELOPE	1478	1584	1581	0.1222	0.1279	0.1254
		ELEM #3			NODE #33		
	SRSS GROUP	4193	4189	4120	0.2757	0.2822	0.2745
		ELEM #1			NODE #32		
	ABS GROUP	9035	9433	-	0.3827	0.3913	-
		NODE #36			NODE #32		
2	ENVELOPE	18505	-	18501	0.0224	-	0.0204
		ELEM #1			NODE #2		
	SRSS GROUP	11621	-	11315	0.0170	-	0.0166
		ELEM #1			NODE #2		
3	ENVELOPE	60150	-	60106	0.0057	-	0.0060
		ELEM #1			NODE #2		
	SRSS GROUP	35408	-	34732	0.0076	-	0.0076
		ELEM #2			NODE #2		
4	ENVELOPE	433014	-	433674	4.85E-05	-	4.90E-05
		ELEM #1			NODE #1		
	SRSS GROUP	277825	-	277929	3.22E-05	-	3.22E-05
		ELEM #1			NODE #1		

6.0 METHODS COMPARISON

The following bar chart prepared for benchmark problem one provides a visual comparison of the differences in the predictions of the different analytical methods: uniform response spectra (URS), and independent support motion (IMS) combining groups by absolute sum (ABS) and sum of the squares (SRSS). From examination of the chart, the following conclusion can be drawn: the difference in predictions using the same methods are small; independent support motion predictions are significantly less than uniform response spectra when groups are combined by sum of the squares; and independent support motion with combination of groups by absolute sum provides predictions significantly greater than grouping by sum of the squares and is often greater than uniform input.


NRC BENCHMARK PROBLEMS
NUREG/CR 1677
PROBLEM #1
300
250
200
150
100
50
0
SUPPORTS LOADS - LBS
1
2
3
4
5
HEAVIEST LOADED SUPPORTS
LEGEND
NRC/URS
NRC/ISM/ABS
NRC/ISM/SRSS
PISYS/ISM/SRSS
PISYS/ISM/ABS
PISYS/URS

6-2

7.0 CONCLUSION

As can be seen from examination of the tables comparing load predictions, the SAP/PISYS soluti n routines predict loads identical to or consistent with the four benchmark problem predictions. The evaluation reconfirms the verification for enveloped response spectra and extends the verification to independent support motion analysis. The benchmark problem combined the modal responses by the square root of the sum of the squares method. In application, General Electric combines the modal responses by the double sum method in accordance with Regulatory Guide 1.92. If the ben .mark problems were computed using double sum, the predicted loads would be somewhat higher.

The comparion of predicted responses are in excellent agreement for all four bench mark problems. The small differences that occur can be attributed to differences in the way the programs interpret the input for the piping mathematical models. The method of calculation originally implemented by General Electric in 1977 has been accepted as correct by the publication of United States Nuclear Regulatory Commission NUREG/CR-1677 .n 1985.

8.0 REFERENCES

1. "Piping Benchmark Problems Dynamic Analysis Independent Sup[illegible] Motion Response Spectrum Method", NUREG/CR-1677 BNL-NUREG-51[illegible] Vol. II.

2. "PISYS Analysis of NRC Benchmark Problems", NEDO-24210 79NED295 Class 1, August 1979.

3. "PISYS - Piping System Analysis Prog[illegible]m", NEDE-24077.

4. "SAP - Structural Analysis Program", NEDO-10909, Rev. 7, 79NED165R.