DEVELOPMENT OF SOLUTIONS TO BENCHMARK PIPING PROBLEMS

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I. Introduction

Dynamic structural analysis of piping systems is one of the most extensive engineering efforts required for the safety design of nuclear power plants. Such analysis is normally performed by using computer programs which can handle complex system geometries and various loading conditions, static or dynamic.

Applicants for nuclear power plant licenses are required to provide confirmation of the adequacy of their programs, as prescribed by the guidelines of the Standard Review Plan and Appendix B, Section III, of 10CFR50.1. Of particular concern to the Mechanical Engineering Branch is the class of programs which are used by the industry to perform dynamic structural analyses of complex piping systems. There are generally large programs based on the finite element method, which consider the structures to be elastic over the entire deformation history and to experience small displacements and rotations (which may, however, contain gaps). Some of these programs are well known, general purpose programs, while others are more of a proprietary nature.

A standard method for verifying computer programs is by means of benchmark problems. By verification we define the assurance that these programs produce correct and valid results, in accordance with the numerical and theoretical methods on which they are based. The verification of these programs can also be considered as their qualification for solving problems of the kind for which they are designed.

To verify and confirm the quality of these programs, the Mechanical Engineering Branch of the Division of Systems Safety, in conjunction with the Structural Analysis Group of Brookhaven National Laboratory, has defined a set of suitable benchmark problems and developed the corresponding solutions. The direct objective of these benchmark problems is to provide assurance that programs perform according to the claims of their authors when applied to typical analysis problems encountered in the design of nuclear piping systems.

The purpose of this report is to describe the adopted benchmark problems and their solutions. The problems consist in calculating the static and dynamic response of selected piping structures subjected to a variety of loading conditions. The structures range from simple pipe geometries to a representative full scale primary nuclear piping system, which includes the various components and their supports. These structures are assumed to behave in a linear elastic fashion only, i.e., they experience small deformations and small displacements with no existing gaps, and remain elastic thru their entire response.

The solutions were obtained by using the program EPIPE, which is a modification of the widely available program SAP IV. A brief outline of the theoretical background of this program, and its verification is also included in this report.

II. Background

The EPIPE program is a modified version of the general purpose program SAP IV⁴, specifically prepared for static and dynamic analysis of the Class 1 nuclear piping according to the ASME requirements.⁵ The piping system may consist of straight elements, elbows and tees with spring hangers and anchor restraints. The loads can be either mechanical loads, weights, thermal loads, support movements, earthquakes, or any combination of the aforementioned conditions.

Since the elastic piping analysis method is a well established procedure, in depth discussions of the theoretical development will not be included herein. Instead, only a brief outline of the theoretical considerations used in obtaining the static and dynamic solutions to be discussed later with this text, is included in this section.

1. Static Analysis

The static analysis of a piping system is carried out by use of the stiffness matrix method, in which the piping is represented by a network of basic elements (straight and curved beams, and one-dimensional elements) interconnected at the nodes. The formulation of stiffness matrices for straight pipe (beam) and curved pipe may be found in several references such as (6) and (7). For a curved pipe or tee, the flexibility factor and stress intensification factor must

be considered in the formulation of the stiffness matrix and in the stress calculations, respectively. These factors are generally functions of pipe geometry and internal pressure.^{5,8}

From the EPIPE program, the static response of a piping system is obtained in the form of nodal displacements, resultant forces, and stresses at designated locations.

2. Dynamic Analysis

The dynamic response of a piping system is described mathematically by the equations of motion

$$[M] \{\ddot{u}\} + [C] \{\dot{u}\} + [K] \{u\} = \{R(t)\} . \quad (1)$$

Only the lumped mass approximation is allowed. Thus, in equation (1) M represents the diagonal mass matrix of the structure, $\ddot{u}$, the nodal acceleration vector; $\dot{u}$, the nodal velocity vector; C , a damping matrix, for which the Ragleigh damping is assumed, ie, $C = \alpha M + \beta K$, where both α and β are the damping coefficients; K , the stiffness matrix (same as the static problem), and $R(t)$, either a vector of arbitrary time-dependent loads or of effective loads resulting from earthquake motion.

The dynamic analysis may be performed by either the mode superposition method, the direct integration method, or the response spectrum analysis. All three methods are available in the EPIPE program.

2.1 Mode Superposition Method

In order to employ the mode superposition method, it is first necessary to compute the natural frequencies (or eigenvalues) and corresponding mode shapes of the piping system. A choice of two different solution procedures is available in the EPIPE program to find the eigenvalues: a determinant search technique, or a subspace iteration method.³ When the stiffness matrix of the structure can be stored in the computer code as a single block, it is more convenient to use the determinant search technique. However, when the structural stiffness has to be stored in several blocks, it is more efficient to use the subspace iteration method.

In the mode superposition method, the dynamic response of the piping is assumed to be adequately described by p - lowest vibration modes. Subsequently, the equations of motion (1) are decomposed into p uncoupled second order differential equations. Each equation is solved by numerical integration and the final response is obtained by superposition of the various contributions of the individual modes.

2.2 Direct Integration Method

The equations of motion (1) can be solved directly by step-by-step numerical integration. From this analysis a complete time-history response of the piping is obtained.

In the EPIPE program, the Wilson θ method is used, which is considered to be unconditionally stable. The numerical algorithm of this method is outlined in references (3) and (4).

2.3 Response Spectrum Analysis

The response spectrum analysis method is often used to determine the dynamic response of a piping system due to earthquake excitations. It is usually offered as an acceptable substitute for the more complex (and hence more costly) time history analysis.

Similar to the mode superposition method, this method assumes that the response of a structure, can be adequately described by p lowest vibration modes. The maximum displacement corresponding to mode n is obtained from the procedure outlined in (8). The total response for displacements and stress resultants at each node is calculated as the square root of the sum of the squares of the modal maximum responses. The response spectrum method normally gives higher (or more conservative) values than those obtained from the two other methods.

III. Benchmark Problems

The EPIPE program was applied to the analyses of the following benchmark problems:

1. Static response of Hovgaard bend.
2. Dynamic response of Hovgaard bend.
Case a, b, and c
3. Dynamic response of a coffee table.
Case a, b and c
4. Static analysis of Spence's pipework.
5. Dynamic response of a low frequency coffee table.

The static Hovgaard problem was solved analytically by Hovgaard for a piping system under temperature load. The benchmark shown here compares this solution with one obtained by Epipe.

For the dynamic problems, 3 and 5, the piping systems were assumed to be subjected to ground motion of the Imperial Valley Earthquake, El Centro Site, May, 1940, in the S-E direction. A digitized acceleration time-history was obtained from reference (9) and corresponding to this accelerogram, the spectral acceleration was generated according to the procedure outlined in reference (10). This information was then used as the load input for the response spectrum analysis. The dynamic response for both problems were analyzed by all three methods outlined previously in section II, i.e.,:

Case a - Time-history analysis (mode superposition),

Case b - Response spectrum analysis,

Case c - Step-by-step (direct) integration.

The output for the dynamic analysis are presented in the form of:

- a) Natural frequencies and vibration modes.
- b) Modal participation factors (for Case b only).
- c) Maximum nodal displacements and their occurrence time.
- d) Maximum forces and moments at nodes.
- e) Maximum stresses.

It is noted that the maximum forces, moments and stresses are the absolute maximum values.

Finally, the last benchmark solution is for a pipework problem provided to BNL by Spence.¹¹ For this case EPIPE results are compared with those obtained from SPANDLE, a British piping program.

Sign Convention.

Element forces and moments are calculated with respect to the local coordinates defined at the nodes i, and j as shown in Fig. 1-1a and 1-1b.

Fig. 1.1 (a)

Local Coordinate Systems (x, y, z)
of Pipe Elements in Relation to the
Global System (X, Y, Z)

Fig. 1.1 (b)

Sign Convention for Forces and Moments

Problem 1 - Static Response of Hovgaard Bend

The response of a three-dimensional three-arm pipe, known as 'Hovgaard bend' subjected to a temperature gradient, has been analyzed. The resultant moments and forces in the pipe were obtained analytically by Hovgaard,^{12,13} and numerically by the computer program PIPDYN¹⁴. A comparison of these solutions is given in the data and tables that follow the problem description.

Problem Description

i. Geometry - The configuration of the Hovgaard bend, as shown in Fig. 1-2, is comprised of a three-arm pipe in which the arms are at right angles to each other and connected by 90 degree bends. Both ends of the pipe are fixed. The member properties are as follows:

Outside diameter (inches) 7.288

Wall thickness (inches) 0.241

ii. Material data -

Young's modulus (psi) 24.0 E6

Poisson's ratio 0.3

Unit weight (lb/inch³) 0.283

Coefficient of thermal expansion (in/in/°F) 7.1E-6

iii. Loading conditions - The piping system is subjected to a uniform temperature of 850°F.

"No internal pressure was applied to the system"

Fig. 1-2
A Hovgaard Bend
(Figure not to scale)

Analysis Results

In Table 1-1, the end reactions at ends A and B are compared with those given in references (12, 13, 14). Note that in the analytical method, the flexibility factor does not account for the effects of internal pressure. Furthermore, it should also be mentioned that the analytical results shown in the tables that follow were obtained from a computerized solution of equations 20, 21, 22, 23, 24 and 25, given in reference 13.

For the purpose of comparison, Tables 1-2 and 1-3 show the resultant forces of each member obtained by "EPIPE" program (Case a) and by the analytical method, respectively. A comparison of the resulting stresses is shown in Table 1-4. As can be seen from the tables, the differences among the three different solutions are rather small and can be considered to be within an acceptable range.

Table 1-5 to 1-7 show the computer output of the nodal displacements, resultant forces, and pipe stresses for the case under consideration.

Table 1-1

Moments and Forces Acting on the Pipe from the Restraints

	EPIPE		Analytical Method [18]		PIPDYN [14]	
	End A	End B	End A	End B	End A	End B
M_x (in-lb)	-54876.1	92504.8	-56040	+95295*	-55624.8	+93732.5
M_y (in-lb)	+14336.0	-78555.0	+14400	-80363*	+14494.8	-79972.8
M_z (in-lb)	+130165.2	-62255.6	+133080	-64173*	+132303.6	-62868
F_x (lb)	-1711.0	+1711.0	-1750	+1750	-1737.2	+1737.2
F_y (lb)	-1666.9	+1666.9	-1710	+1710	-1686.3	+1686.3
F_z (lb)	-628.2	+628.2	-640	+640	-636.7	+636.7

* Evaluated from the static equilibrium based on the solutions at End-A from Ref. [18].

Table 1-2

Pipes Forces and Moments from 'EPIPE'

Member	Type	Station	Axial	Y-Axis Shear	Z-Axis Shear	Torsional Moment	Y-Axis Moment	Z-Axis Moment
1	Tangent	End-I	-1666.9	-628.2	-1711.0	14336.0	130165.2	-54876.1
		End-J	-1666.9	-628.2	-1711.0	14336.0	-56159.2	13539.6
2	Bend	End-I	-1666.9	-1711.0	628.2	14336.0	13539.6	56159.2
		Center	-2388.5	- 31.2	628.2	26390.5	15562.7	82353.9
		End-J	-1711.0	1666.9	628.2	36344.9	8469.3	57759.6
3	Tangent	End-I	-1711.0	-1666.9	- 628.2	36344.9	- 8469.3	-57759.6
		End-J	-1711.0	-1666.9	- 628.2	36344.9	-30897.6	1747.9
4	Bend	End-I	-1711.0	- 628.2	1666.9	36344.9	1747.9	30897.6
		Center	-1654.1	765.6	1666.9	44657.9	18321.6	28832.3
		End-J	- 628.2	1711.0	1666.9	62255.6	24162.8	- 8405.3
5	Tangent	End-I	- 628.2	-1666.9	1711.0	62255.6	8405.3	24162.8
		End-J	- 628.2	-1666.9	1711.0	62255.6	78555.0	92504.8

Table 1-3

Pipes Forces and Moments (Analytical Method)*

Member	Type	Station	Axial	Y-Axis Shear	Z-Axis Shear	Torsional Moment	Y-Axis Moment	Z-Axis Moment
1	Tangent	End-I	-1710	- 640	-1750	14400	133080	-56040
		End-J	-1710	- 640	-1750	14400	- 57495	13656
2	Bend	End-I	-1710	-1750	640	14400	13656	57495
		Center	-2446	- 28	640	26670	15899	84344
		End-J	-1750	1710	640	36888	8832	58947
3	Tangent	End-I	-1750	-1710	- 640	36888	- 8832	-58947
		End-J	-1750	-1710	- 640	36888	- 31616	1929
4	Bend	End-I	-1750	- 640	1710	36888	- 1929	31616
		Center	-1690	785	1710	45699	19170	29514
		End-J	- 640	1750	1710	64173	25185	- 8613
5	Tangent	End-I	- 640	-1710	1750	64173	8613	25185
		End-J	- 640	-1710	1750	64173	80363	95295

Evaluation based on the solution at End-A from Ref. 18 and static equilibrium of the system.

Table 1-4
Pipes Stresses

a) Longitudinal Stress

Member	Type	Station	EPIPE		Analytical Method		% Difference	
			Tension	Comp.	Tension	Comp.	Tension	Comp.
1	Tangent	End-I	15212	-15836	15548	-16188	2.16	2.17
		End-J	6036	- 6661	6174	- 6814	2.24	2.24
2	Bend	End-I	6903	- 7528	7083	- 7723	2.54	2.52
		Center	10021	-10916	10257	-11173	2.30	2.30
		End-J	6971	- 7612	7139	- 7795	2.35	2.35
3	Tangent	End-I	6095	- 6736	6222	- 6878	2.04	2.06
		End-J	3080	- 3722	3153	- 3809	2.31	2.28
4	Bend	End-I	3548	- 4186	3640	- 4296	2.53	2.56
		Center	3957	- 4577	4093	- 4725	3.32	3.13
		End-J	3078	- 3313	3215	- 3455	4.26	4.11
5	Tangent	End-I	2694	- 2929	2805	- 3045	3.96	3.81
		End-J	13219	-13455	13579	-13819	2.65	2.63

Table 1-4 (cont'd)

Pipes Stresses

b) Circumferential Stress

Member	Type	Station	EPIPE ^b		Analytical Method		% Difference	
			Tension	Comp.	Tension	Comp.	Tension	Comp.
1	Tangent	End-I	0	0	0	0	0	0
		End-J	0	0	0	0	0	0
2	Bend	End-I	10565	-11935	10453	11809	1.07	1.15
		Center	15492	-17502	15334	-17325	1.03	1.02
		End-J	10866	-12275	10716	-12108	1.40	1.38
3	Tangent	End-I	0	0	0	0	0	0
		End-J	0	0	0	0	0	0
4	Bend	End-I	5812	- 6566	5748	- 6494	1.11	1.11
		Center	5424	- 6127	5366	- 6062	1.08	1.07
		End-J	1581	- 1786	1565	- 1769	1.02	1.00
5	Tangent	End-I	0	0	0	0	0	0
		End-J	0	0	0	0	0	0

Table 1-4 (cont'd)

Pipes Stresses

c) Shear Stress

Member	Type	Station	EPIPE		Analytical Method		% Difference	
			Max	Min	Max	Min	Max	Min
1	Tangent	End-I	1129	446	1141	443	1.05	0.70
		End-J	1129	446	1141	443	1.05	0.70
2	Bend	End-I	1129	446	1141	443	1.05	0.70
		Center	1568	1332	1585	1545	1.07	1.00
		End-J	2331	1663	2369	1685	1.60	1.31
3	Tangent	End-I	2331	1663	2369	1685	1.60	1.31
		End-J	2331	1663	2369	1685	1.60	1.31
4	Bend	End-I	2331	1663	2369	1685	1.60	1.31
		Center	2798	2110	2863	2159	2.27	2.26
		End-J	3869	2973	3984	3068	2.88	3.10
5	Tangent	End-I	3869	2973	3984	3068	2.88	3.10
		End-J	3869	2973	3984	3068	2.88	3.10

Table 1-4

Pipes Stresses (cont'd)

Member	Type	Station	Longitudinal Stress		Circumferential Stress		Shear Stress	
			EPIPE	Analytical Method	EPIPE	Analytical Method	EPIPE	Analytical Method
1	Tangent	End-I	17986.3	17953.4	5848.1	5848.1	1077.1	1115.1
		End-J	9385.1	8885.9	5848.1	5848.1	1077.1	1115.1
2	Bend	End-I	9699.4	8812.3	18657.4	16308.5	1077.1	1115.1
		Center	12667.3	11574.3	24261.5	21175.6	1534.0	1536.5
		End-J	9817.4	8969.3	18880.2	16572.7	2373.0	2303.6
3	Tangent	End-I	9416.9	8932.7	5848.1	5848.1	2373.0	2303.6
		End-J	6194.2	5947.4	5848.1	5848.1	2373.0	2303.6
4	Bend	End-I	6455.9	6004.0	12820.5	15583.3	2373.0	2310.6
		Center	6224.0	6025.2	12382.7	11600.0	2768.7	2749.0
		End-J	5760.1	5499.4	4369.0	4045.6	3844.8	3827.4
5	Tangent	End-I	5663.4	5613.4	5848.1	5848.1	3844.8	3827.4
		End-J	16308.7	16047.4	5848.1	5848.1	3844.8	3827.4

TABLE 1-5. HOVGGAARD PROBLEM, STATIC ANALYSIS, CASE A
 NODE DISPLACEMENTS / ROTATIONS

NODE NUMBER	LOAD CASE	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
6	1	0.	0.	0.	0.	0.	0.
5	1	.61117E-01	.76413E-01	-.24912E+00	.30054E-02	-.22401E-02	-.41696E-02
4	1	-.10313E+00	.48275E+00	-.40248E+00	.26112E-02	.15931E-02	-.85596E-02
3	1	-.31974E+00	.77626E+00	-.40594E+00	.49160E-03	.24761E-02	-.73033E-02
2	1	-.51466E+00	.66079E+00	-.24174E+00	-.28283E-02	.25503E-02	.50636E-02
1	1	0.	0.	0.	0.	0.	0.

TABLE 1-6 HOUGAARD PROBLEM STATIC ANALYSIS CASE A
FORCES AND MOMENTS

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSIONAL MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1	TANGENT	1	END-I	-1666.878	-628.243	-1710.968	14335.95	130165.22	-54876.09
			END-J	-1666.878	-628.243	-1710.968	14335.95	-56159.15	13539.63
2	BEND	1	END-I	-1666.878	-1710.968	628.243	14335.95	13539.63	56159.15
			CENTER	-2388.497	-31.176	628.243	26390.51	15562.65	82353.94
			END-J	-1710.968	1666.878	628.243	36344.86	8469.29	57759.62
3	TANGENT	1	END-I	-1710.968	-1666.878	-628.243	36344.86	-8469.29	-57759.62
			END-J	-1710.968	-1666.878	-628.243	36344.86	-30897.58	1747.91
4	BEND	1	END-I	-1710.968	-628.243	1666.878	36344.86	1747.91	30892.58
			CENTER	-1654.072	765.602	1666.878	44657.94	18321.64	28832.27
			END-J	-628.243	1710.968	1666.878	62255.57	24162.79	-8405.30
5	TANGENT	1	END-I	-628.243	-1666.878	1710.968	62255.57	8405.30	24162.79
			END-J	-628.243	-1666.878	1710.968	62255.57	78554.97	92504.77

TABLE 1-7 HUYGAARD PROBLEM STATIC ANALYSIS CASE A
PIPE STRESSES

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LONGITUDINAL STRESS		HOOP STRESS		SHEAR STRESS	
				POSITIVE	NEGATIVE	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
1	TANGENT	1	END-I	15211.45	-15036.29	0.00	0.00	1129.34	446.12
			END-J	6036.07	-6660.90	0.00	0.00	1129.34	446.12
2	BEND	1	END-I	6903.02	-7927.85	10564.40	-11934.78	1129.34	446.12
			CENTER	10020.66	-10915.99	15492.16	-17501.62	1568.00	1332.21
			END-J	6970.82	-7612.18	10865.55	-12274.90	2330.94	1663.20
3	TANGENT	1	END-I	6094.73	-6736.09	0.00	0.00	2330.94	1663.20
			END-J	3086.26	-3721.62	0.00	0.00	2330.94	1663.20
4	BEND	1	END-I	3544.70	-4186.06	5812.35	-6566.26	2330.94	1663.20
			CENTER	3956.82	-4576.85	5423.83	-6127.35	2797.65	2110.07
			END-J	3077.65	-3313.15	1581.18	-1786.27	3868.52	2973.11
5	TANGENT	1	END-I	2693.71	-2929.21	0.00	0.00	3868.52	2973.11
			END-J	13219.10	-13454.59	0.00	0.00	3868.52	2973.11

STATIC SOLUTION TIME 1.00

EQUATION SOLUTION = .01
DISPLACEMENT OUTPUT = .01
STRESS RECOVERY = .02

Problem 2 - Dynamic Response of Hovgaard Bend

The dynamic response of the same piping configuration as Problem 1 has been analyzed. The piping system is assumed subjected to the 1940 El Centro earthquake. Three different methods of analyses are employed, i.e.:

Case a - Time-history analysis using mode superposition.

Case b - Response spectrum analysis.

Case c - Direct step-by-step integrating method.

The answers gotten from the three different methods of solution are quite close. As expected, the results obtained from the response spectrum analysis are higher than those gotten from the other two methods.

Problem Description

i. Geometry - The piping geometry is the same as the one discussed previously in Problem 1. Table 2-1 shows the input nodal coordinates. In this analysis, the lumped mass method is used; each member is lumped at three points: one-half of the mass at the center points and one-fourth of the mass at both ends. The proportion of the masses at each point are as shown in Fig. 2-1. Table 2-2 shows the input masses applied the various individual at nodal points.

ii. Material data - Same as given in Problem 1.

Note: Circles represent elements.

Fig. 2-1

Lumped Mass System for Hovgaard Bend

TABLE 2-1 Input data for Dynamic Response of Hovgaard Bend

NODAL COORDINATES

NODE NUMBER	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES				
	X	Y	Z	XX	YY	ZZ	X	Y	Z	T	
1	1	1	1	1	1	1	0.0	0.0	0.0	0	0.0
2	0	0	0	0	0	0	0.0	54.450	0.0	0	0.0
3	0	0	0	0	0	0	0.0	108.900	0.0	0	0.0
4	0	0	0	0	0	0	10.632	134.568	0.0	0	0.0
5	0	0	0	0	0	0	36.300	145.200	0.0	0	0.0
6	0	0	0	0	0	0	54.150	145.200	0.0	0	0.0
7	0	0	0	0	0	0	72.000	145.200	0.0	0	0.0
8	0	0	0	0	0	0	97.668	145.200	10.632	0	0.0
9	0	0	0	0	0	0	108.300	145.200	36.300	0	0.0
10	0	0	0	0	0	0	108.300	145.200	56.800	0	0.0
11	1	1	1	1	1	1	108.300	145.200	77.300	0	0.0

TABLE 2-2 INPUT DATA FOR HOWGAARD PROBLEM

LUMPED MASSES DATA

NODE NUMBER	LOAD CASE	X-AXIS FORCE	Y-AXIS FORCE	Z-AXIS FORCE	X-AXIS MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
2	0	0.39880E-01	0.39880E-01	0.39880E-01	0.0	0.0	0.0
3	0	0.50320E-01	0.50320E-01	0.50320E-01	0.0	0.0	0.0
4	0	0.20880E-01	0.20880E-01	0.20880E-01	0.0	0.0	0.0
5	0	0.16980E-01	0.16980E-01	0.16980E-01	0.0	0.0	0.0
6	0	0.13070E-01	0.13070E-01	0.13070E-01	0.0	0.0	0.0
7	0	0.16980E-01	0.16980E-01	0.16980E-01	0.0	0.0	0.0
8	0	0.10440E-01	0.10440E-01	0.10440E-01	0.0	0.0	0.0
9	0	0.17950E-01	0.17950E-01	0.17950E-01	0.0	0.0	0.0
10	0	0.15010E-01	0.15010E-01	0.15010E-01	0.0	0.0	0.0

2. Z

iii. Loading conditions - The piping system is subjected to the ground motion of the Imperial Valley Earthquake, El Centro site, May 1940, in S-E direction. The ground acceleration of the piping system is assumed in the X-direction. Table 2-3 shows the data of the accelerograph up to 16 seconds at equal intervals of 0.02 seconds. The corresponding accelerograph is plotted in Fig. 2-2.

The same acceleration time-history is used to calculate the spectral acceleration used for the response spectrum analysis. The spectral acceleration resulting from the time history is listed in Table 2-4. These values are shown as the dashed lines in Fig. 2-3. The dark lines in Fig. 2-3 show the modified spectrum as per NRC Reg. Guide 1.122. The input values shown in Table 2-10 correspond to those of the modified spectrum.

Analyses Results

The computer outputs for all three analyses are included in the tables that follow. Tables 2-5 to 2-9 give the results for the time-history analysis, including the natural frequencies of the first 5 modes, their associated mode shapes, the maximum displacements with the time of their occurrence, the maximum forces and moments, and the maximum stress components.

Results from the response spectrum analysis are given in Tables 2-10 to 2-13, where the natural frequencies, the mode shapes, the modal participation factors, and the square root of the sum of the squares of the modal forces and the stresses are shown. Finally, tables 2-14 to 2-16 show the displacement,

forces and stress results obtained from the step-by-step integration method. The solutions obtained from all three methods appear to be analogous except as noted previously, the response spectrum analysis gives generally higher resultant forces and stresses than those of the other two methods.

It is to be noted that the outputs shown in the tables are maximum values over the specified time span. For some computer methods these values are dependent on the integration time step size as well as the print time step size. A complete discussion of this topic can be found in Appendix D of reference 18. For this particular analysis the time span was 16 seconds with 800 integration steps of 0.02 seconds each. The printout time was consistent with the integration step time, i.e., every integration step was printed.

TABLE 2-3 IMPERIAL VALLEY EARTHQUAKE, EL CENTRO SITE, MAY 18, 1940

TIME HISTORY ACCELERATION IN./SEC**2

TIME VALUE	FUNCTION	TIME VALUE	FUNCTION	TIME VALUE	FUNCTION	TIME VALUE	FUNCTION	TIME VALUE	FUNCTION
0.0	0.0	0.02000	-0.5510E 00	0.04000	-0.4252E 01	0.06000	-0.3976E 01	0.08000	-0.3465E 01
0.10000	-0.3740E 01	0.12000	-0.4724E 01	0.14000	-0.5591E 01	0.16000	-0.5039E 01	0.18000	-0.4331E 01
0.20000	-0.3346E 01	0.22000	-0.3346E 01	0.24000	-0.5157E 01	0.26000	-0.6929E 01	0.28000	-0.7638E 01
0.30000	-0.6378E 01	0.32000	-0.5669E 01	0.34000	-0.4252E 01	0.36000	-0.3228E 01	0.38000	-0.1654E 01
0.40000	-0.2598E 01	0.42000	-0.5157E 01	0.44000	-0.7480E 01	0.46000	-0.7717E 01	0.48000	-0.2598E 01
0.50000	0.1181E 01	0.52000	0.5551E 01	0.54000	-0.1929E 01	0.56000	-0.5039E 01	0.58000	-0.5669E 01
0.60000	-0.7992E 01	0.62000	-0.1024E 02	0.64000	-0.1279E 02	0.66000	-0.1205E 02	0.68000	-0.6772E 01
0.70000	-0.7756E 01	0.72000	-0.6417E 01	0.74000	-0.6457E 01	0.76000	-0.2638E 01	0.78000	0.9840E 00
0.80000	0.5906E 01	0.82000	0.9055E 01	0.84000	0.9921E 01	0.86000	0.1323E 02	0.88000	0.1823E 02
0.90000	0.1937E 02	0.92000	0.1650E 02	0.94000	0.1413E 02	0.96000	0.1067E 02	0.98000	0.9252E 01
1.00000	0.1335E 02	1.02000	0.1622E 02	1.04000	0.2087E 02	1.06000	0.2516E 02	1.08000	0.2882E 02
1.10000	0.2567E 02	1.12000	0.2358E 02	1.14000	0.1575E 02	1.16000	0.1575E 02	1.18000	0.2480E 01
1.20000	-0.2028E 02	1.22000	-0.3098E 02	1.24000	-0.2374E 02	1.26000	-0.1905E 02	1.28000	-0.9843E 01
1.30000	-0.2323E 01	1.32000	0.5276E 01	1.34000	0.1213E 02	1.36000	0.1965E 02	1.38000	0.2795E 02
1.40000	0.3917E 02	1.42000	0.4799E 02	1.44000	0.6020E 02	1.46000	0.5705E 02	1.48000	0.4547E 02
1.50000	0.3681E 02	1.52000	0.3512E 02	1.54000	0.3646E 02	1.56000	0.3303E 02	1.58000	0.3547E 02
1.60000	0.3909E 02	1.62000	0.4760E 02	1.64000	0.1291E 02	1.66000	-0.5807E 02	1.68000	-0.8134E 02
1.70000	-0.7831E 02	1.72000	-0.8908E 02	1.74000	-0.7150E 02	1.76000	-0.6791E 02	1.78000	-0.6898E 02
1.80000	-0.6902E 02	1.82000	-0.7106E 02	1.84000	-0.6417E 02	1.86000	-0.5303E 02	1.88000	-0.4279E 02
1.90000	-0.3079E 02	1.92000	-0.1689E 02	1.94000	-0.6690E 00	1.96000	0.1417E 02	1.98000	0.3091E 02
2.00000	0.4583E 02	2.02000	0.6291E 02	2.04000	0.7716E 02	2.06000	0.9496E 02	2.08000	0.1074E 03
2.10000	0.1195E 03	2.12000	0.1260E 03	2.14000	0.1345E 03	2.16000	0.1111E 03	2.18000	0.9150E 02
2.20000	-0.4716E 02	2.22000	-0.9342E 02	2.24000	-0.6457E 02	2.26000	-0.7342E 02	2.28000	-0.4311E 02
2.30000	-0.2965E 02	2.32000	-0.6811E 01	2.34000	0.4449E 01	2.36000	0.2098E 02	2.38000	0.3524E 02
2.40000	0.4669E 02	2.42000	0.6917E 02	2.44000	0.2268E 02	2.46000	-0.1036E 03	2.48000	-0.6091E 02
2.50000	-0.6907E 02	2.52000	-0.3984E 02	2.54000	-0.2279E 02	2.56000	0.9331E 01	2.58000	-0.2638E 02
2.60000	-0.7795E 02	2.62000	-0.6461E 02	2.64000	-0.6634E 02	2.66000	-0.5831E 02	2.68000	-0.4846E 02
2.70000	-0.3941E 02	2.72000	-0.2957E 02	2.74000	-0.2059E 02	2.76000	-0.1067E 02	2.78000	-0.1732E 01
2.80000	0.7402E 01	2.82000	-0.3740E 01	2.84000	-0.1705E 02	2.86000	-0.3299E 02	2.88000	-0.3744E 02
2.90000	-0.2996E 02	2.92000	-0.2358E 02	2.94000	-0.1315E 02	2.96000	-0.4252E 01	2.98000	0.7283E 01
3.00000	0.1653E 02	3.02000	0.2650E 02	3.04000	-0.3819E 01	3.06000	-0.1465E 02	3.08000	-0.1575E 01
3.10000	0.4330E 00	3.12000	0.1354E 02	3.14000	0.2224E 02	3.16000	0.3476E 02	3.18000	0.4449E 02
3.20000	0.5366E 02	3.22000	0.8622E 01	3.24000	0.9488E 01	3.26000	0.2689E 02	3.28000	0.2713E 02
3.30000	0.5189E 02	3.32000	0.5327E 02	3.34000	0.8031E 02	3.36000	-0.3665E 02	3.38000	-0.5150E 02
3.40000	-0.2724E 02	3.42000	-0.2150E 02	3.44000	0.2835E 01	3.46000	0.2657E 02	3.48000	-0.4201E 02
3.50000	-0.5858E 02	3.52000	-0.4216E 02	3.54000	-0.4575E 02	3.56000	-0.3000E 02	3.58000	-0.2201E 02
3.60000	-0.8465E 01	3.62000	-0.4961E 01	3.64000	-0.2653E 02	3.66000	-0.1276E 02	3.68000	-0.1327E 02
3.70000	-0.4291E 01	3.72000	0.6690E 00	3.74000	0.1177E 02	3.76000	0.1921E 02	3.78000	0.2394E 02
3.80000	0.8740E 01	3.82000	-0.1260E 01	3.84000	-0.9646E 01	3.86000	0.3031E 01	3.88000	0.8307E 01
3.90000	0.2236E 02	3.92000	0.3252E 02	3.94000	0.4748E 02	3.96000	0.5819E 02	3.98000	0.6839E 02
4.00000	0.1657E 02	4.02000	0.1142E 01	4.04000	0.1020E 02	4.06000	0.1153E 02	4.08000	-0.2165E 01
4.10000	-0.5787E 01	4.12000	0.5630E 01	4.14000	0.8110E 01	4.16000	0.1965E 02	4.18000	0.2539E 02
4.20000	0.3768E 02	4.22000	0.4441E 02	4.24000	0.5697E 02	4.26000	0.6413E 02	4.28000	0.7657E 02
4.30000	0.7307E 02	4.32000	0.7811E 02	4.34000	0.6965E 02	4.36000	0.4921E 02	4.38000	-0.4752E 02
4.40000	-0.2134E 02	4.42000	-0.1512E 02	4.44000	-0.1224E 02	4.46000	-0.4402E 02	4.48000	-0.6539E 02
4.50000	-0.9701E 02	4.52000	-0.7972E 02	4.54000	-0.7224E 02	4.56000	-0.5185E 02	4.58000	-0.3779E 02
4.60000	-0.1279E 02	4.62000	0.6063E 01	4.64000	0.3213E 02	4.66000	0.5193E 02	4.68000	0.7157E 02
4.70000	-0.2283E 01	4.72000	-0.6654E 01	4.74000	0.1122E 02	4.76000	0.1760E 02	4.78000	0.3870E 02
4.80000	0.5606E 02	4.82000	0.7295E 02	4.84000	0.9669E 02	4.86000	0.6634E 02	4.88000	-0.5433E 02
4.90000	-0.3933E 02	4.92000	-0.4287E 02	4.94000	-0.3571E 02	4.96000	-0.1846E 02	4.98000	-0.4921E 02
5.00	-0.8311E 02	5.02000	-0.6366E 02	5.04000	-0.6661E 02	5.06000	-0.5142E 02	5.08000	-0.4374E 02
5.10	-0.3043E 02	5.12000	-0.2000E 02	5.14000	-0.2142E 02	5.16000	-0.4724E 02	5.18000	-0.4760E 02

5.20000	-0.4559E 02	5.22000	-0.4508E 02	5.24000	-0.2823E 02	5.26000	-0.2150E 02	5.28000	0.2520E 01
5.30000	-0.3165E 02	5.32000	-0.6433E 02	5.34000	-0.3382E 02	5.36000	-0.3783E 02	5.38000	-0.1559E 02
5.40000	-0.5787E 01	5.42000	0.1256E 02	5.44000	0.2551E 02	5.46000	0.3549E 02	5.48000	0.1858E 02
5.50000	0.7795E 01	5.52000	-0.1063E 01	5.54000	0.1150E 02	5.56000	0.1752E 02	5.58000	0.3091E 02
5.60000	0.4067E 02	5.62000	0.5323E 02	5.64000	0.6323E 02	5.66000	0.7327E 02	5.68000	0.5043E 02
5.70000	0.2520E 02	5.72000	0.8031E 01	5.74000	0.1236E 02	5.76000	0.1468E 02	5.78000	0.1953E 02
5.80000	0.9252E 01	5.82000	-0.3307E 01	5.84000	-0.6614E 01	5.86000	-0.4449E 01	5.88000	-0.9016E 01
5.90000	-0.9764E 01	5.92000	-0.6181E 01	5.94000	-0.2717E 01	5.96000	0.5787E 01	5.98000	0.1492E 02
6.00000	0.2279E 02	6.02000	0.1004E 02	6.04000	-0.1614E 01	6.06000	-0.1685E 02	6.08000	-0.5236E 01
6.10000	0.3740E 01	6.12000	0.9055E 01	6.14000	-0.5079E 01	6.16000	-0.1969E 01	6.18000	0.3150E 01
6.20000	0.8268E 01	6.22000	0.1496E 02	6.24000	0.2008E 02	6.26000	0.6181E 01	6.28000	-0.1260E 01
6.30000	-0.4370E 01	6.32000	0.1570E 00	6.34000	0.2992E 01	6.36000	0.1378E 01	6.38000	-0.3740E 01
6.40000	-0.1417E 01	6.42000	-0.6300E 00	6.44000	0.1496E 01	6.46000	0.3346E 01	6.48000	-0.2205E 01
6.50000	-0.1197E 02	6.52000	-0.1657E 02	6.54000	-0.9606E 01	6.56000	-0.9291E 01	6.58000	-0.6969E 01
6.60000	-0.5079E 01	6.62000	-0.7090E 00	6.64000	0.1992E 01	6.66000	-0.4252E 01	6.68000	-0.3583E 01
6.70000	-0.1339E 01	6.72000	-0.4173E 01	6.74000	-0.4370E 01	6.76000	-0.3898E 01	6.78000	-0.7900E 01
6.80000	0.2874E 01	6.82000	0.9252E 01	6.84000	0.1398E 02	6.86000	0.2776E 02	6.88000	0.3067E 02
6.90000	0.7244E 01	6.92000	-0.1035E 02	6.94000	-0.4882E 01	6.96000	-0.1654E 01	6.98000	0.6260E 01
7.00000	0.1890E 01	7.02000	-0.8622E 01	7.04000	-0.1839E 02	7.06000	-0.1685E 02	7.08000	-0.8504E 01
7.10000	-0.1693E 01	7.12000	0.6260E 01	7.14000	0.1260E 02	7.16000	0.1650E 02	7.18000	0.4843E 01
7.20000	-0.6299E 01	7.22000	-0.8031E 01	7.24000	-0.3228E 01	7.26000	-0.8110E 01	7.28000	-0.5394E 01
7.30000	-0.2165E 01	7.32000	0.2087E 01	7.34000	0.5276E 01	7.36000	0.1047E 02	7.38000	0.9134E 01
7.40000	0.3110E 01	7.42000	-0.3150E 00	7.44000	0.7874E 01	7.46000	0.1713E 02	7.48000	0.1937E 02
7.50000	0.7520E 01	7.52000	0.3622E 01	7.54000	-0.8660E 00	7.56000	-0.8270E 00	7.58000	0.2047E 01
7.60000	0.3661E 01	7.62000	0.1004E 02	7.64000	0.1449E 02	7.66000	0.2067E 02	7.68000	0.2130E 02
7.70000	0.1673E 02	7.72000	0.1567E 02	7.74000	0.2201E 02	7.76000	0.2976E 02	7.78000	0.1437E 02
7.80000	0.1618E 02	7.82000	0.3858E 01	7.84000	-0.8031E 01	7.86000	-0.9803E 01	7.88000	-0.1594E 02
7.90000	-0.1626E 02	7.92000	-0.1854E 02	7.94000	-0.1705E 02	7.96000	-0.1803E 02	7.98000	-0.2244E 01
8.00000	0.7008E 01	8.02000	-0.8189E 01	8.04000	-0.1937E 02	8.06000	-0.2087E 02	8.08000	-0.1425E 02
8.10000	-0.1594E 02	8.12000	-0.1213E 02	8.14000	-0.1244E 02	8.16000	-0.1043E 02	8.18000	-0.1043E 02
8.20000	-0.1059E 02	8.22000	-0.1358E 02	8.24000	-0.1216E 02	8.26000	-0.8543E 01	8.28000	-0.3071E 01
8.30000	0.3425E 01	8.32000	0.1106E 02	8.34000	0.1220E 02	8.36000	0.1409E 02	8.38000	0.1342E 02
8.40000	0.1409E 02	8.42000	0.1130E 02	8.44000	0.1201E 02	8.46000	0.4409E 01	8.48000	0.8425E 01
8.50000	0.5354E 01	8.52000	0.1512E 02	8.54000	-0.3390E 02	8.56000	-0.5311E 02	8.58000	-0.5283E 02
8.60000	-0.5331E 02	8.62000	-0.4697E 02	8.64000	-0.4102E 02	8.66000	-0.3264E 02	8.68000	-0.2563E 02
8.70000	-0.1748E 02	8.72000	-0.1016E 02	8.74000	-0.2362E 01	8.76000	-0.3583E 01	8.78000	-0.7165E 01
8.80000	-0.5787E 01	8.82000	0.3346E 01	8.84000	0.6417E 01	8.86000	0.1969E 01	8.88000	0.1039E 02
8.90000	0.2291E 02	8.92000	0.3413E 02	8.94000	0.4724E 02	8.96000	0.6673E 02	8.98000	0.4374E 02
9.00000	-0.4331E 02	9.02000	-0.1441E 02	9.04000	-0.1752E 02	9.06000	-0.9291E 01	9.08000	-0.3779E 02
9.10000	-0.2583E 02	9.12000	-0.2350E 02	9.14000	-0.2638E 02	9.16000	-0.2173E 02	9.18000	-0.1063E 01
9.20000	0.1488E 02	9.22000	0.4220E 02	9.24000	0.6571E 02	9.26000	0.3728E 02	9.28000	0.1606E 02
9.30000	0.2626E 02	9.32000	0.5197E 01	9.34000	-0.3740E 01	9.36000	-0.2047E 02	9.38000	-0.3256E 02
9.40000	-0.4535E 02	9.42000	-0.4528E 02	9.44000	-0.3161E 02	9.46000	-0.1453E 02	9.48000	0.1142E 01
9.50000	0.2146E 02	9.52000	0.4630E 02	9.54000	0.6339E 02	9.56000	-0.1063E 02	9.58000	0.1339E 01
9.60000	-0.2205E 01	9.62000	0.7870E 00	9.64000	0.5748E 01	9.66000	0.2114E 02	9.68000	0.3142E 02
9.70000	-0.8071E 01	9.72000	-0.2323E 02	9.74000	-0.6654E 01	9.76000	-0.6890E 01	9.78000	-0.1102E 01
9.80000	0.2913E 01	9.82000	0.1504E 02	9.84000	0.2232E 02	9.86000	0.2965E 02	9.88000	0.3153E 02
9.90000	0.2331E 02	9.92000	0.1197E 02	9.94000	0.9060E 00	9.96000	0.2520E 01	9.98000	-0.1599E 02
10.00000	-0.1776E 02	10.02000	-0.3110E 01	10.04000	0.6614E 01	10.06000	0.2232E 02	10.08000	0.3661E 01
10.10000	-0.2165E 01	10.12000	0.1732E 01	10.14000	-0.4843E 01	10.16000	-0.1110E 02	10.18000	-0.1720E 02
10.20000	-0.1386E 02	10.22000	-0.1004E 02	10.24000	-0.4370E 01	10.26000	0.8071E 01	10.28000	0.2043E 02
10.30000	0.3362E 02	10.32000	0.4504E 02	10.34000	0.2886E 02	10.36000	0.9331E 01	10.38000	-0.1449E 02
10.40000	-0.1067E 02	10.42000	-0.8543E 01	10.44000	-0.3437E 02	10.46000	-0.3831E 02	10.48000	-0.2319E 02
10.50000	-0.1323E 02	10.52000	0.3031E 01	10.54000	0.1020E 02	10.56000	0.2000E 02	10.58000	0.1421E 02
10.60000	0.3189E 01	10.62000	-0.2205E 01	10.64000	-0.8228E 01	10.66000	-0.1248E 02	10.68000	-0.9370E 01
10.70000	-0.1480E 02	10.72000	-0.2165E 02	10.74000	-0.2842E 02	10.76000	-0.3161E 02	10.78000	-0.2059E 02
10.80000	-0.1339E 02	10.82000	-0.4330E 00	10.84000	0.2559E 01	10.86000	-0.1457E 01	10.88000	-0.1970E 00
10.90000	-0.6614E 01	10.92000	-0.1614E 02	10.94000	-0.3150E 01	10.96000	0.3110E 01	10.98000	0.1472E 02
11.00000	0.2421E 02	11.02000	0.2618E 02	11.04000	0.1000E 02	11.06000	-0.2244E 01	11.08000	-0.1866E 02
11.10000	-0.1402E 02	11.12000	-0.9567E 01	11.14000	-0.1890E 01	11.16000	0.4961E 01	11.18000	0.1492E 02
11.20000	0.9488E 01	11.22000	-0.8937E 01	11.24000	-0.1685E 02	11.26000	-0.2673E 02	11.28000	-0.2602E 02

11.30000	-0.2323E 02	11.32000	-0.2020F 02	11.34000	-0.1606E 02	11.36000	-0.1216E 02	11.38000	-0.1047E 02
11.40000	-0.2130E 02	11.42000	-0.2472E 02	11.44000	-0.3575E 02	11.46000	-0.4358E 02	11.48000	-0.3468E 02
11.50000	-0.3031E 02	11.52000	-0.2291E 02	11.54000	-0.1862E 02	11.56000	-0.1311E 02	11.58000	-0.7835E 01
11.60000	0.7870E 00	11.62000	0.8307E 01	11.64000	0.1701E 02	11.66000	0.2413E 02	11.68000	0.3020E 02
11.70000	0.3673E 02	11.72000	0.4197E 02	11.74000	0.4449E 02	11.76000	0.4673E 02	11.78000	0.4909E 02
11.80000	0.5252E 02	11.82000	0.6276E 02	11.84000	0.7075E 02	11.86000	0.8020E 02	11.88000	0.4866E 02
11.90000	0.1740E 02	11.92000	-0.5512E 01	11.94000	-0.2622E 02	11.96000	-0.2185E 02	11.98000	-0.2728E 02
12.00000	-0.3874E 02	12.02000	-0.4905E 02	12.04000	-0.4642E 02	12.06000	-0.4134E 02	12.08000	-0.3622E 02
12.10000	-0.2925E 02	12.12000	-0.3185E 02	12.14000	-0.3346E 02	12.16000	-0.3386E 02	12.18000	-0.3398E 02
12.20000	-0.3437E 02	12.22000	-0.3417E 02	12.24000	-0.3484E 02	12.26000	-0.2114E 02	12.28000	0.2047E 01
12.30000	0.8465F 01	12.32000	0.9646E 01	12.34000	0.2283E 02	12.36000	0.1236E 02	12.38000	0.9291E 01
12.40000	0.1909E 02	12.42000	0.2319E 02	12.44000	0.2067E 02	12.46000	0.1398E 02	12.48000	0.7756E 01
12.50000	0.7835E 01	12.52000	0.1937E 02	12.54000	0.1350E 02	12.56000	0.1134E 02	12.58000	0.1701E 02
12.60000	0.9409E 01	12.62000	0.3465E 01	12.64000	0.3031E 01	12.66000	-0.5827E 01	12.68000	-0.3031E 01
12.70000	-0.7480E 00	12.72000	0.2953E 01	12.74000	0.1732E 01	12.76000	-0.5709E 01	12.78000	-0.1244E 02
12.80000	-0.9488E 01	12.82000	-0.1102E 01	12.84000	0.7165E 01	12.86000	0.1677E 02	12.88000	0.1728E 02
12.90000	0.2016E 02	12.92000	0.1835E 02	12.94000	0.1886E 02	12.96000	0.7598E 01	12.98000	0.8740E 01
13.00000	0.1079E 02	13.02000	0.1547E 02	13.04000	0.1984E 02	13.06000	0.2272E 02	13.08000	0.2315E 02
13.10000	0.3236E 02	13.12000	0.3138E 02	13.14000	0.3736E 02	13.16000	0.1358E 02	13.18000	0.1772E 01
13.20000	-0.4843E 01	13.22000	-0.1366E 02	13.24000	-0.1677E 02	13.26000	-0.1638E 02	13.28000	-0.1083E 02
13.30000	-0.1063E 02	13.32000	0.2913E 01	13.34000	0.1685E 02	13.36000	-0.9094E 01	13.38000	-0.1524E 02
13.40000	-0.3268E 01	13.42000	0.5472E 01	13.44000	0.1752E 02	13.46000	0.1063E 01	13.48000	-0.2744E 02
13.50000	-0.3134E 02	13.52000	-0.9882E 01	13.54000	-0.5315E 01	13.56000	0.3110E 01	13.58000	-0.4528E 01
13.60000	-0.9882E 01	13.62000	-0.1311E 02	13.64000	-0.1059E 02	13.66000	-0.1185E 02	13.68000	-0.7874E 01
13.70000	-0.2638E 01	13.72000	-0.1494E 01	13.74000	0.4134E 01	13.76000	0.1165E 02	13.78000	0.1354E 02
13.80000	0.3768E 02	13.82000	0.3535E 02	13.84000	0.7047E 01	13.86000	-0.1425E 02	13.88000	-0.3913E 02
13.90000	-0.3177E 02	13.92000	-0.2929E 02	13.94000	-0.2122E 02	13.96000	-0.1299E 02	13.98000	-0.5039E 01
14.00000	0.1220E 01	14.02000	0.5827E 01	14.04000	0.2000E 02	14.06000	-0.8660E 00	14.08000	-0.1925E 02
14.10000	-0.1409E 02	14.12000	-0.2720E 02	14.14000	-0.2031E 02	14.16000	-0.1461E 02	14.18000	0.3465E 01
14.20000	0.2488E 02	14.22000	0.3311E 02	14.24000	0.5024E 02	14.26000	0.5465E 02	14.28000	0.4697E 02
14.30000	0.2957E 02	14.32000	0.8850E 01	14.34000	-0.3465E 01	14.36000	-0.8937E 01	14.38000	0.2913E 01
14.40000	0.7126E 01	14.42000	0.2142E 02	14.44000	0.1571E 02	14.46000	0.1772E 01	14.48000	-0.3228E 01
14.50000	-0.7283E 01	14.52000	-0.7870E 00	14.54000	0.2360E 00	14.56000	-0.4606E 01	14.58000	-0.8268E 01
14.60000	-0.1193E 02	14.62000	-0.2016E 02	14.64000	-0.2862E 02	14.66000	-0.2279E 02	14.68000	-0.1047E 02
14.70000	-0.7008E 01	14.72000	0.1575E 01	14.74000	0.3858E 01	14.76000	0.5394E 01	14.78000	0.8701E 01
14.80000	0.1720E 02	14.82000	0.3583E 01	14.84000	-0.2157E 02	14.86000	-0.2185E 02	14.88000	-0.9567E 01
14.90000	-0.3189E 01	14.92000	0.9843E 01	14.94000	0.1614E 02	14.96000	0.7165E 01	14.98000	-0.1063E 01
15.00000	-0.9567E 01	15.02000	-0.5910E 00	15.04000	0.9724E 01	15.06000	0.1898E 02	15.08000	0.3083E 02
15.10000	0.2449E 02	15.12000	0.1303E 02	15.14000	-0.5510E 00	15.16000	-0.7677E 01	15.18000	-0.9724E 01
15.20000	-0.8346E 01	15.22000	-0.4331E 01	15.24000	0.1969E 01	15.26000	0.9488E 01	15.28000	-0.1339E 01
15.30000	-0.8504E 01	15.32000	-0.1854E 02	15.34000	-0.1429E 02	15.36000	-0.7677E 01	15.38000	-0.7090E 00
15.40000	0.6693E 01	15.42000	-0.3150E 01	15.44000	0.1970E 00	15.46000	0.9055E 01	15.48000	0.1472E 02
15.50000	0.2366E 02	15.52000	0.2031E 02	15.54000	0.1701E 02	15.56000	0.1354E 02	15.58000	0.1988E 02
15.60000	0.2571E 02	15.62000	0.2689E 02	15.64000	0.6772E 01	15.66000	-0.6693E 01	15.68000	-0.2075E 02
15.70000	-0.2614E 02	15.72000	-0.1524E 02	15.74000	-0.8740E 01	15.76000	-0.1299E 01	15.78000	0.4685E 01
15.80000	-0.5039E 01	15.82000	-0.1382E 02	15.84000	-0.2024E 02	15.86000	-0.1319E 02	15.88000	-0.8583E 01
15.90000	-0.4720E 00	15.92000	0.5591E 01	15.94000	0.2756E 01	15.96000	-0.2480E 01	15.98000	-0.4724E 01
16.00000	-0.1268E 02

FIG. 2-2 TIME HISTORY ACCELERATION OF THE IMPERIAL VALLEY EARTHQUAKE EI CENTRO SITE MAY 18, 1940 S00E DIRECTION

TABLE 2-4

Imperial Valley Earthquake, May 18, 1940

I. Acceleration Spectrum Before Modified (shown dotted line in Fig. 2-3)

<u>Period</u>	<u>Frequency</u>	<u>Spectral Accel.</u>
.0017	588.24	136.6073
.0329	30.39	333.9189
.0641	15.60	744.0145
.0953	10.50	342.2616
.1265	7.91	1186.5160
.1977	6.34	509.5554
.1839	5.29	665.5077
.2201	4.54	870.3499
.2513	3.98	631.5481
.2825	3.54	406.5282

II. Acceleration Spectrum After Modified (shown solid line in Fig. 2-3)

<u>Period</u>	<u>Frequency</u>	<u>Spectral Accel.</u>
.001698	588.93	145.0
.029600	34.97	380.0
.058000	17.24	755.0
.071000	14.08	775.0
.091000	10.99	440.0
.114000	8.77	1188.0
.141000	7.09	1188.0
.172000	5.81	700.0
.200000	5.00	871.0
.250000	4.00	871.0
.32300	3.09	400.0

FIGURE 2-3 EARTHQUAKE SPECTRUM

TABLE 2-5 HOYGAARD PROBLEY DYNAMIC CASE A (TIME HISTORY ANALYSIS)
N A T U R A L F R E Q U E N C I E S

MODE NUMBER	CIRCULAR FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	.1793E+03	.2853E+02	.3504E-01
2	.3564E+03	.5577E+02	.1793E-01
3	.5121E+03	.8150E+02	.1227E-01
4	.8906E+03	.1417E+03	.7055E-02
5	.1023E+04	.1620E+03	.6142E-02

TABLE 2-6A HOVGGAARD PIPING SYSTEM CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 1

FREQUENCY = 28.5350 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	3.42220E-01	-5.68485E-05	-8.45645E-01	-2.79575E-02	-1.00245E-02	-1.07313E-02
3	1.01698E+00	-1.12766E-04	-2.66879E+00	-3.37631E-02	-2.00490E-02	-1.25227E-02
4	1.30013E+00	-1.10545E-01	-3.19652E+00	-2.65499E-02	-2.72373E-02	-9.05107E-03
5	1.38233E+00	-2.90462E-01	-2.62144E+00	-2.08346E-02	-3.67169E-02	-5.17444E-03
6	1.38218E+00	-3.73702E-01	-1.94797E+00	-1.85808E-02	-3.83704E-02	-4.15648E-03
7	1.38154E+00	-4.39014E-01	-1.25435E+00	-1.63271E-02	-3.88531E-02	-7.20969E-03
8	9.58890E-01	-3.46124E-01	-3.01433E-01	-1.24720E-02	-3.28633E-02	-1.57579E-03
9	3.57079E-01	-1.24825E-01	-1.31918E-03	-5.78975E-03	-1.61227E-02	-1.38556E-03
10	9.59511E-02	-3.27589E-02	-6.54614E-04	-3.07759E-03	-8.85114E-03	-6.92778E-04

MODE NUMBER 1

EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	0.	0.	0.	0.	0.	0.
2	1.07060E-01	-1.77845E-05	-2.77065E-01	-8.74623E-03	-3.13606E-03	-3.35719E-03
3	3.18154E-01	-3.55193E-05	-8.74905E-01	-1.05625E-02	-6.27212E-03	-3.91759E-03
4	4.06735E-01	-3.45820E-02	-1.00600E+00	-8.30589E-03	-8.51567E-03	-2.84405E-03
5	4.32449E-01	-9.08681E-02	-6.20092E-01	-6.51790E-03	-1.14865E-02	-1.61877E-03
6	4.32401E-01	-1.16880E-01	-6.09402E-01	-5.81283E-03	-1.20038E-02	-1.30031E-03
7	4.32325E-01	-1.37341E-01	-3.92410E-01	-5.10777E-03	-1.21540E-02	-1.00412E-03
8	3.12495E-01	-1.08281E-01	-9.43003E-02	-3.90173E-03	-1.02810E-02	-4.92970E-04
9	1.11705E-01	-3.90535E-02	-4.12692E-04	-1.81127E-03	-5.04282E-03	-4.32458E-04
10	3.00174E-02	-1.02483E-02	-2.06354E-04	-9.62793E-04	-2.76895E-03	-2.16729E-04
11	0.	0.	0.	0.	0.	0.

TABLE 2-6B HOVGGAARD PIPING SYSTEM CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 2
FREQUENCY = 55.7724 Hz

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	9.04855E-01	-2.07745E-04	7.23290E-01	2.03365E-02	1.39412E-02	-2.54586E-02
3	2.21235E+00	-4.15056E-04	1.76570E+00	1.42084E-02	2.70825E-02	-1.79003E-02
4	2.43128E+00	-5.91614E-02	1.56927E+00	1.68264E-04	3.67200E-02	-1.28283E-03
5	2.42082E+00	-3.34369E-02	5.76743E-01	-1.48105E-03	3.52568E-02	1.01100E-03
6	2.41826E+00	-1.84942E-02	-1.84269E-02	-1.17404E-03	2.57510E-02	7.02217E-04
7	2.41517E+00	-8.13543E-03	-4.76724E-01	-8.67035E-04	1.59653E-02	4.93019E-04
8	2.28098E+00	3.39875E-03	-4.76210E-01	-3.09250E-04	-2.76535E-02	4.00310E-05
9	1.15743E+00	4.35425E-03	2.96750E-03	1.13667E-04	-4.40585E-02	-4.55960E-05
10	3.73511E-01	1.61722E-03	1.48397E-03	1.18205E-04	-3.07772E-02	-2.27980E-05

MODE NUMBER 2
EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	0.	0.	0.	0.	0.	0.
2	3.72172E-01	-8.54465E-05	2.97493E-01	8.36450E-03	5.73411E-03	-1.04713E-02
3	9.05950E-01	-1.70715E-04	7.26241E-01	5.84398E-03	1.14682E-02	-7.26250E-02
4	1.00000E+00	-2.42334E-02	6.45448E-01	6.92077E-05	1.51032E-02	-5.27635E-04
5	9.95655E-01	-1.77527E-02	2.37218E-01	-6.06166E-04	1.45178E-02	4.15828E-04
6	9.94646E-01	-7.60678E-03	-7.57908E-03	-4.42891E-04	1.22532E-02	2.88826E-04
7	9.93374E-01	-5.74615E-03	-1.96079E-01	-3.56616E-04	8.21183E-03	2.02781E-04
8	4.38175E-01	1.75365E-03	-1.67076E-01	-1.27156E-04	-1.13505E-02	1.64650E-05
9	4.52505E-01	1.90742E-03	1.22055E-03	4.67518E-05	-1.81215E-02	-1.87539E-05
10	1.57627E-01	6.65172E-04	6.10765E-04	4.86184E-05	-1.26588E-02	-9.37694E-06
11	0.	0.	0.	0.	0.	0.

TABLE 2-6C HOVGGAARD PIPING SYSTEM CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 3

FREQUENCY = 41.5000 1/2

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	-9.11753E-01	-1.25395E-02	4.68251E-01	1.01245E-02	-4.96765E-04	1.97079E-02
3	-1.20689E+00	-2.50233E-02	6.20428E-01	-8.17178E-03	-9.93529E-04	-1.59548E-02
4	-7.66579E-02	-6.02984E-01	2.54954E-02	-3.64076E-02	2.31327E-03	-6.73028E-02
5	6.98456E-01	-2.47147E+00	-4.89100E-01	-5.21965E-02	6.86809E-05	-6.57881E-02
6	6.98894E-01	-3.56108E+00	-4.66191E-01	-6.08808E-02	-2.77863E-03	-5.41198E-02
7	6.98908E-01	-4.79551E+00	-3.89744E-01	-6.45650E-02	-5.69373E-03	-3.90026E-02
8	5.80963E-01	-3.95203E+00	-1.39614E-01	-8.66527E-02	-1.27204E-02	1.21125E-04
9	2.58512E-01	-1.75695E+00	-2.81195E-04	-6.95974E-02	-1.03030E-02	2.54053E-03
10	7.67149E-02	-5.22574E-01	-4.40736E-04	-4.46162E-02	-6.55702E-03	1.27026E-03

MODE NUMBER 2

EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	0.	0.	0.	0.	0.	0.
2	-2.07428E-01	-2.45281E-03	1.06529E-01	2.30337E-03	-1.13016E-04	4.48365E-03
3	-2.74574E-01	-5.65293E-03	1.41150E-01	-1.85912E-03	-2.26033E-04	-3.62980E-03
4	-1.74400E-02	-1.77409E-01	5.80033E-03	-8.28292E-03	5.26280E-04	-1.53117E-02
5	1.58902E-01	-5.62773E-01	-1.11273E-01	-1.18750E-02	1.56252E-05	-1.49671E-02
6	1.59002E-01	-8.10162E-01	-1.06061E-01	-1.38507E-02	-6.32151E-04	-1.23125E-02
7	1.59025E-01	-1.00000E+00	-8.85688E-02	-1.58264E-02	-1.29535E-03	-8.87328E-03
8	1.32172E-01	-6.95334E-01	-3.17628E-02	-1.47139E-02	-2.89396E-03	2.75565E-05
9	5.88126E-02	-3.88715E-01	-2.00476E-04	-1.58338E-02	-2.34399E-03	5.77983E-04
10	1.74530E-02	-1.15116E-01	-1.00270E-04	-1.01504E-02	-1.49194E-03	2.88992E-04
11	0.	0.	0.	0.	0.	0.

TABLE 2-6D HOVGAARD PIPING SYSTEM CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 4

FREQUENCY = 141.742 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	1.63015E-01	-6.30600E-03	-2.59579E+00	-3.87677E-02	-2.76003E-02	-3.10802E-03
3	2.42166E-01	-1.25272E-02	-1.71408E+00	7.02914E-02	-5.52006E-02	-5.39572E-04
4	3.12033E-01	-6.21472E-02	1.79015E+00	1.19713E-01	-6.12623E-02	-7.68300E-03
5	4.24076E-01	-3.76639E-01	3.70256E+00	8.34849E-02	1.68665E-02	-1.34464E-02
6	4.21862E-01	-6.02670E-01	3.11288E+00	6.40801E-02	4.77748E-02	-1.06929E-02
7	4.18237E-01	-7.53797E-01	2.02108E+00	4.46753E-02	6.83542E-02	-5.97563E-03
8	1.05557E+00	-5.15707E-01	2.26237E-01	9.95421E-03	4.49590E-02	1.04846E-02
9	1.15490E+00	-5.56224E-01	2.28673E-02	-1.79443E-02	-3.04828E-02	1.06237E-02
10	4.25617E-01	-2.98297E-01	1.14446E-02	-1.57618E-02	-3.09592E-02	5.31184E-03

MODE NUMBER 4

EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	0.	0.	0.	0.	0.	0.
2	4.40286E-02	-1.70315E-03	-7.02160E-01	-1.04705E-02	-7.45439E-03	-8.39425E-04
3	6.54057E-02	-3.38329E-03	-4.62946E-01	1.89846E-02	-1.49088E-02	-1.45730E-04
4	8.45450E-02	-1.47849E-02	4.83491E-01	3.23325E-02	-1.65459E-02	-2.07505E-03
5	1.14752E-01	-1.01724E-01	1.00000E+00	2.25479E-02	4.55537E-03	-3.63165E-03
6	1.13938E-01	-1.62774E-01	8.40738E-01	1.73070E-02	1.29032E-02	-2.88798E-03
7	1.12955E-01	-2.03588E-01	5.45861E-01	1.20661E-02	1.84614E-02	-1.61392E-03
8	2.95855E-01	-2.46398E-01	6.11029E-02	2.68847E-03	1.21535E-02	2.83172E-03
9	3.11515E-01	-1.61030E-01	6.17609E-03	-4.84645E-03	-0.23291E-03	2.86928E-03
10	1.14952E-01	-5.62577E-02	3.09099E-03	-4.25702E-03	-8.37237E-03	1.43464E-03
11	0.	0.	0.	0.	0.	0.

TABLE 2-6E HØVGAARD PIPING SYSTEM CASE A (TIME HISTORY)

M O D E S H A P E

MODE NUMBER 5
FREQUENCY = 162.020 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	-3.26947E+00	1.85720E-03	-2.59724E-01	-2.60102E-03	5.53053E-03	4.04174E-02
3	-1.54153E+00	2.40144E-03	-1.70891E-02	1.08414E-02	1.10611E-02	-8.77539E-02
4	1.14521E+00	-1.06510E+00	2.72620E-01	2.10019E-02	1.31944E-02	-7.53788E-02
5	1.49734E+00	-1.20183E+00	1.55074E-01	2.81283E-02	1.40426E-02	5.91981E-02
6	1.50466E+00	1.36131E-01	-8.85964E-02	3.28020E-02	1.22623E-02	8.34935E-02
7	1.50911E+00	1.73410E+00	-2.76960E-01	3.74756E-02	8.02499E-03	8.86161E-02
8	1.44624E+00	3.18733E+00	-2.28086E-01	5.49813E-02	-1.42102E-02	5.48752E-02
9	8.28226E-01	1.92073E+00	-6.07465E-04	6.82498E-02	-2.81082E-02	2.72084E-02
10	2.73838E-01	6.24066E-01	-3.04115E-04	4.99306E-02	-2.15497E-02	1.36042E-02

MODE NUMBER 6
EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	0.	0.	0.	0.	0.	0.
2	-1.00000E+00	5.68043E-04	-7.94393E-02	-8.20017E-04	1.69157E-03	1.23621E-02
3	-4.71494E-01	1.12600E-03	-5.22689E-03	3.31596E-03	3.38314E-03	-2.68404E-02
4	3.50275E-01	-3.27010E-11	8.33837E-02	6.42364E-03	4.03564E-03	-2.30554E-02
5	4.57975E-01	-2.67596E-11	4.74310E-02	8.60333E-03	4.29508E-03	1.81063E-02
6	4.60214E-01	4.16370E-02	-2.70981E-02	1.00328E-02	3.75054E-03	2.55373E-02
7	4.61574E-01	5.30016E-01	-8.47109E-02	1.14623E-02	2.45452E-03	2.71041E-02
8	4.42346E-01	5.74878E-01	-6.97625E-02	1.68172E-02	-4.34634E-03	1.67841E-02
9	2.52352E-01	5.90524E-01	-1.85799E-04	2.08749E-02	-8.59716E-03	8.32198E-03
10	8.27562E-02	1.90889E-01	-5.30165E-05	1.52718E-02	-6.59115E-03	4.16099E-03
11	0.	0.	0.	0.	0.	0.

TABLE 2-7. HOGGAARD PROBLEM DYNAMIC CASE 1 (TIME HISTORY ANALYSIS)
DISPLACEMENT MAXIMA

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
2	1	8.8100E-04	2.2200E+00	NA
	2	1.6853E-07	2.2200E+00	VA
	3	6.2993E-04	2.4800E+00	NA
3	1	2.2050E-03	2.4800E+00	NA
	2	3.3738E-07	2.2200E+00	NA
	3	1.9837E-03	2.4800E+00	NA
4	1	2.5416E-03	2.4800E+00	VA
	2	1.1368E-04	2.4800E+00	VA
	3	2.5596E-03	2.4800E+00	NA
5	1	2.5453E-03	2.4800E+00	NA
	2	2.3299E-04	2.4800E+00	VA
	3	2.3916E-03	2.4800E+00	NA
6	1	2.5938E-03	2.4800E+00	VA
	2	2.9584E-04	2.4800E+00	NA
	3	1.9834E-03	2.4800E+00	VA
7	1	2.5919E-03	2.4800E+00	NA
	2	3.5449E-04	2.4800E+00	VA
	3	1.4980E-03	2.4800E+00	NA
8	1	2.1407E-03	2.4800E+00	NA
	2	2.8551E-04	2.4800E+00	NA
	3	5.0300E-04	2.4800E+00	NA
9	1	9.6589E-04	2.2200E+00	VA
	2	1.0416E-04	2.4800E+00	NA
	3	1.1174E-06	2.5200E+00	VA
10	1	2.8910E-04	2.2200E+00	NA
	2	2.7302E-05	2.4800E+00	VA
	3	5.5492E-07	2.5200E+00	NA
11	3	9.6589E-04	2.2200E+00	VA
	2	1.0416E-04	2.4800E+00	NA
	3	1.1174E-06	2.5200E+00	VA

TABLE 2-A HOUFGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)
 FORCE COMPONENT MAXIMUM

ELEMENT TYPE NUMBER 2

ELEMENT NUMBER	LOCATION	FORCE COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	3.9634E-01	2.2200E+00
		FY	4.0268E+00	2.4800E+00
		FZ	1.0837E+01	2.2200E+00
		TX	4.7300E+01	2.4800E+00
		TY	6.5679E+02	2.2200E+00
		TZ	4.0648E+02	2.4800E+00
1	END-J	FX	3.9634E-01	2.2200E+00
		FY	4.0268E+00	2.4800E+00
		FZ	1.0837E+01	2.2200E+00
		TX	4.7300E+01	2.4800E+00
		TY	8.5760E+01	2.4800E+00
		TZ	1.8722E+02	2.4800E+00
2	END-I	FX	3.9707E-01	2.2200E+00
		FY	3.1932E+00	2.4800E+00
		FZ	5.5696E+00	2.2200E+00
		TX	4.7300E+01	2.4800E+00
		TY	8.5760E+01	2.4800E+00
		TZ	1.8722E+02	2.4800E+00
2	END-J	FX	3.9707E-01	2.2200E+00
		FY	3.1932E+00	2.4800E+00
		FZ	5.5696E+00	2.2200E+00
		TX	4.7300E+01	2.4800E+00
		TY	2.3654E+02	2.2200E+00
		TZ	3.6054E+01	2.5200E+00
3	END-I	FX	3.9883E-01	2.2200E+00
		FY	5.2949E+00	2.2200E+00
		FZ	2.5199E+00	2.4800E+00
		TX	4.7300E+01	2.4800E+00
		TY	3.6059E+01	2.5200E+00
		TZ	2.3654E+02	2.2200E+00
3	END-J	FX	3.4624E+00	2.2200E+00
		FY	4.0261E+00	2.2200E+00
		FZ	2.5199E+00	2.4800E+00
		TX	1.5433E+01	2.4800E+00
		TY	2.1253E+01	2.4800E+00
		TZ	1.0021E+02	2.4800E+00

4	END-I	FX	6.4349E+00	2.2200E+00
		FY	6.5709E+00	2.2200E+00
		FZ	3.2222E+00	2.2200E+00
		TX	1.5033E+01	2.4800E+00
		TY	9.1253E+01	2.4800E+00
		TZ	1.0021E+02	2.4800E+00

4	END-J	FX	9.1964E+00	2.2200E+00
		FY	1.0062E-01	5.0000E+00
		FZ	3.2222E+00	2.2200E+00
		TX	8.3043E+01	2.4800E+00
		TY	1.4552E+02	2.4800E+00
		TZ	2.4238E+01	2.5400E+00

5	END-I	FX	1.2202E+01	2.2200E+00
		FY	3.6308E-01	2.2200E+00
		FZ	3.6572E+00	2.2200E+00
		TX	8.3043E+01	2.4800E+00
		TY	1.4552E+02	2.4800E+00
		TZ	2.4238E+01	2.5400E+00

5	END-J	FX	1.2202E+01	2.2200E+00
		FY	3.6308E-01	2.2200E+00
		FZ	3.6572E+00	2.2200E+00
		TX	8.3043E+01	2.4800E+00
		TY	1.4552E+02	2.4800E+00
		TZ	2.1096E+01	2.5400E+00

6	END-I	FX	1.4511E+01	2.2200E+00
		FY	5.2669E-01	2.2200E+00
		FZ	3.6494E+00	2.2200E+00
		TX	8.3043E+01	2.4800E+00
		TY	1.9684E+02	2.2200E+00
		TZ	2.1096E+01	2.5400E+00

6	END-J	FX	1.4511E+01	2.2200E+00
		FY	5.2669E-01	2.2200E+00
		FZ	3.6494E+00	2.2200E+00
		TX	8.3043E+01	2.4800E+00
		TY	2.6194E+02	2.2200E+00
		TZ	2.1713E+01	2.4800E+00

7	END-I	FX	1.7505E+01	2.2200E+00
		FY	3.5962E+00	2.5200E+00
		FZ	4.0274E-01	2.5200E+00
		TX	8.3043E+01	2.4800E+00
		TY	2.1713E+01	2.4800E+00
		TZ	2.5194E+02	2.2200E+00

7	END-J	FX	1.4633E+01	2.2200E+00
		FY	1.0294E+01	2.4800E+00
		FZ	4.8279E-01	2.5200E+00
		TX	7.6090E+01	2.4800E+00
		TY	3.8499E+01	2.4800E+00
		TZ	1.5791E+02	2.2200E+00

8	END-I	FX	1.5691E+01	2.2200E+00
		FY	1.1692E+01	2.4800E+00
		FZ	2.8569E-01	2.5200E+00
		TX	7.6090E+01	2.4800E+00
		TY	3.8499E+01	2.4800E+00
		TZ	1.5791E+02	2.2200E+00

9	END-J	FX	3.4814E+00	2.5200E+00
		FY	1.9275E+01	2.2200E+00
		FZ	2.8569E-01	2.5200E+00
		TX	2.5399E+01	2.4800E+00
		TY	0.3870E+01	2.4800E+00
		TZ	3.3874E+02	2.4800E+00

9	END-I	FX	3.4885E+00	2.5200E+00
		FY	4.7653E-01	2.4800E+00
		FZ	2.0945E+01	2.2200E+00
		TX	2.5399E+01	2.4800E+00
		TY	3.3874E+02	2.4800E+00
		TZ	0.3870E+01	2.4800E+00

9	END-J	FX	3.4885E+00	2.5200E+00
		FY	4.7653E-01	2.4800E+00
		FZ	2.0945E+01	2.2200E+00
		TX	2.5399E+01	2.4800E+00
		TY	7.3946E+02	2.4800E+00
		TZ	9.3647E+01	2.4800E+00

10	END-I	FX	3.4913E+00	2.5200E+00
		FY	5.7995E-01	2.4800E+00
		FZ	2.1387E+01	2.2200E+00
		TX	2.5399E+01	2.4800E+00
		TY	7.3946E+02	2.4800E+00
		TZ	9.3647E+01	2.4800E+00

10	END-J	FX	3.4913E+00	2.5200E+00
		FY	5.7995E-01	2.4800E+00
		FZ	2.1387E+01	2.2200E+00
		TX	2.5399E+01	2.4800E+00
		TY	1.1737E+03	2.2200E+00
		TZ	1.0554E+02	2.4800E+00

TABLE 2-9 HJUGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)
STRESS COMPONENT MAXIMA

ELEMENT NUMBER	LOCATION	LONGITUDINAL STRESS	CIRCUMFER STRESS	SHEAR STRESS
1	END-I	84.96	0.00	4.77
	END-J	22.71	0.00	4.77
2	END-I	22.71	0.00	3.80
	END-J	26.37	0.00	3.80
3	END-I	29.62	43.03	3.71
	END-J	13.17	18.23	1.73
4	END-I	13.72	18.23	2.20
	END-J	19.90	4.41	5.17
5	END-I	18.50	0.00	5.25
	END-J	24.04	0.00	5.25
6	END-I	24.44	0.00	5.25
	END-J	31.61	0.00	5.25
7	END-I	36.00	47.65	5.24
	END-J	22.47	28.72	6.11
8	END-I	22.66	28.72	6.37
	END-J	42.96	61.61	5.01
9	END-I	39.09	0.00	5.32
	END-J	82.57	0.00	5.32
10	END-I	82.57	0.00	5.41
	END-J	130.16	0.00	5.41

TABLE 2-10 HOVGGAARD PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

MODAL PARTICIPATION FACTORS AND EARTHQUAKE RESPONSE

DIRECTION FACTORS

X = 1.0000 Y = -0.0000 Z = -0.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT

EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	.1752E+00	-.2593E-01	-.3308E+00
2	.3628E+00	-.2074E-02	.1478E+00
3	-.5397E-01	-.2582E+00	.2793E-01
4	.8361E-01	-.5268E-01	-.1174E-01
5	-.7925E-01	.6605E-01	-.1115E-01

SPECTRUM TABLE (IMPERIAL VALLEY E.Q. ELCENTRO 1940 SE)

NUMBER OF POINTS = 11

SCALE FACTOR = .10000E+01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	.1490E-02	.1450E+03
2	.2860E-01	.3800E+03
3	.5800E-01	.7750E+03
4	.7100E-01	.7750E+03
5	.9100E-01	.4400E+03
6	.1140E+00	.1180E+04
7	.1410E+00	.1180E+04
8	.1720E+00	.7000E+03
9	.2000E+00	.8710E+03
10	.2500E+00	.8710E+03
11	.3230E+00	.4000E+03

TABLE 2-11A HØVGAARD PIPING SYSTEM CASE R (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 1
FREQUENCY = 28.5350 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	8.70524E-04	-1.44609E-07	-2.25286E-03	-7.11170E-05	-2.54998E-05	-2.72979E-05
3	2.58696E-03	-2.89139E-07	-6.78874E-03	-8.58851E-05	-5.09996E-05	-3.18546E-05
4	3.30722E-03	-2.81200E-04	-8.13116E-03	-6.75365E-05	-6.92748E-05	-2.31254E-05
5	3.51631E-03	-7.38863E-04	-6.66830E-03	-5.29980E-05	-9.33989E-05	-1.31625E-05
6	3.51592E-03	-9.50369E-04	-4.95514E-03	-4.72651E-05	-9.76048E-05	-1.05731E-05
7	3.51533E-03	-1.11674E-03	-3.19075E-03	-4.15321E-05	-9.88327E-05	-8.16467E-06
8	2.54095E-03	-8.80454E-04	-7.66771E-04	-3.17256E-05	-8.35562E-05	-4.00842E-06
9	9.08322E-04	-3.17550E-04	-3.35566E-06	-1.47277E-05	-4.10121E-05	-3.52452E-06
10	2.44076E-04	-8.32305E-05	-1.67790E-06	-7.82863E-06	-2.25151E-05	-1.76226E-06

RESPONSE FOR MODE 2
FREQUENCY = 55.7724 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	7.66709E-04	-1.76028E-07	6.12864E-04	1.72317E-05	1.18128E-05	-2.15718E-05
3	1.87458E-03	-3.51689E-07	1.49613E-03	1.20391E-05	2.36256E-05	-1.51674E-05
4	2.06009E-03	-5.01291E-05	1.32968E-03	1.42574E-07	3.11139E-05	-1.08698E-06
5	2.05123E-03	-2.83319E-05	4.88691E-04	-1.25494E-06	2.99080E-05	8.56645E-07
6	2.04906E-03	-1.56707E-05	-1.56136E-05	-9.94801E-07	2.52428E-05	5.95008E-07
7	2.04644E-03	-6.85338E-06	-4.03941E-04	-7.34663E-07	1.69172E-05	4.17749E-07
8	1.93274E-03	-2.87105E-06	-3.44193E-04	-2.62036E-07	-2.34655E-05	3.39194E-08
9	1.01461E-03	3.72346E-06	2.51445E-06	9.63131E-08	-3.73320E-05	-3.86348E-08
10	3.16486E-04	1.37032E-06	1.25741E-06	1.00159E-07	-2.60784E-05	-1.93174E-08

TABLE 2-118 MOVGAAARD PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 3
 FREQUENCY = 11.5000 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	-4.45408E-05	-6.12579E-07	2.28749E-05	4.94598E-07	-2.42679E-08	9.62767E-07
3	-5.89588E-05	-1.22243E-06	3.03090E-05	-3.99206E-07	-4.85357E-08	-7.79422E-07
4	-3.74488E-06	-2.45057E-05	1.24550E-06	-1.77858E-06	1.13007E-07	-3.28787E-06
5	3.41209E-05	-1.20736E-04	-2.38934E-05	-2.54989E-06	3.35519E-09	-3.21387E-06
6	3.41422E-05	-1.73965E-04	-2.27743E-05	-2.97413E-06	-1.35741E-07	-2.64385E-06
7	3.41473E-05	-2.14729E-04	-1.90397E-05	-3.39838E-06	-2.78149E-07	-1.90535E-06
8	2.83811E-05	-1.92113E-04	-6.82038E-06	-4.23314E-06	-6.21417E-07	5.91717E-09
9	1.26288E-05	-8.58301E-05	-4.30480E-08	-3.39996E-06	-5.03321E-07	1.24109E-07
10	3.74766E-06	-2.55776E-05	-2.15308E-08	-2.17958E-06	-3.20361E-07	6.20547E-08

RESPONSE FOR MODE 4
 FREQUENCY = 141.742 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	3.29595E-06	-1.27496E-07	-5.25629E-05	-7.83811E-07	-5.58028E-07	-6.28384E-08
3	4.89620E-06	-2.53277E-07	-3.46556E-05	1.42116E-06	-1.11606E-06	-1.09092E-08
4	6.32895E-06	-1.25650E-06	3.61936E-05	2.42037E-06	-1.23861E-06	-1.55336E-07
5	8.59022E-06	-7.61495E-06	7.48589E-05	1.68791E-06	3.41010E-07	-2.71861E-07
6	8.52927E-06	-1.21851E-05	6.29367E-05	1.29558E-06	9.65919E-07	-2.16191E-07
7	8.45599E-06	-1.52404E-05	4.08626E-05	9.03253E-07	1.38200E-06	-1.20816E-07
8	2.21504E-05	-1.85948E-05	4.57410E-06	2.01256E-07	9.09797E-07	2.11979E-07
9	2.33499E-05	-1.20546E-05	4.62335E-07	-3.62800E-07	-6.16306E-07	2.14791E-07
10	8.60520E-06	-4.21139E-06	2.31388E-07	-3.18676E-07	-6.26747E-07	1.07396E-07

TABLE 2-11C MOVGARD PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 5
 FREQUENCY = 162.820 HZ

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	-4.55092E-05	2.58512E-08	-3.61522E-06	-3.73183E-08	7.69819E-08	5.62588E-07
3	-2.14573E-05	5.12435E-08	-2.37871E-07	1.50907E-07	1.53964E-07	-1.22149E-06
4	1.59407E-05	-1.48824E-05	3.79472E-06	2.92335E-07	1.83658E-07	-1.04923E-06
5	2.08421E-05	-1.67287E-05	2.15854E-06	3.91530E-07	1.95466E-07	8.24004E-07
6	2.09440E-05	1.89486E-06	-1.23321E-06	4.56585E-07	1.70684E-07	1.16218E-06
7	2.10060E-05	2.41389E-05	-3.85513E-06	5.21639E-07	1.11703E-07	1.23349E-06
8	2.01308E-05	4.43659E-05	-3.17483E-06	7.65337E-07	-1.97798E-07	7.63832E-07
9	1.15298E-05	2.68747E-05	-8.45556E-09	9.50000E-07	-3.91250E-07	3.78726E-07
10	3.81167E-06	8.68692E-06	-4.23311E-09	6.95006E-07	-2.99960E-07	1.89363E-07

TABLE 2-110 MOVGAAED PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

Response Spectrum Displacement Components

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE NODAL DEFLECTIONS

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	1.16178E-03	6.66389E-07	2.33544E-03	7.31807E-05	2.81087E-05	3.48104E-05
3	3.19537E-03	1.32981E-06	6.95180E-03	8.67375E-05	5.62175E-05	3.53110E-05
4	3.29641E-03	2.87541E-04	8.23924E-03	6.76040E-05	7.59517E-05	2.34073E-05
5	4.07107E-03	7.49424E-04	6.68664E-03	5.31025E-05	9.80714E-05	1.36039E-05
6	4.06965E-03	9.66366E-04	4.95562E-03	4.73889E-05	1.00221E-04	1.09787E-05
7	4.06782E-03	1.13758E-03	3.21653E-03	4.16904E-05	1.00280E-04	8.48544E-06
8	3.19274E-03	9.02670E-04	8.40526E-04	3.20176E-05	8.68343E-05	4.08619E-06
9	1.26210E-03	3.30287E-04	4.21884E-06	1.51495E-05	5.54658E-05	3.55369E-06
10	3.99799E-04	8.77112E-05	2.10960E-05	8.16288E-06	3.44615E-05	1.77684E-06

TABLE 2-12 HOVGGAARD PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE MODAL FORCES
(FOR ALL ELEMENTS)

PX = X-AXIAL FORCE
VY = Y-SHEAR FORCE
VZ = Z-SHEAR FORCE

TX = X-TWISTING MOMENT
MY = Y-BENDING MOMENT
MZ = Z-BENDING MOMENT

I = INITIAL NODE
C = CENTER NODE (FOR PIPE BEND ONLY)
J = FINAL NODE

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (1)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1567E+01	.1828E+02	.1166E+02	.3160E+03	.8166E+03	.1560E+04	.1567E+01	.1828E+02	.1166E+02	.3160E+03	.2286E+03	.5912E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (2)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1560E+01	.1441E+02	.7926E+01	.3160E+03	.2286E+03	.5912E+03	.1560E+01	.1441E+02	.7926E+01	.3160E+03	.2644E+03	.2559E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (3)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.1542E+01	.6285E+01	.5626E+01	.3160E+03	.2559E+03	.2644E+03	.3006E+01	.5732E+01	.5626E+01	.2064E+03	.3379E+03	.1980E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (3)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4761E+01	.4384E+01	.5626E+01	.6471E+02	.3994E+03	.1596E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (4)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.8279E+01	.7855E+01	.8631E+01	.6471E+02	.3994E+03	.1596E+03	.1059E+02	.4242E+01	.8631E+01	.8381E+02	.3403E+03	.1210E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (4)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1132E+02	.1378E+01	.8631E+01	.1978E+03	.2769E+03	.1219E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (5)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1578E+02	.1058E+01	.1117E+02	.1978E+03	.2769E+03	.1219E+03	.1578E+02	.1058E+01	.1117E+02	.1978E+03	.3188E+03	.1184E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (6)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1929E+02	.9528E+00	.1249E+02	.1978E+03	.3188E+03	.1184E+03	.1929E+02	.9528E+00	.1249E+02	.1978E+03	.4533E+03	.1074E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (7)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.2389E+02	.1323E+02	.1549E+01	.1978E+03	.1074E+03	.4533E+03	.2457E+02	.1191E+02	.1549E+01	.2174E+03	.2794E+02	.5353E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (7)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2240E+02	.1562E+02	.1549E+01	.1977E+03	.1014E+03	.5465E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (8)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.2379E+02	.1761E+02	.2118E+01	.1977E+03	.1014E+03	.5465E+03	.1848E+02	.2312E+02	.2118E+01	.1403E+03	.1896E+03	.5454E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (8)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1317E+02	.2651E+02	.2118E+01	.5306E+02	.2517E+03	.6586E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (9)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1318E+02	.2649E+01	.2882E+02	.5306E+02	.6586E+03	.2517E+03	.1318E+02	.2649E+01	.2882E+02	.5306E+02	.1074E+04	.2937E+03

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (10)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1318E+02	.2752E+01	.2941E+02	.5306E+02	.1074E+04	.2937E+03	.1318E+02	.2793E+01	.2941E+02	.5306E+02	.1615E+04	.3409E+03

TABLE 2-13 HØVGAARD PIPING SYSTEM CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM STRESS COMPONENTS

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LONGITD STRESS	CIRCUMF STRESS	SPEAR STRESS
1	TANGENT	1	END-I	193.801	0.000	21.427
			END-J	69.949	0.000	21.427
2	TANGENT	1	END-I	69.947	0.000	20.447
			END-J	40.730	0.000	20.447
3	BEND	1	END-I	46.249	49.740	18.945
			CENTER	49.476	37.243	12.848
			END-J	54.616	30.025	4.893
4	BEND	1	END-I	55.275	30.025	5.743
			CENTER	47.097	22.770	6.408
			END-J	39.913	22.923	12.508
5	TANGENT	1	END-I	36.207	0.000	12.973
			END-J	40.335	0.000	12.973
6	TANGENT	1	END-I	40.992	0.000	13.217
			END-J	54.814	0.000	13.217
7	BEND	1	END-I	62.668	85.280	13.367
			CENTER	71.557	100.698	14.198
			END-J	73.617	102.798	13.805
8	BEND	1	END-I	73.878	102.798	14.188
			CENTER	75.587	102.603	12.061
			END-J	90.534	123.894	7.899
9	TANGENT	1	END-I	79.954	0.000	8.339
			END-J	124.844	0.000	8.339
10	TANGENT	1	END-I	124.844	0.000	8.453
			END-J	183.836	0.000	8.453

TABLE 2-14 HUVGAARD PROBLEM DYNAMIC CASE 3 (STEP-BY-STEP INTEGRATION)
DISPLACEMENT MAXIMUM

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
2	1	9.0197E-04	2.2209E+00	NA
	2	4.6186E-04	2.6000E+00	NA
	3	6.1844E-04	2.4400E+00	NA
3	1	2.1360E-03	2.4800E+00	NA
	2	9.2410E-04	2.6000E+00	NA
	3	1.9460E-03	2.4800E+00	NA
4	1	2.6442E-03	2.4800E+00	NA
	2	1.1832E-04	2.4800E+00	NA
	3	2.5634E-03	2.4800E+00	NA
5	1	2.5972E-03	2.4800E+00	NA
	2	2.4451E-04	2.4800E+00	NA
	3	2.3708E-03	2.4800E+00	NA
6	1	2.5658E-03	2.4800E+00	NA
	2	3.0588E-04	2.4800E+00	NA
	3	1.9749E-03	2.4800E+00	NA
7	1	2.6940E-03	2.4800E+00	NA
	2	3.5369E-04	2.4800E+00	NA
	3	1.4834E-03	2.4800E+00	NA
8	1	2.1481E-03	2.4800E+00	NA
	2	2.7204E-04	2.4800E+00	NA
	3	4.6544E-04	2.4800E+00	NA
9	1	9.6952E-04	2.2200E+00	NA
	2	9.3060E-05	2.4800E+00	NA
	3	1.2334E-06	2.5200E+00	NA
10	1	3.0149E-04	2.2200E+00	NA
	2	2.3409E-05	2.4800E+00	NA
	3	6.1664E-07	2.5200E+00	NA

Note: Displacement components 1, 2, and 3 respectively correspond to x, y, and z.

TABLE 2-15 HOGGAARD PROBLEM DYNAMIC CASE 3 (STEP-BY-STEP INTEGRATION)
FORCE COMPONENT MAXIMA

ELEMENT TYPE NUMBER 2

ELEMENT NUMBER	LOCATION COMPONENT	FORCE	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	1.0462E-01	2.6000E+00
		FY	3.5216E+00	2.4000E+00
		FZ	1.2030E+01	2.2200E+00
		TX	4.8761E+01	2.4000E+00
		TY	6.8829E+02	2.2200E+00
		TZ	3.9174E+02	2.4000E+00
1	END-J	FX	1.0462E-01	2.6000E+00
		FY	3.5216E+00	2.4000E+00
		FZ	1.2030E+01	2.2200E+00
		TX	4.8761E+01	2.4000E+00
		TY	5.9381E+01	2.4000E+00
		TZ	1.9999E+02	2.4000E+00
2	END-I	FX	1.0870E-01	2.6000E+00
		FY	3.3940E+00	2.4000E+00
		FZ	4.7261E+00	2.4000E+00
		TX	4.8761E+01	2.4000E+00
		TY	5.9381E+01	2.4000E+00
		TZ	1.9999E+02	2.4000E+00
2	END-J	FX	1.0870E-01	2.6000E+00
		FY	3.3940E+00	2.4000E+00
		FZ	4.7261E+00	2.4000E+00
		TX	4.8761E+01	2.4000E+00
		TY	2.1204E+02	2.2200E+00
		TZ	4.7714E+01	2.5200E+00
3	END-I	FX	1.0492E-01	2.6000E+00
		FY	4.5055E+00	2.2200E+00
		FZ	2.8194E+00	2.4000E+00
		TX	4.8761E+01	2.4000E+00
		TY	3.7714E+01	2.5200E+00
		TZ	2.1204E+02	2.2200E+00
3	END-J	FX	1.2274E+00	2.2200E+00
		FY	1.1444E+00	2.2200E+00
		FZ	2.8194E+00	2.4000E+00
		TX	1.5424E+01	2.4000E+00
		TY	3.6534E+01	2.4000E+00
		TZ	1.0966E+02	2.4000E+00

4	END-I	FX	5.9514E+00	2.2200E+00
		FY	5.7518E+00	2.2200E+00
		FZ	2.9445E+00	2.2200E+00
		TX	1.5024E+01	2.4400E+00
		TY	9.6635E+01	2.4400E+00
		TZ	1.0063E+02	2.4400E+00

4	END-J	FX	8.2054E+00	2.2200E+00
		FY	1.1645E+01	2.6000E+00
		FZ	2.9445E+00	2.2200E+00
		TX	8.4549E+01	2.4400E+00
		TY	1.4375E+02	2.4400E+00
		TZ	2.3335E+01	2.4400E+00

5	END-I	FX	1.1211E+01	2.2200E+00
		FY	1.1181E+01	2.5200E+00
		FZ	3.1383E+00	2.2200E+00
		TX	8.4549E+01	2.4400E+00
		TY	1.4375E+02	2.4400E+00
		TZ	2.3335E+01	2.4400E+00

5	END-J	FX	1.1211E+01	2.2200E+00
		FY	1.1181E+01	2.5200E+00
		FZ	3.1383E+00	2.2200E+00
		TX	8.4549E+01	2.4400E+00
		TY	1.4375E+02	2.2200E+00
		TZ	2.3305E+01	2.4400E+00

6	END-I	FX	1.3525E+01	2.2200E+00
		FY	1.8167E+01	2.5200E+00
		FZ	3.2712E+00	2.2200E+00
		TX	8.4549E+01	2.4400E+00
		TY	1.4537E+02	2.2200E+00
		TZ	2.4905E+01	2.4400E+00

6	END-J	FX	1.3525E+01	2.2200E+00
		FY	1.8167E+01	2.5200E+00
		FZ	3.2712E+00	2.2200E+00
		TX	8.4549E+01	2.4400E+00
		TY	2.4376E+02	2.2200E+00
		TZ	2.4994E+01	2.4400E+00

7	END-I	FX	1.4532E+01	2.2200E+00
		FY	1.7462E+00	2.5200E+00
		FZ	2.9753E+01	2.5200E+00
		TX	8.4549E+01	2.4400E+00
		TY	2.4394E+01	2.4400E+00
		TZ	2.4375E+02	2.2200E+00

7	END-J	FX	1.4100E+01	2.2200E+00
		FY	1.6290E+00	2.4800E+00
		FZ	2.8753E-01	2.5200E+00
		TX	7.6390E+01	2.4800E+00
		TY	4.3695E+01	2.4800E+00
		TZ	1.5571E+02	2.2200E+00
8	END-I	FX	1.5457E+01	2.2200E+00
		FY	1.8404E+01	2.4800E+00
		FZ	3.3750E-01	2.5200E+00
		TX	7.6390E+01	2.4800E+00
		TY	4.3695E+01	2.4800E+00
		TZ	1.5571E+02	2.2200E+00
8	END-J	FX	3.8526E+00	2.5200E+00
		FY	1.8407E+01	2.2200E+00
		FZ	3.3750E-01	2.5200E+00
		TX	2.2559E+01	2.4800E+00
		TY	8.6265E+01	2.4800E+00
		TZ	3.1843E+02	2.4800E+00
9	END-I	FX	3.8522E+00	2.5200E+00
		FY	3.6655E-01	2.5200E+00
		FZ	2.1784E-01	2.2200E+00
		TX	2.2559E+01	2.4800E+00
		TY	3.1843E+02	2.4800E+00
		TZ	8.6265E+01	2.4800E+00
9	END-J	FX	3.8522E+00	2.5200E+00
		FY	3.6655E-01	2.5200E+00
		FZ	2.1784E-01	2.2200E+00
		TX	2.2559E+01	2.4800E+00
		TY	7.3272E+02	2.4800E+00
		TZ	8.7560E+01	2.4800E+00
10	END-I	FX	3.8529E+00	2.5200E+00
		FY	3.7259E-01	2.5200E+00
		FZ	2.4692E-01	2.2200E+00
		TX	2.2559E+01	2.4800E+00
		TY	7.3272E+02	2.4800E+00
		TZ	8.7560E+01	2.4800E+00
10	END-J	FX	3.8520E+00	2.5200E+00
		FY	3.7259E-01	2.5200E+00
		FZ	2.4692E-01	2.2200E+00
		TX	2.2559E+01	2.4800E+00
		TY	1.2379E+01	2.2200E+00
		TZ	8.8700E+01	2.4800E+00

TABLE 2-16 NOVGAAARD PROBLEM DYNAMIC CASE C (STEP-BY-STEP INTEGRATION)

		S T R E S S G O I N G O N E N T M A X I M A		
		LONGITUDINAL	CIRCUMFER	SHEAR
	END-I	STRESS	STRESS	STRESS
	END-J			
1	END-I	87.05	0.00	5.03
	END-J	22.95	0.00	5.03
2	END-I	22.95	0.00	3.77
	END-J	23.69	0.00	3.77
3	END-I	26.50	38.57	3.68
	END-J	13.18	18.31	1.62
4	END-I	13.67	18.31	2.04
	END-J	19.69	4.24	5.20
5	END-I	18.11	0.00	5.23
	END-J	22.64	0.00	5.23
6	END-I	23.00	0.00	5.26
	END-J	29.45	0.00	5.26
7	END-I	33.55	44.34	5.35
	END-J	22.09	28.32	6.00
8	END-I	22.35	28.32	6.24
	END-J	40.50	57.92	4.69
9	END-I	36.99	0.00	5.32
	END-J	81.82	0.00	5.32
10	END-I	81.82	0.00	5.87
	END-J	136.55	0.00	5.87

Problem 3 - Dynamic Analysis of a Coffee Table

The third problem to be investigated was the dynamic response of a coffee table subjected to the identical earthquake motion discussed previously for Problem 2. Results gotten for the three different methods of analysis are given in the tables that follow shortly.

Problem Description

i. Geometry - The configuration is as shown in Fig. 3-1a. The structure is comprised of lengths of 2 in. steel pipes with internal lining of damping material, and four 2 3/4 in. steel cubes welded with the pipes at the corners as shown in the figure. The entire assembly is fixed to a heavy base. The lumped mass system used for the analysis is shown in Fig. 3-1b. The system is the same as the one used by Swanson¹⁶, in which the mass of the cube plus three adjacent 3-5/8 in. lengths of the piping were lumped at each corner. Intermediate mass points M_2 and M_1 respectively, comprising the masses of 10 in. and 5 in. segments of the piping were positioned as shown in the figure. The horizontal dimensions of the pipes are considered only between the outside edges of two adjacent cubes. The input nodal coordinates and the values used for the lumped masses are shown in Table 3-1 and Table 3-2, respectively.

ii. Material data - The member properties are as follows:

FIGURE 3-1a

ISOMETRIC SKETCH OF COFFEE TABLE

FINITE ELEMENT MODEL AND LUMPED MASS
LOCATIONS FOR COFFEE TABLE PROBLEM

Pipe outside diameter (inches)	2.375
Pipe wall thickness (inches)	0.154
Young's modulus (psi)	27.9 E6
Poisson's ratio	0.3
Unit Weight (lb per in. ³)	0.34517

iii. Loading condition - The same earthquake response as given in Problem 2.

Analyses Results

For the purpose of comparison Table 3-3a shows values for resonant frequencies of the coffee table obtained from EPIPE and those obtained by Crede¹⁵, Tuba and Wright¹⁷, Swanson¹⁶ (by use of ANSYS) and experimental means.¹⁵ With the exception of resonant frequencies obtained for the 5th mode which are within 13% of Crede's values, 5% of Tuba and Wright's values and almost identical with Swanson's values, the various answers are quite close. As mentioned, the lumped mass model used for this problem is the same as that used by Swanson with ANSYS and thus the results of the two methods should be closer than those gotten by the other references shown in the table.

Computer results for all three analysis cases are shown in Tables 3-3 to 3-14. Tables 3-3 to 3-7 respectively list the

natural frequencies, mode shapes, maximum displacements, resultant forces, stresses, and their time of occurrence obtained from the time-history analysis. Similarly, tables 3-8 and 3-9 show the modal participation factors, displacements and relations, and the square root of the sum of the squares, or root mean square (RMS), of the modal forces and stresses obtained from the response spectrum analysis. Finally, the maximum displacements, forces and stresses and the time of occurrence from the step-by-step integration solution are given in Tables 3-10 to 3-14. Again, for this problem the numerical results from all three methods appear to be similar with the response spectrum analysis yielding generally higher resultant forces and stresses.

For this problem, the time span was 16 seconds with 800 integration steps of 0.02 seconds each. Unlike the Hovgaard problem, only every fifth integration step was printed.

TABLE 3-1 INPUT DATA FOR COFFEE TABLE PROBLEM

N O D A L C O O R D I N A T E S

NODE NUMBER	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES				
	X	Y	Z	XX	YY	ZZ	X	Y	Z	T	
1	0	0	0	0	0	0	0.0	10.000	0.0	0	0.0
2	0	0	0	0	0	0	27.250	10.000	0.0	0	0.0
3	0	0	0	0	0	0	27.250	10.000	17.250	0	0.0
4	0	0	0	0	0	0	0.0	10.000	17.250	0	0.0
5	0	0	0	0	0	0	0.0	10.625	17.250	0	0.0
6	0	0	0	0	0	0	0.0	10.625	8.625	0	0.0
7	0	0	0	0	0	0	0.0	10.625	0.0	0	0.0
8	0	0	0	0	0	0	8.625	10.625	0.0	0	0.0
9	0	0	0	0	0	0	10.625	10.625	0.0	0	0.0
10	0	0	0	0	0	0	27.250	10.625	0.0	0	0.0
11	0	0	0	0	0	0	27.250	10.625	8.625	0	0.0
12	0	0	0	0	0	0	27.250	10.625	17.250	0	0.0
13	0	0	0	0	0	0	10.625	10.625	17.250	0	0.0
14	0	0	0	0	0	0	8.625	10.625	17.250	0	0.0
15	1	1	1	1	1	1	0.0	0.0	0.0	0	0.0
16	1	1	1	1	1	1	27.250	0.0	0.0	0	0.0
17	1	1	1	1	1	1	27.250	0.0	17.250	0	0.0
18	1	1	1	1	1	1	0.0	0.0	17.250	0	0.0

TABLE 3-2 INPUT DATA FOR COFFEE TABLE PROBLEM

LUMPED MASSES DATA

NODE NUMBER	LOAD CASE	X-AXIS FORCE	Y-AXIS FORCE	Z-AXIS FORCE	X-AXIS MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
2	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
3	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
4	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
5	0	0.25380E-01	0.25380E-01	0.25380E-01	0.0	0.0	0.0
6	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
7	0	0.25380E-01	0.25380E-01	0.25380E-01	0.0	0.0	0.0
8	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
9	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
10	0	0.25380E-01	0.25380E-01	0.25380E-01	0.0	0.0	0.0
11	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
12	0	0.25380E-01	0.25380E-01	0.25380E-01	0.0	0.0	0.0
13	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0
14	0	0.89400E-02	0.89400E-02	0.89400E-02	0.0	0.0	0.0

TABLE 3-3a

Comparison of Natural Frequency Values for Coffee Table Problem

Experimental Values <u>Ref. [15]</u>	Crede <u>Ref. [15]</u>	Tuba and Wright <u>Ref. [17]</u>	ANSYS <u>Ref. [16]</u>	EPIPE <u>Model A</u>
110	109.0	110.5	111.5	111.2
117	115.9	115.0	115.9	115.8
134	135.0	134.7	137.6	137.2
214	212.5	211.7	218.0	215.8
359	350.4	385.5	404.2	404.3

NATURAL FREQUENCIES

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TABLE 3-4 COEFF TABLE DYNAMIC CASE A (TIME HISTORY ANALYSIS)

M O D E S H A P E S							
MODE NUMBER	EIGEN- VECTOR	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
18	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
17	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
16	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
15	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
14	1	0.24735E-01	-0.18533E-00	0.68573E-02	-0.33469E-05	0.75470E-03	0.20460E-01
	2	-0.98867E-03	-0.31297E-01	0.25875E-01	0.75624E-01	-0.12461E-01	-0.11435E-03
	3	-0.14041E-01	0.97433E-01	-0.89588E-00	-0.23207E-01	-0.17426E-00	-0.11563E-01
	4	0.22087E-01	-0.12473E-00	-0.97781E-01	-0.13907E-01	-0.15377E-00	0.13097E-01
	5	0.12671E-01	-0.88194E-01	0.50181E-01	0.34647E-02	-0.38397E-00	-0.66329E-02
13	1	0.24735E-01	0.18533E-00	-0.69596E-02	0.27160E-06	0.75400E-03	0.20460E-01
	2	0.10120E-02	-0.31295E-01	0.25876E-01	0.75626E-01	0.12450E-01	0.11452E-03
	3	-0.14041E-01	-0.97433E-01	0.89588E-00	0.23207E-01	-0.17426E-00	-0.11563E-01
	4	0.22087E-01	0.12474E-00	0.97780E-00	0.13907E-01	-0.15376E-00	0.13097E-01
	5	-0.12269E-01	-0.88173E-01	0.50201E-01	0.34678E-02	0.38382E-00	0.66347E-02
12	1	0.24704E-01	-0.16264E-01	0.82124E-03	0.33894E-05	-0.35502E-02	-0.93464E-01
	2	0.27267E-02	-0.30090E-01	0.24398E-01	0.75627E-01	0.94195E-02	0.14663E-04
	3	-0.14041E-01	-0.17914E-01	0.23112E-01	0.63242E-01	-0.15192E-00	0.42264E-01
	4	0.21983E-01	-0.25776E-01	0.14124E-01	0.37896E-01	0.10484E-00	-0.65241E-01
	5	-0.34590E-01	-0.32593E-02	0.87442E-01	0.34702E-02	0.46651E-00	0.79154E-02
11	1	0.25101E-01	-0.16669E-01	0.54338E-03	-0.44822E-05	-0.79143E-04	-0.93483E-01
	2	0.57808E-04	-0.68975E-06	0.24414E-01	-0.20173E-01	-0.26764E-02	-0.18595E-05
	3	-0.78712E-03	0.31660E-05	0.23134E-01	-0.17985E-01	-0.16583E-00	0.28937E-04
	4	0.23924E-03	-0.15064E-05	0.14158E-01	-0.84614E-02	0.30405E-00	-0.76878E-05
	5	-0.23409E-01	0.13440E-01	0.44777E-04	-0.19307E-06	0.49220E-05	0.78913E-02
10	1	0.24737E-01	-0.16259E-01	0.24483E-03	0.26041E-04	0.34363E-02	-0.93503E-01
	2	-0.26409E-02	0.30089E-01	0.24398E-01	0.75627E-01	0.94238E-02	-0.18372E-04
	3	0.13999E-01	0.17923E-01	0.23112E-01	0.63242E-01	-0.15192E-00	-0.42206E-01
	4	-0.21978E-01	0.24774E-01	0.14124E-01	0.37896E-01	0.10484E-00	0.65226E-01
	5	-0.34609E-01	-0.32603E-02	-0.87354E-01	-0.34695E-02	-0.46653E-00	0.78673E-02
9	1	0.24744E-01	0.16562E-00	0.72902E-02	0.86770E-05	-0.83513E-03	0.20470E-01

	2	-0.51657E-03	0.31303E-01	0.25876E 01	0.75626E-01	0.12454E-01	-0.11383E-03
	3	0.14026E 01	0.97315E-01	0.89506E 00	0.23207E-01	-0.17426E 00	0.11551E-01
	4	-0.22203E 01	-0.12471E 00	0.97781E 00	0.13907E-01	-0.15377E 00	-0.13094E-01
	5	-0.12262E-01	-0.88094E-01	-0.50204E 01	-0.34692E-02	-0.38385E 00	0.66595E-02
6	1	0.24748E 01	-0.18542E 00	-0.73395E-02	-0.14449E-04	-0.83445E-03	0.20469E-01
	2	0.10840E-02	0.31291E-01	0.25876E 01	0.75624E-01	-0.12465E-01	0.11521E-03
	3	0.14026E 01	-0.97317E-01	-0.89602E 00	-0.23211E-01	-0.17426E 00	0.11551E-01
	4	-0.22083E 01	0.12471E 00	-0.97782E 00	-0.13907E-01	-0.15377E 00	-0.13094E-01
	5	0.12757E-01	-0.88647E-01	-0.50184E 01	-0.34688E-02	0.38400E 00	-0.66300E-02
7	1	0.24717E 01	0.16257E-01	-0.35822E-03	-0.28817E-04	0.34364E-02	-0.93502E-01
	2	0.28811E-02	0.30089E-01	0.24396E 01	0.75623E-01	-0.94373E-02	0.12622E-04
	3	0.11999E 01	-0.17925E-01	-0.23113E 01	-0.63246E-01	-0.15192E 00	-0.42206E-01
	4	-0.21978E 01	-0.25771E-01	-0.14124E 01	-0.37896E-01	0.10484E 00	0.65224E-01
	5	0.34021E-01	-0.33642E-02	-0.67277E-01	-0.34686E-02	0.46610E 00	-0.79089E-02
8	1	0.25101E 01	0.16447E-01	-0.63682E-03	0.52090E-05	-0.80805E-04	-0.93483E-01
	2	0.36560E-04	0.55616E-06	0.24413E 01	-0.20172E-01	0.26679E-02	-0.17347E-05
	3	-0.78806E-03	-0.55564E-05	-0.23135E 01	0.17986E-01	-0.16583E 00	0.28960E-04
	4	0.25051E-03	0.46435E-05	-0.14158E 01	0.86615E-02	0.30405E 00	-0.80873E-05
	5	0.23376E 01	0.13250E-01	0.40200E-04	-0.43705E-05	-0.74799E-05	-0.79069E-02
9	1	0.24704E 01	0.16265E-01	-0.91462E-03	-0.65229E-05	-0.35496E-02	-0.93463E-01
	2	-0.27129E-02	-0.30088E-01	0.24396E 01	0.75623E-01	-0.94272E-02	-0.16093E-04
	3	-0.14014E 01	0.17915E-01	-0.23113E 01	-0.63246E-01	-0.15192E 00	0.42264E-01
	4	0.21983E 01	0.25771E-01	-0.14124E 01	-0.37896E-01	0.10483E 00	-0.65240E-01
	5	0.33961E-01	-0.32936E-02	0.87373E-01	0.34621E-02	-0.46608E 00	-0.79050E-02
4	1	0.11494E 01	0.87388E-02	-0.49565E-03	-0.64274E-04	-0.19050E-02	-0.16534E 00
	2	-0.15603E-02	-0.16166E-01	0.11770E 01	0.16549E 00	-0.50616E-02	0.19745E-03
	3	-0.68295E 00	0.96287E-02	-0.11426E 01	-0.15783E 00	-0.81567E-01	0.95172E-01
	4	0.11023E 01	0.13875E-01	-0.71864E 00	-0.96275E-01	0.56287E-01	-0.14901E 00
	5	-0.90292E-03	-0.17842E-02	0.46753E-01	0.57302E-02	-0.25025E 00	-0.13883E-02
3	1	0.11494E 01	-0.87382E-02	0.45174E-03	0.58663E-04	-0.19061E-02	-0.16534E 00
	2	0.15697E-02	-0.16168E-01	0.11779E 01	0.16550E 00	0.50574E-02	-0.19894E-03
	3	-0.68295E 00	-0.96280E-02	0.11425E 01	0.15782E 00	-0.81566E-01	0.95172E-01
	4	0.11023E 01	-0.13875E-01	0.71863E 00	0.96274E-01	0.56287E-01	-0.14901E 00
	5	0.13628E-02	-0.17652E-02	0.46850E-01	0.57329E-02	0.25048E 00	0.13640E-02
2	1	0.11500E 01	-0.37353E-02	0.83089E-04	0.15579E-04	0.18450E-02	-0.16542E 00
	2	-0.15258E-02	0.16157E-01	0.11779E 01	0.16550E 00	0.50597E-02	0.19257E-03
	3	0.68123E 00	0.96329E-02	0.11425E 01	0.15782E 00	-0.81568E-01	-0.95069E-01
	4	-0.11021E 01	0.13871E-01	0.71863E 00	0.96275E-01	0.56289E-01	0.14898E 00
	5	0.80110E-03	-0.17657E-02	-0.46786E-01	-0.57269E-02	-0.25049E 00	0.13650E-02
1	1	0.11509E 01	0.37343E-02	-0.12840E-03	-0.21931E-04	0.18451E-02	-0.16542E 00
	2	0.15053E-02	0.16167E-01	0.11778E 01	0.16549E 00	-0.50643E-02	-0.20303E-03
	3	0.68223E 00	-0.96341E-02	-0.11426E 01	-0.15783E 00	-0.81568E-01	-0.95069E-01
	4	-0.11021E 01	-0.13871E-01	-0.71864E 00	-0.96275E-01	0.56290E-01	0.14398E 00
	5	-0.69501E-03	-0.18240E-02	-0.46638E-01	-0.57231E-02	0.25025E 00	-0.13892E-02

EIGENSOLUTION TIME LOG

EIGENSOLUTION = 44.19
PRINTING = 0.62

TABLE 3-5 COFFEE TABLE DYNAMIC CASE A (TIME HISTORY ANALYSIS)

D I S P L A C E M E N T M A X I M A				
NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
1	1	1.2472E-04	4.9000E 00	NA
	2	9.4765E-07	4.9000E 00	NA
	3	1.2378E-08	2.6000E 00	NA
2	1	1.2472E-04	4.9000E 00	NA
	2	9.4770E-07	4.9000E 00	NA
	3	1.2608E-08	2.6000E 00	NA
3	1	1.2469E-04	4.9000E 00	NA
	2	9.4767E-07	4.9000E 00	NA
	3	2.3050E-08	4.9000E 00	NA
4	1	1.2469E-04	4.9000E 00	NA
	2	9.4768E-07	4.9000E 00	NA
	3	2.8282E-08	4.9000E 00	NA
5	1	2.6000E-04	4.9000E 00	NA
	2	1.7639E-06	4.9000E 00	NA
	3	4.7450E-08	4.9000E 00	NA
6	1	2.7227E-04	4.9000E 00	NA
	2	1.7061E-06	4.9000E 00	NA
	3	1.7200E-08	4.9000E 00	NA
7	1	2.6807E-04	4.9000E 00	NA
	2	1.7638E-06	4.9000E 00	NA
	3	1.5164E-08	2.6000E 00	NA
8	1	2.6840E-04	4.9000E 00	NA
	2	2.0110E-05	4.9000E 00	NA
	3	7.7429E-07	4.9000E 00	NA
9	1	2.6840E-04	4.9000E 00	NA
	2	2.0110E-05	4.9000E 00	NA
	3	7.7275E-07	4.9000E 00	NA
10	1	2.6807E-04	4.9000E 00	NA
	2	1.7639E-06	4.9000E 00	NA
	3	1.5257E-08	2.6000E 00	NA
11	1	2.7227E-04	4.9000E 00	NA
	2	1.7063E-06	4.9000E 00	NA
	3	1.6523E-08	4.9000E 00	NA
12	1	2.6800E-04	4.9000E 00	NA
	2	1.7638E-06	4.9000E 00	NA
	3	4.6704E-08	4.9000E 00	NA
13	1	2.6834E-04	4.9000E 00	NA
	2	2.0106E-05	4.9000E 00	NA
	3	7.6677E-07	4.9000E 00	NA
14	1	2.6834E-04	4.9000E 00	NA
	2	2.0105E-05	4.9000E 00	NA
	3	7.6622E-07	4.9000E 00	NA

*All values represent the absolute maximum

Note: Displacement Components 1, 2, and 3 respectively correspond to x, y, and z

TABLE 3-6. COFFEE TABLE DYNAMIC CASE A (TIME HISTORY ANALYSIS)

FORCE COMPONENT MAXIMA

ELEMENT TYPE NUMBER = 2

ELEMENT NUMBER	LOCATION	FORCE COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	2.8410E-00	4.9000E-00
		FY	9.5104E-04	2.6000E-00
		FZ	5.6344E-00	4.9000E-00
		TX	2.8872E-01	4.9000E-00
		MY	6.1496E-01	4.9000E-00
		MZ	7.1576E-03	2.6000E-00
1	END-J	FX	2.8410E-00	4.9000E-00
		FY	9.5104E-04	2.6000E-00
		FZ	5.6344E-00	4.9000E-00
		TX	2.8872E-01	4.9000E-00
		MY	5.1517E-00	4.9000E-00
		MZ	2.5094E-03	4.9000E-00
2	END-I	FX	2.8369E-00	4.9000E-00
		FY	8.5761E-04	2.6000E-00
		FZ	5.0897E-00	4.9000E-00
		TX	2.8872E-01	4.9000E-00
		MY	5.1520E-00	4.9000E-00
		MZ	2.5093E-03	4.9000E-00
2	END-J	FX	2.8369E-00	4.9000E-00
		FY	8.5761E-04	2.6000E-00
		FZ	5.0897E-00	4.9000E-00
		TX	2.8872E-01	4.9000E-00
		MY	3.8746E-01	4.9000E-00
		MZ	9.7496E-03	2.6000E-00
3	END-I	FX	1.0487E-01	4.9000E-00
		FY	3.5878E-03	4.9000E-00
		FZ	5.9378E-01	4.9000E-00
		TX	1.6874E-03	4.9000E-00
		MY	1.7410E-00	4.9000E-00
		MZ	1.1501E-02	4.9000E-00
3	END-J	FX	1.0487E-01	4.9000E-00
		FY	3.5878E-03	4.9000E-00
		FZ	5.9378E-01	4.9000E-00
		TX	1.6874E-03	4.9000E-00
		MY	3.3804E-00	4.9000E-00
		MZ	1.9444E-02	4.9000E-00
4	END-I	FX	1.0487E-01	4.9000E-00
		FY	4.2222E-03	4.9000E-00

MY	5.1523E 00	4.9000E 00
MZ	2.5102E-03	4.9000E 00

8	FND-I	FX	2.8370E C0	4.9000E 00
		FY	8.7489E-04	2.6000E 00
		FZ	5.0897E 00	4.9000E 00
		TX	2.8869E-01	4.9000E 00
		MY	5.1525E 00	4.9000E 00
		MZ	2.5101E-03	4.9000E 00

9	FND-J	FX	2.8370E 00	4.9000E 00
		FY	8.7489E-04	2.6000E 00
		FZ	5.0897E 00	4.9000E 00
		TX	2.8869E-01	4.9000E 00
		MY	3.8747E 01	4.9000E 00
		MZ	9.9237E-03	4.9000E 00

9	FND-I	FX	1.0491E-01	4.9000E 00
		FY	3.6257E-03	4.9000E 00
		FZ	5.9383E-01	4.9000E 00
		TX	1.6604E-03	4.9000E 00
		MY	1.7415E 00	4.9000E 00
		MZ	1.1691E-02	4.9000E 00

9	FND-J	FX	1.0491E-01	4.9000E 00
		FY	3.6257E-03	4.9000E 00
		FZ	5.9383E-01	4.9000E 00
		TX	1.6604E-03	4.9000E 00
		MY	3.3803E 00	4.9000E 00
		MZ	1.9582E-02	4.9000E 00

10	FND-I	FX	1.0491E-01	4.9000E 00
		FY	4.2287E-03	4.9000E 00
		FZ	5.9541E-01	4.9000E 00
		TX	1.6943E-03	4.9000E 00
		MY	3.3801E 00	4.9000E 00
		MZ	1.9581E-02	4.9000E 00

10	FND-J	FX	1.0491E-01	4.9000E 00
		FY	4.2287E-03	4.9000E 00
		FZ	5.9541E-01	4.9000E 00
		TX	1.6943E-03	4.9000E 00
		MY	1.7552E C0	4.9000E 00
		MZ	1.6891E-02	4.9000E 00

11	FND-I	FX	2.8369E 00	4.9000E 00
		FY	1.6138E-03	4.9000E 00
		FZ	5.0893E 00	4.9000E 00
		TX	2.9262E-01	4.9000E 00
		MY	1.8715E 01	4.9000E 00

		HZ	1.6099E-02	4.9000E 00
11	END-J	FX	2.0369E 00	4.9000E 00
		FY	1.6130E-03	4.9000E 00
		FZ	5.0003E 00	4.9000E 00
		IX	2.9262E-01	4.9000E 00
		IY	5.1515E 00	4.9000E 00
		HZ	2.1798E-03	4.9000E 00
12	END-I	FX	2.0411E 00	4.9000E 00
		FY	1.7239E-03	4.9000E 00
		FZ	5.6329E 00	4.9000E 00
		IX	2.9262E-01	4.9000E 00
		IY	5.1511E 00	4.9000E 00
		HZ	2.1790E-03	4.9000E 00
12	END-J	FX	2.0411E 00	4.9000E 00
		FY	1.7239E-03	4.9000E 00
		FZ	5.6329E 00	4.9000E 00
		IX	2.9262E-01	4.9000E 00
		IY	6.1480E 01	4.9000E 00
		HZ	1.5059E-02	4.9000E 00
13	END-I	FX	1.1623E 00	4.9000E 00
		FY	2.8108E 00	4.9000E 00
		FZ	1.0613E-01	4.9000E 00
		IX	0.3295E-04	2.6000E 00
		IY	1.4628E 00	4.9000E 00
		HZ	3.9736E 01	4.9000E 00
13	END-J	FX	1.1693E 00	4.9000E 00
		FY	2.8109E 00	4.9000E 00
		FZ	1.0613E-01	4.9000E 00
		IX	0.3295E-04	2.6000E 00
		IY	5.4736E-01	4.9000E 00
		HZ	1.4493E 01	4.9000E 00
14	END-I	FX	2.7189E-03	4.9000E 00
		FY	2.8986E 00	4.9000E 00
		FZ	1.0948E-01	4.9000E 00
		IX	0.3242E-04	2.6000E 00
		IY	5.4738E-01	4.9000E 00
		HZ	1.4493E 01	4.9000E 00
14	END-J	FX	2.7189E-03	4.9000E 00
		FY	2.8986E 00	4.9000E 00
		FZ	1.0948E-01	4.9000E 00
		IX	0.3242E-04	2.6000E 00
		IY	5.4745E-01	4.9000E 00
		HZ	1.4493E 01	4.9000E 00

15	END-I	FX	1.1696E 00	4.9000E 00
		FY	2.8100E 00	4.9000E 00
		FZ	1.0614E-01	4.9000E 00
		TX	8.2304E-04	2.6000E 00
		MY	5.4737E-01	4.9000E 00
		MZ	1.4493E 01	4.9000E 00
15	END-J	FX	1.1696E 00	4.9000E 00
		FY	2.8100E 00	4.9000E 00
		FZ	1.0614E-01	4.9000E 00
		TX	8.2304E-04	2.6000E 00
		MY	1.4620E 00	4.9000E 00
		MZ	3.8736E 01	4.9000E 00
16	END-I	FX	1.1718E 00	4.9000E 00
		FY	2.8114E 00	4.9000E 00
		FZ	1.0533E-01	4.9000E 00
		TX	1.7682E-03	4.9000E 00
		MY	1.4523E 00	4.9000E 00
		MZ	3.8744E 01	4.9000E 00
16	END-J	FX	1.1718E 00	4.9000E 00
		FY	2.8114E 00	4.9000E 00
		FZ	1.0533E-01	4.9000E 00
		TX	1.7682E-03	4.9000E 00
		MY	5.4379E-01	4.9000E 00
		MZ	1.4496E 01	4.9000E 00
17	END-I	FX	5.5844E-04	4.9000E 00
		FY	2.8992E 00	4.9000E 00
		FZ	1.0873E-01	4.9000E 00
		TX	1.7665E-03	4.9000E 00
		MY	5.4380E-01	4.9000E 00
		MZ	1.4496E 01	4.9000E 00
17	END-J	FX	5.5844E-04	4.9000E 00
		FY	2.8992E 00	4.9000E 00
		FZ	1.0873E-01	4.9000E 00
		TX	1.7665E-03	4.9000E 00
		MY	5.4354E-01	4.9000E 00
		MZ	1.4496E 01	4.9000E 00
18	END-I	FX	1.1719E 00	4.9000E 00
		FY	2.8114E 00	4.9000E 00
		FZ	1.0541E-01	4.9000E 00
		TX	1.7674E-03	4.9000E 00
		MY	5.4355E-01	4.9000E 00
		MZ	1.4496E 01	4.9000E 00

18	END-1	FX	1.1719E 00	4.9000E 00
		FY	2.8114E 00	4.9000E 00
		FZ	1.0541E-01	4.9000E 00
		TX	1.7674E-03	4.9000E 00
		MY	1.4527E 00	4.9000E 00
		MZ	3.8744E 01	4.9000E 00

TABLE 3-7 COFFE TABLE DYNAMIC CASE A (TIME HISTORY ANALYSIS)

ELEMENT NUMBER	LOCATION	STRESS COMPONENT MAXIMA		
		LONGITUDINAL STRESS	CIRCUMFER STRESS	SHEAR STRESS
1	ENC-I	105.22	0.0	5.48
	ENC-J	11.24	0.0	5.48
2	ENC-I	11.23	0.0	4.98
	ENC-J	67.27	0.0	4.98
3	ENC-I	3.00	0.0	0.55
	ENC-J	5.74	0.0	0.55
4	ENC-I	5.74	0.0	0.56
	ENC-J	3.03	0.0	0.56
5	ENC-I	67.25	0.0	4.98
	ENC-J	11.23	0.0	4.98
6	ENC-I	11.24	0.0	5.49
	ENC-J	105.20	0.0	5.49
7	ENC-I	105.22	0.0	5.48
	ENC-J	11.24	0.0	5.48
8	ENC-I	11.23	0.0	4.98
	ENC-J	67.27	0.0	4.98
9	ENC-I	3.00	0.0	0.55
	ENC-J	5.74	0.0	0.55
10	ENC-I	5.74	0.0	0.56
	ENC-J	3.03	0.0	0.56
11	ENC-I	67.25	0.0	4.98
	ENC-J	11.23	0.0	4.98
12	ENC-I	11.24	0.0	5.49
	ENC-J	105.20	0.0	5.49
13	ENC-I	65.75	0.0	2.62
	ENC-J	25.28	0.0	2.62
14	ENC-I	24.19	0.0	2.70
	ENC-J	24.19	0.0	2.70

TABLE 3-AA COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

MODAL PARTICIPATION FACTORS AND EARTHQUAKE SPECTRUM

DIRECTION FACTORS

X = 1.0000 Y = -0.0000 Z = -0.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT

EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	-.4253E+00	.5967E-15	.1297E-07
2	.6129E-09	.5031E-16	.4260E+00
3	-.1074E-11	.4753E-15	.3487E-10
4	.4508E-12	.5645E-12	.5240E-13
5	.1041E-13	-.3316E-02	.2334E-12

SPECTRUM TABLE (IMPERIAL VALLEY E.Q. ELCENTRO 1940 SE)

NUMBER OF POINTS = 11
SCALE FACTOR = .1000E+01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	.1698E-02	.1450E-03
2	.2860E-01	.3800E-03
3	.5800E-01	.7750E-03
4	.7100E-01	.7750E-03
5	.9100E-01	.4400E-03
6	.1140E+00	.1188E+04
7	.1410E+00	.1188E+04
8	.1720E+00	.7000E+03
9	.2000E+00	.8710E+03
10	.2500E+00	.8710E+03
11	.3230E+00	.4000E+03

TABLE 3-9A COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 1
FREQUENCY = 111.230 F7

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-2.08945E-04	-1.58781E-06	-3.33297E-08	-3.90865E-09	-3.40757E-07	3.00562E-05
2	-2.08945E-04	1.58781E-06	3.33427E-08	3.91048E-09	-3.40757E-07	3.00562E-05
3	-2.08945E-04	1.58781E-06	-3.33296E-08	-3.90865E-09	3.40757E-07	3.00562E-05
4	-2.08945E-04	-1.58781E-06	3.33427E-08	3.91048E-09	3.40757E-07	3.00562E-05
5	-4.49095E-04	-2.95530E-06	5.05570E-08	-2.01945E-09	6.34661E-07	1.69898E-05
6	-4.56184E-04	-2.95256E-06	1.35063E-11	-1.11602E-13	1.46049E-14	1.69898E-05
7	-4.49095E-04	-2.95530E-06	-5.05300E-08	2.02028E-09	-6.34661E-07	1.69898E-05
8	-4.49660E-04	3.36914E-05	1.28983E-06	7.41653E-10	1.44368E-07	-3.71931E-06
9	-4.49660E-04	-3.36914E-05	-1.28980E-06	-7.40817E-10	1.44368E-07	-3.71931E-06
10	-4.49095E-04	2.95530E-06	5.05570E-08	-2.01945E-09	-6.34661E-07	1.69898E-05
11	-4.56184E-04	2.95256E-06	1.35089E-11	-1.11624E-13	-1.49608E-14	1.69898E-05
12	-4.49095E-04	2.95530E-06	-5.05300E-08	2.02028E-09	6.34661E-07	1.69898E-05
13	-4.49660E-04	-3.36914E-05	1.28983E-06	7.41653E-10	-1.44368E-07	-3.71931E-06
14	-4.49660E-04	3.36914E-05	-1.28980E-06	-7.40817E-10	-1.44368E-07	-3.71931E-06

RESPONSE FOR MODE 2
FREQUENCY = 115.796 F7

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	3.72584E-16	3.84870E-15	2.80400E-13	3.93976E-14	-1.20476E-15	-4.71828E-17
2	-3.72583E-16	3.84870E-15	2.80400E-13	3.93976E-14	1.20476E-15	4.71827E-17
3	3.72584E-16	-3.84870E-15	2.80400E-13	3.93976E-14	1.20476E-15	-4.71828E-17
4	-3.72584E-16	-3.84870E-15	2.80400E-13	3.93976E-14	-1.20476E-15	4.71827E-17
5	-6.48588E-16	-7.16296E-15	5.80787E-13	1.80032E-14	-2.24387E-15	-3.67625E-18
6	8.61097E-22	5.64808E-24	5.81183E-13	-4.80230E-15	6.36143E-16	-3.20688E-23
7	6.48590E-16	7.16296E-15	5.80787E-13	1.80032E-14	-2.24387E-15	3.67619E-18
8	2.38134E-16	7.45044E-15	6.15992E-13	1.80032E-14	-2.96566E-15	2.72594E-17
9	-2.38132E-16	7.45044E-15	6.15992E-13	1.80032E-14	2.96566E-15	-2.72593E-17
10	-6.48587E-16	7.16296E-15	5.80787E-13	1.80032E-14	2.24387E-15	-3.67628E-18
11	8.61041E-22	-5.64378E-24	5.81183E-13	-4.80230E-15	-6.36143E-16	-3.20688E-23
12	6.48589E-16	-7.16296E-15	5.80787E-13	1.80032E-14	2.24387E-15	3.67621E-18
13	2.38133E-16	-7.45044E-15	6.15992E-13	1.80032E-14	2.96566E-15	2.72594E-17
14	-2.38133E-16	-7.45044E-15	6.15992E-13	1.80032E-14	-2.96566E-15	-2.72593E-17

TABLE 3-9B COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 3
FREQUENCY = 137.161 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.91415E-16	2.70035E-18	3.20362E-16	4.42525E-17	2.28726E-17	2.66744E-17
2	-1.91415E-16	-2.70035E-18	-3.20362E-16	-4.42525E-17	2.28726E-17	2.66744E-17
3	1.91415E-16	2.70035E-18	-3.20362E-16	-4.42525E-17	2.28726E-17	-2.66744E-17
4	1.91415E-16	-2.70035E-18	3.20362E-16	4.42525E-17	2.28726E-17	-2.66744E-17
5	3.92779E-16	-5.02424E-18	6.48054E-16	1.77333E-17	4.26002E-17	-1.18438E-17
6	-1.77358E-27	-1.47496E-29	6.48674E-16	-5.04306E-18	4.65038E-17	6.55179E-29
7	-3.92779E-16	5.02424E-18	6.48054E-16	1.77333E-17	4.26002E-17	1.18438E-17
8	-3.93531E-16	2.73062E-17	2.51210E-16	6.50763E-18	4.88619E-17	-3.24086E-18
9	-3.93531E-16	-2.73062E-17	-2.51210E-16	-6.50763E-18	4.88619E-17	-3.24086E-18
10	-3.92779E-16	-5.02424E-18	-6.48054E-16	-1.77333E-17	4.26002E-17	1.18438E-17
11	-1.80951E-27	7.44775E-30	-6.48674E-16	5.04306E-18	4.65038E-17	6.63012E-29
12	3.92779E-16	5.02424E-18	-6.48054E-16	-1.77333E-17	4.26002E-17	-1.18438E-17
13	3.93531E-16	2.73062E-17	-2.51210E-16	-6.50763E-18	4.88619E-17	3.24086E-18
14	3.93531E-16	-2.73062E-17	2.51210E-16	6.50763E-18	4.88619E-17	3.24086E-18

RESPONSE FOR MODE 4
FREQUENCY = 215.787 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	4.61179E-17	5.80563E-19	3.00727E-17	4.02883E-18	-2.35511E-18	-6.23411E-18
2	4.61179E-17	-5.80563E-19	-3.00727E-17	-4.02883E-18	-2.35511E-18	-6.23411E-18
3	-4.61179E-17	5.80563E-19	-3.00727E-17	-4.02883E-18	-2.35511E-18	6.23411E-18
4	-4.61179E-17	-5.80563E-19	3.00727E-17	4.02883E-18	-2.35511E-18	6.23411E-18
5	-9.19704E-17	-1.07855E-18	5.91067E-17	1.58584E-18	-4.38638E-18	2.72951E-18
6	3.26624E-28	3.62804E-29	5.92467E-17	-3.54101E-19	-1.27221E-17	4.12463E-29
7	9.19704E-17	1.07855E-18	5.91067E-17	1.58584E-18	-4.38638E-18	-2.72951E-18
8	9.24073E-17	-5.21862E-18	4.09169E-17	5.81960E-19	6.43450E-18	5.47953E-19
9	9.24073E-17	5.21862E-18	-4.09169E-17	-5.81960E-19	6.43450E-18	5.47953E-19
10	9.19704E-17	-1.07855E-18	-5.91067E-17	-1.58584E-18	-4.38638E-18	-2.72951E-18
11	-9.18266E-29	3.46988E-29	-5.92467E-17	3.54101E-19	-1.27221E-17	-4.91240E-29
12	-9.19704E-17	1.07855E-18	-5.91067E-17	-1.58584E-18	-4.38638E-18	2.72951E-18
13	-9.24073E-17	-5.21862E-18	-4.09169E-17	-5.81960E-19	6.43450E-18	-5.47953E-19
14	-9.24073E-17	5.21862E-18	4.09169E-17	5.81960E-19	6.43450E-18	-5.47953E-19

TABLE 3-9C COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 5
FREQUENCY = 404.275 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-2.23040E-22	-4.37079E-22	-1.14527E-20	-1.40312E-21	6.13402E-20	-3.38229E-22
2	2.23040E-22	-4.37079E-22	-1.14527E-20	-1.40312E-21	-6.13402E-20	3.38229E-22
3	2.23040E-22	-4.37079E-22	1.14527E-20	1.40312E-21	6.13402E-20	3.38229E-22
4	-2.23040E-22	-4.37079E-22	1.14527E-20	1.40312E-21	-6.13402E-20	-3.38229E-22
5	8.29472E-21	-8.06806E-22	2.13986E-20	8.49229E-22	-1.14246E-19	-1.93594E-21
6	5.73227E-19	3.26728E-21	8.19491E-31	-3.42682E-33	1.15300E-32	-1.93594E-21
7	8.29472E-21	-8.06806E-22	-2.13986E-20	-8.49229E-22	1.14246E-19	-1.93594E-21
8	3.06259E-21	-2.16222E-20	-1.22961E-18	-8.49229E-22	9.40478E-20	-1.62699E-21
9	-3.06259E-21	-2.16222E-20	-1.22961E-18	-8.49229E-22	-9.40478E-20	1.62699E-21
10	-8.29472E-21	-8.06806E-22	-2.13986E-20	-8.49229E-22	-1.14246E-19	1.93594E-21
11	-5.73227E-19	3.26728E-21	-3.03658E-31	1.60881E-33	-8.03908E-33	1.93594E-21
12	8.29472E-21	-8.06806E-22	2.13986E-20	8.49229E-22	1.14246E-19	1.93594E-21
13	-3.06259E-21	-2.16222E-20	1.22961E-18	8.49229E-22	9.40478E-20	1.62699E-21
14	3.06259E-21	-2.16222E-20	1.22961E-18	8.49229E-22	-9.40478E-20	-1.62699E-21

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE NODAL DEFLECTIONS

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	2.08949E-04	1.58781E-06	3.33297E-08	3.90865E-09	3.40757E-07	3.00562E-05
2	2.08949E-04	1.58781E-06	3.33427E-08	3.91048E-09	3.40757E-07	3.00562E-05
3	2.08949E-04	1.58781E-06	3.33296E-08	3.90865E-09	3.40757E-07	3.00562E-05
4	2.08949E-04	1.58781E-06	3.33427E-08	3.91048E-09	3.40757E-07	3.00562E-05
5	4.49095E-04	2.95530E-06	5.05570E-08	2.01945E-09	6.34661E-07	1.69898E-05
6	4.56184E-04	2.95256E-06	1.35188E-11	1.11706E-13	1.46189E-14	1.69898E-05
7	4.49095E-04	2.95530E-06	5.05300E-08	2.02028E-09	6.34661E-07	1.69898E-05
8	4.49660E-04	3.36914E-05	1.28983E-06	7.41653E-10	1.44368E-07	3.71931E-06
9	4.49660E-04	3.36914E-05	1.28980E-06	7.40817E-10	1.44368E-07	3.71931E-06
10	4.49095E-04	2.95530E-06	5.05570E-08	2.01945E-09	6.34661E-07	1.69898E-05
11	4.56184E-04	2.95256E-06	1.35214E-11	1.11727E-13	1.49744E-14	1.69898E-05
12	4.49095E-04	2.95530E-06	5.05300E-08	2.02028E-09	6.34661E-07	1.69898E-05
13	4.49660E-04	3.36914E-05	1.28983E-06	7.41653E-10	1.44368E-07	3.71931E-06
14	4.49660E-04	3.36914E-05	1.28980E-06	7.40817E-10	1.44368E-07	3.71931E-06

TABLE 3-10 COFFEE TABLE DYNAMIC CASE B (RESPONSE-SPECTRUM)

RESPONSE SPECTRUM FORCE COMPONENTS

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE MODAL FORCES
(FOR ALL ELEMENTS)

PX = X-AXIAL FORCE
VY = Y-SHEAR FORCE
VZ = Z-SHEAR FORCE

TX = X-TWISTING MOMENT
MY = Y-BENDING MOMENT
MZ = Z-BENDING MOMENT

I = INITIAL NODE

C = CENTER NODE (FOR PIPE HEAD ONLY)

J = FINAL NODE

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (1)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4760E+01	.2218E-02	.9439E+01	.4869E+00	.1030E+03	.1835E-01	.4760E+01	.2218E-02	.9439E+01	.4869E+00	.8632E+01	.3830E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (2)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4753E+01	.2073E-02	.8527E+01	.4869E+00	.8632E+01	.3830E-02	.4753E+01	.2073E-02	.8527E+01	.4869E+00	.6491E+02	.2171E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (3)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1757E+00	.6533E-02	.9960E+00	.7149E-10	.2928E+01	.2382E-01	.1757E+00	.6533E-02	.9960E+00	.7149E-10	.5662E+01	.3253E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (4)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1757E+00	.6534E-02	.9960E+00	.7160E-10	.5662E+01	.3253E-01	.1757E+00	.6534E-02	.9960E+00	.7160E-10	.2928E+01	.2383E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (5)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4753E+01	.2073E-02	.8527E+01	.4869E+00	.6491E+02	.2171E-01	.4753E+01	.2073E-02	.8527E+01	.4869E+00	.8632E+01	.3830E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (6)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4760E+01	.2218E-02	.9439E+01	.4869E+00	.8632E+01	.3830E-02	.4760E+01	.2218E-02	.9439E+01	.4869E+00	.1030E+03	.1835E-01

TABLE 3-10 COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM FORCE COMPONENTS

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (7)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4760E+01	.2219E-02	.9439E+01	.4869E+00	.1030E+03	.1836E-01	.4760E+01	.2219E-02	.9439E+01	.4869E+00	.8632E+01	.3830E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (8)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4753E+01	.2073E-02	.8527E+01	.4869E+00	.8632E+01	.3830E-02	.4753E+01	.2073E-02	.8527E+01	.4869E+00	.6491E+02	.2171E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (9)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1757E+00	.6534E-02	.9960E+00	.2145E-09	.2928E+01	.2382E-01	.1757E+00	.6534E-02	.9960E+00	.2145E-09	.5662E+01	.3253E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (10)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1757E+00	.6533E-02	.9960E+00	.2141E-09	.5662E+01	.3253E-01	.1757E+00	.6533E-02	.9960E+00	.2141E-09	.2928E+01	.2382E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (11)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4753E+01	.2073E-02	.8527E+01	.4869E+00	.6491E+02	.2171E-01	.4753E+01	.2073E-02	.8527E+01	.4869E+00	.8632E+01	.3830E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (12)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.4760E+01	.2218E-02	.9439E+01	.4869E+00	.8632E+01	.3830E-02	.4760E+01	.2218E-02	.9439E+01	.4869E+00	.1030E+03	.1835E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (13)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1963E+01	.4710E+01	.1771E+00	.2118E-02	.2442E+01	.6491E+02	.1963E+01	.4710E+01	.1771E+00	.2118E-02	.9138E+00	.2429E+02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (14)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.3330E-07	.4857E+01	.1828E+00	.2118E-02	.9138E+00	.2429E+02	.3330E-07	.4857E+01	.1828E+00	.2118E-02	.9138E+00	.2429E+02

TABLE 3-10 COFFEE TABLE DYNAMIC CASE H (RESPONSE SPECTRUM)

RESPONSE SPECTRUM FORCE COMPONENTS

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (15)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1963E+01	.4710E+01	.1771E+00	.2118E-02	.9138E+00	.2429E+02	.1963E+01	.4710E+01	.1771E+00	.2118E-02	.2442E+01	.6491E+02

ELEMENT TYPE (3/D F I P E) / / / ELEMENT NUMBER (16)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1963E+01	.4710E+01	.1771E+00	.2118E-02	.2442E+01	.6491E+02	.1963E+01	.4710E+01	.1771E+00	.2118E-02	.9138E+00	.2429E+02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (17)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.3325E-07	.4857E+01	.1828E+00	.2118E-02	.9138E+00	.2429E+02	.3325E-07	.4857E+01	.1828E+00	.2118E-02	.9138E+00	.2429E+02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (18)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(J)	MZ(J)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1963E+01	.4710E+01	.1771E+00	.2118E-02	.9138E+00	.2429E+02	.1963E+01	.4710E+01	.1771E+00	.2118E-02	.2442E+01	.6491E+02

TABLE 3-11 COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM STRESS COMPONENTS

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LONGIT STRESS	CIRCUMF STRESS	SHEAR STRESS
1	TANGENT	1	END-I	188.192	0.000	9.219
			END-J	19.827	0.000	9.219
2	TANGENT	1	END-I	19.821	0.000	8.369
			END-J	120.205	0.000	8.369
3	TANGENT	1	END-I	5.387	0.000	.927
			END-J	10.263	0.000	.927
4	TANGENT	1	END-I	10.263	0.000	.927
			END-J	5.387	0.000	.927
5	TANGENT	1	END-I	120.205	0.000	8.369
			END-J	19.821	0.000	8.369
6	TANGENT	1	END-I	19.827	0.000	9.219
			END-J	188.192	0.000	9.219
7	TANGENT	1	END-I	188.192	0.000	9.219
			END-J	19.827	0.000	9.219
8	TANGENT	1	END-I	19.821	0.000	8.369
			END-J	120.205	0.000	8.369
9	TANGENT	1	END-I	5.387	0.000	.927
			END-J	10.263	0.000	.927
10	TANGENT	1	END-I	10.263	0.000	.927
			END-J	5.387	0.000	.927
11	TANGENT	1	END-I	120.205	0.000	8.369
			END-J	19.821	0.000	8.369
12	TANGENT	1	END-I	19.827	0.000	9.219
			END-J	188.192	0.000	9.219
13	TANGENT	1	END-I	117.690	0.000	4.388
			END-J	45.177	0.000	4.388
14	TANGENT	1	END-I	43.350	0.000	4.525
			END-J	43.350	0.000	4.525
15	TANGENT	1	END-I	45.177	0.000	4.388
			END-J	117.690	0.000	4.388
16	TANGENT	1	END-I	117.690	0.000	4.388
			END-J	45.177	0.000	4.388
17	TANGENT	1	END-I	43.350	0.000	4.525
			END-J	43.350	0.000	4.525
18	TANGENT	1	END-I	45.177	0.000	4.388
			END-J	117.690	0.000	4.388

TABLE 3-12. COEFF TABLE DYNAMIC CASE C (STEP-BY-STEP INTEGRATION)

D I S P L A C E M E N T M A X I M A				
NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
1	1	1.2653E-04	4.9000E 00	NA
	2	9.3341E-07	4.9000E 00	NA
	3	5.9745E-09	4.9000E 00	NA
2	1	1.2653E-04	4.9000E 00	NA
	2	9.3341E-07	4.9000E 00	NA
	3	6.5518E-09	4.9000E 00	NA
3	1	1.2650E-04	4.9000E 00	NA
	2	9.3342E-07	4.9000E 00	NA
	3	2.0086E-08	4.9000E 00	NA
4	1	1.2650E-04	4.9000E 00	NA
	2	9.3344E-07	4.9000E 00	NA
	3	2.0677E-08	4.9000E 00	NA
5	1	2.6787E-04	4.9000E 00	NA
	2	1.7385E-06	4.9000E 00	NA
	3	4.3908E-08	4.9000E 00	NA
6	1	2.7187E-04	4.9000E 00	NA
	2	1.7348E-06	4.9000E 00	NA
	3	1.5166E-08	4.9000E 00	NA
7	1	2.6793E-04	4.9000E 00	NA
	2	1.7384E-06	4.9000E 00	NA
	3	1.5175E-08	2.6000E 00	NA
8	1	2.6825E-04	4.9000E 00	NA
	2	1.9548E-05	4.9000E 00	NA
	3	7.1983E-07	4.9000E 00	NA
9	1	2.6825E-04	4.9000E 00	NA
	2	1.9548E-05	4.9000E 00	NA
	3	7.1905E-07	4.9000E 00	NA
10	1	2.6793E-04	4.9000E 00	NA
	2	1.7384E-06	4.9000E 00	NA
	3	1.6039E-08	2.6000E 00	NA
11	1	2.7188E-04	4.9000E 00	NA
	2	1.7348E-06	4.9000E 00	NA
	3	1.3933E-08	4.9000E 00	NA
12	1	2.6787E-04	4.9000E 00	NA
	2	1.7384E-06	4.9000E 00	NA
	3	4.2749E-08	4.9000E 00	NA
13	1	2.6819E-04	4.9000E 00	NA
	2	1.9544E-05	4.9000E 00	NA
	3	7.1424E-07	4.9000E 00	NA
14	1	2.6819E-04	4.9000E 00	NA
	2	1.9544E-05	4.9000E 00	NA
	3	7.1240E-07	4.9000E 00	NA

* All values represent the absolute maximum.

TABLE 3-13 COEFFICIENT TABLE DYNAMIC CASE C (STEP-BY-STEP INTEGRATION)

FORCE COMPONENT MAXIMA				
ELEMENT TYPE NUMBER = 2				
ELEMENT NUMBER	LOCATION	FORCE COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	2.7993E-00	4.9000E-00
		FY	2.3873E-04	4.9000E-00
		FZ	5.9278E-00	4.9000E-00
		TX	2.7096E-01	4.9000E-00
		MY	6.2956E-01	4.9000E-00
		MZ	2.8619E-03	4.9000E-00
1	END-J	FX	2.7983E-00	4.9000E-00
		FY	2.3873E-04	4.9000E-00
		FZ	5.9278E-00	4.9000E-00
		TX	2.7096E-01	4.9000E-00
		MY	3.6797E-00	4.9000E-00
		MZ	1.1772E-03	2.6000E-00
2	END-I	FX	2.7981E-00	4.9000E-00
		FY	2.3759E-04	4.9000E-00
		FZ	4.8478E-00	4.9000E-00
		TX	2.7096E-01	4.9000E-00
		MY	3.6789E-00	4.9000E-00
		MZ	1.1772E-03	2.6000E-00
2	END-J	FX	2.7981E-00	4.9000E-00
		FY	2.3759E-04	4.9000E-00
		FZ	4.8478E-00	4.9000E-00
		TX	2.7096E-01	4.9000E-00
		MY	3.8133E-01	4.9000E-00
		MZ	1.6724E-03	4.5000E-00
3	END-I	FX	1.0019E-01	4.9000E-00
		FY	9.2201E-04	2.6000E-00
		FZ	5.5846E-01	4.9000E-00
		TX	1.4954E-03	4.9000E-00
		MY	1.6402E-00	4.9000E-00
		MZ	1.6681E-03	4.5000E-00
3	END-J	FX	1.0019E-01	4.9000E-00
		FY	9.2201E-04	2.6000E-00
		FZ	5.5846E-01	4.9000E-00
		TX	1.4954E-03	4.9000E-00
		MY	3.1769E-00	4.9000E-00
		MZ	6.4309E-03	2.6000E-00
4	END-I	FX	1.0018E-01	4.9000E-00
		FY	7.7429E-04	4.5000E-00

		FZ	5.5987E-01	4.9000E 00
		TX	1.4640E-03	4.9000E 00
		MY	3.1767E 00	4.9000E 00
		MZ	6.4269E-03	2.6000E 00

4	END-J	FX	1.0018E-01	4.9000E 00
		FY	7.7489E-04	4.9000E 00
		FZ	5.5987E-01	4.9000E 00
		TX	1.4640E-03	4.9000E 00
		MY	1.6521E 00	4.9000E 00
		MZ	5.6712E-03	4.9000E 00

5	END-I	FX	2.7982E C0	4.9000E 00
		FY	9.3375E-04	4.9000E 00
		FZ	4.8645E 00	4.9000E 00
		TX	2.7433E-01	4.9000E 00
		MY	3.8123E 01	4.9000E 00
		MZ	7.2196E-03	4.9000E 00

5	END-J	FX	2.7982E 00	4.9000E 00
		FY	9.3375E-04	4.9000E 00
		FZ	4.8645E 00	4.9000E 00
		TX	2.7433E-01	4.9000E 00
		MY	3.6775E 00	4.9000E 00
		MZ	1.4810E-03	2.6000E 00

6	END-I	FX	2.7984E 00	4.9000E 00
		FY	9.3685E-04	4.9000E 00
		FZ	5.9265E 00	4.9000E 00
		TX	2.7433E-C1	4.9000E 00
		MY	3.4778E 00	4.9000E 00
		MZ	1.4811E-03	2.6000E 00

6	END-J	FX	2.7984E 00	4.9000E 00
		FY	9.3685E-04	4.9000E 00
		FZ	5.9265E 00	4.9000E 00
		TX	2.7433E-C1	4.9000E 00
		MY	6.2943E 01	4.9000E 00
		MZ	1.0203E-02	4.9000E 00

7	END-I	FX	2.7983E 00	4.9000E 00
		FY	2.6501E-04	4.9000E 00
		FZ	5.9277E 00	4.9000E 00
		TX	2.7102E-01	4.9000E 00
		MY	6.2956E C1	4.9000E 00
		MZ	3.1471E-03	4.9000E 00

7	END-J	FX	2.7983E 00	4.9000E 00
		FY	2.6501E-04	4.9000E 00
		FZ	5.9277E 00	4.9000E 00
		TX	2.7102E-01	4.9000E 00

		MY	3.6787E-00	4.9000E-00
		MZ	1.1928E-03	2.6000E-00
8	END-I	FX	2.7981E-00	4.9000E-00
		FY	2.6378E-04	4.9000E-00
		FZ	4.8479E-00	4.9000E-00
		TX	2.7102E-01	4.9000E-00
		MY	3.6789E-00	4.9000E-00
		MZ	1.1927E-03	2.6000E-00
8	END-J	FX	2.7981E-00	4.9000E-00
		FY	2.6378E-04	4.9000E-00
		FZ	4.8478E-00	4.9000E-00
		TX	2.7102E-01	4.9000E-00
		MY	3.8133E-01	4.9000E-00
		MZ	1.8025E-03	4.5000E-00
9	END-I	FX	1.0016E-01	4.9000E-00
		FY	9.0414E-04	2.6000E-00
		FZ	5.5854E-01	4.9000E-00
		TX	1.4648E-03	4.9000E-00
		MY	1.6403E-00	4.9000E-00
		MZ	1.8015E-03	4.5000E-00
9	END-J	FX	1.0016E-01	4.9000E-00
		FY	9.0414E-04	2.6000E-00
		FZ	5.5854E-01	4.9000E-00
		TX	1.4648E-03	4.9000E-00
		MY	3.1772E-00	4.9000E-00
		MZ	6.4294E-03	2.6000E-00
10	END-I	FX	1.0016E-01	4.9000E-00
		FY	7.5912E-04	4.5000E-00
		FZ	5.5921E-01	4.9000E-00
		TX	1.3885E-03	4.9000E-00
		MY	3.1771E-00	4.9000E-00
		MZ	6.4308E-03	2.6000E-00
10	END-J	FX	1.0016E-01	4.9000E-00
		FY	7.5912E-04	4.5000E-00
		FZ	5.5921E-01	4.9000E-00
		TX	1.3885E-03	4.9000E-00
		MY	1.6520E-00	4.9000E-00
		MZ	5.4626E-03	4.9000E-00
11	END-I	FX	2.7981E-00	4.9000E-00
		FY	9.0641E-04	4.9000E-00
		FZ	4.8465E-00	4.9000E-00
		TX	2.7437E-01	4.9000E-00
		MY	3.8123E-01	4.9000E-00

MZ 7.0030E-03 4.9000E 00

11	END-J	FX	2.7981E 00	4.9000E 00
		FY	9.0641E-04	4.9000E 00
		FZ	4.8465E 00	4.9000E 00
		TX	2.7437E-01	4.9000E 00
		MY	3.6778E 00	4.9000E 00
		MZ	1.4661E-03	2.6000E 00

12	END-I	FX	2.7983E 00	4.9000E 00
		FY	9.0941E-04	4.9000E 00
		FZ	5.9265E 00	4.9000E 00
		TX	2.7436E-01	4.9000E 00
		MY	3.6780E 00	4.9000E 00
		MZ	1.4661E-03	2.6000E 00

12	END-J	FX	2.7983E 00	4.9000E 00
		FY	9.0941E-04	4.9000E 00
		FZ	5.9265E 00	4.9000E 00
		TX	2.7436E-01	4.9000E 00
		MY	6.2943E 01	4.9000E 00
		MZ	9.9089E-03	4.9000E 00

13	END-I	FX	1.1150E 00	4.9000E 00
		FY	2.7963E 00	4.9000E 00
		FZ	1.0104E-01	4.9000E 00
		TX	1.9770E-03	2.6000E 00
		MY	1.3776E 00	4.9000E 00
		MZ	3.8125E 01	4.9000E 00

13	END-J	FX	1.1150E 00	4.9000E 00
		FY	2.7963E 00	4.9000E 00
		FZ	1.0104E-01	4.9000E 00
		TX	1.9770E-03	2.6000E 00
		MY	5.0618E-01	4.9000E 00
		MZ	1.4007E 01	4.9000E 00

14	END-I	FX	2.6855E-03	3.5000E 00
		FY	2.8014E 00	4.9000E 00
		FZ	1.0122E-01	4.9000E 00
		TX	1.9769E-03	2.6000E 00
		MY	5.0618E-01	4.9000E 00
		MZ	1.4007E 01	4.9000E 00

14	END-J	FX	2.6855E-03	3.5000E 00
		FY	2.8014E 00	4.9000E 00
		FZ	1.0122E-01	4.9000E 00
		TX	1.9769E-03	2.6000E 00
		MY	5.0602E-01	4.9000E 00
		MZ	1.4007E 01	4.9000E 00

15	END-I	FX	1.1152E 00	4.9000E 00
		FY	2.7964E 00	4.9000E 00
		FZ	1.0109E-01	4.9000E 00
		TX	1.9006E-03	2.6000E 00
		MY	5.0594E-01	4.9000E 00
		MZ	1.4007E 01	4.9000E 00
15	END-J	FX	1.1152E 00	4.9000E 00
		FY	2.7964E 00	4.9000E 00
		FZ	1.0109E-01	4.9000E 00
		TX	1.9406E-03	2.6000E 00
		MY	1.3779E 00	4.9000E 00
		MZ	3.8125E 01	4.9000E 00
16	END-I	FX	1.1177E 00	4.9000E 00
		FY	2.7968E 00	4.9000E 00
		FZ	1.0041E-01	4.9000E 00
		TX	1.3220E-03	2.6000E 00
		MY	1.3689E 00	4.9000E 00
		MZ	3.8132E 01	4.9000E 00
16	END-J	FX	1.1177E 00	4.9000E 00
		FY	2.7968E 00	4.9000E 00
		FZ	1.0041E-01	4.9000E 00
		TX	1.3220E-03	2.6000E 00
		MY	5.0291E-01	4.9000E 00
		MZ	1.4010E 01	4.9000E 00
17	END-I	FX	1.7090E-03	2.2000E 00
		FY	2.8019E 00	4.9000E 00
		FZ	1.0059E-01	4.9000E 00
		TX	1.3211E-03	2.6000E 00
		MY	5.0288E-01	4.9000E 00
		MZ	1.4010E 01	4.9000E 00
17	END-J	FX	1.7090E-03	2.2000E 00
		FY	2.8019E 00	4.9000E 00
		FZ	1.0059E-01	4.9000E 00
		TX	1.3211E-03	2.6000E 00
		MY	5.0300E-01	4.9000E 00
		MZ	1.4010E 01	4.9000E 00
18	END-I	FX	1.1177E 00	4.9000E 00
		FY	2.7968E 00	4.9000E 00
		FZ	1.0041E-01	4.9000E 00
		TX	1.3203E-03	2.6000E 00
		MY	5.0299E-01	4.9000E 00
		MZ	1.4010E 01	4.9000E 00

18	FND-J	FX	1.1177E 00	4.9000E 00
		FY	2.7968E 00	4.9000E 00
		FZ	1.0041E-01	4.9000E 00
		TX	1.3293E-03	2.5000E 00
		MY	1.3690E 00	4.9000E 00
		MZ	3.8132E 01	4.9000E 00

TABLE 2-14 COFFE TABLE DYNAMIC CASE C (STEP-BY-STEP INTEGRATION)

ELEMENT NUMBER	LOCATION	STRESS COMPONENT MAXIMA		
		LONGITUDINAL STRESS	CIRCUMFER STRESS	SHEAR STRESS
1	ENC-I	107.62	0.0	5.74
	ENC-J	8.74	0.0	5.74
2	ENC-I	8.74	0.0	4.74
	ENC-J	66.21	0.0	4.74
3	ENC-I	2.83	0.0	0.52
	ENC-J	5.39	0.0	0.52
4	ENC-I	5.39	0.0	0.52
	ENC-J	2.85	0.0	0.52
5	ENC-I	66.20	0.0	4.74
	ENC-J	8.74	0.0	4.74
6	ENC-I	8.74	0.0	5.74
	ENC-J	107.60	0.0	5.74
7	ENC-I	107.62	0.0	5.74
	ENC-J	8.74	0.0	5.74
8	ENC-I	8.74	0.0	4.74
	ENC-J	66.21	0.0	4.74
9	ENC-I	2.83	0.0	0.52
	ENC-J	5.39	0.0	0.52
10	ENC-I	5.39	0.0	0.52
	ENC-J	2.85	0.0	0.52
11	ENC-I	66.20	0.0	4.74
	ENC-J	8.74	0.0	4.74
12	ENC-I	8.74	0.0	5.74
	ENC-J	107.60	0.0	5.74
13	ENC-I	44.67	0.0	2.61
	ENC-J	24.42	0.0	2.61
14	ENC-I	23.38	0.0	2.61
	ENC-J	23.38	0.0	2.61

Problem 4 - Static Analysis of Spence's Pipe Work Problem

In this problem, a piping system provided by Spence was analyzed. Comparisons are made between results obtained from the 'EPIPE' program and those obtained by Spence¹¹, from the SPANDLE program.

Problem Description

i. Geometry - The layout of this piping system is shown in Fig. 4-1. The piping elements 2-3 and 10-11 are stiffened by taking the internal diameter of the pipe as zero. Table 4-1 shows the input nodal coordinates data.

The element properties of the pipe are as follows:

Outside diameter (inches) 12.75

Inside diameter (inches) 7.625

Mean radius of curvature
for all bends (inches) 48.0

ii. Material data -

Young's modulus (psi) 3.0 E7

Poisson's ratio 0.3

iii. Loading conditions - The piping system is assumed fixed at node 1 and subjected to the prescribed displacement at node 19 resulting from the temperature change. The amount of the imposed displacements are as follows:

X - displacement = 6.8526 in.

Y - displacement = 1.9602 in

Z - displacement = 2.6487 in.

Analysis Results

The computer output is given in Tables 4-2 to 4-4, showing the nodal displacements/rotations, pipe forces and moments, and pipe stresses respectively. It is to be noted that due to extreme bending different fiber stresses result at the same cross-section of the tubes. These are shown as the positive and negative values given in Table 4-4. A comparison of the results are made on a selected number of nodes and elements as shown in Tables 4-5 to 4-6. The results obtained from the EPIPE agree quite well with those obtained from SPANDLE.

Fig. 4-1

Isometric Sketch of Spence's Problem

TABLE 4-1 INPUT DATA FOR SPENCE'S PIPEWORK PROBLEM

NODAL COORDINATES

NODE NUMBER	BOUNDARY CONDITION CODES							NODAL POINT COORDINATES				
	X	Y	Z	XX	YY	ZZ		X	Y	Z	T	
1	1	1	1	1	1	1		0.0	0.0	0.0	0	0.0
2	0	0	0	0	0	0		0.0	0.0	90.000	0	0.0
3	0	0	0	0	0	0		0.0	0.0	150.000	0	0.0
4	0	0	0	0	0	0		0.0	0.0	168.000	0	0.0
5	0	0	0	0	0	0		48.000	0.0	216.000	0	0.0
6	0	0	0	0	0	0		228.000	0.0	216.000	0	0.0
7	0	0	0	0	0	0		275.000	-49.000	216.000	0	0.0
8	0	0	0	0	0	0		324.000	-96.000	216.000	0	0.0
9	0	0	0	0	0	0		348.000	-96.000	216.000	0	0.0
10	0	0	0	0	0	0		396.000	-48.000	216.000	0	0.0
11	0	0	0	0	0	0		396.000	24.000	216.000	0	0.0
12	0	0	0	0	0	0		396.000	72.000	264.000	0	0.0
13	0	0	0	0	0	0		396.000	72.000	279.000	0	0.0
14	0	0	0	0	0	0		444.000	72.000	327.000	0	0.0
15	0	0	0	0	0	0		615.000	72.000	327.000	0	0.0
16	0	0	0	0	0	0		627.000	72.000	327.000	0	0.0
17	0	0	0	0	0	0		798.000	72.000	327.000	0	0.0
18	0	0	0	0	0	0		846.000	120.000	327.000	0	0.0
19	0	0	0	1	1	1		846.000	242.000	327.000	0	0.0
20	1	1	1	1	1	1		846.000	245.000	327.000	0	0.0
21	1	1	1	1	1	1		846.000	242.000	330.000	0	0.0
22	1	1	1	1	1	1		850.000	242.000	327.000	0	0.0

TABLE 4-2 ANALYSIS OF SPENCE'S PIPING SYSTEM

LOAD CASE 1

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
2	-5.58334E-01	-1.53742E-01	-3.68224E-04	3.10312E-03	-1.06489E-02	-4.97690E-03
3	-1.26611E+00	-3.73223E-01	-5.25909E-04	4.08380E-03	-1.22190E-02	-7.87042E-03
4	-1.48557E+00	-4.48815E-01	-5.99554E-04	4.27385E-03	-1.19325E-02	-8.86580E-03
5	-2.00122E+00	-1.19401E+00	4.53685E-01	4.16340E-03	-7.61060E-03	-1.22469E-02
6	-2.00414E+00	-3.72315E+00	9.93568E-01	3.83544E-03	-3.23189E-05	-1.46915E-02
7	-2.66166E+00	-4.40949E+00	8.08533E-01	3.25691E-03	5.27791E-04	-1.22597E-02
8	-3.13007E+00	-4.76453E+00	6.53792E-01	1.10661E-03	3.95750E-04	-3.84996E-03
9	-3.13046E+00	-4.81692E+00	6.48230E-01	1.74483E-04	-3.28691E-06	-4.65823E-04
10	-3.42594E+00	-4.65381E+00	6.12935E-01	-2.21525E-03	-2.75455E-03	9.25048E-03
11	-4.27930E+00	-4.65402E+00	4.29822E-01	-2.57242E-03	-5.97654E-03	1.32278E-02
12	-5.25990E+00	-4.55540E+00	3.18596E-01	-1.73394E-03	-7.45887E-03	1.09260E-02
13	-5.37050E+00	-4.53061E+00	3.18534E-01	-1.60931E-03	-7.03493E-03	1.00636E-02
14	-5.63365E+00	-4.08702E+00	5.07213E-01	-1.89972E-03	-1.71419E-03	6.52214E-03
15	-5.63643E+00	-3.29880E+00	-1.55632E-01	-2.64149E-03	7.97870E-03	3.74952E-03
16	-5.63656E+00	-3.25376E+00	-2.53433E-01	-2.68689E-03	8.28788E-03	3.78076E-03
17	-5.63933E+00	-2.37290E+00	-1.83304E+00	-3.42866E-03	8.69505E-03	7.57431E-03
18	-6.08251E+00	-1.95985E+00	-2.38545E+00	-3.53719E-03	5.89872E-03	9.53453E-03
19	-6.85260E+00	-1.96020E+00	-2.64870E+00	0.	0.	0.

TABLE 4-3 ANALYSIS OF SPENCE'S PIPING SYSTEM

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

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSIONAL MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1	TANGENT	1	END-I	-10066.348	-7121.233	39962.731	-1443657.08	-5813934.79	-1490620.72
			END-J	-10066.348	-7121.233	39962.731	-1443657.08	-2217288.98	-849709.76
2	TANGENT	1	END-I	-10066.348	-7121.233	39962.731	-1443657.08	-2217288.98	-849709.76
			END-J	-10066.348	-7121.233	39962.731	-1443657.08	180474.90	-422435.78
3	TANGENT	1	END-I	-10066.348	-7121.233	39962.731	-1443657.08	180474.90	-422435.78
			END-J	-10066.348	-7121.233	39962.731	-1443657.08	899804.06	-294253.59
4	BEND	1	END-I	-10066.348	-39962.731	-7121.233	-1443657.08	294253.59	899804.06
			CENTER	-35375.901	-21139.935	-7121.233	-912867.52	987185.76	2114662.62
			END-J	-39962.731	10066.348	-7121.233	-47565.59	1101837.90	2334830.47
5	TANGENT	1	END-I	-39962.731	-7121.233	-10066.348	-47565.59	2334830.47	-1101837.90
			END-J	-39962.731	-7121.233	-10066.348	-47565.59	522887.86	179984.02
6	BEND	1	END-I	-39962.731	7121.233	10066.348	-47565.59	-522887.86	-179984.02
			CENTER	-23222.446	33293.390	10066.348	-261849.98	5559.58	-983517.70
			END-J	7121.233	39962.731	10066.348	-39703.16	530750.29	-2440014.30
7	BEND	1	END-I	7121.233	-39962.731	-10066.348	-39703.16	-530750.29	2440014.30
			CENTER	-23222.446	-33293.390	-10066.348	-544893.02	-688885.93	3896510.90
			END-J	-39962.731	-7121.233	-10066.348	-1013934.98	-443481.53	4700044.58
8	TANGENT	1	END-I	-39962.731	-7121.233	-10066.348	-1013934.98	-443481.53	4700044.58
			END-J	-39962.731	-7121.233	-10066.348	-1013934.98	-685073.88	4870954.17
9	BEND	1	END-I	-39962.731	-7121.233	-10066.348	-1013934.98	-685073.88	4870954.17
			CENTER	-33293.390	23222.446	-10066.348	-1342902.21	-109123.26	4550825.81
			END-J	-7121.233	39962.731	-10066.348	-1168258.58	530750.29	3294562.25
10	TANGENT	1	END-I	-7121.233	-10066.348	-39962.731	-1168258.58	3294562.25	-530750.29
			END-J	-7121.233	-10066.348	-39962.731	-1168258.58	417245.60	194026.76
11	BEND	1	END-I	-7121.233	-10066.348	-39962.731	-1168258.58	417245.60	194026.76
			CENTER	-12153.455	-2082.511	-39962.731	-1092877.40	-235259.32	435573.41
			END-J	-10066.348	7121.233	-39962.731	-1500965.51	-749952.52	325392.28
12	TANGENT	1	END-I	-10066.348	-7121.233	39962.731	-1500965.51	749952.52	-325392.28
			END-J	-10066.348	-7121.233	39962.731	-1500965.51	1349393.49	-228573.78
13	BEND	1	END-I	-10066.348	-39962.731	-7121.233	-1500965.51	228573.78	1349393.49
			CENTER	-35375.901	-21139.935	-7121.233	-999833.34	981266.30	2564252.05
			END-J	-39962.731	10066.348	-7121.233	-113245.40	1159146.33	2784419.90
14	TANGENT	1	END-I	-39962.731	-7121.233	-10066.348	-113245.40	2784419.90	-1159146.33
			END-J	-39962.731	-7121.233	-10066.348	-113245.40	1063074.42	58584.50
15	TANGENT	1	END-I	-39962.731	-7121.233	-10066.348	-113245.40	1063074.42	58584.50
			END-J	-39962.731	-7121.233	-10066.348	-113245.40	942218.24	144639.25

TABLE 4-3 ANALYSIS OF SEWAGE PIPING SYSTEM

PIPE FORCES AND MOMENTS

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	AXIAL FORCE	Y-AXIS SHEAR	Z-AXIS SHEAR	TORSIONAL MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
16	TANGENT	1	END-I	-39962.731	-7121.233	-10066.348	-113245.40	942278.24	144039.29
			END-J	-39962.731	-7121.233	-10066.348	-113245.40	-779067.24	1361770.12
17	BEND	1	END-I	-39962.731	-7121.233	-10066.348	-113245.40	-779067.24	1361770.12
			CENTER	-33293.390	23222.446	-10066.348	-772481.84	-812470.31	1041641.76
			END-J	-7121.233	39962.731	-10066.348	-1262251.93	-369939.30	-214621.00
18	TANGENT	1	END-I	-7121.233	-10066.348	-39962.731	-1262251.93	-214621.00	369939.30
			END-J	-7121.233	-10066.348	-39962.731	-1262251.93	-5090075.02	1598033.74

TABLE 4-4 ANALYSIS OF SPENCER'S PIPING SYSTEM

PIPE STRESSES

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LONGITUDINAL STRESS		BEND STRESS		SHEAR STRESS	
				POSITIVE	NEGATIVE	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
1	TANGENT	1	END-I	33699.70	-33945.19	0.00	0.00	-3572.71	-4562.61
			END-J	13258.22	-13503.70	0.00	0.00	-3572.71	-4562.61
2	TANGENT	1	END-I	11590.51	-11748.19	0.00	0.00	-3229.42	-3865.28
			END-J	2178.69	-2336.38	0.00	0.00	-3229.42	-3865.28
3	TANGENT	1	END-I	2465.92	-2711.40	0.00	0.00	-3572.71	-4562.61
			END-J	5212.09	-5457.57	0.00	0.00	-3572.71	-4562.61
4	BEND	1	END-I	5212.09	-5457.57	1058.42	-2138.58	-3572.71	-4562.61
			CENTER	12719.76	-13582.46	2487.43	-5025.95	-2300.11	-2844.10
			END-J	14061.49	-15036.04	2746.41	-5545.22	16.33	-284.37
5	TANGENT	1	END-I	14061.49	-15036.04	0.00	0.00	16.33	-284.37
			END-J	2628.98	-3603.53	0.00	0.00	16.33	-284.37
6	BEND	1	END-I	2628.98	-3603.53	211.71	-427.77	16.33	-284.37
			CENTER	5259.26	-5825.58	1156.85	-2337.54	-313.69	-1161.89
			END-J	14158.36	-13984.70	2870.14	-5795.21	390.63	-614.36
7	BEND	1	END-I	14158.36	-13984.70	2870.14	-5795.21	390.63	-614.36
			CENTER	22015.03	-22581.35	4583.38	-9260.89	-1111.19	-1959.40
			END-J	26116.12	-27090.67	5528.56	-11170.66	-2706.52	-3007.22
8	TANGENT	1	END-I	26116.12	-27090.67	0.00	0.00	-2706.52	-3007.22
			END-J	27231.74	-28206.29	0.00	0.00	-2706.52	-3007.22
9	BEND	1	END-I	27231.74	-28206.29	5729.60	-11576.86	-2706.52	-3007.22
			CENTER	25246.29	-26058.20	5353.04	-10816.01	-3475.16	-4092.38
			END-J	18718.10	-18891.76	3875.32	-7830.23	-2789.20	-3794.19
10	TANGENT	1	END-I	18718.10	-18891.76	0.00	0.00	-2789.20	-3794.19
			END-J	2506.23	-2679.89	0.00	0.00	-2789.20	-3794.19
11	BEND	1	END-I	2506.23	-2679.89	228.23	-461.15	-2789.20	-3794.19
			CENTER	2641.50	-2937.88	512.36	-1035.23	-2591.36	-3567.23
			END-J	4506.77	-4752.26	394.51	-797.17	-3734.18	-4724.08
12	TANGENT	1	END-I	4506.77	-4752.26	0.00	0.00	-3734.18	-4724.08
			END-J	7589.70	-7835.18	0.00	0.00	-3734.18	-4724.08
13	BEND	1	END-I	7589.70	-7835.18	1587.26	-3207.12	-3734.18	-4724.08
			CENTER	15040.65	-15903.34	3016.28	-6094.49	-2545.14	-3089.13
			END-J	16508.86	-17483.41	3275.26	-6617.77	-168.73	-469.43
14	TANGENT	1	END-I	16508.86	-17483.41	0.00	0.00	-168.73	-469.43
			END-J	5512.47	-6487.01	0.00	0.00	-168.73	-469.43

TABLE 4-4 ANALYSIS OF SPENCE'S PIPING SYSTEM

PIPE STRESSES

15	TANGENT	1	END-I	4919.29	-5545.29	0.00	0.00	-181.69	-374.84
			END-J	4371.51	-4997.51	0.00	0.00	-181.69	-374.84
16	TANGENT	1	END-I	4884.34	-5858.89	0.00	0.00	-168.73	-469.43
			END-J	8353.66	-9328.21	0.00	0.00	-168.73	-469.43
17	BEND	1	END-I	8353.66	-9328.21	1601.02	-3236.54	-168.73	-469.43
			CENTER	7038.34	-7850.25	1225.26	-2475.68	-1867.94	-2485.16
			END-J	2323.29	-2496.95	252.46	-510.09	-3054.03	-4059.02
18	TANGENT	1	END-I	2323.29	-2496.95	0.00	0.00	-3054.03	-4059.02
			END-J	29977.21	-30150.88	0.00	0.00	-3054.03	-4059.02

Table 4-5

Comparison of Nodal Displacements/Rotations

Solution	Node	X-DISP	Y-DISP	Z-DISP	XR	YR	ZR
EPIPE	6	-2.0041	-3.7232	0.99358	3.8354E-3	-3.2319E-5	-1.4692E-2
Spence	6	-2.0044	-3.7244	0.99407	3.8338E-3	-3.4540E-5	-1.4697E-2
EPIPE	10	-3.4259	-4.6538	0.61294	-2.2153E-3	-2.7546E-3	9.2905E-3
Spence	10	-3.4265	-4.6560	0.61375	-2.2179E-3	-2.7548E-3	9.2867E-3

Table 4-6

Comparison of Forces and Moments

Solution Element		FX	FY	FZ	TX	MY	MZ
EPIPE	1-I	10066	39963	7121	1443657	-1490620	5813935
	-J	10066	39963	-7121	1443657	-849709	-2217288
Spence	1-I	10065	39963	7123.7	1444200	-1490900	5814300
	-J	10065	39963	-7123.7	1444200	- 849790	-2217600

Problem 5 - DYNAMIC RESPONSE OF A LOW FREQUENCY COFFEE TABLE

It is important to realize that there can be greater differences between the response spectrum results and those obtained from either time-history or direct integration methods, when the natural frequencies of the system are in the vicinity of the peak earthquake values. To demonstrate this, the legs of the coffee table (problem 3) were extended so the natural frequencies come out to be in the vicinity of the earthquake peak shown in Figure 2-3. As can be seen by comparing results shown in Tables 3-7 and 3-11 with those of Tables 5-7 and 5-10, there are indeed greater differences (about three to one) between the response spectrum and the time history and direct integration method results for the case where the coffee table's natural frequencies fall out near the peaks.

TABLE 5-1 LOW-FREQUENCY COFFEE TABLE CASE A (TIME HISTORY ANALYSIS)

N O D A L C O O R D I N A T E S

NODE NUMBER	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES				
	X	Y	Z	XX	YY	ZZ	X	Y	Z	T	
1	0	0	0	0	0	0	0.000	-30.000	0.000	-0	-0.000
2	0	0	0	0	0	0	27.250	-30.000	0.000	-0	-0.000
3	0	0	0	0	0	0	27.250	-30.000	17.250	-0	-0.000
4	0	0	0	0	0	0	0.000	-30.000	17.250	-0	-0.000
5	0	0	0	0	0	0	0.000	18.625	17.250	-0	-0.000
6	0	0	0	0	0	0	0.000	18.625	8.625	-0	-0.000
7	0	0	0	0	0	0	0.000	18.625	0.000	-0	-0.000
8	0	0	0	0	0	0	8.625	18.625	0.000	-0	-0.000
9	0	0	0	0	0	0	18.625	18.625	0.000	-0	-0.000
10	0	0	0	0	0	0	27.250	18.625	0.000	-0	-0.000
11	0	0	0	0	0	0	27.250	18.625	8.625	-0	-0.000
12	0	0	0	0	0	0	27.250	18.625	17.250	-0	-0.000
13	0	0	0	0	0	0	18.625	18.625	17.250	-0	-0.000
14	0	0	0	0	0	0	8.625	18.625	17.250	-0	-0.000
15	1	1	1	1	1	1	0.000	-80.000	0.000	-0	-0.000
16	1	1	1	1	1	1	27.250	-80.000	0.000	-0	-0.000
17	1	1	1	1	1	1	27.250	-80.000	17.250	-0	-0.000
18	1	1	1	1	1	1	0.000	-80.000	17.250	-0	-0.000

TABLE 5-2 LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY ANALYSIS)

LUMPED MASS DATA

NODE NUMBER	LOAD CASE	X-AXIS FORCE	Y-AXIS FORCE	Z-AXIS FORCE	X-AXIS MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
1	-0	.44700E-01	.44700E-01	.44700E-01	-0.	-0.	-0.
2	-0	.44700E-01	.44700E-01	.44700E-01	-0.	-0.	-0.
3	-0	.44700E-01	.44700E-01	.44700E-01	-0.	-0.	-0.
4	-0	.44700E-01	.44700E-01	.44700E-01	-0.	-0.	-0.
5	-0	.43270E-01	.43270E-01	.43270E-01	-0.	-0.	-0.
6	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.
7	-0	.43270E-01	.43270E-01	.43270E-01	-0.	-0.	-0.
8	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.
9	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.
10	-0	.43270E-01	.43270E-01	.43270E-01	-0.	-0.	-0.
11	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.
12	-0	.43270E-01	.43270E-01	.43270E-01	-0.	-0.	-0.
13	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.
14	-0	.89400E-02	.89400E-02	.89400E-02	-0.	-0.	-0.

TABLE 5-3. LOW FREQUENCY COEFFICIENT TABLE CASE A (TIME HISTORY ANALYSIS)
N A T U R A L F R E Q U E N C I E S

MODE NUMBER	CIRCULAR FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	.5474E+02	.8712E+01	.1148E+00
2	.5533E+02	.8805E+01	.1136E+00
3	.1108E+03	.1751E+02	.5712E-01
4	.2536E+03	.4037E+02	.2477E-01
5	.2615E+03	.4163E+02	.2402E-01

TABLE 5-4A LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY)

M O D E S H A P E

MODE NUMBER 1
 FREQUENCY = 8.71197 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	9.57401E-01	2.06221E-03	1.85150E-03	4.57369E-08	9.12521E-06	-2.79462E-02
2	9.57401E-01	-2.06221E-03	-1.15299E-06	-2.54470E-08	9.12522E-06	-2.79462E-02
3	9.57401E-01	-2.06221E-03	1.85145E-06	4.57354E-08	-9.12520E-06	-2.79462E-02
4	9.57401E-01	2.06221E-03	-1.15294E-06	-2.54455E-08	-9.12522E-06	-2.79462E-02
5	1.92035E+00	4.06727E-03	-7.76167E-07	5.72030E-08	-1.79995E-05	-4.62897E-03
6	1.92054E+00	4.06775E-03	6.92336E-07	-8.21298E-11	8.31443E-12	-4.62897E-03
7	1.92035E+00	4.06727E-03	2.16083E-06	-5.44550E-08	1.79995E-05	-4.62897E-03
8	1.92037E+00	-7.41379E-03	-3.55664E-05	-1.91138E-08	-4.07819E-06	7.14639E-04
9	1.92037E+00	7.41380E-03	3.69514E-05	2.18616E-08	-4.07815E-06	7.14639E-04
10	1.92035E+00	-4.06727E-03	-7.76267E-07	5.72029E-08	1.79995E-05	-4.62897E-03
11	1.92054E+00	-4.06775E-03	6.92236E-07	-8.21072E-11	-6.98041E-13	-4.62897E-03
12	1.92035E+00	-4.06727E-03	2.16073E-06	-5.44552E-08	-1.79995E-05	-4.62897E-03
13	1.92037E+00	7.41379E-03	-3.55664E-05	-1.91138E-08	4.07820E-06	7.14639E-04
14	1.92037E+00	-7.41380E-03	3.69515E-05	2.18617E-08	4.07816E-06	7.14639E-04

MODE NUMBER 1
 EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	4.98505E-01	1.07377E-03	9.64051E-07	2.38145E-08	4.75137E-06	-1.45512E-02
2	4.98505E-01	-1.07376E-03	-6.00348E-07	-1.32499E-08	4.75138E-06	-1.45512E-02
3	4.98505E-01	-1.07377E-03	9.64025E-07	2.38138E-08	-4.75137E-06	-1.45512E-02
4	4.98505E-01	1.07376E-03	-6.00321E-07	-1.32491E-08	-4.75137E-06	-1.45512E-02
5	9.99901E-01	2.11777E-03	-4.04140E-07	2.97848E-08	-9.37208E-06	-2.41024E-03
6	1.00000E+00	2.11802E-03	3.60490E-07	-4.27638E-11	4.32921E-12	-2.41024E-03
7	9.99901E-01	2.11777E-03	1.12512E-06	-2.83540E-08	9.37207E-06	-2.41024E-03
8	9.99909E-01	-3.86026E-03	-1.85189E-05	-9.95227E-09	-2.12346E-06	3.72103E-04
9	9.99909E-01	3.86026E-03	1.92401E-05	1.13830E-08	-2.12344E-06	3.72103E-04
10	9.99901E-01	-2.11777E-03	-4.04192E-07	2.97847E-08	9.37209E-06	-2.41024E-03
11	1.00000E+00	-2.11802E-03	3.60438E-07	-4.27521E-11	-3.63460E-13	-2.41024E-03
12	9.99901E-01	-2.11777E-03	1.12506E-06	-2.83541E-08	-9.37207E-06	-2.41024E-03
13	9.99909E-01	3.86026E-03	-1.85189E-05	-9.95230E-09	2.12346E-06	3.72103E-04
14	9.99909E-01	-3.86026E-03	1.92401E-05	1.13831E-08	2.12344E-06	3.72103E-04
15	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.

TABLE 5-4B LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 2
 FREQUENCY = 8.80624 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-9.96853E-06	-3.35970E-03	-9.66873E-01	-2.80852E-02	2.22923E-05	2.51739E-07
2	1.00868E-05	-3.35970E-03	-9.66873E-01	-2.80852E-02	-2.22923E-05	-2.55193E-07
3	-9.96850E-06	3.35970E-03	-9.66873E-01	-2.80852E-02	-2.22923E-05	2.51738E-07
4	1.00869E-05	3.35970E-03	-9.66873E-01	-2.80852E-02	2.22923E-05	-2.55193E-07
5	1.29226E-05	6.62626E-03	-1.91651E+00	-3.80356E-03	4.39715E-05	2.49156E-07
6	1.18703E-07	2.51415E-10	-1.91652E+00	2.27336E-04	-1.24515E-05	-2.86103E-10
7	-1.26853E-05	-6.62626E-03	-1.91651E+00	-3.80356E-03	4.39715E-05	-2.49728E-07
8	-4.58004E-06	-6.62910E-03	-1.91717E+00	-3.80356E-03	5.46972E-05	-2.24828E-07
9	4.81737E-06	-6.62910E-03	-1.91717E+00	-3.80356E-03	-5.46972E-05	2.24917E-07
10	1.29226E-05	-6.62626E-03	-1.91651E+00	-3.80356E-03	-4.39715E-05	2.49156E-07
11	1.18703E-07	-2.51417E-10	-1.91652E+00	2.27336E-04	1.24515E-05	-2.86103E-10
12	-1.26852E-05	6.62626E-03	-1.91651E+00	-3.80356E-03	-4.39715E-05	-2.49728E-07
13	-4.57998E-06	6.62910E-03	-1.91717E+00	-3.80356E-03	5.46972E-05	-2.24828E-07
14	4.81742E-06	6.62910E-03	-1.91717E+00	-3.80356E-03	5.46972E-05	2.24917E-07

MODE NUMBER 2
 EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-5.19961E-06	-1.75243E-03	-5.04323E-01	-1.46493E-02	1.16277E-05	1.31308E-07
2	5.26132E-06	-1.75243E-03	-5.04323E-01	-1.46493E-02	-1.16277E-05	-1.33109E-07
3	-5.19959E-06	1.75243E-03	-5.04323E-01	-1.46493E-02	-1.16277E-05	1.31307E-07
4	5.26134E-06	1.75243E-03	-5.04323E-01	-1.46493E-02	1.16277E-05	-1.33109E-07
5	6.74040E-06	3.45628E-03	-9.99658E-01	-1.98394E-03	2.29356E-05	1.29960E-07
6	6.19158E-08	1.31139E-10	-9.99662E-01	1.18579E-04	-6.49475E-06	-1.49232E-10
7	-6.61666E-06	-3.45628E-03	-9.99658E-01	-1.98394E-03	2.29357E-05	-1.30259E-07
8	-2.38896E-06	-3.45776E-03	-1.00000E+00	-1.98394E-03	2.85302E-05	-1.17271E-07
9	2.51275E-06	-3.45776E-03	-1.00000E+00	-1.98394E-03	-2.85302E-05	1.17317E-07
10	6.74045E-06	-3.45628E-03	-9.99658E-01	-1.98394E-03	-2.29356E-05	1.29960E-07
11	6.19158E-08	-1.31140E-10	-9.99662E-01	1.18579E-04	6.49476E-06	-1.49232E-10
12	-6.61663E-06	3.45628E-03	-9.99658E-01	-1.98394E-03	-2.29356E-05	-1.30259E-07
13	-2.38893E-06	3.45776E-03	-1.00000E+00	-1.98394E-03	2.85302E-05	-1.17271E-07
14	2.51278E-06	3.45776E-03	-1.00000E+00	-1.98394E-03	2.85302E-05	1.17317E-07
15	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.

TABLE 5-4C LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY)

M O D E S I M P L E

MODE NUMBER 3
 FREQUENCY = 17.5079 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-6.03147E-01	1.14969E-03	9.70100E-01	2.46567E-02	6.03597E-02	1.53263E-02
2	-6.03147E-01	-1.14969E-03	-9.70100E-01	-2.46567E-02	6.03597E-02	1.53263E-02
3	6.03147E-01	1.14969E-03	-9.70100E-01	-2.46567E-02	6.03597E-02	-1.53263E-02
4	6.03147E-01	-1.14969E-03	9.70100E-01	2.46567E-02	6.03597E-02	-1.53263E-02
5	1.03461E+00	-2.26675E-03	1.66517E+00	1.85501E-03	1.19060E-01	-1.12523E-03
6	-9.82459E-11	-1.48437E-13	1.66520E+00	-2.59441E-04	1.20248E-01	1.68731E-13
7	-1.03461E+00	2.26675E-03	1.66517E+00	1.85501E-03	1.19060E-01	1.12523E-03
8	-1.03464E+00	3.48884E-03	-6.17688E-01	6.80738E-04	1.22958E-01	-4.68575E-04
9	-1.03464E+00	-3.48884E-03	-6.17688E-01	-6.80738E-04	1.22958E-01	-4.68575E-04
10	-1.03461E+00	-2.26675E-03	-1.66517E+00	-1.85501E-03	1.19060E-01	1.12523E-03
11	-9.82386E-11	1.48267E-13	-1.66520E+00	2.59441E-04	1.20248E-01	1.68781E-13
12	1.03461E+00	2.26675E-03	-1.66517E+00	-1.85501E-03	1.19060E-01	-1.12523E-03
13	1.03464E+00	3.48884E-03	-6.17688E-01	6.80738E-04	1.22958E-01	4.68575E-04
14	1.03464E+00	-3.48884E-03	6.17688E-01	6.80738E-04	1.22958E-01	4.68575E-04

MODE NUMBER 3
 EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-3.62207E-01	6.90422E-04	5.82574E-01	1.48071E-02	3.62478E-02	9.20388E-03
2	-3.62207E-01	-6.90422E-04	-5.82574E-01	-1.48071E-02	3.62478E-02	9.20388E-03
3	3.62207E-01	6.90422E-04	-5.82574E-01	-1.48071E-02	3.62478E-02	-9.20388E-03
4	3.62207E-01	-6.90422E-04	5.82574E-01	1.48071E-02	3.62478E-02	-9.20388E-03
5	6.21313E-01	-1.36125E-03	9.99984E-01	1.11399E-03	7.14988E-02	-6.75732E-04
6	-5.89996E-11	-8.91405E-14	1.00000E+00	-1.55802E-04	7.22126E-02	1.01328E-13
7	-6.21313E-01	1.36125E-03	9.99984E-01	-1.11399E-03	7.14988E-02	6.75732E-04
8	-6.21333E-01	2.09515E-03	3.70940E-01	4.08803E-04	7.38399E-02	-2.81393E-04
9	-6.21333E-01	-2.09515E-03	-3.70940E-01	-4.08803E-04	7.38399E-02	-2.81393E-04
10	6.21313E-01	-1.36125E-03	-9.99984E-01	1.11399E-03	7.14988E-02	6.75732E-04
11	-5.90552E-11	8.90389E-14	-1.00000E+00	1.55802E-04	7.22126E-02	1.01358E-13
12	6.21313E-01	1.36125E-03	-9.99984E-01	-1.11399E-03	7.14988E-02	-6.75732E-04
13	6.21333E-01	2.09515E-03	-3.70940E-01	4.08803E-04	7.38399E-02	2.81393E-04
14	6.21333E-01	-2.09515E-03	3.70940E-01	4.08803E-04	7.38399E-02	2.81393E-04
15	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.

TABLE 5-4D LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 4
 FREQUENCY = 40.3668 Hz

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-2.36247E+00	-2.34097E-04	-4.13419E-05	-1.43475E-07	-2.35729E-07	8.20167E-03
2	2.36247E+00	-2.34097E-04	-4.13419E-05	-1.43475E-07	2.35729E-07	-8.20167E-03
3	2.36247E+00	-2.34097E-04	4.13419E-05	1.43475E-07	-2.35729E-07	-8.20167E-03
4	-2.36247E+00	-2.34097E-04	4.13419E-05	1.43475E-07	2.35729E-07	8.20167E-03
5	-1.36755E-03	-4.60664E-04	1.46837E-08	-7.09631E-07	4.66948E-07	-4.05301E-02
6	-1.37129E-03	-4.64308E-04	1.52100E-14	1.06656E-16	2.20167E-15	-4.05301E-02
7	-1.36755E-03	-4.60664E-04	-1.46836E-08	7.09631E-07	-4.66948E-07	-4.05301E-02
8	-5.01883E-04	-2.40431E-01	2.74993E-06	7.09631E-07	-1.72519E-07	-1.49751E-02
9	5.01883E-04	-2.40431E-01	2.74993E-06	7.09631E-07	1.72519E-07	1.49751E-02
10	1.36755E-03	-4.60664E-04	-1.46836E-08	7.09631E-07	4.66948E-07	4.05301E-02
11	1.37129E-03	-4.64308E-04	-2.36265E-15	2.97748E-16	2.27177E-15	4.05301E-02
12	1.36755E-03	-4.60664E-04	1.46836E-08	-7.09631E-07	-4.66948E-07	4.05301E-02
13	5.01883E-04	-2.40431E-01	-2.74993E-06	-7.09631E-07	-1.72519E-07	1.49751E-02
14	-5.01883E-04	-2.40431E-01	-2.74993E-06	-7.09631E-07	1.72519E-07	-1.49751E-02

MODE NUMBER 4
 EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.00000E+00	-9.90898E-05	-1.74994E-05	-6.07308E-08	-1.00204E-07	3.47164E-03
2	1.00000E+00	-9.90898E-05	-1.74994E-05	-6.07308E-08	1.00204E-07	-3.47164E-03
3	1.00000E+00	-9.90898E-05	1.74994E-05	6.07308E-08	-1.00204E-07	-3.47164E-03
4	-1.00000E+00	-9.90898E-05	1.74994E-05	6.07308E-08	1.00204E-07	3.47164E-03
5	-5.78864E-04	-1.94992E-04	6.21537E-09	-3.00376E-07	1.97652E-07	-1.71558E-02
6	-5.80445E-04	-1.96535E-04	6.43818E-15	4.51459E-17	9.31934E-16	-1.71558E-02
7	-5.78864E-04	-1.94992E-04	-6.21536E-09	3.00376E-07	-1.97652E-07	-1.71558E-02
8	-2.12440E-04	-1.01771E-01	1.16401E-06	3.00376E-07	-7.30249E-08	-6.33872E-03
9	2.12440E-04	-1.01771E-01	1.16401E-06	3.00376E-07	7.30249E-08	6.33872E-03
10	5.78864E-04	-1.94992E-04	-6.21537E-09	3.00376E-07	1.97652E-07	1.71558E-02
11	5.80445E-04	-1.96535E-04	-1.00008E-15	1.26032E-16	9.61608E-16	1.71558E-02
12	5.78864E-04	-1.94992E-04	6.21537E-09	-3.00376E-07	-1.97652E-07	1.71558E-02
13	2.12440E-04	-1.01771E-01	-1.16401E-06	-3.00376E-07	-7.30249E-08	6.33872E-03
14	-2.12440E-04	-1.01771E-01	-1.16401E-06	-3.00376E-07	7.30249E-08	-6.33872E-03
15	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.

TABLE 5-4E LOW FREQUENCY COFFEE TABLE CASE A (TIME HISTORY)

MODE SHAPE

MODE NUMBER 5
 FREQUENCY = 41.6264 HZ

EIGENVECTORS NORMALIZED TO A UNIT MASS MATRIX

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-4.67960E-05	6.98736E-05	2.36453E+00	5.84921E-03	-4.85179E-07	1.15822E-07
2	4.67960E-05	6.98736E-05	2.36453E+00	5.84921E-03	4.85179E-07	-1.15822E-07
3	4.67939E-05	6.98736E-05	-2.36453E+00	-5.84921E-03	-4.85179E-07	-1.15818E-07
4	-4.67938E-05	6.98736E-05	-2.36453E+00	-5.84921E-03	4.85179E-07	1.15818E-07
5	-3.06139E-08	1.37479E-04	-9.60379E-04	3.11645E-02	9.57016E-07	-6.16270E-07
6	-4.16331E-06	1.34714E-01	-8.36108E-13	-5.23628E-15	2.22221E-13	-6.16281E-07
7	-3.06172E-08	1.37479E-04	9.60379E-04	-3.11645E-02	-9.57016E-07	-6.16293E-07
8	-1.12370E-08	1.34466E-04	9.70496E-04	-3.11645E-02	-7.87350E-07	-1.65732E-07
9	1.12351E-08	1.34466E-04	9.70496E-04	-3.11645E-02	7.87350E-07	1.65732E-07
10	3.06153E-08	1.37479E-04	9.60379E-04	-3.11645E-02	9.57016E-07	6.16292E-07
11	4.16331E-06	1.34714E-01	-2.79403E-13	-2.69589E-14	4.40446E-14	6.16281E-07
12	3.06158E-08	1.37479E-04	-9.60379E-04	3.11645E-02	-9.57016E-07	6.16270E-07
13	1.12365E-08	1.34466E-04	-9.70496E-04	3.11645E-02	-7.87350E-07	1.65723E-07
14	-1.12346E-08	1.34466E-04	-9.70496E-04	3.11645E-02	7.87350E-07	-1.65724E-07

MODE NUMBER 5
 EIGENVECTORS NORMALIZED TO 1.000

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.97908E-05	2.95507E-05	1.00000E+00	2.47373E-03	-2.05190E-07	4.89829E-08
2	1.97908E-05	2.95507E-05	1.00000E+00	2.47373E-03	2.05190E-07	-4.89829E-08
3	1.97899E-05	2.95507E-05	-1.00000E+00	-2.47373E-03	-2.05190E-07	-4.89813E-08
4	-1.97899E-05	2.95507E-05	-1.00000E+00	-2.47373E-03	2.05190E-07	4.89813E-08
5	-1.29471E-08	5.81422E-05	-4.06160E-04	1.31800E-02	4.04738E-07	-2.60630E-07
6	-1.76073E-06	5.69729E-02	-3.53604E-13	-2.21451E-15	9.39807E-14	-2.60635E-07
7	-1.29485E-08	5.81422E-05	4.06160E-04	-1.31800E-02	-4.04737E-07	-2.60640E-07
8	-4.75232E-09	5.68679E-05	4.10438E-04	-1.31800E-02	-3.32983E-07	-7.00907E-08
9	4.75150E-09	5.68679E-05	4.10438E-04	-1.31800E-02	3.32983E-07	7.00907E-08
10	1.29477E-08	5.81422E-05	4.06160E-04	-1.31800E-02	4.04738E-07	2.60640E-07
11	1.76073E-06	5.69729E-02	1.18164E-13	1.14014E-14	1.86272E-14	2.60635E-07
12	1.29479E-08	5.81422E-05	-4.06160E-04	1.31800E-02	-4.04738E-07	2.60631E-07
13	4.75210E-09	5.68679E-05	-4.10438E-04	1.31800E-02	-3.32983E-07	7.00871E-08
14	-4.75128E-09	5.68679E-05	-4.10438E-04	1.31800E-02	3.32983E-07	-7.00872E-08
15	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.

TABLE 5-5. LOW-FREQUENCY-COEFF. TABLE CASE A (TIME HISTORY ANALYSIS)
DISPLACEMENT MAXIMA

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
1	1	5.0100E-02	2.5000E+00	NA
	2	1.0791E-04	2.5000E+00	NA
	3	9.3716E-08	2.5000E+00	NA
2	1	5.0100E-02	2.5000E+00	NA
	2	1.0791E-04	2.5000E+00	NA
	3	6.3506E-06	2.5000E+00	NA
3	1	5.0100E-02	2.5000E+00	NA
	2	1.0791E-04	2.5000E+00	NA
	3	9.3712E-08	2.5000E+00	NA
4	1	5.0100E-02	2.5000E+00	NA
	2	1.0791E-04	2.5000E+00	NA
	3	6.3503E-08	2.5000E+00	NA
5	1	1.0049E-01	2.5000E+00	NA
	2	2.1283E-04	2.5000E+00	NA
	3	4.6900E-08	2.5000E+00	NA
6	1	1.0050E-01	2.5000E+00	NA
	2	2.1286E-04	2.5000E+00	NA
	3	2.9944E-08	2.5000E+00	NA
7	1	1.0049E-01	2.5000E+00	NA
	2	2.1283E-04	2.5000E+00	NA
	3	1.0679E-07	2.5000E+00	NA
8	1	1.0049E-01	2.5000E+00	NA
	2	3.8795E-04	2.5000E+00	NA
	3	1.8674E-06	2.5000E+00	NA
9	1	1.0049E-01	2.5000E+00	NA
	2	3.8795E-04	2.5000E+00	NA
	3	1.9273E-06	2.5000E+00	NA
10	1	1.0049E-01	2.5000E+00	NA
	2	2.1283E-04	2.5000E+00	NA
	3	4.6908E-08	2.5000E+00	NA
11	1	1.0050E-01	2.5000E+00	NA
	2	2.1286E-04	2.5000E+00	NA
	3	2.9937E-08	2.5000E+00	NA
12	1	1.0049E-01	2.5000E+00	NA
	2	2.1283E-04	2.5000E+00	NA
	3	1.0670E-07	2.5000E+00	NA
13	1	1.0049E-01	2.5000E+00	NA
	2	3.8795E-04	2.5000E+00	NA
	3	1.8674E-06	2.5000E+00	NA
14	1	1.0049E-01	2.5000E+00	NA
	2	3.8795E-04	2.5000E+00	NA
	3	1.9273E-06	2.5000E+00	NA

TABLE 5-5. LOW-FREQUENCY COFFEE-TABLE CASE A (TIME-HISTORY ANALYSIS)
FORCE COMPONENT MAXIMA

ELEMENT TYPE NUMBER = 2

ELEMENT NUMBER	LOCATION	FORCE COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	6.4703E+01	2.5000E+00
		FY	6.3543E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	1.1377E+03	2.5000E+00
		MZ	2.4435E-03	2.5000E+00
1	END-J	FX	6.4703E+01	2.5000E+00
		FY	6.3543E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	7.3369E-04	2.5000E+00
2	END-I	FX	6.4689E+01	2.5000E+00
		FY	5.0947E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	7.3369E-04	2.5000E+00
2	END-J	FX	6.4689E+01	2.5000E+00
		FY	5.0947E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	8.9102E+02	2.5000E+00
		MZ	3.2110E-03	2.5000E+00
3	END-I	FX	2.6710E-01	2.5000E+00
		FY	2.8824E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	1.3095E-03	2.5000E+00
		MY	3.7765E+00	2.5000E+00
		MZ	6.2746E-03	2.5000E+00
3	END-J	FX	2.6710E-01	2.5000E+00
		FY	2.8824E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	1.3095E-03	2.5000E+00
		MY	7.6333E+00	2.5000E+00
		MZ	1.8586E-02	2.5000E+00

4	END-I	FX	2.6710E-01	2.5000E+00
		FY	2.8195E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	1.3104E-08	2.5000E+00
		MY	7.2333E+00	2.5000E+00
		MZ	1.8586E-02	2.5000E+00

4	END-J	FX	2.6710E-01	2.5000E+00
		FY	2.8195E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	1.3104E-08	2.5000E+00
		MY	3.7765E+00	2.5000E+00
		MZ	5.7321E-03	2.5000E+00

5	END-I	FX	6.4689E+01	2.5000E+00
		FY	4.0554E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	8.8102E+02	2.5000E+00
		MZ	2.6685E-03	2.5000E+00

5	END-J	FX	6.4689E+01	2.5000E+00
		FY	4.0554E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	6.9652E-04	2.5000E+00

6	END-I	FX	6.4703E+01	2.5000E+00
		FY	4.9015E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	6.9652E-04	2.5000E+00

6	END-J	FX	6.4703E+01	2.5000E+00
		FY	4.9015E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	1.1377E+03	2.5000E+00
		MZ	1.7542E-03	2.5000E+00

7	END-I	FX	6.4703E+01	2.5000E+00
		FY	4.9015E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	1.1377E+03	2.5000E+00
		MZ	1.7543E-03	2.5000E+00

7	END-J	FX	6.4703E+01	2.5000E+00
		FY	4.9017E+05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	6.9653E-04	2.5000E+00

8	END-I	FX	6.4689E+01	2.5000E+00
		FY	4.0555E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	6.9653E-04	2.5000E+00

8	END-J	FX	6.4689E+01	2.5000E+00
		FY	4.0555E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	8.8102E+02	2.5000E+00
		MZ	2.6685E-03	2.5000E+00

9	END-I	FX	2.6710E-01	2.5000E+00
		FY	2.8195E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	6.0287E-10	5.0000E+00
		MY	3.7765E+00	2.5000E+00
		MZ	5.7321E-03	2.5000E+00

9	END-J	FX	2.6710E-01	2.5000E+00
		FY	2.8195E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	6.0287E-10	5.0000E+00
		MY	7.8333E+00	2.5000E+00
		MZ	1.8586E-02	2.5000E+00

10	END-I	FX	2.6710E-01	2.5000E+00
		FY	2.8824E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	6.0297E-10	5.0000E+00
		MY	7.8333E+00	2.5000E+00
		MZ	1.8586E-02	2.5000E+00

10	END-J	FX	2.6710E-01	2.5000E+00
		FY	2.8824E-03	2.5000E+00
		FZ	1.3461E+00	2.5000E+00
		TX	6.0297E-10	5.0000E+00
		MY	3.7765E+00	2.5000E+00
		MZ	6.2745E-03	2.5000E+00

11	END-I	FX	6.4689E+01	2.5000E+00
		FY	5.0945E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	8.8102E+02	2.5000E+00
		MZ	3.2109E-03	2.5000E+00

11	END-J	FX	6.4689E+01	2.5000E+00
		FY	5.0945E-05	2.5000E+00
		FZ	1.7067E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	7.3368E-04	2.5000E+00

12	END-I	FX	6.4703E+01	2.5000E+00
		FY	6.3541E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	5.1160E+01	2.5000E+00
		MZ	7.3368E-04	2.5000E+00

12	END-J	FX	6.4703E+01	2.5000E+00
		FY	6.3541E-05	2.5000E+00
		FZ	2.3777E+01	2.5000E+00
		TX	1.3645E-01	2.5000E+00
		MY	1.1377E+03	2.5000E+00
		MZ	2.4434E-03	2.5000E+00

13	END-I	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	3.6400E+00	2.5000E+00
		MZ	8.8102E+02	2.5000E+00

13	END-J	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3359E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

14	END-I	FX	4.2383E-07	2.5000E+00
		FY	6.4669E+01	2.5000E+00
		FZ	2.6719E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3359E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

14	END-J	FX	4.2383E-07	2.5000E+00
		FY	6.4669E+01	2.5000E+00
		FZ	2.6719E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3360E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

15	END-I	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3360E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

15	END-J	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	3.6400E+00	2.5000E+00
		MZ	6.8102E+02	2.5000E+00

16	END-I	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	3.6400E+00	2.5000E+00
		MZ	6.8102E+02	2.5000E+00

16	END-J	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3359E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

17	END-I	FX	4.3787E-07	2.5000E+00
		FY	6.4669E+01	2.5000E+00
		FZ	2.6719E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3359E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

17	END-J	FX	4.3787E-07	2.5000E+00
		FY	6.4669E+01	2.5000E+00
		FZ	2.6719E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3360E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

18	END-I	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.3360E+00	2.5000E+00
		MZ	3.2334E+02	2.5000E+00

18	END-J	FX	2.6919E+00	2.5000E+00
		FY	6.4658E+01	2.5000E+00
		FZ	2.6714E-01	2.5000E+00
		TX	3.0636E-03	2.5000E+00
		MY	1.6400E+00	2.5000E+00
		MZ	8.8102E+02	2.5000E+00

TABLE 5-7. LOW-FREQUENCY COEFFICIENT TABLE CASE A (TIME HISTORY ANALYSIS)
STRESS COMPONENT MAXIMA

ELEMENT NUMBER	LOCATION	LONGITUDINAL STRESS	CIRCUMFERENTIAL STRESS	SHEAR STRESS
1	END-I	2089.50	0.00	22.25
	END-J	151.47	0.00	22.25
2	END-I	151.46	0.00	16.00
	END-J	1631.69	0.00	16.00
3	END-I	6.98	0.00	1.25
	END-J	14.22	0.00	1.25
4	END-I	14.22	0.00	1.25
	END-J	6.98	0.00	1.25
5	END-I	1631.69	0.00	16.00
	END-J	151.46	0.00	16.00
6	END-I	151.47	0.00	22.25
	END-J	2089.50	0.00	22.25
7	END-I	2089.50	0.00	22.25
	END-J	151.47	0.00	22.25
8	END-I	151.46	0.00	16.00
	END-J	1631.69	0.00	16.00
9	END-I	6.98	0.00	1.25
	END-J	14.22	0.00	1.25
10	END-I	14.22	0.00	1.25
	END-J	6.98	0.00	1.25
11	END-I	1631.69	0.00	16.00
	END-J	151.46	0.00	16.00
12	END-I	151.47	0.00	22.25
	END-J	2089.50	0.00	22.25

13	END-I	1574.01	0.00	60.18
	END-J	579.26	0.00	60.18

14	END-I	576.76	0.00	60.19
	END-J	576.76	0.00	60.19

15	END-I	579.26	0.00	60.18
	END-J	1574.01	0.00	60.18

16	END-I	1574.01	0.00	60.18
	END-J	579.26	0.00	60.18

17	END-I	576.76	0.00	60.19
	END-J	576.76	0.00	60.19

18	END-I	579.26	0.00	60.18
	END-J	1574.01	0.00	60.18

TABLE 5-8 LOW FREQUENCY CCFEE TABLE CASE B (RESPONSE SPECTRUM)

MODAL PARTICIPATION FACTORS AND EARTHQUAKE RESPONSE

DIRECTION FACTORS

X = 1.0000 Y = -0.0000 Z = -0.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT
EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	.6066E+00	.4814E-16	.2194E-06
2	.3749E-07	-.9541E-17	-.6074E+00
3	-.3236E-10	.4532E-16	.6087E-11
4	-.1251E-13	-.8728E-02	.2261E-14
5	.2258E-14	.2450E-02	.9110E-13

SPECTRUM TABLE (IMPERIAL VALLEY E.Q. ELCENTRO 1940 SE)

NUMBER OF POINTS = 11
SCALE FACTOR = .10000E+01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	.1498E-02	.1450E+03
2	.2860E-01	.3800E+03
3	.5800E-01	.7750E+03
4	.7100E-01	.7750E+03
5	.9100E-01	.4400E+03
6	.1140E+00	.1180E+04
7	.1410E+00	.1180E+04
8	.1720E+00	.7000E+03
9	.2000E+00	.8710E+03
10	.2500E+00	.8710E+03
11	.3230E+00	.4000E+03

TABLE 5-9A LOW FREQUENCY COFFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 1
 FREQUENCY = 8.71197 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	2.30250E-01	4.95951E-04	4.45276E-07	1.09995E-08	2.19456E-06	-6.72092E-03
2	2.30250E-01	-4.95950E-04	-2.77289E-07	-6.11985E-09	2.19456E-06	-6.72092E-03
3	2.30250E-01	-4.95951E-04	4.45264E-07	1.09991E-08	-2.19456E-06	-6.72092E-03
4	2.30250E-01	4.95950E-04	-2.77276E-07	-6.11950E-09	-2.19456E-06	-6.72092E-03
5	4.61834E-01	9.78154E-04	-1.86664E-07	1.37570E-08	-4.32878E-06	-1.11324E-03
6	4.61880E-01	9.78270E-04	1.66503E-07	-1.97518E-11	1.99957E-12	-1.11324E-03
7	4.61834E-01	9.78156E-04	5.19669E-07	-1.30961E-08	4.32877E-06	-1.11324E-03
8	4.61838E-01	-1.78298E-03	-8.55351E-06	-4.59675E-09	-9.80783E-07	1.71867E-04
9	4.61838E-01	1.78298E-03	8.88661E-06	5.25760E-09	-9.80773E-07	1.71867E-04
10	4.61834E-01	-9.78154E-04	-1.86608E-07	1.37570E-08	4.32878E-06	-1.11324E-03
11	4.61880E-01	-9.78270E-04	1.66479E-07	-1.97463E-11	-1.67875E-13	-1.11324E-03
12	4.61834E-01	9.78156E-04	5.19645E-07	-1.30962E-08	-4.32877E-06	-1.11324E-03
13	4.61838E-01	1.78298E-03	-8.55352E-06	-4.59677E-09	9.80785E-07	1.71867E-04
14	4.61838E-01	-1.78298E-03	8.88662E-06	5.25761E-09	9.80775E-07	1.71867E-04

RESPONSE FOR MODE 2
 FREQUENCY = 8.80624 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.43256E-13	-4.82816E-11	-1.38947E-08	-4.03607E-10	3.20358E-13	3.61769E-15
2	1.44956E-13	-4.82816E-11	-1.38947E-08	-4.03607E-10	-3.20358E-13	-3.66732E-15
3	-1.43255E-13	4.82816E-11	-1.38947E-08	-4.03607E-10	-3.20358E-13	3.61768E-15
4	1.44956E-13	4.82816E-11	-1.38947E-08	-4.03607E-10	3.20358E-13	-3.66733E-15
5	1.85709E-13	9.52247E-11	-2.75418E-08	-5.46601E-11	6.31906E-13	3.58057E-15
6	1.70586E-15	3.61303E-18	-2.75420E-08	3.26700E-12	-1.78939E-13	-4.11153E-18
7	-1.82297E-13	-9.52247E-11	-2.75418E-08	-5.46601E-11	6.31906E-13	-3.58879E-15
8	-6.58188E-14	-9.52655E-11	-2.75513E-08	-5.46601E-11	7.86043E-13	-3.23096E-15
9	6.92294E-14	9.52655E-11	-2.75513E-08	-5.46601E-11	-7.86043E-13	3.23223E-15
10	1.85709E-13	-9.52247E-11	-2.75418E-08	-5.46601E-11	-6.31906E-13	3.58057E-15
11	1.70586E-15	-3.61306E-18	-2.75420E-08	3.26700E-12	1.78939E-13	-4.11153E-18
12	-1.82297E-13	9.52247E-11	-2.75418E-08	-5.46601E-11	-6.31906E-13	-3.58879E-15
13	-6.58188E-14	9.52655E-11	-2.75513E-08	-5.46601E-11	-7.86043E-13	-3.23096E-15
14	6.92302E-14	9.52655E-11	-2.75513E-08	-5.46601E-11	7.86043E-13	3.23223E-15

TABLE 5-9B LOW FREQUENCY COFFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 3
 FREQUENCY = 17.5079 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.23072E-12	2.34595E-15	1.97950E-12	5.03121E-14	1.23164E-13	3.12733E-14
2	-1.23072E-12	-2.34595E-15	-1.97950E-12	-5.03121E-14	1.23164E-13	3.12733E-14
3	1.23072E-12	2.34595E-15	-1.97950E-12	-5.03121E-14	1.23164E-13	-3.12733E-14
4	1.23072E-12	-2.34595E-15	1.97950E-12	5.03121E-14	1.23164E-13	-3.12733E-14
5	2.11113E-12	-4.62532E-15	3.39779E-12	3.78516E-15	2.42942E-13	-2.29603E-15
6	-2.00471E-22	-3.02886E-25	3.39784E-12	-5.29392E-16	2.45367E-13	3.44297E-25
7	-2.11113E-12	4.62532E-15	3.39779E-12	3.78516E-15	2.42942E-13	2.29603E-15
8	-2.11119E-12	7.11900E-15	1.26040E-12	1.38905E-15	2.50896E-13	-9.56130E-16
9	-2.11119E-12	-7.11900E-15	-1.26040E-12	-1.38905E-15	2.50896E-13	-9.56130E-16
10	-2.11113E-12	-4.62532E-15	-3.39779E-12	-3.78516E-15	2.42942E-13	2.29603E-15
11	-2.00661E-22	3.02540E-25	-3.39784E-12	5.29392E-16	2.45367E-13	3.44399E-25
12	2.11113E-12	4.62532E-15	-3.39779E-12	-3.78516E-15	2.42942E-13	-2.29603E-15
13	2.11119E-12	7.11900E-15	-1.26040E-12	-1.38905E-15	2.50896E-13	9.56130E-16
14	2.11119E-12	-7.11900E-15	1.26040E-12	1.38905E-15	2.50896E-13	9.56130E-16

RESPONSE FOR MODE 4
 FREQUENCY = 40.3668 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-1.71970E-16	-1.70405E-20	-3.00938E-21	-1.04439E-23	-1.72321E-23	5.97019E-19
2	1.71970E-16	-1.70405E-20	-3.00938E-21	-1.04439E-23	1.72321E-23	-5.97019E-19
3	1.71970E-16	-1.70405E-20	3.00938E-21	1.04439E-23	-1.72321E-23	-5.97019E-19
4	-1.71970E-16	-1.70405E-20	3.00938E-21	1.04439E-23	1.72321E-23	5.97019E-19
5	-9.95472E-20	-3.35329E-20	1.06886E-24	-5.16558E-23	3.39903E-23	-2.95029E-18
6	-9.98192E-20	-3.37981E-20	1.10718E-30	7.76375E-33	1.60265E-31	-2.95029E-18
7	-9.95472E-20	-3.35329E-20	-1.06886E-24	5.16558E-23	-3.39903E-23	-2.95029E-18
8	-3.65333E-20	-1.75016E-17	2.00174E-22	5.16558E-23	-1.25581E-23	-1.09007E-18
9	3.65333E-20	-1.75016E-17	2.00174E-22	5.16558E-23	1.25581E-23	1.09007E-18
10	-9.95472E-20	-3.35329E-20	-1.06886E-24	5.16558E-23	3.39903E-23	2.95029E-18
11	9.98192E-20	-3.37981E-20	-1.17198E-31	7.16738E-32	1.65368E-31	2.95029E-18
12	9.95472E-20	-3.35329E-20	1.06886E-24	-5.16558E-23	-3.39903E-23	2.95029E-18
13	3.65333E-20	-1.75016E-17	-2.00174E-22	-5.16558E-23	-1.25581E-23	1.09007E-18
14	-3.65333E-20	-1.75016E-17	-2.00174E-22	-5.16558E-23	1.25581E-23	-1.09007E-18

TABLE 5-9C LOW FREQUENCY COEFFE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM DISPLACEMENT COMPONENTS

RESPONSE FOR MODE 5
 FREQUENCY = 41.6264 Hz

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	-5.25204E-22	7.84211E-22	2.65378E-17	6.56473E-20	-5.44530E-24	1.29990E-24
2	5.25204E-22	7.84211E-22	2.65378E-17	6.56473E-20	5.44530E-24	-1.29990E-24
3	5.25180E-22	7.84211E-22	-2.65378E-17	-6.56473E-20	-5.44530E-24	-1.29986E-24
4	-5.25180E-22	7.84211E-22	-2.65378E-17	-6.56473E-20	5.44530E-24	1.29986E-24
5	-3.43588E-25	1.54297E-21	-1.07786E-20	3.49767E-19	1.07409E-23	-6.91656E-24
6	-4.67260E-23	1.51194E-18	-9.38387E-30	-5.87682E-32	2.49404E-30	-6.91669E-24
7	-3.43626E-25	1.54297E-21	1.07786E-20	-3.49767E-19	-1.07409E-23	-6.91682E-24
8	-1.26116E-25	1.50915E-21	1.08921E-20	-3.49767E-19	-8.83664E-24	-1.86005E-24
9	1.26094E-25	1.50915E-21	1.08921E-20	-3.49767E-19	8.83664E-24	1.86005E-24
10	3.43604E-25	1.54297E-21	1.07786E-20	-3.49767E-19	1.07409E-23	6.91682E-24
11	4.67260E-23	1.51194E-18	3.13581E-30	-3.02567E-31	4.94324E-31	6.91669E-24
12	3.43610E-25	1.54297E-21	-1.07786E-20	3.49767E-19	-1.07409E-23	6.91657E-24
13	1.26110E-25	1.50915E-21	-1.08921E-20	3.49767E-19	-8.83664E-24	1.85996E-24
14	-1.26088E-25	1.50915E-21	-1.08921E-20	3.49767E-19	8.83664E-24	-1.85996E-24

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE NODAL DEFLECTIONS

DISPLACEMENTS/ROTATIONS OF UNRESTRAINED NODES

NODE NUMBER	X- TRANSLATION	Y- TRANSLATION	Z- TRANSLATION	X- ROTATION	Y- ROTATION	Z- ROTATION
1	2.30250E-01	4.95951E-04	4.45493E-07	1.10069E-08	2.19456E-06	6.72092E-03
2	2.30250E-01	4.95950E-04	2.77637E-07	6.13315E-09	2.19456E-06	6.72092E-03
3	2.30250E-01	4.95951E-04	4.45480E-07	1.10065E-08	2.19456E-06	6.72092E-03
4	2.30250E-01	4.95950E-04	2.77624E-07	6.13280E-09	2.19456E-06	6.72092E-03
5	4.61834E-01	9.78154E-04	1.88685E-07	1.37571E-08	4.32878E-06	1.11324E-03
6	4.61880E-01	9.78270E-04	1.68766E-07	2.00201E-11	2.02250E-12	1.11324E-03
7	4.61834E-01	9.78156E-04	5.20398E-07	1.30962E-08	4.32877E-06	1.11324E-03
8	4.61838E-01	1.78298E-03	8.55356E-06	4.59708E-09	9.80783E-07	1.71867E-04
9	4.61839E-01	1.78298E-03	8.88665E-06	5.25788E-09	9.80773E-07	1.71867E-04
10	4.61834E-01	9.78154E-04	1.88709E-07	1.37571E-08	4.32878E-06	1.11324E-03
11	4.61880E-01	9.78270E-04	1.68742E-07	2.00148E-11	3.46596E-13	1.11324E-03
12	4.61834E-01	9.78156E-04	5.20374E-07	1.30963E-08	4.32877E-06	1.11324E-03
13	4.61838E-01	1.78298E-03	8.55357E-06	4.59709E-09	9.80785E-07	1.71867E-04
14	4.61838E-01	1.78298E-03	8.88666E-06	5.25789E-09	9.80775E-07	1.71867E-04

TABLE 5-9D LOW FREQUENCY CCFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM FORCE COMPONENTS

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE MODAL FORCES
(FOR ALL ELEMENTS)

PX = X-AXIAL FORCE
VY = Y-SHEAR FORCE
VZ = Z-SHEAR FORCE

TX = X-TWISTING MOMENT
MY = Y-BENDING MOMENT
MZ = Z-BENDING MOMENT

I = INITIAL NODE

C = CENTER NODE (FOR PIPE HEAD ONLY)

J = FINAL NODE

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (1)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2974E+03	.2991E-03	.1093E+03	.6271E+00	.5229E+04	.1157E-01	.2974E+03	.2991E-03	.1093E+03	.6271E+00	.2351E+03	.3390E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (2)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2973E+03	.2392E-03	.7844E+02	.6271E+00	.2351E+03	.3390E-02	.2973E+03	.2392E-03	.7844E+02	.6271E+00	.4049E+04	.1502E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (3)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1228E+01	.1328E-01	.6186E+01	.5645E-07	.1736E+02	.2910E-01	.1228E+01	.1328E-01	.6186E+01	.5645E-07	.3600E+02	.8542E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (4)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1228E+01	.1293E-01	.6186E+01	.5645E-07	.3600E+02	.8542E-01	.1228E+01	.1293E-01	.6186E+01	.5645E-07	.1736E+02	.2608E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (5)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2973E+03	.1814E-03	.7844E+02	.6271E+00	.4049E+04	.1200E-01	.2973E+03	.1814E-03	.7844E+02	.6271E+00	.2351E+03	.3183E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (6)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2974E+03	.2184E-03	.1093E+03	.6271E+00	.2351E+03	.3183E-02	.2974E+03	.2184E-03	.1093E+03	.6271E+00	.5229E+04	.7736E-02

TABLE 5-9E LOW FREQUENCY COFFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM FORCE COMPONENTS

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (7)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2974E+03	.2184E-03	.1093E+03	.6271E+00	.5229E+04	.7737E-02	.2974E+03	.2184E-03	.1093E+03	.6271E+00	.2351E+03	.3183E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (8)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2973E+03	.1814E-03	.7844E+02	.6271E+00	.2351E+03	.3183E-02	.2973E+03	.1814E-03	.7844E+02	.6271E+00	.4049E+04	.1200E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (9)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1228E+01	.1293E-01	.6186E+01	.1734E-07	.1736E+02	.2608E-01	.1228E+01	.1293E-01	.6186E+01	.1734E-07	.3600E+02	.8542E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (10)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1228E+01	.1328E-01	.6186E+01	.1736E-07	.3600E+02	.8542E-01	.1228E+01	.1328E-01	.6186E+01	.1736E-07	.1736E+02	.2910E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (11)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2973E+03	.2392E-03	.7844E+02	.6271E+00	.4049E+04	.1502E-01	.2973E+03	.2392E-03	.7844E+02	.6271E+00	.2351E+03	.3390E-02

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (12)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2974E+03	.2991E-03	.1093E+03	.6271E+00	.2351E+03	.3390E-02	.2974E+03	.2991E-03	.1093E+03	.6271E+00	.5229E+04	.1157E-01

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (13)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1237E+02	.2972E+03	.1228E+01	.1408E-01	.1673E+02	.4049E+04	.1237E+02	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04

TABLE 5-9F LOW FREQUENCY COFFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM FCRCE COMPONENTS

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (14)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2411E-05	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04	.2411E-05	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (15)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1237E+02	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04	.1237E+02	.2972E+03	.1228E+01	.1408E-01	.1673E+02	.4049E+04

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (16)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1237E+02	.2972E+03	.1228E+01	.1408E-01	.1673E+02	.4049E+04	.1237E+02	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (17)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.2455E-05	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04	.2455E-05	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (18)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1237E+02	.2972E+03	.1228E+01	.1408E-01	.6140E+01	.1486E+04	.1237E+02	.2972E+03	.1228E+01	.1408E-01	.1673E+02	.4049E+04

TABLE 5-10 LOW FREQUENCY COFFEE TABLE CASE B (RESPONSE SPECTRUM)

RESPONSE SPECTRUM STRESS COMPONENTS

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LONGITUDINAL STRESS	CIRCUMFERENCE STRESS	SHEAR STRESS
1	TANGENT	1	END-I	9603.027	0.000	102.254
			END-J	696.134	0.000	102.254
2	TANGENT	1	END-I	696.073	0.000	73.554
			END-J	7499.001	0.000	73.554
3	TANGENT	1	END-I	32.101	0.000	5.757
			END-J	65.357	0.000	5.757
4	TANGENT	1	END-I	65.357	0.000	5.757
			END-J	32.101	0.000	5.757
5	TANGENT	1	END-I	7499.001	0.000	73.554
			END-J	696.072	0.000	73.554
6	TANGENT	1	END-I	696.134	0.000	102.254
			END-J	9603.027	0.000	102.254
7	TANGENT	1	END-I	9603.027	0.000	102.254
			END-J	696.134	0.000	102.254
8	TANGENT	1	END-I	696.072	0.000	73.554
			END-J	7499.001	0.000	73.554
9	TANGENT	1	END-I	32.101	0.000	5.757
			END-J	65.357	0.000	5.757
10	TANGENT	1	END-I	65.357	0.000	5.757
			END-J	32.101	0.000	5.757
11	TANGENT	1	END-I	7499.001	0.000	73.554
			END-J	696.073	0.000	73.554
12	TANGENT	1	END-I	696.134	0.000	102.254
			END-J	9603.027	0.000	102.254
13	TANGENT	1	END-I	7233.897	0.000	276.563
			END-J	2662.199	0.000	276.563
14	TANGENT	1	END-I	2650.686	0.000	276.608
			END-J	2650.686	0.000	276.608
15	TANGENT	1	END-I	2662.199	0.000	276.563
			END-J	7233.897	0.000	276.563
16	TANGENT	1	END-I	7233.897	0.000	276.563
			END-J	2662.199	0.000	276.563
17	TANGENT	1	END-I	2650.686	0.000	276.608
			END-J	2650.686	0.000	276.608

TABLE 5-11 LOW FREQUENCY COFFEE TABLE CASE (STEP-BY-STEP INTEGRATION)
DISPLACEMENT MAXIMA

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM VALUE	TIME AT MAXIMUM	PLOT SYMBOL
1	1	4.9985E-02	2.5000E+00	NA
	2	1.0853E-04	2.5000E+00	NA
	3	7.8501E-08	2.5000E+00	NA
2	1	4.9985E-02	2.5000E+00	NA
	2	1.0853E-04	2.5000E+00	NA
	3	7.8501E-08	2.5000E+00	NA
3	1	4.9985E-02	2.5000E+00	NA
	2	1.0853E-04	2.5000E+00	NA
	3	7.8506E-08	2.5000E+00	NA
4	1	4.9985E-02	2.5000E+00	NA
	2	1.0853E-04	2.5000E+00	NA
	3	7.8506E-08	2.5000E+00	NA
5	1	1.0054E-01	2.5000E+00	NA
	2	2.1405E-04	2.5000E+00	NA
	3	7.7840E-08	2.5000E+00	NA
6	1	1.0055E-01	2.5000E+00	NA
	2	2.1408E-04	2.5000E+00	NA
	3	4.9954E-12	2.5000E+00	NA
7	1	1.0054E-01	2.5000E+00	NA
	2	2.1405E-04	2.5000E+00	NA
	3	7.7830E-08	2.5000E+00	NA
8	1	1.0054E-01	2.5000E+00	NA
	2	3.9016E-04	2.5000E+00	NA
	3	1.9219E-06	2.5000E+00	NA
9	1	1.0054E-01	2.5000E+00	NA
	2	3.9016E-04	2.5000E+00	NA
	3	1.9219E-06	2.5000E+00	NA
10	1	1.0054E-01	2.5000E+00	NA
	2	2.1405E-04	2.5000E+00	NA
	3	7.7830E-08	2.5000E+00	NA
11	1	1.0055E-01	2.5000E+00	NA
	2	2.1408E-04	2.5000E+00	NA
	3	5.1728E-12	2.5000E+00	NA
12	1	1.0054E-01	2.5000E+00	NA
	2	2.1405E-04	2.5000E+00	NA
	3	7.7841E-08	2.5000E+00	NA
13	1	1.0054E-01	2.5000E+00	NA
	2	3.9016E-04	2.5000E+00	NA
	3	1.9219E-06	2.5000E+00	NA
14	1	1.0054E-01	2.5000E+00	NA
	2	3.9016E-04	2.5000E+00	NA
	3	1.9219E-06	2.5000E+00	NA

TABLE 5-12 LOW FREQUENCY COFFEE TABLE CASE C (STEP-BY-STEP INTEGRATION)
FORCE COMPONENT MAXIMA

ELEMENT TYPE NUMBER = 2

ELEMENT NUMBER	LOCATION COMPONENT	FORCE	MAXIMUM VALUE	TIME AT MAXIMUM
1	END-I	FX	6.5074E+01	2.5000E+00
		FY	5.5248E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	1.1323E+03	2.5000E+00
		MZ	2.0497E-03	2.5000E+00
1	END-J	FX	6.5074E+01	2.5000E+00
		FY	5.5248E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00
2	END-I	FX	6.5058E+01	2.5000E+00
		FY	5.3474E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00
2	END-J	FX	6.5058E+01	2.5000E+00
		FY	5.3474E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	8.8603E+02	2.5000E+00
		MZ	3.2207E-03	2.5000E+00
3	END-I	FX	2.7055E-01	2.5000E+00
		FY	3.0510E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.8021E-09	2.5000E+00
		MY	3.8253E+00	2.5000E+00
		MZ	6.4759E-03	2.5000E+00

3	END-J	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.8021E-09	2.5000E+00
		MY	7.9345E+00	2.5000E+00
		MZ	1.9846E-02	2.5000E+00

4	END-I	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.8003E-09	2.5000E+00
		MY	7.9345E+00	2.5000E+00
		MZ	1.9846E-02	2.5000E+00

4	END-J	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.8003E-09	2.5000E+00
		MY	3.8253E+00	2.5000E+00
		MZ	6.4760E-03	2.5000E+00

5	END-I	FX	6.5058E+01	2.5000E+00
		FY	5.3476E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	8.8603E+02	2.5000E+00
		MZ	3.2208E-03	2.5000E+00

5	END-J	FX	6.5058E+01	2.5000E+00
		FY	5.3476E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00

6	END-I	FX	6.5074E+01	2.5000E+00
		FY	5.5250E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00

6	END-J	FX	6.5074E+01	2.5000E+00
		FY	5.5250E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	1.1323E+03	2.5000E+00
		MZ	2.0490E-03	2.5000E+00

7	END-I	FX	6.5074E+01	2.5000E+00
		FY	5.5248E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	1.1323E+03	2.5000E+00
		HZ	2.0497E-03	2.5000E+00

7	END-J	FX	6.5074E+01	2.5000E+00
		FY	5.5248E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		HZ	9.0951E-04	3.5000E+00

8	END-I	FX	6.5058E+01	2.5000E+00
		FY	5.3474E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		HZ	9.0951E-04	3.5000E+00

8	END-J	FX	6.5058E+01	2.5000E+00
		FY	5.3474E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	8.8603E+02	2.5000E+00
		HZ	3.2207E-03	2.5000E+00

9	END-I	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.7839E-09	2.5000E+00
		MY	3.8253E+00	2.5000E+00
		HZ	6.4759E-03	2.5000E+00

9	END-J	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.7839E-09	2.5000E+00
		MY	7.9345E+00	2.5000E+00
		HZ	1.9846E-02	2.5000E+00

10	END-I	FX	2.7055E-01	2.5000E+00
		FY	3.0518E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.7712E-09	2.5000E+00
		MY	7.9345E+00	2.5000E+00
		HZ	1.9846E-02	2.5000E+00

10	END-J	FX	2.7055E-01	2.5000E+00
		FY	3.0510E-03	2.5000E+00
		FZ	1.3634E+00	2.5000E+00
		TX	8.7712E-09	2.5000E+00
		MY	3.8253E+00	2.5000E+00
		MZ	6.4760E-03	2.5000E+00

11	END-I	FX	6.5058E+01	2.5000E+00
		FY	5.3476E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	8.8603E+02	2.5000E+00
		MZ	3.2208E-03	2.5000E+00

11	END-J	FX	6.5058E+01	2.5000E+00
		FY	5.3476E-05	2.5000E+00
		FZ	1.7287E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00

12	END-I	FX	6.5074E+01	2.5000E+00
		FY	5.5250E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	4.8981E+01	4.9000E+00
		MZ	9.0951E-04	3.5000E+00

12	END-J	FX	6.5074E+01	2.5000E+00
		FY	5.5250E-05	3.5000E+00
		FZ	2.3555E+01	2.5000E+00
		TX	1.3822E-01	2.5000E+00
		MY	1.1323E+03	2.5000E+00
		MZ	2.0498E-03	2.5000E+00

13	END-I	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	3.6870E+00	2.5000E+00
		MZ	8.8603E+02	2.5000E+00

13	END-J	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.1532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

14	END-I	FX	1.0245E-08	2.7000E+00
		FY	6.5037E+01	2.5000E+00
		FZ	2.7064E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

14	END-J	FX	1.0245E-08	2.7000E+00
		FY	6.5037E+01	2.5000E+00
		FZ	2.7064E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

15	END-I	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

15	END-J	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	3.6870E+00	2.5000E+00
		MZ	8.8603E+02	2.5000E+00

16	END-I	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	3.6870E+00	2.5000E+00
		MZ	8.8603E+02	2.5000E+00

16	END-J	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

17	END-I	FX	5.5879E-09	2.5000E+00
		FY	6.5037E+01	2.5000E+00
		FZ	2.7064E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

17	END-J	FX	5.5879E-09	2.5000E+00
		FY	6.5037E+01	2.5000E+00
		FZ	2.7064E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

18	END-I	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	1.3532E+00	2.5000E+00
		MZ	3.2519E+02	2.5000E+00

18	END-J	FX	2.7266E+00	2.5000E+00
		FY	6.5026E+01	2.5000E+00
		FZ	2.7059E-01	2.5000E+00
		TX	3.2552E-03	2.5000E+00
		MY	3.6870E+00	2.5000E+00
		MZ	8.8603E+02	2.5000E+00

TABLE 5-13 LOW FREQUENCY COFFEE TABLE CASE C (STEP-BY-STEP INTEGRATION)
S T R E S S C O M P O N E N T M A X I M A

1	END-I	2080.27	0.00	22.04
	END-J	147.93	0.00	22.04
2	END-I	147.91	0.00	16.21
	END-J	1640.97	0.00	16.21
3	END-I	7.07	0.00	1.27
	END-J	14.40	0.00	1.27
4	END-I	14.40	0.00	1.27
	END-J	7.07	0.00	1.27
5	END-I	1640.97	0.00	16.21
	END-J	147.91	0.00	16.21
6	END-I	147.93	0.00	22.04
	END-J	2080.27	0.00	22.04
7	END-I	2080.27	0.00	22.04
	END-J	147.93	0.00	22.04
8	END-I	147.91	0.00	16.21
	END-J	1640.97	0.00	16.21
9	END-I	7.07	0.00	1.27
	END-J	14.40	0.00	1.27
10	END-I	14.40	0.00	1.27
	END-J	7.07	0.00	1.27
11	END-I	1640.97	0.00	16.21
	END-J	147.91	0.00	16.21
12	END-I	147.93	0.00	22.04
	END-J	2080.27	0.00	22.04
13	END-I	1582.98	0.00	60.52
	END-J	582.53	0.00	60.52
14	END-I	582.04	0.00	60.53
	END-J	1582.04	0.00	60.53

15	END-I	582.54	0.00	60.52
	END-J	1582.98	0.00	60.52
16	END-I	1582.98	0.00	60.52
	END-J	582.54	0.00	60.52
17	END-I	580.04	0.00	60.53
	END-J	580.04	0.00	60.53
18	END-I	582.58	0.00	60.52
	END-J	1582.98	0.00	60.52

References

1. Reich, M., Esztergar, E.P., Spence, J., Boyle, J., Chang, T.Y., "Elastic and Inelastic Methods of Piping Systems Analysis: A Preliminary Review" Brookhaven National Laboratory, Upton, New York 11973, BNL-19768, February, 1975
2. Pressure Vessel and Piping - 1972 Computer Programs Verification, Ed. by Tuba, I.S. and Wright, W.B., The American Society of Mechanical Engineers, New York, (1972).
3. "EPIPE - An Elastic Piping Program for Static and Dynamic Analyses" - A BNL report in publication.
4. Bathe, K.J., Wilson, E.L., and Peterson, F.E., "SAP IV - A Structural Analysis Program for Static and Dynamic Responses of Linear Systems," Report No. EERC 73-11, University of California, Berkeley, California, (1973).
5. ASME Boiler and Pressure Vessel Code, Section III-1971, Nuclear Power Plant Components, American Society of Mechanical Engineers, New York, (July 1, 1971).
6. Martin, H.C., Introduction to Matrix Methods of Structural Analysis, McGraw-Hill, New York, (1966).
7. Poley, S., "Mesh Analysis of Piping Systems," IBM New York Scientific Center Technical Report No. 320-2939, (March 1968).
8. Rodabough, E.C. and George, H.H., "Effect of Internal Pressure on Flexibility and Stress Intensification Factors of Curved Pipe or Welding Elbows," Trans. ASME, Vol. 79, (1957).
9. Cal Tech Report.
10. Clough, W.R., "Earthquake Response of Structures," Earthquake Engineering, Ed. by Wiegel, R.L., Prentice-Hall, New Jersey, (1970).
11. Spence, J., "Private Communication," (November, 1975).

12. Hovgaard, W., "Stresses in Three Dimensional Pipe Bends," Trans. ASME, Vol. 57, FSP-57-12, P401-476, (1935).
13. Hovgaard, N., "Further Studies of Three Dimensional Pipe Bends," Trans. ASME, FSP-50-13, Vol. 59, p. 647-650, (1937).
14. PIPDYN II - A Computer Program for the Complete Analysis and Evaluation of Piping Systems by Zudans, Z., et. al., Applied Mechanics Lab., The Franklin Institute Research Lab., Philadelphia, PA.
15. Crede, C.E., "Shock and Vibration Concepts in Engineering Design," Englewood Cliffs, NJ, Prentice-Hall (1965).
16. Swanson, J., "A Problem on Dynamic Analysis of Three Dimensional Structure," Pressure Vessel and Piping, 1972 Computer Program Verification, Ed. by Tuba, I.S. and Wright, W.B., American Society of Mechanical Engineers, New York, (1972).
17. Tuba, I. S. and Wright, W. B., "Pressure Vessel and Piping, 1972 Computer Programs Verification," ASME Pressure Vessel and Piping Division, New York (1972).
18. Bezler, P., Gardner, D, and Hartzman, M., "A Benchmark Solution for a Hypothetical Reactor System," BNL-NUREG 23645, July, 1977.