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DEPARTMENT of APPLIED SCIENCE

Development of Solutions to

Benchmark Piping Problems

M. Reich, T.Y. Chang, S. Prachuktam

January, 1976

BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

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Development of Solutions to Benchmark Piping Problems

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January 1976

Structural Analysis Group
for the
Materials Engineering Branch, Division of Technical Review,
Nuclear Regulatory Commission

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I. Introduction

Piping analysis is one of the most extensive engineering efforts required for the design of nuclear reactors. Such analysis is normally carried out by use of computer programs which can handle complex piping geometries and various loading conditions, (static or dynamic).

There are many computer programs, some of which are available free or at a nominal fee, and others that are either commercially available or the proprietary property of individual companies engaged in the analysis of piping systems. While it is generally recognized that the theoretical basis for elastic piping analysis is well founded,[1] there can still be deviations when comparing answers obtained from different computer codes. These can be due either to limitations on applicability of particular programs, or even unintentional coding errors introduced into the various thousands of statements and commands comprising the typical piping code. Such deviations, can be determined by appropriate benchmark solutions. In this connection, several relatively simple benchmark problems have been published for computer program verifications.[2]

The objective of this report is to first verify EPIPE, an existing piping program at Brookhaven National Laboratories (BNL) and at the same time generate solutions for benchmark problems, that are more complex than those published in (2) with regards

to loading conditions and piping system geometrices, etc. Solutions can then be used as an effective tool for piping program verifications.

This report contains a brief outline of the theoretical background for the EPIPE program, together with four benchmark problems: two for the static case and two for the dynamic case.

The results obtained from EPIPE runs compare well with those available from known analytical solutions or from other independent computer programs.

II. Background

The EPIPE program is a modified version of the general purpose program SAP IV[4] , 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

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

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 ecitations. 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.

   Case a and b

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.

In the first problem, two different cases were considered; case b includes the effect of internal pressure on the flexibility calculation for the pipe bends, and case a neglects such effects.

The dynamic problems, (2 and 3), 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. 1-1c.

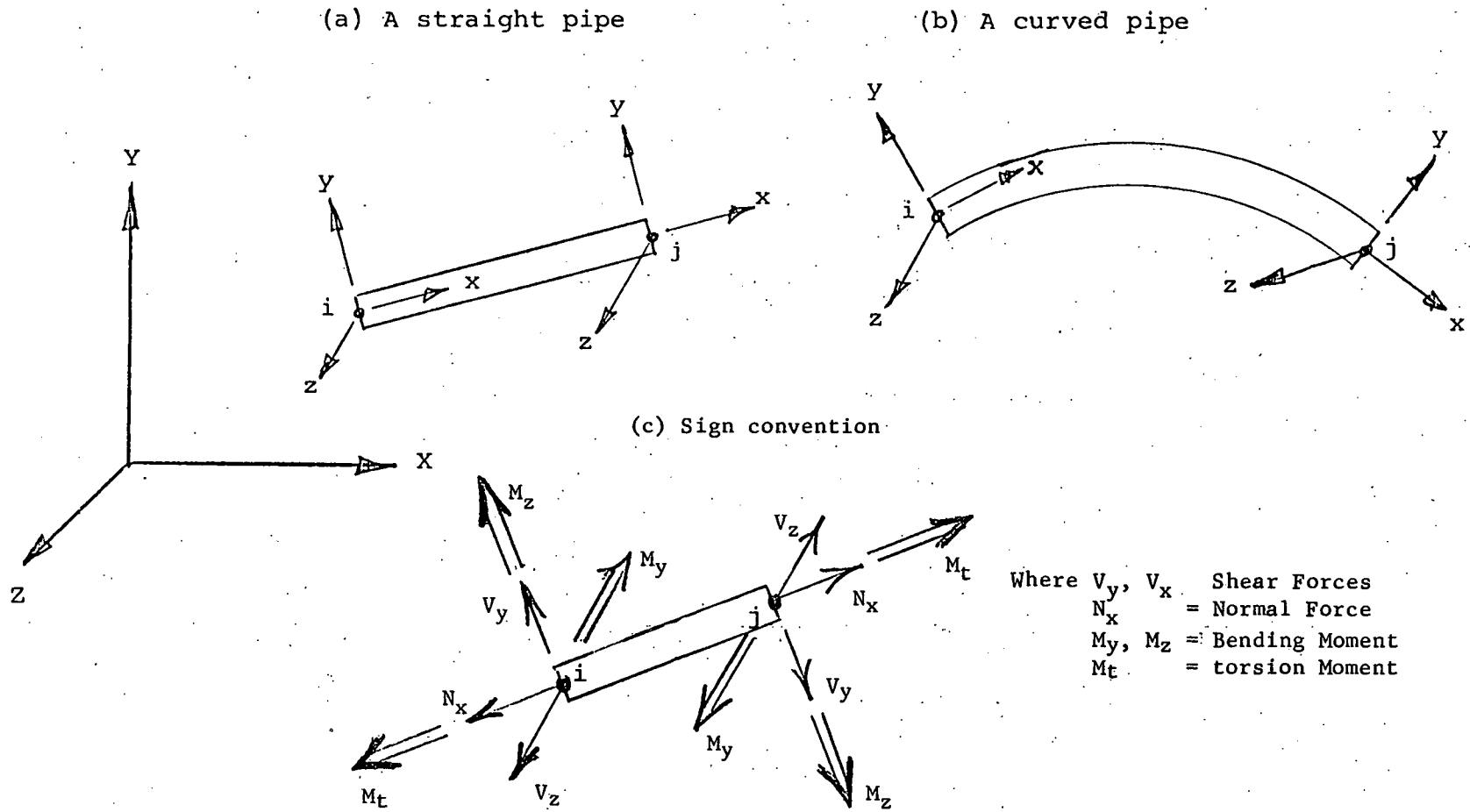


Fig 1.1
Local Coordinate Systems (x, y, z) of Pipe Elements
in Relation to the Global System (X, Y, Z)

and

Sign Convention for Forces and Moments

-8A-

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 PIPDYN[14]. 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 ($lb/inch^3$)	0.283
Coefficient of thermal expansion ($in/in/^oF$)	7.1E-6

iii. Loading conditions - The piping system is subjected to an internal pressure of 400 psi and a uniform temperature of 850^oF. Two cases were considered:

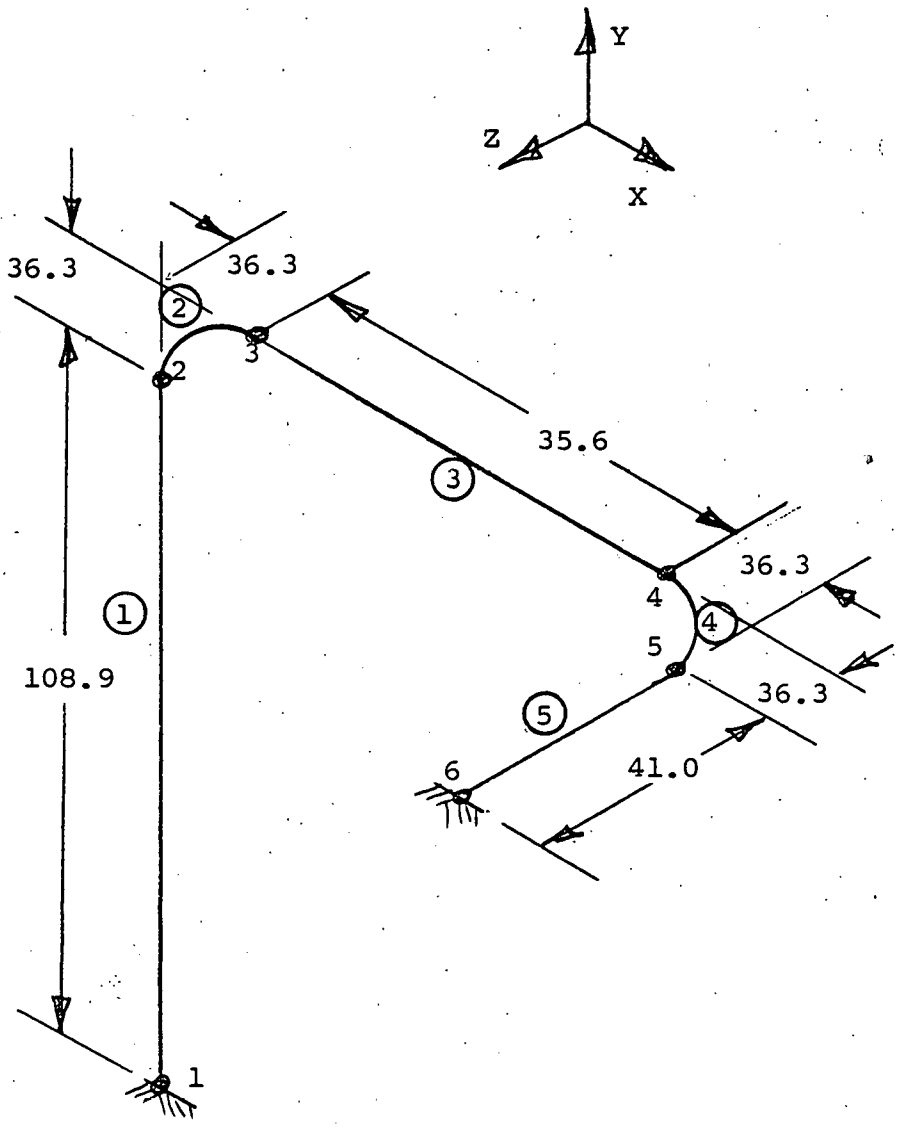


Fig. 1-2
A Hovgaard Bend
(Figure not to scale)

Case a - Effect of internal pressure was neglected in the pipe bend flexibility.

Case b - Effect of internal pressure was included.

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.

Tables 1-5 to 1-10 show the computer output of the nodal displacements, resultant forces, and pipe stresses for Cases a and b. It is important to note from Tables 1-6 and 1-9 that the maximum moments for Case b (which as mentioned consider the effect of internal pressure for the pipe bends) are much higher than the corresponding values shown for Case a.

Table 1-1

Moments and Forces Acting on Restraints

	EPIPE		Analytical Method* [12, 13]		PIPDYN [14]	
	End A	End B	End A	End B	End A	End B
M_x (in-lb)	-57700.8	98234.4	-56040	+95040	-55624.8	+93732.5
M_y (in-lb)	+13536.0	-80684.4	+14400	-80520	+14494.8	-79972.8
M_z (in-lb)	+132865.0	-63495.6	+133080	-63360	+132303.6	-62868
F_x (lb)	-1792.5	+1792.4	-1750	+1750	-1737.2	+1737.2
F_y (lb)	-1761.4	+1762.7	-1710	+1710	-1686.3	+1686.3
F_z (lb)	-659.3	+659.2	-640	+640	-636.7	+636.7

*evaluated from equations 20 through 25 in reference 13.

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	-1761.4	- 659.3	-1792.5	13535.8	132865	-57700.7
		End-J	-1761.4	- 659.3	-1792.5	13535.8	- 62336.7	14092.2
2	Bend	End-I	-1762.8	-1792.5	659.3	13535.9	14092.2	62335.5
		Center	-2514.0	- 21.1	659.3	26545.3	17315.4	89607.3
		End-J	-1792.5	1762.7	659.3	38023.5	10395.5	63419.8
3	Tangent	End-I	-1792.9	-1762.7	- 659.3	38023.5	- 10395.6	-63418
		End-J	-1792.9	-1762.7	- 659.3	38023.5	- 33933.1	- 492.1
4	Bend	End-I	-1792.4	- 659.4	1762.7	38023.5	- 490.9	33930.0
		Center	-1733.7	801.2	1762.7	45280.6	18011.6	31800.0
		End-J	- 659.4	1792.4	1762.7	63495.6	25963.1	- 7197.9
5	Tangent	End-I	- 659.2	-1762.7	1792.4	63495.8	7197.6	25962.9
		End-J	- 659.2	-1762.7	1792.4	63495.8	80684.1	98234.3

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	133880	-56040
		End-J	-1710	- 640	-1750	14400	- 57495	13656
2	Bend	End-I	-1710	-1750	640	14400	13656	57495
		Center	-2446.2	- 28.3	640	26642.6	15899	84296
		End-J	-1750	1710	640	36888	8832	58947
3	Tangent	End-I	-1750	-1710	- 640	36888	- 8832	-58947
		End-J	-1750	-1710	- 640	36888	- 31523	- 472
4	Bend	End-I	-1750	- 640	1710	36888	- 472	31523
		Center	-1689.7	784.8	1710	45070	17531	31615
		End-J	- 640	1750	1710	63360	24930	- 8770
5	Tangent	End-I	- 640	-1710	1750	63360	8770	24930
		End-J	- 640	-1710	1750	63360	80520	95042

* see note page 11

Table 1-4

Pipes Stresses

			Longitudinal Stress		Circumferential Stress		Shear Stress	
Member	Type	Station	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 HOVGAARD PROBLEM STATIC ANALYSIS CASE A

NODE DISPLACEMENTS/ROTATIONS

NODE NUMBER	LCAD CASE	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
6	1	0.0	0.0	0.0	0.0	0.0	0.0
5	1	0.62326E-01	0.81240E-01	-0.24922E 00	0.31993E-02	-0.22638E-02	-0.42527E-02
4	1	-0.99051E-01	0.49205E 00	-0.48841E 00	0.25608E-02	0.13077E-02	-0.84623E-02
3	1	-0.31574E 00	C.77952E CO	-0.41988E 00	0.34333E-03	0.23020E-02	-0.70288E-02
2	1	-0.51309E 00	0.66102E 00	-0.25453E 00	-0.29838E-02	0.24079E-02	0.48256E-02
1	1	0.0	0.0	0.0	0.0	0.0	0.0

TABLE I-6 HOVGAARD 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	-1761.438	-659.257	-1792.484	13535.82	132865.00	-57700.88
			END-J	-1761.438	-659.257	-1792.484	13535.82	-62336.69	14092.19
2	BEND	1	END-I	-1762.789	-1792.453	659.264	13535.92	14092.23	62335.50
			CENTER	-2514.027	-21.070	659.264	26545.25	17315.41	89607.31
			END-J	-1792.516	1762.730	659.264	38023.53	10395.49	63419.81
3	TANGENT	1	END-I	-1792.938	-1762.691	-659.324	38023.49	-10395.61	-63418.75
			END-J	-1792.938	-1762.691	-659.324	38023.49	-33933.13	-492.06
4	BEND	1	END-I	-1792.418	-659.345	1762.711	38023.45	-490.89	33930.55
			CENTER	-1733.723	801.166	1762.711	45280.63	18011.63	31800.02
			END-J	-659.356	1792.391	1762.711	63495.63	25963.14	-7197.88
5	TANGENT	1	END-I	-659.125	-1762.715	1792.355	63495.80	7197.56	25962.94
			END-J	-659.125	-1762.715	1792.355	63495.80	80684.13	98234.25

TABLE I-7 HOVGAARD PROBLEM STATIC ANALYSIS CASE A

PIPE STRESSES

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LNGTDL STRESS	CIRCUMF STRESS	SHEAR STRESS
1	TANGENT	1	END-I	17986.293	5848.129	1077.128
			END-J	9385.070	5848.129	1077.128
2	BEND	1	END-I	9699.387	18657.422	1077.129
			CENTER	12667.340	24261.500	1533.998
			END-J	9817.418	18880.238	2372.952
3	TANGENT	1	END-I	9416.941	5848.129	2372.948
			END-J	6194.191	5848.129	2372.948
4	BEND	1	END-I	6455.910	12820.500	2372.951
			CENTER	6224.051	12382.699	2768.699
			END-J	5760.059	4369.039	3844.751
5	TANGENT	1	END-I	5663.441	5848.129	3844.756
			END-J	16308.684	5848.129	3844.756

TABLE 1-8 HOVGAARD PROBLEM STATIC ANALYSIS CASE B

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	0.0	0.0	0.0
5	1	0.61079E-01	0.76371E-01	-0.24898E 00	0.30037E-02	-0.22387E-02	-0.41673E-02
4	1	-0.10309E 00	0.48246E 00	-0.48220E 00	0.26098E-02	0.15924E-02	-0.85549E-02
3	1	-0.31958E 00	0.77583E 00	-0.40570E 00	0.49145E-03	0.24748E-02	-0.72992E-02
2	1	-0.51438E 00	0.66042E 00	-0.24159E 00	-0.28265E-02	0.25489E-02	0.50609E-02
1	1	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 1-9 HOVGAARD PROBLEM STATIC ANALYSIS CASE B

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	-1664.688	-627.866	-1710.020	14328.34	130093.88	-54842.59
			END-J	-1664.688	-627.866	-1710.020	14328.34	-56127.38	13532.06
2	BEND	1	END-I	-1665.584	-1710.023	627.874	14328.38	13532.14	56126.38
			CENTER	-2387.223	-31.137	627.874	26375.88	15553.24	82308.56
			END-J	-1710.086	1665.988	627.874	36323.93	8463.40	57727.13
3	TANCENT	1	END-I	-1710.813	-1665.934	-627.898	36323.86	-8463.66	-57727.69
			END-J	-1710.813	-1665.934	-627.898	36323.86	-30879.31	1747.88
4	BEND	1	END-I	-1710.051	-627.988	1665.935	36323.82	1746.92	30877.36
			CENTER	-1653.230	765.119	1665.935	44632.41	18311.81	28817.04
			END-J	-627.584	1710.090	1665.935	62220.57	24149.67	-8399.69
5	TANGENT	1	END-I	-627.625	-1665.945	1709.953	62220.68	8398.69	24149.63
			END-J	-627.625	-1665.945	1709.953	62220.68	78506.88	92453.38

TABLE I-10 HOVGAARD PROBLEM STATIC ANALYSIS CASE B

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	STRESS COMPONENTS LNGTDL STRESS	CIRCUMF STRESS	SHEAR STRESS
1	TANGENT	1	END-I	17614.215	5848.129	1102.699
			END-J	8747.137	5848.129	1102.699
2	BEND	1	END-I	9009.742	17381.512	1102.702
			CENTER	11859.109	22761.680	1519.198
			END-J	9183.949	17710.449	2263.610
3	TANGENT	1	END-I	8803.230	5848.129	2263.598
			END-J	5889.953	5848.129	2263.598
4	BEND	1	END-I	6123.313	12193.102	2263.602
			CENTER	5899.102	11769.723	2714.954
			END-J	5559.219	4122.078	3753.294
5	TANGENT	1	END-I	5523.371	5848.129	3753.284
			END-J	15694.777	5848.129	3753.284

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.

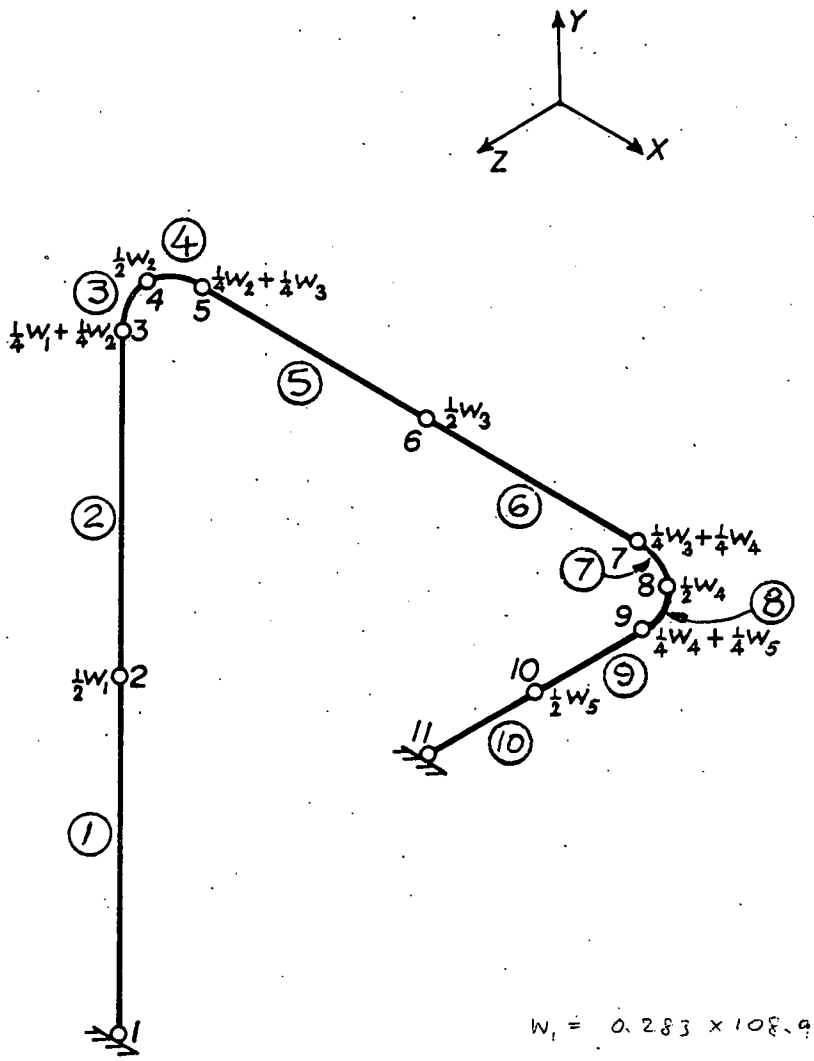
Case c - Direct step-by-step integrating method.

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.



$W_1 = 0.283 \times 108.9 = 30.8187$ lb.

$W_2 = 0.283 \times 57.02 = 16.1367$ lb.

$W_3 = 0.283 \times 35.7 = 10.1$ lb.

$W_4 = 0.283 \times 57.02 = 16.1367$ lb.

$W_5 = 0.283 \times 41.0 = 11.603$ lb

Fig. 2-1

Lumped Mass System for Hovgaard Bend

TABLE 2-1 INPUT DATA FOR HOVGAAPD PROBLEM

NODAL COORDINATES

NODE NUMBER	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES 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 HOVGAARD 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

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 is listed in Table 2-4 at equal intervals of 1 cycle/sec. These values are also plotted graphically in Fig. 2-3.

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,

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	-0.8008E 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	-0.6807E 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
5.00000	-0.8311E 02	5.02000	-0.6366E 02	5.04000	-0.6661E 02	5.06000	-0.5142E 02	5.08000	-0.4374E 02
5.10000	-0.3043E 02	5.12000	-0.2008E 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	0.3449E 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	0.7992E 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	-0.1598E 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	-0.2020E 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	0.8465E 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	-0.1496E 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	0.8858E 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								

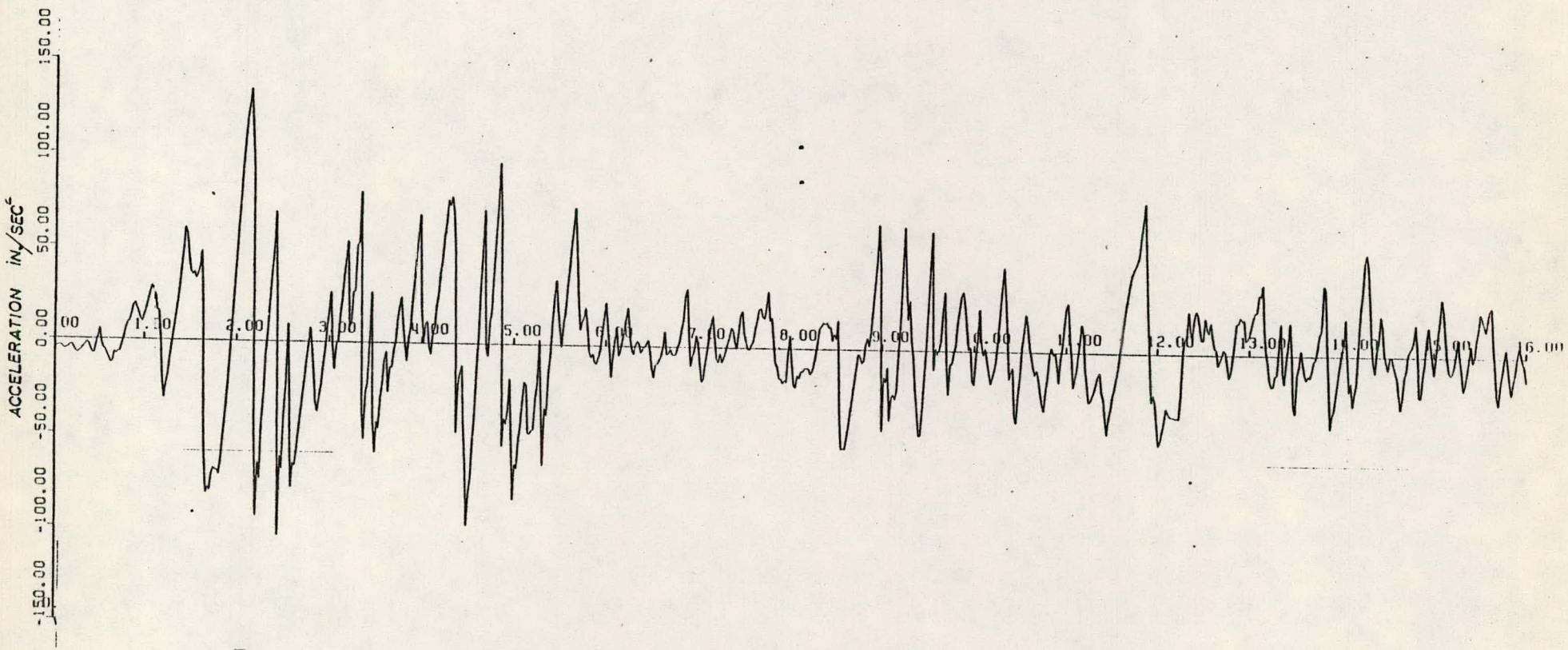


FIG. 2-2 TIME HISTORY ACCELERATION OF THE IMPERIAL VALLEY EARTHQUAKE EI CENTRO SITE MAY 18, 1940 SOOE DIRECTION

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
1.00	320.60352	2.00	457.66919
3.00	438.13916	4.00	678.33057
5.00	642.80347	6.00	1079.00635
7.00	708.60718	8.00	719.58057
9.00	786.48755	10.00	875.14917
11.00	679.57837	12.00	584.00879
13.00	495.42676	14.00	582.74634
15.00	399.33887	16.00	423.79102
17.00	272.02759	18.00	859.14966
19.00	333.38184	20.00	388.56470
21.00	587.21167	22.00	397.34424
23.00	200.66594	24.00	486.54541
25.00	229.93297	26.00	457.79346
27.00	185.70261	28.00	280.10889
29.00	393.44751	30.00	284.62793
31.00	205.38451	32.00	418.97974
33.00	163.34241	34.00	188.51627
35.00	178.23006	36.00	190.78685
37.00	186.92078	38.00	166.10120
39.00	173.62234	40.00	156.40381
41.00	144.68747	42.00	136.17026
43.00	149.02924	44.00	139.68484
45.00	136.59206	46.00	136.70769
47.00	134.33875	48.00	134.45705
49.00	136.71747	50.00	136.71045
51.00	136.40935	52.00	136.32866
53.00	135.65813	54.00	137.10062
55.00	135.88010	56.00	139.04291
57.00	136.15819	58.00	139.93581
59.00	138.76253	60.00	142.10712
61.00	152.13022	62.00	141.25342
63.00	139.08466	64.00	151.72667
65.00	132.65918	66.00	146.36800
67.00	137.94559	68.00	233.73540
69.00	141.78606	70.00	148.27968
71.00	181.33899	72.00	135.87279
73.00	134.51346	74.00	175.65703
75.00	136.84836	76.00	180.72504
77.00	138.16872	78.00	140.05872
79.00	166.10744	80.00	140.05280

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
81.00	139.76433	82.00	186.67798
83.00	144.67650	84.00	131.23708
85.00	142.88837	86.00	136.05936
87.00	142.59697	88.00	138.93660
89.00	141.88982	90.00	135.83614
91.00	139.81438	92.00	134.80739
93.00	137.72217	94.00	132.96042
95.00	134.60645	96.00	133.76320
97.00	134.66454	98.00	134.08594
99.00	134.48511	100.00	135.07841
101.00	135.31815	102.00	135.38158
103.00	134.96402	104.00	135.45978
105.00	134.76877	106.00	136.52698
107.00	137.42090	108.00	137.58191
109.00	135.91486	110.00	137.96587
111.00	139.04723	112.00	137.69542
113.00	129.35497	114.00	135.64113
115.00	137.90816	116.00	141.39391
117.00	132.45827	118.00	169.62354
119.00	135.83594	120.00	137.04482
121.00	136.27811	122.00	135.00516
123.00	134.73920	124.00	134.41820
125.00	135.51746	126.00	137.03191
127.00	136.70482	128.00	133.85132
129.00	136.92827	130.00	135.99071
131.00	137.46869	132.00	133.43393
133.00	140.81020	134.00	137.10828
135.00	139.77736	136.00	133.47173
137.00	139.60547	138.00	134.46593
139.00	139.35126	140.00	134.42258
141.00	138.19315	142.00	133.52254
143.00	136.83173	144.00	134.43268
145.00	134.46634	146.00	133.25092
147.00	133.59334	148.00	134.09514
149.00	134.63759	150.00	135.07840
151.00	135.19368	152.00	135.09331
153.00	134.71306	154.00	134.94661
155.00	133.58519	156.00	135.77071
157.00	132.59357	158.00	136.75879
159.00	135.02295	160.00	136.90723

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
161.00	136.95801	162.00	136.47339
163.00	136.77916	164.00	135.18758
165.00	134.43326	166.00	139.44957
167.00	136.13361	168.00	143.35155
169.00	134.82309	170.00	136.23856
171.00	133.43390	172.00	134.71407
173.00	133.18474	174.00	133.64754
175.00	135.30420	176.00	136.44121
177.00	136.08736	178.00	133.09708
179.00	136.08765	180.00	132.45769
181.00	136.54413	182.00	133.12331
183.00	139.15619	184.00	134.38306
185.00	138.37819	186.00	133.66643
187.00	138.15912	188.00	133.11998
189.00	138.08147	190.00	132.96706
191.00	137.38965	192.00	133.74257
193.00	136.35567	194.00	133.69164
195.00	134.38202	196.00	133.32123
197.00	133.74306	198.00	134.20482
199.00	134.71280	200.00	135.07787
201.00	135.12996	202.00	134.95601
203.00	134.58257	204.00	134.69684
205.00	133.71831	206.00	135.41124
207.00	133.16704	208.00	136.34163
209.00	132.69089	210.00	136.36731
211.00	133.33650	212.00	135.86017
213.00	133.58359	214.00	134.96123
215.00	131.64571	216.00	138.41272
217.00	131.95444	218.00	138.37917
219.00	133.00380	220.00	135.77521
221.00	132.34145	222.00	134.57100
223.00	133.40250	224.00	133.71732
225.00	135.21541	226.00	136.10979
227.00	135.74547	228.00	133.93987
229.00	135.61977	230.00	132.29097
231.00	136.04784	232.00	131.49915
233.00	138.24016	234.00	131.92328
235.00	137.58333	236.00	133.78696
237.00	137.30704	238.00	132.56473
239.00	137.32050	240.00	133.31801

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
241.00	136.90990	242.00	134.00928
243.00	136.06061	244.00	133.74802
245.00	134.32799	246.00	133.44800
247.00	133.83147	248.00	134.27315
249.00	134.75716	250.00	135.07805
251.00	135.09081	252.00	134.87459
253.00	134.50322	254.00	134.54944
255.00	133.79546	256.00	135.20267
257.00	133.50516	258.00	136.08870
259.00	133.14928	260.00	136.03934
261.00	131.31229	262.00	135.49054
263.00	130.90799	264.00	134.82584
265.00	132.21390	266.00	137.76868
267.00	132.51189	268.00	137.71416
269.00	133.24660	270.00	135.47559
271.00	132.63950	272.00	134.48682
273.00	133.61142	274.00	133.93996
275.00	135.17186	276.00	135.89771
277.00	135.53011	278.00	133.97159
279.00	135.32219	280.00	132.62299
281.00	135.73987	282.00	132.08719
283.00	137.65923	284.00	132.46313
285.00	137.07204	286.00	133.86823
287.00	136.74544	288.00	132.80359
289.00	136.81194	290.00	133.55034
291.00	136.58971	292.00	134.18616
293.00	135.86098	294.00	133.85271
295.00	134.29018	296.00	133.53419
297.00	133.89014	298.00	134.31984
299.00	134.78560	300.00	135.07831
301.00	135.06482	302.00	134.82100
303.00	134.45064	304.00	134.45250
305.00	133.84528	306.00	135.06662
307.00	134.18570	308.00	135.91907
309.00	133.45653	310.00	135.81818
311.00	133.52541	312.00	135.24390
313.00	133.99055	314.00	134.73604
315.00	132.79889	316.00	137.32953
317.00	132.90114	318.00	137.25879
319.00	134.88068	320.00	135.26587

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
321.00	132.84581	322.00	134.43166
323.00	133.75661	324.00	134.09354
325.00	135.14557	326.00	135.74988
327.00	135.38033	328.00	134.05016
329.00	135.11583	330.00	134.36020
331.00	135.52887	332.00	134.04915
333.00	137.25705	334.00	133.94629
335.00	136.71378	336.00	133.92743
337.00	136.34737	338.00	134.36678
339.00	136.45067	340.00	133.71596
341.00	136.36275	342.00	134.31232
343.00	135.71666	344.00	133.92986
345.00	134.26244	346.00	133.64415
347.00	133.93204	348.00	134.35315
349.00	134.80724	350.00	135.07828
351.00	135.04657	352.00	134.78351
353.00	134.41266	354.00	134.38396
355.00	133.88091	356.00	134.97121
357.00	133.88860	358.00	135.79796
359.00	133.67699	360.00	135.66125
361.00	134.70868	362.00	135.06088
363.00	135.06161	364.00	134.67148
365.00	134.22469	366.00	137.01085
367.00	133.54294	368.00	136.92760
369.00	133.90050	370.00	135.11095
371.00	133.94333	372.00	134.39359
373.00	133.86327	374.00	134.20531
375.00	135.12900	376.00	135.64194
377.00	135.27065	378.00	134.01778
379.00	134.96468	380.00	133.76859
381.00	135.37645	382.00	133.99402
383.00	136.96297	384.00	133.91655
385.00	136.44942	386.00	133.97327
387.00	136.05077	388.00	133.73366
389.00	136.18004	390.00	133.83939
391.00	136.19298	392.00	134.40674
393.00	135.60750	394.00	133.98964
395.00	134.24106	396.00	133.64391
397.00	133.96312	398.00	134.37845
399.00	134.82262	400.00	135.07834

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
401.00	135.03203	402.00	134.75615
403.00	134.38358	404.00	134.33304
405.00	133.90706	406.00	134.89960
407.00	134.00731	408.00	135.70627
409.00	133.84267	410.00	135.54201
411.00	134.24437	412.00	134.93683
413.00	134.62868	414.00	134.62375
415.00	133.51854	416.00	136.76923
417.00	133.72501	418.00	136.67644
419.00	133.64554	420.00	134.99251
421.00	133.11292	422.00	134.36487
423.00	133.94524	424.00	134.29131
425.00	135.11794	426.00	135.55884
427.00	135.18689	428.00	134.03351
429.00	134.84903	430.00	133.14458
431.00	135.26096	432.00	133.03539
433.00	136.73820	434.00	133.34021
435.00	136.24651	436.00	134.00806
437.00	135.82117	438.00	133.20476
439.00	135.96843	440.00	133.93549
441.00	136.06102	442.00	134.47992
443.00	135.52193	444.00	134.03595
445.00	134.22408	446.00	133.68059
447.00	133.98717	448.00	134.39850
449.00	134.83382	450.00	135.07854
451.00	135.02126	452.00	134.73404
453.00	134.36153	454.00	134.29323
455.00	133.92682	456.00	134.84492
457.00	134.09946	458.00	135.63509
459.00	133.97162	460.00	135.44901
461.00	132.63054	462.00	134.83405
463.00	132.26624	464.00	134.58652
465.00	133.27271	466.00	136.57985
467.00	133.57941	468.00	136.47803
469.00	133.72559	470.00	134.89803
471.00	133.20418	472.00	134.34302
473.00	134.00966	474.00	134.35080
475.00	135.11104	476.00	135.49294
477.00	135.12183	478.00	134.04657
479.00	134.75754	480.00	133.24434

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
481.00	135.17C06	482.00	133.22063
483.00	136.56096	484.00	133.51195
485.00	136.08664	486.00	134.03621
487.00	135.63802	488.00	133.28531
489.00	135.80034	490.00	134.01224
491.00	135.95479	492.00	134.53847
493.00	135.45377	494.00	134.07329
495.00	134.21103	496.00	133.71004
497.00	134.00568	498.00	134.41434
499.00	134.84357	500.00	135.07845
501.00	135.01221	502.00	134.71651
503.00	134.34331	504.00	134.26149
505.00	133.94286	506.00	134.80173
507.00	134.17200	508.00	135.57808
509.00	134.07500	510.00	135.37453
511.00	132.79601	512.00	134.75191
513.00	132.43860	514.00	134.55704
515.00	133.41013	516.00	136.42725
517.00	133.71982	518.00	136.31792
519.00	133.79024	520.00	134.82123
521.00	133.27805	522.00	134.32538
523.00	134.06125	524.00	134.41347
525.00	135.10509	526.00	135.44011
527.00	135.06812	528.00	134.05733
529.00	134.68364	530.00	133.32497
531.00	135.09698	532.00	133.37105
533.00	136.41762	534.00	133.65198
535.00	135.95583	536.00	134.05925
537.00	135.48859	538.00	133.35135
539.00	135.66309	540.00	134.07442
541.00	135.86847	542.00	134.58643
543.00	135.39728	544.00	134.10416
545.00	134.19968	546.00	133.73430
547.00	134.02135	548.00	134.42747
549.00	134.85146	550.00	135.07848
551.00	135.00461	552.00	134.70313
553.00	134.32834	554.00	134.23595
555.00	133.95589	556.00	134.76552
557.00	134.23192	558.00	135.53098
559.00	134.15970	560.00	135.31337

TABLE 2-4 IMPERIAL VALLEY EARTHQUAKE, MAY 18,1940

ACCELERATION RESPONSE SPECTRUM

FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.	FREQUENCY CYCLES/SEC.	SPECTRAL ACCEL. IN./SEC.*SEC.
561.00	132.93163	562.00	134.68477
563.00	132.82030	564.00	134.53223
565.00	133.52328	566.00	136.30128
567.00	133.83585	568.00	136.18715
569.00	134.13161	570.00	134.75838
571.00	133.33925	572.00	134.31116
573.00	134.10492	574.00	134.45778
575.00	135.10094	576.00	135.39545
577.00	135.02431	578.00	134.06757
579.00	134.62256	580.00	133.72104
581.00	135.03725	582.00	133.49524
583.00	136.29926	584.00	133.76826
585.00	135.84766	586.00	134.07935
587.00	135.36432	588.00	133.69771
589.00	135.54857	590.00	134.12665
591.00	135.79694	592.00	134.62613
593.00	135.35019	594.00	134.13097
595.00	134.19019	596.00	133.75452
597.00	134.03438	598.00	134.43805
599.00	134.85793	600.00	135.07837

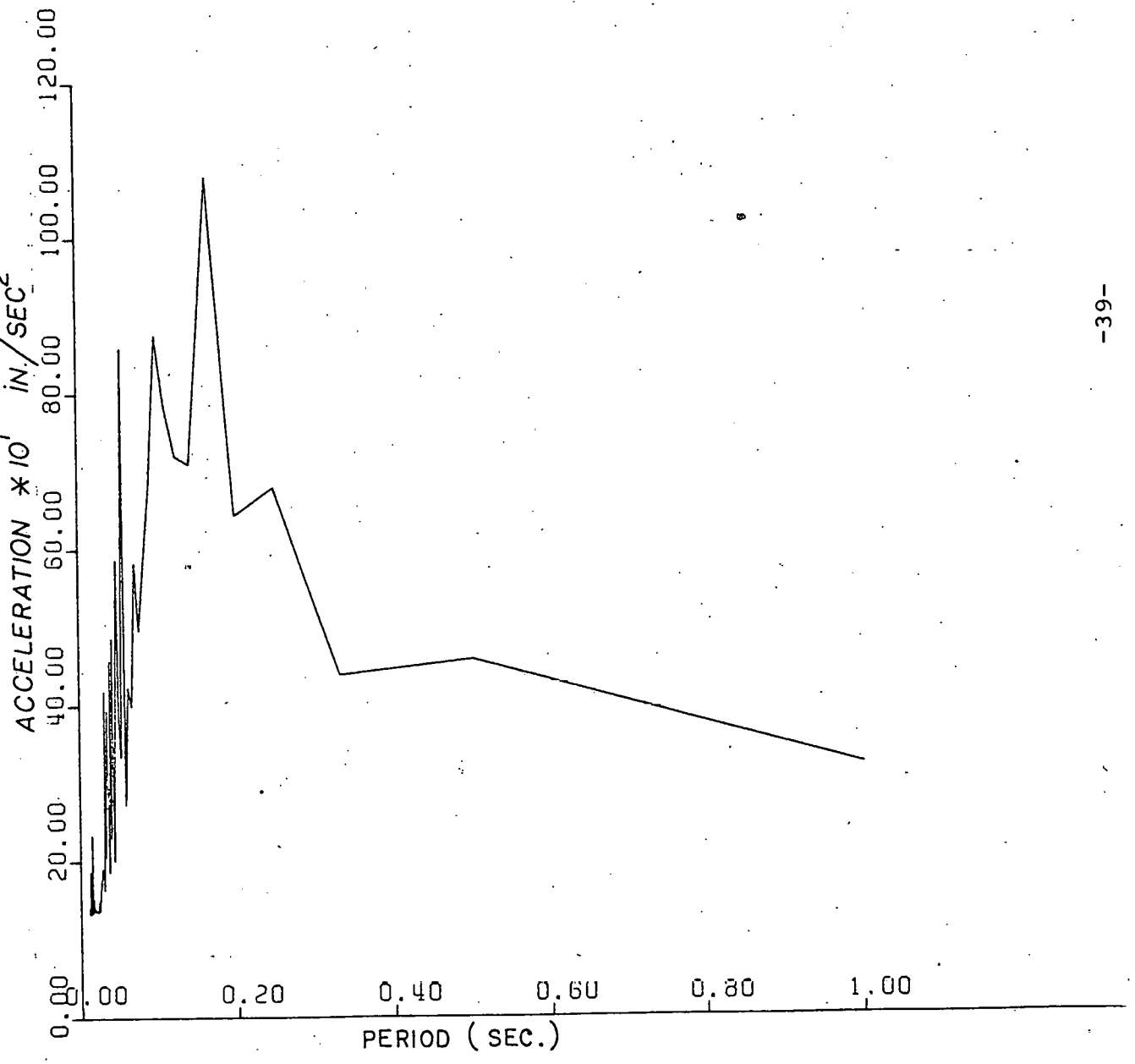


FIG. 2-3 RESPONSE SPECTRUM ACCELERATION

TABLE 2-5 HOVGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)

NATURAL FREQUENCIES

MODE NUMBER	CIRCULAR FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	0.1837E 03	0.2924E 02	0.3420E-01
2	0.3431E 03	0.5461E 02	0.1831E-01
3	0.5009E 03	0.7971E 02	0.1254E-01
4	0.9608E 03	0.1529E 03	0.6540E-02
5	0.1073E 04	0.1708E 03	0.5854E-02

PRINT OF EIGENVECTORS

TABLE 2-6 HOVGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)

MODE SHAPES

NODE NUMBER	EIGEN-VECTOR	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
11	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
10	1	0.10011E 00	-0.38196E-01	-0.63723E-03	-0.35660E-02	-0.91697E-02	-0.86576E-03
	2	-0.35534E 00	0.15620E-01	-0.17242E-02	0.13021E-02	0.29373E-01	-0.49776E-03
	3	-0.36961E-01	0.52774E 00	0.20034E-03	0.45061E-01	0.31579E-02	0.24645E-02
	4	-0.43259E 00	0.19442E 00	-0.13609E-01	0.14626E-01	0.31671E-01	-0.32467E-02
	5	-0.25647E 00	-0.57799E 00	0.39717E-04	-0.45769E-01	0.20024E-01	-0.17568E-01
9	1	0.36914E 00	-0.14438E 00	-0.12744E-02	-0.66363E-02	-0.16488E-01	-0.17315E-02
	2	-0.11440E 01	0.50863E-01	-0.34479E-02	0.19192E-02	0.42386E-01	-0.99553E-03
	3	-0.12446E 00	0.17756E 01	0.40056E-03	0.70588E-01	0.49539E-02	0.49290E-02
	4	-0.11832E 01	0.55234E 00	-0.27188E-01	0.16406E-01	0.32043E-01	-0.64934E-02
	5	-0.76782E 00	-0.17642E 01	0.79324E-04	-0.61026E-01	0.25616E-01	-0.35135E-01
8	1	0.10162E 01	-0.40236E 00	-0.17192E 00	-0.13992E-01	-0.32419E-01	-0.23802E-02
	2	-0.22102E 01	0.11107E 00	0.20385E 00	0.16598E-02	0.28868E-01	-0.15321E-02
	3	-0.28089E 00	0.39499E 01	0.37385E-01	0.89389E-01	0.62774E-02	0.98669E-02
	4	-0.11735E 01	0.75980E 00	-0.18352E 00	-0.95878E-02	-0.43006E-01	-0.71424E-02
	5	-0.13170E 01	-0.29338E 01	0.98776E-01	-0.44961E-01	0.12672E-01	-0.62856E-01
7	1	0.15266E 01	-0.56289E 00	-0.99014E 00	-0.17986E-01	-0.38552E-01	-0.37958E-02
	2	-0.23776E 01	0.15720E 00	0.30951E 00	0.11473E-03	-0.17237E-01	-0.91889E-03
	3	-0.35908E 00	0.46026E 01	0.15102E 00	0.70461E-01	0.34634E-02	0.42389E-01
	4	-0.22559E 00	0.46681E 00	-0.18016E 01	-0.41777E-01	-0.74619E-01	0.47910E-02
	5	-0.13852E 01	-0.15051E 01	0.15626E 00	-0.26468E-01	-0.43206E-02	-0.94307E-01
6	1	0.15269E 01	-0.48571E 00	-0.16794E 01	-0.20262E-01	-0.38186E-01	-0.49077E-02
	2	-0.23805E 01	0.17028E 00	-0.11161E 00	-0.88428E-03	-0.28228E-01	-0.43870E-03
	3	-0.35903E 00	0.37216E 01	0.20136E 00	0.60245E-01	0.21020E-02	0.56029E-01
	4	-0.22863E 00	0.35639E 00	-0.30182E 01	-0.59712E-01	-0.53659E-01	0.74603E-02
	5	-0.13805E 01	0.11391E 00	0.48001E-01	-0.23575E-01	-0.72179E-02	-0.88669E-01
5	1	0.15271E 01	-0.38744E 00	-0.23506E 01	-0.22537E-01	-0.36626E-01	-0.61277E-02
	2	-0.23829E 01	0.17231E 00	-0.68745E 00	-0.18833E-02	-0.34597E-01	0.27933E-03
	3	-0.35883E 00	0.26099E 01	0.22589E 00	0.50029E-01	0.66933E-03	0.66445E-01
	4	-0.23129E 00	0.20324E 00	-0.36834E 01	-0.77646E-01	-0.18224E-01	0.89427E-02
	5	-0.13729E 01	0.15345E 01	-0.97350E-01	-0.20681E-01	-0.83697E-02	-0.63355E-01
4	1	0.14727E 01	-0.17430E 00	-0.30449E 01	-0.27106E-01	-0.27729E-01	-0.10550E-01
	2	-0.23694E 01	0.12727E 00	-0.16623E 01	-0.43133E-02	-0.38089E-01	0.44839E-02
	3	0.49533E-01	0.75495E 00	-0.10808E-01	0.33687E-01	-0.61171E-03	0.66426E-01
	4	-0.20434E 00	0.15026E-01	-0.21389E 01	-0.11040E 00	0.78765E-01	0.33388E-02
	5	-0.11069E 01	0.14798E 01	-0.20629E 00	-0.16505E-01	-0.69059E-02	0.71878E-01
3	1	0.11879E 01	-0.15562E-03	-0.27009E 01	-0.34024E-01	-0.20085E-01	-0.14502E-01
	2	-0.21299E 01	0.16695E-03	-0.19378E 01	-0.16861E-01	-0.29042E-01	0.18360E-01
	3	0.10317E 01	0.25177E-01	-0.46597E 00	0.88215E-02	0.33375E-02	0.18208E-01
	4	-0.21504E 00	0.76688E-02	0.15195E 01	-0.78160E-01	0.77627E-01	-0.15129E-02
	5	0.12864E 01	0.15668E-01	0.68424E-02	-0.90890E-02	-0.58544E-02	0.96980E-01
2	1	0.40169E 00	-0.77834E-04	-0.39884E 00	-0.28326E-01	-0.10043E-01	-0.12563E-01

	2	-0.85329E 00	0.83558E-04	-0.77413E 00	-0.22032E-01	-0.14521E-01	0.24254E-01
	3	0.84441E 00	0.12615E-01	-0.39034E 00	-0.82099E-02	0.16688E-02	-0.17880E-01
	4	-0.19766E 00	0.38646E-02	0.28136E 01	0.37953E-01	0.38813E-01	0.32106E-02
	5	0.35005E 01	0.79114E-02	0.24610E 00	0.23288E-02	-0.29272E-02	-0.39103E-01
1	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

TABLE 2-7 HOVGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)

DISPLACEMENT MAXIMA

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM* VALUE	TIME AT MAXIMUM	PLOT SYMBOL
2	1	9.4569E-04	2.4800E 00	NA
	2	5.3962E-07	2.2200E 00	NA
	3	6.6749E-04	2.4800E 00	NA
3	1	2.4358E-03	2.4800E 00	NA
	2	1.0755E-06	2.2200E 00	NA
	3	2.0922E-03	2.4800E 00	NA
4	1	2.8052E-03	2.4800E 00	NA
	2	2.1037E-04	2.4800E 00	NA
	3	2.5511E-03	2.4800E 00	NA
5	1	2.8534E-03	2.4800E 00	NA
	2	3.9766E-04	2.4800E 00	NA
	3	2.2287E-03	2.4800E 00	NA
6	1	2.8519E-03	2.4800E 00	NA
	2	4.7971E-04	2.4800E 00	NA
	3	1.7722E-03	2.4800E 00	NA
7	1	2.8500E-03	2.4800E 00	NA
	2	5.4467E-04	2.4800E 00	NA
	3	1.2272E-03	2.4800E 00	NA
8	1	2.2137E-03	2.4800E 00	NA
	2	3.8794E-04	2.4800E 00	NA
	3	2.8758E-04	2.4800E 00	NA
9	1	9.7801E-04	2.2200E 00	NA
	2	1.4181E-04	2.4800E 00	NA
	3	1.1790E-06	2.5200E 00	NA
10	1	2.9065E-04	2.2200E 00	NA
	2	3.8119E-05	2.4800E 00	NA
	3	5.8972E-07	2.5200E 00	NA
11	3	9.7801E-04	2.2200E 00	NA
	2	1.4181E-04	2.4800E 00	NA
	3	1.1790E-06	2.5200E 00	NA

*All values represent the absolute maximum.

TABLE 2-8 HOVGAARD PROBLEM 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	1.2690E 00	2.2200E 00
		FY	4.3313E 00	2.4800E 00
		FZ	1.1301E 01	2.2200E 00
		TX	5.0256E 01	2.4800E 00
		MY	6.9815E 02	2.2200E 00
		MZ	4.3181E 02	2.4800E 00
1	END-J	FX	1.2690E 00	2.2200E 00
		FY	4.3313E 00	2.4800E 00
		FZ	1.1301E 01	2.2200E 00
		TX	5.0256E 01	2.4800E 00
		MY	1.0510E 02	2.4800E 00
		MZ	1.9597E 02	2.4800E 00
2	END-I	FX	1.2603E 00	2.2200E 00
		FY	3.4744E 00	2.4800E 00
		FZ	5.9010E 00	2.4800E 00
		TX	5.0256E 01	2.4800E 00
		MY	1.0510E 02	2.4800E 00
		MZ	1.9597E 02	2.4800E 00
2	END-J	FX	1.2603E 00	2.2200E 00
		FY	3.4744E 00	2.4800E 00
		FZ	5.9010E 00	2.4800E 00
		TX	5.0256E 01	2.4800E 00
		MY	2.3199E 02	2.2200E 00
		MZ	3.4677E 01	2.5200E 00
3	END-I	FX	2.6900E-01	2.2200E 00
		FY	5.0173E 00	2.2200E 00
		FZ	2.9303E 00	2.4800E 00
		TX	5.0615E 01	2.4800E 00
		MY	3.9699E 01	2.5200E 00
		MZ	2.3198E 02	2.2200E 00
3	END-J	FX	3.2004E 00	2.2200E 00
		FY	3.8732E 00	2.2200E 00
		FZ	2.9303E 00	2.4800E 00
		TX	7.0074E 00	2.4800E 00
		MY	1.0863E 02	2.4800E 00
		MZ	1.1182E 02	2.4800E 00
4	END-I	FX	6.7909E 00	2.2200E 00
		FY	5.5393E 00	2.2200E 00

		FZ	3.5662E 00	2.2200E 00
		TX	2.5208E 00	2.4800E 00
		MY	1.0882E 02	2.4800E 00
		MZ	1.1182E 02	2.4800E 00
4	END-J	FX	8.7493E 00	2.2200E 00
		FY	5.2608E-01	2.4800E 00
		FZ	3.5662E 00	2.2200E 00
		TX	1.0069E 02	2.4800E 00
		MY	1.5565E 02	2.4800E 00
		MZ	4.9112E 01	2.4800E 00
5	END-I	FX	1.1762E 01	2.2200E 00
		FY	3.6621E-01	2.4800E 00
		FZ	3.9337E 00	2.2200E 00
		TX	7.5458E 01	2.4800E 00
		MY	1.6933E 02	2.4800E 00
		MZ	4.9113E 01	2.4800E 00
5	END-J	FX	1.1762E 01	2.2200E 00
		FY	3.6621E-01	2.4800E 00
		FZ	3.9337E 00	2.2200E 00
		TX	7.5458E 01	2.4800E 00
		MY	2.2816E 02	2.2200E 00
		MZ	4.2578E 01	2.4800E 00
6	END-I	FX	1.4073E 01	2.2200E 00
		FY	3.0530E-01	2.5400E 00
		FZ	3.9214E 00	2.2200E 00
		TX	7.5458E 01	2.4800E 00
		MY	2.2816E 02	2.2200E 00
		MZ	4.2577E 01	2.4800E 00
6	END-J	FX	1.4073E 01	2.2200E 00
		FY	3.0530E-01	2.5400E 00
		FZ	3.9214E 00	2.2200E 00
		TX	7.5458E 01	2.4800E 00
		MY	2.9815E 02	2.2200E 00
		MZ	3.7598E 01	2.4800E 00
7	END-I	FX	1.7471E 01	2.2200E 00
		FY	1.9590E 00	2.5400E 00
		FZ	4.5018E-01	2.4800E 00
		TX	8.1338E 01	2.4800E 00
		MY	2.2170E 01	2.4800E 00
		MZ	2.9814E 02	2.2200E 00
7	END-J	FX	1.2957E 01	2.2200E 00
		FY	1.1820E 01	2.4800E 00
		FZ	4.5018E-01	2.4800E 00
		TX	7.0545E 01	2.4800E 00

		MY	4.9835E 01	2.4800E 00
		MZ	1.3433E 02	2.5200E 00
8	END-I	FX	1.3300E 01	2.2200E 00
		FY	1.3769E 01	2.2200E 00
		FZ	7.5219E-01	2.4800E 00
		TX	6.8415E 01	2.4800E 00
		MY	5.2723E 01	2.4800E 00
		MZ	1.3433E 02	2.5200E 00
8	END-J	FX	2.1548E 00	2.5200E 00
		FY	1.9139E 01	2.2200E 00
		FZ	7.5219E-01	2.4800E 00
		TX	7.3990E 00	2.4800E 00
		MY	1.0362E 02	2.4800E 00
		MZ	3.6313E 02	2.4800E 00
9	END-I	FX	3.6807E 00	2.5200E 00
		FY	1.1095E 00	2.4800E 00
		FZ	2.0418E 01	2.2200E 00
		TX	2.3307E 01	2.4800E 00
		MY	3.6314E 02	2.4800E 00
		MZ	1.0124E 02	2.4800E 00
9	END-J	FX	3.6807E 00	2.5200E 00
		FY	1.1095E 00	2.4800E 00
		FZ	2.0418E 01	2.2200E 00
		TX	2.3307E 01	2.4800E 00
		MY	7.5960E 02	2.4800E 00
		MZ	1.2398E 02	2.4800E 00
10	END-I	FX	3.6836E 00	2.5200E 00
		FY	1.2119E 00	2.4800E 00
		FZ	2.0831E 01	2.2200E 00
		TX	2.3307E 01	2.4800E 00
		MY	7.5961E 02	2.4800E 00
		MZ	1.2398E 02	2.4800E 00
10	END-J	FX	3.6836E 00	2.5200E 00
		FY	1.2119E 00	2.4800E 00
		FZ	2.0831E 01	2.2200E 00
		TX	2.3307E 01	2.4800E 00
		MY	1.1775E 03	2.2200E 00
		MZ	1.4883E 02	2.4800E 00

TABLE 2-9 HOVGAARD PROBLEM DYNAMIC CASE A (TIME HISTORY ANALYSIS)

ELEMENT NUMBER	LOCATION	STRESS COMPONENT MAXIMA LONGITUDNL STRESS	CIRCUMER STRESS	SHEAR STRESS
1	END-I	87.47	0.0	4.94
	END-J	23.87	0.0	4.94
2	END-I	23.87	0.0	3.95
	END-J	25.16	0.0	3.95
3	END-I	28.07	47.67	3.78
	END-J	14.11	22.98	1.28
4	END-I	14.78	22.98	1.37
	END-J	20.44	10.09	6.03
5	END-I	20.94	0.0	4.75
	END-J	26.87	0.0	4.75
6	END-I	27.30	0.0	4.75
	END-J	34.57	0.0	4.75
7	END-I	39.28	61.27	4.70
	END-J	19.65	27.60	5.97
8	END-I	18.72	27.60	6.22
	END-J	44.26	74.62	3.98
9	END-I	40.75	0.0	5.07
	END-J	82.47	0.0	5.07
10	END-I	82.48	0.0	5.15
	END-J	126.81	0.0	5.15

TABLE 2-10 HOVGAARD PROBLEM DYNAMIC CASE B (RESPONSE SPECTRUM)

MODAL PARTICIPATION FACTORS

DIRECTION FACTORS

X = 1.0000 Y = 0.0 Z = 0.0

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT
EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	0.1971E 00	-0.3350E-01	-0.3158E 00
2	-0.3516E 00	0.1280E-01	-0.1689E 00
3	0.6402E-01	0.2697E 00	-0.2980E-01
4	-0.7370E-01	0.3765E-01	0.8817E-02
5	0.8497E-01	-0.3834E-01	0.8512E-02

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

NUMBER OF POINTS = 10
SCALE FACTOR = 0.10000E 01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	0.5850E-02	0.1334E 03
2	0.5880E-02	0.1362E 03
3	0.6540E-02	0.1347E 03
4	0.6580E-02	0.1351E 03
5	0.1250E-01	0.1401E 03
6	0.1266E-01	0.1661E 03
7	0.1818E-01	0.1359E 03
8	0.1852E-01	0.1371E 03
9	0.3333E-01	0.2846E 03
10	0.3448E-01	0.3934E 03

TABLE 2-11 HOVGAARD PROBLEM DYNAMIC CASE B (RESPONSE SPECTRUM)

DISPLACEMENTS / ROTATIONS

NODE NUMBER	MODE NUMBER *	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
11	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
	RMS	0.0	0.0	0.0	0.0	0.0	0.0
10	1	0.21459E-03	-0.81875E-04	-0.13659E-05	-0.76438E-05	-0.19655E-04	-0.18558E-05
	2	-0.14469E-03	0.63600E-05	-0.70206E-06	0.53019E-06	0.11960E-04	-0.20268E-06
	3	-0.13901E-05	0.19848E-04	0.75348E-08	0.16948E-06	0.11877E-06	0.92691E-07
	4	-0.46527E-05	0.20911E-05	-0.14637E-06	0.15730E-06	0.34063E-06	-0.34919E-07
	5	-0.25303E-05	-0.57023E-05	0.39183E-09	-0.45154E-06	0.19755E-06	-0.17332E-06
	RMS	0.25887E-03	0.84704E-04	0.15427E-05	0.78619E-05	0.23012E-04	0.18774E-05
9	1	0.79126E-03	-0.30948E-03	-0.27317E-05	-0.14225E-04	-0.35343E-04	-0.37115E-05
	2	-0.46583E-03	0.20711E-04	-0.14039E-05	0.78146E-06	0.17259E-04	-0.40536E-06
	3	-0.46810E-05	0.66779E-04	0.15065E-07	0.26549E-05	0.18632E-06	0.18538E-06
	4	-0.12726E-04	0.59406E-05	-0.29241E-06	0.17645E-06	0.34463E-06	-0.69838E-07
	5	-0.75750E-05	-0.17405E-04	0.78258E-09	-0.60206E-06	0.25272E-06	-0.34663E-06
	RMS	0.91833E-03	0.31782E-03	0.30853E-05	0.14505E-04	0.39335E-04	0.37549E-05
8	1	0.21783E-02	-0.86247E-03	-0.36851E-03	-0.29991E-04	-0.69490E-04	-0.51020E-05
	2	-0.89998E-03	0.45225E-04	0.83006E-04	0.67584E-06	0.11755E-04	-0.62383E-06
	3	-0.10564E-04	0.14856E-03	0.14061E-05	0.33619E-05	0.23610E-06	0.37110E-06
	4	-0.12621E-04	0.81719E-05	-0.19738E-05	-0.10312E-06	-0.46254E-06	-0.76818E-07
	5	-0.12993E-04	-0.28944E-04	0.97449E-06	-0.44357E-06	0.12502E-06	-0.62012E-06
	RMS	0.23570E-02	0.87685E-03	0.37775E-03	0.30190E-04	0.70479E-04	0.51911E-05
7	1	0.32724E-02	-0.12066E-02	-0.21224E-02	-0.38554E-04	-0.82637E-04	-0.81364E-05
	2	-0.96811E-03	0.64011E-04	0.12603E-03	0.46716E-07	-0.70186E-05	-0.37416E-06
	3	-0.13505E-04	0.17311E-03	0.56798E-05	0.26501E-05	0.13026E-06	0.15943E-05
	4	-0.24263E-05	0.50207E-05	-0.19376E-04	-0.44933E-06	-0.80255E-06	0.51528E-07
	5	-0.13666E-04	-0.15638E-04	0.15416E-05	-0.26113E-06	-0.42626E-07	-0.93040E-06
	RMS	0.34126E-02	0.12207E-02	0.21262E-02	0.38648E-04	0.82939E-04	0.83517E-05
6	1	0.32730E-02	-0.10411E-02	-0.35999E-02	-0.43431E-04	-0.81852E-04	-0.10520E-04
	2	-0.96929E-03	0.69335E-04	-0.45447E-04	-0.36006E-06	-0.11494E-04	-0.17863E-06
	3	-0.13503E-04	0.13997E-03	0.75731E-05	0.22658E-05	0.79056E-07	0.21073E-05
	4	-0.24590E-05	0.38831E-05	-0.32461E-04	-0.64222E-06	-0.57712E-06	0.80237E-07
	5	-0.13619E-04	0.11238E-05	0.47356E-06	-0.23258E-06	-0.71210E-07	-0.87478E-06
	RMS	0.34135E-02	0.10528E-02	0.36004E-02	0.43497E-04	0.82657E-04	0.10766E-04
5	1	0.32734E-02	-0.83048E-03	-0.50385E-02	-0.48309E-04	-0.78508E-04	-0.13135E-04
	2	-0.97026E-03	0.70163E-04	-0.27992E-03	-0.76684E-06	-0.14088E-04	0.11374E-06
	3	-0.13496E-04	0.98159E-04	0.94958E-05	0.18816E-05	0.25174E-07	0.24990E-05
	4	-0.24076E-05	0.21860E-05	-0.39616E-04	-0.83511E-06	-0.19601E-06	0.96181E-07
	5	-0.13544E-04	0.15138E-04	-0.96042E-06	-0.20403E-06	-0.82572E-07	-0.62504E-06
	RMS	0.34142E-02	0.83934E-03	0.50464E-02	0.48359E-04	0.79762E-04	0.13386E-04
4	1	0.31569E-02	-0.37361E-03	-0.65263E-02	-0.58102E-04	-0.59437E-04	-0.22615E-04
	2	-0.96480E-03	0.51823E-04	-0.67686E-03	-0.17563E-05	-0.15509E-04	0.18258E-05
	3	0.18530E-05	0.28394E-04	-0.40650E-06	0.12670E-05	-0.23007E-07	0.24983E-05
	4	-0.21977E-05	0.16161E-06	-0.23004E-04	-0.11873E-05	0.84714E-06	0.35910E-07
	5	-0.10920E-04	0.14599E-04	-0.20352E-05	-0.16283E-06	-0.68131E-07	0.70912E-06
	RMS	0.33010E-02	0.37853E-03	0.65618E-02	0.58154E-04	0.61433E-04	0.22836E-04

3	1	0.25462E-02	-0.33358E-06	-0.57894E-02	-0.72932E-04	-0.43053E-04	-0.31085E-04
	2	-0.86724E-03	0.67979E-07	-0.78905E-03	-0.68654E-05	-0.11825E-04	0.74759E-05
	3	0.38801E-04	0.94603E-06	-0.17522E-04	0.33178E-06	0.12553E-06	0.68480E-06
	4	-0.23128E-05	0.82480E-07	0.16343E-04	-0.84063E-06	0.83490E-06	-0.16271E-07
	5	0.12692E-04	0.15458E-06	0.67505E-07	-0.97561E-07	-0.57757E-07	0.95677E-06
RMS	*	0.26902E-02	0.10214E-05	0.58429E-02	0.73260E-04	0.44656E-04	0.31993E-04
2	1	0.86104E-03	-0.16684E-06	-0.19267E-02	-0.60718E-04	-0.21527E-04	-0.26928E-04
	2	-0.34745E-03	0.34023E-07	-0.31521E-03	-0.89712E-05	-0.59127E-05	0.98760E-05
	3	0.31759E-04	0.47447E-06	-0.14681E-04	-0.30878E-06	0.62763E-07	-0.67249E-06
	4	-0.21259E-05	0.41565E-07	0.30261E-04	0.40819E-06	0.41745E-06	0.34531E-07
	5	0.34535E-04	0.78051E-07	0.24280E-05	0.22975E-07	-0.28879E-07	-0.38577E-06
RMS	*	0.92968E-03	0.51180E-06	0.19526E-02	0.61379E-04	0.22328E-04	0.28693E-04
1	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
RMS	*	0.0	0.0	0.0	0.0	0.0	0.0

* RMS represents the root mean square of the displacements from all mode shapes considered.

TABLE 2-12 HOVGAARD PROBLEM 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 — TX = X-TWISTING MOMENT
VY = Y-SHEAR FORCE — MY = Y- BENDING MOMENT
VZ = Z-SHEAR FORCE — 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)
0.1204E 01	0.1483E 02	0.7985E 01	0.2510E 03	0.6321E 03	0.1299E 04	0.1204E 01	0.1483E 02	0.7985E 01	0.2510E 03	0.2160E 03	0.4990E 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)
0.1198E 01	0.1194E 02	0.6084E 01	0.2510E 03	0.2160E 03	0.4990E 03	0.1198E 01	0.1194E 02	0.6084E 01	0.2510E 03	0.1401E 03	0.1691E 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)
0.1228E 01	0.3095E 01	0.3209E 01	0.2152E 03	0.2128E 03	0.1401E 03	0.1819E 01	0.2790E 01	0.3209E 01	0.1245E 03	0.2856E 03	0.1299E 03

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

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.2508E 01	0.2192E 01	0.3209E 01	0.1964E 02	0.3285E 03	0.1316E 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)
0.4349E 01	0.3011E 01	0.4937E 01	0.1806E 02	0.3286E 03	0.1316E 03	0.5076E 01	0.1482E 01	0.4937E 01	0.1162E 03	0.2670E 03	0.1210E 03

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

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.5139E 01	0.1251E 01	0.4937E 01	0.1967E 03	0.1876E 03	0.1222E 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)
0.7573E 01	0.8188E 00	0.7288E 01	0.1685E 03	0.2132E 03	0.1222E 03	0.7573E 01	0.8188E 00	0.7288E 01	0.1685E 03	0.1866E 03	0.1164E 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)
0.9514E 01	0.9948E 00	0.8624E 01	0.1685E 03	0.1866E 03	0.1164E 03	0.9514E 01	0.9948E 00	0.8624E 01	0.1685E 03	0.2436E 03	0.1020E 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(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.1194E 02	0.9778E 01	0.1706E 01	0.1841E 03	0.7007E 02	0.2436E 03	0.1122E 02	0.1060E 02	0.1706E 01	0.1909E 03	0.3328E 02	0.2958E 03

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

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.1028E 02	0.1152E 02	0.1706E 01	0.1645E 03	0.1142E 03	0.3609E 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(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.1058E 02	0.1273E 02	0.2154E 01	0.1597E 03	0.1209E 03	0.3609E 03	0.9654E 01	0.1345E 02	0.2154E 01	0.1007E 03	0.1940E 03	0.4418E 03

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

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
0.9870E 01	0.1328E 02	0.2154E 01	0.2030E 02	0.2420E 03	0.5382E 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)
0.9635E 01	0.2531E 01	0.1456E 02	0.5606E 02	0.5382E 03	0.2363E 03	0.9635E 01	0.2531E 01	0.1456E 02	0.5606E 02	0.7624E 03	0.2812E 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)
0.9637E 01	0.2630E 01	0.1484E 02	0.5606E 02	0.7624E 03	0.2812E 03	0.9637E 01	0.2630E 01	0.1484E 02	0.5606E 02	0.1030E 04	0.3296E 03

TABLE 2-13 HOVGAARD PROBLEM DYNAMIC CASE B (RESPONSE SPECTRUM)

ELEMENT NUMBER	LOCATION	RESPONSE SPECTRUM STRESS COMPONENTS LNGTDL STRESS	CIRCUMF STRESS	SHEAR STRESS
1	END-I	153.699	0.0	16.494
	END-J	58.008	0.0	16.494
2	END-I	58.007	0.0	15.848
	END-J	23.563	0.0	15.848
3	END-I	25.933	28.794	12.271
	CENTER	34.839	26.689	7.413
	END-J	40.148	27.049	1.772
4	END-I	40.503	27.047	2.043
	CENTER	33.192	24.860	7.140
	END-J	23.614	25.119	11.403
5	END-I	27.533	0.0	10.327
	END-J	24.785	0.0	10.327
6	END-I	25.148	0.0	10.580
	END-J	29.844	0.0	10.580
7	END-I	31.657	50.054	11.641
	CENTER	37.829	60.785	12.153
	END-J	45.508	74.153	10.924
8	END-I	45.565	74.152	10.904
	CENTER	55.169	90.790	7.903
	END-J	66.051	110.594	3.600
9	END-I	64.266	0.0	5.749
	END-J	88.157	0.0	5.749
10	END-I	88.157	0.0	5.803
	END-J	116.732	0.0	5.803

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

DISPLACEMENT MAXIMA

NODE NUMBER	DISPLACEMENT COMPONENT	MAXIMUM * VALUE	TIME AT MAXIMUM	PLOT SYMBOL
2	1	9.6084E-04	2.2200E 00	NA
	2	2.6312E-07	2.2200E 00	NA
	3	6.5622E-04	2.4800E 00	NA
3	1	2.4271E-03	2.4800E 00	NA
	2	5.2629E-07	2.2200E 00	NA
	3	2.0242E-03	2.4800E 00	NA
4	1	2.8021E-03	2.4800E 00	NA
	2	2.1572E-04	2.4800E 00	NA
	3	2.5576E-03	2.4800E 00	NA
5	1	2.8527E-03	2.4800E 00	NA
	2	4.0857E-04	2.4800E 00	NA
	3	2.2251E-03	2.4800E 00	NA
6	1	2.8513E-03	2.4800E 00	NA
	2	4.8593E-04	2.4800E 00	NA
	3	1.7619E-03	2.4800E 00	NA
7	1	2.8496E-03	2.4800E 00	NA
	2	5.4327E-04	2.4800E 00	NA
	3	1.2141E-03	2.4800E 00	NA
8	1	2.2208E-03	2.4800E 00	NA
	2	3.7524E-04	2.4800E 00	NA
	3	2.8374E-04	2.4800E 00	NA
9	1	1.0008E-03	2.2200E 00	NA
	2	1.3173E-04	2.4800E 00	NA
	3	1.2412E-06	2.5200E 00	NA
10	1	3.0314E-04	2.2200E 00	NA
	2	3.4524E-05	2.4800E 00	NA
	3	6.2057E-07	2.5200E 00	NA
11	3	1.0008E-03	2.2200E 00	NA
	2	1.3173E-04	2.4800E 00	NA
	3	1.2412E-06	2.5200E 00	NA

* All values represent the absolute maximum.

TABLE 2-15 HOVGAARD PROBLEM 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	6.1879E-01	2.2200E 00
		FY	3.8322E 00	2.4800E 00
		FZ	1.2324E 01	2.2200E 00
		TX	5.1553E 01	2.4800E 00
		MY	7.2488E 02	2.2200E 00
		MZ	4.1729E 02	2.4800E 00
1	END-J	FX	6.1879E-01	2.2200E 00
		FY	3.8322E 00	2.4800E 00
		FZ	1.2324E 01	2.2200E 00
		TX	5.1553E 01	2.4800E 00
		MY	8.2195E 01	2.4800E 00
		MZ	2.0863E 02	2.4800E 00
2	END-I	FX	6.1890E-01	2.2200E 00
		FY	3.6905E 00	2.4800E 00
		FZ	5.1439E 00	2.4800E 00
		TX	5.1553E 01	2.4800E 00
		MY	8.2201E 01	2.4800E 00
		MZ	2.0864E 02	2.4800E 00
2	END-J	FX	6.1890E-01	2.2200E 00
		FY	3.6905E 00	2.4800E 00
		FZ	5.1439E 00	2.4800E 00
		TX	5.1553E 01	2.4800E 00
		MY	2.0876E 02	2.2200E 00
		MZ	3.5523E 01	2.5200E 00
3	END-I	FX	2.1358E-01	2.4800E 00
		FY	4.1593E 00	2.2200E 00
		FZ	3.0866E 00	2.4800E 00
		TX	5.2067E 01	2.4800E 00
		MY	4.0284E 01	2.5200E 00
		MZ	2.0875E 02	2.2200E 00
3	END-J	FX	2.9563E 00	2.2200E 00
		FY	2.9269E 00	2.2200E 00
		FZ	3.0866E 00	2.4800E 00
		TX	7.0156E 00	2.4800E 00
		MY	1.1297E 02	2.4800E 00
		MZ	1.1362E 02	2.4800E 00
4	END-I	FX	6.1297E 00	2.2200E 00
		FY	4.8165E 00	2.2200E 00

		FZ	3.2623E 00	2.2200E 00
		TX	2.3515E 00	2.4800E 00
		MY	1.1316E 02	2.4800E 00
		MZ	1.1361E 02	2.4800E 00
4	END-J	FX	7.7742E 00	2.2200E 00
		FY	6.1202E-01	2.2200E 00
		FZ	3.2623E 00	2.2200E 00
		TX	1.0144E 02	2.4800E 00
		MY	1.5279E 02	2.4800E 00
		MZ	5.9988E 01	2.4800E 00
5	END-I	FX	1.0750E 01	2.2200E 00
		FY	5.6261E-01	2.2200E 00
		FZ	3.4423E 00	2.2200E 00
		TX	7.6637E 01	2.4800E 00
		MY	1.6662E 02	2.4800E 00
		MZ	5.9988E 01	2.4800E 00
5	END-J	FX	1.0750E 01	2.2200E 00
		FY	5.6261E-01	2.2200E 00
		FZ	3.4423E 00	2.2200E 00
		TX	7.6637E 01	2.4800E 00
		MY	2.1604E 02	2.2200E 00
		MZ	5.0043E 01	2.4800E 00
6	END-I	FX	1.3035E 01	2.2200E 00
		FY	6.0303E-01	2.4800E 00
		FZ	3.5614E 00	2.2200E 00
		TX	7.6637E 01	2.4800E 00
		MY	2.1604E 02	2.2200E 00
		MZ	5.0031E 01	2.4800E 00
6	END-J	FX	1.3035E 01	2.2200E 00
		FY	6.0303E-01	2.4800E 00
		FZ	3.5614E 00	2.2200E 00
		TX	7.6637E 01	2.4800E 00
		MY	2.7961E 02	2.2200E 00
		MZ	3.9266E 01	2.4800E 00
7	END-I	FX	1.6429E 01	2.2200E 00
		FY	2.1895E 00	2.5200E 00
		FZ	6.6882E-01	2.4800E 00
		TX	8.2818E 01	2.4800E 00
		MY	2.3572E 01	2.4800E 00
		MZ	2.7962E 02	2.2200E 00
7	END-J	FX	1.2415E 01	2.2200E 00
		FY	1.1060E 01	2.4800E 00
		FZ	6.6882E-01	2.4800E 00
		TX	7.0488E 01	2.4800E 00

		MY	5.5180E 01	2.4800E 00
		MZ	1.3418E 02	2.5200E 00
8	END-I	FX	1.3022E 01	2.2200E 00
		FY	1.2996E 01	2.4800E 00
		FZ	6.9625E-01	2.4800E 00
		TX	6.8135E 01	2.4800E 00
		MY	5.8061E 01	2.4800E 00
		MZ	1.3416E 02	2.5200E 00
8	END-J	FX	2.4557E 00	2.5200E 00
		FY	1.8246E 01	2.2200E 00
		FZ	6.9625E-01	2.4800E 00
		TX	4.1148E 00	2.4800E 00
		MY	1.0598E 02	2.4800E 00
		MZ	3.4258E 02	2.4800E 00
9	END-I	FX	3.8765E 00	2.5200E 00
		FY	7.1315E-01	2.4800E 00
		FZ	2.1260E 01	2.2200E 00
		TX	2.0426E 01	2.4800E 00
		MY	3.4257E 02	2.4800E 00
		MZ	1.0408E 02	2.4800E 00
9	END-J	FX	3.8765E 00	2.5200E 00
		FY	7.1315E-01	2.4800E 00
		FZ	2.1260E 01	2.2200E 00
		TX	2.0426E 01	2.4800E 00
		MY	7.5262E 02	2.4800E 00
		MZ	1.1870E 02	2.4800E 00
10	END-I	FX	3.8763E 00	2.5200E 00
		FY	7.1683E-01	2.4800E 00
		FZ	2.4165E 01	2.2200E 00
		TX	2.0426E 01	2.4800E 00
		MY	7.5262E 02	2.4800E 00
		MZ	1.1870E 02	2.4800E 00
10	END-J	FX	3.8763E 00	2.5200E 00
		FY	7.1683E-01	2.4800E 00
		FZ	2.4165E 01	2.2200E 00
		TX	2.0426E 01	2.4800E 00
		MY	1.2371E 03	2.2200E 00
		MZ	1.3339E 02	2.4800E 00

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

ELEMENT NUMBER	LOCATION	STRESS COMPONENT MAXIMA LONGITUDNL STRESS	CIRCUMFR STRESS	SHEAR STRESS
1	END-I	88.99	0.0	5.16
	END-J	23.94	0.0	5.16
2	END-I	23.95	0.0	3.93
	END-J	22.62	0.0	3.93
3	END-I	25.25	42.90	3.74
	END-J	14.28	23.35	1.17
4	END-I	14.87	23.35	1.22
	END-J	19.91	12.33	6.01
5	END-I	20.83	0.0	4.73
	END-J	25.58	0.0	4.73
6	END-I	26.01	0.0	4.75
	END-J	32.45	0.0	4.75
7	END-I	36.85	57.46	4.83
	END-J	18.53	27.57	5.82
8	END-I	18.64	27.57	6.06
	END-J	41.83	70.40	3.64
9	END-I	38.77	0.0	5.07
	END-J	81.69	0.0	5.07
10	END-I	81.69	0.0	5.62
	END-J	132.94	0.0	5.62

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.

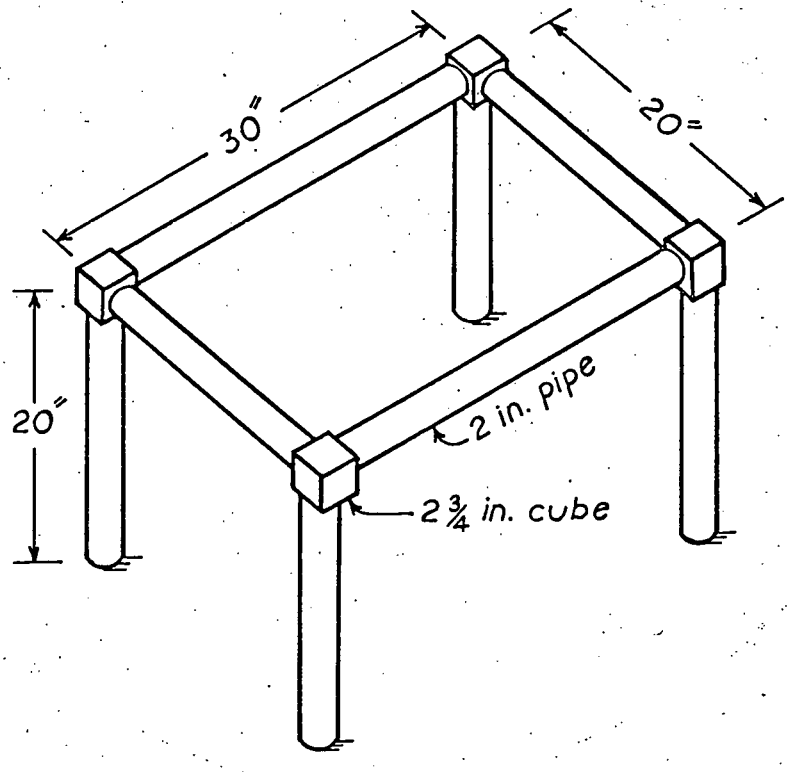
Problem 3 - Dynamic Analysis of a Coffee Table

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

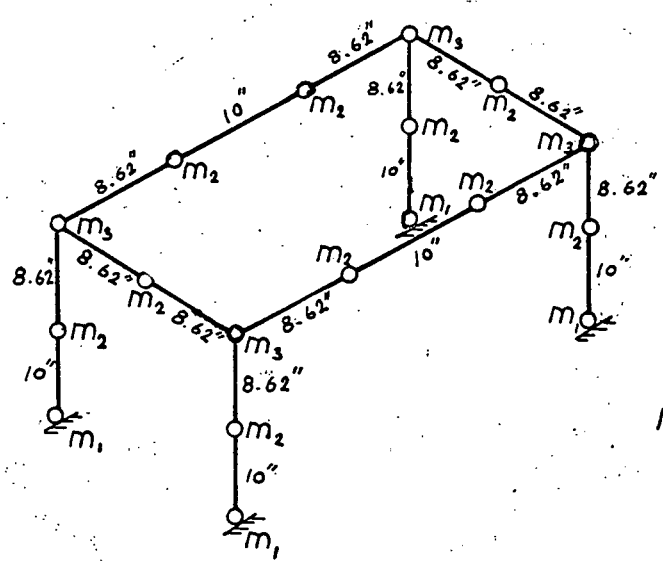
Problem Description

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 Swanson[16], 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.

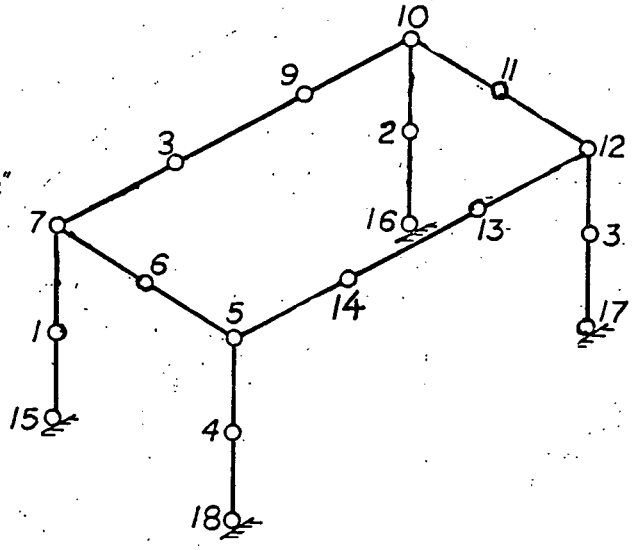
ii. Material data - The member properties are as follows:



(a) Isometric view



(b) Lumped masses and dimensions



(c) Element and node numbers

Fig. 3-1

Coffee Table

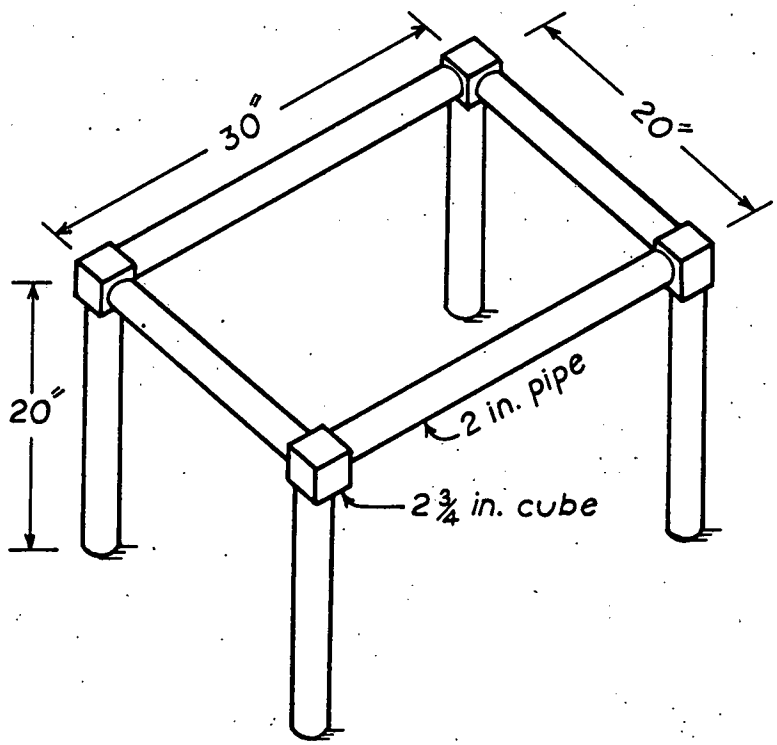


Fig. 3-1a

A Coffee Table

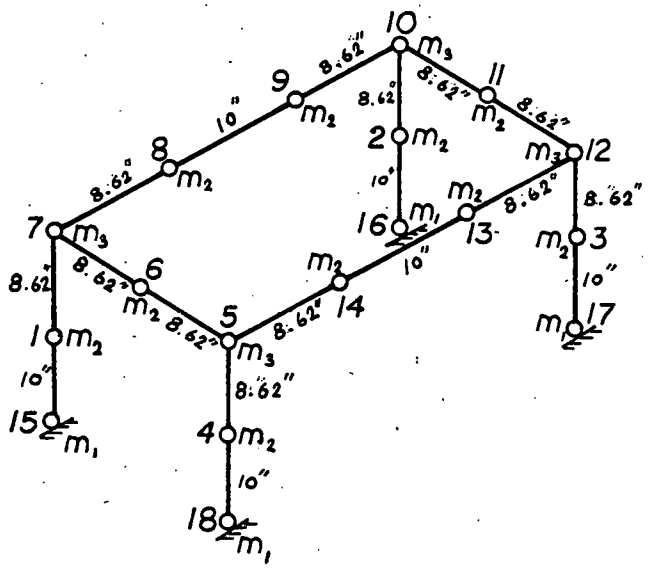


Fig. 3-1b

Lumped Mass System

TABLE 3-1 INPUT DATA FOR COFFEE TABLE PROBLEM

NODAL COORDINATES

NODE NUMBER	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES 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	18.625	17.250	0	0.0
6	0	0	0	0	0	0	0.0	18.625	8.625	0	0.0
7	0	0	0	0	0	0	0.0	18.625	0.0	0	0.0
8	0	0	0	0	0	0	8.625	18.625	0.0	0	0.0
9	0	0	0	0	0	0	18.625	18.625	0.0	0	0.0
10	0	0	0	0	0	0	27.250	18.625	0.0	0	0.0
11	0	0	0	0	0	0	27.250	18.625	8.625	0	0.0
12	0	0	0	0	0	0	27.250	18.625	17.250	0	0.0
13	0	0	0	0	0	0	18.625	18.625	17.250	0	0.0
14	0	0	0	0	0	0	8.625	18.625	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

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 gotten from EPIPE and those obtained by Crede[15], Tuba and Wright[17], Swanson[16] (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 gotten from the time-history analysis. Similarly, tables 3-8 to 3-13 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 3-14 to 3-16. 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.

TABLE 3-3a

Resonant Frequencies (CPS) of a Coffee Table

Experimental Values Ref.[15]	Crede Ref.[15]	Tuba and Wright Ref.[17]	ANSYS Ref.[16]	EPIPE Model A
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

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

NATURAL FREQUENCIES

MODE NUMBER	CIRCULAR FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)	TOLERANCE
1	0.6990E 03	0.1112E 03	0.8989E-02	0.2558E-06
2	0.7276E 03	0.1158E 03	0.8635E-02	0.7083E-06
3	0.8619E 03	0.1372E 03	0.7290E-02	0.3366E-06
4	0.1356E 04	0.2158E 03	0.4634E-02	0.0
5	0.2540E 04	0.4043E 03	0.2474E-02	0.7439E-05

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

NODE NUMBER	EIGEN-VECTOR	MODE SHAPES 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	0.97431E-01	-0.89601E 00	-0.23211E-01	-0.17426E 00	-0.11563E-01
	4	0.22087E 01	-0.12473E 00	-0.97781E 00	-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	0.18534E 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	0.27362E-02	-0.30090E-01	0.24398E 01	0.75627E-01	0.94195E-02	0.14663E-04
	3	-0.14014E 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	-0.33590E-01	-0.32593E-02	0.87442E-01	0.34702E-02	0.46651E 00	0.79154E-02
11	1	0.25101E 01	-0.16469E-01	0.54338E-03	-0.44822E-05	-0.79143E-04	-0.93483E-01
	2	0.57809E-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	0.23024E-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	0.24717E 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	-0.21970E 01	0.25774E-01	0.14124E 01	0.37896E-01	0.10484E 00	0.65226E-01
	5	-0.33609E-01	-0.32603E-02	-0.87354E-01	-0.34695E-02	-0.46653E 00	0.78673E-02
9	1	0.24748E 01	0.18542E 00	0.72392E-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	0.89586E 00	0.23207E-01	-0.17426E 00	0.11551E-01
	4	-0.22083E 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
8	1	0.24748E 01	-0.18542E 00	-0.73395E-02	-0.11449E-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	0.12707E-01	-0.88475E-01	-0.50184E 01	-0.34688E-02	0.38400E 00	-0.66300E-02
7	1	0.24717E 01	0.16257E-01	-0.35822E-03	-0.20817E-04	0.34364E-02	-0.93502E-01
	2	0.28081E-02	0.30089E-01	0.24396E 01	0.75623E-01	-0.94323E-02	0.12622E-04
	3	0.13999E 01	-0.17925E-01	-0.23113E 01	-0.63246E-01	-0.15192E 00	-0.42206E-01
	4	-0.21978E 01	-0.25773E-01	-0.14124E 01	-0.37896E-01	0.10484E 00	0.65224E-01
	5	0.34021E-01	-0.33642E-02	-0.87277E-01	-0.34686E-02	0.46610E 00	-0.79089E-02
6	1	0.25101E 01	0.16467E-01	-0.63682E-03	0.52090E-05	-0.80005E-04	-0.93483E-01
	2	0.30560E-04	0.55616E-06	0.24413E 01	-0.20172E-01	0.26679E-02	-0.17347E-05
	3	-0.78506E-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	0.84615E-02	0.30405E 00	-0.80873E-05
	5	0.23376E 01	0.13250E-01	0.48200E-04	-0.43705E-05	-0.74799E-05	-0.79069E-02
5	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	0.25777E-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	-0.64974E-04	-0.19058E-02	-0.16534E 00
	2	-0.15603E-02	-0.16166E-01	0.11778E 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	-0.16160E-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	0.13928E-02	-0.17652E-02	0.46850E-01	0.57329E-02	0.25048E 00	0.13640E-02
2	1	0.11500E 01	-0.87358E-02	0.83089E-04	0.15579E-04	0.18450E-02	-0.16542E 00
	2	-0.15258E-02	0.16167E-01	0.11779E 01	0.16550E 00	0.50597E-02	0.19257E-03
	3	0.68323E 00	0.96329E-02	0.11425E 01	0.15782E 00	-0.81568E-01	-0.95069E-01
	4	-0.11021E 01	0.13873E-01	0.71863E 00	0.96274E-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	0.11500E 01	0.87347E-02	-0.12040E-03	-0.21931E-04	0.18451E-02	-0.16542E 00
	2	0.16053E-02	0.16167E-01	0.11778E 01	0.16549E 00	-0.50643E-02	-0.20383E-03
	3	0.68323E 00	-0.96341E-02	-0.11426E 01	-0.15783E 00	-0.81568E-01	-0.95069E-01
	4	-0.11021E 01	-0.13873E-01	-0.71864E 00	-0.96275E-01	0.56290E-01	0.14898E 00
	5	-0.68601E-03	-0.18240E-02	-0.46638E-01	-0.57231E-02	0.25025E 00	-0.13892E-02

EIGENSOLUTION TIME LOG

EIGENSOLUTION = 43.19
PRINTING = 0.62

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

DISPLACEMENT MAXIMA

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	2.8050E-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	2.6800E-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	1.7861E-06	4.9000E 00	NA
	3	1.7280E-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	1.5757E-08	2.6000E 00	NA
11	1	2.7227E-04	4.9000E 00	NA
	2	1.7863E-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

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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	END-I	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	5.1525E 00	4.9000E 00
		MZ	2.5101E-03	4.9000E 00
8	END-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	END-I	FX	1.0491E-01	4.9000E 00
		FY	3.6257E-03	4.9000E 00
		FZ	5.9303E-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	END-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	END-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	END-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 00	4.9000E 00
		MZ	1.6891E-02	4.9000E 00
11	END-I	FX	2.8369E 00	4.9000E 00
		FY	1.4138E-03	4.9000E 00
		FZ	5.0894E 00	4.9000E 00
		TX	2.9262E-01	4.9000E 00
		MY	3.8735E 01	4.9000E 00

		MZ	1.6099E-02	4.9000E 00
11	END-J	FX	2.8369E 00	4.9000E 00
		FY	1.6138E-03	4.9000E 00
		FZ	5.0883E 00	4.9000E 00
		TX	2.9262E-01	4.9000E 00
		MY	5.1515E 00	4.9000E 00
		MZ	2.1798E-03	4.9000E 00
12	END-I	FX	2.8411E 00	4.9000E 00
		FY	1.7239E-03	4.9000E 00
		FZ	5.6329E 00	4.9000E 00
		TX	2.9262E-01	4.9000E 00
		MY	5.1511E 00	4.9000E 00
		MZ	2.1798E-03	4.9000E 00
12	END-J	FX	2.8411E 00	4.9000E 00
		FY	1.7239E-03	4.9000E 00
		FZ	5.6329E 00	4.9000E 00
		TX	2.9262E-01	4.9000E 00
		MY	6.1480E 01	4.9000E 00
		MZ	1.5059E-02	4.9000E 00
13	END-I	FX	1.1693E 00	4.9000E 00
		FY	2.8108E 00	4.9000E 00
		FZ	1.0613E-01	4.9000E 00
		TX	8.3295E-04	2.6000E 00
		MY	1.4628E 00	4.9000E 00
		MZ	3.8736E 01	4.9000E 00
13	END-J	FX	1.1693E 00	4.9000E 00
		FY	2.8108E 00	4.9000E 00
		FZ	1.0613E-01	4.9000E 00
		TX	8.3295E-04	2.6000E 00
		MY	5.4736E-01	4.9000E 00
		MZ	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
		TX	8.3242E-04	2.6000E 00
		MY	5.4738E-01	4.9000E 00
		MZ	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
		TX	8.3242E-04	2.6000E 00
		MY	5.4745E-01	4.9000E 00
		MZ	1.4493E 01	4.9000E 00

15	END-I	FX	1.1696E 00	4.9000E 00
		FY	2.8108E 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	2.8108E 00	4.9000E 00
		FZ	1.0614E-01	4.9000E 00
		TX	8.2304E-04	2.6000E 00
		MY	1.4628E 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 COFFEE TABLE DYNAMIC CASE A (TIME HISTORY ANALYSIS)

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

15	END-I	25.28	0.0	2.62
	END-J	65.75	0.0	2.62
16	END-I	65.76	0.0	2.62
	END-J	25.29	0.0	2.62
17	END-I	24.20	0.0	2.70
	END-J	24.20	0.0	2.70
18	END-I	25.29	0.0	2.62
	END-J	65.76	0.0	2.62

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TABLE 3-8 COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	0.4253E 00	0.9313E-08	-0.8184E-05
2	0.3180E-05	0.1630E-07	0.4260E 00
3	-0.1325E-03	-0.8382E-07	-0.1242E-04
4	0.3920E-04	0.1211E-06	-0.1092E-05
5	0.3324E-05	-0.3315E-02	0.3017E-05

TABLE 3-19. COFFEE TABLE DYNAMIC CASE B (RESPONSE SPECTRUM)

NODE NUMBER	MODE NUMBER X	DISPLACEMENTS / ROTATIONS 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
RMS		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
RMS		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
RMS		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
RMS		0.0	0.0	0.0	0.0	0.0	0.0
14	1	0.29868E-03	-0.22379E-04	0.82802E-06	-0.40413E-09	0.91130E-07	0.24705E-05
	2	-0.21496E-11	-0.68047E-10	0.56259E-08	0.16442E-09	-0.27092E-10	-0.24861E-12
	3	-0.34751E-07	0.24114E-08	-0.22176E-07	-0.57448E-09	-0.43130E-08	-0.28619E-09
	4	0.65009E-08	-0.36713E-09	-0.28780E-08	-0.40932E-10	-0.45258E-09	0.38549E-10
	5	0.87526E-12	-0.60923E-11	0.34665E-09	0.23934E-12	-0.26524E-10	-0.45819E-12
RMS		0.29868E-03	0.22379E-04	0.82834E-06	0.72253E-09	0.91233E-07	0.24705E-05
13	1	0.29869E-03	0.22380E-04	-0.84037E-06	0.32795E-10	0.91045E-07	0.24705E-05
	2	0.22003E-11	-0.68043E-10	0.56260E-08	0.16443E-09	0.27069E-10	0.24900E-12
	3	-0.34751E-07	-0.24115E-08	0.22173E-07	0.57436E-09	-0.43130E-08	-0.28619E-09
	4	0.65009E-08	0.36714E-09	0.28780E-08	0.40932E-10	-0.45258E-09	0.38549E-10
	5	-0.84753E-12	-0.60909E-11	0.34678E-09	0.23955E-12	0.26514E-10	0.45831E-12
RMS		0.29868E-03	0.22380E-04	0.84069E-06	0.59973E-09	0.91148E-07	0.24705E-05
12	1	0.29830E-03	-0.19639E-05	0.99164E-07	0.40926E-09	-0.42868E-06	-0.11286E-04
	2	0.59492E-11	-0.65423E-10	0.53046E-08	0.16443E-09	0.20480E-10	0.31880E-13
	3	-0.34685E-07	-0.44336E-09	0.57201E-07	0.15652E-08	-0.37599E-08	0.10460E-08
	4	0.64702E-08	-0.75864E-10	0.41572E-08	0.11154E-09	0.30856E-09	-0.19203E-09
	5	-0.23203E-11	-0.22515E-12	0.60404E-11	0.23972E-12	0.32226E-10	0.54678E-12
RMS		0.29830E-03	0.19639E-05	0.11468E-06	0.16300E-08	0.42870E-06	0.11286E-04
11	1	0.30309E-03	-0.19886E-05	0.46612E-07	-0.54123E-09	-0.95565E-08	-0.11288E-04
	2	0.12569E-12	-0.14998E-14	0.53082E-08	-0.43951E-10	-0.58191E-11	-0.40431E-14
	3	-0.19481E-10	0.78355E-13	0.57256E-07	-0.44512E-09	-0.41043E-08	0.71618E-12
	4	0.70416E-12	-0.44337E-14	0.41671E-09	-0.24905E-10	0.89492E-09	-0.22628E-13
	5	-0.14171E-09	0.92840E-12	0.33931E-14	-0.13337E-16	0.34001E-15	0.54512E-12
RMS		0.30309E-03	0.19986E-05	0.87343E-07	0.70257E-09	0.10439E-07	0.11288E-04

10	1	0.29846E-03	-0.19633E-05	0.31978E-07	0.31444E-08	0.41494E-06	-0.11290E-04
	2	-0.57419E-11	0.65421E-10	0.53046E-08	0.16443E-09	0.20490E-10	-0.39945E-13
	3	0.34647E-07	0.44359E-09	0.57201E-07	0.15652E-08	-0.37600E-08	-0.10446E-08
	4	-0.64689E-08	0.75860E-10	0.41572E-08	0.11154E-09	0.30857E-09	0.19198E-09
	5	-0.23217E-11	-0.22522E-12	-0.60343E-11	-0.23967E-12	-0.32228E-10	0.54346E-12
RMS		0.29846E-03	0.19633E-05	0.65878E-07	0.35180E-08	0.41495E-06	0.11290E-04
9	1	0.29883E-03	0.22389E-04	0.87413E-06	0.10477E-08	-0.10084E-06	0.24717E-05
	2	-0.19928E-11	0.68066E-10	0.56261E-08	0.16443E-09	0.27079E-10	-0.24748E-12
	3	0.34713E-07	0.24085E-08	0.22172E-07	0.57436E-09	-0.43130E-08	0.28588E-09
	4	-0.64996E-08	-0.36705E-09	0.28780E-08	0.40931E-10	-0.45258E-09	-0.38540E-10
	5	-0.84707E-12	-0.60854E-11	-0.34680E-09	-0.23965E-12	-0.26516E-10	0.46003E-12
RMS		0.29883E-03	0.22389E-04	0.87443E-06	0.12068E-08	0.10093E-06	0.24717E-05
8	1	0.29883E-03	-0.22390E-04	-0.88624E-06	-0.13825E-08	-0.10076E-06	0.24717E-05
	2	0.23569E-11	0.68034E-10	0.56260E-08	0.16442E-09	-0.27102E-10	0.25050E-12
	3	0.34713E-07	-0.24086E-08	-0.22176E-07	-0.57447E-09	-0.43130E-08	0.28588E-09
	4	-0.64996E-08	0.36705E-09	-0.28781E-08	-0.40933E-10	-0.45258E-09	-0.38540E-10
	5	0.87791E-12	-0.61110E-11	-0.34666E-09	-0.23962E-12	0.26526E-10	-0.45799E-12
RMS		0.29883E-03	0.22390E-04	0.88654E-06	0.15066E-08	0.10085E-06	0.24717E-05
7	1	0.29846E-03	0.19631E-05	-0.43255E-07	-0.34796E-08	0.41494E-06	-0.11290E-04
	2	0.61054E-11	0.65420E-10	0.53043E-08	0.16442E-09	-0.20508E-10	0.27443E-13
	3	0.34647E-07	-0.44365E-09	-0.57204E-07	-0.15653E-08	-0.37600E-08	-0.10446E-08
	4	-0.64689E-08	-0.75857E-10	-0.41573E-08	-0.11154E-09	0.30857E-09	0.19198E-09
	5	0.23501E-11	-0.23240E-12	-0.60290E-11	-0.23961E-12	0.32198E-10	-0.54633E-12
RMS		0.29846E-03	0.19631E-05	0.72033E-07	0.38206E-08	0.41496E-06	0.11290E-04
6	1	0.30309E-03	0.19883E-05	-0.76895E-07	0.62898E-09	-0.96605E-08	-0.11288E-04
	2	0.79489E-13	0.12092E-14	0.53079E-08	-0.43859E-10	0.58006E-11	-0.37716E-14
	3	-0.19430E-10	-0.13752E-12	-0.57259E-07	0.44515E-09	-0.41043E-08	0.71676E-12
	4	0.73735E-12	0.13667E-13	-0.41671E-08	0.24905E-10	0.89491E-09	-0.23804E-13
	5	0.16148E-09	0.91529E-12	0.33296E-14	-0.30191E-15	-0.51670E-15	-0.54620E-12
RMS		0.30309E-03	0.19883E-05	0.96110E-07	0.77222E-09	0.10534E-07	0.11288E-04
5	1	0.29830E-03	0.19640E-05	-0.11044E-06	-0.78764E-09	-0.42862E-06	-0.11286E-04
	2	-0.58985E-11	-0.65419E-10	0.53043E-08	0.16442E-09	-0.20497E-10	-0.34991E-13
	3	-0.34685E-07	0.44340E-09	-0.57204E-07	-0.15653E-08	-0.37600E-08	0.10460E-08
	4	0.64702E-08	0.75870E-10	-0.41573E-08	-0.11154E-09	0.30856E-09	-0.19202E-09
	5	0.23460E-11	-0.22752E-12	0.60356E-11	0.23916E-12	-0.32196E-10	-0.54606E-12
RMS		0.29830E-03	0.19640E-05	0.12456E-06	0.17636E-08	0.42863E-06	0.11286E-04
4	1	0.13879E-03	0.10552E-05	-0.59849E-07	-0.78456E-08	-0.23013E-06	-0.19964E-04
	2	-0.33925E-11	-0.35150E-10	0.25609E-08	0.35982E-09	-0.11005E-10	0.42930E-12
	3	-0.16903E-07	0.23031E-09	-0.28279E-07	-0.39062E-08	-0.20188E-08	0.23555E-08
	4	0.32445E-08	0.40839E-10	-0.21152E-08	-0.28337E-09	0.16567E-09	-0.43857E-09
	5	-0.62373E-13	-0.12325E-12	0.32296E-11	0.39583E-12	-0.17287E-10	-0.95904E-13
RMS		0.13879E-03	0.10552E-05	0.66277E-07	0.87762E-08	0.23014E-06	0.19964E-04
3	1	0.13879E-03	-0.10551E-05	0.54547E-07	0.70836E-08	-0.23016E-06	-0.19964E-04
	2	0.34124E-11	-0.35152E-10	0.25610E-08	0.35984E-09	0.10996E-10	-0.43254E-12
	3	-0.16903E-07	-0.23029E-09	0.28277E-07	0.39060E-08	-0.20188E-08	0.23555E-08
	4	0.32444E-08	-0.40838E-10	0.21152E-08	0.28337E-09	0.16567E-09	-0.43857E-09
	5	0.96210E-13	-0.12194E-12	0.32363E-11	0.39602E-12	0.17303E-10	0.94220E-13
RMS		0.13879E-03	0.10551E-05	0.61531E-07	0.81021E-08	0.23017E-06	0.19964E-04
2	1	0.13886E-03	-0.10548E-05	0.10033E-07	0.18811E-08	0.22278E-06	-0.19975E-04
	2	-0.33174E-11	0.35151E-10	0.25610E-08	0.35984E-09	0.11001E-10	0.41868E-12
	3	0.16885E-07	0.23041E-09	0.28277E-07	0.39060E-08	-0.20188E-08	-0.23529E-08
	4	-0.32438E-08	0.40834E-10	0.21152E-08	0.28337E-09	0.16568E-09	0.43849E-09
	5	0.55139E-13	-0.12197E-12	-0.32319E-11	-0.39560E-12	-0.17303E-10	0.94292E-13

RMS		0.13886E-03	0.10540E-05	0.30187E-07	0.43595E-08	0.22279E-06	0.19975E-04
1	1	0.13887E-03	0.10547E-05	-0.15504E-07	-0.26402E-08	0.22279E-06	-0.19975E-04
	2	0.34903E-11	0.35151E-10	0.25609E-08	0.35982E-09	-0.11011E-10	-0.44318E-12
	3	0.16885E-07	-0.23844E-09	-0.28279E-07	-0.39062E-08	-0.20188E-08	-0.23529E-08
	4	-0.32438E-08	-0.40832E-10	-0.21152E-08	-0.28337E-09	0.16568E-09	0.43848E-09
	5	-0.47388E-13	-0.12600E-12	-0.32217E-11	-0.39534E-12	0.17287E-10	-0.95966E-13
RMS		0.13887E-03	0.10547E-05	0.32421E-07	0.47414E-08	0.22280E-06	0.19975E-04

*RMS represents the root mean square of the displacements from all mode shapes considered.

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 BEND ONLY)
J = FINAL NODE

ELEMENT TYPE (3/0 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)
0.3162E 01	0.1463E-02	0.6273E 01	0.3183E 00	0.6847E 02	0.1589E-01	0.3162E 01	0.1463E-02	0.6273E 01	0.3183E 00	0.5735E 01	0.3107E-02

ELEMENT TYPE (3/0 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)
0.3157E 01	0.1264E-02	0.5667E 01	0.3183E 00	0.5735E 01	0.3107E-02	0.3157E 01	0.1264E-02	0.5667E 01	0.3183E 00	0.4314E 02	0.1038E-01

ELEMENT TYPE (3/0 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)
0.1169E 00	0.3135E-02	0.6605E 00	0.4285E-02	0.1934E 01	0.9578E-02	0.1169E 00	0.3135E-02	0.6605E 00	0.4285E-02	0.3763E 01	0.2165E-01

ELEMENT TYPE (3/0 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)
0.1166E 00	0.5816E-02	0.6634E 00	0.4326E-02	0.3763E 01	0.2165E-01	0.1166E 00	0.5816E-02	0.6634E 00	0.4326E-02	0.1958E 01	0.2909E-01

ELEMENT TYPE (3/0 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)
0.3159E 01	0.3294E-02	0.5664E 01	0.3288E 00	0.4311E 02	0.3022E-01	0.3159E 01	0.3294E-02	0.5664E 01	0.3288E 00	0.5734E 01	0.2029E-02

ELEMENT TYPE (3/0 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)
0.3163E 01	0.3608E-02	0.6270E 01	0.3288E 00	0.5734E 01	0.2029E-02	0.3163E 01	0.3608E-02	0.6270E 01	0.3288E 00	0.6843E 02	0.3432E-01

ELEMENT TYPE (3/0 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)
0.3162E 01	0.1421E-02	0.6273E 01	0.3183E 00	0.6847E 02	0.1494E-01	0.3162E 01	0.1421E-02	0.6273E 01	0.3183E 00	0.5736E 01	0.2998E-02

ELEMENT TYPE (3/0 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)
0.3158E 01	0.1229E-02	0.5667E 01	0.3183E 00	0.5736E 01	0.2998E-02	0.3158E 01	0.1229E-02	0.5667E 01	0.3183E 00	0.4314E 02	0.1065E-01

ELEMENT TYPE (3/0 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)
0.1169E 00	0.3370E-02	0.6606E 00	0.4257E-02	0.1935E 01	0.1055E-01	0.1169E 00	0.3370E-02	0.6606E 00	0.4257E-02	0.3763E 01	0.2180E-01

ELEMENT TYPE (3/0 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)
0.1166E 00	0.5621E-02	0.6632E 00	0.4271E-02	0.3763E 01	0.2180E-01	0.1166E 00	0.5621E-02	0.6632E 00	0.4271E-02	0.1957E 01	0.2732E-01

ELEMENT TYPE (3/0 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)
0.3159E 01	0.3071E-02	0.5664E 01	0.3289E 00	0.4311E 02	0.2847E-01	0.3159E 01	0.3071E-02	0.5664E 01	0.3289E 00	0.5734E 01	0.2243E-02

ELEMENT TYPE (3/0 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)
0.3163E 01	0.3388E-02	0.6270E 01	0.3289E 00	0.5734E 01	0.2243E-02	0.3163E 01	0.3388E-02	0.6270E 01	0.3289E 00	0.6843E 02	0.3197E-01

ELEMENT TYPE (3/0 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)
0.1301E 01	0.3129E 01	0.1182E 00	0.1760E-02	0.1629E 01	0.4312E 02	0.1301E 01	0.3129E 01	0.1182E 00	0.1760E-02	0.6095E 00	0.1613E 02

ELEMENT TYPE (3/0 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)
0.3418E-02	0.3226E 01	0.1219E 00	0.1760E-02	0.6095E 00	0.1613E 02	0.3418E-02	0.3226E 01	0.1219E 00	0.1760E-02	0.6092E 00	0.1613E 02

ELEMENT TYPE (3/0 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)
0.1301E 01	0.3129E 01	0.1183E 00	0.1764E-02	0.6091E 00	0.1613E 02	0.1301E 01	0.3129E 01	0.1183E 00	0.1764E-02	0.1629E 01	0.4312E 02

ELEMENT TYPE (3/0 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)

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0.1305E 01 0.3130E 01 0.1172E 00 0.3844E-02 0.1616E 01 0.4314E 02 0.1305E 01 0.3130E 01 0.1172E 00 0.3844E-02 0.6054E 00 0.1614E 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)
0.4885E-03	0.3228E 01	0.1210E 00	0.3842E-02	0.6054E 00	0.1614E 02	0.4885E-03	0.3228E 01	0.1210E 00	0.3842E-02	0.6051E 00	0.1614E 02

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)
0.1305E 01	0.3130E 01	0.1173E 00	0.3843E-02	0.6051E 00	0.1614E 02	0.1305E 01	0.3130E 01	0.1173E 00	0.3843E-02	0.1616E 01	0.4314E 02

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

ELEMENT NUMBER	LOCATION	RESPONSE SPECTRUM STRESS COMPONENTS LNGTDL STRESS	CIRCUMF STRESS	SHEAR STRESS
1	END-I	117.151	0.0	6.104
	END-J	12.509	0.0	6.104
2	END-I	12.505	0.0	5.539
	END-J	74.897	0.0	5.539
3	END-I	3.335	0.0	0.618
	END-J	6.386	0.0	0.618
4	END-I	6.385	0.0	0.621
	END-J	3.376	0.0	0.621
5	END-I	74.856	0.0	5.545
	END-J	12.505	0.0	5.545
6	END-I	12.509	0.0	6.109
	END-J	117.089	0.0	6.109
7	END-I	117.150	0.0	6.104
	END-J	12.511	0.0	6.104
8	END-I	12.506	0.0	5.539
	END-J	74.898	0.0	5.539
9	END-I	3.336	0.0	0.618
	END-J	6.386	0.0	0.618
10	END-I	6.385	0.0	0.621
	END-J	3.374	0.0	0.621
11	END-I	74.855	0.0	5.545
	END-J	12.504	0.0	5.545
12	END-I	12.508	0.0	6.109
	END-J	117.089	0.0	6.109
13	END-I	73.184	0.0	2.915
	END-J	28.139	0.0	2.915
14	END-I	26.931	0.0	3.006
	END-J	26.931	0.0	3.006
15	END-I	28.139	0.0	2.915
	END-J	73.184	0.0	2.915
16	END-I	73.217	0.0	2.918
	END-J	28.154	0.0	2.918
17	END-I	26.940	0.0	3.009
	END-J	26.940	0.0	3.009
18	END-I	28.154	0.0	2.918
	END-J	73.218	0.0	2.918

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

DISPLACEMENT MAXIMA

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	4.3988E-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	2.7168E-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 COFFEE 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	2.7983E 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	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	3.6787E 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	1.6691E-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	7.7489E-04	4.5000E 00

		FZ	5.5987E-01	4.9000E 00
		TX	1.4648E-03	4.9000E 00
		MY	3.1767E 00	4.9000E 00
		MZ	6.4209E-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	1.4648E-03	4.9000E 00
		MY	1.6521E 00	4.9000E 00
		MZ	5.6712E-03	4.9000E 00
5	END-I	FX	2.7982E 00	4.9000E 00
		FY	9.3375E-04	4.9000E 00
		FZ	4.8465E 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	4.8465E 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-01	4.9000E 00
		MY	3.6778E 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-01	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 01	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

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		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	4.8478E 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	5.5991E-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	5.5991E-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	1.9806E-03	2.6000E 00
		MY	5.0596E-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	1.9806E-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

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18	END-J	FX	1.1177E 00	4.9000E 00
		FY	2.7968E 00	4.9000E 00
		FZ	1.0041E-01	4.9000E 00
		TX	1.3203E-03	2.6000E 00
		MY	1.3690E 00	4.9000E 00
		MZ	3.8132E 01	4.9000E 00

TABLE 3-14 COFFEE TABLE DYNAMIC CASE C (STEP-BY-STEP INTEGRATION)

ELEMENT NUMBER	LOCATION	STRESS COMPONENT MAXIMA LONGITUDNL STRESS	CIRCUMFR STRESS	SHEAR STRESS
1	END-I	107.62	0.0	5.74
	END-J	8.74	0.0	5.74
2	END-I	8.74	0.0	4.74
	END-J	66.21	0.0	4.74
3	END-I	2.83	0.0	0.52
	END-J	5.39	0.0	0.52
4	END-I	5.39	0.0	0.52
	END-J	2.85	0.0	0.52
5	END-I	66.20	0.0	4.74
	END-J	8.74	0.0	4.74
6	END-I	8.74	0.0	5.74
	END-J	107.60	0.0	5.74
7	END-I	107.62	0.0	5.74
	END-J	8.74	0.0	5.74
8	END-I	8.74	0.0	4.74
	END-J	66.21	0.0	4.74
9	END-I	2.83	0.0	0.52
	END-J	5.39	0.0	0.52
10	END-I	5.39	0.0	0.52
	END-J	2.85	0.0	0.52
11	END-I	66.20	0.0	4.74
	END-J	8.74	0.0	4.74
12	END-I	8.74	0.0	5.74
	END-J	107.60	0.0	5.74
13	END-I	64.67	0.0	2.61
	END-J	24.42	0.0	2.61
14	END-I	23.38	0.0	2.61
	END-J	23.38	0.0	2.61

15	END-I	24.42	0.0	2.61
	END-J	64.67	0.0	2.61
16	END-I	64.69	0.0	2.61
	END-J	24.42	0.0	2.61
17	END-I	23.39	0.0	2.61
	END-J	23.39	0.0	2.61
18	END-I	24.42	0.0	2.61
	END-J	64.69	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 gotten by Spence[11], 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:

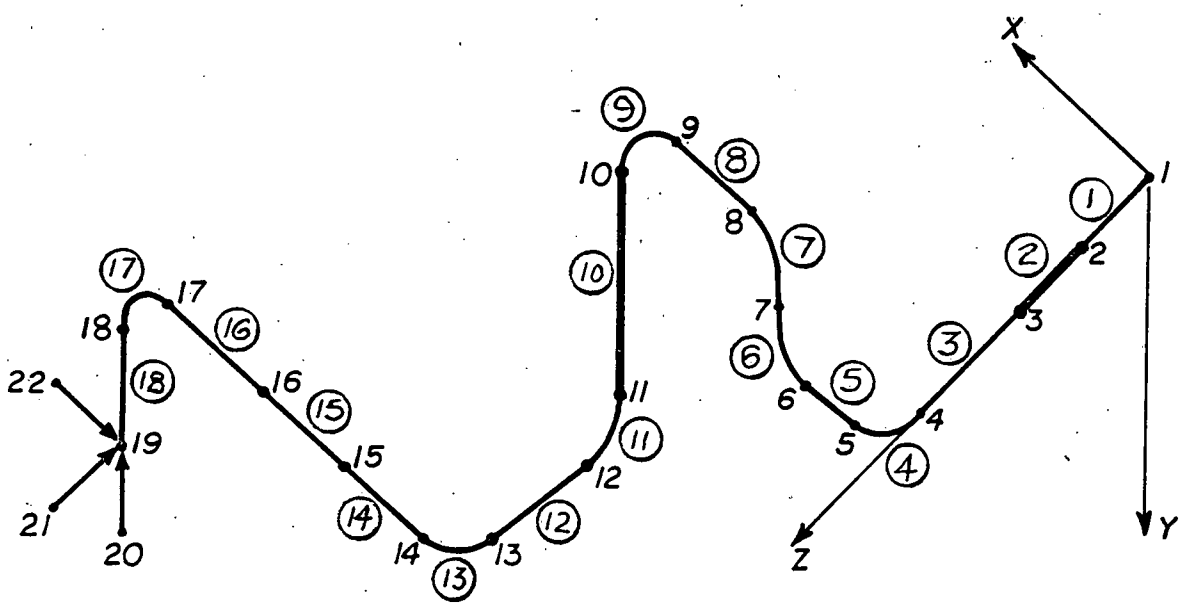

Fig. 4-1

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
2	0	0	0	0	0	0	0.0	0.0	90.000	0.0
3	0	0	0	0	0	0	0.0	0.0	150.000	0.0
4	0	0	0	0	0	0	0.0	0.0	168.000	0.0
5	0	0	0	0	0	0	48.000	0.0	216.000	0.0
6	0	0	0	0	0	0	228.000	0.0	216.000	0.0
7	0	0	0	0	0	0	274.000	-48.000	216.000	0.0
8	0	0	0	0	0	0	324.000	-96.000	216.000	0.0
9	0	0	0	0	0	0	348.000	-96.000	216.000	0.0
10	0	0	0	0	0	0	396.000	-48.000	216.000	0.0
11	0	0	0	0	0	0	396.000	24.000	216.000	0.0
12	0	0	0	0	0	0	396.000	72.000	264.000	0.0
13	0	0	0	0	0	0	396.000	72.000	279.000	0.0
14	0	0	0	0	0	0	444.000	72.000	327.000	0.0
15	0	0	0	0	0	0	615.000	72.000	327.000	0.0
16	0	0	0	0	0	0	627.000	72.000	327.000	0.0
17	0	0	0	0	0	0	798.000	72.000	327.000	0.0
18	0	0	0	0	0	0	846.000	120.000	327.000	0.0
19	0	0	0	1	1	1	846.000	242.000	327.000	0.0
20	1	1	1	1	1	1	846.000	245.000	327.000	0.0
21	1	1	1	1	1	1	846.000	242.000	330.000	0.0
22	1	1	1	1	1	1	850.000	242.000	327.000	0.0

X - displacement = 6.8526 in.

Y - displacement = 1.9602 in.

Z - displacement = 2.6487 in.

The imposed displacements are taken into account by three linear spring elements 20-19, 21-19 and 22-19.

Analyses 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. 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 gotten from SPANDLE.

TABLE 4-2 SPENCE'S PIPEWORK PROBLEM

NODAL DISPLACEMENTS

NODE NUMBER	LOAD CASE	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
22	1	0.0	0.0	0.0	0.0	0.0	0.0
21	1	0.0	0.0	0.0	0.0	0.0	0.0
20	1	0.0	0.0	0.0	0.0	0.0	0.0
19	1	-0.68526E 01	-0.19602E 01	-0.26487E 01	0.0	0.0	0.0
18	1	-0.61174E 01	-0.19598E 01	-0.23823E 01	-0.35861E-02	0.59274E-02	0.90987E-02
17	1	-0.56950E 01	-0.23532E 01	-0.18255E 01	-0.34953E-02	0.87391E-02	0.72061E-02
16	1	-0.56923E 01	-0.31932E 01	-0.23956E 00	-0.27946E-02	0.83129E-02	0.36552E-02
15	1	-0.56922E 01	-0.32369E 01	-0.14153E 00	-0.27518E-02	0.80009E-02	0.36362E-02
14	1	-0.56894E 01	-0.40219E 01	0.51905E 00	-0.20511E-02	-0.17715E-02	0.65889E-02
13	1	-0.54222E 01	-0.44775E 01	0.32684E 00	-0.17682E-02	-0.71344E-02	0.10204E-01
12	1	-0.53101E 01	-0.45047E 01	0.32690E 00	-0.18943E-02	-0.76026E-02	0.11082E-01
11	1	-0.43152E 01	-0.46111E 01	0.44590E 00	-0.27341E-02	-0.60671E-02	0.13443E-01
10	1	-0.34462E 01	-0.46109E 01	0.64030E 00	-0.23666E-02	-0.28211E-02	0.95052E-02
9	1	-0.31412E 01	-0.47829E 01	0.67994E 00	0.50208E-04	-0.48484E-04	-0.30288E-03
8	1	-0.31408E 01	-0.47342E 01	0.68443E 00	0.99258E-03	0.35357E-03	-0.37084E-02
7	1	-0.26775E 01	-0.43849E 01	0.83251E 00	0.31681E-02	0.48609E-03	-0.12174E-01
6	1	-0.20239E 01	-0.37023E 01	0.10114E 01	0.37603E-02	-0.78647E-04	-0.14617E-01
5	1	-0.20209E 01	-0.11857E 01	0.45914E 00	0.41162E-02	-0.77120E-02	-0.12188E-01
4	1	-0.14994E 01	-0.44507E 00	-0.60386E-03	0.42368E-02	-0.12063E-01	-0.98227E-02

3	1	-0.12777E 01	-0.37013E 00	-0.52969E-03	0.40498E-02	-0.12349E-01	-0.78322E-02
2	1	-0.56363E 00	-0.15258E 00	-0.37087E-03	0.30796E-02	-0.10757E-01	-0.49527E-02
1	1	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 4-3 SPENCE'S PIPEWORK PROBLEM

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	-10138.668	-7093.938	40321.500	-1436644.00	-5871017.00	-1480529.00
			END-J	-10138.668	-7093.938	40321.500	-1436644.00	-2242113.00	-842084.00
2	TANGENT	1	END-I	-10138.668	-7093.938	40322.438	-1436647.00	-2242146.00	-842082.00
			END-J	-10138.668	-7093.938	40322.438	-1436647.00	177200.00	-416457.00
3	TANGENT	1	END-I	-10138.688	-7095.625	40359.000	-1436648.00	176775.00	-416456.00
			END-J	-10138.688	-7095.625	40359.000	-1436648.00	903296.00	-288753.00
4	BEND	1	END-I	-10146.875	-40337.750	-7091.625	-1436654.00	288782.00	902828.00
			CENTER	-35697.813	-21349.250	-7091.625	-911391.00	979387.00	2129143.00
			END-J	-40337.625	10147.375	-7091.625	-51617.00	1096278.00	2351840.00
5	TANGENT	1	END-I	-40320.000	-7092.125	-10140.734	-51615.88	2351909.00	-1096278.00
			END-J	-40320.000	-7092.125	-10140.734	-51615.88	526591.63	180318.00
6	BEND	1	END-I	-40283.000	7118.813	10140.328	-51618.56	-526585.94	-179921.00
			CENTER	-23435.000	33511.813	10140.328	-266313.38	8209.94	-987517.13
			END-J	7120.188	40268.000	10140.328	-39890.69	538324.81	-2454800.00
7	BEND	1	END-I	7114.125	-40287.500	-10140.547	-39879.96	-538362.06	2455161.00
			CENTER	-23431.625	-33521.813	-10140.547	-551430.31	-696638.50	-3922603.00
			END-J	-40287.875	-7114.313	-10140.547	-1025080.31	-446850.81	4730652.00
8	TANGENT	1	END-I	-40704.000	-7147.625	-10137.938	-1025084.81	-446877.69	4729894.00
			END-J	-40704.000	-7147.625	-10137.938	-1025084.81	-690196.25	4901309.00
9	BEND	1	END-I	-40328.000	-7099.000	-10140.707	-1025090.88	-690232.69	4900733.00
			CENTER	-33544.438	23484.563	-10140.707	-1355474.00	-107396.06	4575375.00
			END-J	-7113.938	40312.625	-10140.707	-1176973.00	538350.00	3306368.00
10	TANGENT	1	END-I	-7152.000	-10140.813	-40306.125	-1176982.00	3307136.00	-538323.00
			END-J	-7152.000	-10140.813	-40306.125	-1176982.00	405232.00	191784.00
11	BEND	1	END-I	-7130.688	-10162.188	-40304.375	-1177010.00	405275.44	191765.88
			CENTER	-12209.125	-2154.945	-40304.375	-1112326.00	-249069.00	436415.19
			END-J	-10160.438	7132.563	-40304.375	-1529279.00	-757562.00	338090.00
12	TANGENT	1	END-I	-10112.000	-7117.000	40268.000	-1529200.00	757214.00	-338798.00
			END-J	-10112.000	-7117.000	40268.000	-1529200.00	1361184.00	-231706.00
13	BEND	1	END-I	-10166.500	-40294.750	-7068.875	-1529270.00	232249.00	1360357.00
			CENTER	-35656.188	-21295.613	-7068.875	-1016485.00	1005666.00	2584536.00
			END-J	-40290.938	10169.375	-7068.875	-107026.00	1189987.00	2806302.00
14	TANGENT	1	END-I	-40288.000	-7064.688	-10136.715	-106967.63	2806206.00	-1190058.00
			END-J	-40288.000	-7064.688	-10136.715	-106967.63	1072829.00	18021.00
15	TANGENT	1	END-I	-38912.000	-7196.000	-10145.000	-106970.00	1072826.00	18393.00
			END-J	-38912.000	-7196.000	-10145.000	-106970.00	951072.00	104672.00

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	-38368.000	-7021.078	-10134.703	-106969.13	951109.00	104435.00
			END-J	-38368.000	-7021.078	-10134.703	-106969.13	-781932.00	1305077.00
17	BEND	1	END-I	-38316.500	-7055.188	-10136.813	-107008.00	-781899.38	1304549.00
			CENTER	-32072.625	22107.563	-10136.813	-771061.00	-821242.00	1005336.75
			END-J	-7050.188	38301.125	-10136.813	-1268445.00	-379530.00	-195808.00
18	TANGENT	1	END-I	-7056.000	-10133.500	-38289.000	-1268395.00	-195504.00	379440.00
			END-J	-7056.000	-10133.500	-38289.000	-1268395.00	-4866736.00	1615728.00

TABLE 4-4 SPENCER'S PIPEWORK PROBLEM

PIPE STRESSES

ELEMENT NUMBER	ELEMENT TYPE	LOAD CASE	STATION	LNGTDL STRESS	CIRCUMF STRESS	SHEAR STRESS
1	TANGENT	1	END-I	27139.070	0.0	-2735.150
			END-J	10660.355	0.0	-2735.150
2	TANGENT	1	END-I	5805.723	0.0	-1444.393
			END-J	1032.688	0.0	-1444.393
3	TANGENT	1	END-I	1913.469	0.0	-2734.705
			END-J	4146.352	0.0	-2734.705
4	BEND	1	END-I	3941.393	1714.507	-2734.983
			CENTER	9151.504	4043.330	-1777.534
			END-J	10097.656	4466.238	34.744
5	TANGENT	1	END-I	11192.105	0.0	34.683
			END-J	2014.582	0.0	34.683
6	BEND	1	END-I	-1301.301	-341.677	34.860
			CENTER	-248.422	-1875.335	-172.644
			END-J	2510.705	-4661.762	416.519
7	BEND	1	END-I	11141.465	4662.449	416.774
			CENTER	17376.383	7449.180	-814.416
			END-J	20809.211	8983.699	-2156.747
8	TANGENT	1	END-I	20895.559	0.0	-2156.549
			END-J	21790.277	0.0	-2156.549
9	BEND	1	END-I	21574.539	9306.688	-2156.876
			CENTER	20192.277	8688.820	-2739.702
			END-J	14800.664	6278.926	-2142.893
10	TANGENT	1	END-I	14999.633	0.0	-2142.990
			END-J	1931.437	0.0	-2142.990
11	BEND	1	END-I	1737.865	364.171	-2143.010
			CENTER	1816.154	828.770	-2012.063
			END-J	1398.411	642.046	-2943.825
12	TANGENT	1	END-I	3611.884	0.0	-2944.117
			END-J	6093.789	0.0	-2944.117
13	BEND	1	END-I	6001.242	2583.372	-2944.056
			CENTER	11202.488	4908.137	-2014.843
			END-J	12144.508	5329.281	-89.939
14	TANGENT	1	END-I	13233.363	0.0	-90.163
			END-J	4340.008	0.0	-90.163
15	TANGENT	1	END-I	2331.758	0.0	-34.005
			END-J	2046.309	0.0	-34.005
16	TANGENT	1	END-I	3840.416	0.0	-90.490
			END-J	6382.473	0.0	-90.490
17	BEND	1	END-I	5406.719	2477.390	-90.319

			CENTER	4135.605	1909.174	-1439.359
			END-J	-967.979	-371.999	-2372.506
18	TANGENT	1	END-I	1835.896	0.0	-2372.627
			END-J	23003.227	0.0	-2372.627

Table 4-5

Comparison of Nodal Displacements/Rotations

Solution	Node	X-DISP	Y-DISP	Z-DISP	XR	YR	ZR
EPIPE	6	-2.0239	-3.7023	1.0114	3.7603E-3	-7.8647E-5	-1.4617E-2
Spence	6	-2.0044	-3.7244	0.99407	3.8338E-3	-3.4540E-5	-1.4697E-2
EPIPE	10	-3.4462	-4.6109	0.6403	-2.2366E-3	-2.8211E-3	9.5052E-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	10138	40321	7094	1436644	-1480529	5871017
	-J	10138	40321	-7094	1436644	- 842084	-2242113
Spence	1-I	10065	39963	7123.7	1444200	-1490900	5814300
	-J	10065	39963	-7123.7	1444200	- 849790	-2217600

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