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TO TES LETTER 3245A-4

BOOK 1 OF 2

"TMRSAP" VERIFICATION ANALYSIS
ONRR BENCHMARK PROBLEMS

SEPTEMBER 21, 1979

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TABLE OF CONTENTS

1.0 INTRODUCTION

This report addresses the request by the Office of Nuclear Reactor Regulation (ONRR) for the verification of the TMRSAP computer code. The information contained in this report satisfies the requirements of the computer code verification program as stated in IE Bulletin 79-07.

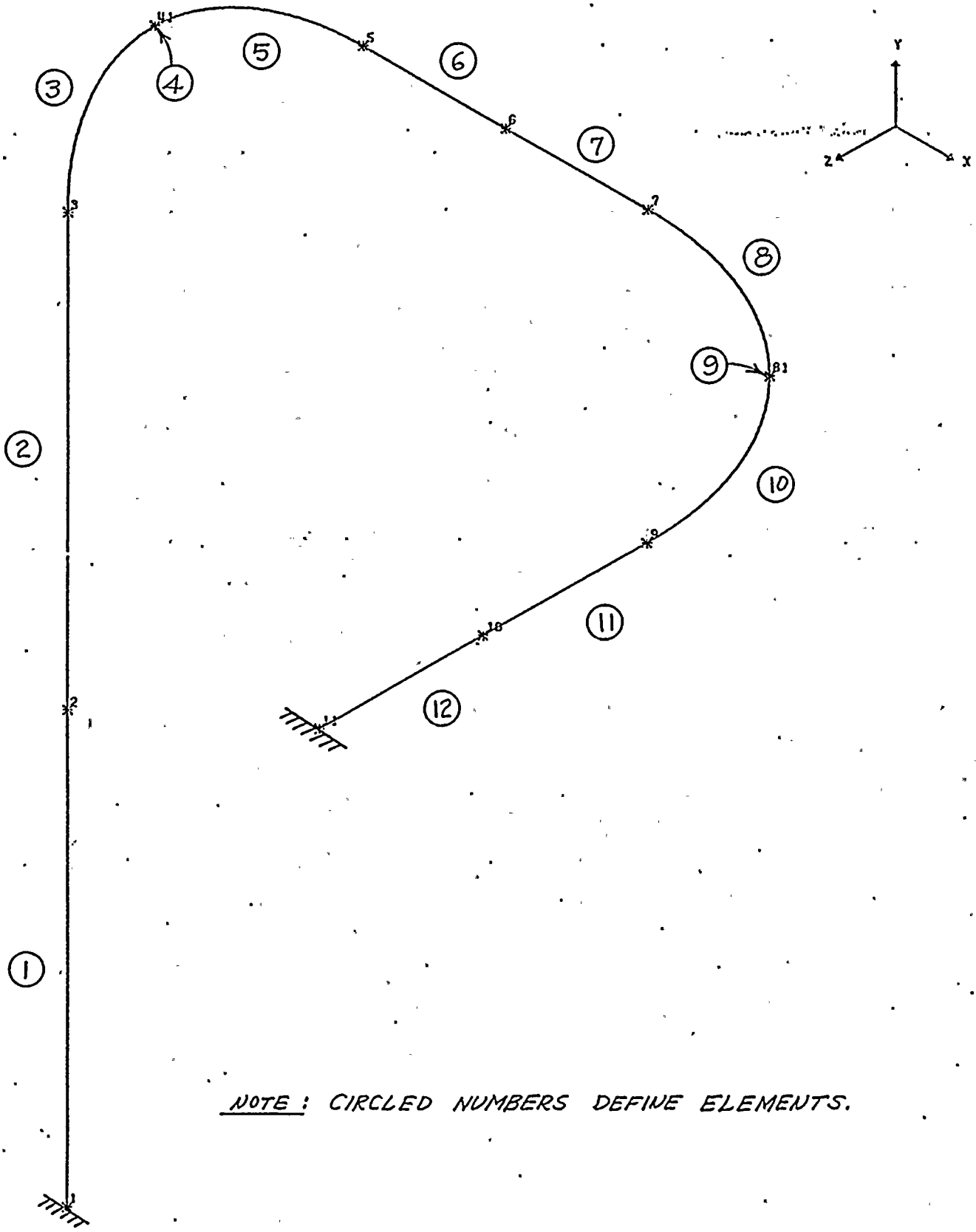
Four benchmark problems defined by the ONRR were analyzed for linear elastic behavior. The structural models were subjected to dynamic loading induced by earthquake type excitation (seismic spectra) in three directions. Dynamic solutions were determined by the modal superposition and response spectrum method of seismic analysis, based on NRC Regulatory Guide 1.92.

2.0 BENCHMARK VERIFICATION PROBLEMS - SUMMARY OF RESULTS

2.1 Problem No. 1 - Hovgaard Bend

The Hovgaard Bend configuration was modified slightly to accommodate a modeling requirement for the TMRSAP computer code. The following computer generated plot shows the equivalent TMRSAP piping model for the Hovgaard Bend benchmark problem. A short segment of straight pipe was added to the model at the arc center of each bend to accommodate an elbow-to-elbow connection. This modeling resulted in slightly higher frequencies and corresponding modal participation.

LUMPED MASS SYSTEM FOR HOVGAARD BEND - BENCHMARK PROB. NO. 1



NOTE : CIRCLED NUMBERS DEFINE ELEMENTS.

BENCHMARK PROBLEM NO. 1

HOVGAARD BEND

FREQUENCIES (CPS)

MODE	EPIPE	TMRSAP
1	28.53	28.53
2	55.77	55.79
3	81.50	81.48
4	141.70	141.70
5	162.80	162.8

MAXIMUM DISPLACEMENTS

COMPONENT	NODE	EPIPE	TMRSAP
u_x	5	0.00784	0.010797
u_y	7	0.00250	0.003453
u_z	4	0.01745	0.024125
θ_x	3	0.00018	0.000255
θ_y	7	0.00021	0.000293
θ_z	3	0.00007	0.0000967

BENCHMARK PROBLEM NO. 1

HOVGAARD BEND

MAXIMUM ELEMENT LOADS

COMPONENT	ELEMENT	EPIPE	ELEMENT	TMRSAP
PX(I)	7	28.1	8	37.0
VY(I)	1	36.4	1	50.2
VZ(I)	10	34.8	12	45.7
MY(I)	10	1871.0	12	2561.0
MZ(I)	1	3227.0	1	4458.0
TX(I)	3	629.6	3	868.2
PX(J)	7	26.7	9	33.8
VY(J)	1	36.4	1	50.3
VZ(J)	10	34.8	12	45.7
MY(J)	10	2477.0	12	3356.0
MZ(J)	8	1380.0	10	1909.0
TX(J)	1	629.6	1	868.2

BENCHMARK PROBLEM NO. 1

HOVGAARD BEND

GENERALIZED MODAL PARTICIPATION

DIRECTION FACTORS: X = 1.0, Y = 0.6667, Z = 1.0

EPIPE

MODAL PARTICIPATION

MODE	P_x	P_y	P_z	$\Sigma \lvert P_i \rvert xD_i$
1	0.1752	-0.02593	-0.3308	0.52328
2	0.3628	-0.002074	0.1478	0.51198
3	-0.05397	-0.2582	-0.02793	0.25404
4	0.08361	-0.05268	-0.01174	0.13047
5	-0.07925	0.06605	-0.01115	0.13473

TMRSAP

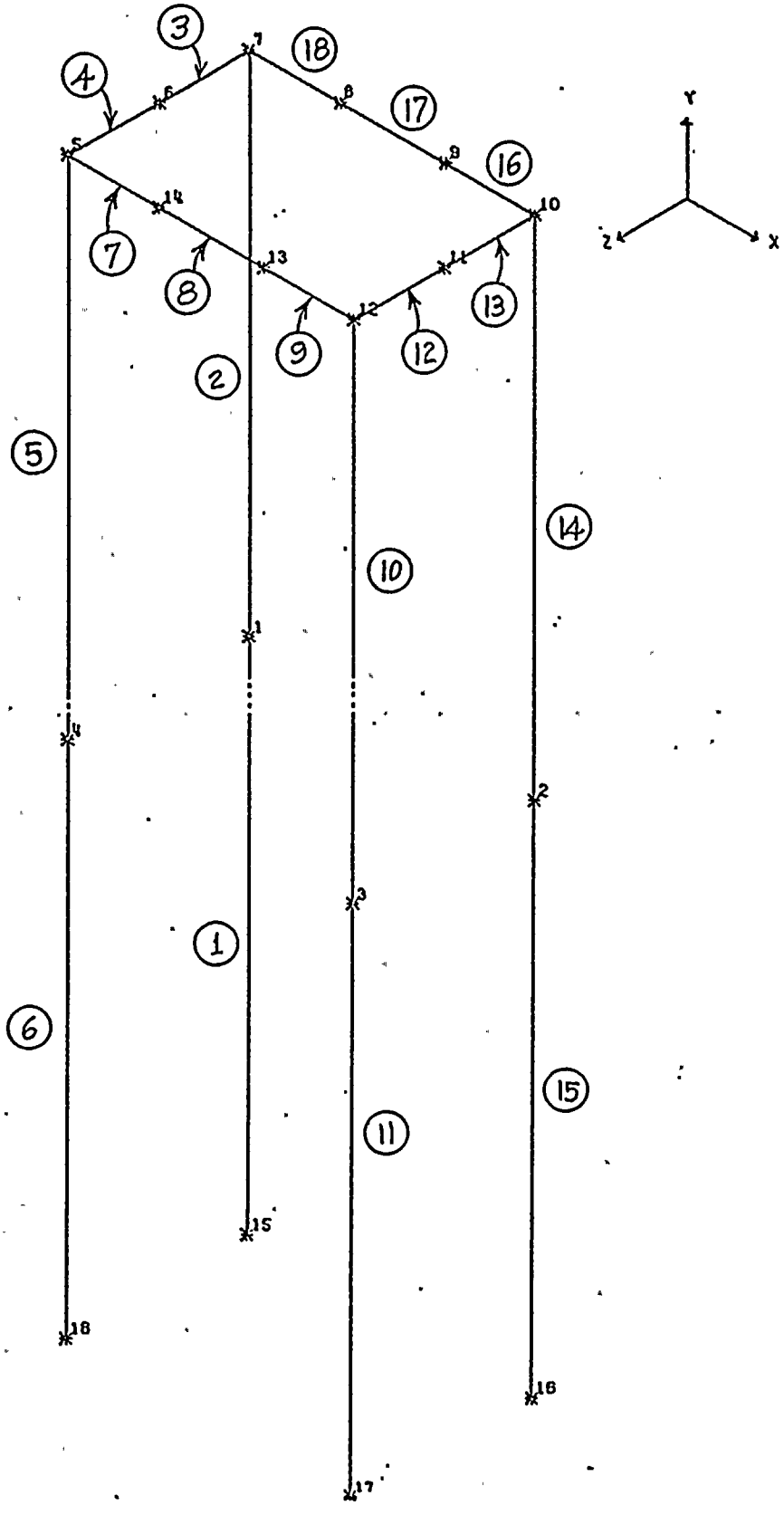
MODAL PARTICIPATION

MODE	P_x	P_y	P_z	$\Sigma \lvert P_i \rvert xD_i$
1	0.1754	-.02596	-.3309	0.52360
2	0.3628	.002035	.1479	0.51205
3	-.05405	-.2582	.02795	0.25414
4	0.08386	-.05280	-.01153	0.13059
5	-.07926	.06634	-.01116	0.13465

2.2 Problem No. 2 - Coffee Table

A computer generated isometric plot of Benchmark Problem No. 2 is shown on the following page. The configuration for the TMRSAP computer code is the same as the EPIPE model with the exception of the element numbering. The element connectivity was defined differently for ease of input to TMRSAP. The results between TMRSAP and EPIPE are in excellent agreement as shown in the following tables which summarize the frequencies, maximum displacements and maximum element loads.

DYNAMIC RESPONSE OF A COFFEE TABLE (RESPONSE SPECTRUM ANALYSIS)



BENCHMARK PROBLEM NO. 2

COFFEE TABLE

FREQUENCIES (CPS)

MODE	EPIPE	TMRSAP
1	8.71	8.71
2	8.81	8.804
3	17.51	17.50
4	40.37	40.36
5	41.63	41.62

MAXIMUM DISPLACEMENTS

COMPONENT	NODE	EPIPE	TMRSAP
u_x	11	0.46188	0.46203
u_y	13	0.00236	0.0023598
u_z	13	0.4464	0.44691
θ_x	3	0.00654	0.006546
θ_y	14	0.00001	0.0000127
θ_z	4	0.00672	0.006722

BENCHMARK PROBLEM NO. 2

COFFEE TABLE

MAXIMUM ELEMENT LOADS

COMPONENT	ELEMENT	EPIPE	ELEMENT	TMRSAP
PX(I)	1	555.4	1	555.8
VY(I)	3	468.7	3	469.2
VZ(I)	1	109.3	1	109.3
MY(I)	1	5229.0	1	5230.0
MZ(I)	1	5135.0	1	5141.0
TX(I)	1	1.61	1	1.61
PX(J)	1	555.4	1	555.8
VY(J)	3	468.7	3	469.2
VZ(J)	1	109.3	1	109.3
MY(J)	6	5229.0	6	5230.0
MZ(J)	6	5135.0	6	5141.0
TX(J)	1	1.61	1	1.61

2.3 Problem No. 3 - Modified Reactor System

The Modified Reactor System model was modified to accommodate elbow-to-elbow connections from the four corners of the model to the center point, node 8. The following computer generated plot shows the equivalent TMRSAP piping model for the Modified Reactor System. Each of the four outside loops (bend elements) were modeled as an equivalent series of three elements (tangent-bend-tangent). The results between the TMRSAP and EPIPE computer codes are in good agreement as shown in the following tables which summarize the frequencies, maximum displacements, and maximum element loads.

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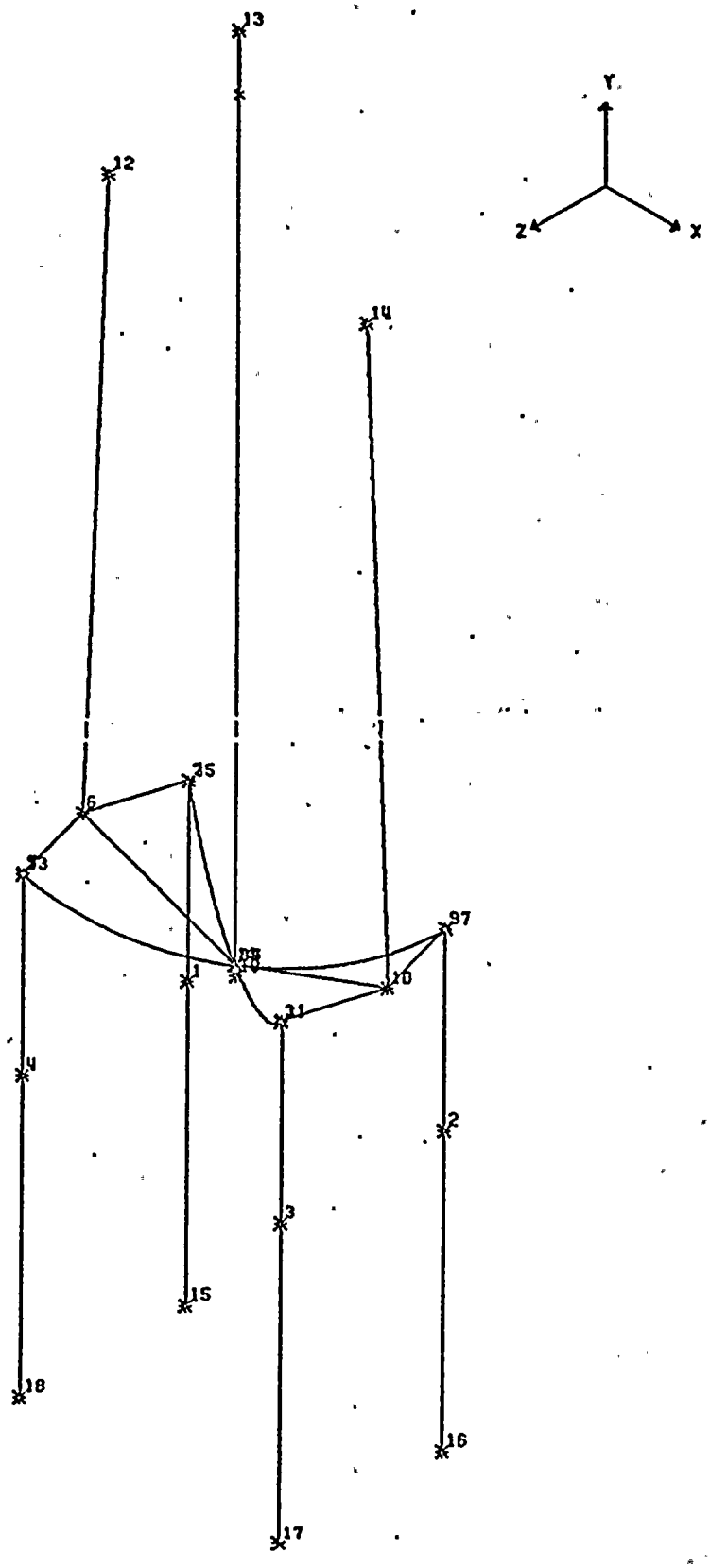
BENCHMARK PROBLEM NO. 3 DYNAMIC RESPONSE OF A MODIFIED REACTOR SYSTEM



NRC BENCHMARK PROBLEM NO. 3

FREQUENCIES (CPS)

MODE	EPIPE	TMRSAP
1	1.806	1.805
2	1.875	1.874
3	3.205	3.204
4	3.480	3.480
5	3.539	3.540
6	3.645	3.645

MAXIMUM DISPLACEMENTS

COMPONENT	NODE	EPIPE	TMRSAP (SRSS)	TMRSAP (CLUSTER)
u_x	13	5.32223	4.5717	6.2988
u_y	12	0.04657	0.04456	0.04908
u_z	13	5.39637	4.7243	6.4084
θ_x	13	0.09062	0.07763	0.10689
θ_y	12	0.00192	0.001866	0.001968
θ_z	13	0.09036	0.07763	0.10689

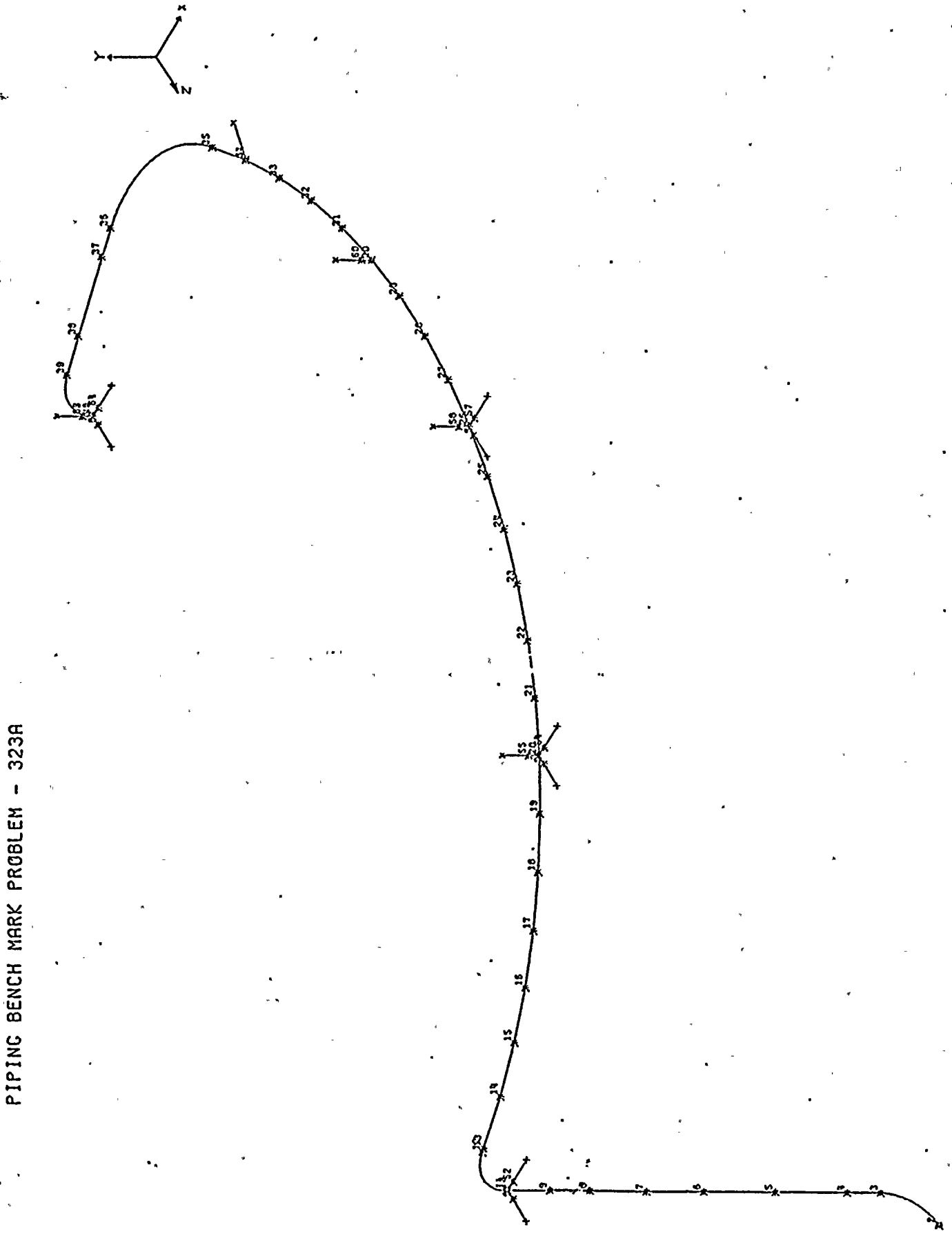
NRC BENCHMARK PROBLEM NO. 3

MAXIMUM ELEMENT LOADS

COMPONENT	ELEMENT NO.	EPIPE (CLUSTER)	ELEMENT NO.	TMRSAP (SRSS)	TMRSAP (CLUSTER)
PX(I)	1	3243.0	1	3028.0	3574.0
VY(I)	3	2109.0	3	2009.0	2155.0
VZ(I)	3	635.0	3	563.0	747.0
TX(I)	14	4110.0	20	3596.0	4592.0
MY(I)	1	7823.0	1	7623.0	8181.0
MZ(I)	20	37100.0	16	32570.0	44140.0
PX(J)	1	3243.0	1	3028.0	3574.0
VY(J)	3	2109.0	3	2009.0	2155.0
VZ(J)	16	930.0	25	430.0	590.0
TX(J)	18	3866.0	14	3454.0	4484.0
MY(J)	6	7891.0	6	7611.0	8243.0
MZ(J)	15	14030.0	13	10840.0	12070.0

2.4 Problem No. 323A - Piping System

The piping system defined in problem 323A was analyzed with the TMRSAP computer code for each seismic spectra separately and the results of each response spectrum analysis were combined by taking the square root of the sum of the squares (SRSS) of corresponding maximum values of the spectrum response. The results of the maximum displacements are shown on the following pages and they are in close agreement with the EPIPE results supplied by the NRC. The NRC supplied data for this benchmark problem did not include element loads; therefore, they are not summarized for this problem.



PIPING BENCH MARK PROBLEM - 323A

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BENCHMARK PROBLEM NO. 323A

PIPING SYSTEM

FREQUENCIES (CPS)

MODE	EPIPE	TMRSAP
1	6.39	6.39
2	9.99	9.99
3	13.27	13.27
4	14.49	14.49
5	15.33	15.33
6	17.50	17.50
7	19.09	19.09
8	19.62	19.63
9	21.44	21.44
10	28.71	28.71
11	29.86	29.87
12	31.48	31.49
13	32.01	32.01
14	36.37	36.37
15	40.99	40.99
16	41.37	41.37
17	47.39	47.40
18	49.77	49.77
19	50.13	50.13
20	52.93	52.94
21	56.90	56.91
22	58.51	58.52
23	67.47	67.47
24	70.46	70.47
25	75.41	75.42
26	79.18	79.20
27	80.74	80.75
28	86.11	86.12
29	88.28	88.33
30	92.74	92.74
31	99.36	99.37

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NRC BENCHMARK PROBLEM 323A PIPING SYSTEM

TMRSAP MAXIMUM DISPLACEMENTS

		SRSS	CLUSTER
u_x NODE 31	X-SPECTRA	.020751	.020785
	Y-SPECTRA	.0020513	.0020675
	Z-SPECTRA	.010887	.010943
	SRSS =	.023523	.0235805
u_y NODE 35	X-SPECTRA	.051633	.051638
	Y-SPECTRA	.057385	.057386
	Z-SPECTRA	.010441	.010448
	SRSS =	.077897	.077902
u_z NODE 36	X-SPECTRA	.013009	.013101
	Y-SPECTRA	.0028254	.0028406
	Z-SPECTRA	.0068936	.0069855
	SRSS =	.014991	.015116
θ_x NODE 35	X-SPECTRA	.00021197	.00021198
	Y-SPECTRA	.00023513	.00023518
	Z-SPECTRA	.000043568	.000043607
	SRSS =	.00031955	.000319604
θ_y NODE 35	X-SPECTRA	.000084048	.000084152
	Y-SPECTRA	.000012717	.000013047
	Z-SPECTRA	.000043608	.000043729
	SRSS =	.000095565	.000095728

NRC BENCHMARK PROBLEM 323A PIPING SYSTEM

MAXIMUM DISPLACEMENTS

		SRSS	CLUSTER
θ_x NODE 38	X-SPECTRA	.00020599	.00020606
	Y-SPECTRA	.00022871	.00022872
	Z-SPECTRA	.000042008	.000042082
	SRSS =	.00031065	.00031071

DISPLACEMENT SUMMARY

COMPONENT	NODE	EPIPE	TMRSAP
u_x	31	0.02354	0.02352
u_y	35	0.07789	0.07789
u_z	36	0.01500	0.01499
θ_x	35	0.00032	0.00032
θ_y	35	0.00010	0.000095
θ_z	38	0.00031	0.00031

NOTE: ELEMENT LOAD DATA WERE NOT SUPPLIED BY NRC.