

NIAGARA MOHAWK POWER CORPORATION  
300 ERIE BOULEVARD WEST  
SYRACUSE, NY 13201

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ATTACHMENT  
TO TES LETTER 3245A-4

BOOK 1 OF 2

"TMRSAP" VERIFICATION ANALYSIS  
ONRR BENCHMARK PROBLEMS

50-220  
Ltr 10-26-79  
7910310283

SEPTEMBER 21, 1979

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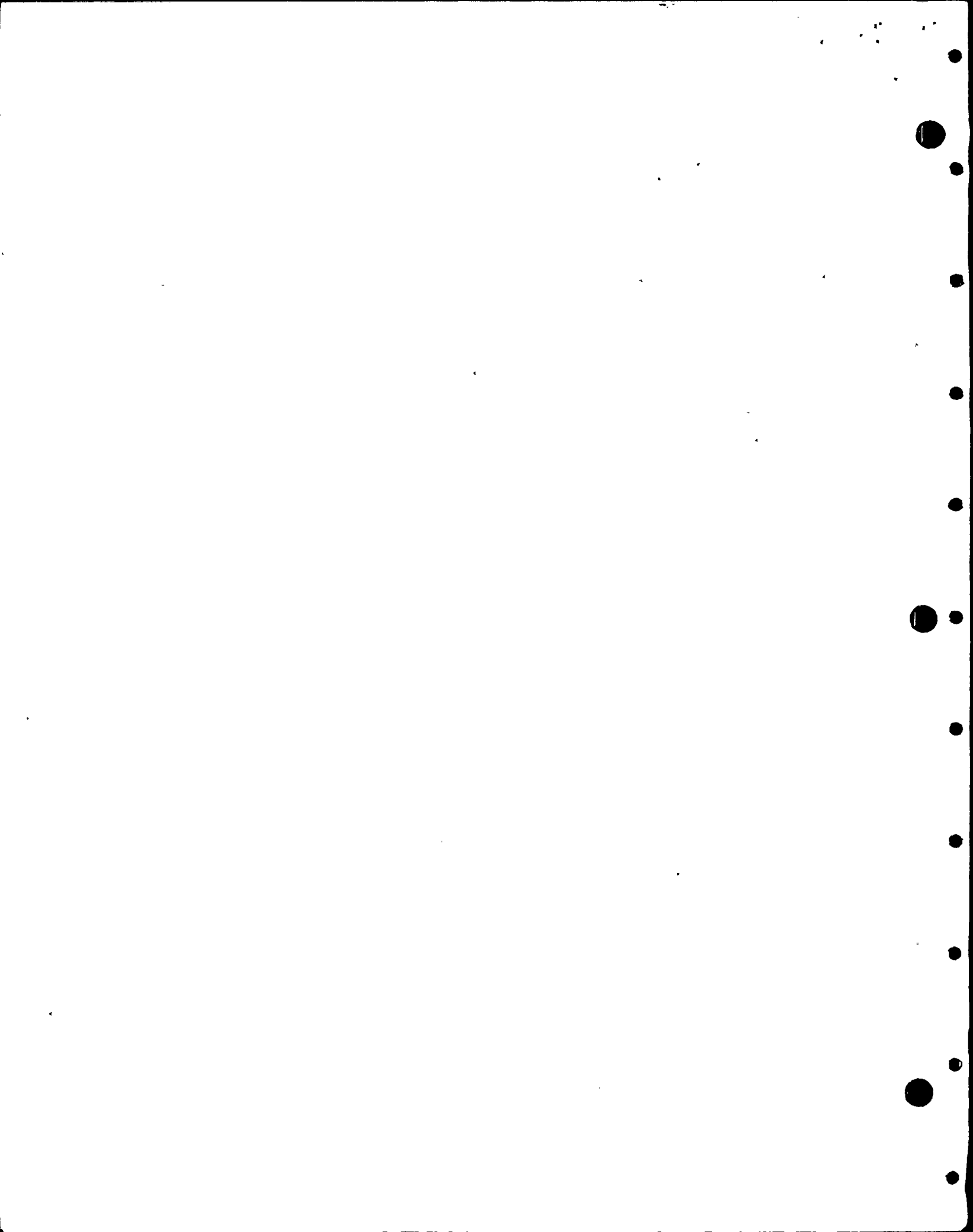
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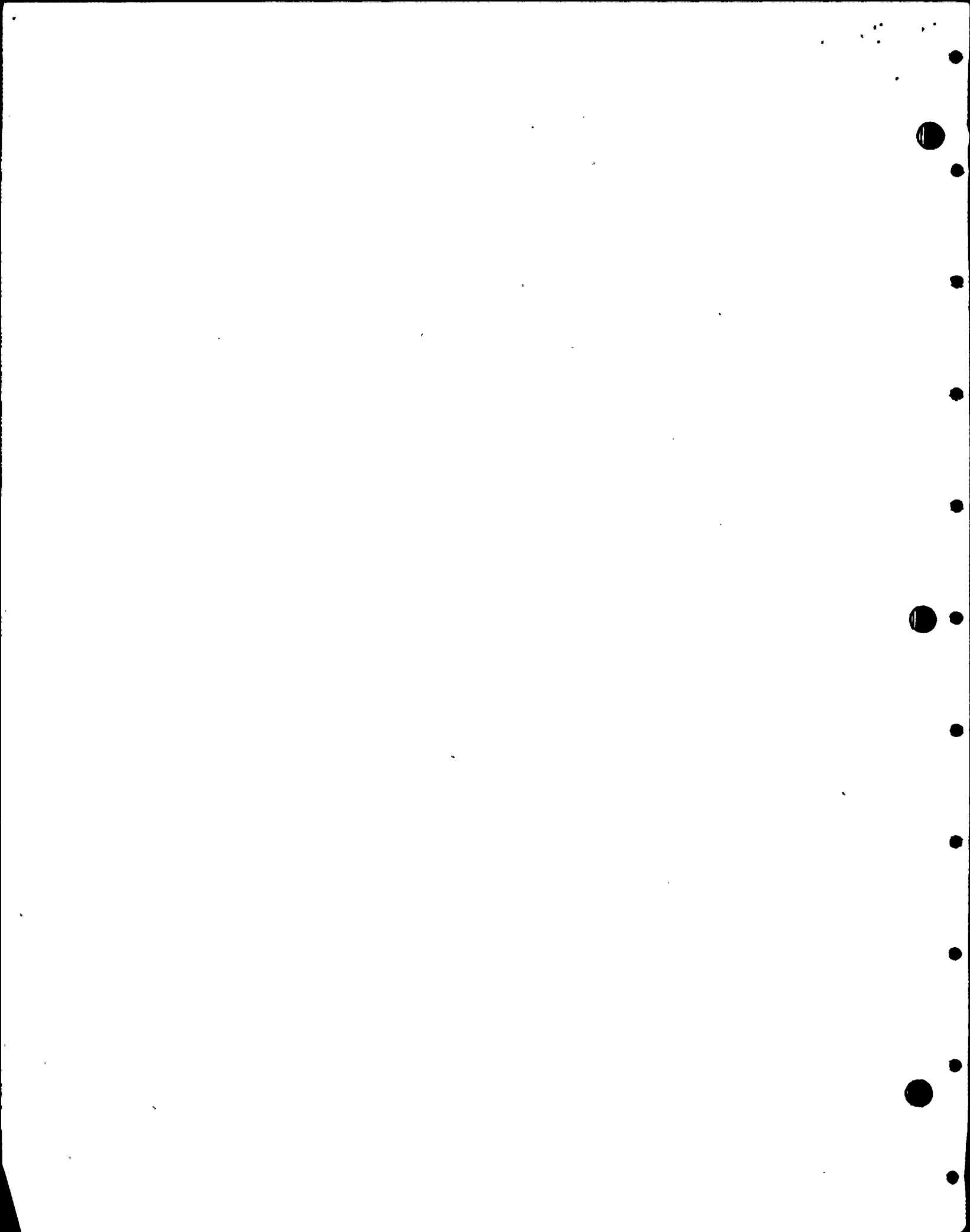
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## 1.0 INTRODUCTION

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.

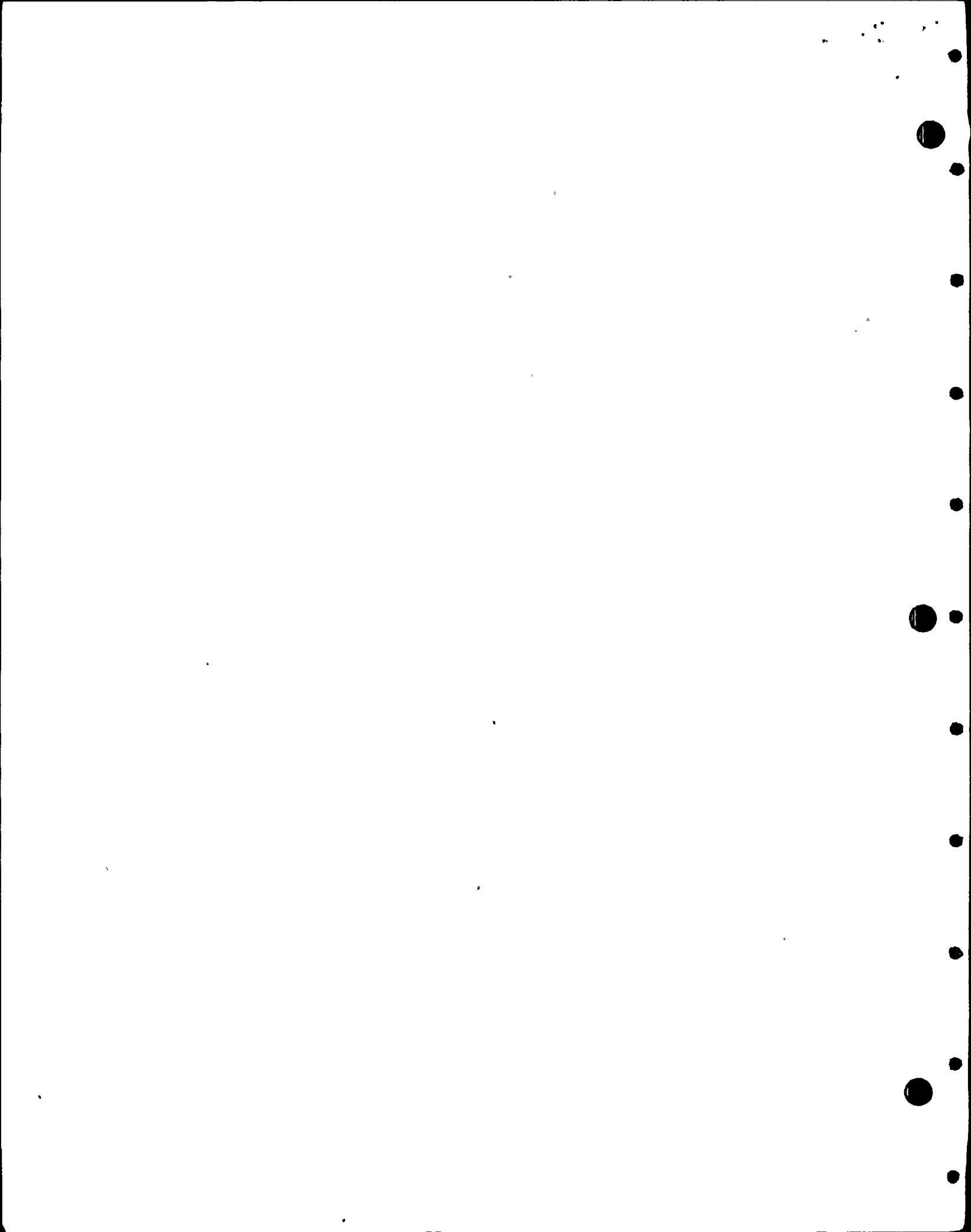
Four benchmark problems defined by the ONRR were analyzed for linear elastic behavior. The structural models were subjected to dynamic loading induced by earthquake type excitation (seismic spectra) in three directions. Dynamic solutions were determined by the modal superposition and response spectrum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



## 2.0 BENCHMARK VERIFICATION PROBLEMS - SUMMARY OF RESULTS

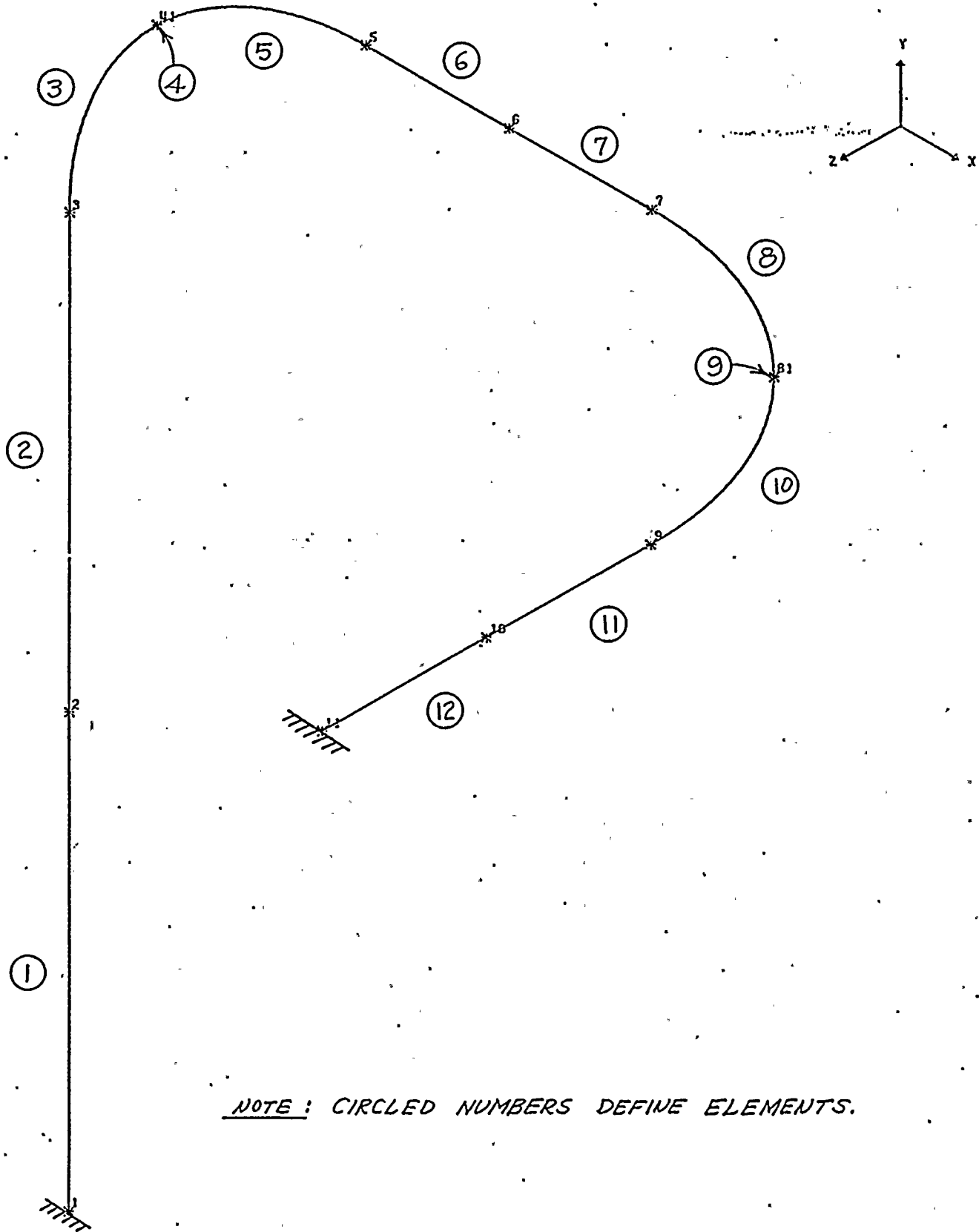
### 2.1 Problem No. 1 - Hovgaard Bend

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.

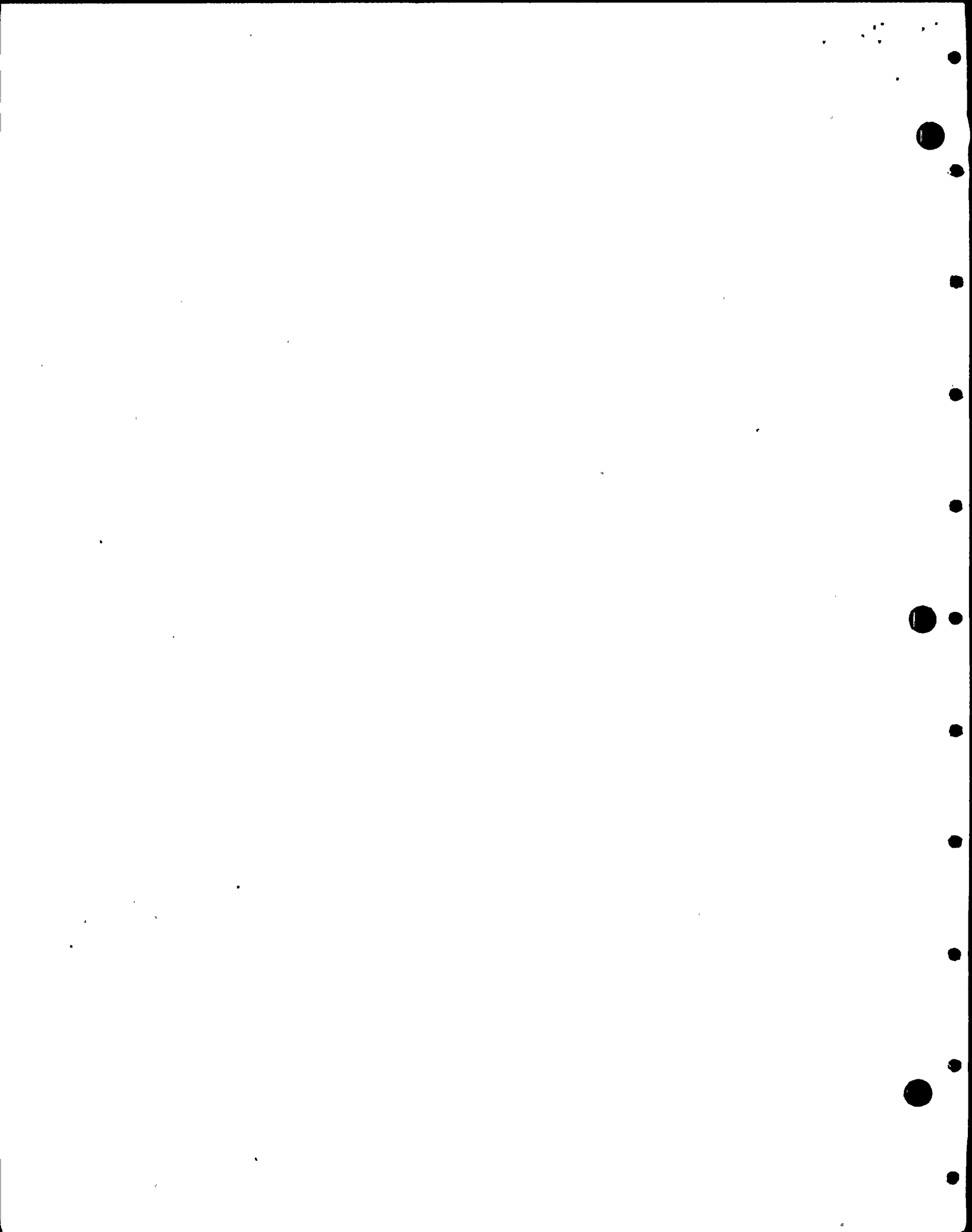




LUMPED MASS SYSTEM FOR HOVGAARD BEND - BENCHMARK PROB. NO. 1



NOTE : CIRCLED NUMBERS DEFINE ELEMENTS.



BENCHMARK PROBLEM NO. 1

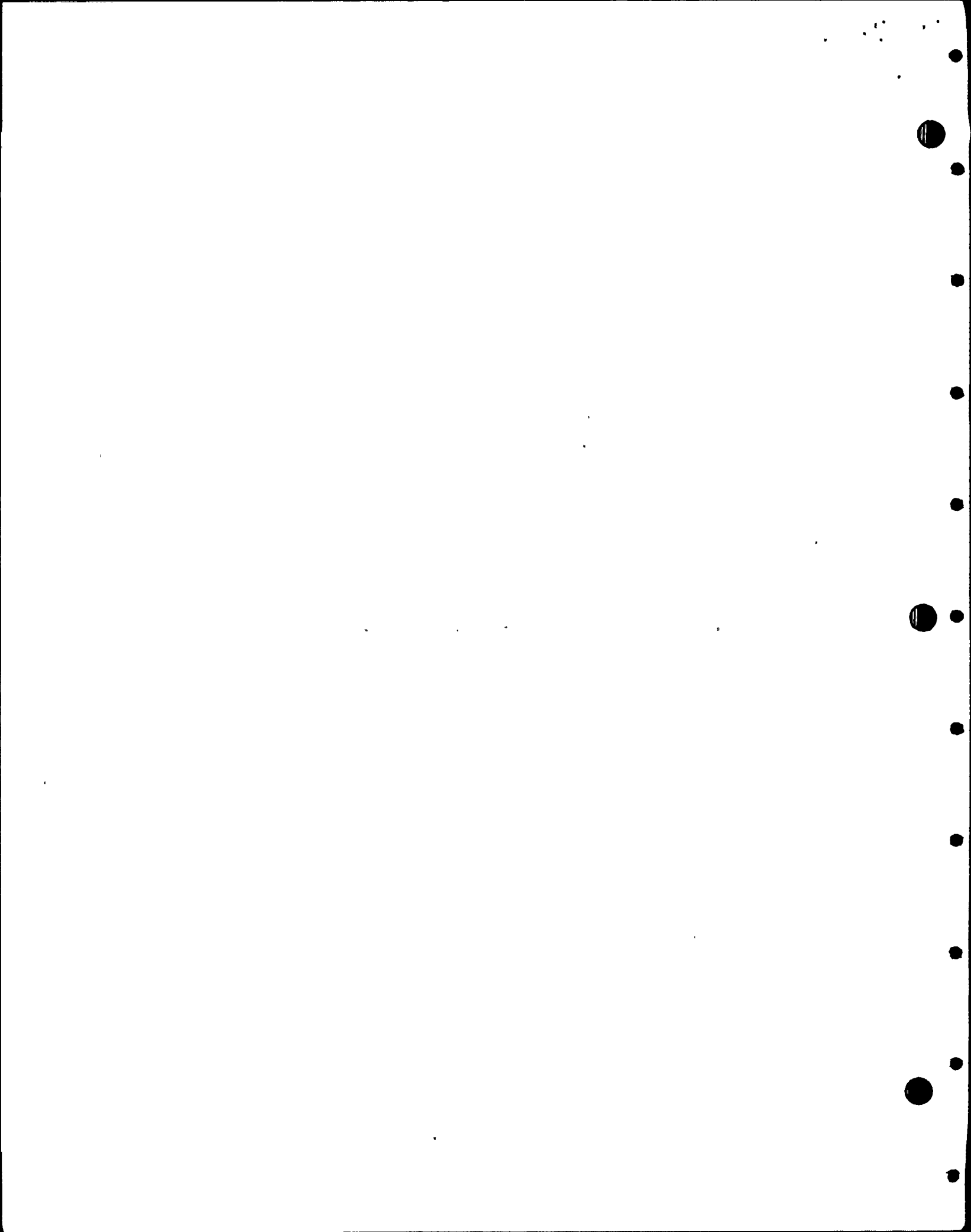
HOVGAARD BEND

FREQUENCIES (CPS)

<u>MODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>
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

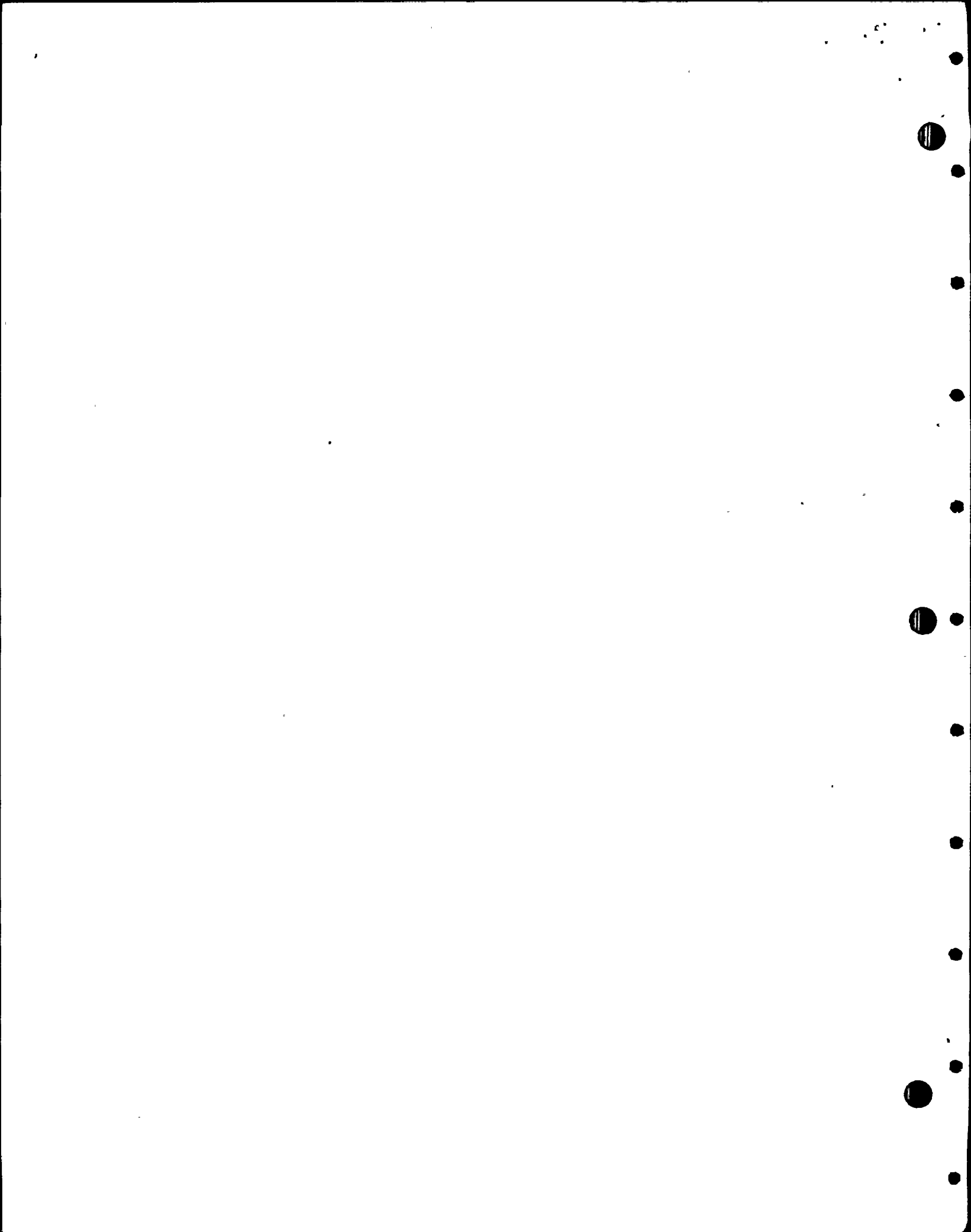
MAXIMUM DISPLACEMENTS

<u>COMPONENT</u>	<u>NODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>
$u_x$	5	0.00784	0.010797
$u_y$	7	0.00250	0.003453
$u_z$	4	0.01745	0.024125
$\theta_x$	3	0.00018	0.000255
$\theta_y$	7	0.00021	0.000293
$\theta_z$	3	0.00007	0.0000967



BENCHMARK PROBLEM NO. 1
HOVGAARD BEND

<u>COMPONENT</u>	<u>MAXIMUM ELEMENT LOADS</u>			
	<u>ELEMENT</u>	<u>EPIPE</u>	<u>ELEMENT</u>	<u>TMRSAF</u>
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

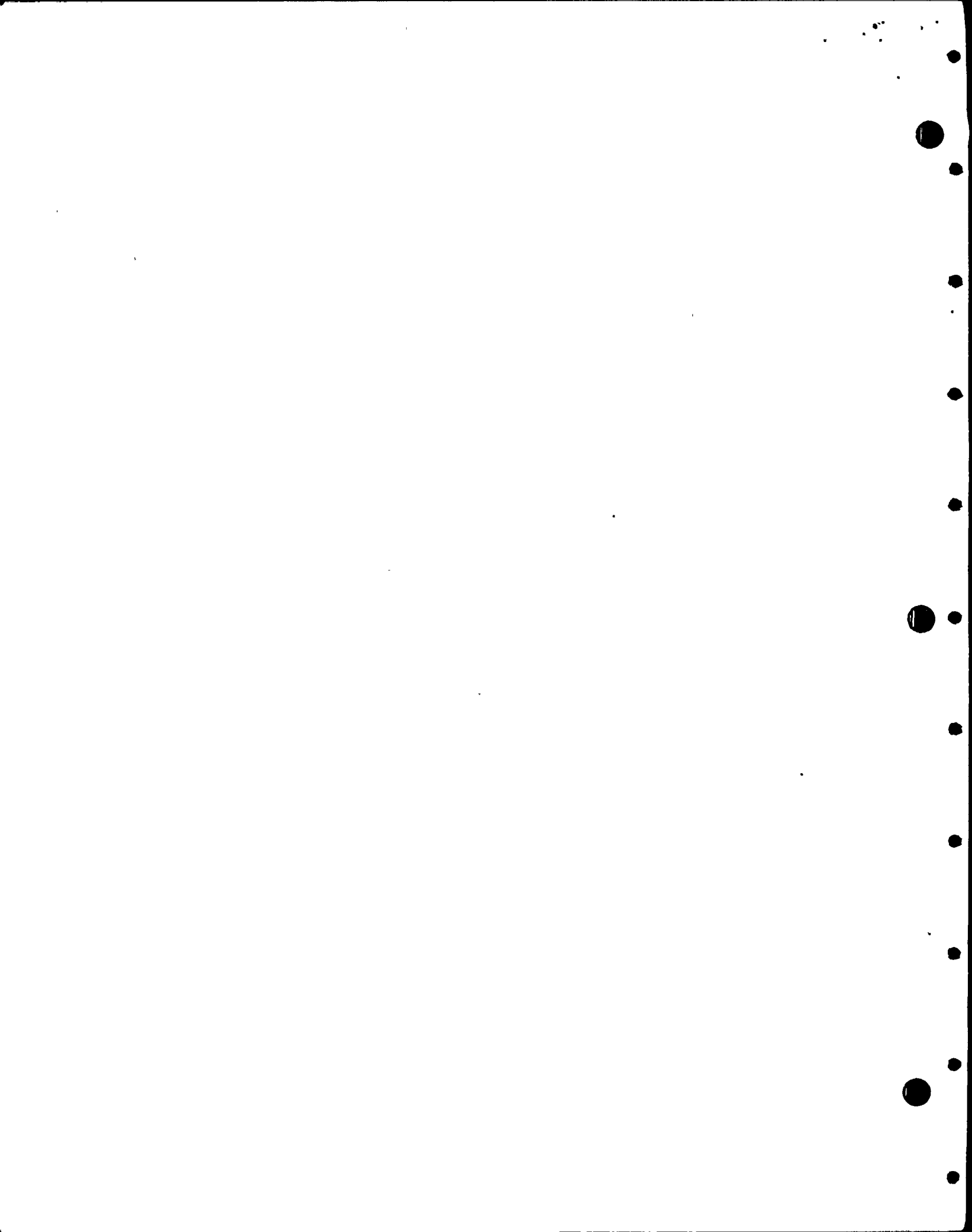
MODAL PARTICIPATION

<u>MODE</u>	$P_x$	$P_y$	$P_z$	$\Sigma  P_i  x D_i$
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

TMRAP

MODAL PARTICIPATION

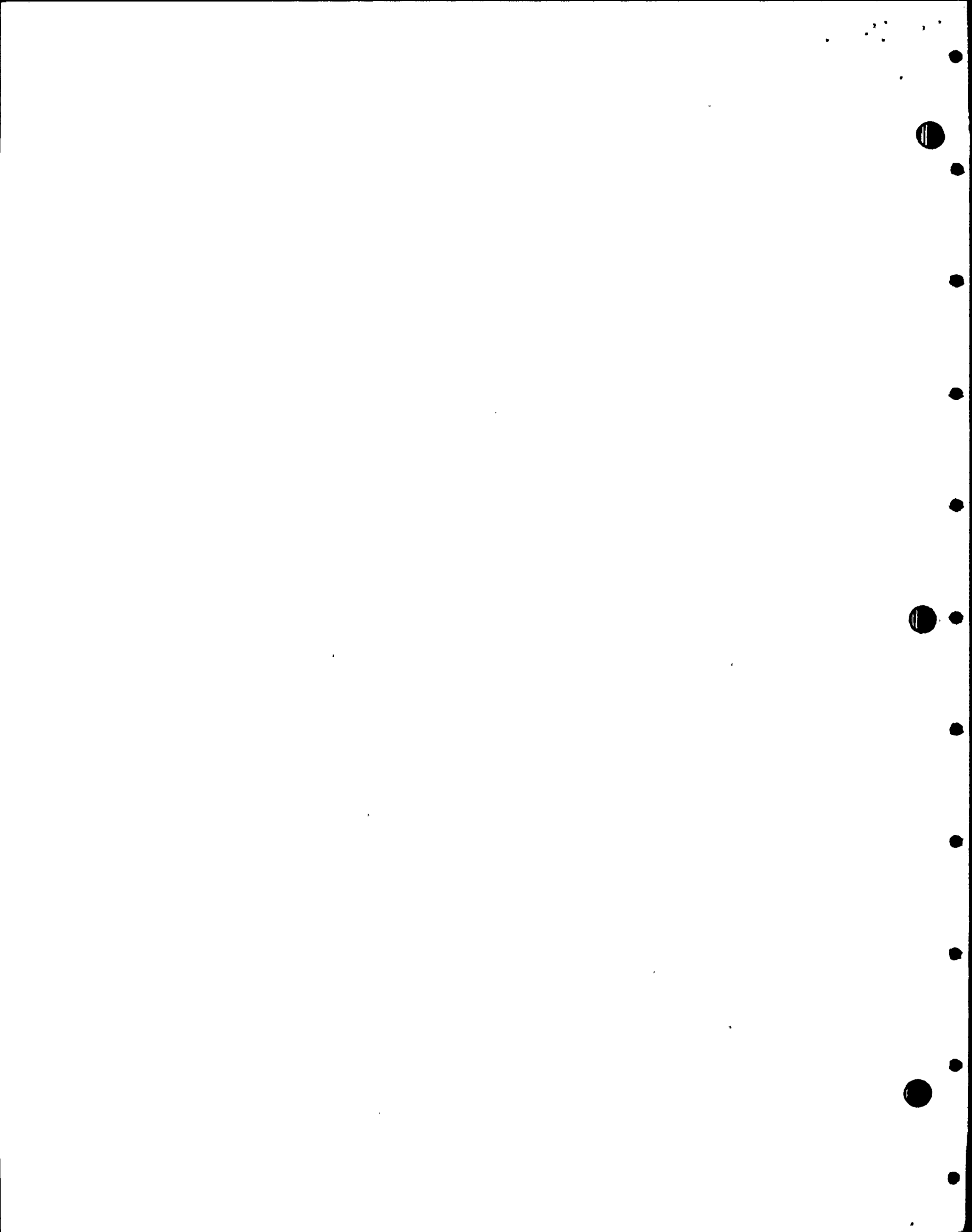
<u>MODE</u>	$P_x$	$P_y$	$P_z$	$\Sigma  P_i  x D_i$
1	0.1754	-.02596	-.3309	0.52360
2	0.3628	.002035	.1479	0.51205
3	-.05405	-.2582	.02795	0.25414
4	0.08386	-.05280	-.01153	0.13059
5	-.07926	.06634	-.01116	0.13465



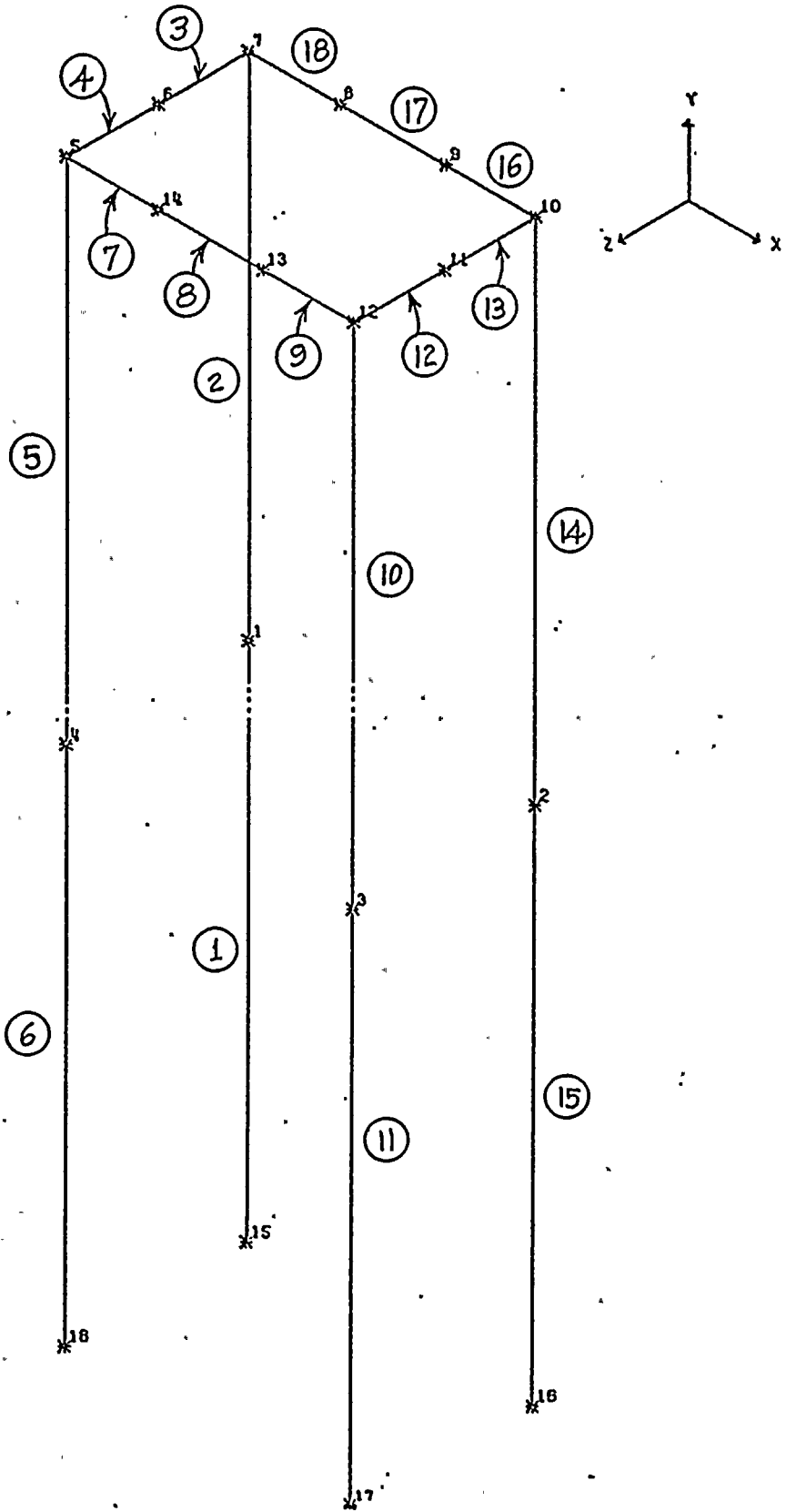


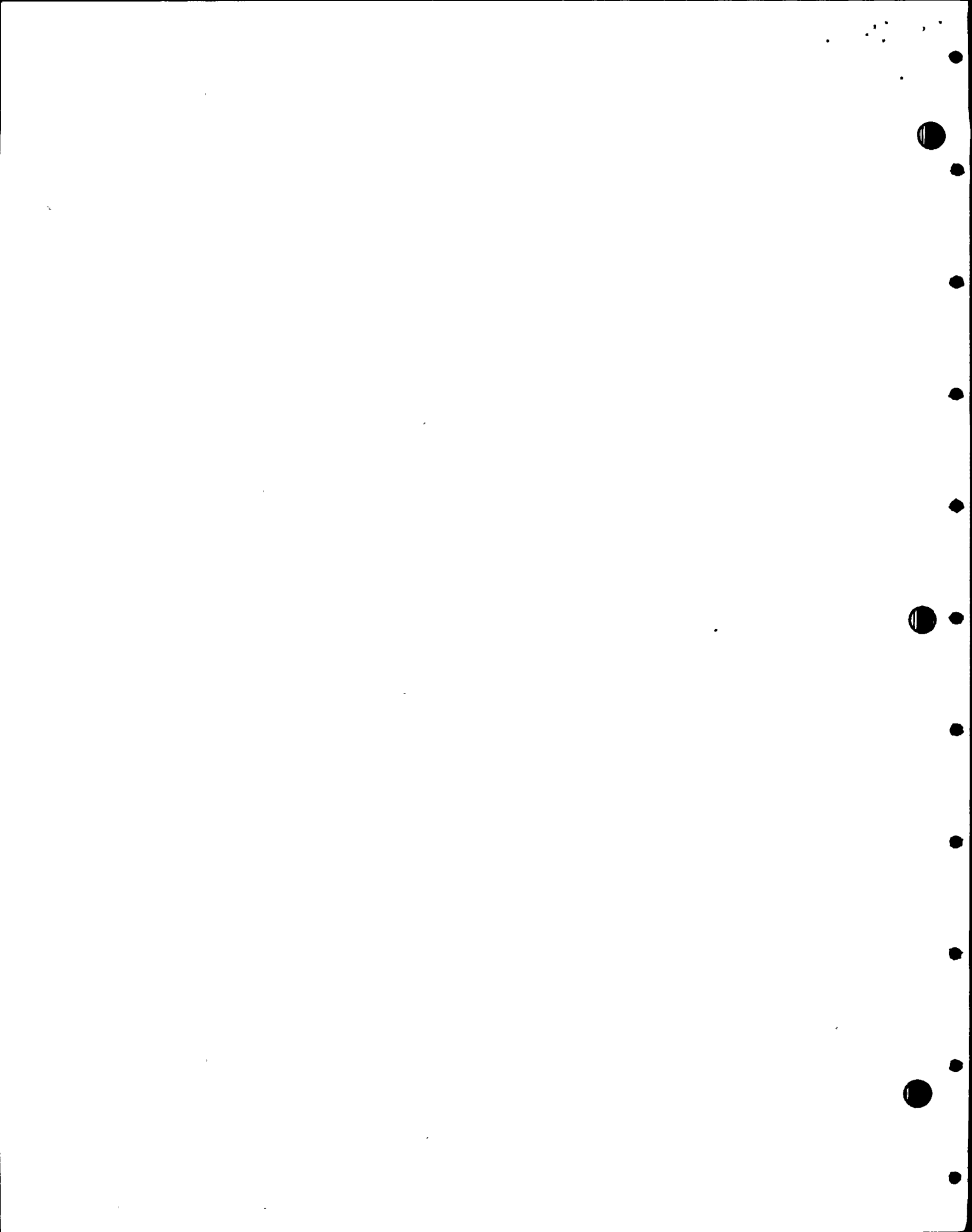
## 2.2 Problem No. 2 - Coffee Table

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)





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BENCHMARK PROBLEM NO. 2

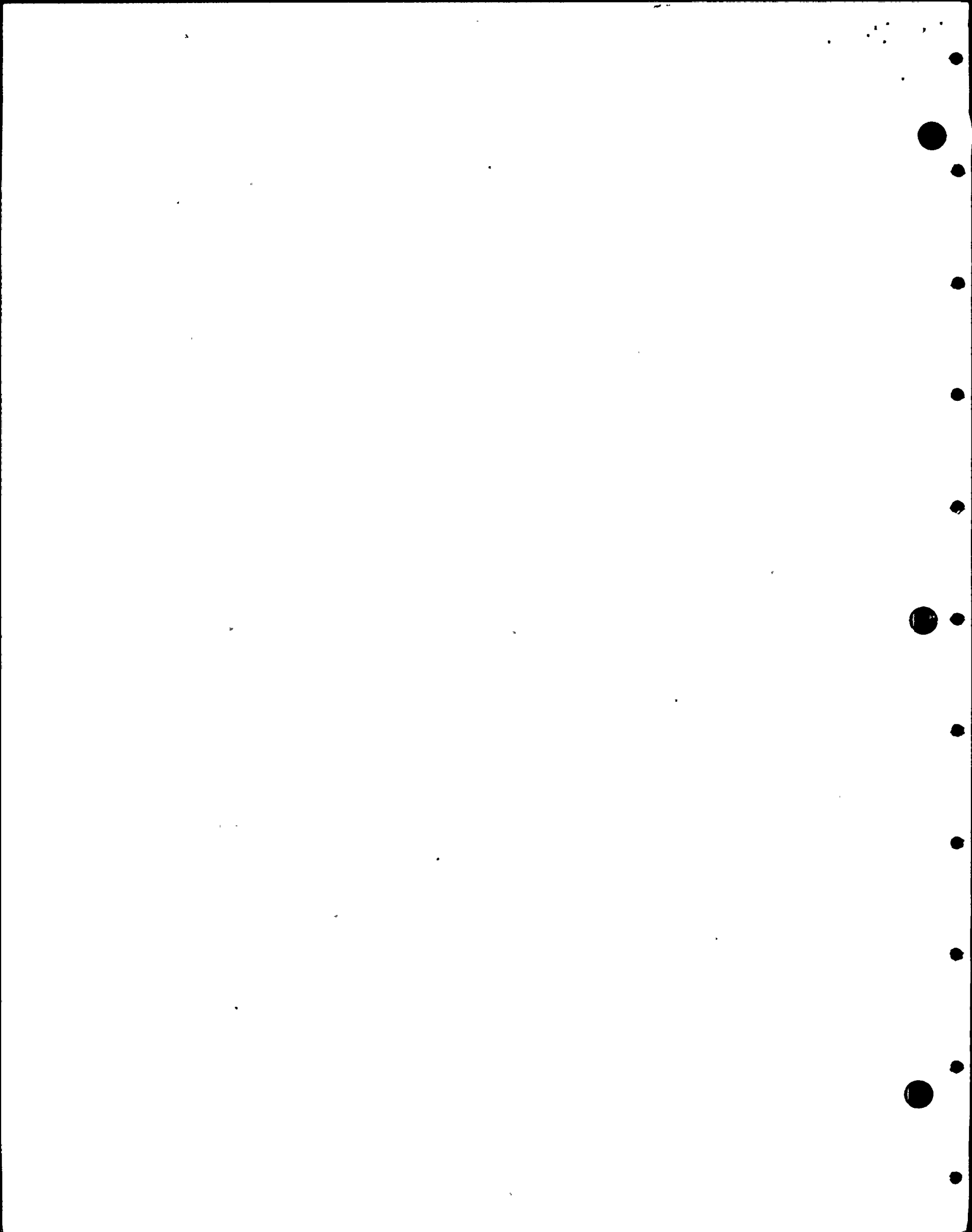
COFFEE TABLE

FREQUENCIES (CPS)

<u>MODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>
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

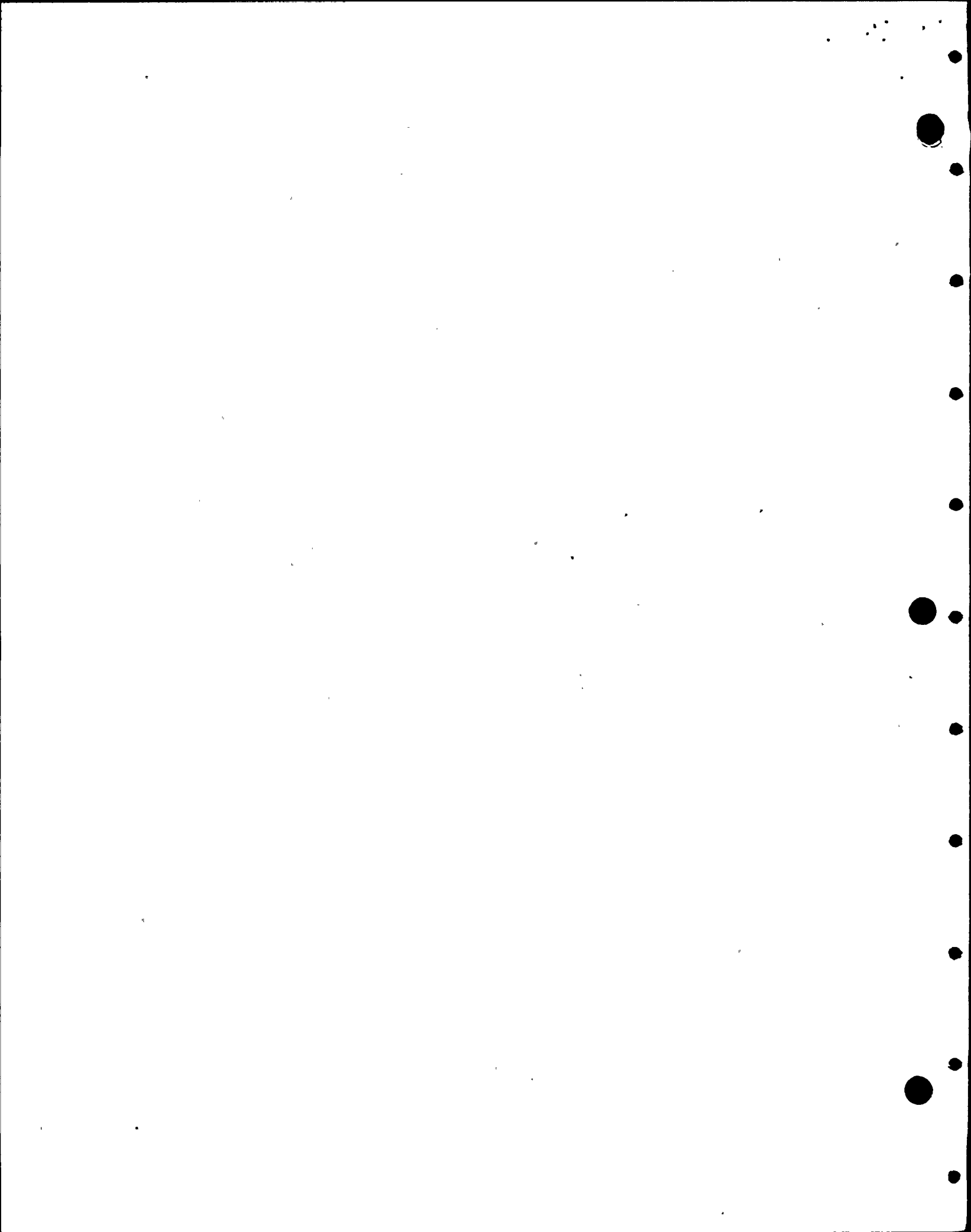
<u>COMPONENT</u>	<u>NODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>
$u_x$	11	0.46188	0.46203
$u_y$	13	0.00236	0.0023598
$u_z$	13	0.4464	0.44691
$\theta_x$	3	0.00654	0.006546
$\theta_y$	14	0.00001	0.0000127
$\theta_z$	4	0.00672	0.006722



BENCHMARK PROBLEM NO. 2

COFFEE TABLE

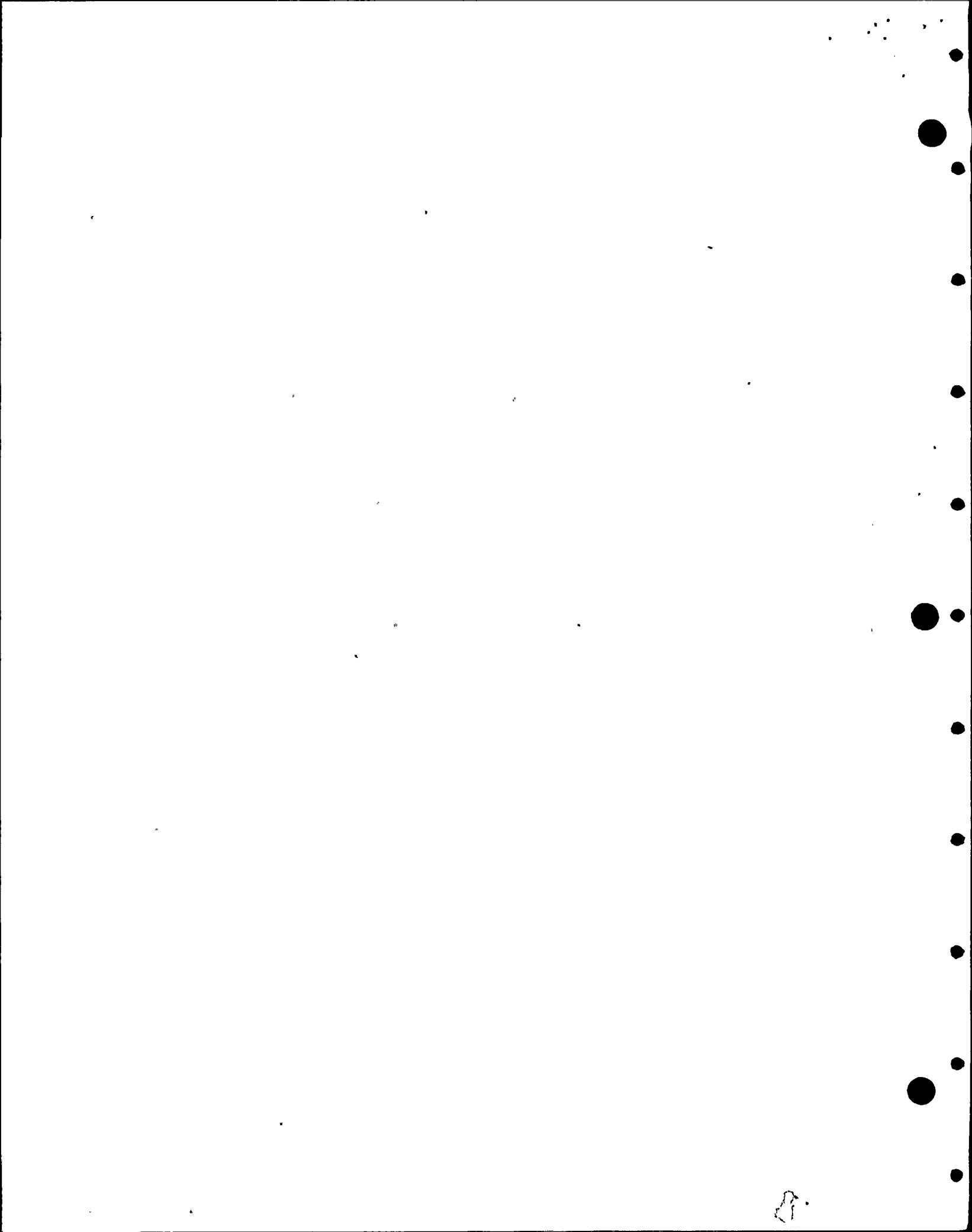
<u>COMPONENT</u>	<u>MAXIMUM ELEMENT LOADS</u>			
	<u>ELEMENT</u>	<u>EPIPE</u>	<u>ELEMENT</u>	<u>TMRSA</u>
PX(I)	1	555.4	1	555.8
VY(I)	3	468.7	3	469.2
VZ(I)	1	109.3	1	109.3
MY(I)	1	5229.0	1	5230.0
MZ(I)	1	5135.0	1	5141.0
TX(I)	1	1.61	1	1.61
PX(J)	1	555.4	1	555.8
VY(J)	3	468.7	3	469.2
VZ(J)	1	109.3	1	109.3
MY(J)	6	5229.0	6	5230.0
MZ(J)	6	5135.0	6	5141.0
TX(J)	1	1.61	1	1.61



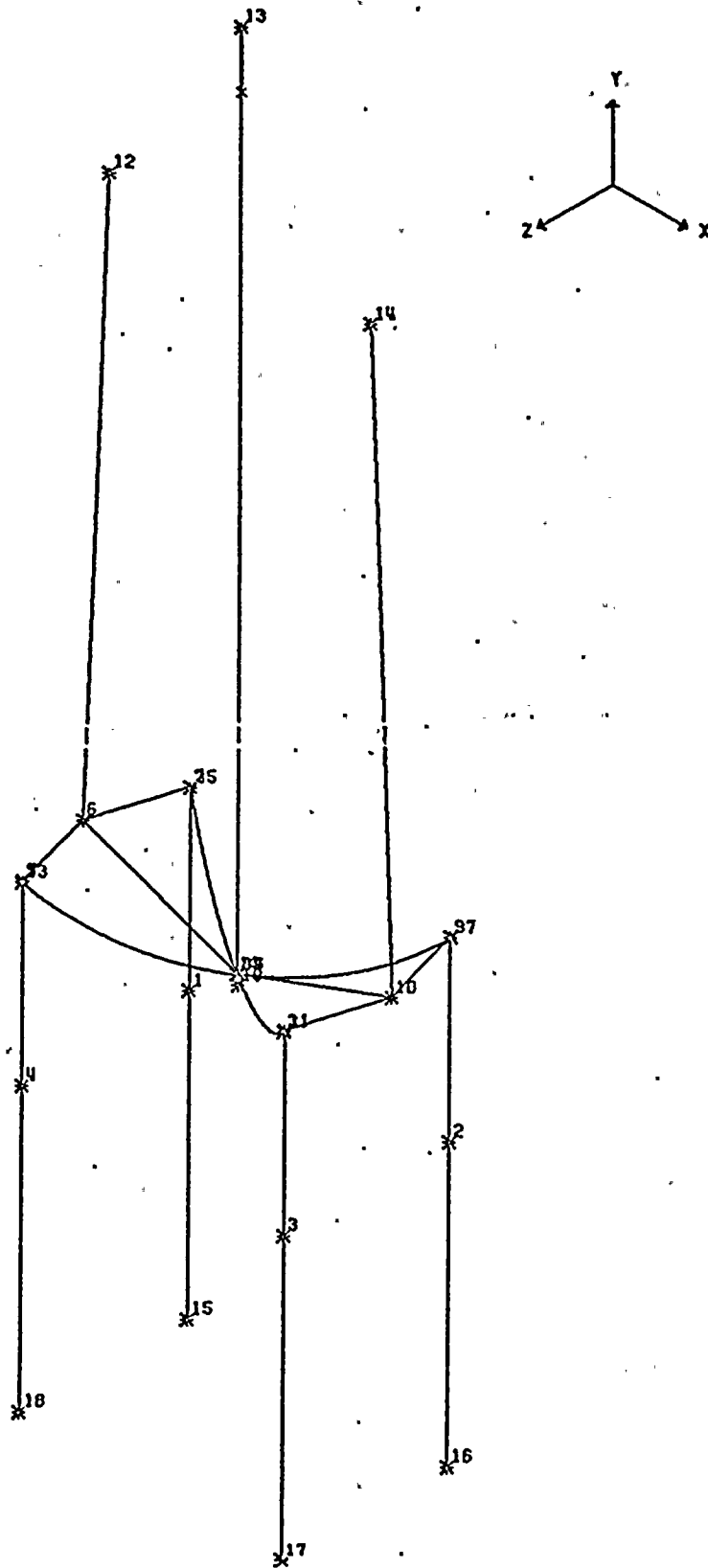


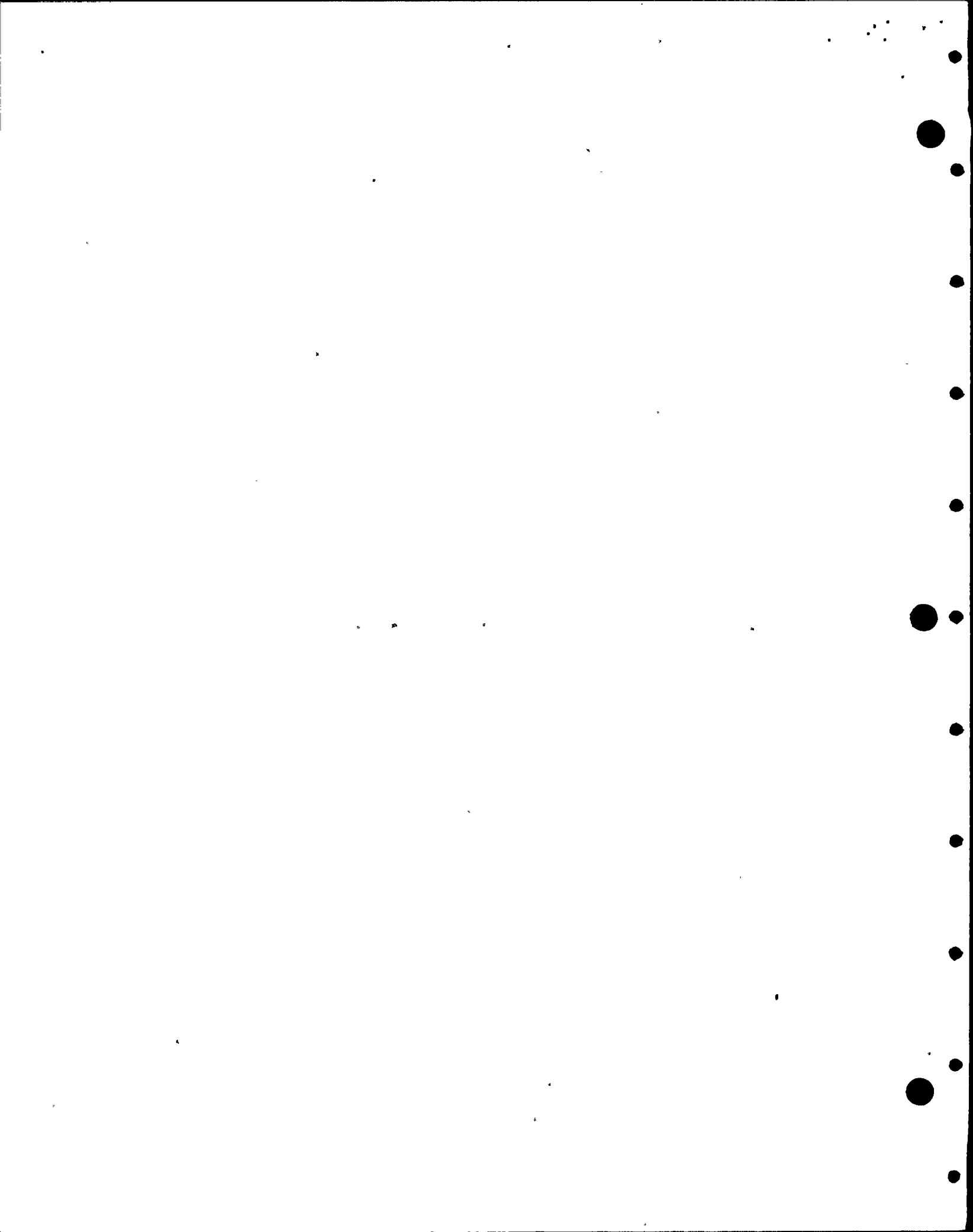
### 2.3 Problem No. 3 - Modified Reactor System

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.



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





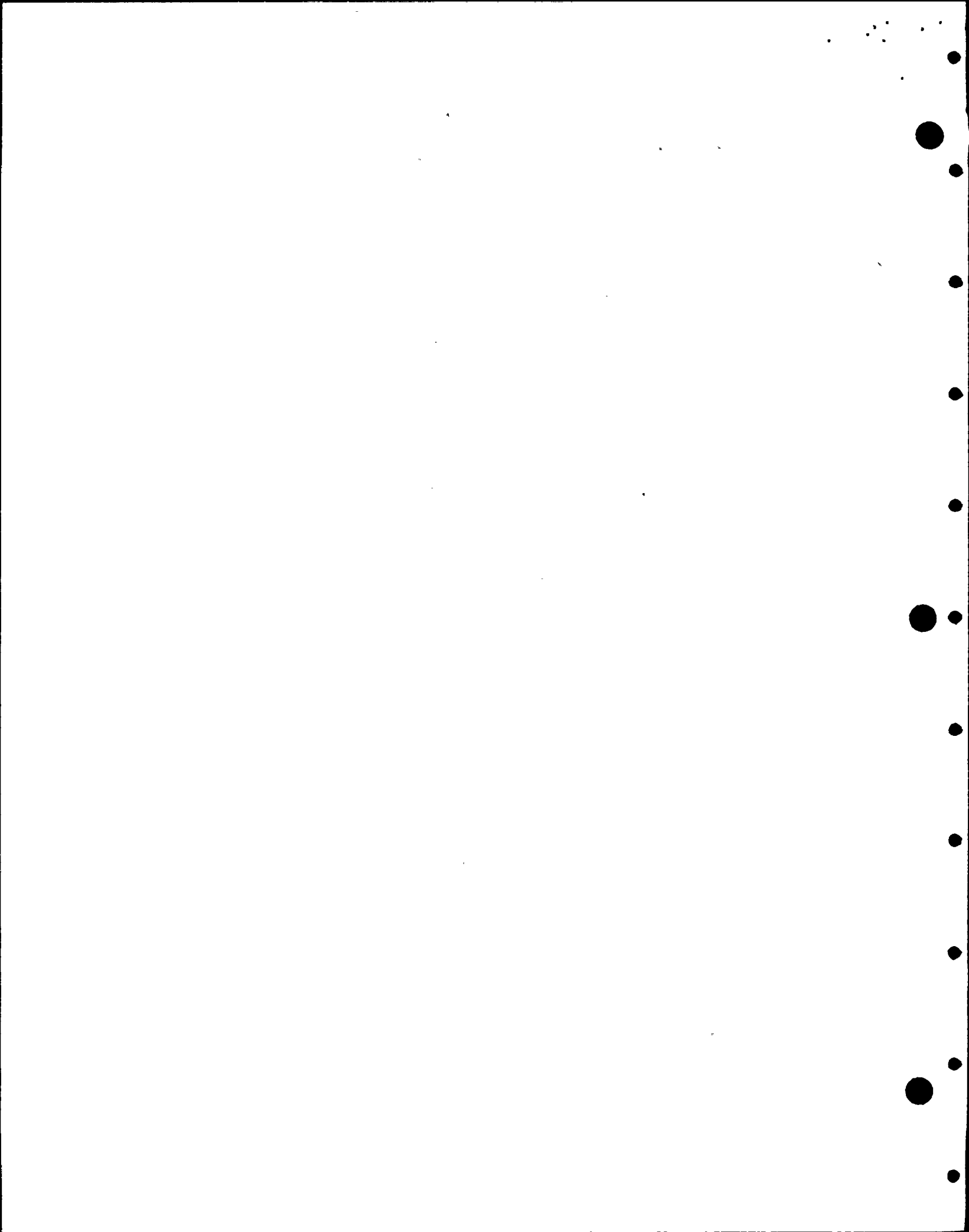
NRC BENCHMARK PROBLEM NO. 3

FREQUENCIES (CPS)

<u>MODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>
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

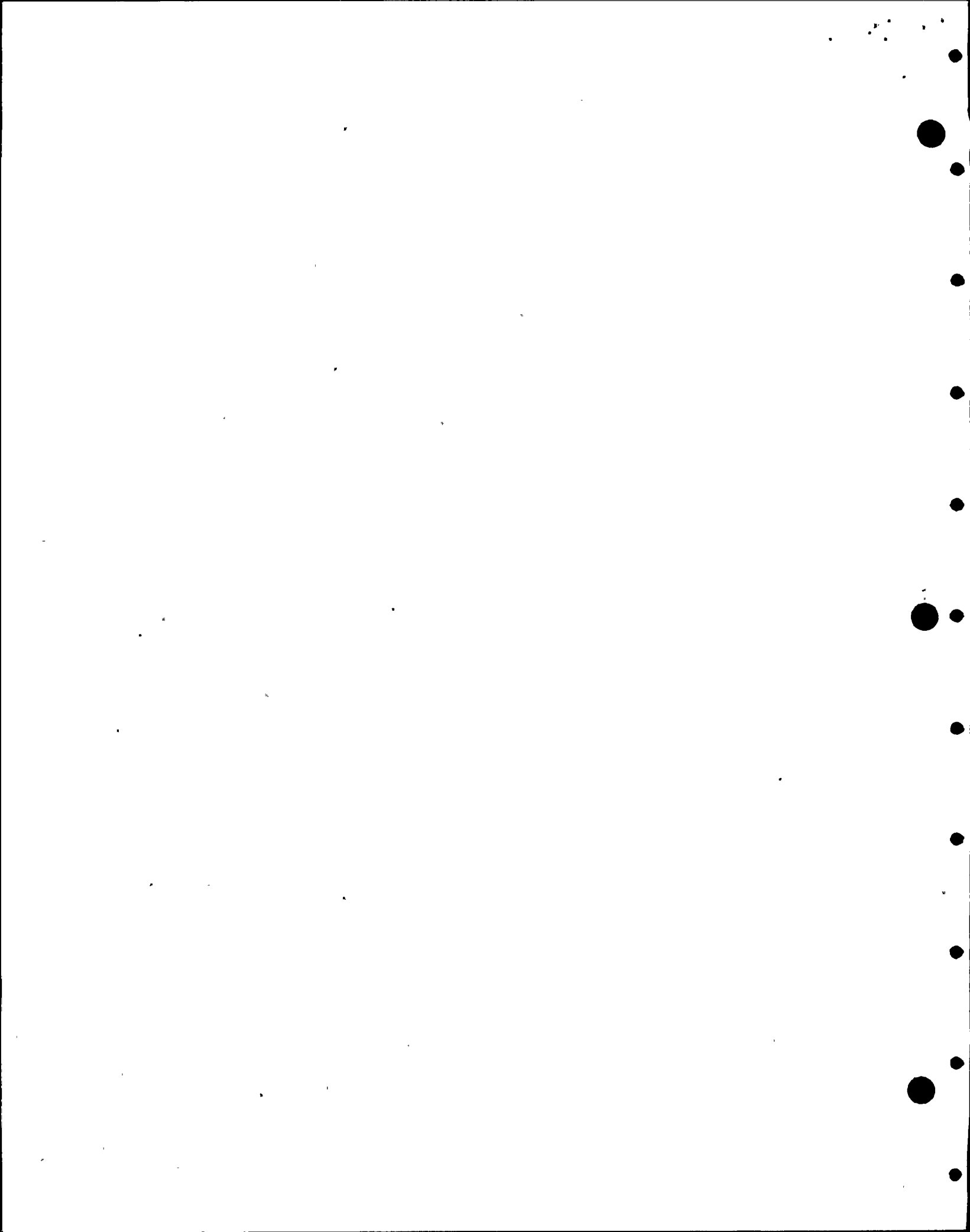
MAXIMUM DISPLACEMENTS

<u>COMPONENT</u>	<u>NODE</u>	<u>EPIPE</u>	<u>TMR SAP</u>	
			<u>(SRSS)</u>	<u>(CLUSTER)</u>
$u_x$	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
$\theta_x$	13	0.09062	0.07763	0.10689
$\theta_y$	12	0.00192	0.001866	0.001968
$\theta_z$	13	0.09036	0.07763	0.10689



NRC BENCHMARK PROBLEM NO. 3

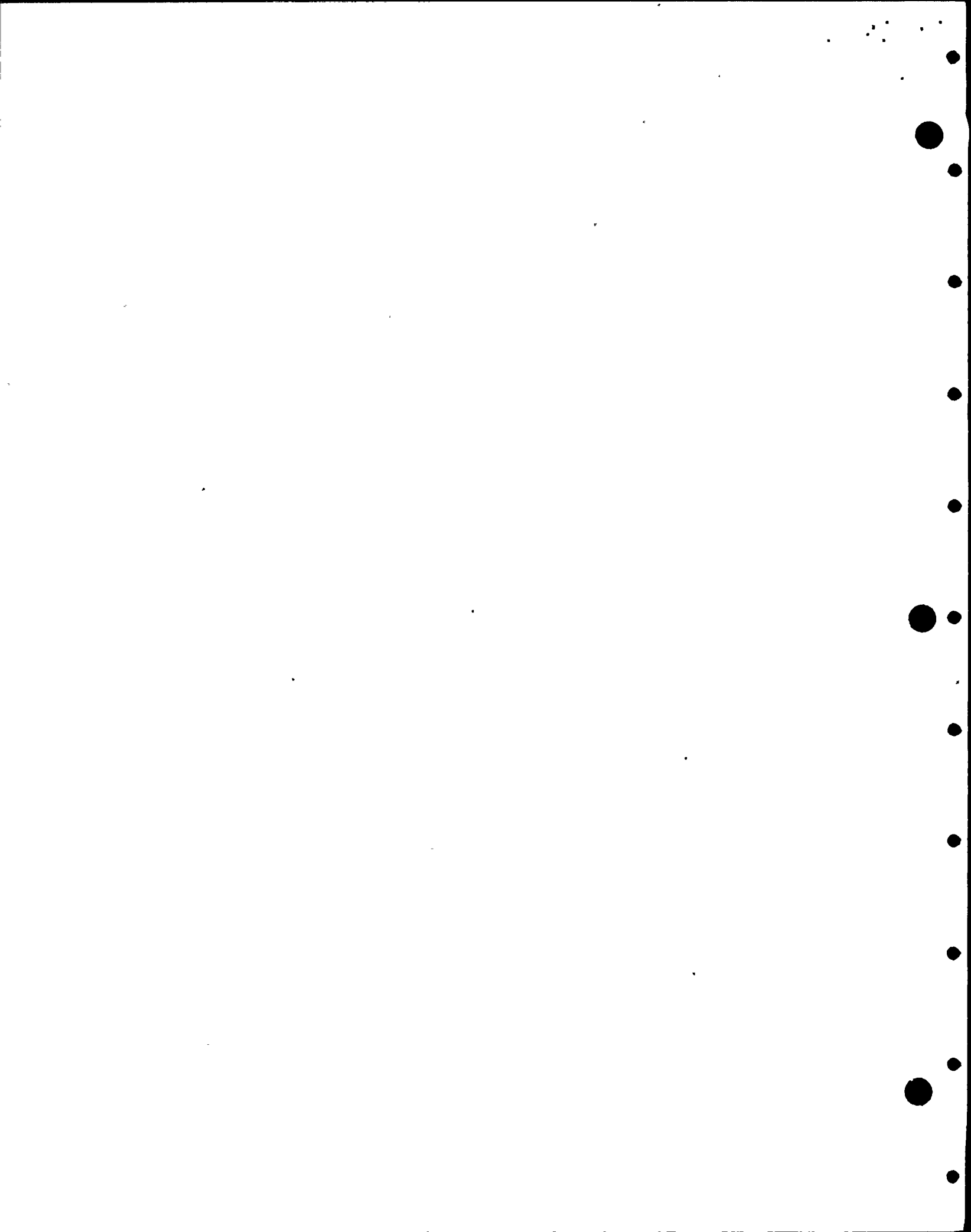
<u>COMPONENT</u>	<u>MAXIMUM ELEMENT LOADS</u>				
	<u>ELEMENT</u> <u>NO.</u>	<u>EPIPE</u> <u>(CLUSTER)</u>	<u>ELEMENT</u> <u>NO.</u>	<u>TMRSA</u> <u>(SRSS)</u>	<u>TMRSA</u> <u>(CLUSTER)</u>
PX(I)	1	3243.0	1	3028.0	3574.0
VY(I)	3	2109.0	3	2009.0	2155.0
VZ(I)	3	635.0	3	563.0	747.0
TX(I)	14	4110.0	20	3596.0	4592.0
MY(I)	1	7823.0	1	7623.0	8181.0
MZ(I)	20	37190.0	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.

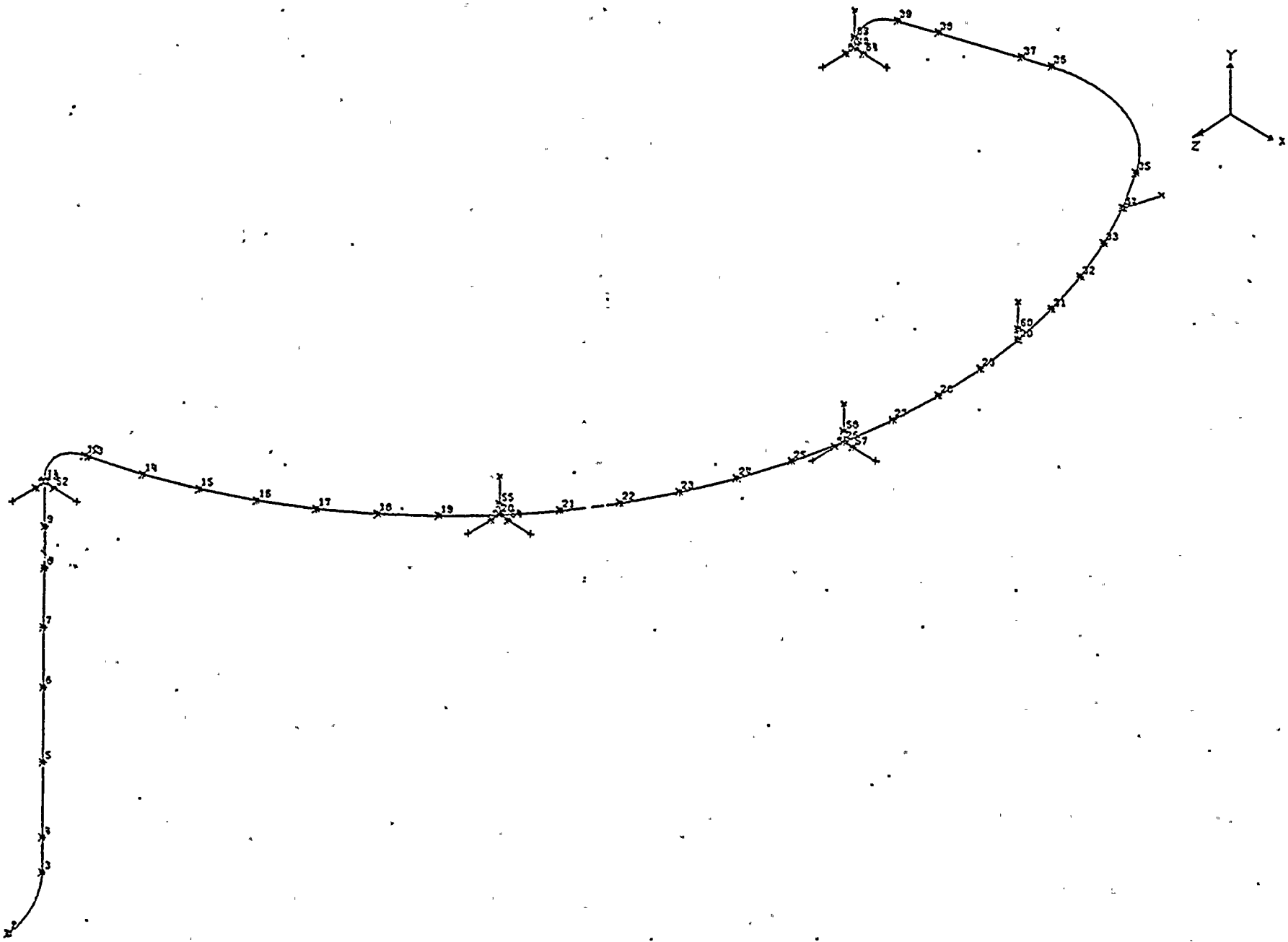


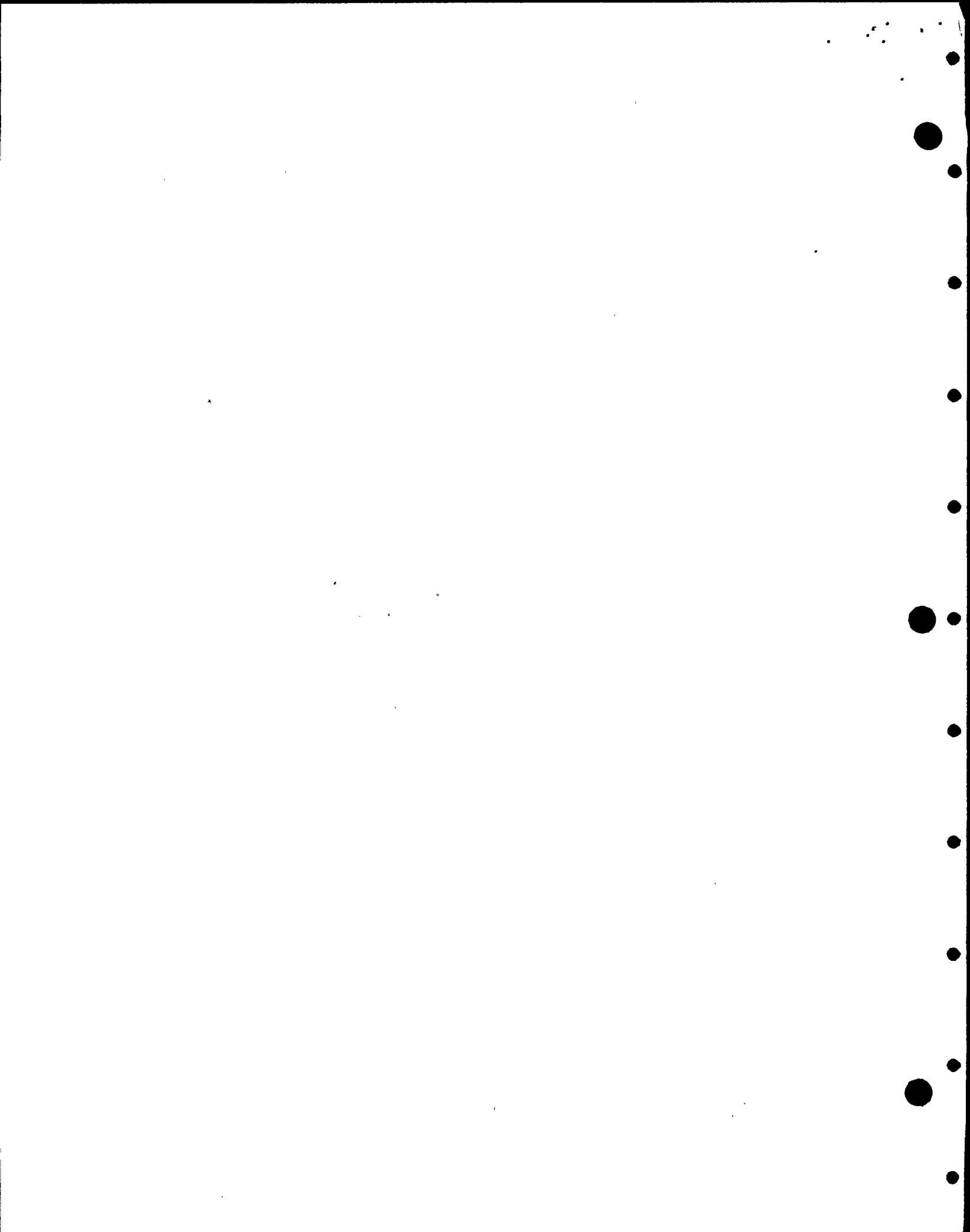
PIPING BENCH MARK PROBLEM - 323A

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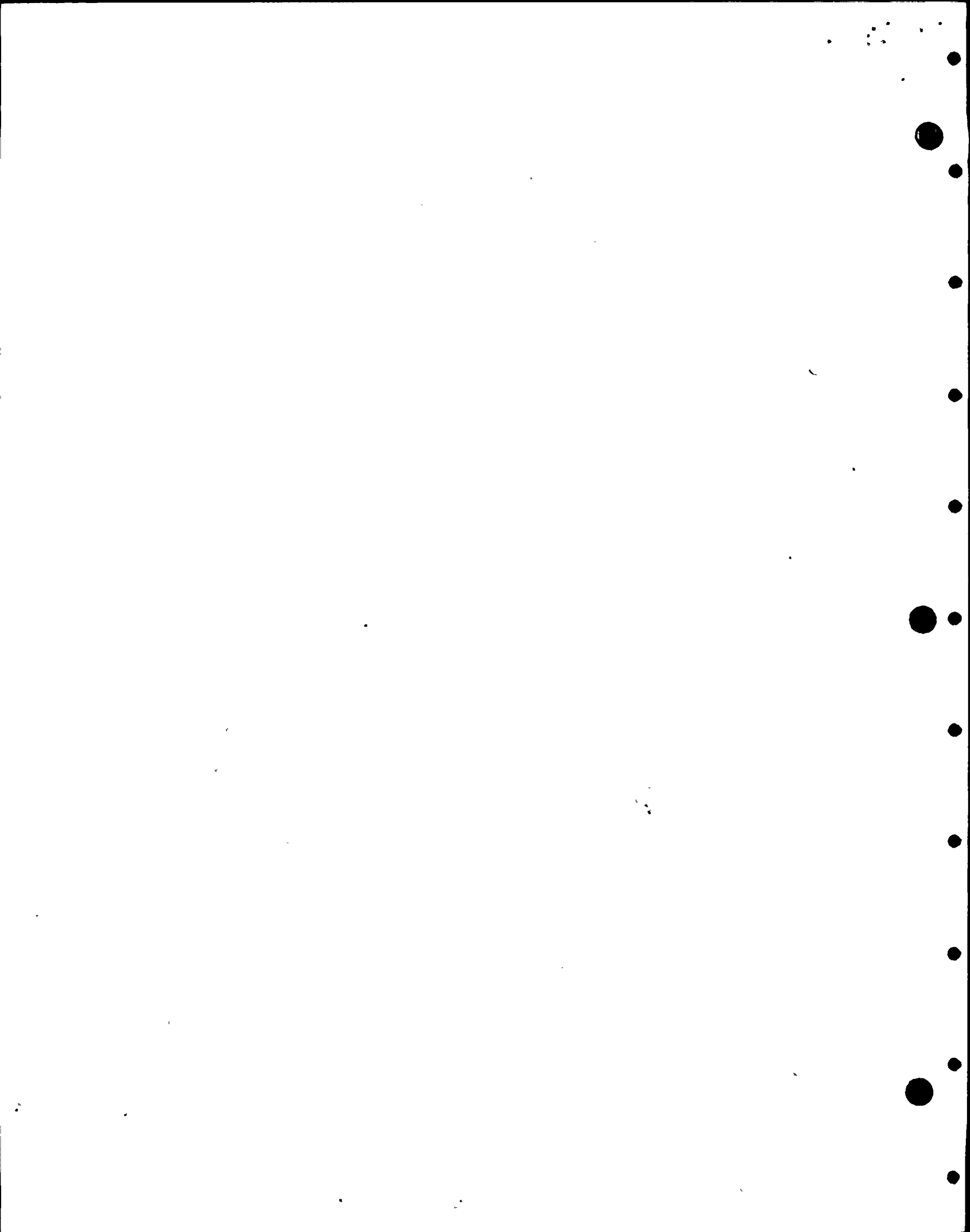


BENCHMARK PROBLEM NO. 323A

PIPING SYSTEM

FREQUENCIES (CPS)

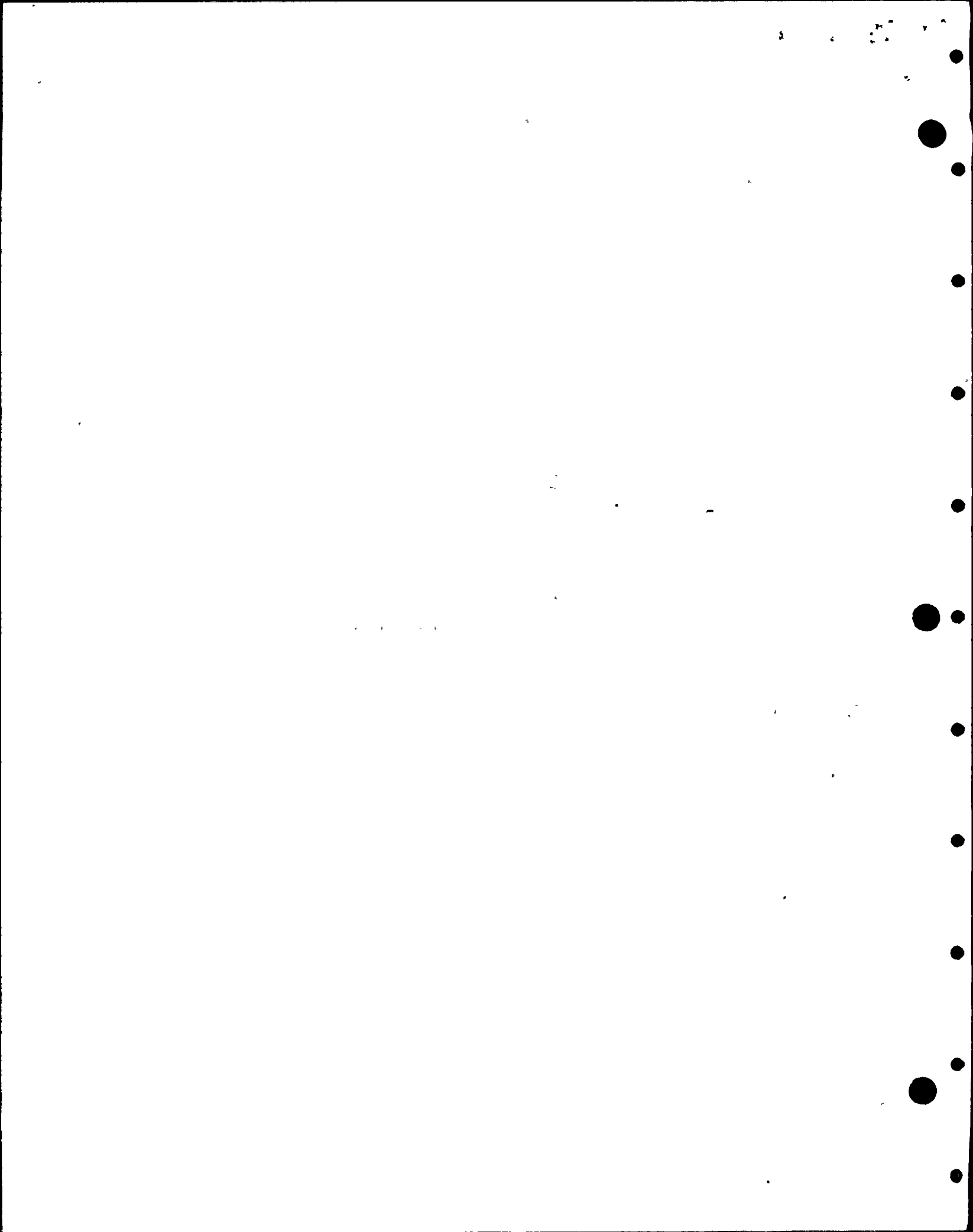
<u>MODE</u>	<u>EPIPE</u>	<u>TMRAP</u>
1	6.39	6.39
2	9.99	9.99
3	13.27	13.27
4	14.49	14.49
5	15.33	15.33
6	17.50	17.50
7	19.09	19.09
8	19.62	19.63
9	21.44	21.44
10	28.71	28.71
11	29.86	29.87
12	31.48	31.49
13	32.01	32.01
14	36.37	36.37
15	40.00	40.00
16	41.37	41.37
17	47.39	47.40
18	49.77	49.77
19	50.13	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



NRC BENCHMARK PROBLEM 323A PIPING SYSTEM

TMRSAP MAXIMUM DISPLACEMENTS

		<u>SRSS</u>	<u>CLUSTER</u>
u <sub>x</sub> NODE 31	X-SPECTRA	.020751	.020785
	Y-SPECTRA	.0020513	.0020675
	Z-SPECTRA	<u>.010887</u>	<u>.010943</u>
	SRSS =	.023523	.0235805
u <sub>y</sub> NODE 35	X-SPECTRA	.051633	.051638
	Y-SPECTRA	.057385	.057386
	Z-SPECTRA	<u>.010441</u>	<u>.010448</u>
	SRSS =	.077897	.077902
u <sub>z</sub> NODE 36	X-SPECTRA	.013009	.013101
	Y-SPECTRA	.0028254	.0028406
	Z-SPECTRA	<u>.0068936</u>	<u>.0069855</u>
	SRSS =	.014991	.015116
θ <sub>x</sub> NODE 35	X-SPECTRA	.00021197	.00021198
	Y-SPECTRA	.00023513	.00023518
	Z-SPECTRA	<u>.000043568</u>	<u>.000043607</u>
	SRSS =	.00031955	.000319604
θ <sub>y</sub> NODE 35	X-SPECTRA	.000084048	.000084152
	Y-SPECTRA	.000012717	.000013047
	Z-SPECTRA	<u>.000043608</u>	<u>.000043729</u>
	SRSS =	.000095565	.000095728





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NRC BENCHMARK PROBLEM 323A PIPING SYSTEM

MAXIMUM DISPLACEMENTS

		<u>SRSS</u>	<u>CLUSTER</u>
$\theta_x$ NODE 38	X-SPECTRA	.00020599	.00020606
	Y-SPECTRA	.00022871	.00022872
	Z-SPECTRA	<u>.000042008</u>	<u>.000042082</u>
	SRSS =	.00031065	.00031071

DISPLACEMENT SUMMARY

<u>COMPONENT</u>	<u>NODE</u>	<u>EPIPE</u>	<u>TMRAP</u>
$u_x$	31	0.02354	0.02352
$u_y$	35	0.07789	0.07789
$u_z$	36	0.01500	0.01499
$\theta_x$	35	0.00032	0.00032
$\theta_y$	35	0.00010	0.000095
$\theta_z$	38	0.00031	0.00031

NOTE: ELEMENT LOAD DATA WERE NOT SUPPLIED BY NRC.

