WHITING CORPORATION
PRODUCTION ENGINEERING DEPT.
HARVEY, ILLINOIS 60426 U.S.A.
AREA CODE 312 331-4000

CUSTOMER AMERICAN ELECTRIC POWER

C.O. NO. ______ REQN. 79183

DATE 3-9-87 BY MJM

CRANE SEISMIC REPORT

CASK HANDLING CRANE

150 TON CAPACITY

EXISTING BRIDGE, NEW TROLLEY

PRELIMINARY

CUSTOMER: AMERICAN ELECTRIC POWER CORP.
COLUMBUS, OHIO

FOR: DONALD C COOK FACILITY
BRIDGMAN, MICHIGAN

BY *M. McMahon*
M. McMahon
Staff Engineer

ABSTRACT

The equipment reviewed in this report is an 'Electric Overhead Crane.' The crane is designed and rated for a capacity load of 150 tons on the main hook.

The crane was analyzed for the resistance to the specified Operational Base Earthquake (OBE) and the specified Safe Shutdown Eqrthquake(SSE). This was done with loads of 50 and 55 tons on the main hook and the trolley at mid-span.

The crane was mathematically modeled as a multi-degree of freedom system of node points, interconnected by various finite elements. "ANSYS", a large scale general purpose computer program was used to perform a static and a reduced modal analysis. It was found that excitations parallel the runway (Y direction) would produce slip. This excitation was then proportioned to produce a maximum Y reaction that would not produce slip.

It was found that the stresses in the principal.structural components did not exceed the allowable stresses with a 50 ton load on the main hook.

ANALYSIS DESCRIPTION

The crane was analyzed to determine the effect of seismic excitations. For this analysis, the matrix displacement method was used based upon finite element techniques. The crane was mathematically modeled as a system of node points interconnected by various finite elements representing straight beams. All masses and inertias were distributed among the nodes whose degrees of freedom characterize the response of the structure. The interconnecting finite elements were assigned stiffnesses equivalent to that of the actual structure.

The mathematical model represents as accurately as possible the flexibility of the bridge girders, hoist rope, and girder end connection. The trolley, the drive units and the bridge trucks were represented as rigid bodies.

The crane was analyzed with the trolley positioned at mid-span. This was done with loads of 50 and 55 tons in the down position. Preliminary calculations showed that this condition would produce the maximum girder stress for a given load.

The dynamic analysis was of the mode frequency (MODAL) type, solving for the resonant frequencies and the mode shapes that characterize the crane. The modes with meaningful participation in a given direction are directly expanded by the computer program to yield the expanded mode shapes, the element stresses and the reaction values. This type of analysis is linear and plastic deformation, sliding, friction, and slack rope are not taken into account.

The amplified response spectra used in the analysis are shown in Appendix 'A'. These include the three orthogonal excitations for the specified earthquakes. Also included in this Appendix are the mode coefficients and natural frequencies for mode shapes considered.

The normal mode approach was employed for the analysis of the components. All significant eigen-values and eigen-vectors were extracted, and these modes were combined by the method specified by the U. S. Nuclear Regulatory Commission, Regulatory Guide 1.92, Rev. 1, Section 1.2.2 (Combination of Modal Responses with Closely Spaced Modes by the 10% Method). Those modes with mode coefficient ratios less than 1% in the x direction or 0.5% in the y and z directions were dropped because their contribution is proportionally small when compared to the largest mode coefficient of the related directional excitation. The results of the three orthogonal dynamic excitations were combined by the square root of the sum of the squares method (SRSS) and then absolutely added to the results of the static condition.

Because the y reaction exceeds the frictional resistance of those bridge wheels that are braked, slip will occur. The maximum acceleration in the y direction will be reduced from that predicted by the modal analysis. The primary y mode was therefore reduced by a scale factor such that the resulting y reaction approaches the maximum that could be sustained before slip. The results were then resummed as previously described.

In order to assure structural integrity, the job specification requires that the maximum stresses not exceed the minimum yield strength of the material divided by 1.5 for the OBE and 1.1 for the SSE.

The crane is constructed of ASTM A36 structural steel except for components which are specifically noted in the report. A36 material has a specified minimum yield strength of 36 ksi. The combined bending and axial stresses are limited to 24 ksi for the OBE and 32.7 kis for the SSE.

The actual properties of the specified materials show a great deal of variation and are generally considerably higher than the minimum required by the material specification. Also the maximum stresses occur only at a point on a section and cannot of themselves be indicative of the tendency of the section to permanently deform, especially when the nominal stresses on the extreme fibers of the adjoining faces are significantly lower. It is therefore conservative to compare the combined bending and axial stresses at the corners with the specified allowables to assure structural integrity.

Impact factors for wheel flange to rail contact, etc., have been considered negligible. The state of the art today is such that these impacts cannot rigorously be studied; however, independent time history analyses have been run in many cases, all indicating slow relative motion between the rail and the wheel. This is because of the time dependency of the forcing function comming from the building into the crane. Note that the only coupling through which these forces can be transmitted is dynamic friction. Upon reaching the rail the wheel will first rise through the corner radius and then contact the rail. During this period, the structure is starting to deflect as the end of the crane in this direction is flexible.

The computer analysis was performed using ANSYS, a large scale finite element program.

SUMMARY OF RESULTS

The crane was mathematically modeled using finite elements. On the basis of preliminary runs, the number of degrees of freedom and the significance criteria for modal expansion were adjusted. Static and three load step reduced modal runs were made and the results summed. Because slip occurs, the y excitation was proportioned and these results resummed.

The crane was analyzed with the new trolley at mid-span. For this position the analysis was done with 50 and 55 ton loads on the main hook in the low position. From preliminary studies, the load case considered should yield the maximum stresses in the girders.

Tables 1 through 4 summarize the maximum stresses in the members from the finite element model. All stresses are within the allowables required by the job specification with a 50 ton load.

Table 5 summarizes the rope load from the finite element model. Because of the seismic acceleration a slack rope condition was found to exist under certain conditions. This cannot be truly simulated with a linear modal analysis. However our experience with time history analyses shows that a modal analysis tends to produce conservative results. The rope load predicated by the modal analysis is well below the allowable rope load.

Table 15 summarizes the maximum crane bridge wheel loads. When the excess dynamic rope load (that which produces a slack rope) is deducted, a small upkick is produced by the loading conditions examined. When the wheel loads parallel to the runway are compared with the vertical wheel load times the coefficient of friction, it is found that the crane bridge will tend to slide under certain loading conditions examined. This sliding is oscillatory in nature and the loadings predicted by a modal analysis are conservative. The reported wheel loads have been adjusted to account for frictional effects.

Although some non-linearities are produced by the specified excitations the specified linear analysis will conservatively predict the behavior of the crane during a seismic excitation.

Additional information on the response of the crane may be found in Appendix 'A'.

The crane was found to meet the job specification requirements for a seismic excitation with a 50 ton load on the main hook. With a 55 ton load, the stress on girder A exceeds the allowable by less than 1% for the SSE.

50 TON

TABLE 1

MAXIMUM STRESSES FROM PF1AMDO
OBE MID 50 D

COMPONENT	ELEM	NODE	X	Y	Z	SRSS	STATIC	SUM
GIRDER A	30	311	712.	6137.	10502.	12184.	10191.	22375.
GIRDER B	47	357	686.	6239.	10255.	12023.	9681.	21704.
END CONNECT-RHE	21	155	860.	11116.	100.	11150.	504.	11654.
END CONNECT-LHE	67	253	831.	11805.	147.	11835.	390.	12225.

OBE ALLOWABLE STRESS 24 KSI

$$\frac{22375}{24000} = .932$$

TABLE 2

MAXIMUM STRESSES FROM PF1AMDS
SSE MID 50 D

COMPONENT	ELEM	NODE	X	Y	Z	SRSS	STATIC	SUM
GIRDER A	30	311	1362.	8699.	19716.	21594.	10191.	31785.
GIRDER B	47	359	1323.	8844.	19245.	21221.	9681.	30902.
END CONNECT-RHE	21	155	1571.	15759.	194.	15838.	504.	16342.
END CONNECT-LHE	67	253	1523.	16736.	277.	16807.	390.	17197.

SSE ALLOWABLE STRESS 32.7 KSI

$$\frac{31785}{32700} = .972$$

TABLE 3

MAXIMUM STRESSES FROM PF1BMDO
OBE MID 55 D

COMPONENT	ELEM	NODE	X	Y	Z	SRSS	STATIC	SUM
GIRDER A	30	311	687.	6302.	10859.	12575.	10497.	23071.
GIRDER B	47	359	663.	6407.	10627.	12427.	9987.	22414.
END CONNECT-RHE	21	155	860.	11416.	89.	11449.	504.	11953.
END CONNECT-LHE	67	253	831.	12124.	138.	12153.	390.	12543.

OBE ALLOWABLE STRESS 24 KSI

$$\frac{23071}{24000} = .961$$

TABLE 4

MAXIMUM STRESSES FROM PF1BMDS
SSE MID 55 D

COMPONENT	ELEM	NODE	X	Y	Z	SRSS	STATIC	SUM
GIRDER A	30	311	1339.	8940.	20387.	22301.	10497.	32798.
GIRDER B	47	359	1282.	9089.	19944.	21954.	9987.	31942.
END CONNECT-RHE	21	155	1572.	16195.	175.	16272.	504.	16776.
END CONNECT-LHE	67	253	1524.	17199.	260.	17268.	390.	17657.

SSE ALLOWABLE STRESS 32.7 KSI

$$\frac{32798}{32700} = 1.00 \ast$$

TABLE 5

ROPE LOADS

KIPS

LOAD	POS	STATIC	OBE		SSE	
			ST + DYN	ST - DYN	ST + DYN	ST - DYN
50T	MID DN	118.	363.	- 127.	577.	-341.
55T	MID DN	128.	388.	-132.	616.	-360.

ROPE 2-6 PART SYSTEMS

RATED BREAKING STRENGTH - 125 T

ELASTIC LIMIT .6 x BREAKING STRENGTH

OBE ALLOWABLE

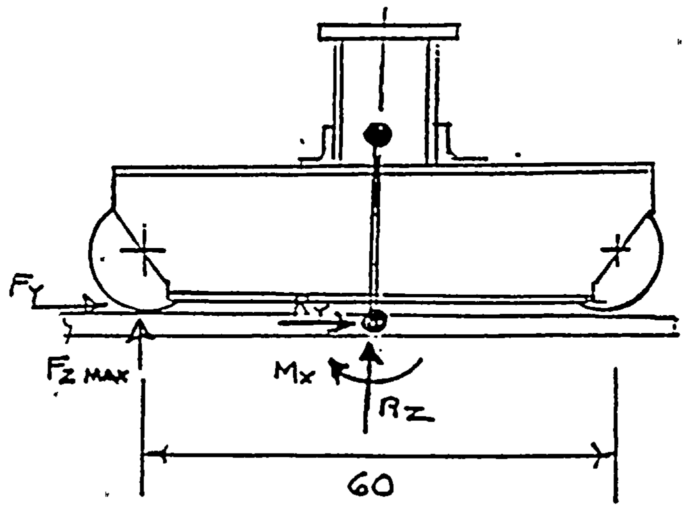
$$\frac{6 \times 125 \times 2 \times .6}{1.5} = 600 \times 2 = 1200 \text{ KIP/BOTH SYSTEMS}$$

SSE ALLOWABLE

$$\frac{6 \times 125 \times 2 \times .6}{1.1} = 818 \times 2 = 1636 \text{ KIP/BOTH SYSTEMS}$$

SCALE FACTOR

BECAUSE SLIP WILL OCCUR AT THE RAIL WHEEL INTERFACE IF THE REACTION IN THE Y DIRECTION EXCEEDS THE MAXIMUM WHEEL LOAD IN THE Z DIRECTION TIMES THE COEFFICIENT OF FRICTION, THE ACCELERATION IN THE Y DIRECTION WILL BE LESS THAN PREDICTED BY A MODAL ANALYSIS. THE PRIMARY Y MODE MAY BE PROPORTIONED BY A SCALE FACTOR THAT ACCOUNTS FOR SLIDING AND THAT IS DERIVED AS FOLLOWS:



WHERE

R_Z, R_Y & M_X ARE MAXIMUM REACTIONS FROM FINITE ELEMENT MODAL ANALYSIS

AND

$F_{Z\,MAX}$ IS MAX Z REACTION AT A DRIVE WHEEL

F_Y IS MAX Y REACTION BY FRICTION

SCF IS SCALE FACTOR

$$F_{Z\,MAX} = \frac{R_Z}{2} + \frac{M_X}{60}$$

$$F_Y = .25\ F_{Z\,MAX}$$

$$SCF = \frac{F_Y}{R_Y}$$

OBSERVING THAT M_X IS DUE PRIMARILY TO Y EXCITATIONS

$$SCF = \frac{.25}{R_Y}\left(\frac{R_Z}{2} + \frac{SCF(M_X)}{60}\right)$$

$$SCF = \frac{R_Z}{8 R_Y \left(1 - \frac{M_X}{240(R_Y)}\right)}$$

TABLE .6
SCALE FACTORS

LOAD	REACTIONS FACTOR	OBE 1ST SUM	OBE 2ND SUM	SSE 1ST SUM	SSE 2ND SUM
50T	RZ KIP	193.9	191.1	275.1	268.6
	RY KIP	182.6	33.8	379.0	48.0
	MX IN KIP	12417.	2326.4	25738.	3287.9
	SCF	.1852		.1265	
55T	RZ KIP	199.1	196.4	282.7	276.4
	RY KIP	182.6	34.7	379.0	49.3
	MX IN KIP	12417.	2388.2	25738.	3377.6
	SCF	.1902		.1300	

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 50T LD DN / OBE 'X'

REACTION SUMMARY

LOAD STEP / NODE LABEL	1	2	3	SRSS	STATIC	SUM	DIFFE
101 FY	861.	182118.	131.	182120.	-0.	182120.	-1821
101 FZ	6363.	22645.	86788.	89919.	102692.	192611.	127
101 MX	76157.	12385891.	58556.	12386263.	30557.	12416820.	-123557
102 FZ	6134.	22230.	84202.	87380.	96898.	184278.	95
102 MX	39147.	365501.	6815.	367655.	97029.	464684.	-2706
123 FY	0.	0.	0.	0.	0.	0.	
123 FZ	0.	0.	0.	0.	0.	0.	
123 MX	0.	0.	0.	0.	0.	0.	
123 MY	0.	0.	0.	0.	0.	0.	
124 FX	34350.	1555.	15074.	37544.	0.	37544.	-375
124 FY	0.	0.	0.	0.	0.	0.	
124 FZ	0.	0.	0.	0.	0.	0.	
124 MX	0.	0.	0.	0.	0.	0.	
124 MY	0.	0.	0.	0.	0.	0.	
124 MZ	0.	0.	0.	0.	0.	0.	
201 FY	825.	182611.	294.	182613.	0.	182613.	-1826
201 FZ	5866.	22803.	88075.	91168.	102714.	193882.	115
201 MX	62142.	12287309.	48300.	12287561.	29689.	12317250.	-122578
202 FZ	5608.	22796.	85659.	88818.	96877.	185694.	80
202 MX	24203.	335544.	10095.	336567.	96161.	432728.	-2404

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SRSS-4.3 WHITING CORPORATION ANSYS SRSS PROGRAM . 87/03/06.
TABLE # 8 LS 2 MODE 1 SCALE FACTOR = .1852 BY MJM PAGE 14 OF 27

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 50T LD DN / OBE 'X'

REACTION SUMMARY

LOAD STEP NODE	LABEL	1	2	3	SRSS	STATIC	SUM	DIFFE
101	FY	861.	33728.	131.	33739.	-0.	33739.	-337
101	FZ	6363.	4194.	86758.	87122.	102692.	189814.	155
101	MX	76157.	2293867.	58556.	2295878.	30557.	2326435.	-22653
102	FZ	6134.	4117.	84282.	84605.	96898.	181503.	122
102	MX	39147.	67691.	6815.	78492.	97029.	175522.	185
123	FY	0.	0.	0.	0.	0.	0.	
123	FZ	0.	0.	0.	0.	0.	0.	
123	MX	0.	0.	0.	0.	0.	0.	
123	MY	0.	0.	0.	0.	0.	0.	
124	FX	34350.	288.	15074.	37513.	0.	37513.	-375
124	FY	0.	0.	0.	0.	0.	0.	
124	FZ	0.	0.	0.	0.	0.	0.	
124	MX	0.	0.	0.	0.	0.	0.	
124	MY	0.	0.	0.	0.	0.	0.	
124	MZ	0.	0.	0.	0.	0.	0.	
201	FY	825.	33820.	294.	33831.	0.	33831.	-338
201	FZ	5866.	4223.	88075.	88371.	102714.	191085.	143
201	MX	62142.	2275610.	48300.	2276970.	29689.	2306659.	-22472
202	FZ	5608.	4222.	85659.	85946.	96877.	182823.	109
202	MX	24203.	62143.	10095.	67449.	96161.	163610.	287

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SRSS-4.3 WHITING CORPORATION ANSYS SRSS PROGRAM 87/03/06.
TABLE # 9 BY MJM PAGE 15 OF 27

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 50T LD DN / SSE 'X'

REACTION SUMMARY

LOAD STEP / NODE LABEL		1	2	3	SRSS	STATIC	SUM	DIFFE
101	FY	1776.	377981.	310.	377985.	-0.	377985.	-3779
101	FZ	12271.	46999.	162950.	170036.	102692.	272728.	-673
101	MX	149223.	25706557.	115418.	25707249.	30557.	25737806.	-256766
102	FZ	11732.	46137.	158168.	165176.	96898.	262075.	-682
102	MX	70998.	758587.	16276.	762076.	97029.	859106.	-6650
123	FY	0.	0.	0.	0.	0.	0.	
123	FZ	0.	0.	0.	0.	0.	0.	
123	MX	0.	0.	0.	0.	0.	0.	
123	MY	0.	0.	0.	0.	0.	0.	
124	FX	64711.	3227.	29060.	71010.	0.	71010.	-710
124	FY	0.	0.	0.	0.	0.	0.	
124	FZ	0.	0.	0.	0.	0.	0.	
124	MX	0.	0.	0.	0.	0.	0.	
124	MY	0.	0.	0.	0.	0.	0.	
124	MZ	0.	0.	0.	0.	0.	0.	
201	FY	1698.	379004.	593.	379008.	0.	379008.	-3790
201	FZ	11413.	47327.	165396.	172412.	102714.	275126.	-696
201	MX	126012.	25501954.	96598.	25502448.	29689.	25532137.	-254727
202	FZ	10799.	47312.	160774.	167938.	96877.	264815.	-710
202	MX	45924.	696411.	22901.	698300.	96161.	794460.	-6021

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SRSS-4.3 WHITING CORPORATION ANSYS SRSS PROGRAM 87/03/06.
TABLE # 10 LS 2 MODE 1 SCALE FACTOR = .1265 BY MJM PAGE 16 OF 27

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 50T LD DN / SSE 'X'

REACTION SUMMARY

LOAD STEP NODE	LABEL	1	2	3	SRSS	STATIC	SUM	DIFFER
101	FY	1776.	47815.	310.	47848.	-0.	47848.	-4784
101	FZ	12271.	5945.	162950.	163520.	102692.	266212.	-6082
101	MX	149223.	3251879.	115418.	3257347.	30557.	3287904.	-322679
102	FZ	11732.	5836.	158168.	158710.	96898.	255608.	-6181
102	MX	70998.	95961.	16276.	120475.	97029.	217505.	-2344
123	FY	0.	0.	0.	0.	0.	0.	
123	FZ	0.	0.	0.	0.	0.	0.	
123	MX	0.	0.	0.	0.	0.	0.	
123	MY	0.	0.	0.	0.	0.	0.	
124	FX	64711.	408.	29060.	70937.	0.	70937.	-7093
124	FY	0.	0.	0.	0.	0.	0.	
124	FZ	0.	0.	0.	0.	0.	0.	
124	MX	0.	0.	0.	0.	0.	0.	
124	MY	0.	0.	0.	0.	0.	0.	
124	MZ	0.	0.	0.	0.	0.	0.	
201	FY	1698.	47944.	593.	47978.	0.	47978.	-4797
201	FZ	11413.	5987.	165396.	165897.	102714.	268611.	-6318
201	MX	126012.	3225997.	96598.	3229902.	29689.	3259591.	-320021
202	FZ	10799.	5985.	160774.	161247.	96877.	258124.	-6437
202	MX	45924.	88096.	22901.	101953.	96161.	198114.	-579

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TABLE # 11 BY MJM PAGE 17 OF 27

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 55T LD DN / OBE 'X'

REACTION SUMMARY

LOAD STEP NODE LABEL	1	2	3	SRSS	STATIC	SUM	DIFFE[illegible]
101 FY	861.	182118.	132.	182120.	-0.	182120.	-1821[illegible]
101 FZ	6174.	22649.	89672.	92694.	105194.	197888.	125[illegible]
101 MX	76158.	12385871.	55613.	12386250.	30557.	12416808.	-123556[illegible]
102 FZ	5957.	22226.	67288.	90270.	99400.	189670.	91[illegible]
102 MX	39173.	365501.	6893.	367659.	97026.	464685.	-2706[illegible]
123 FY	0.	0.	0.	0.	0.	0.	
123 FZ	0.	0.	0.	0.	0.	0.	
123 MX	0.	0.	0.	0.	0.	0.	
123 MY	0.	0.	0.	0.	0.	0.	
124 FX	34348.	1554.	14519.	37323.	0.	37323.	-373[illegible]
124 FY	0.	0.	0.	0.	0.	0.	
124 FZ	0.	0.	0.	0.	0.	0.	
124 MX	0.	0.	0.	0.	0.	0.	
124 MY	0.	0.	0.	0.	0.	0.	
124 MZ	0.	0.	0.	0.	0.	0.	
201 FY	825.	182611.	289.	182613.	0.	182613.	-1826
201 FZ	5651.	22807.	90909.	93896.	105216.	199111.	113[illegible]
201 MX	62130.	12287310.	45965.	12287553.	29692.	12317245.	-122578[illegible]
202 FZ	5402.	22792.	88606.	91649.	99379.	191028.	77[illegible]
202 MX	24210.	335544.	10045.	336566.	96160.	432726.	-2404[illegible]

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SRSS-4.3 WHITING CORPORATION ANSYS SRSS PROGRAM 87/03/09.

TABLE # 12 LS 2 MODE 1 SCALE FACTOR = .1902 BY MJM PAGE 18 OF 27

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 55T LD DN / OBE 'X'

REACTION SUMMARY

LOAD STEP / NODE LABEL		1	2	3	SRSS	STATIC	SUM	DIFFE
101	FY	861.	34639.	132.	34650.	-0.	34650.	-346
101	FZ	6174.	4308.	89672.	89788.	105194.	195182.	152
101	MX	76158.	2355797.	55613.	2357683.	30557.	2388241.	-23271
102	FZ	5757.	4227.	87288.	87593.	99400.	186994.	118
102	MX	39173.	69518.	6873.	80093.	97026.	177119.	169
123	FY	0.	0.	0.	0.	0.	0.	
123	FZ	0.	0.	0.	0.	0.	0.	
123	MX	0.	0.	0.	0.	0.	0.	
123	MY	0.	0.	0.	0.	0.	0.	
124	FX	34348.	296.	14519.	37292.	0.	37292.	-372
124	FY	0.	0.	0.	0.	0.	0.	
124	FZ	0.	0.	0.	0.	0.	0.	
124	MX	0.	0.	0.	0.	0.	0.	
124	MY	0.	0.	0.	0.	0.	0.	
124	MZ	0.	0.	0.	0.	0.	0.	
201	FY	825.	34733.	289.	34744.	0.	34744.	-347
201	FZ	5651.	4338.	90909.	91187.	105216.	196403.	140
201	MX	62130.	2337046.	45965.	2338324.	29692.	2368016.	-23086
202	FZ	5402.	4335.	88606.	88876.	99379.	188255.	105
202	MX	24210.	63820.	10045.	68993.	96160.	165154.	271

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 55T LD DN / SSE 'X'

REACTION SUMMARY

LOAD STEP NODE	LABEL	1	2	3	SRSS	STATIC	SUM	DIFFE
101	FY	1775.	377980.	312.	377985.	-0.	377985.	-3779
101	FZ	11939.	47007.	168361.	175208.	105194.	280402.	-700
101	MX	149220.	25706558.	110326.	25707223.	30557.	25737785.	-256766
102	FZ	11416.	46130.	163807.	170561.	99400.	269962.	-711
102	MX	71044.	758587.	16451.	762084.	97026.	859111.	-6650
123	FY	0.	0.	0.	0.	0.	0.	
123	FZ	0.	0.	0.	0.	0.	0.	
123	MX	0.	0.	0.	0.	0.	0.	
123	MY	0.	0.	0.	0.	0.	0.	
124	FX	64709.	3226.	28081.	70613.	0.	70613.	-706.
124	FY	0.	0.	0.	0.	0.	0.	
124	FZ	0.	0.	0.	0.	0.	0.	
124	MX	0.	0.	0.	0.	0.	0.	
124	MY	0.	0.	0.	0.	0.	0.	
124	MZ	0.	0.	0.	0.	0.	0.	
201	FY	1697.	379004.	584.	379008.	0.	379008.	-3790
201	FZ	11039.	47335.	170713.	177497.	105216.	282713.	-722
201	MX	125987.	25501954.	92647.	25502434.	29692.	25532126.	-254727
202	FZ	10436.	47305.	166302.	173214.	99379.	272593.	-738
202	MX	45928.	696411.	22878.	698299.	96160.	794459.	-6021

JE6756/MJM/AEP, DCC, EXIST, TROLLEY MID, 55T LD DN / SSE 'X'

REACTION SUMMARY

LOAD STEP / NODE LABEL	1	2	3	SRSS	STATIC	SUM	DIFFER
101 FY	1775.	49137.	312.	49171.	-0.	49171.	-4917
101 FZ	11939.	6111.	168361.	168895.	105194.	274089.	-6370
101 MX	149220.	3341853.	110326.	3347001.	30557.	3377559.	-331644
102 FZ	11416.	5997.	163807.	164314.	99400.	263715.	-6491
102 MX	71044.	98616.	16451.	122650.	97026.	219676.	-2562
123 FY	0.	0.	0.	0.	0.	0.	
123 FZ	0.	0.	0.	0.	0.	0.	
123 MX	0.	0.	0.	0.	0.	0.	
123 MY	0.	0.	0.	0.	0.	0.	
124 FX	64709.	419.	28081.	70540.	0.	70540.	-7054
124 FY	0.	0.	0.	0.	0.	0.	
124 FZ	0.	0.	0.	0.	0.	0.	
124 MX	0.	0.	0.	0.	0.	0.	
124 MY	0.	0.	0.	0.	0.	0.	
124 MZ	0.	0.	0.	0.	0.	0.	
201 FY	1697.	49271.	584.	49303.	0.	49303.	-4930
201 FZ	11039.	6153.	170713.	171180.	105216.	276396.	-6596
201 MX	125987.	3315254.	92647.	3318940.	29692.	3348632.	-328924
202 FZ	10436.	6150.	166302.	166743.	99379.	266121.	-6736
202 MX	45928.	90533.	22878.	104063.	96160.	200223.	-790

CRANE WHEEL LOADS

F_x The R_x at 124 is divided by 4 for the 4 wheels on the held side and multiplied by 2/3 to account for frictional resistance at the unrestrained wheels. The minimum wheel load is the negative of the maximum considering complete reversal.

$$F_x \doteq \frac{2}{3}\left(\frac{R_x}{4}\right) = \frac{R_x}{6}$$

F_y The wheel load at each held wheel is the R_y as provided by the post processing computer program after the application of the scale factor as previously described. The minimum wheel load is the negative of the maximum considering complete reversal.

$$F_Y = R_Y$$

F_z The wheel load at the more heavily loaded wheel on a truck is the R_z (static+dynamic) divided by 2 plus the M_x divided by the wheel base where both are provided by the post processing computer program after the application of the scale factor as previously described.

$$F_Z = \frac{R_Z}{2} + \frac{M_x}{WB}$$

WB = 60 FOR DRIVE TRUCKS
WB = 48 FOR IDLER TRUCKS

The minimum wheel load at the less heavily loaded wheel on a truck is the R_z (static-dynamic) divided by 2 less the M_x divided by the wheel base plus the rope upkick (F'_{RZ}) per wheel. The rope upkick is a negative value of static-dynamic in table 5.

$$F'_Z = \frac{R'_Z}{2} - \frac{M_x}{WB} + \frac{1}{4}\left(\frac{X}{932}\right) F'_{RZ}$$

WHERE X DEPENDS ON TROLLEY POSITION AND EQUALS 466 FOR TROLLEY AT MID.

TABLE 15
CRANE WHEEL LOADS
TROLLEY AT MID
LOAD DOWN
KIPS

LOAD	SEISMIC	TRUCK	MAXIMUM			MINIMUM		
			Fx	Fy	Fz	Fx'	Fy'	Fz'
50T	OBE	101	6.2	33.7	133.7	-6.2	-33.7	-15.1
		102	6.2		94.4	-6.2		+18.4
		201	6.2	33.8	134.0	-6.2	-33.8	-15.4
		202	6.2		94.8	-6.2		+17.9
	SSE	101	11.8	47.8	187.9	-11.8	-47.8	-42.6
		102	11.8		132.3	-11.8		+7.2
		201	11.8	48.0	188.6	-11.8	-48.0	-43.3
		202	11.8		133.2	-11.8		+6.3
55T	OBE	101	6.2	34.6	137.4	-6.2	-34.6	-15.7
		102	6.2		97.2	-6.2		+18.7
		201	6.2	34.7	137.7	-6.2	-34.7	-16.0
		202	6.2		97.6	-6.2		+18.3
	SSE	101	11.8	49.2	193.3	-11.8	-49.2	-43.1
		102	11.8		136.4	-11.8		+8.0
		201	11.8	49.3	194.0	-11.8	-49.3	-43.8
		202	11.8		137.2	-11.8		+7.1

NOTE: TROLLEY AT END (WHICH WAS NOT RUN) NORMALLY PROVIDES HIGHER LOADS

FOR TRUCK LOADS SEE PRECEDING TABLES

GEOMETRY SECTION

The equipment analyzed in this report is an 'Electric Overhead Crane' which is designed and rated for a capacity load of 150 tons on the main hook. This is based on using a new SRP design trolley on the existing bridge (S/N 10038).

The mathematical model of the crane with node numbering and global coordinates is illustrated on page 26.

The boundary conditions are selected to provide the most realistic linear approximation to actual conditions in a seismic event as follows:

NODES - 101, 102, 201, 202

UZ: Simulates wheel to rail contact in the vertical direction.

NODES - 101, 201

UY: Simulates the drive brake which is automatically set and which provides stability parallel the runway.

NODES - 101, 102, 201, 202

MX: Simulates the differential wheel loads of a fixed bogie truck subject to overturning.

NODE - 124

UX: Simulates wheel to rail contact perpendicular to the runway.

The other restraints of nodes 123 and 124 were selected to simplify the analysis.

Those nodes which are coupled have the same displacement in the indicated directions only. Their displacements in all other directions are independent (released). This coupling is used to simulate load transfer between various components.

BRIDGE TRUCK

NODES - 101-121, 102-122

UX: Simulates the load transfer from the bridge wheels to the runway rail perpendicular the runway.

TROLLEY

NODES - 371-401, 372-402, 373-403, 374-404

UZ: Simulates wheel to rail contact in the vertical direction.

NODES - 371-401, 372-402

UX: Simulates the driv_ brake which is automatically set and which provides stability parallel the girders.

NODES - 372-402, 373-403

UY: Simulates wheel to rail contact perpendicular to the girders.

[illegible]

The master dynamic degrees of freedom for a reduced modal analysis are selected to obtain those modal shapes which characterize the principal vibrations of the structure. Placement is such as to include coupled modal shapes due to eccentricities. Higher degrees of freedom were not included because they will not contribute significantly to the system response. This can be justified by the responses obtained.

The girders, and the girder end connections are modeled as uniform beams. The rope is modeled as a spar element which is capable of supporting axial loads only. These elements have the properties of the corresponding parts of the actual crane. The trolley, the drive, the bridge trucks and certain short connections are modeled as rigid members capable of transmitting loads only. Lumped masses, were assigned to represent the masses of the trolley, the bridge trucks, the drive and the wheels. Additionally the beam members were assigned distributed masses.

The trolley, trucks, etc. were modeled as rigid members because past experience shows that components of this type are very stiff structures with high natural frequencies in excess of 40 Hz.

The simulation of the restraint of the crane perpendicular the runway is modeled on only one side consisting of a linear spring and two rigid beams capable of transmitting the load to the bridge wheels. The spring stiffness is selected so that the resulting frequency of the x mode yields an acceleration value from the high frequency region of the response spectrum curve. The resulting loads are distributed to the two runway rails by the 2/3, 1/3 method. The reason for the 2/3, 1/3 distribution is to account for manufacturing tolerances in which case one end of the crane would tend to contact the runway rail before the other end. The other end would however carry a portion of the reaction due to frictional resistance to sliding before flanging of the wheels.

Although certain simplifications are employed in making the linear mathematical model, these simplifications are in accordance with accepted practice. Such simplifications are employed to provide a model solveable with available resources while predicting the seismic response with reasonable accuracy.

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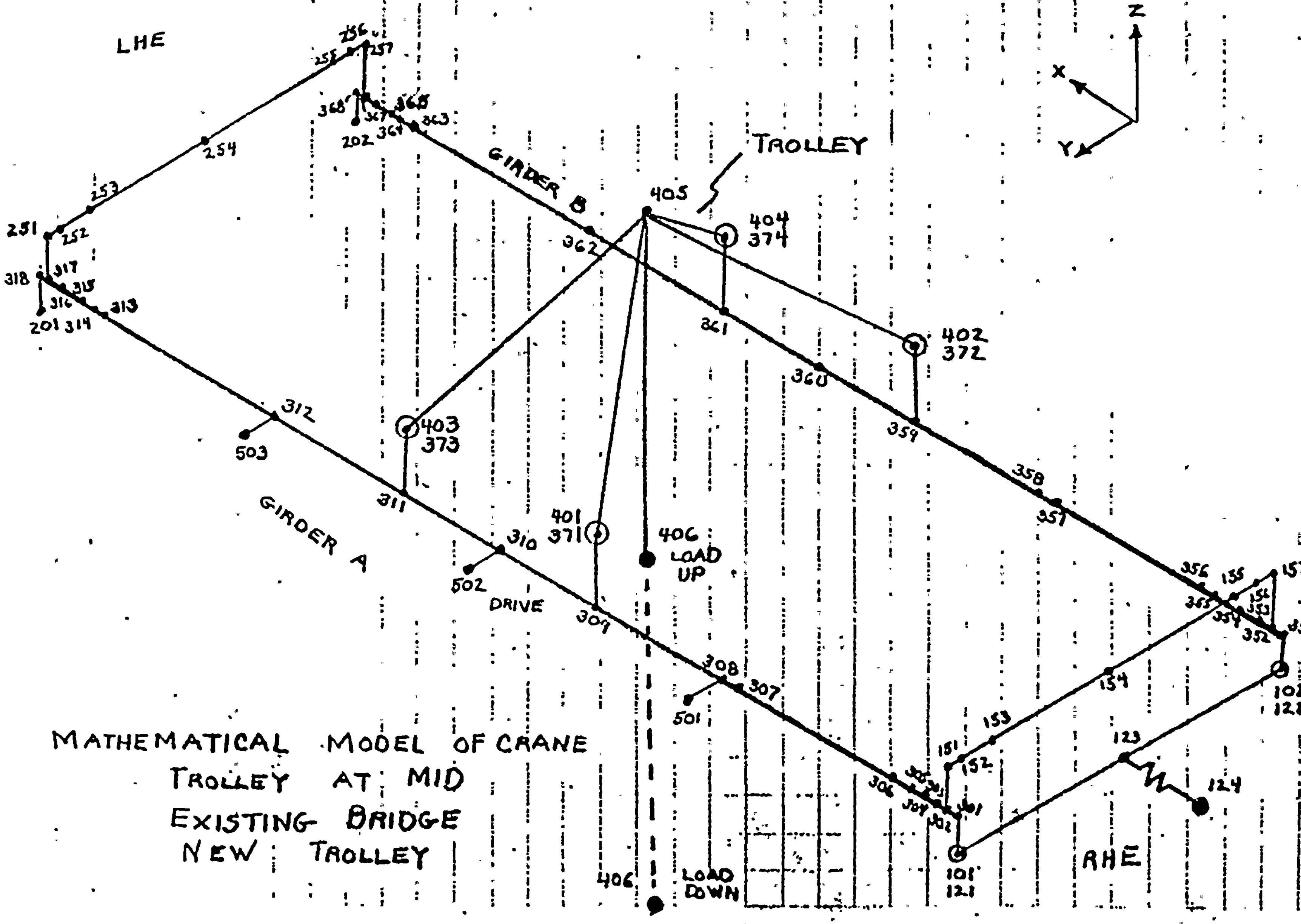

MATHEMATICAL MODEL OF CRANE
TROLLEY AT MID
EXISTING BRIDGE
NEW TROLLEY

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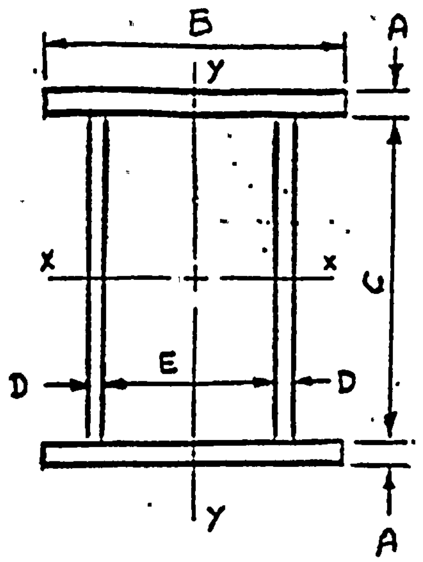
FORM N-2494

MMETRICAL BOX GIRDER PROPERTI



PROGRAM 107 PROGRAM ID 1-A-1-09(019)
WHITING REQN 79183 DATE 3-5-87
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ORIGINAL GIRDER

....
107.
....

		READ		ENTER
1.2500	--------	1	A	1.25
21.0000	--------	2	B	21.
93.0000	--------	3	C	93.
0.3125	--------	4	D	.3125
17.0000	--------	5	E	17.

....

58,490.6250	--------	Ixx
3,319.1753	--------	Sxx
6,285.1928	--------	Iyy
598.5897	--------	Syy
110.6250	--------	AREA
16,880.3619	--------	TORSIONAL CONSTANT (K)

....

APPENDIX A

This appendix summarizes the amplified response spectra and the modal response of the crane.

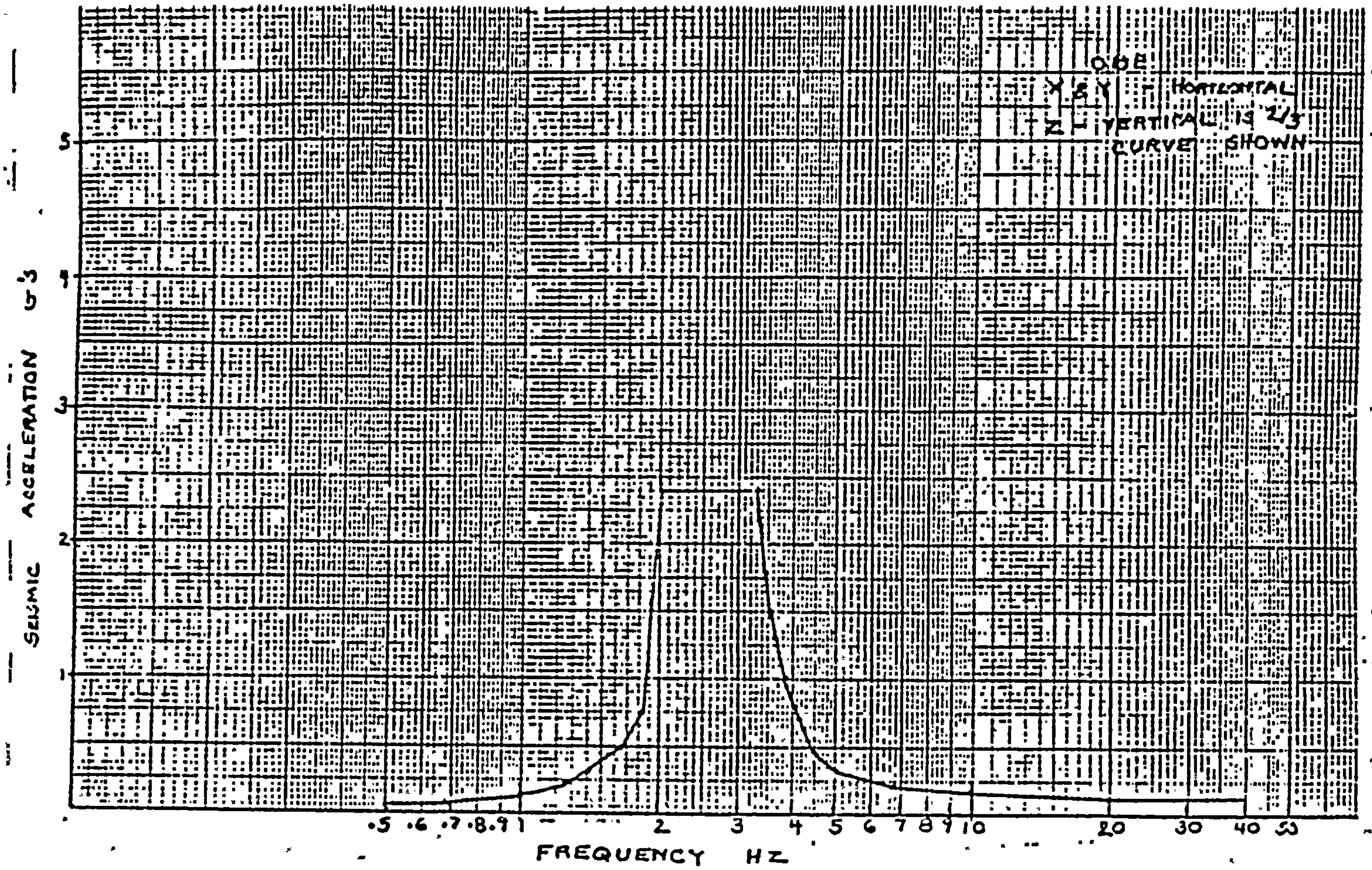

TABLE A1
OBE

POINT	FREQ HZ	X OR Y G's	X OR Y in/sec²	Z G's	Z in/sec²	POINT	FREQ HZ	X OR Y G's	X OR Y in/sec²	Z G's	Z in/sec²
1	0.01	.001	.4	.001	.4	11	3.57	1.5	579.6	1.0	386.4
2	.50	.07	27.0	.05	19.3	12	3.85	1.0	386.4	.67	258.9
3	.67	.09	34.8	.06	23.2	13	4.17	.68	262.8	.45	173.9
4	1.0	.15	58.0	.10	38.6	14	4.45	.47	181.6	.31	119.8
5	1.25	.23	88.9	.15	58.0	15	5.0	.34	131.4	.23	88.9
6	1.42	.32	123.6	.21	81.1	16	6.67	.22	85.0	.15	58.0
7	1.67	.50	193.2	.33	127.5	17	10.	.17	65.7	.11	42.5
8	1.81	.75	289.8	.50	193.2	18	20.	.13	50.2	.09	34.8
9	2.0	2.4	927.4	1.6	618.2	19	33.	.12	46.4	.08	30.9
10	3.33	2.4	927.4	1.6	618.2	20	50,	.12	46.4	.08	30.9

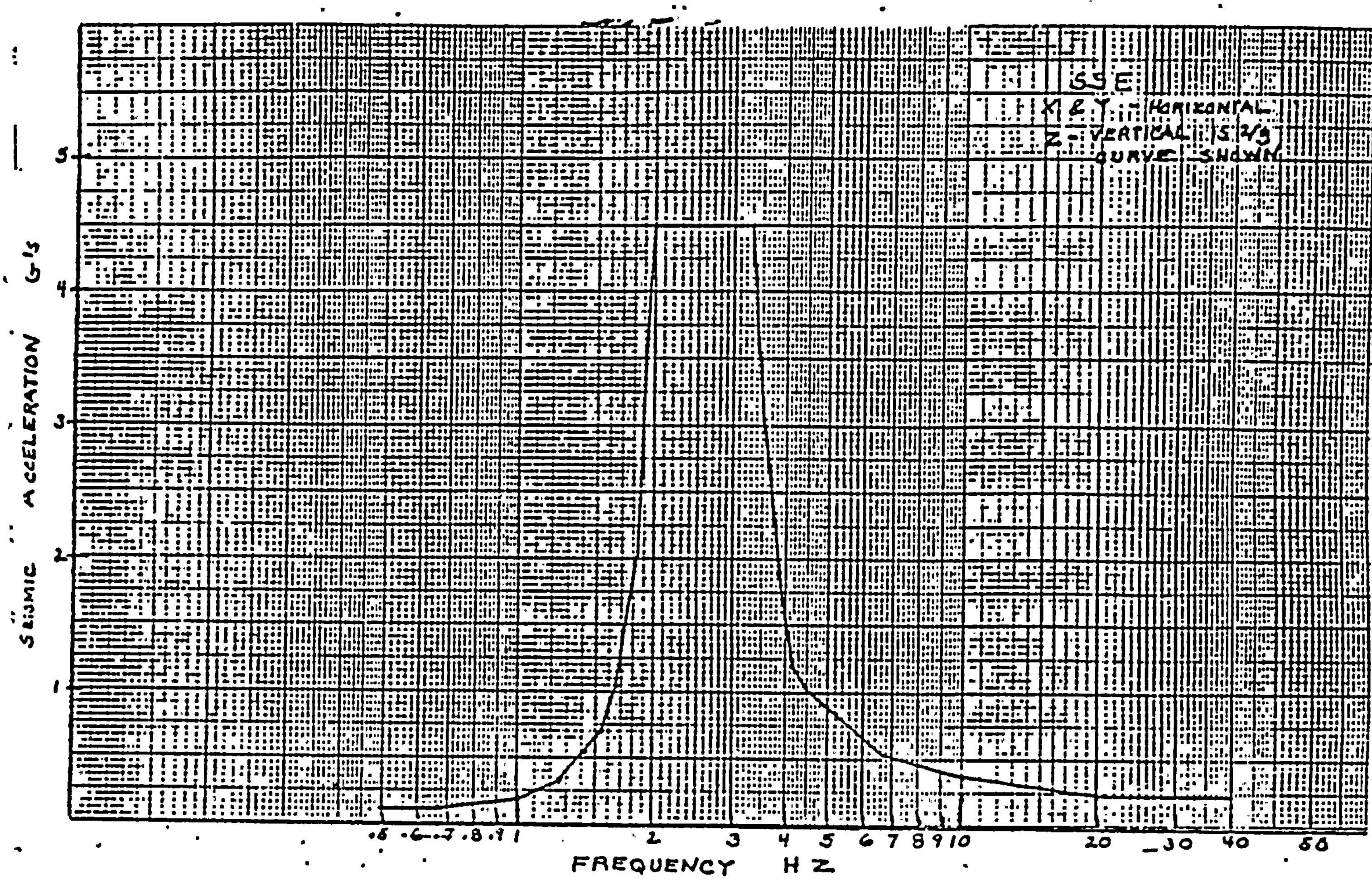

TABLE A2

SSE

POINT	FREQ HZ	X OR Y		Z		POINT	FREQ HZ	X OR Y		Z	
		G's	in/sec²	G's	in/sec²			G's	in/sec²	G's	in/sec²
1	0.01	.001	.4	.001	.4	11	3.57	2.9	1121.	1.9	734.2
2	.50	.11	42.5	.07	27.0	12	3.85	1.9	734.2	1.3	502.3
3	.67	.12	46.4	.08	30.9	13	4.17	1.2	463.7	.80	309.1
4	1.0	.21	81.1	.14	54.1	14	4.45	1.05	405.7	.70	270.5
5	1.25	.34	131.4	.23	88.9	15	5.0	.83	320.7	.55	212.5
6	1.42	.54	208.7	.36	139.1	16	6.67	.54	208.7	.36	139.1
7	1.67	1.05	405.7	.70	270.5	17	10.	.36	139.1	.24	92.7
8	1.81	2.0	772.8	1.3	502.3	18	20.	.23	88.9	.15	58.0
9	2.0	4.5	1739.	3.0	1159.	19	33.	.23	88.9	.15	58.0
10	3.33	4.5	1739.	3.0	1159.	20	50.	.23	88.9	.15	58.0

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TABLE A3 60 T-08E

SUMMARY OF NATURAL FREQUENCIES AND MODE COEFFICIENTS - PAEPAMDO

MODE	FREQUENCY HZ	MODE COEFFICIENT FOR SPECIFIED DIRECTION X	Y	Z
1	1.94	0.4447 *	104.3000 * MAX	0.0806
2	2.77	3.0250 * MAX	0.0596	48.2800 * MAX
3	4.08	0.6157 *	0.0205	0.0255
4	5.90	0.2720 *	0.0164	0.9012 *
5	7.50	0.0420 *	0.1132	0.0251
6	8.69	0.0133	0.0261	0.0005
7	9.25	0.0136	0.0003	0.0087
8	11.20	0.0144	0.0279	0.0004
9	12.48	0.0124	0.0063	0.0011
10	15.77	0.1401 *	0.0008	0.0123
11	17.55	0.0070	0.0099	0.0017
12	21.75	0.0006	0.0075	0.0005
13	27.84	0.0006	0.0006	0.0002
14	29.89	0.0042	0.0002	0.0001
15	34.08	0.0004	0.0002	0.0002
16	42.43	0.0001	0.0000	0.0002
17	52.70	0.0004	0.0002	0.0001
18	53.12	0.0002	0.0000	0.0000
19	59.49	0.0002	0.0000	0.0001
20	61.70	0.0000	0.0000	0.0006
21	72.68	0.0000	0.0000	0.0000
22	80.51	0.0001	0.0001	0.0000
23	82.47	0.0001	0.0000	0.0002
24	84.00	0.0001	0.0000	0.0001
25	93.26	0.0000	0.0000	0.0001
26	93.30	0.0000	0.0000	0.0002
27	119.10	0.0000	0.0000	0.0000
28	193.30	0.0000	0.0000	0.0000
SIGNIFICANCE FACTOR		1.00%	0.50%	0.50%

* INDICATES EXPANDED MODE

TABLE A4 50T- SSE

SUMMARY OF NATURAL FREQUENCIES AND MODE COEFFICIENTS - PAEPAMDS

MODE	FREQUENCY HZ	MODE COEFFICIENT FOR SPECIFIED DIRECTION X	Y	Z
1	1.94	0.9229 *	216.5000 * MAX	0.1661
2	2.77	5.6730 * MAX	0.1118	90.5100 * MAX
3	4.08	1.1090 *	0.0369	0.0464
4	5.90	0.6661 *	0.0402	2.1580 *
5	7.50	0.0988 *	0.2662	0.0586
6	8.69	0.0308	0.0583	0.0012
7	9.25	0.0297	0.0006	0.0193
8	11.20	0.0296	0.0574	0.0008
9	12.48	0.0248	0.0126	0.0023
10	15.77	0.2637 *	0.0015	0.0226
11	17.55	0.0128	0.0181	0.0030
12	21.75	0.0011	0.0135	0.0008
13	27.84	0.0011	0.0012	0.0004
14	29.89	0.0078	0.0003	0.0002
15	34.08	0.0007	0.0003	0.0004
16	42.43	0.0002	0.0001	0.0003
17	52.70	0.0008	0.0003	0.0002
18	53.12	0.0004	0.0001	0.0001
19	59.49	0.0004	0.0000	0.0001
20	61.70	0.0001	0.0001	0.0011
21	72.68	0.0001	0.0000	0.0000
22	80.51	0.0002	0.0001	0.0000
23	82.47	0.0002	0.0001	0.0003
24	84.00	0.0002	0.0000	0.0002
25	93.26	0.0000	0.0000	0.0002
26	93.30	0.0000	0.0000	0.0003
27	119.10	0.0000	0.0000	0.0000
28	193.30	0.0000	0.0000	0.0000
SIGNIFICANCE FACTOR		1.00%	0.50%	0.50%

* INDICATES EXPANDED MODE

TABLE A5 55T-00E

SUMMARY OF NATURAL FREQUENCIES AND MODE COEFFICIENTS - RAEPBMDO

MODE	FREQUENCY HZ	MODE COEFFICIENT FOR SPECIFIED DIRECTION X		Y		Z	
1	1.94	0.4446	*	104.3000	* MAX	0.0833	
2	2.66	3.0710	* MAX	0.0630		52.9200	* MA
3	4.08	0.6161	*	0.0205		0.0285	
4	5.89	0.2761	*	0.0164		0.9211	*
5	7.50	0.0419	*	0.1132		0.0250	
6	8.69	0.0138		0.0261		0.0005	
7	9.25	0.0136		0.0003		0.0087	
8	11.20	0.0144		0.0279		0.0004	
9	12.48	0.0124		0.0063		0.0011	
10	15.77	0.1401	*	0.0008		0.0123	
11	17.55	0.0070		0.0099		0.0017	
12	21.75	0.0006		0.0075		0.0005	
13	27.84	0.0006		0.0006		0.0002	
14	29.89	0.0042		0.0002		0.0001	
15	34.08	0.0004		0.0002		0.0002	
16	42.43	0.0001		0.0000		0.0002	
17	52.70	0.0004		0.0002		0.0001	
18	53.12	0.0002		0.0000		0.0000	
19	59.49	0.0002		0.0000		0.0001	
20	61.70	0.0000		0.0000		0.0006	
21	72.68	0.0000		0.0000		0.0000	
22	80.51	0.0001		0.0001		0.0000	
23	82.47	0.0001		0.0000		0.0002	
24	84.00	0.0001		0.0000		0.0001	
25	93.26	0.0000		0.0000		0.0001	
26	93.30	0.0000		0.0000		0.0002	
27	119.10	0.0000		0.0000		0.0000	
28	193.30	0.0000		0.0000		0.0000	
SIGNIFICANCE FACTOR		1.00%		0.50%		0.50%	

* INDICATES EXPANDED MODE

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TABLE A6 55T-55E

SUMMARY OF NATURAL FREQUENCIES AND MODE COEFFICIENTS - PAEPBMDS

MODE	FREQUENCY HZ	MODE COEFFICIENT FOR SPECIFIED DIRECTION X	Y	Z
1	1.94	0.9228 *	216.5000 * MAX	0.1715
2	2.66	5.7580 * MAX	0.1131	99.2100 * MAX
3	4.08	1.1100 *	0.0369	0.0520
4	5.89	0.6761 *	0.0402	2.2060 *
5	7.50	0.0986 *	0.2662	0.0583
6	8.69	0.0308	0.0583	0.0012
7	9.25	0.0297	0.0006	0.0193
8	11.20	0.0296	0.0574	0.0008
9	12.48	0.0248	0.0126	0.0023
10	15.77	0.2637 *	0.0015	0.0226
11	17.55	0.0128	0.0181	0.0030
12	21.75	0.0011	0.0135	0.0008
13	27.84	0.0011	0.0012	0.0004
14	29.89	0.0078	0.0003	0.0002
15	34.03	0.0007	0.0003	0.0004
16	42.43	0.0002	0.0001	0.0003
17	52.70	0.0008	0.0003	0.0002
18	53.12	0.0004	0.0001	0.0001
19	59.49	0.0004	0.0000	0.0001
20	61.70	0.0001	0.0001	0.0011
21	72.68	0.0001	0.0000	0.0000
22	80.51	0.0002	0.0001	0.0000
23	82.47	0.0002	0.0001	0.0003
24	84.00	0.0002	0.0000	0.0002
25	93.26	0.0000	0.0000	0.0002
26	93.30	0.0000	0.0000	0.0003
27	119.10	0.0000	0.0000	0.0000
28	193.30	0.0000	0.0000	0.0000
SIGNIFICANCE FACTOR		1.00%	0.50%	0.50%

* INDICATES EXPANDED MODE

[illegible]

<u>Referen s</u>

1. NU. G-0612, Control of Heavy Loads at Nuclear Power Plants, July 1980.

2. NUF G-0554, Single-Failure-Proof Cranes For Nuclear Power Plants, May 19 .

3. Enc.osure 3 of letter from NRC dated December 22, 1980 on Control of Hea y Loads.