IMPELL CORPORATION

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: ROTC-06

Title: Multimode Factor Evaluation Train C

Client: TUGCo Project: Comanche Peak

Job No: 0210-052-1355

Design Input/References:

Stated within.

Assumptions:

Stated within.

Method:

Stated within.

Remarks:

This calculation was prepared to demonstrate the adequacy of a multimode factor of 1.25 for evaluation of conduit supports. The calculation is based on calculation M-30, Job No. 0210-041.

REV. NO.	REVISION	APPROVED	DATE
0	Original Issue	Miguel A. Manriquez	5/30/86
1	add Appendix B and C	W. J. Lo Hutin	9-19-86
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					Train C	
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Purpose

The purpose of this calculation is to demonstrate the adequacy of the use of a 1.25 multi-mode factor when performing analyses of conduit systems using the equivalent static analysis method.

Method

A parametric analysis is performed to investigate the influence of the various parameters important to conduit system response. The following parameters were varied [See Eq. in p. C, Appendix]

a) Ratio of support stiffnesses

b) Ratio of beam (conduit) stiffness to support stiffness.

c) Effect of variation in support span length

d) Effect of variation in support mass

The analyses performed are described in the attached Appendix A. The calculation described in this Appendix was performed specifically for cable tray systems. The parametric variations are applicable however, to conduit systems.

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					Train C Conduit 2" and under
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Specific Conclusions Applicable to Conduit System

The analyses described in this calculation demonstrate that a multimode factor of 1.20 is a reasonable upper bound factor to use when qualifying conduit supports by the equivalent static analysis procedure.

The above conclusion is supported by the following facts:

a) The multimode factors obtained from the various analyses in this study are biased to the conservative side. This is because a flat spectra (equal input acceleration for all modes) was used, and therefore, the contribution from higher modes is higher than in actual applications, where the input spectral values are lower at higher frequencies.

b) It is shown in this study that the worst case (highest multimode factor) occurs for fairly uniform support stiffnesses and span lengths. For actual conduit systems, wide variation of support stiffnesses and span lengths are common. The multimode factor in actual systems is likely to be smaller. In addition, the case of very high conduit stiffness relative to the support stiffness ($\beta = 10$), which yields higher multimode factor, is not realistic for conduit systems ($\beta = 5$ are more realistic [illegible]

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APPENDIX A

PARAMETRIC STUDY - MULTIMODE FACTOR EVALUATION

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: M-30.

Title: MULTIMODE FACTOR EVALUATION - PARAMETRIC STUDY

Client: TUGCo Project: CPSES CABLE TRAY ANALYSIS

Job No: 0210-041

Design Input/References:

See Section V.

Assumptions:

As noted within.

Method:

As noted within.

Remarks:

This calculation was prepared to demonstrate the adequacy of the use of a 1.25 multimode factor. The calculation was prepared specifically for cable tray systems. The calculation is however sufficiently generic and thus it is also applicable to conduit systems.

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I. PURPOSE

THIS CALCULATION WILL EVALUATE THE REQUIRED MULTIMODE FACTOR (MMF) FOR EQUIVALENT STATIC ANALYSIS OF COMANCHE PEAK STEAM ELECTRICAL STATION (CPSES) CABLE TRAY AND CONDUIT SYSTEMS.

THE MULTIMODE FACTOR WILL BE DETERMINED BY COMPARING SUPPORT REACTION LOADS FOR A SIMPLIFIED ANALYTICAL MODEL OF A CABLETRAY SYSTEM. REACTIONS AT CABLETRAY HANGER ANCHORAGE POINTS WILL BE DETERMINED BY TWO INDEPENDENT METHODS :

- REACTIONS PREDICTED FROM EQUIVALENT STATIC ANALYSIS, USING THE PROCEDURE DEFINED IN REF [1]. THIS REACTION IS DESIGNATED R_{ES}.
- REACTIONS PREDICTED FROM DYNAMIC ANALYSIS USING RESPONSE SPECTRA LOADING. THIS REACTION IS DESIGNATED R_{RS}.

THE REQUIRED MMF IS EVALUATED BY ;

$$MMF = \frac{R_{RS}}{R_{ES}}$$

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PER REF [1] THE SYSTEM FREQUENCY IS EVALUATED USING DUNKERLEY'S FORMULA.

THE SIMPLE MODEL USED IN THIS CALCULATION WILL EXAMINE THE EFFECTS OF HIGHER ORDER MODES ON SYSTEM RESPONSE (I.E. "MULT-MODE" EFFECTS). CERTAIN GEOMETRICAL EFFECTS, SUCH AS RELATIVELY UNSUPPORTED CHANGES IN DIRECTION, WILL ALSO BE MODELED THROUGH THE USE OF LARGE LUMPED MASSES.

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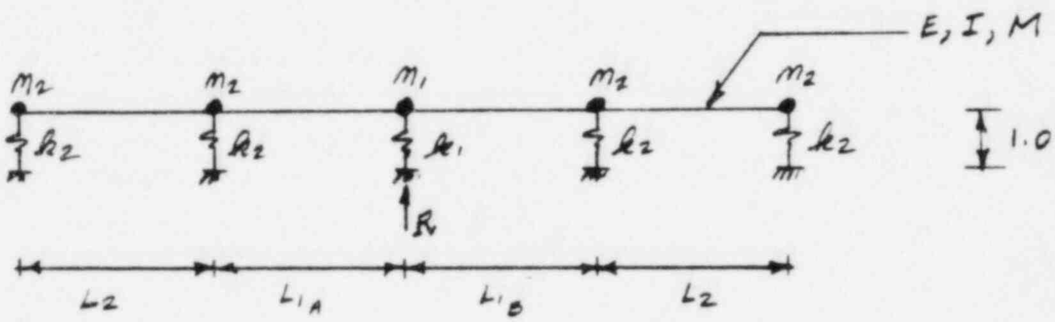
II. METHOD

A. MODEL DESCRIPTION

THE FOLLOWING SIMPLIFIED ANALYTICAL MODEL IS USED TO REPRESENT THE CABLE TRAY (OR CONDUIT) SYSTEM



DYNAMIC ANALYSIS IS PERFORMED USING THE IMPELL LINEAR STRUCTURAL ANALYSIS PROGRAM EDSGAP (REF [2]). NODES 1 THROUGH 17 ARE CONNECTED USING BEAM ELEMENTS. NODES 1 AND 18, 5 AND 19, 9 AND 20, 13 AND 21, 17 AND 22 ARE CONNECTED USING TRUSS ELEMENTS.

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NODES 1 THROUGH 17 ARE FIXED FOR ALL DOF'S EXCEPT y TRANSLATION AND z ROTATION. NODES 18 THROUGH 23 ARE FIXED FOR ALL DOF'S.

BEAM PROPERTIES :

$E = 29 \times 10^6$ LB/IN^2

$I_{xx} = 0.0069$ IN^4

I_{yy}, I_{zz} = VARIED WITH PARAMETER β ($I = 2.68$ in^4 for $\beta = 1.0$)

$A_x = 0.949$ IN^2

$A_y, A_z = 0$ IN^2

$M = 0.01591$ LB·S^2/IN^4 (≈ 70 LB/FT UNIT WEIGHT)

TRUSS PROPERTIES :

$A = 1.0$ IN^2

$L = 1.0$ IN

$\therefore k = \frac{EA}{L} = E$

FOR k_2 ; $E = 10000$ LB/IN^2

FOR k_1 ; E VARIED WITH PARAMETER κ

$m_2 = .479$ LB·S^2/IN

m_1 = VARIED WITH PARAMETER $\frac{m_1}{m_2}$

SPAN LENGTHS :

$L_2 = 72.0$ IN.

L_{1A}, L_{1B} VARIED WITH PARAMETER $\frac{L}{L_2}$ AND $\frac{L_{1A}}{L_{1B}}$

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ELEMENT PROPERTIES AND SPAN LENGTHS WERE CHOSEN TO REPRESENT TYPICAL CPSES CABLETRAY SYSTEMS, USING REF [3] AS A GUIDE. BEAM PROPERTIES, EXCEPT FOR BENDING MOMENTS OF INERTIA, ARE IDENTICAL TO 24×4" TRAY W/O THERMOLAG. THE FOLLOWING PARAMETERS ARE VARIED IN THIS STUDY:

i. $\alpha = \dfrac{k_1}{k_2}$

ii. $\beta = \dfrac{k_{TRAY}}{k_2}$ WHERE $k_{TRAY} = \dfrac{48EI}{(L_2)^3}$

iii. $\dfrac{L_1}{L_2}$ WHERE $L_1 = L_{1A} = L_{1B}$

iv. $\dfrac{L_{1A}}{L_{1B}}$ WHERE $L_{1A} + L_{1B} = 144.0$ IN.

v. $\dfrac{m_1}{m_2}$

B. LOADING

THE LOADING WAS ASSUMED TO BE A FLAT SPECTRA AT 1.0g. THIS LOADING SHOULD GIVE A WORST CASE MMF SINCE HIGHER FREQUENCY MODES ARE ACCELERATED AT THE SAME SPECTRAL ORDINATE AS LOWER FREQUENCY MODES.

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C. DYNAMIC ANALYSIS

DYNAMIC ANALYSIS IS PERFORMED USING THE PREVIOUSLY SPECIFIED RESPONSE SPECTRA. AN EIGEN SOLUTION IS PERFORMED FOR THE FIRST FIFTEEN MODES. MODAL RESPONSES ARE COMBINED USING THE COMPLETE QUADRATIC COMBINATION METHOD (CQC) TO GIVE THE CLOSEST REPRESENTATION TO TRUE TIME-HISTORY RESULTS.

D. EQUIVALENT STATIC ANALYSIS

THE EQUIVALENT STATIC ANALYSIS IS PERFORMED IN ACCORDANCE WITH REF [1]. SINCE A FLAT SPECTRA IS USED, THE LOADING IS INDEPENDENT OF SYSTEM FREQUENCY. THE PREDICTED REACTION FROM EQUIVALENT STATIC LOADING IS THEREFORE :

$$R_{RS} = \left\{ M A \left(\frac{L_{1A} + L_{1B}}{2} \right) + m_1 \right\} \times a$$

WHERE $a = 1.0\,g$ FOR ALL CASES.

III. RESULTS

A. ANALYSIS SET 1

FOR THIS SET OF ANALYSES, $L_2 = L_{1_A} = L_{1_B} = 72.0$ IN.

THEREFORE: $\frac{L_1}{L_2} = 1.0$; $\frac{L_{1_A}}{L_{1_B}} = 1.0$ FOR ALL CASES.

ALL COMBINATIONS OF THE STIFFNESS PARAMETERS (α, β) WERE ANALYZED.

$\alpha = \frac{k_1}{k_2}$ $\langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 5.0, 10.0, 50.0 \rangle$

$\beta = \frac{k_{TRAY}}{k_2}$ $\langle \beta = 0.10, 0.50, 0.75, 1.0, 3.0, 10.0 \rangle$

$\frac{m_1}{m_2}$ $\langle = 1.0 \rangle$

REACTION LOADS FROM DYNAMIC ANALYSIS (R_{RS}) FOR THE CENTRAL SUPPORT ARE PRESENTED IN TABLE 1. THE CORRESPONDING DLF ARE PRESENTED IN TABLE 2 AND PLOTTED IN FIGURE 1. THE SAME PROCEDURE IS FOLLOWED FOR THE ADJACENT SUPPORT IN TABLES 3,4 AND FIGURE 2.

$$DLF = \frac{R_{RS}}{R_{ES}}$$

SINCE ALL SPANS = 72.0 IN FOR ANALYSIS SET 1:

$$R_{ES} = \{(.01591)(.949)(72.0) + (.479)\}(386.4)$$

$$R_{ES} = 605. \text{ LB}$$

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Table 1: Comparison of Center Support Reaction from Dynamic Analysis (R_{BC}) in lbs
For all cases $L_{1A} = L_{1B} = L_2 = 72$ inches

Reaction (static) = 605 lb.

$\beta = K_{trag} / K_2$

$\alpha = K_1 / K_2$

α \ β	0.1	0.5	0.75	1.0	1.5	3.0	10.0
0.01	156.0	50.5	39.3	33.5	27.4	20.8	
0.25	435.3	466.4	449.6	433.8	407.7	360.5	296.5
0.50	686.1	581.8	606.7	608.4	595.6	556.4	492.0
0.75	733.3	655.0	712.7	719.6	710.6	681.3	630.5
1.0	704.5	588.4	696.1	731.0	750.9	754.5	729.3
1.25	674.2	472.4	549.8	630.4	710.9	778.5	795.1
1.50	653.2	446.1	460.4	533.0	638.7	762.9	831.4
1.75	639.1	432.9	424.4	477.8	577.3	726.6	842.8
2.0	628.3	420.8	410.0	450.7	535.8	686.2	835.9
5.0	540.4	346.9	401.3	444.4	490.8	539.4	691.7
10.0	500.0	329.5	362.6	397.0	450.2	534.2	665.1
50.0	447.1	271.6	307.6	332.5	378.0	448.8	607.5
Run	-01	-02	-03	-04	-05	-06	-07
Ref	[4]	[5]	[6]	[7]	[8]	[9]	[10]

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0	AA	5/15/86	[illegible]	5/21/86

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Table 2. Comparison of Center Support MMF

α \ β	0.1	0.5	0.75	1.0	1.5	3.0	10.0
0.01	0.258	0.083	0.065	0.055	0.045	0.034	
0.25	0.720	0.771	0.743	0.717	0.674	0.596	0.49
0.5	1.134	0.962	1.003	1.006	0.984	0.920	0.813
0.75	1.212	1.083	1.178	1.189	1.175	1.126	1.042
1.0	1.164	0.973	1.151	1.208	1.241	1.247	1.205
1.25	1.114	0.781	0.909	1.042	1.175	1.287	1.314
1.50	1.080	0.737	0.761	0.881	1.056	1.261	1.374
1.75	1.056	0.716	0.701	0.790	0.954	1.201	1.393
2.0	1.039	0.696	0.678	0.745	0.886	1.134	1.382
5.0	0.893	0.573	0.663	0.735	0.811	0.895	1.143
10.0	0.826	0.545	0.599	0.656	0.744	0.883	1.099
50.0	0.739	0.449	0.508	0.550	0.625	0.742	1.004
Run	-01	-02	-03	-04	-05	-06	-07

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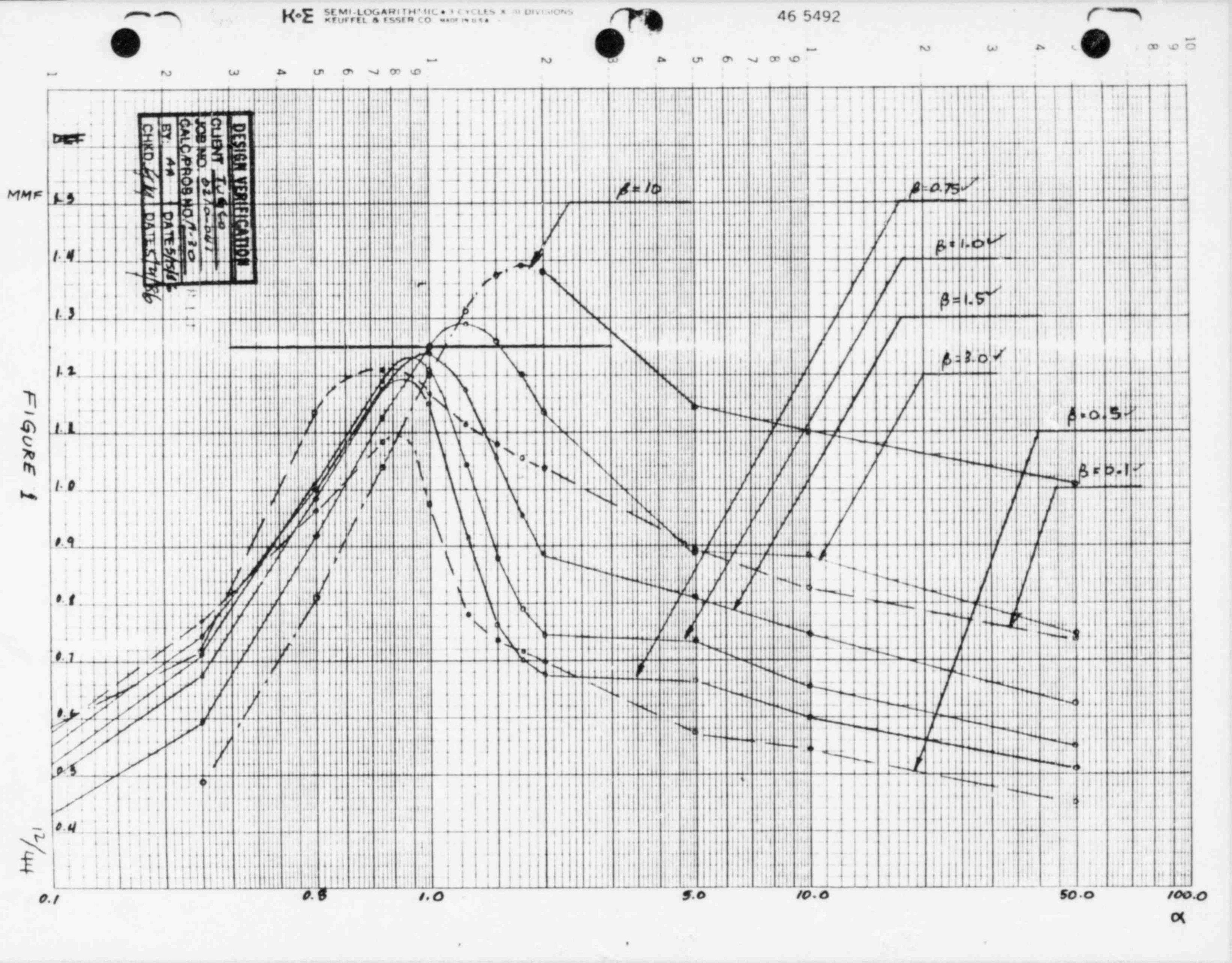

K•E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5492
DESIGN VERIFICATION
CLIENT IV&Co
JOB NO. 8210-061
CALC/PROB NO. A-20
BY AA DATE 5/16/86
CHKD DATE 5/16/86
DEF
MMF
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β=1.0
β=1.5
β=3.0
β=0.5
β=0.1
0.1
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1.0
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10.0
50.0
100.0
α
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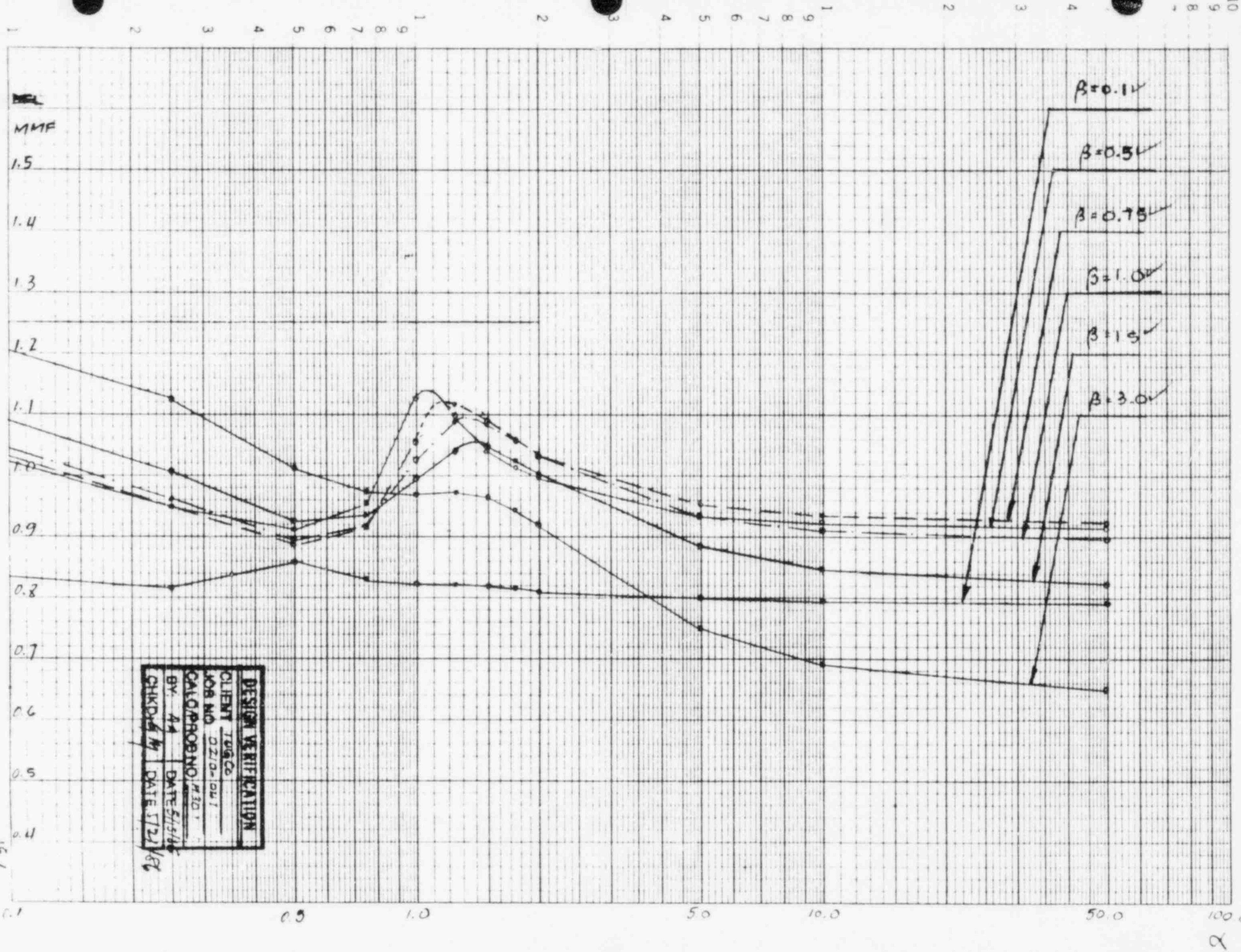
FIGURE 1

Table 3 Comparison of Adjacent Support Reaction from Dynamic Analysis (R_{AS}) in lbs. For all cases $L_A = L_{1B} = L_2 = 72$ in

α \ β	0.1	0.5	0.75	1.0	1.5	3.0
0.01	535.1	730.5	749.8	762.7	788.3	847.3
0.25	493.9	573.0	575.1	582.2	608.9	680.8
0.50	519.8	551.3	536.3	538.5	559.2	612.6
0.75	502.7	578.9	552.8	554.0	565.4	589.4
1.00	499.3	681.9	640.2	619.4	601.5	586.6
1.25	497.6	663.9	676.4	659.0	629.1	587.9
1.50	495.6	631.6	660.6	655.2	631.6	583.5
1.75	493.6	613.4	641.6	639.7	620.4	571.9
2.00	491.9	602.3	627.1	625.2	606.4	556.6
5.00	484.4	567.4	577.0	566.0	533.6	452.0
10.00	480.8	559.8	565.9	551.6	513.0	417.8
50.00	477.5	555.1	558.6	541.8	498.9	394.1
Run	-01	-02	-03	-04	-05	-06
Ref	[4]	[5]	[6]	[7]	[8]	[9]

Table 4. Comparison of Adjacent Support MMF

α \ β	0.10	0.50	0.75	1.00	1.50	3.00
0.01	0.884	1.207	1.239	1.261	1.303	1.400
0.25	0.816	0.947	0.951	0.962	1.006	1.125
0.50	0.859	0.911	0.886	0.890	0.924	1.013
0.75	0.831	0.957	0.914	0.916	0.935	0.974
1.00	0.825	1.127	1.058	1.024	0.994	0.970
1.25	0.822	1.097	1.118	1.089	1.040	0.972
1.50	0.819	1.044	1.092	1.083	1.044	0.964
1.75	0.816	1.014	1.060	1.057	1.025	0.945
2.00	0.813	0.996	1.037	1.033	1.002	0.920
5.00	0.801	0.938	0.954	0.936	0.882	0.747
10.00	0.795	0.925	0.935	0.912	0.848	0.691
50.00	0.789	0.918	0.923	0.896	0.825	0.651
Run	-01	-02	-03	-04	-05	-06


K•E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5492
MMF
β=0.1
β=0.5
β=0.75
β=1.0
β=1.5
β=3.0
α
DESIGN VERIFICATION
CLIENT TUGCo
JOB NO 0210-041
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CHKD DATE 7/21/86

FIGURE 2

B. ANALYSIS SET 2

THIS SET OF ANALYSES FOCUSES ON ALTERING THE RELATIVE SPAN LENGTHS. AGAIN $L_{1A} = L_{1B} = L_1$, AND $L_2 = 72.0$ IN., BUT $\frac{L_1}{L_2}$ IS VARIED.

THE FOLLOWING PARAMETER RATIOS WERE VARIED:

$$\alpha = \frac{k_1}{k_2} \quad \langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 5.0, 10.0, 50.0 \rangle$$

$$\beta = \frac{k_{tray}}{k_2} \quad \langle \beta = 1.0 \rangle$$

$$\frac{L_1}{L_2} = \frac{L_1}{72.0\text{IN}} \quad \left\langle \frac{L_1}{L_2} = 0.67, 1.50 \right\rangle$$

$$\frac{m_1}{m_2} \langle = 1.0 \rangle$$

REACTION LOADS (R_{ES}) AND DLF FOR THE CENTRAL SUPPORT ARE PRESENTED IN TABLES 5, 6 AND PLOTTED IN FIGURE 3.

$$DLF = \frac{R_{ES}}{R_{ES}}$$

$R_{ES} = 465.$ LB FOR $\frac{L_1}{L_2} = 0.67$

$R_{ES} = 815.$ LB FOR $\frac{L_1}{L_2} = 1.50$

Table 5 Comparison of Center Support Reaction from Dynamic Analysis (R_{RS}) in lbs.
For all cases $L_2 = 72$ in ; $L_{1A} = L_{1B}$

	$\frac{L_1}{L_2} = 0.67$	$\frac{L_1}{L_2} = 1.50$	$\frac{L_1}{L_2} = 1.0$			
α \ β	1.0	1.0	1.0			
0.01	15.2	99.9	33.5			
0.25	279.7	733.7	433.8			
0.50	432.5	875.0	608.4			
0.75	471.7	947.6	719.6			
1.00	438.1	983.0	731.0			
1.25	401.7	986.8	630.4			
1.50	380.5	967.1	533.0			
1.75	370.9	934.6	477.8			
2.00	368.8	898.2	450.7			
5.00	417.8	673.2	444.4			
10.00	389.8	604.1	397.0			
50.00	327.9	557.1	332.5			
Run	-08 (Ref. [11])	-09 (Ref. [12])	-04 (Ref. [7])			
R_{EG} (lb.)	465	815	605			

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Table 6: Comparison of Center Support MMF

α \ β	$\frac{L_1}{L_2}=0.67$	$\frac{L_1}{L_2}=1.50$	$\frac{L_1}{L_2}=1.0$			
	1.0	1.0	1.0			
0.01	0.033	0.123	0.055			
0.25	0.602	0.900	0.717			
0.50	0.930	1.074	1.006			
0.75	1.014	1.163	1.189			
1.00	0.942	1.206	1.208			
1.25	0.864	1.211	1.042			
1.50	0.818	1.187	0.881			
1.75	0.798	1.147	0.790			
2.00	0.793	1.102	0.745			
5.00	0.898	0.826	0.735			
10.00	0.838	0.741	0.656			
50.00	0.705	0.684	0.550			
Run	-08	-09	-04			

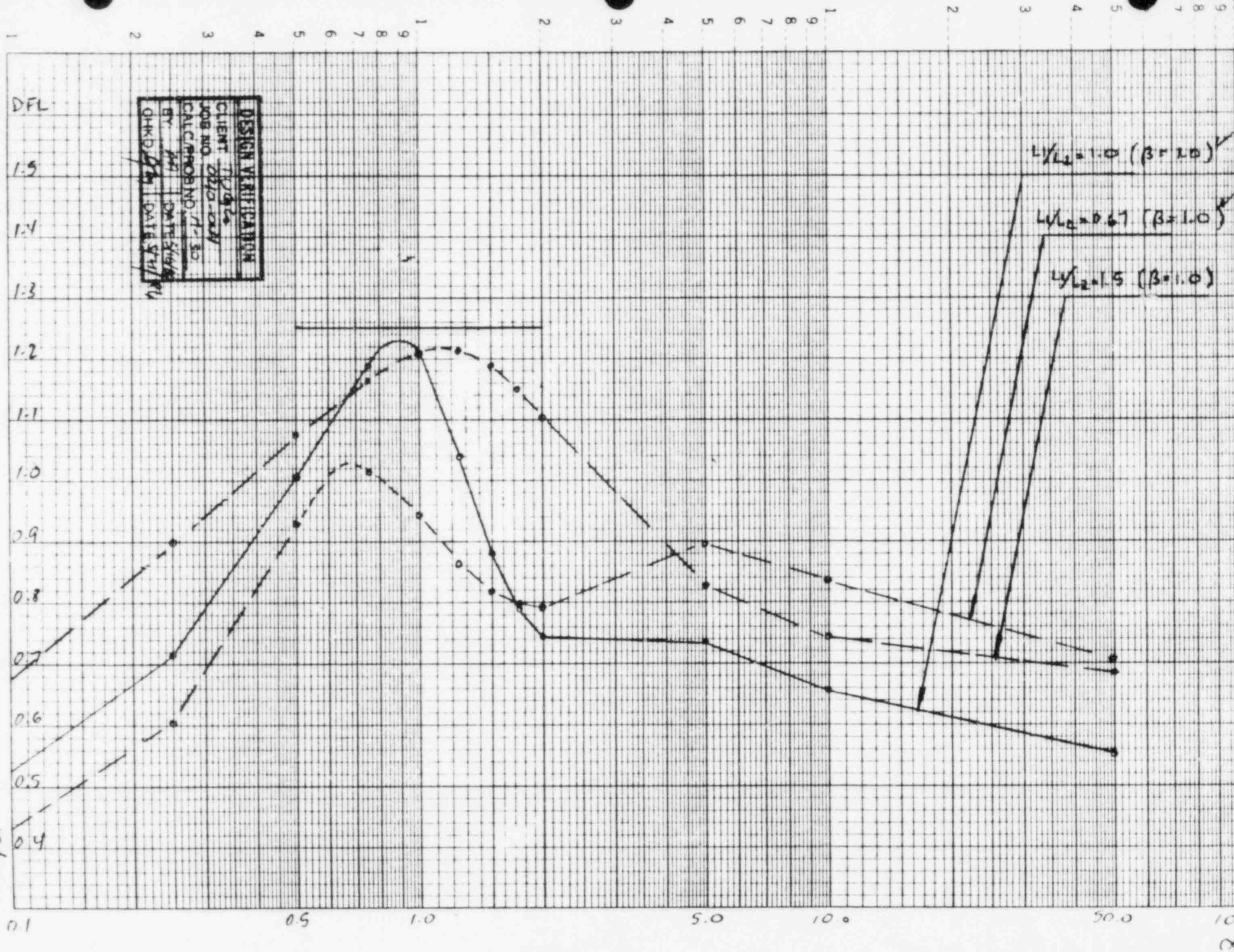

FIGURE 3

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c. <u>ANALYSIS SET 3</u>

THIS SET OF ANALYSES FOCUSES ON ALTERING THE SYMMETRY OF THE PROBLEM. FOR ALL CASES $L_{1A} + L_{1B} = 144.0$ IN., AND $L_2 = 72.0$ IN.; BUT $\frac{L_{1A}}{L_{1B}}$ IS VARIED. THE FOLLOWING PARAMETER RATIOS WERE VARIED:

$$\alpha = \frac{K_1}{K_2} \quad \langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.00, 5.00, 10.0, 50.0 \rangle$$

$$\beta = \frac{K_{FTANG}}{K_2} \quad \langle \beta = 1.0 \rangle$$

$$\frac{L_{1A}}{L_{1B}} \quad \langle = 0.33, 0.67 \rangle$$

$$\frac{m_1}{m_2} \quad \langle = 1.0 \rangle$$

REACTION LOADS (R_{RS}) AND DLF FOR THE CENTRAL SUPPORT ARE PRESENTED IN TABLES 7, 8 AND PLOTTED IN FIGURE 4.

$$DLF = \frac{R_{RS}}{R_{ES}}$$

$R_{ES} = 605.$ LB FOR ALL CASES

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Table 7 Comparison of Center Support Reaction from Dynamic Analysis (R_{RS}) in lbs.

For all cases: $L_2 = 72$ in, $L_{1A} + L_{1B} = 144$ in

L_{1A}/L_{1B}	0.33	0.67	1.0			
α \ β	1.0	1.0	1.0			
0.01	24.4	31.9	33.5			
0.25	353.7	421.6	433.8			
0.50	465.1	573.6	608.4			
0.75	492.0	628.8	719.6			
1.00	488.1	604.2	731.0			
1.25	476.0	542.8	630.4			
1.50	463.6	482.7	533.0			
1.75	452.9	440.8	477.8			
2.00	444.2	415.1	450.7			
5.00	406.4	368.8	444.4			
10.00	388.6	336.6	397.0			
50.00	363.2	294.5	332.5			
Run	-10 Ref [13]	-11 Ref [14]	-04 Ref [4]			
R_{ES} (lb)	605	605	605			

REV	BY	DATE	CHECKED	DATE
0	AA	5/21/86	GH	5/22/86

IMPELL CORPORATION

JOB NO 0210-041

CALC NO M-30

Table 8: Comparison of Center Support MMF

L1A/L4B	0.33	0.67	1.0			
α \ β	1.0	1.0	1.0			
0.01	0.040	0.053	0.055			
0.25	0.585	0.697	0.717			
0.50	0.769	0.948	1.006			
0.75	0.813	1.039	1.189			
1.00	0.807	0.999	1.208			
1.25	0.787	0.897	1.042			
1.50	0.766	0.798	0.881			
1.75	0.749	0.729	0.790			
2.00	0.734	0.686	0.745			
5.00	0.672	0.610	0.735			
10.00	0.642	0.556	0.656			
50.00	0.600	0.487	0.550			
Run	-10	-11	-04			

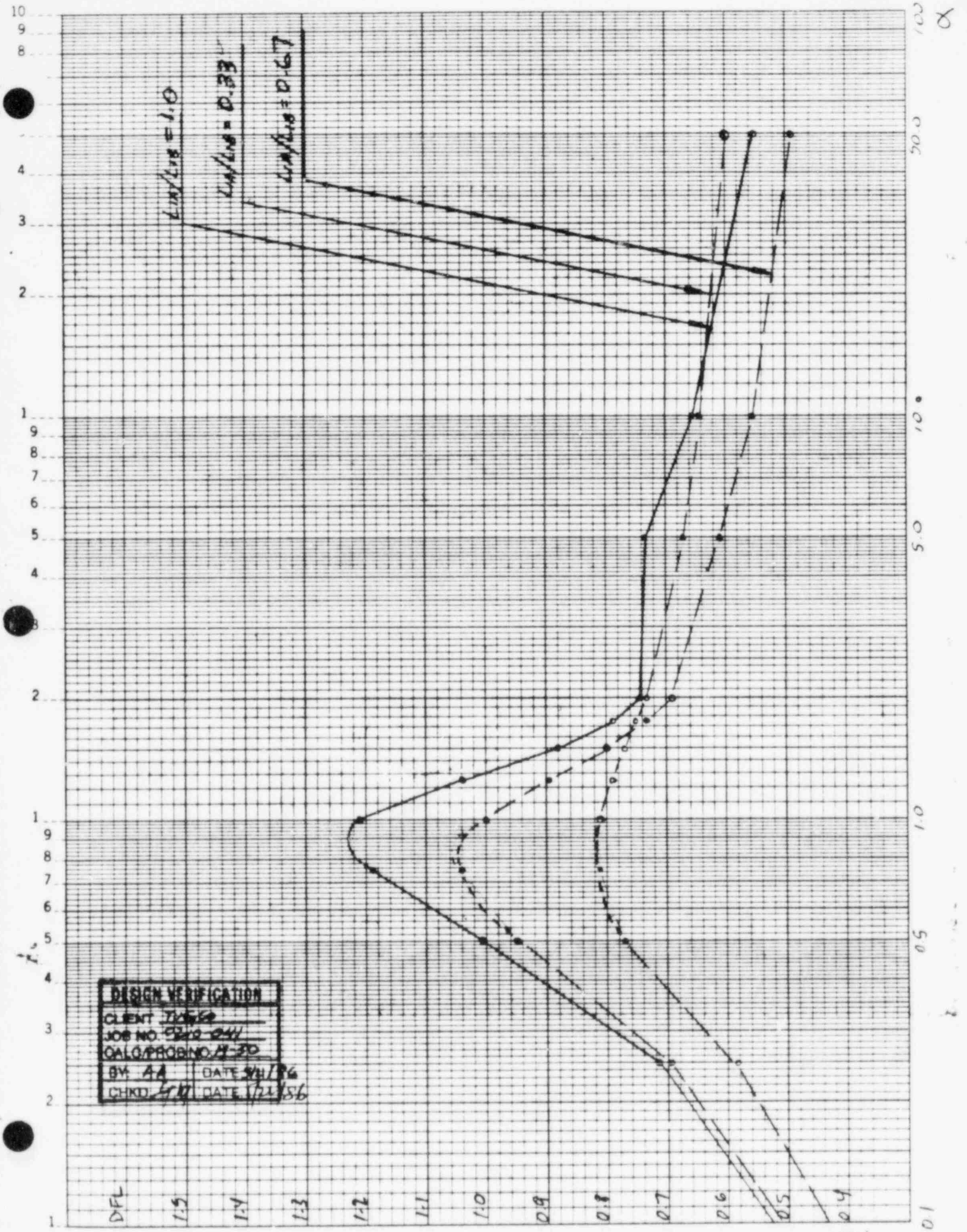

DESIGN VERIFICATION
CLIENT
JOB NO.
CALC/PROB NO.
BY
DATE
CHKD
DATE
DFL
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.1
0.5
1.0
5.0
10
50.0
100.0
α
46 5492
K·E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 4

Comparison of adjacent supports (M-30-10)   Case $L_{IA}/L_{IB} = 0.33$, $\beta = 1.0$

	Left Support		Right Support	
L_{IA}/L_{IB}	0.33	0.33 (DLF)	0.33	0.33 (DLF)
α \ β	1.0	1.0	1.0	1.0
0.01 *	829.3	1.66	708.0	1.00
0.25	553.8	1.11	654.8	0.92
0.50	491.2	0.98	642.1	0.90
0.75	506.6	1.01	631.8	0.89
1.00	529.5	1.06	623.1	0.88
1.25	537.5	1.08	619.6	0.87
1.50	533.9	1.07	619.1	0.87
1.75	525.6	1.05	619.2	0.87
2.00	516.6	1.03	618.9	0.87
5.00	470.9	0.94	602.2	0.85
10.00	458.4	0.92	590.7	0.83
50.00	448.8	0.90	580.6	0.82
Run	-10		-10	

* $\alpha = 0.01$ is an unrealistic case and it is used only as a limit value.

R_{BS} (lb)   500.   770.

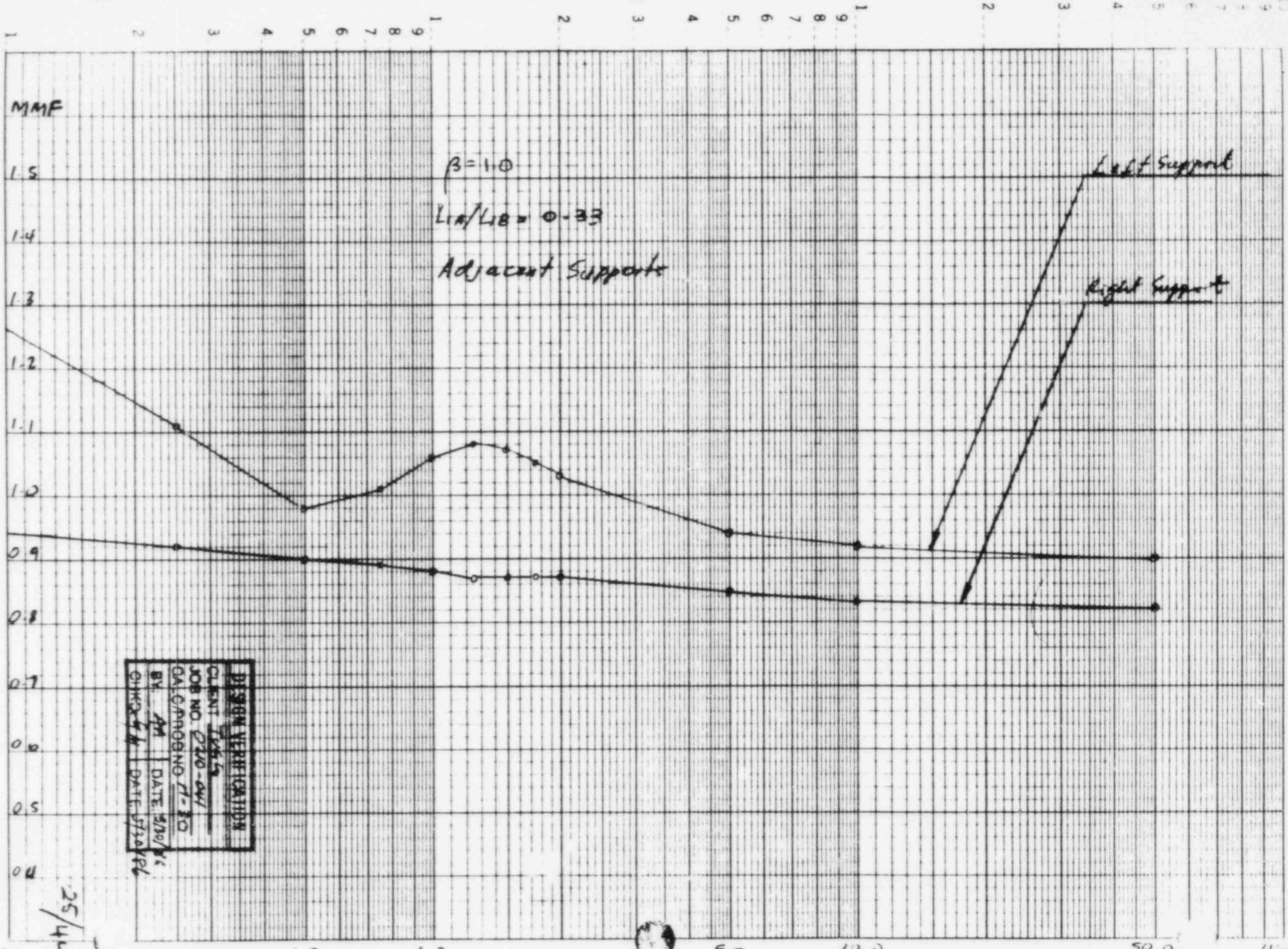
$R_{BS}(lb) = [0.0151 \times \text{trib. length} + 0.479] \times 386.4$

REV	BY	DATE	CHECKED	DATE
0	AA	5/30/86	GG	5/30/86

IMPELL CORPORATION

JOB NO 0210-041   CALC NO M-30   PAGE 24 OF 44

K·E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 5492



25/44

D. ANALYSIS SET 4

THIS SET OF ANALYSES FOCUS ON ALTERING THE RELATIVE SUPPORT TO SUPPORT MASS AND SUPPORT TO TRAY MASS. FOR ALL CASES $L_2 = L_{1A} = L_{1B} = 72.0$ IN. THE FOLLOWING PARAMETER RATIOS WERE VARIED:

$$\alpha = \frac{k_1}{k_2} \quad \langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 5.0, 10.0, 50.0 \rangle$$

$$\beta = \frac{k_{tray}}{k_2} \quad \langle \beta = 1.0 \rangle$$

$$\frac{m_1}{m_2} \quad \langle = 0.1, 0.33, 3.0, 10.0 \rangle$$

REACTION LOADS (R_{RS}) AND DLF FOR THE CENTRAL SUPPORT ARE PRESENTED IN TABLES 9, 10 AND PLOTTED IN FIGURE 5

$$DLF = \frac{R_{RS}}{R_{ES}}$$

R_{ES} = 438.5 LB. FOR $m_1 = 0.10\ m_2$
= 481.0 LB. FOR $m_1 = 0.33\ m_2$
= 976.4 LB. FOR $m_1 = 3.0\ m_2$
= 2270.9 LB. FOR $m_1 = 10.0\ m_2$

∅	RTK	4/11/86	AA	5/21/86	IMPELL CORPORATION
REV	BY	DATE	CHECKED	DATE	

Table 9: Comparison of Support Reaction from Dynamic Analysis (R_{RS}) in lbs.

For all cases $L_2 = L_{1A} = L_{1B} = 72$ in

m_1/m_2	0.1	0.33	1.0	3.0	10.0	
α \ β	1.0	1.0	1.0	1.0	1.0	
0.01	26.8	23.4	33.5	48.9	104.2	
0.25	362.1	379.4	433.8	613.6	1286.0	
0.50	520.7	544.7	608.4	823.7	1689.0	
0.75	551.0	606.0	719.6	947.9	1891.0	
1.00	472.7	536.0	731.0	1043.0	2015.0	
1.25	406.8	452.7	630.4	1115.0	2103.0	
1.50	372.5	405.5	533.0	1131.0	2171.0	
1.75	356.7	383.0	477.8	1043.0	2228.0	
2.00	350.2	373.5	450.7	897.1	2277.0	
5.00	338.3	362.8	444.4	707.7	1781.0	
10.00	312.6	331.6	397.0	659.6	1734.0	
50.00	271.8	283.7	332.5	608.5	1600.0	
Run	-12 Ref [15]	-13 Ref [16]	-04 Ref [17]	-14 Ref [17]	-15 Ref [18]	
R_{ES} (lb.)	438.5	481.0	605.0	976.4	2270.9	

REV	BY	DATE	CHECKED	DATE	
0	AA	5/15/86	GM	5/21/86	IMPELL CORPORATION

JOB NO 0210-041

CALC NO M-30

Table 10. Comparison of Support MMF

m_1/m_2	0.1	0.33	1.0	3.0	10.0
α \ β	1.0	1.0	1.0	1.0	1.0
0.01	0.061	0.059	0.055	0.050	0.046
0.25	0.826	0.789	0.717	0.628	0.566
0.50	1.187	1.132	1.006	0.844	0.744
0.75	1.257	1.260	1.189	0.971	0.833
1.00	1.078	1.114	1.208	1.068	0.887
1.25	0.928	0.941	1.042	1.142	0.926
1.50	0.849	0.843	0.881	1.158	0.956
1.75	0.813	0.796	0.790	1.068	0.981
2.00	0.799	0.777	0.745	0.919	1.003
5.00	0.771	0.754	0.735	0.725	0.784
10.00	0.713	0.689	0.656	0.676	0.764
50.00	0.620	0.590	0.550	0.623	0.705
Run	-12	-13	-04	-14	-15

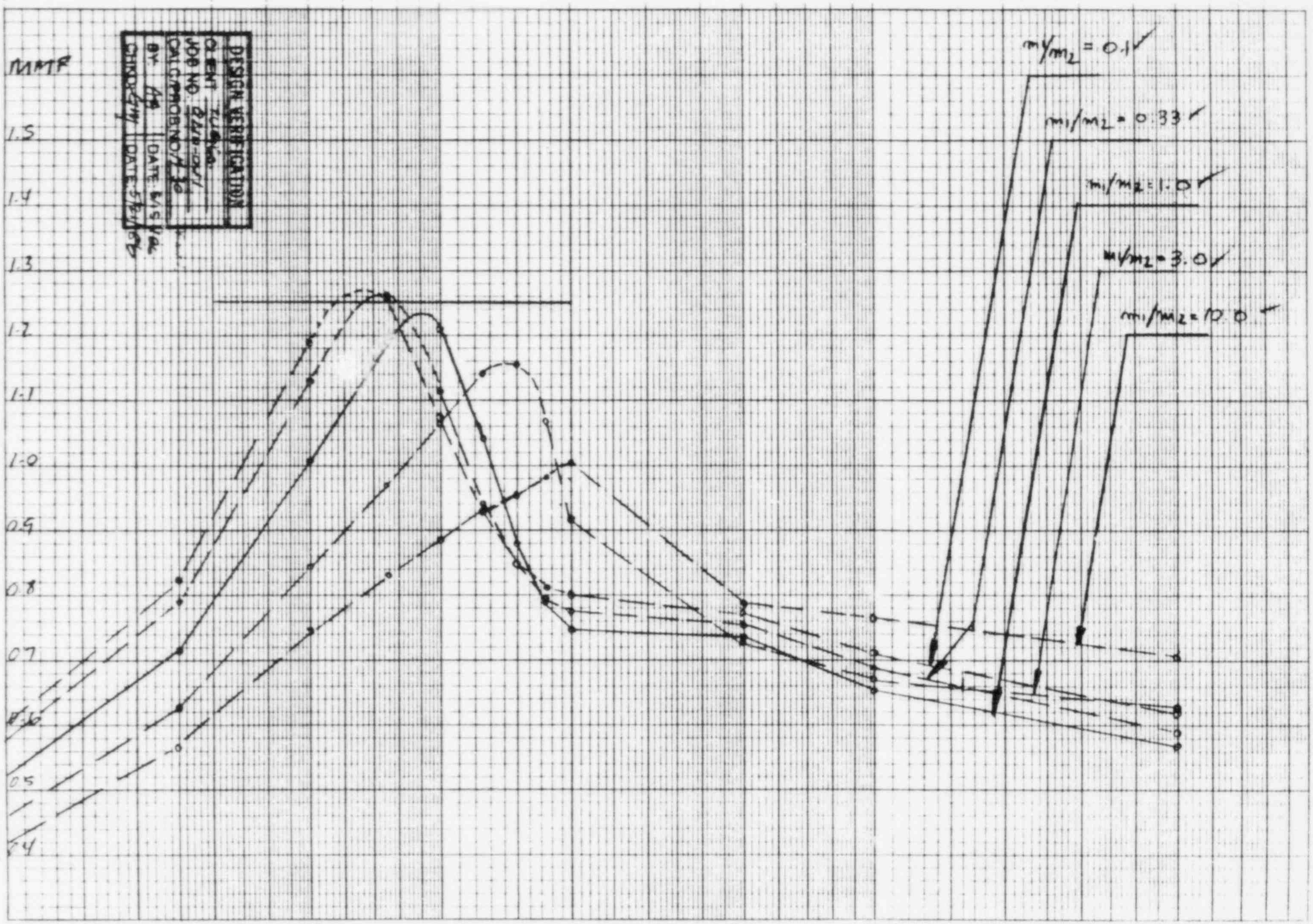


FIGURE 5

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E. ANALYSIS SET 5

THIS SET OF ANALYSES PLACES A LARGE LUMPED MASS ON EITHER THE END SUPPORT OR THE ADJACENT SUPPORT TO THE CENTER SUPPORT. THIS IS TO SIMULATE THE EFFECT OF A LONGITUDINALLY UNSUPPORTED TRAY RUN IN THE DIRECTION OF SEISMIC EXCITATION. FOR ALL CASES $L_2 = L_{1A} = L_{1B} = 72.0$ IN THE FOLLOWING PARAMETER RATIOS WERE VARIED:

$\alpha = \frac{K_1}{K_2}$ $\langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 5.0, 10.0, 50.0 \rangle$

$\beta = \frac{K_{tray}}{K_2}$ $\langle \beta = 1.0 \rangle$

$\frac{m_1}{m_2}$ $\langle = 1.0 \rangle$ FOR ALL SUPPORTS OTHER THAN THE SUPPORT WITH THE LARGE LUMPED WEIGHT.

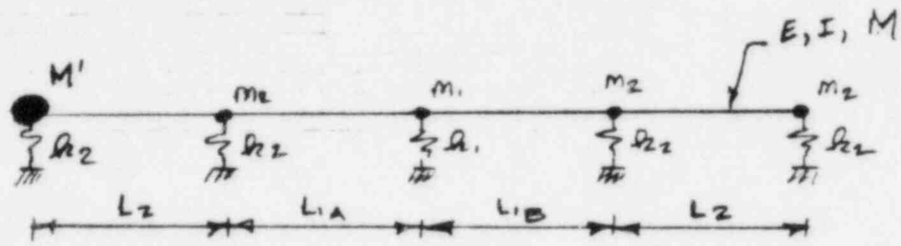
THE FOLLOWING LARGE LUMPED WEIGHTS WERE USED:

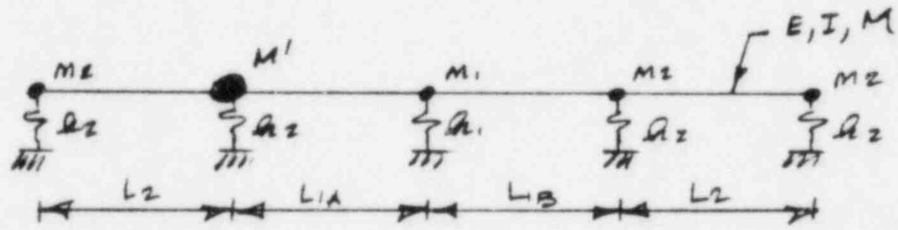
$M' = 3.26$ lb·s²/in (≈ 3 TRAY SPANS)

$M' = 6.52$ lb·s²/in (≈ 6 TRAY SPANS)

WHERE THE TRAY WAS ASSUMED TO WEIGH 70 LB./FT AND A TYPICAL SPAN WAS ASSUMED TO BE 72.0 IN.

THE FOLLOWING MODELS WERE THEREFORE ANALYZED:





REACTION LOADS (R_{RS}) AND DLF FOR THE CENTRAL SUPPORT ARE PRESENTED IN TABLES 11, 12 AND PLOTTED IN FIGURE 6

$$DLF = \frac{R_{RS}}{R_{ES}}$$

R_{ES} = 605. LB FOR ALL CASES

0	RTK	4/11/86	AA	3/21/86	IMPELL CORPORATION	JOB NO 0210-041 CALC NO M-30	PAGE 31 OF 44
REV	BY	DATE	CHECKED	DATE			

Table 11. Comparison of Center Support Reaction from Dynamic Analysis (R_{RC}) in lbs
For all cases $L_{1A} = L_{1B} = L_2 = 72$ in

	$M_{end} = 3.26$ lb sec²/in	$M_{end} = 6.52$ lb sec²/in	$M_{end} = M_{adj} = M_{center} = 0.479$ lb sec²/in	$M_{adj} = 3.26$ lb sec²/in	$M_{adj} = 6.52$ lb sec²/in	
α \ β	1.0	1.0	1.0	1.0	1.0	
0.01	29.3	34.8	33.5	45.4	57.1	
0.25	430.6	496.1	433.8	520.6	498.6	
0.50	645.7	642.4	608.4	527.9	598.7	
0.75	711.5	720.5	719.6	580.9	670.4	
1.00	703.6	718.2	731.0	563.1	655.9	
1.25	626.1	641.9	630.4	501.2	606.4	
1.50	547.6	562.4	533.0	469.3	585.4	
1.75	495.0	509.3	477.8	462.8	584.9	
2.00	465.8	479.6	450.7	469.5	594.1	
5.00	408.9	420.6	444.4	507.7	629.8	
10.00	383.9	396.8	397.0	442.6	576.7	
50.00	328.0	343.9	332.5	391.5	539.1	
Run	-16 ref [19]	-17 ref [20]	-04 ref [7]	-18 ref [21]	-19 ref [22]	
R_{ES} (lb)	605	605	605	605	605	

REV	BY	DATE	CHECKED	DATE		
0	AA	5/15/86	GM	5/21/86	IMPELL CORPORATION	JOB NO 0210-041; CALC NO M-30; PAGE 32 OF 44

Table 12. Comparison of Center Support MMF

	$m_{end} = 3.26$	$m_{end} = 6.52$	$m_{end} = m_{adj} = m_{center} = 0.479$	$m_{adj} = 3.26$	$m_{adj} = 6.52$	
α \ β	1.0	1.0	1.0	1.0	1.0	
0.01	0.048	0.058	0.055	0.075	0.094	
0.25	0.712	0.820	0.717	0.860	0.824	
0.50	1.067	1.062	1.006	0.873	0.990	
0.75	1.176	1.191	1.189	0.960	1.108	
1.00	1.163	1.187	1.208	0.931	1.084	
1.25	1.035	1.061	1.042	0.828	1.002	
1.50	0.905	0.930	0.881	0.776	0.968	
1.75	0.818	0.842	0.790	0.765	0.967	
2.00	0.770	0.793	0.745	0.776	0.982	
5.00	0.676	0.695	0.735	0.839	1.041	
10.00	0.635	0.656	0.656	0.732	0.953	
50.00	0.542	0.568	0.550	0.647	0.891	
Run	-16	-17	-04	-18	-19	

REV	BY	DATE	CHECKED	DATE		
0	AA	5/15/86	GM	5/22/86	IMPELL CORPORATION	JOB NO 0210-041 CALC NO M-30

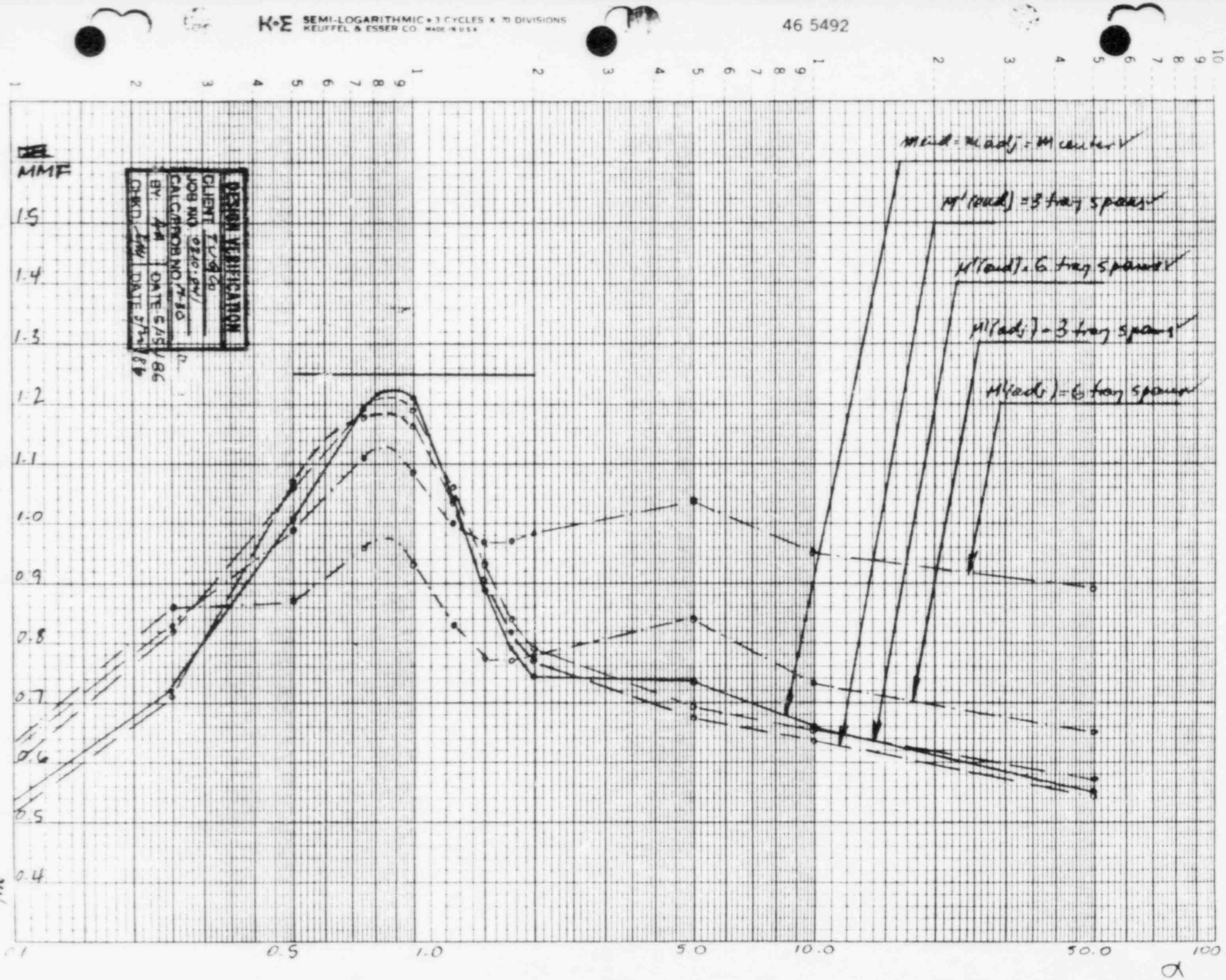


FIGURE 6

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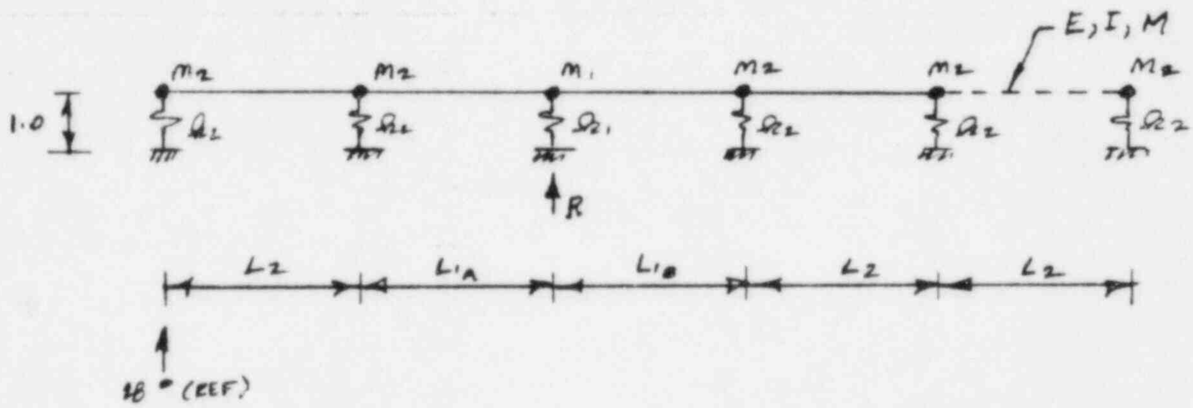
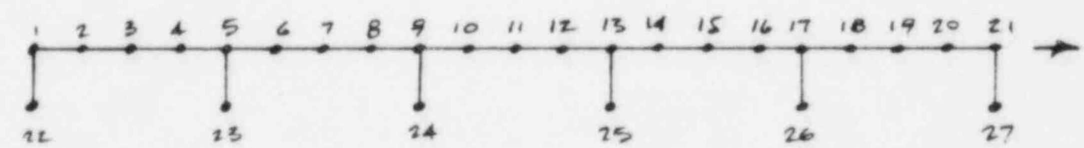
F. ANALYSIS SET 6

THIS SET OF ANALYSES PLACES AN ADDITIONAL END SPAN ON THE SYSTEM MODEL, AS SHOWN BELOW.





THE MODEL WILL SHOW THE CHANGE IN SUPPORT REACTION DUE TO AN UNSYMMETRIC MODEL WITH AN ODD NUMBER OF SPANS. THE FOLLOWING PARAMETER RATIOS WERE VARIED:

$\alpha = \frac{K_1}{K_2}$ $\langle \alpha = 0.01, 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 5.0, 10.0, 50.0 \rangle$

$\beta = \frac{K_{tray}}{K_2}$ $\langle \beta = 1.0 \rangle$

$\frac{m_1}{m_2}$ $\langle = 1.0 \rangle$

REV	BY	DATE	CHECKED	DATE
0	RTK	4/11/86	AA	4/16/86

IMPELL CORPORATION

JOB NO 0210-041

CALC NO M-30

REACTION LOADS (R_{RS}) AND MMF FOR THE FIVE SPAN MODEL ARE PRESENTED IN TABLES 13 & 14. FIGURE 7 PLOTS A COMPARISON OF THE DLF FOR THE SYMMETRIC (FOUR SPAN) AND UNSYMMETRIC (FIVE SPAN) MODELS WITH ALL OTHER PARAMETERS IDENTICAL.

$$MMF = \frac{R_{RS}}{R_{ES}}$$

R_{ES} = 605. LB

						JOB NO 0210-041	PAGE 36 OF 44
ø	RTK	4/11/86	AA	5/21/86	IMPELL CORPORATION	CALC NO M-30	
REV	BY	DATE	CHECKED	DATE			

Table 13. Support Reaction from Dynamic Analysis (R_{RS}) in lbs. for Unsymmetric (five span) Model
For all cases $L_2 = L_{1A} = L_{1B} = 72$ in

	5 span case	4 span Case				
α \ β	1.0	1.0				
0.01	33.0	33.5				
0.25	422.5	433.8				
0.50	582.7	608.4				
0.75	677.3	719.6				
1.00	653.9	731.0				
1.25	529.5	630.4				
1.50	449.0	533.0				
1.75	412.8	477.8				
2.00	397.4	450.7				
5.00	367.5	444.4				
10.00	319.0	397.0				
50.00	259.7	332.5				
Run	-20 Ref[23]	-04 Ref[7]				

R_{ES} (lb) 605 605

REV	BY	DATE	CHECKED	DATE
0	AA	5/16/86	GKI	5/27/86

IMPELL CORPORATION

JOB NO 0210-041
CALC NO M-30
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Table 14. Support Reaction Comparison. MMF

	5 Span Case	4 Span Case				
α \ β	1.0	1.0				
0.01	0.055	0.055				
0.25	0.698	0.717				
0.50	0.963	1.006				
0.75	1.120	1.189				
1.00	1.081	1.208				
1.25	0.875	1.042				
1.50	0.742	0.881				
1.75	0.682	0.790				
2.00	0.657	0.745				
5.00	0.607	0.735				
10.00	0.527	0.656				
50.00	0.429	0.550				
Run	-20	-04				

REV	BY	DATE	CHECKED	DATE
0	AA	5/16/86	[illegible]	5/22/86

IMPELL CORPORATION

JOB NO 0210-041

CALC NO M-30

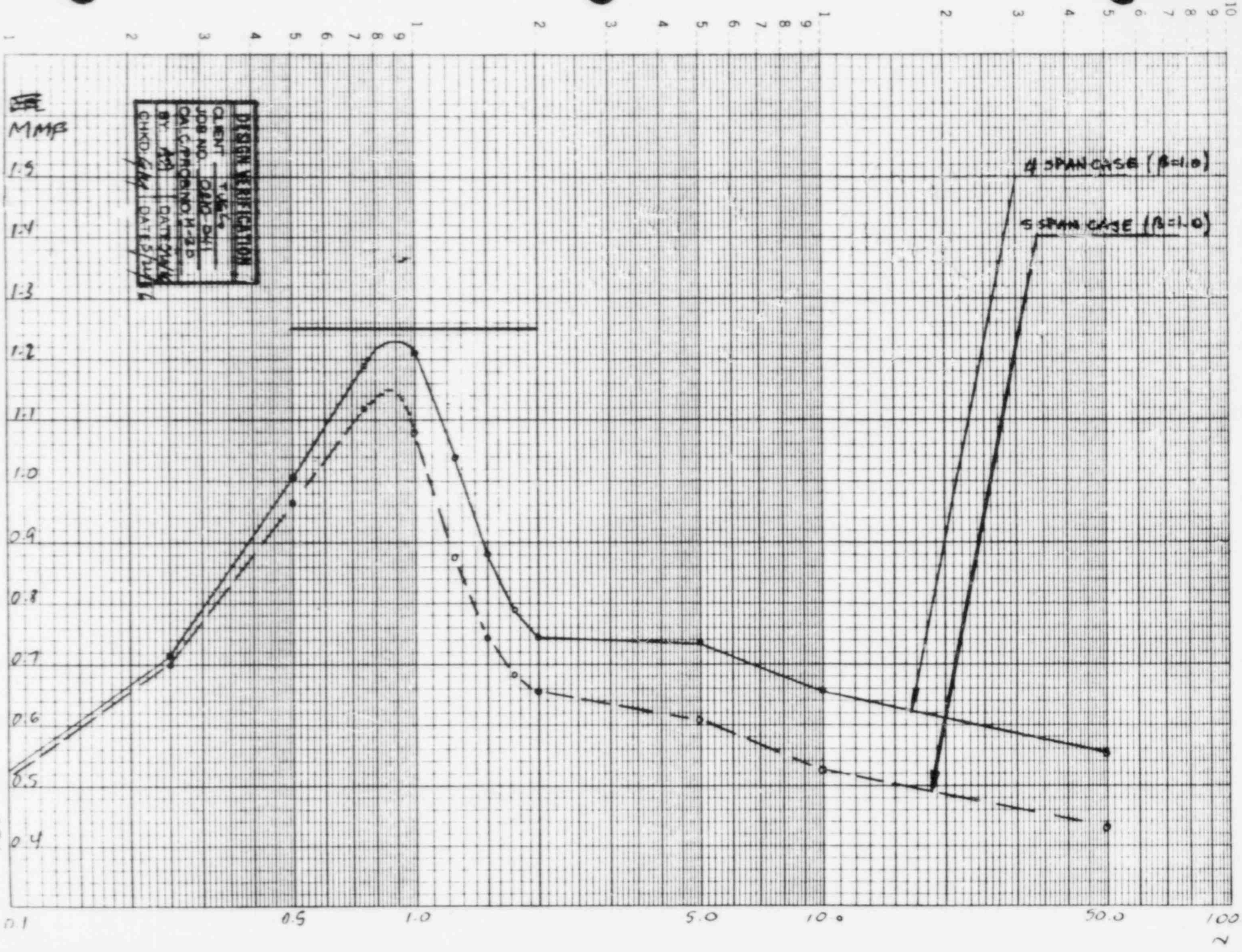

MMP
DESIGN VERIFICATION
CLIENT
JOB NO. OAIO-041
CALC/PROB NO. H-20
BY
DATE
CHKD
DATE
4 SPAN CASE (β=1.0)
5 SPAN CASE (β=1.0)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.1
0.5
1.0
5.0
10.0
50.0
100.0
Z

FIGURE 7

IV CONCLUSIONS

THE ANALYSES PRESENTED IN THIS CALCULATION HAVE VARIED THE RELATIVE SUPPORT STIFFNESS, THE RELATIVE TRAY TO SUPPORT STIFFNESS, THE RELATIVE SPAN LENGTHS, THE RELATIVE SUPPORT MASSES, AND THE MODEL SYMMETRY IN AN EFFORT TO DETERMINE THE RANGE AND SENSITIVITY OF THE MMF FACTOR.

THE RESULTS PRESENTED IN FIGURES 1,2 INDICATE THAT THE MAXIMUM MMF ≈ 1.40 AND OCCURS WHEN $\beta = 10.0$ (AN EXTREMELY HIGH TRAY STIFFNESS RELATIVE TO THE SUPPORT). FOR THE RANGE OF VERTICAL AND TRANSVERSE STIFFNESSES COMMONLY FOUND IN CPSES CABLETRAY SYSTEMS, $\beta \leq 1.0$. FOR THESE ANALYSES THE MAXIMUM MMF ≈ 1.25, AND OCCURS FOR FAIRLY EQUAL SUPPORT STIFFNESSES $(0.5 \leq \alpha \leq 2.0)$.

SUBSEQUENT ANALYSES (Figures 3 - 4) SHOW THAT THE MAXIMUM MMF WILL TYPICALLY OCCUR FOR FAIRLY UNIFORM SPAN LENGTHS.

Ø	AA	5/21/86	[illegible]	5/23/86	IMPELL CORPORATION	JOB NO 0210-041 CALC NO M-30	PAGE 40 OF 44
REV	BY	DATE	CHECKED	DATE			

FIGURE 5 INDICATES THAT THE MAXIMUM MMF WILL OCCUR IF THE SUPPORT IN QUESTION HAS RELATIVELY SMALL MASS IN COMPARISON TO THE ADJACENT SUPPORTS AND IN COMPARISON TO THE TRAY. THIS INDICATES THAT THE INCLUSION OF THE ENTIRE SUPPORT MASS IN THE EQUIVALENT STATIC LOAD IS GENERALLY CONSERVATIVE, (BECAUSE THE LARGER MMF, ASSOCIATED WITH SMALLER SUPPORT MASSES IS USED)

FIGURE 6 INDICATES THAT RELATIVELY LARGE MASSES (i.e. UNSUPPORTED CHANGES IN DIRECTION, ETC.) DO NOT RESULT IN A MAXIMUM MMF, ALTHOUGH THEY DO ALTER THE SYSTEM RESPONSE.

FIGURE 7 INDICATES THAT THE SYMMETRY OF THE SYSTEM DOES NOT SIGNIFICANTLY ALTER THE RESULTS.

IN GENERAL, THE WORST CASE MMF OCCURS FOR FAIRLY UNIFORM SUPPORT STIFFNESSES AND SPAN LENGTHS, PARTICULARLY WHEN THE SUPPORT IN QUESTION HAS RELATIVELY LOW MASS. ALTHOUGH IT WOULD BE DIFFICULT

TO CONFIDENTLY PREDICT A MMF FOR AN ACTUAL SYSTEM USING THE CURVES GENERATED IN THIS CALC, IT SEEMS CLEAR THAT THE MAXIMUM EXPECTED MMF WOULD BE ≈ 1.25 FOR A WIDE RANGE OF PARAMETERS.

THE FLAT SPECTRA USED TO GENERATE THESE CURVES IS CONSERVATIVE, SINCE THE EFFECTS OF HIGHER ORDER MODES WOULD BE EXAGGERATED. HOWEVER, DUNKERLEY'S FORMULA MUST BE PROPERLY APPLIED TO OBTAIN A TRUE SYSTEM LOWER BOUND.

AS PREVIOUSLY MENTIONED, THE EFFECTS OF ROTATIONAL RESTRAINT IN THE CLIP MEMBER CANNOT BE EVALUATED IN THIS SIMPLIFIED MODEL AND MUST BE SEPERATELY EVALUATED.

I. REFERENCES

[1] GENERAL INSTRUCTIONS FOR CABLE TRAY HANGER ANALYSIS FOR COMANCHE PEAK STEAM ELECTRICAL STATION NO. 1 AND 2 EBASCO SERVICES INC. REV. R2.

[2] EDSGAP VERS NOV, 1985.

[3] IMPELL PROJECT INSTRUCTION PI-02 REV. 2 "DYNAMIC ANALYSIS OF CABLETRAY SYSTEMS". JOB NO. 0210-040

[4] IMPELL EDSGAP OUTPUT M-30-01

[5] ——— " " ——— M-30-02

[6] ——— " " ——— M-30-03

[7] ——— " " ——— M-30-04

[8] ——— " " ——— M-30-05

[9] ——— " " ——— M-30-06

[10] ——— " " ——— M-30-07

[11] ——— " " ——— M-30-08

[12] ——— " " ——— M-30-09

[13] IMPELL EDSGAP OUTPUT M-30-10

[14] ——— " " ——— M-30-11

[15] ——— " " ——— M-30-12

[16] ——— " " ——— M-30-13

[17] ——— " " ——— M-30-14

[18] ——— " " ——— M-30-15

[19] ——— " " ——— M-30-16

[20] ——— " " ——— M-30-17

[21] ——— " " ——— M-30-18

[22] ——— " " ——— M-30-19

[23] ——— " " ——— M-30-20

						JOB NO 07:0-041	PAGE 44
0	RTK	4/11/86	AA	9/24/86	IMPELL CORPORATION	CALC NO M-30	OF 44
REV	BY	DATE	CHECKED	DATE			

IMF

COMPUTER RUN LOG

Job No. 0210-041 Project

RUN NO.	DATE	TITLE	BY
M-30-01	5/15/86	EDSGAP: $\beta = 0.1$	AA
-02	5/15/86	" $\beta = 0.5$	AA
-03	5/15/86	" $\beta = 0.75$	AA
-04	5/15/86	" $\beta = 1.0$	AA
-05	5/15/86	" $\beta = 1.5$	AA
-06	5/15/86	" $\beta = 3.0$	AA
-07	5/21/86	" $\beta = 10.0$	AA
-08	5/16/86	" $\beta = 1.0$ $L_1/L_2 = 0.67$	AA
-09	5/16/86	" $\beta = 1.0$ $L_1/L_2 = 1.50$	AA
-10	5/21/86	" $\beta = 1.0$ $L_{1A}/L_{1B} = 0.33$	AA
-11	5/21/86	" $\beta = 1.0$ $L_{1A}/L_{1B} = 0.67$	AA
-12	5/16/86	" $\beta = 1.0$ $m_1/m_2 = 0.1$	AA
-13	5/16/86	" $\beta = 1.0$ $m_1/m_2 = 0.33$	AA
-14	5/16/86	" $\beta = 1.0$ $m_1/m_2 = 3.0$	AA
-15	5/16/86	" $\beta = 1.0$ $m_1/m_2 = 10.0$	AA
M-30-16	5/16/86	" $\beta = 1.0$ M'(end) = 3 long spans	AA

IMPELL

COMPUTER RUN LOG

Job No. 0210-041 Project

RUN NO.	DATE	TITLE	BY
M-30-17	5/16/86	EDSGAD β = 1.0 μ'(adj) = 6 tray spans	AA
-18	5/16/86	" β = 1.0 μ'(adj) = 3 tray spans	AA
-19	5/23/86	" β = 1.0 μ'(adj) = 6 tray spans	AA
-20	5/16/86	" β = 1.0 5 span case	AA

PAGE OF

VI - Appendix A

Verification of CQC modal combination

The maximum total response can be evaluated as

$$R = \left[\sum_i \sum_j R_i R_j \rho_{ij} \right]^{1/2} \quad [\text{Ref A.1}]$$

where

R maximum total response

R_i maximum response of mode i

ρ_{ij} correlation coefficient between modes i and j

$$\rho_{ij} = \frac{8 \xi^2 (1+r) r^{3/2}}{(1-r^2)^2 + 4\xi^2 r (1+r)^2}$$

$r = \omega_j / \omega_i$

ξ = modal damping ratio [assumed constant for all the modes]

A computer program was written to verify the results given by program EDSGAP. This program was named CQC and requires as input data the individual modal responses and the frequencies. The program CQC evaluates the correlation coefficients and then performs the modal combination. Listing of program CQC is given in the next page.

REV	BY	DATE	CHECKED	DATE			
0	AA	5/30/86	GM	5/30/86	IMPELL CORPORATION	JOB NO 0710-041 CALC NO M-30	PAGE A1 OF A3

PROGRAM CQC 74/940 OPT=1

```
      PROGRAM CQC(INPUT,OUTPUT,TAPE1)
      DIMENSION R(15,15),W(15),S(15)
      READ(1,101) NC
      READ(1,102) (W(I),I=1,15)
      PRINT 300,(W(I),I=1,15)
  300 FORMAT(5E15.6)
      Z = 0.04
      DO 10 K=1,NC
      READ(1,100) (S(I),I=1,15)
      PRINT 301, (S(I),I=1,15)
  301 FORMAT(5E15.4)
      SS = 0.0
      DO 1 I=1,15
      DO 1 J=1,15
      F = W(J)/W(I)
      A1 = 8.*Z*Z*(1.+F)*SQRT(F**3)
      A2 = (1.-F*F)*(1.-F*F)
      A3 = 4.*Z*Z*F*(1.+F)*(1.+F)
      R(I,J) = A1/(A2+A3)
    1 SS = SS + R(I,J)*S(I)*S(J)
      SS = SQRT(SS)
      PRINT 200, K
      PRINT 201, SS
   10 CONTINUE
  101 FORMAT(16I5)
  102 FORMAT(5F15.0)
  100 FORMAT(8F10.0)
  200 FORMAT(5X,4HCASE,2X,I5,//)
  201 FORMAT(5X,17HCOMBINED RESPONSE,E15.4)
      STOP
      END
```

For this verification 4% damping was assumed.

The case ($\beta = 0.75$, $\alpha = 0.75$ (Run M-30-03, Calc M-30, Job 0210-041) was verified. The total reaction were evaluated using the CQC program and compared with those evaluated using program #DSGAP (Run M-30-03)

The results from program CQC are:

.114916E+02	.125734E+02	.134003E+02	.160990E+02	.197511E+02	Freq.
.229904E+02	.297414E+02	.397315E+02	.512853E+02	.758590E+02	(Input)
.872134E+02	.104147E+03	.121359E+03	.159124E+03	.168463E+03	
-.7470E+01	-.3011E-07	.2475E+03	.9713E-10	.1014E+03	Modal
.5400E-11	.1412E+02	-.8490E-11	.9501E+00	-.2704E-12	Resp.
-.1896E-01	.2238E-12	-.9350E-03	-.3804E-13	.5250E-03	(Input)

CASE 1

COMBINED RESPONSE .2704E+03 Reaction at support 1

.4234E+03	-.8735E-07	.2757E+03	-.3586E-10	-.5176E+02	Modal
-.1246E-11	.8570E+01	-.1353E-10	.1808E+01	-.3384E-13	Resp.
.2238E-01	-.6558E-12	.3382E-02	.2908E-14	.1034E-02	(Input)

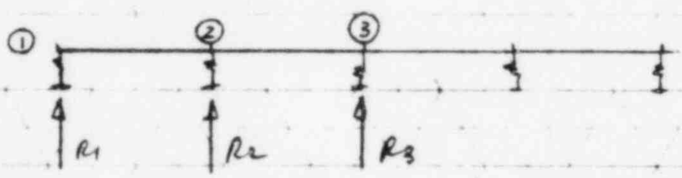
CASE 2

COMBINED RESPONSE .5529E+03 Reaction at support 2

.7276E+03	-.6788E-17	-.1769E+03	.1968E-21	.3556E+02	Modal
.7756E-24	-.1037E+02	.4997E-22	.1763E+01	-.4403E-24	Resp.
.2526E-01	-.5582E-22	-.3502E-02	-.5581E-23	-.1124E-02	(Input)

CASE 3

COMBINED RESPONSE .7127E+03 Reaction at support 3



Reactions given by EDSGAP: (Run M-30-03)

$R_1 = 270.4$ lb

$R_2 = 552.8$ lb

$R_3 = 712.7$ lb

Ref. A1: Wilson, E. L. et al. "A Replacement for the SRSS Method in Seismic Analysis," Earth. Eng. and Structural Dynamics, Vol 9, pp. 187-194, 1981.

REV	BY	DATE	CHECKED	DATE		JOB NO / CALC NO	PAGE
0	AA	5/30/86	[illegible]	5/30/86	IMPELL CORPORATION	JOB NO 0210-041 CALC NO M-30	A3 OF A3

Appendix B

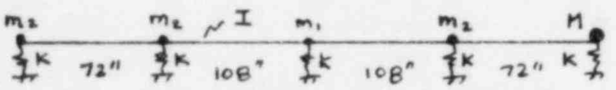
Additional Studies to Answer Design Review Questions

☐ 1 **ITEM NO.** ☐ **DEFICIENCY** ☒ **RECOMMENDATION**

The variation of the dynamic load factor (DLF) was calculated separately for each of the parameters which were considered in this study. What would the DLF be for a case in which the parameters of the conduit system are such that the maximum DLF from each of Figures 1, 3, 4, 5 and 6 is obtained? If the DLF is the product of the individual DLFs, the "combined" DLF ~~will~~ may be higher than 1.25.

CORRECTIVE ACTION

The extreme case of $\beta = 1.5$, $\alpha = 1.0$, $L_1/L_2 = 1.5$, $m_1/m_2 = 1/3$, and lumped mass at the end support of 6.52 lb.sec²/in was analyzed.



$I = 4.02\ in^4$, $M = 6.52$ lb sec^2/in, $K = 10,000$ lb/in. The resultant DFL is 1.30. The combination of "worst" cases (1.24, 1.21, 1.11 and 1.19) does not increase the DFL too much (4.8%).

PROJECT ENGINEER DATE

From run ROTC-06-01, the load at the middle support is

$R_{dyn} = 899.7$ lb

$R_{static} = (108 \times 0.0151 + \frac{0.479}{3})\ 386.4 = 691.8$ lb

$DFL = 899.7/691.8 = 1.30$

REV	BY	DATE	CHECKED	DATE		
1	AR	6/20/86	DMK	9/10/86	IMPELL CORPORATION	JOB NO 0310-092-1580; CALC NO ROTC-06; PAGE B OF B3

2	ITEM NO.		DEFICIENCY	X	RECOMMENDATION

Figure 1 shows the variation of the DLF with the relative stiffness of the tray. The $\beta = 0.1$ curve does not follow the trend of the rest of the curves, i.e., obtain increased DLFs with increasing β. In the case of a very stiff support ($\beta < 0.1$) is it possible that the DLF will considerably exceed the 1.25 value?

CORRECTIVE ACTION

The model studied in Figure 1 of calculation file was re-studied for the case of β equal to 0.01. The evaluated DFL for this case is 478.5/605 = 0.79. Actually two runs were made; one for Ksupp = 10,000 lb/in, Ibeam = 0.0268 in^4 and one for Ksupp = 1,000,000 lb/in, Ibeam = 2.68 in^4. In both cases, the DFL was the same.

PROJECT ENGINEER ____________ DATE ____________

To study the case $\beta = 0.01$, two runs were made

ROTC-06-02 $K_{supp} = 10{,}000$ lb/in $I_{beam} = 0.0268\ in^4$

ROTC-06-03 $K_{supp} = 1{,}000{,}000$ lb/in $I_{beam} = 2.68\ in^4$

In both cases

$R_{dyn} = 478.5$ lb

$R_{static} = (72 \times 0.0151 + 0.479)\, 386.4 = 605$ lb

$DFL = 478.5/605 = 0.79$

REV	BY	DATE	CHECKED	DATE
1	AA	6/10/86	DMR	9/10/86

IMPELL CORPORATION

JOB NO 0210-052-135

CALC NO ROTC-06

PAGE B2 OF B3

IMPELL

COMPUTER RUN LOG

Job No. 0210-052-1355 Project Comanche Peak

RUN NO.	DATE	TITLE	BY
ROTC-06-01	6/20/86	EDSGAP : Design Review Item 1	AA
ROTC-06-02	6/20/86	EDSGAP : Design Review Item 2 . Iwan : 0.0268	AA
ROTC-06-03	6/20/86	EDSGAP . Design Review Item 2 . Iwan : 2.68	AA

Appendix C

Flat spectrum concern (Answer to TERA question on the use of flat spectrum)

1. It will be demonstrated that the use of constant response spectrum does not affect the final conclusion of the study done to determine a realistic multimode factor

2. Also, it will be shown that the use of CQC for the problem gives similar results to those that would be obtained by using SRSS modal combination

Examples

- Case $\beta = 1.0$ $\alpha = 1.0$ (Run M-30-04 Job 0210-041)

Freq (Hz)	Modal Responses (for 1G)
12.48	750.6
14.38	- 185.6
20.53	52.64

The response of the other modes is negligible

Correlation coefficients for $\xi = 0.04$

$$\rho_{ij} = \begin{bmatrix} 1.0 & 0.241 & 0.024 \\ 0.241 & 1.0 & 0.047 \\ 0.024 & 0.047 & 1.0 \end{bmatrix}$$

0	AF	6/20/86	DMP	9/13/86	IMPELL CORPORATION	JOB NO 0210-052-[illegible]
						CALC NO 052-02
REV	BY	DATE	CHECKED	DATE		PAGE [illegible] OF 2[illegible]

assume

$Sa(12.48) = 1.0\ G$

$Sa(14.38) = \beta_2\ G \qquad \beta_2 < 1$

$Sa(20.53) = \beta_3\ G \qquad \beta_3 < \beta_2$

Response by CQC is

$$R = 750.6\left[1.0 + \beta_2^2 0.061 + \beta_3^2 0.005 - \beta_2 0.119 + \beta_3 0.003 - \beta_2\beta_3 0.002\right]^{1/2}$$

if $\beta_2 = \beta_3 = 1$ (Computer run)

$R_1 = 730.8$ (computer run 731 ✓✓)

suppose $\beta_2 = 0.5 \quad \beta_3 = 0.3$

$R_2 = 734.2$

$\frac{R_2}{R_1} = 1.0047$ 0.47% difference. Using constant spectrum is unconservative by 0.47%

Now $SRSS(\beta_2 = \beta_3 = 1) = 775.0$
$SRSS(\beta_2 = 0.5,\ \beta_3 = 0.3) = 756.5$ } Conservative by 6% and 3% respectively

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REV	BY	DATE	CHECKED	DATE	IMPELL CORPORATION

JOB NO [illegible]
CALC NO [illegible]
PAGE [illegible] OF [illegible]

- Case $\beta = 1.0$ $\alpha = 2.0$ (Run M.30.04 ... 0110.04)

Freq (Hz) Modal Response (for 1G)

13.32	371.5	The response of the other modes is negligible
16.60	114.5	
21.70	187.9	

Correlation coefficients for $\xi = 0.04$

$$\rho_{ij} = \begin{bmatrix} 1.0 & 0.116 & 0.025 \\ 0.116 & 1.0 & 0.081 \\ 0.025 & 0.081 & 1.0 \end{bmatrix}$$

Response by CQC is:

$$R = 371.5 \left[1.0 + \beta_2^2\, 0.095 + \beta_3^2\, 0.256 + \beta_2 0.072 + \beta_3 0.025 + \beta_2 \beta_3 0.025 \right]^{1/2}$$

if $\beta_2 = \beta_3 = 1$

R = 450.9 (Computer run 450.7 ✓✓)

if $\beta_2 = 0.5$ $\beta_3 = 0.3$

R = 388.6 So, using constant spectrum is conservative

SRSS ($\beta_2 = \beta_3 = 1$) = 431.8
SRSS ($\beta_2 = 0.5, \beta_3 = .3$) = 380.1

Unconservative by 4.4% and 2.2% respectively

0	JA	6/20/86	LTT	6/27/86	IMPELL CORPORATION
REV	BY	DATE	CHECKED	DATE	

JOB NO 0??-0??-1??
CALC NO ??-0?
PAGE
OF

VALIDITY OF CQC AND CONSTANT SPECTRUM

From Computer Run M-30-04

Case $\beta = 1.0$; $\alpha = 2.0$

Freq. (Hz.)	Modal Responses (for 1.0 G)
13.22	371.5
16.60	114.5
21.70	187.3

For constant spectrum with A(13.32) = A(16.60) = A(21.70) = 1.0 G

R(CQC) = ~~452.1~~ 450.9

$$\frac{R(SRSS)}{R(CQC)} = \cancel{0.955} \ 0.95[illegible]$$

R(SRSS) = 431.8

For variable spectrum with
A(13.32) = 1.0 G
A(16.60) = 0.5 G
A(21.70) = 0.3 G

R(CQC) = 388.~~8~~6

$$\frac{R(SRSS)}{R(CQC)} = 0.978$$

R(SRSS) = 380.1

$$\frac{\text{R(CQC) constant spectrum}}{\text{R(CQC) variable spectrum}} = 1.1628$$

DESIGN VERIFICATION

CLIENT [illegible]

JOB NO. [illegible]

CALC/PROB NO. [illegible]

BY: [illegible]	DATE: [illegible]
CHKD: DHP	DATE: [illegible]

VALIDITY OF CQC AND CONSTANT SPECTRUM

From Computer Run M-30-04

Case $\beta = 1.0$; $\alpha = 1.0$

Freq. (Hz.)	Modal Responses (for 1.0 G)
12.48	750.60
14.38	-185.60
20.53	52.64

For constant spectrum with A(12.48) = A(14.38) = A(20.53) = 1.0 G

R(CQC) = 730.9

$$\frac{R(SRSS)}{R(CQC)} = 1.06$$

R(SRSS) = 775.0

For variable spectrum with
A(12.48) = 1.0 G
A(14.38) = 0.5 G
A(20.53) = 0.3 G

R(CQC) = 734.2

$$\frac{R(SRSS)}{R(CQC)} = 1.03$$

R(SRSS) = 756.5

$$\frac{R(CQC)\ \text{constant spectrum}}{R(CQC)\ \text{variable spectrum}} = 0.9954$$

DESIGN VERIFICATION	
CLIENT TU&G	
JOB NO. 0210-052-1355	
CALC/PROB NO.	
BY:	DATE: 6/20/86
CHKD: DMR	DATE 9/17/86