CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: M-28

Title: JUSTIFICATION OF CLIP MODELLING PROCEDURE

Client: TUGCO Project: CABLETRAY ANALYSIS

Job No: 0210-041

Design Input/References:

SEE SECTION VII.

Assumptions:

SEE SECTION II.

Method:

SEE SECTION III.

Remarks:

AS NOTED WITHIN.

REV. NO.	REVISION	APPROVED	DATE
0	ORIGINAL ISSUE	G. L. Ashley	9-31-86

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TABLE OF CONTENTS

I. INTRODUCTION

DESIGN VERIFICATION OF COMANCHE PEAK UNIT I SEISMIC CATEGORY I CABLE TRAY SYSTEMS IS CURRENTLY BEING PERFORMED USING THE IMPELL COMPUTER CODE SUPERPIPE (REF [2]). AN ANALYTICAL SYSTEM MODEL IS CREATED USING LINEAR ELASTIC ELEMENTS TO REPRESENT EACH OF THE COMPONENTS OF THE SYSTEM — TRAYS, TRAY CLIPS (CLAMPS), AND SUPPORTS. THE MODELLING TECHNIQUE MUST APPROPRIATELY REPRESENT THE LOCAL COMPONENT BEHAVIOR AS WELL AS THE OVERALL COMPONENT INTERACTION.

THE PURPOSE OF THIS CALCULATION IS TO PROVIDE A DISCUSSION OF THE BASIC ASSUMPTIONS USED TO DEVELOP CLIP MODELLING DETAILS. ALSO PRESENTED IS THE JUSTIFICATION OF THESE ASSUMPTIONS. THE JUSTIFICATION IS PROVIDED IN TERMS OF CONSERVATIVE RESPONSE PREDICTION AND ALSO IN TERMS OF ACTUAL CLIP BEHAVIOR AS DEMONSTRATED DURING TESTING.

THE FOLLOWING SECTIONS ARE INCLUDED IN THIS CALCULATION :

- A DISCUSSION OF THE MAJOR ASSUMPTIONS MADE REGARDING CLIP BEHAVIOR
- A DISCUSSION OF THE IMPELL CLIP MODELLING PROCEDURES WHICH ARE BASED ON THESE ASSUMPTIONS
- A DISCUSSION OF THE MODELLING PROCEDURE MADE BY COMPARING RESPONSE BETWEEN DIFFERENT ANALYTICAL MODELS.
- A DISCUSSION OF THE MODELLING PROCEDURE MADE BY COMPARING ANALYTICAL RESPONSE WITH TEST DATA.

II. BEHAVIORAL ASSUMPTIONS

COMANCHE PEAK UNIT I HAS TWO DIFFERENT TYPES OF TRAY-TO-SUPPORT CLIP CONNECTIONS. A "LONGITUDINAL" CLIP REFERS TO ONE WHICH HAS A MECHANICAL CONNECTION (BOLT OR WELD) BETWEEN THE CLIP AND TRAY. A "TRANSVERSE" CLIP HAS NO MECHANICAL CONNECTION BETWEEN THE CLIP AND TRAY.

THE IMPELL PROCEDURE FOR MODELLING CLIPS WAS DEVELOPED BASED ON THE FOLLOWING ASSUMPTIONS:

(1.) LONGITUDINAL RESTRAINT AT A "TRANSVERSE" CLIP IS GENERATED BY A FRICTIONAL FORCE WHICH CAN BE MODELLED AS AN ELASTIC STIFFNESS. THIS STIFFNESS IS DETERMINED FROM FINITE ELEMENT ANALYSES IN REF [5] BY ASSUMING A LOAD TRANSFER POINT FOR THE TRAY TO CLIP FRICTION.

(2.) BOTH TYPES OF CLIPS RESTRAIN ALL SIX DEGREES OF FREEDOM. CLIP RESTRAINT MAY AGAIN BE CONSERVATIVELY MODELLED USING ELASTIC STIFFNESSES GENERATED IN REFS [5, 6].

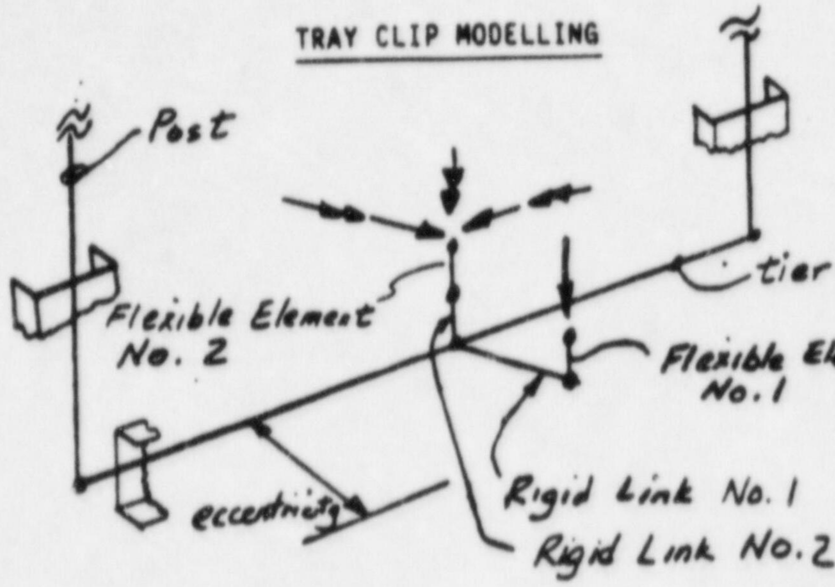
(3.) THE TWO CLIPS RESTRAINING EACH SIDE OF THE TRAY MAY BE MODELLED BY A SINGLE ELEMENT ASSEMBLY AT THE TRAY CENTERLINE. THIS WILL BE SHOWN TO BE CONSERVATIVE FOR BOTH LOCAL SUPPORT RESPONSE AND GLOBAL SYSTEM RESPONSE.

EACH OF THESE THREE ASSUMPTIONS WILL BE JUSTIFIED IN THIS CALCULATION BY USING BOTH ANALYTICAL MEANS AND TEST DATA.

III. CLIP MODELLING PROCEDURE

THE IMPELL MODELLING PROCEDURE IS SPECIFIED IN REF [1]. THE ELEMENTS USED IN MODELLING THE CLIP CONNECTION ARE SHOWN IN FIGURE 1 (p. 8). THE LINEAR ELASTIC STIFFNESSES FOR THESE ELEMENTS ARE SHOWN IN FIGURE 2 (p. 9). BOTH FIGURES ARE REPRODUCED FROM REF [1]. LINEAR ELEMENTS HAVE BEEN USED IN ALL MODELLING.

TRAY CLIP MODELLING



NOTES:

1. Flexible element No. 1 transmits the vertical force from the tray to the support.
2. Flexible element No. 2 transmits all other forces and moments.
3. Rigid link No. 1 is the eccentricity as defined in 3.2.4.
4. Rigid link No. 2 is the distance through the support steel member to its C.G.
5. Cantilever supports shall use the same clip modelling as is done for tiers shown above.

FIGURE 1: (from REF [1])

FIGURE 2 : (from REF [1])

CABLE TRAY CLIP STIFFNESSES

W = WIDTH OF CABLE TRAY   H = HEIGHT OF SIDERAIL

CLIP TYPE	Cable Tray Size	Translational Stiffness-K/IN Kx	Ky	Kz	Rotational Stiffness Kxx	Kyy	K-IN/RAD Kzz
Transverse Clips	36 x 6	3.60	69.3	653.0	770.0	1.2E4	22.4
	30 x 6				660.0	1.1E4	
	24 x 6				563.0	9.9E3	
	18 x 6				472.0	776.0	
	36 x 4	5.40	73.2		5.6E3	3.5E4	
	30 x 4				5.2E3	3.3E4	
	24 x 4				871.0	3.1E4	
	18 x 4				679.0	913.0	
	12 x 4				507.0	640.0	
	6 x 4				360.0	411.0	
Longitudinal Clips	W x H	580.0	150.0	7.1E3	1.5E5	4.7E5	804.0

LOCAL AXES : x = TRAY VERTICAL
y = TRAY LONGITUDINAL
z = TRAY TRANSVERSE

CLIP MODELLING JUSTIFICATION

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JOB NO 0210-041
CALC NO M-28

IV. JUSTIFICATION OF MODELLING PROCEDURES THROUGH ANALYTICAL COMPARISONS

A. LONGITUDINAL RESTRAINT PROVIDED BY FRICTION AT "TRANSVERSE" CLIPS

FOR STRUCTURES UTILIZING FRICTION-TYPE CONNECTIONS, GENERALLY BOLTED OR CLAMPED, THERE ARE THREE POTENTIAL SEISMIC BEHAVIOR SCENARIOS FOR CONNECTIONS — A FREELY SLIDING (SLIP) SCENARIO, AN ALTERNATING "STICK/SLIP" SCENARIO, OR A CONSTANT DISPLACEMENT/ROTATION COMPATIBILITY SCENARIO. THE POTENTIAL FOR THESE SCENARIOS DEPENDS ON THE RESISTANCE OF THE CONNECTIONS TO SLIP DURING THE OSCILLATORY MOTIONS INDUCED BY THE EARTHQUAKE.

AS DISCUSSED IN SECTION II, THE CABLE TRAY HANGERS AT CPSES USE "TRANSVERSE" TYPE CLIPS WHICH ARE INTENDED TO PROVIDE A FRICTION-TYPE CONNECTION BETWEEN THE TRAYS AND THE HANGERS. AS APPLIED TO THE CABLE TRAY SYSTEMS THE THREE SEISMIC BEHAVIOR SCENARIOS INTRODUCED ABOVE ARE:

1.) FRICTIONAL FORCES PARALLEL TO THE LONGITUDINAL TRAY AXIS ARE NOT DEVELOPED IN THE TRAY/HANGER CONNECTION. THIS COULD BE DUE TO LARGE INSTALLED GAPS IN THE CLIP ASSEMBLY WHICH PREVENTS THE GENERATION OF FORCES NORMAL TO THE TRAY. CONSEQUENTLY, HANGER

					CLIP MODELLING JUSTIFICATION	
					JOB NO 0210-041	PAGE 10
0	RPR	9/2/86	G.T.	9/2/86	IMPELL CORPORATION CALC NO M-28	OF 54
REV	BY	DATE	CHECKED	DATE		

SEISMIC RESPONSE IS UNAFFECTED BY TRAY INTERACTION AND IS SOLELY A RESULT OF THE HANGER'S OWN INERTIA.

2. FRICTIONAL FORCES PARALLEL TO THE TRAY LONGITUDINAL AXIS MAY DEVELOP, BUT ARE A TIME VARYING FUNCTION OF THE NORMAL FORCE AND THE STATIC AND SLIDING FRICTIONAL COEFFICIENTS. FOR CERTAIN TIME INTERVALS THESE FORCES MAY NOT EXIST. THIS INDICATES THAT HANGER DISPLACEMENTS PARALLEL TO THE TRAY AXIS ARE LIMITED, RELATIVE TO SCENARIO 1, AND THAT THE HANGER RESPONSE PERIOD MAY AT CERTAIN INTERVALS RESEMBLE THAT OF SCENARIO 1.

3. SUFFICIENT FRICTIONAL FORCES PARALLEL TO THE TRAY LONGITUDINAL AXIS ARE DEVELOPED IN THE TRAY / HANGER CONNECTION SUCH THAT THERE IS ESSENTIALLY NO RELATIVE MOVEMENT BETWEEN THE TRAY AND THE HANGER. THE CONNECTION BEHAVIOR IS PREDICTABLE AND EXHIBITS ESSENTIALLY LINEAR RESPONSE. THE OVERALL SEISMIC RESPONSE OF THE HANGER IS CONTROLLED BY SIGNIFICANT HANGER AND TRAY INTERACTION.

AS WILL BE DISCUSSED IN SECTION V TESTING HAS SHOWN THAT SCENARIO 3 REPRESENTS THE ACTUAL FRICTION CLIP BEHAVIOR FOR THE CABLE TRAY SYSTEMS

					CLIP MODELLING JUSTIFICATION	
					IMPELL CORPORATION	JOB NO 0210-041 / CALC NO M-28 / PAGE 11 OF 59
2	RTK	8/15/86	GR	8/27/86		
REV	BY	DATE	CHECKED	DATE		

AT CPSES. THESE RESULTS INDICATE THAT THIS IS THE ONLY TYPE OF BEHAVIOR WHICH WOULD REQUIRE CONSIDERATION IN DESIGN VERIFICATION. IT WILL NEVERTHELESS BE SHOWN ANALYTICALLY THAT GIVEN THE SAME POTENTIAL FOR ANY OF THE THREE SCENARIOS, SCENARIO 3 ALSO REPRESENTS THE LIMITING CASE WHICH MUST BE CONSIDERED FOR DESIGN VERIFICATION.

TOTAL HORIZONTAL CLEARANCE = a + b ≤ 3/8"

TOTAL VERTICAL CLEARANCE = c + d ≤ 3/8"

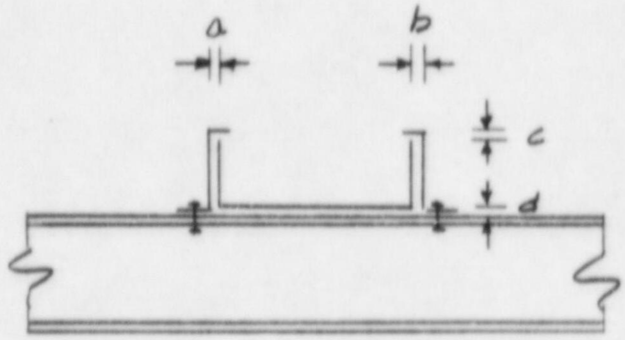

FIGURE 3 TYPICAL PERMISSIBLE GAPS FOR CLIP INSTALLATION (REF [4]).

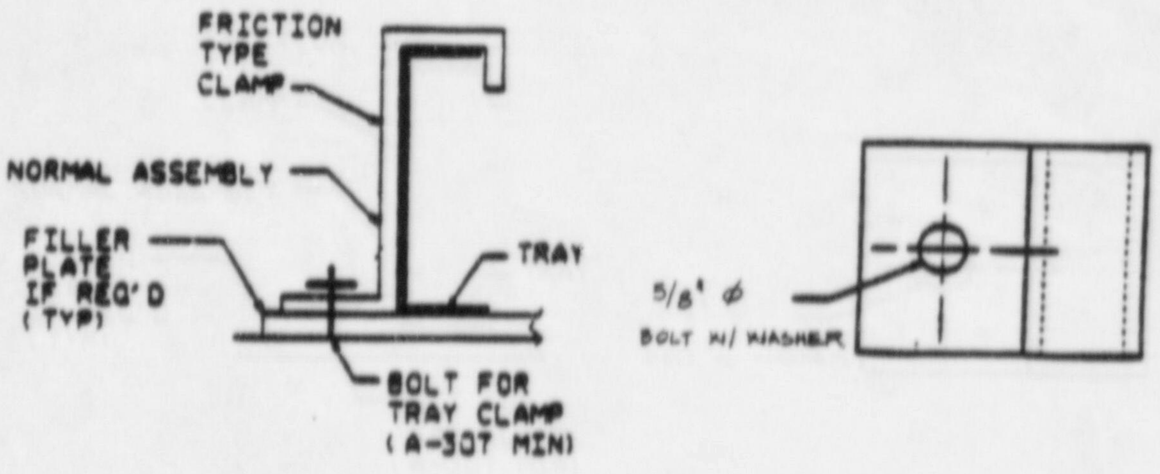

FIGURE 4 TYPICAL TRANSVERSE CLIP (REF [1])

REV	BY	DATE	CHECKED	DATE	CLIP MODELING JUSTIFICATION		
0	RMC	7/25/86	GR	7/28/8?	IMPELL CORPORATION	JOB NO 0216-041 / CALC NO M-28	PAGE 13 OF 69

THE POSSIBILITY OF A SUPPORT EXCEEDING FSAR STRESS ALLOWABLES WHEN RELEASED FROM THE CABLE TRAY (SCENARIO 1) IS ASSESSED BY CONSIDERING THE CPSES ENVELOPED HORIZONTAL SSE SPECTRUM @ 7% DAMPING (FROM REF [9]). THE SPECTRUM IS INCLUDED IN ATTACHMENT A. THIS SPECTRUM ENVELOPES ALL BUILDINGS AT CPSES AND INCLUDES THE WORST CASE EFFECTS OF THE RANGE OF SOIL PROPERTIES — I.E "LOWER BOUND", "BEST GUESS", AND "UPPER BOUND."

MAXIMUM RESULTING DISPLACEMENTS ARE ESTIMATED USING THE FOLLOWING FORMULA:

$$\Delta = \frac{(a)(MPF)(\phi)}{\omega^2} = \frac{(a)(MPF)(\phi)}{4\pi^2 f^2}$$

WHERE:

a = spectral acceleration
ϕ = modal amplitude
ω = fundamental frequency (RAD/S)
f = fundamental frequency (Hz)
MPF = modal mass participation

					CLIP MODELLING JUSTIFICATION
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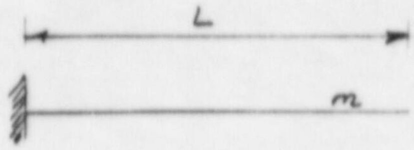
REV	BY	DATE	CHECKED	DATE	



FOR CANTILEVER:

$$MPF = \frac{\int_0^L \phi \, dx}{\int_0^L \phi^2 \, dx} = \frac{2\sigma L}{\lambda_i}\left(\frac{1}{L}\right) = \frac{2\sigma}{\lambda}$$

FROM REF [16], p. 108;

FOR FIRST MODE $(i=1)$ $\sigma = 0.7341$
$\lambda = 1.8751$

$$\Rightarrow MPF = 0.783$$

FROM REF [16], p. 119;

$\phi = 2.0$ AT CANTILEVER TIP

$$\therefore \quad \Delta = \frac{(a)(MPF)(\phi)}{4\pi^2 (f)^2}$$

$$= \frac{1.566\,(a)}{4\pi^2 (f)^2}$$

THE QUANTITIES ϕ AND MPF ARE CALCULATED ASSUMING A CANTILEVER BEAM OF UNIFORM MASS. A SUPPLEMENTAL FINITE ELEMENT CALCULATION IS DONE LATER TO VERIFY THAT THE SIMPLIFIED FORMULA WILL ALSO GIVE REASONABLE ESTIMATES FOR TRAPEZES, WHERE THE OUT-OF-PLANE MOMENT IS RESISTED BY CANTILEVER TYPE BENDING OF THE POSTS AND THE UNIFORM MASS OF THE POST IS INCREASED TO ACCOUNT FOR THE MASS EFFECTS OF THE TIERS.

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					SLIP MODELLING JUSTIFICATION		
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TABLE 1 : MAXIMUM DISPLACEMENTS UNDER ENVELOPED PLANT SPECTRA
OBE 4% DAMPING SPECTRUM
SSE 7% DAMPING SPECTRUM

← ENVELOPED OBE SPECTRA →			← ENVELOPED SSE SPECTRA →		
f (Hz)	accel (g)	Δ (in)	f (Hz)	accel (g)	Δ (in)
1.0	0.15	2.30	1.0	0.20	3.07
1.5	0.32	2.18	1.5	0.40	2.72
2.0	0.52	1.99	2.0	0.70	2.68
2.4	0.72	1.92	2.4	1.00	2.66
3.0	0.72	1.23	3.0	1.00	1.70
3.3	0.72	1.01	3.4	1.00	1.33
4.0	1.10	1.05	4.0	1.60	1.53
4.4	1.45	1.15	4.4	2.35	1.86
5.0	1.90	1.16	5.0	2.35	1.44
5.4	2.30	1.21	5.4	2.80	1.47
5.8	2.80	1.28	5.8	3.00	1.36
6.0	3.00	1.28	6.2	3.00	1.19
6.5	3.00	1.09	6.6	3.00	1.06
7.0	3.00	0.94	7.0	2.75	0.86
7.5	2.80	0.63	7.5	2.75	0.75
8.0	2.80	0.55	8.0	2.75	0.66
8.5	2.80	0.49	8.5	2.75	0.58
9.0	2.80	0.44	9.0	2.75	0.52
10.0	2.60	0.35	10.0	2.30	0.35
12.0	1.80	0.16	12.0	1.85	0.20
13.5	1.10	0.09	14.0	1.65	0.13
16.0	1.10	0.07	16.0	1.40	0.08
18.0	0.95	0.04	18.0	1.26	0.06
20.0	0.88	0.03	20.0	1.15	0.05
30.0	0.60	0.01	30.0	0.75	0.02

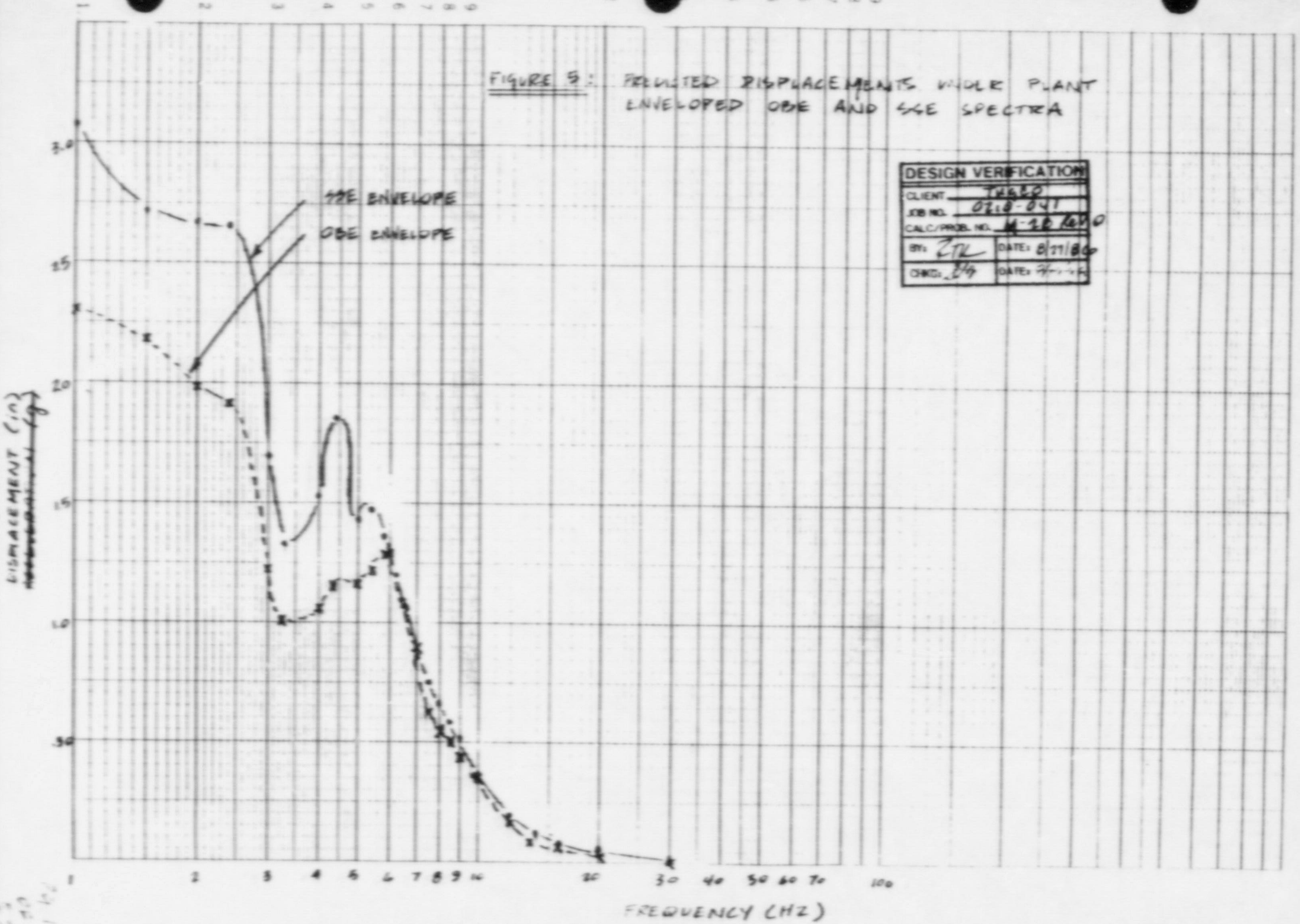

FIGURE 5: PREDICTED DISPLACEMENTS WHOLE PLANT ENVELOPED OBE AND SSE SPECTRA

THE COMPLETE RELEASE OF A TRANSVERSE SUPPORT IN THE LONGITUDINAL DIRECTION REQUIRES THE ABSENCE OF ANY SIGNIFICANT TRAY LOAD IN THE TRANSVERSE OR VERTICAL DIRECTION WHICH MAY PROVIDE FRICTIONAL RESTRAINT. THEREFORE THE LONGITUDINAL, OR OUT OF PLANE MOMENT, IS THE ONLY LOAD GENERATING SIGNIFICANT STRESSES IN THE MEMBER.

THE TRANSVERSE SUPPORTS TYPICALLY RESIST LONGITUDINAL LOAD BY WEAK AXIS BENDING OF POSTS (FOR TRAPEZE-TYPE SUPPORTS) OR CANTILEVERS. THE LONGITUDINAL DISPLACEMENT REQUIRED TO EXCEED FSAR ALLOWABLES IS CALCULATED BELOW. NOTE THAT CPSES FSAR LOAD FACTORS OF 1.0 (FOR OBE) AND 1.6 (FOR SSE) ARE APPLIED.

THE POSTS ARE ASSUMED TO BE C6x8.2 CHANNELS, THE SMALLEST MEMBERS TYPICALLY USED FOR TRAPEZE POSTS.

$$\Delta = PL^3/3EI$$

$$\sigma_{allow} = M/S = PL/S$$

$$\therefore \Delta = (S)(\sigma_{allow})(L^2)/(3)(E)(I)$$

WHERE: $E = 29 \times 10^3$ ksi
$I = 0.693 \ in^4$
$S = 0.492 \ in^3$

$\sigma_{allow} = 0.6 \times 36 \times 1.0 = 21.6$ ksi
$0.6 \times 36 \times 1.6 = 34.6$ ksi

FOR OBE: $\Delta = 0.1763 \times 10^{-3} (L)^2$
FOR SSE: $\Delta = 0.2824 \times 10^{-3} (L)^2$

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REV	BY	DATE	CHECKED	DATE	

DISPLACEMENT REQUIRED FOR STRESSES TO EXCEED FSAR ALLOWABLES :

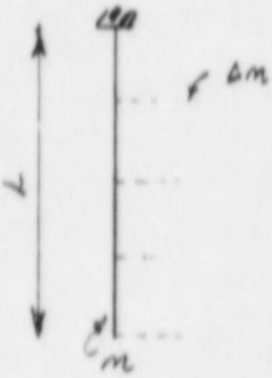
LENGTH	Δ_{OBE}	Δ_{SSE}
4' = 48"	0.41"	0.65"
5' = 60"	0.63	1.02
6' = 72"	0.91	1.46
7' = 84"	1.24	1.99
8' = 96"	1.62	2.60
9' = 108"	2.06	3.29
10' = 120"	2.54	4.07
12' = 144"	3.66	5.86
15' = 180"	5.71	9.15
18' = [illegible]"	8.23	13.18

USING FIGURE 5, IT IS FOUND THAT SUPPORTS LONGER THAN 9' CANNOT GENERATE DISPLACEMENTS HIGH ENOUGH TO EXCEED FSAR ALLOWABLE STRESSES REGARDLESS OF FREQUENCY. ALTHOUGH ONLY OUT-OF-PLANE LOADING IS CONSIDERED, IT WILL BE SHOWN LATER IN THIS CALCULATION (SEE TABLE II, p. 27) THAT IF SUPPORTS OF THIS LENGTH ARE RELEASED STRESSES DUE TO IN-PLANE RESPONSE ARE VERY SMALL.

THE ACTUAL OUT-OF-PLANE FREQUENCY FOR SUPPORTS IN THIS LENGTH RANGE CAN BE ESTIMATED BY TEXTBOOK FORMULAS. A TYPICAL TRAPEZE CONFIGURATION IS DEFINED AS FOLLOWS :

POST C6×8.2
TIER C4×7.25

THE TRAPEZE IS ASSUMED TO HAVE A MAXIMUM NUMBER OF TIERS AT 16" INTERVALS, THE MOST COMMON SPACING. THE MAXIMUM WIDTH OF A TYPICAL CPSES TRAPEZE IS APPROXIMATELY 5'. FOR PURPOSES OF ESTIMATING THE FUNDAMENTAL OUT-OF-PLANE FREQUENCY, THE POST IS IDEALIZED AS A SIMPLE CANTILEVER WITH THE TIER MASS UNIFORMLY DISTRIBUTED OVER THE 16" INTERVAL —



$$m_{post} = \frac{8.2}{12 \times 386.4} = 0.0018$$

$$m_{tier} = \frac{7.25 \times 5 \times 0.5}{12 \times 1.33 \times 386.4} = 0.0029$$

$$m_{total} = 0.0047 \ lb \cdot s^2/in^2$$

REF [16], p. 108 : $f = \frac{\lambda_1^2}{2\pi L^2} \left(\frac{EI}{m} \right)^{1/2}$

$\lambda = 1.8751$
$E = 29 \times 10^6$ psi
$I = 0.693$ in^4
$m = 0.0047$ lb·s^2/in^2

∴ FOR THE FUNDAMENTAL OUT-OF-PLANE FREQUENCY —

$$f = \frac{36592}{L^2}$$

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OVERLAP VERIFICATION

IMPELL CORPORATION

JOB NO 0210-071

CALC NO M-28

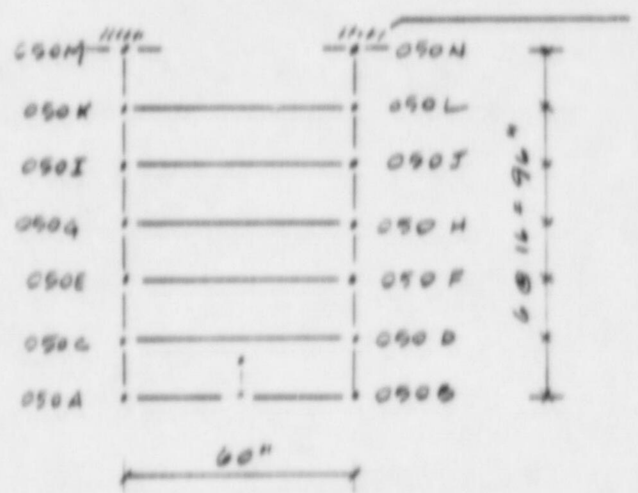
PAGE 20 OF 69

FOR EACH LENGTH BELOW 9', THE ESTIMATED FUNDAMENTAL OUT-OF-PLANE FREQUENCY IS SHOWN BELOW. USING FIGURE 5, THE ACTUAL OUT-OF-PLANE DISPLACEMENT IS DETERMINED FOR BOTH OBE AND SSE EVENTS. THIS IS COMPARED TO THE DISPLACEMENT REQUIRED TO EXCEED FSAR ALLOWABLES. TO ACCOUNT FOR POSSIBLE INCREASES IN FREQUENCY (SUCH AS FOR SUPPORTS HAVING LESS THAN THE MAXIMUM NUMBER OF TIERS), THE MAXIMUM DISPLACEMENT FOR ALL FREQUENCIES GREATER OR EQUAL TO THE CALCULATED FREQUENCY IS PRESENTED.

		← ACTUAL	→	← ALLOWABLE	→	
LENGTH	FREQ (Hz)	Δ_{OBE}	Δ_{SSE}	Δ_{OBE}	Δ_{SSE}	
4' (48")	15.9	0.07	0.09	0.41	0.65	OK
5' (60")	10.2	0.34	0.34	0.63	1.02	OK
6' (72")	7.1	0.83	0.84	0.91	1.46	OK
7' (84")	5.2	1.28	1.46	1.24	1.99	N.G
8' (96")	4.0	1.28	1.86	1.62	2.60	OK
9' (108")	3.1	1.28	1.86	2.06	3.29	OK

FOR THE 7' (84") SUPPORT LENGTH, THE OBE DISPLACEMENT EXCEEDS FSAR ALLOWABLES BY A VERY SMALL MARGIN (APPROXIMATELY 3%). FOR ALL OTHER CASES, RELEASED SUPPORT BEHAVIOR (SCENARIO 1) WILL NOT RESULT IN MEMBER DISQUALIFICATION.

THE ACCURACY OF THE SIMPLIFIED ESTIMATE OF FREQUENCY AND DISPLACEMENT IS VERIFIED BY CHOOSING THE L=96" TRAPEZE SUPPORT AND PERFORMING A RIGOROUS SUPERPIPE ANALYSIS FOR THE ENVELOPED SSE SPECTRUM. DISPLACEMENT IS CALCULATED USING NRC R.G. 1.92 MODE-GROUPING TO A CUT-OFF FREQUENCY OF 33 Hz. THE SUPERPIPE OUTPUT IS DOCUMENTED IN REF [1.9]. THE SUPPORT IS ASSUMED TO HAVE A MAXIMUM NUMBER OF TIERS TO MINIMIZE THE OUT OF PLANE FREQUENCY.



POSTS C6×8.2
TIERS C4×7.25

$f = 3.6$ Hz

$\delta_{MAX} = 1.32$ in.

THE ANALYTICALLY PREDICTED FREQUENCY (3.6 Hz), IS APPROXIMATELY 10% BELOW THE FREQUENCY ESTIMATED BY THE SIMPLIFIED METHOD (4.0 Hz). HOWEVER, THE ANALYTICALLY PREDICTED DISPLACEMENT (1.32 in) IS CONSERVATIVELY LESS THAN THAT WHICH IS ESTIMATED BY THE FORMULA ON p. 15 (1.43 in). THE SIMPLIFIED METHOD THEREFORE GIVES REASONABLY ACCURATE RESULTS.

THIS VERIFICATION CONFIRMS THE CONCLUSION THAT THE RELEASED SUPPORT CASE (SCENARIO 1) WILL ONLY APPROACH FSAR ALLOWABLES FOR A SMALL FREQUENCY RANGE, AND FSAR ALLOWABLE STRESSES WILL POTENTIALLY BE EXCEEDED BY ONLY A FEW PERCENT.

A COMPARISON OF SCENARIOS 1 AND 3 IS PERFORMED USING LINEAR ELASTIC ANALYSES WITH THE IMPELL PROGRAM SUPERPIPE (REF [2]). THE ANALYTICAL MODEL STUDIED IS SHOWN IN FIGURE 6 (P. 26). THE MODEL USED IS A TYPICAL CONFIGURATION OF A STRAIGHT CROSS CABLE TRAY RUN. ALTHOUGH THE ANALYSIS OF A SINGLE REPRESENTATIVE CASE IS NOT CONCLUSIVE FOR ALL MODELS, THE ANALYSIS YIELDS TRENDS WHICH ARE INDICATIVE OF GENERAL SYSTEM BEHAVIOR. ALL PROPERTIES AND PROCEDURES USED IN MODELLING ARE PER REF [1].

TRAY: THE TRAY IS CYPRUS CAT. NO. 9924[illegible], A 24x4x1/4 LADDER TYPE TRAY WITHOUT THERMOLAG.

CLIPS: BOTH "TRANSVERSE" AND "LONGITUDINAL" TYPE CLIPS ARE MODELLED, PER REF [1].

SUPPORTS: LONGITUDINAL —

LONGITUDINAL SUPPORTS ARE MODELLED AS ANCHORAGE NODES AT THE BASE OF THE LONGITUDINAL CLIPS. THE FOLLOWING UPPER AND LOWER BOUNDS ARE CALCULATED FOR LONGITUDINAL SUPPORT STIFFNESS:

$K_{long} = 31$ K/IN (LOWER BOUND)
$K_{long} = \infty$ (UPPER BOUND)

THE SYSTEM IS ANALYZED WITH BOTH UPPER AND LOWER BOUND LONGITUDINAL STIFFNESSES. THE LOWER BOUND STIFFNESS IS CALCULATED USING A REPRESENTATIVE TYPE OF LONGITUDINAL SUPPORT - A BRACED TRAPEZE - WHERE THE TRAY TIER IS 3' BELOW THE LONGITUDINAL BRACING MEMBER.

					CLIP MODELLING JUSTIFICATION	
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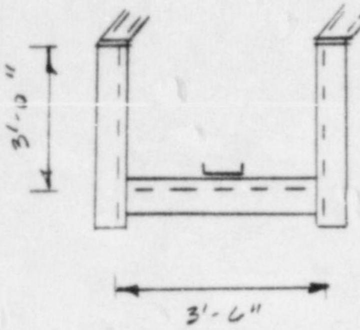
REV	BY	DATE	CHECKED	DATE		PAGE 23 OF 69



LONGITUDINAL BRACING ASSUMED TO PROVIDE RIGID RESTRAINT

$$K_{long} = \frac{1}{\dfrac{H^3}{2(3EI_{post})} + \dfrac{W^3}{48EI_{tier}}} = 31\ K/IN.$$

POST C6x8.2
TIER C4x7.25

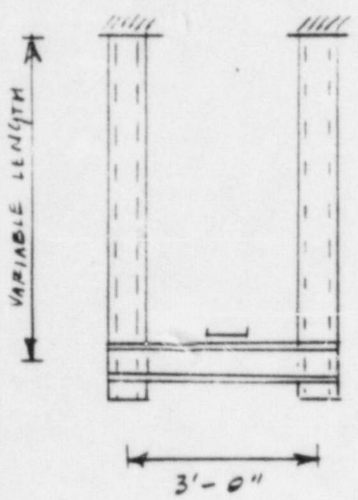
$E = 29 \times 10^3\ K/IN^2$
$H = 36\ IN$
$W = 42\ IN$
$I_{post} = 13.1\ IN^4$
$I_{tier} = 4.59\ IN^4$

SUPPORTS : TRANSVERSE —

A TRAPEZE HANGER IS CHOSEN AS A REPRESENTATIVE TRAPEZE SUPPORT. THE LENGTH OF THE SUPPORT IS VARIED TO STUDY THE EFFECTS OF CHANGING SUPPORT MASS AND STIFFNESS. CORRESPONDINGLY, THE SUPPORT FREQUENCIES FOR THE RELEASED CASE WILL BE VARIED.

THE FOLLOWING LENGTHS ARE ANALYZED :

$L = 3', 6', 8', 12', 18'$



POST C6x8.2
TIER C4x7.25

					CLIP MODELLING JUSTIFICATION
2	RTK	7/9/86	JR	7/ /86	IMPELL CORPORATION — JOB NO C210-C41 — CALC NO M-28 — PAGE 24 OF 34
REV	BY	DATE	CHECKED	DATE	

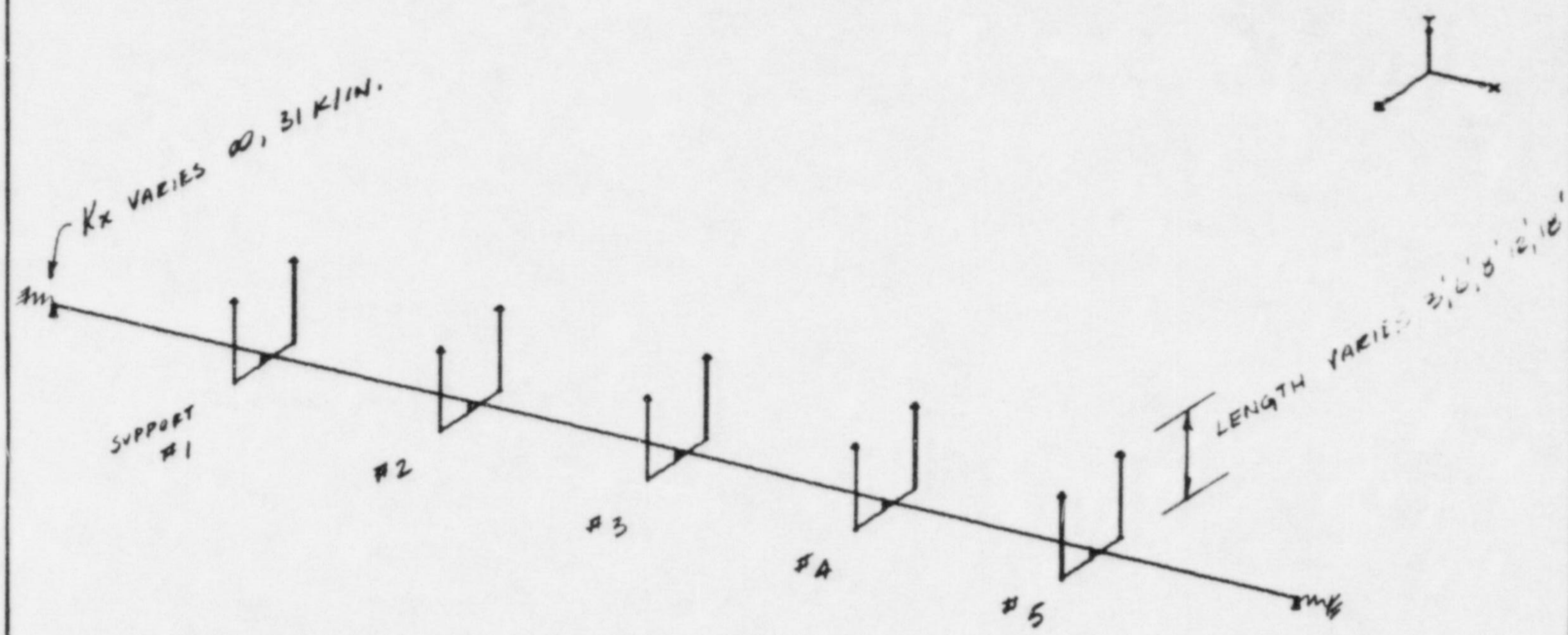
LOADING : A REPRESENTATIVE CPSES RESPONSE SPECTRA LOADING IS USED (REF [25]) USE 4% DAMPING SAFEGUARDS BUILDING ELEV 852' FOR THE THREE ORTHOGONAL DIRECTIONS.

A PLOT OF THIS SPECTRA IS INCLUDED IN THIS CALCULATION AS ATTACHMENT "B".

ANALYSES : SCENARIO I, FREE SWINGING MOTION OF THE TRANSVERSE SUPPORT; IS ANALYZED IN FIVE SEPERATE CASES FOR THE VARYING SUPPORT LENGTHS. THE LENGTH OF THE TRANSVERSE SUPPORTS IS VARIED SIMULTANEOUSLY FOR EACH SUPPORT IN THE MODEL. THE CENTRAL SUPPORT IN EACH MODEL IS DETACHED FROM THE CABLE TRAY TO ANALYZE FREE SWINGING MOTION.

: A TOTAL OF TEN SEPERATE ANALYSES ARE USED TO EXAMINE SCENARIO 3 (CONSTANT FRICTIONAL RESTRAINT MODELLED BY AN ELASTIC STIFFNESS). EACH COMBINATION OF TRANSVERSE SUPPORT LENGTH (L=3', 6', 9', 12', 15') AND LONGITUDINAL STIFFNESS (K=3K/IN, ∞) IS ANALYZED. AGAIN, EACH LENGTH AND STIFFNESS IS VARIED SIMULTANEOUSLY.

: RESULTS FROM THE ANALYSES OF SCENARIOS 1 AND 3 ARE COMPARED TO DRAW CONCLUSIONS REGARDING THE CRITICAL LOAD CASE. COMPARISONS ARE MADE FOR ALL ANCHORAGE REACTIONS AT THE CENTRAL TRANSVERSE SUPPORT (SUPPORT #3); THE LONGITUDINAL REACTION AT THE END LONGITUDINAL SUPPORT; AND THE FUNDAMENTAL FREQUENCY FOR OUT OF-PLANE UNRESTRAINED MOTION FOR THE TRANSVERSE TRAPEZES.



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CHKG: JCR	DATE: 7/10/86

FIGURE 6: SUPERPIPE GEOMETRY PLOT

TABLE II : ANCHORAGE REACTION COMPARISON FOR CENTRAL TRANSVERSE SUPPORT

	3'-0" LONG			[illegible]'-0" LONG			8'-0" LONG			12'-0" LONG			1[illegible]'-0" LONG		
GLOBAL DIRECTION	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Fx (kip)	.01	.05	.01	.01	.02	.06	.02	.02	.06	.05	.04	.03	.10	.09	.05
Fy	.72	.72	.02	.84	.84	.04	1.52	1.51	.06	1.88	1.88	.14	[illegible]	1.23	.51
Fz	.26	.26	.01	.34	.34	.02	.70	.70	.03	.56	.56	.06	.22	.22	.15
Mx (in.kip)	4.25	4.25	.21	14.51	14.51	.66	38.75	38.75	1.09	44.69	44.17	3.88	24.34	24.34	15.39
My	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Mz	.36	1.76	.36	.24	.07	3.69	.51	.71	4.53	1.66	1.75	2.00	5.21	4.44	3.25
σNORMAL (ksi)	2.00	4.85	.79	4.15	5.47	7.67	10.52	10.92	9.48	14.36	14.54	6.23	16.66	16.22	10.33
	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]	REF [illegible]

$$\sigma_{NORMAL} = \frac{F_y}{A} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

WHERE FOR C6x8.2 : $A = 2.40\ in^2$; $S_x = 4.38\ in^3$; $S_z = 0.492\ in^3$

LOAD CASES :
a. NON-RELEASED CLIPS ; $K_{long'l} = \infty$
b. —— " —— CLIPS ; $K_{long'l} = 31$ k/in
c. RELEASED CLIPS ; FREE SUPPORT MOTION AT SUPPORT 3

REV	BY	DATE	CHECKED	DATE
0	[illegible]	8/22/86	[illegible]	8/26/86

IMPELL CORPORATION

CLIP MODELLING JUSTIFICATION

JOB NO 0210-041
CALC NO M 28

TABLE III: LONGITUDINAL FORCE REACTION COMPARISON FOR END LONGITUDINAL SUPPORTS (IN KIPS)

TRANSVERSE SUPPORT LENGTH	LONGITUDINAL REACTION CENTRAL TRANSVERSE SUPPORT RELEASED	LONGITUDINAL REACTION CENTRAL TRANSVERSE SUPPORT NOT RELEASED
3'-0"	0.67 *	0.67 *
6'-0"	1.37	1.38
8'-0"	1.42	1.45
12'-0"	1.46	1.54
18'-0"	1.34	1.37

* NOTE: ALL COMPARISONS ARE BASED ON A LONGITUDINAL STIFFNESS OF [illegible] K/IN EXCEPT FOR THE 3'-0" TRANSVERSE WHERE AN INFINITE LONGITUDINAL STIFFNESS IS ASSUMED FOR BOTH CASES.

REV	BY	DATE	CHECKED	DATE	
[illegible]	[illegible]	7/9/86	[illegible]	7/10/86	CLIP MODELLING JUSTIFICATION

IMPELL CORPORATION

JOB NO [illegible]-047

CALC NO M-28

PAGE 28 OF 59

TABLE IV: FUNDAMENTAL FREQUENCY COMPARISON FOR RELEASED TRANSVERSE SUPPORT

LENGTH	FREQUENCY (Hz)	SPECTRAL ACCELERATION (g's)
3'-0"	23.4	2.469
6'-0"	8.2	1.584
8'-0"	5.0	1.198
12'-0"	2.4	0.356
18'-0"	1.2	0.146

THE RESULTS FROM TABLE II SHOW THAT ALL SIGNIFICANT ANCHORAGE REACTIONS ARE BOUNDED BY THE NON-RELEASED CONFIGURATION (SCENARIO 3) EXCEPT FOR THE OUT OF PLANE MOMENT, M_z, IN INTERMEDIATE LENGTH SUPPORTS (L = 6', 8', 12'). THE STRESSES DUE TO OTHER REACTION COMPONENTS FOR THE RELEASED CONFIGURATION ARE VERY SMALL FOR THE INTERMEDIATE LENGTH SUPPORTS, THEREFORE WHEN A TOTAL NORMAL STRESS IS CALCULATED THE RELEASED CONFIGURATION YIELDS A HIGHER STRESS ONLY FOR THE POST OF A 6' TRAPEZE.

ALTHOUGH THE NORMAL STRESS FOR A 6' TRAPEZE IS HIGHER FOR THE RELEASED CONFIGURATION, THE STRESS LEVELS FOR SUPPORTS OF THIS LENGTH ARE SHOWN TO BE LOW (7.67 KSI). THIS AGREES WITH THE CONCLUSION REACHED EARLIER IN THIS SECTION THAT THE RELEASED CASE OF A FREELY SWINGING SUPPORT WILL ONLY APPROACH FSAR ALLOWABLES FOR A NARROW FREQUENCY RANGE UNDER PLANT ENVELOPED SPECTRA.

THE GENERAL BEHAVIORAL TRENDS SHOWN IN THIS STUDY ARE AS FOLLOWS:

FOR HANGERS WHICH ARE RELATIVELY SHORT (HIGH STIFFNESS, LOW MASS) THE SCENARIO OF FREELY SWINGING MOTION WILL NOT GENERATE SUFFICIENT STRESS TO CAUSE A CRITICAL LOADING WHEN COMPARED TO A NON-RELEASED CASE.

FOR HANGERS OF INTERMEDIATE LENGTH

(INTERMEDIATE STIFFNESS, INTERMEDIATE MASS) THE SCENARIO OF FREELY SWINGING MOTION MAY GENERATE HIGHER LOADS FOR OUT-OF-PLANE MOMENT THAN THE RESTRAINED SCENARIO. HOWEVER, STRESSES DUE TO OTHER LOADS WILL BE VERY SMALL AND THE OVERALL STRESS INTERACTION WILL BE AT (FOR PLANT ENVELOPE SPECTRA) OR BELOW FSAR ALLOWABLES.

FOR HANGERS OF VERY LONG LENGTH (LOW STIFFNESS, HIGH MASS) THE SCENARIO OF FREELY SWINGING MOTION WILL AGAIN NOT BE THE CRITICAL LOADING, BECAUSE OF VERY LOW SUPPORT FREQUENCIES, AS SHOWN IN TABLE II)

THE RESULTS FROM TABLE III SHOW THAT THE LONGITUDINAL LOAD PASSED ON TO THE END LONGITUDINAL SUPPORTS IS NOT GREATER FOR THE RELEASED CASE SCENARIO. THIS IS DUE TO THE MUCH HIGHER LONGITUDINAL STIFFNESS OF THE LONGITUDINAL SUPPORTS WHEN COMPARED TO THE TRANSVERSE SUPPORTS. FOR THE SHORT HANGERS (L=3') THE LONGITUDINAL LOAD AT THE END SUPPORTS IS IDENTICAL FOR THE TWO CASES. AS THE TRANSVERSE SUPPORT LENGTH IS INCREASED, THE NON RELEASED CASE IS SHOWN TO PRODUCE A HIGHER END LONGITUDINAL LOAD DUE TO THE ADDED MASS IN THE SYSTEM WHICH PARTICIPATES IN THE LONGITUDINAL DIRECTION.

IT IS THEREFORE CONCLUDED THAT THE RELEASED CONFIGURATION (SCENARIO 1) DOES NOT REQUIRE ANALYSIS.

SCENARIO 2 IS A NON-LINEAR RESPONSE OF A COMBINATION OF FREE SWINGING SUPPORT ACTION AND FRICTIONAL TRAY LOAD. TO BEGIN THE OUT OF-PLANE SUPPORT MOTION, THE FRICTIONAL RESTRAINT BETWEEN THE CLIP AND TRAY MUST BE OVERCOME. SINCE THE TRANSVERSE SUPPORTS ARE TYPICALLY VERY FLEXIBLE IN THE OUT-OF-PLANE DIRECTION, ONLY A SMALL RESTRAINING FORCE IS REQUIRED TO PREVENT FREE SWINGING. THIS FRICTIONAL RESTRAINT WILL ALMOST ALWAYS BE PROVIDED BY A NORMAL FORCE DUE TO TRAY DEAD WEIGHT, WHICH IS SELDOM OVERCOME BY DESIGN SEISMIC LOADS.

EVEN IF SLIPPAGE SHOULD OCCUR DURING A RESPONSE CYCLE, GRAVITY WOULD ACT AS A RESTORING FORCE ON THE HANGER TO RETURN IT TOWARD A PLUMB EQUILIBRIUM SHAPE. TESTS (REF [B]) PERFORMED ON SYSTEMS SUBJECT TO SEISMIC MOTION SHOW THAT A DEFORMED EQUILIBRIUM SHAPE ("RATCHETING") WILL NOT OCCUR IN THE PRESENCE OF SUCH A RESTORING FORCE. THEREFORE THE SUPPORT WILL NOT BE DRIFTING OR "WALKING" TO PROGRESSIVELY INCREASING DISPLACEMENTS THAT WOULD CAUSE A CRITICAL LOAD CASE WHICH COULD NOT BE ANALYZED BY LINEAR ELASTIC METHODS.

IT IS THEREFORE CONCLUDED THAT SCENARIO 3, USE OF A LINEAR ELASTIC STIFFNESS TO REPRESENT FRICTIONAL TRAY RESTRAINT, REPRESENTS THE ONLY LOAD CASE REQUIRING ANALYSIS FOR DESIGN VERIFICATION.

IV

B. MODELLING OF CLIPS AS ELASTIC STIFFNESSES RESTRAINING ALL SIX DEGREES OF FREEDOM

ELASTIC STIFFNESSES FOR EACH CLIP TYPE WERE GENERATED FROM FINITE ELEMENT MODELS IN REF [5]. STIFFNESS RANGES WERE THEN DEFINED BY GROUPING 'LONGITUDINAL-TYPE' AND 'TRANSVERSE-TYPE' CLIPS. 'TRANSVERSE-TYPE' CLIPS WERE THEN FURTHER GROUPED BY TRAY SIZE. FOR SYSTEM MODELLING, A SINGLE GENERIC STIFFNESS VALUE WAS CHOSEN WHICH WOULD TEND TO CONSERVATIVELY OVERPREDICT RESPONSE FOR TYPICAL CPSES CABLETRAY SYSTEMS. FOR EXAMPLE, VERTICAL TRAY RESPONSE IS TYPICALLY ON THE RIGID SIDE OF THE SPECTRAL PEAK DUE TO HIGH VERTICAL SUPPORT STIFFNESS. A LOWER BOUND VERTICAL CLIP STIFFNESS WAS THEREFORE CHOSEN TO LOWER THE VERTICAL TRAY FREQUENCIES TOWARD THE SPECTRAL PEAK.

A SECOND SOURCE OF CONSERVATISM IS INVOLVED IN USING AN ELASTIC STIFFNESS TO MODEL THE NON-LINEAR BEHAVIOR OF A CLIP WITH GAPS. THE TRUE RESPONSE OF THE GAPPED SYSTEM WOULD INCLUDE A FREELY SLIDING MOTION (IF THE FRICTIONAL RESISTING FORCE WERE EXCEEDED) UNTIL GAP CLOSURE FOLLOWED BY ELASTIC DEFORMATION OF THE CLIP. THE NON-LINEAR NATURE OF THE RESPONSE WOULD INCREASE THE EFFECTIVE DAMPING OF THE

SYSTEM TO VALUES ABOVE THOSE ASSUMED FOR ANALYSIS PURPOSES (IE 4% FOR OBE, 7% FOR SSE). ALTHOUGH THE LINEAR ELASTIC IMPELL CLIP MODELLING PROCEDURE CANNOT DUPLICATE THE ACTUAL NON-LINEAR RESPONSE BEHAVIOR, IT DOES PROVIDE A MEANS OF ENSURING A CONSERVATIVE SYSTEM DESIGN ON A PRODUCTION BASIS. NUMERICAL COMPARISONS BASED ON TEST DATA ARE PERFORMED IN SECTION I WHICH CONFIRM THESE CONSERVATISMS.

IV

c MODELLING OF CLIPS AS SINGLE ELEMENTS AT TRAY CENTERLINE

THE TRAY IS MODELLED AS A THREE DIMENSIONAL BEAM ELEMENT ALONG THE CENTERLINE. A SINGLE CLIP ELEMENT IS ACCORDINGLY MODELLED WITH THE STIFFNESS PROPERTIES OF THE CLIP PAIR. THIS CAN BE SHOWN TO BE CONSERVATIVE FOR BOTH STRESSES IN THE SUPPORT AND GLOBAL RESPONSE OF THE SYSTEM.

THE INFLUENCE DIAGRAMS ON THE FOLLOWING PAGES ILLUSTRATE THE MAXIMUM BENDING MOMENTS ON A SUPPORT TIER ASSUMING THE LOAD IS APPLIED IN THREE WAYS:

a. A SINGLE LOAD = 1.0 P OR A SINGLE MOMENT = 1.0 M AT TRAY ℄.

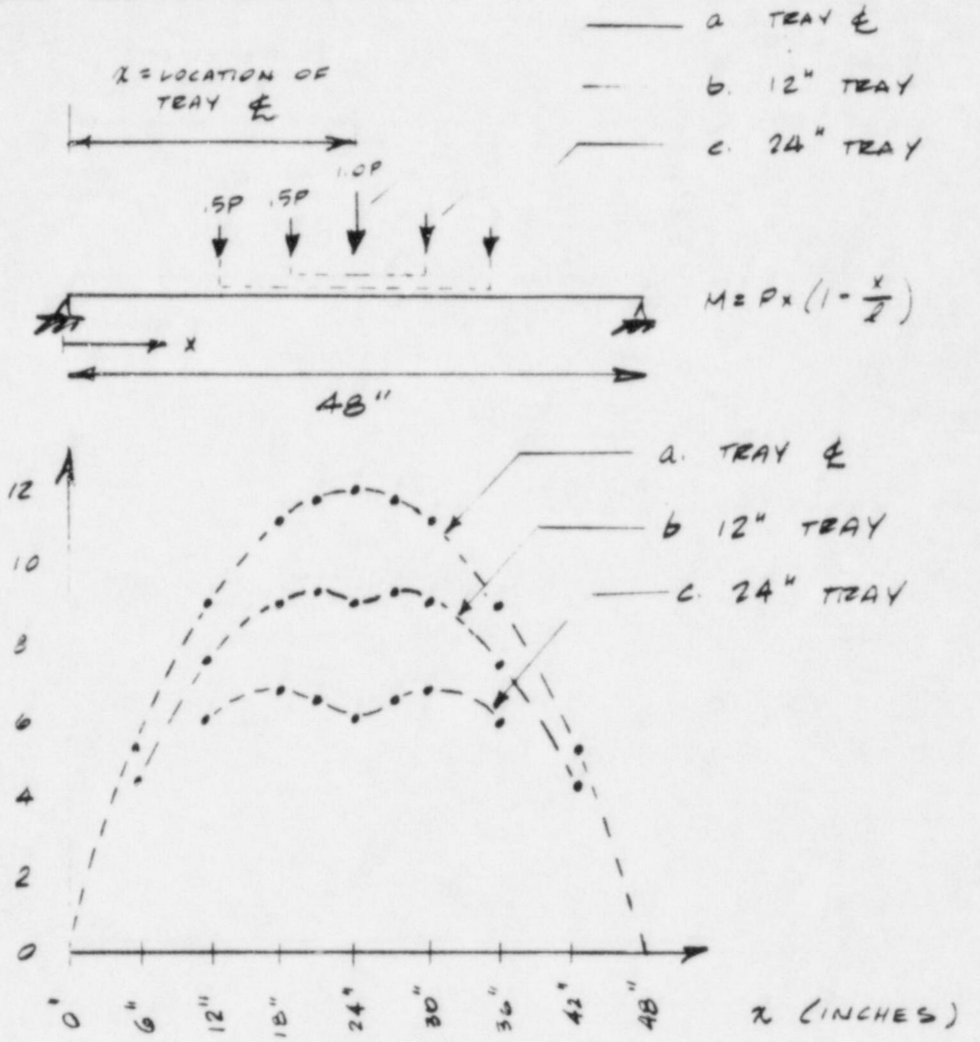
b. TWO EQUAL LOADS = 0.5 P SPACED 12" APART

c. TWO EQUAL LOADS = 0.5 P SPACED 24" APART

A TYPICAL CPSES HANGER TIER OF 48" WIDTH IS ASSUMED. THE TIER IS ASSUMED SIMPLY SUPPORTED, HOWEVER THE RELATIVE COMPARISONS WOULD BE VALID FOR VARIOUS DEGREES OF END FIXITY. THE INFLUENCE DIAGRAM ON p 36 ASSUMES LOADS OF IDENTICAL SIGN (A FORCE TRANSFER); THE INFLUENCE DIAGRAM ON p. 37 ASSUMES LOADS OF OPPOSITE SIGN (A MOMENT TRANSFER).

FIGURE 7

INFLUENCE DIAGRAM : FORCE TRANSFER

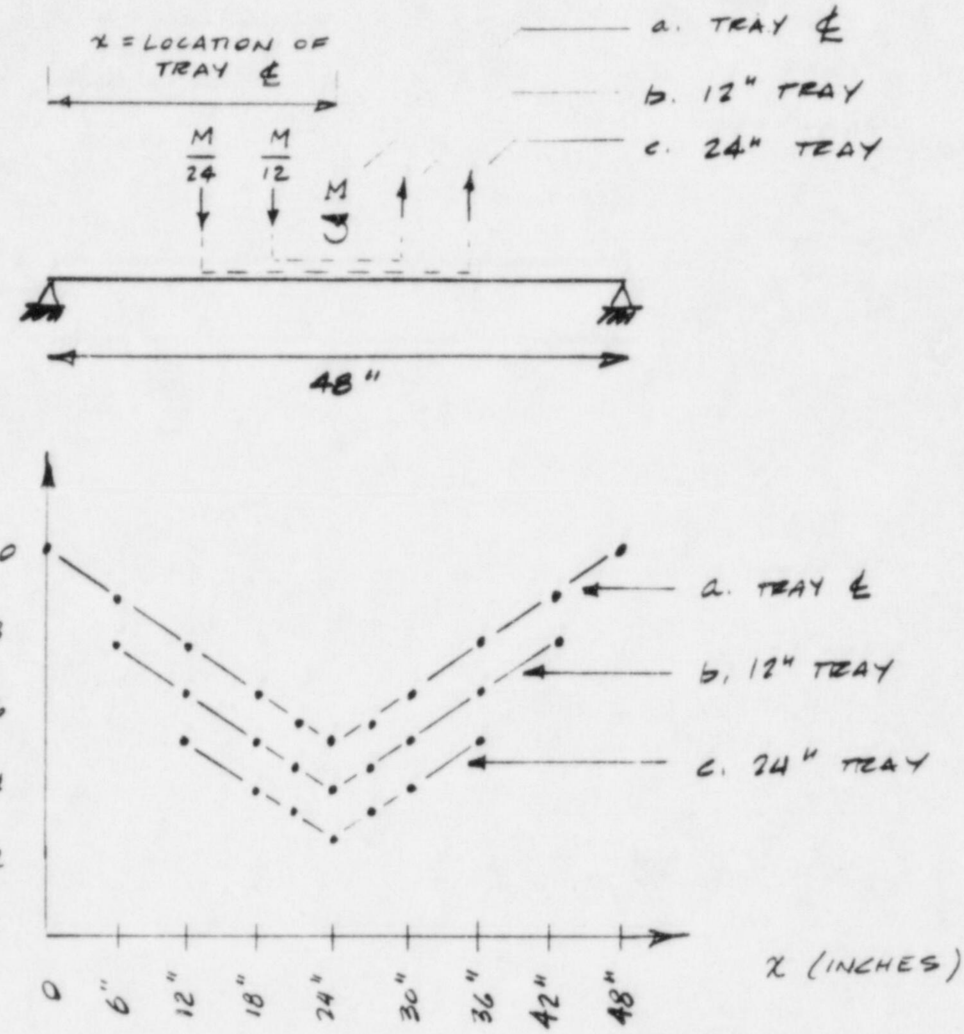


IT IS CLEAR FROM THE FIGURE ABOVE THAT THE MODELLING PROCEDURE ("a") MAXIMIZES TIER BENDING MOMENTS FOR A TRAY-TO-SUPPORT TRANSFER OF FORCE. THE CONSERVATISM IS GREATEST FOR WIDER TRAYS AND ALSO GREATEST FOR TRAYS LOCATED NEAR THE TIER CENTER. FOR EXAMPLE, THE BENDING MOMENT FOR A 24" TRAY AT THE TIER ℄ IS OVERPREDICTED BY A FACTOR OF 2.0.

				SLIP MODELLING JUSTIFICATION	
				IMPELL CORPORATION — JOB NO 0210-041	PAGE 36 OF 39
C	RTK	7/9/80	JLP	7/2/80	CALC NO M-23
REV	BY	DATE	CHECKED	DATE	

FIGURE 8:

INFLUENCE DIAGRAM : MOMENT TRANSFER

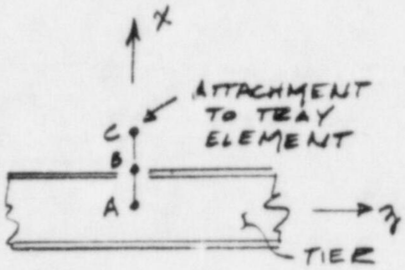


AGAIN MODELLING PROCEDURE ("a") MAXIMIZES TIER BENDING MOMENTS FOR A TRAY-TO-SUPPORT TRANSFER OF MOMENT. THE CONSERVATISM IS AGAIN GREATEST FOR TRAYS LOCATED NEAR THE TIER CENTER. FOR EXAMPLE, THE BENDING MOMENT FOR A 24" TRAY AT THE TIER ℄ IS OVERPREDICTED BY A FACTOR OF 2.0.

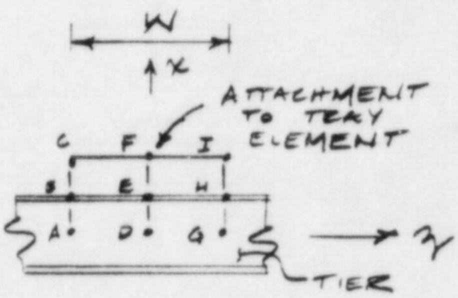
REV	BY	DATE	CHECKED	DATE	CLIP MODELLING JUSTIFICATION		
0	RTK	7/9/86	J.R.	7/6/82	IMPELL CORPORATION	JOB NO 0210-041	PAGE 37
						CALC NO M-23	OF 59

THE FIGURES ON THE PRECEDING PAGES SHOW THAT FOR IDENTICAL FORCES AND MOMENTS A WORST CASE STRESS DISTRIBUTION WILL ALWAYS BE GIVEN BY THE SINGLE CLIP MODEL.

THE EFFECTS OF DUAL CLIP MODELLING ON SYSTEM RESPONSE ARE EVALUATED BY ANALYZING A REPRESENTATIVE FULL SYSTEM MODEL. THE ANALYSIS MODEL FROM TEST CASE 7 (REF [7]) IS ANALYZED FOR BOTH THE SINGLE AND DUAL CLIP CONFIGURATIONS, AS SHOWN BELOW:



SINGLE CLIP



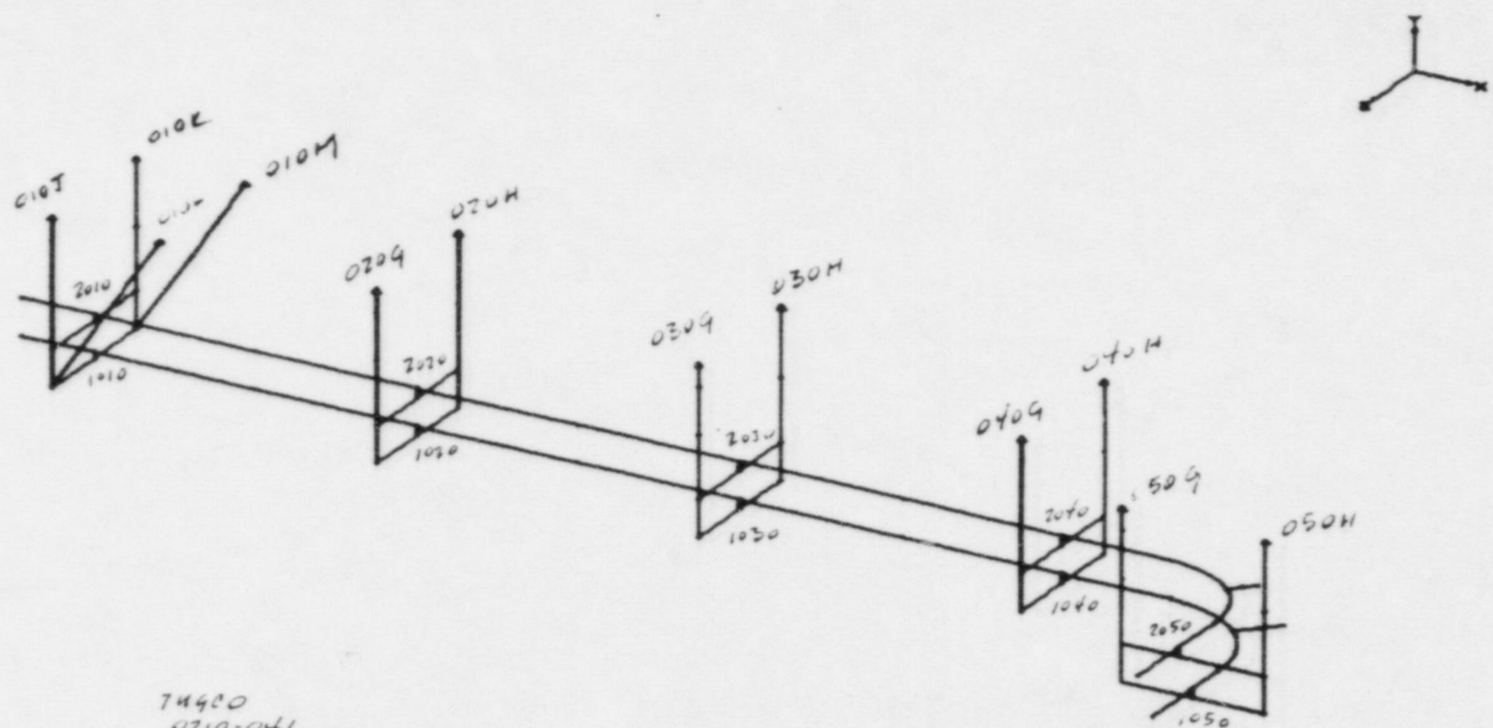
DUAL CLIP

IN THE SINGLE CLIP MODEL, THE CLIP ASSEMBLY IS MODELLED ALONG THE TRAY ℄. IN THE DUAL CLIP ASSEMBLY, A RIGID ELEMENT REPRESENTING THE TRAY WIDTH CONNECTS THE TWO SIDE CLIPS. THE FOLLOWING STIFFNESSES ARE USED:

SINGLE CLIP	DUAL CLIP
k_x	$1/2\ k_x$ (SIDE CLIPS)
k_y	$1/2\ k_y$ (SIDE CLIPS)
k_z	k_z (CENTRAL CLIP)
k_{xx}	0
k_{yy}	0
k_{zz}	$1/2\ k_{zz}$ (SIDE CLIPS)

STIFFNESSES AT CLIP PAIRS ARE REDUCED BY 1/2 SO THAT THE TOTAL STIFFNESS ACTING ON THE TRAY IS UNCHANGED. THE STIFFNESSES k_{xx}, k_{zz} ARE RELEASED SINCE THE ASSOCIATED MOMENTS WILL NOW BE GENERATED BY FORCE COUPLES ACROSS THE TRAY WIDTH. ANY SIGNIFICANT TRANSVERSE RESTRAINT F_z WILL BE GENERATED BY THE TRAY PUSHING AGAINST THE CLIP. FOR CYCLIC LOADING, THIS FORCE WILL ALTERNATELY BE PROVIDED BY THE TWO CLIPS. THE STIFFNESS k_z IS THEREFORE MODELLED AT THE CENTRAL CLIP TO GIVE THE CLOSEST LINEAR APPROXIMATION TO THE ACTUAL NON LINEAR BEHAVIOR.

FIGURES 9 AND 10 ON THE FOLLOWING PAGES ILLUSTRATE PLOTS OF THE SINGLE CLIP AND DUAL CLIP SYSTEM MODELS. TABLE V COMPARES SYSTEM FREQUENCIES AND SHOWS THE PERCENTAGE SHIFT FOR FREQUENCIES BETWEEN THE TWO MODELLING METHODS. MAXIMUM TIER FORCES AND MOMENTS ARE COMPARED IN TABLE VI. A RESPONSE SPECTRUM LOADING IS APPLIED WITH NRC R.G. 1.92 GROUPING METHOD OF MODAL COMBINATION TO A CUT-OFF FREQUENCY OF 33.0 Hz. THE CPSES SAFEGUARDS BUILDING ELEV 852.5' OBE SPECTRA (REF [18]) IS USED AS A REPRESENTATIVE PLANT SPECTRA. THE SUPERPIPE OUTPUT IS DOCUMENTED IN REFS [13,14].



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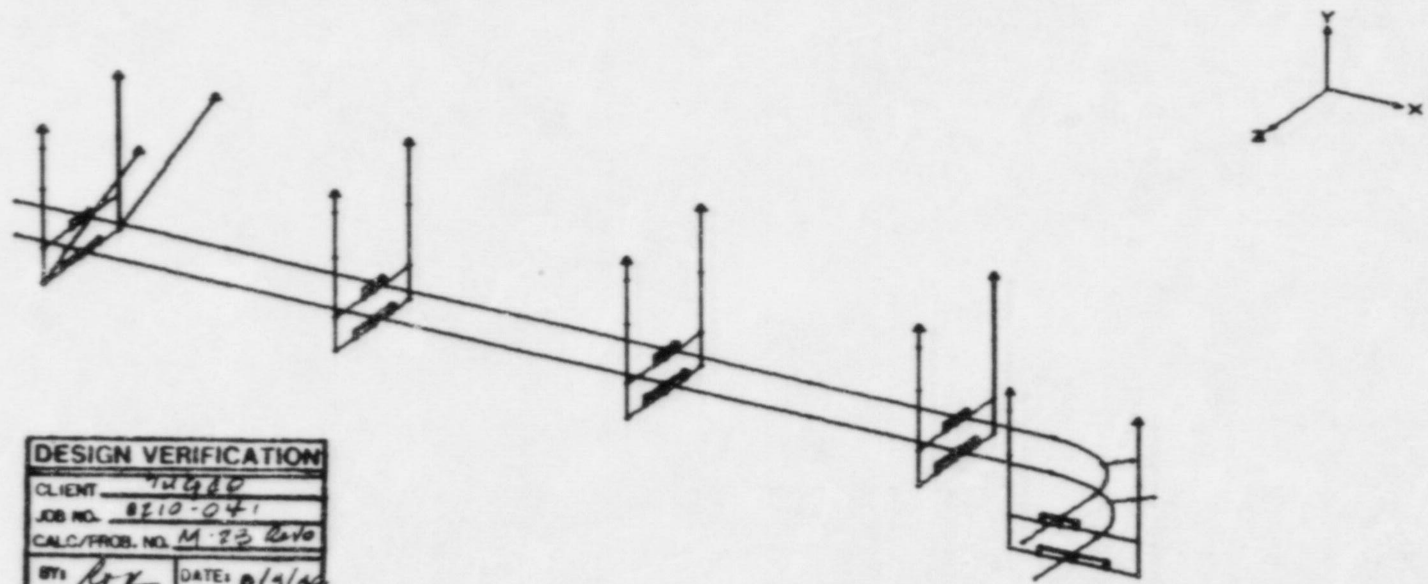
JOR 7/9/86

FIGURE 9 SUPERPIPE GEOMETRY PLOT
SINGLE CLIPS MODELLED



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BY: RPK	DATE: 8/3/84
CHKD: JAF	DATE: 8/12/84

FIGURE 10: SUPERPIPE GEOMETRY PLOT
DUAL CLIPS MODELLED

TABLE I : COMPARISON OF SYSTEM FREQUENCIES

DIRECTION	← SINGLE CLIP MODE No	EFFECTIVE WGT.	FREQ. (Hz)	DOUBLE CLIP → MODE No	EFFECTIVE WGT	FREQ. (Hz)	ΔFREQ
X	1	.045	2.5	1	.037	1.7	[illegible]
Y	2	.008	3.1	2	.012	1.9	39
Z	3	.156	4.0	3	.164	3.9	3
Y	4	.011	5.1	4	.014	5.0	2
Y	5	.001	5.6	5	.001	5.4	4
Z	6	.230	6.1	6	.230	6.0	2
X,Y	7	.051, .049	6.8	7	.052, .039	6.9	1
Y	8	.037	7.1	8	.020	7.2	1
Y	9	.343	7.2	9	.393	7.3	1
Y	10	.027	7.3	10	.005	7.4	1
X	11	.115	8.1	11	.102	8.0	1
Y	12	.003	8.6	12	.002	8.6	0
Y	13	.111	9.4	14	.109	9.4	0
Y	14	.060	9.9	15	.059	10.0	1
Z	15	.427	10.3	16	.441	10.5	5
Z	16	.027	11.1	17	.003	10.5	3
Z	17	.023	12.0	17	.003	10.5	[illegible]
X	18	.425	12.6	19	.276	13.2	5
				20	.178	13.6	8
X,Y	[illegible]	.024, .018	13.5	19	.276, .028	13.2	[illegible]
X	20	.018	14.1	21	.043	13.6	4
X	21	.048	15.3	22	.007	15.4	1
Z	22	.003	16.2	22	.005	15.4	5
X	23	.022	16.7	25	.008	15.5	7
X,Y	27	.026, .011	18.3	27	.046, .007	18.6	2
X	32	.039	21.1	32	.037	21.6	2

TABLE VI. COMPARISON OF MAXIMUM FORCE AND MOMENT ON TIER MEMBERS

SUPPORT NUMBER	TIER NUMBER	COMPONENT (local)	SINGLE CLIP	DUAL CLIP	Δ (%)
010	1	Fx (kip)	0.33	0.31	+
		Fy	0.97	0.97	0
		Fz	0.36	0.37	- 3%
		Mx (in·kip)	0.74	1.24	- 40%
		My	8.52	8.62	- 1%
		Mz	23.83	12.26	+
	2	Fx	0.21	0.18	+
		Fy	0.37	0.34	+
		Fz	0.59	0.61	- 3%
		Mx	0.72	0.55	+
		My	14.59	14.96	- 4%
		Mz	9.09	6.31	+
020	1	Fx	0.69	0.62	+
		Fy	0.81	0.79	+
		Fz	0.04	0.03	+
		Mx	0.64	0.70	- 9%
		My	0.83	0.33	+
		Mz	10.56	7.33	+
	2	Fx	0.58	0.44	+
		Fy	0.38	0.42	- 10%
		Fz	0.05	0.04	+
		Mx	0.19	0.20	- 5%
		My	1.11	0.73	+
		Mz	8.84	9.85	- 10%
030	1	Fx	0.81	0.84	- 4%
		Fy	0.82	0.85	- 4%
		Fz	0.03	0.03	0
		Mx	0.53	0.66	- 20%
		My	0.76	0.31	+
		Mz	12.31	12.46	- 1%

TABLE VI : COMPARISON OF MAXIMUM FORCE AND MOMENT ON TIER MEMBERS

SUPPORT NUMBER	TIER NUMBER	COMPONENT (local)	SINGLE CLIP	DUAL CLIP	Δ (%)
	2	Fx	0.57	0.49	+
		Fy	0.58	0.64	-9%
		Fz	0.05	0.04	+
		Mx	0.23	0.22	+
		My	1.13	0.66	+
		Mz	13.05	15.05	-13%
040	1	Fx	0.70	0.64	+
		Fy	0.56	0.56	0
		Fz	0.04	0.03	+
		Mx	0.38	0.46	-17%
		My	0.87	0.39	+
		Mz	9.61	8.46	+
	2	Fx	0.43	0.35	+
		Fy	0.49	0.45	+
		Fz	0.05	0.05	0
		Mx	0.22	0.20	+
		My	1.08	0.72	+
		Mz	11.11	10.30	+
050	1	Fx	0.30	0.28	+
		Fy	0.44	0.44	0
		Fz	0.12	0.08	+
		Mx	0.73	0.44	+
		My	2.64	1.65	+
		Mz	9.67	9.63	+
	2	Fx	0.21	0.18	+
		Fy	0.62	0.63	-2%
		Fz	0.14	0.08	+
		Mx	0.66	0.34	+
		My	2.57	1.40	+
		Mz	14.63	14.67	0

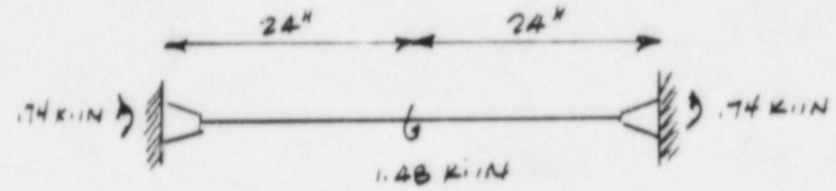
THE FREQUENCY RESPONSE OF THE CPSES CABLE TRAY SYSTEMS IS GOVERNED BY THE TRAY PROPERTIES, SPAN LENGTHS, AND THE OVERALL MASS/STIFFNESS OF THE SUPPORTS. THE RELATIVELY MINOR CHANGE IN STIFFNESS RESULTING FROM LOCATING A SINGLE CLIP AT THE TRAY CENTERLINE RATHER THAN A PAIR OF CLIPS AT THE TRAY SIDES DOES NOT SIGNIFICANTLY ALTER SYSTEM FREQUENCIES.

THIS IS DEMONSTRATED FOR THE REPRESENTATIVE CASE BY THE COMPARISON SHOWN IN TABLE 2. FREQUENCIES ARE COMPARED FOR ALL MODES EXCEPT THOSE WITH VERY LOW MASS PARTICIPATIONS. THE MODES COMPARED SHOW VERY LOW FREQUENCY SHIFTS, LESS THAN OR EQUAL TO 10%, FOR ALL MODES OTHER THAN THE FIRST TWO MODES. THE FIRST TWO MODES ARE LOCALIZED LOW FREQUENCY MODES AT THE ELBOW WHICH DO NOT SIGNIFICANTLY CONTRIBUTE TO TOTAL SYSTEM RESPONSE.

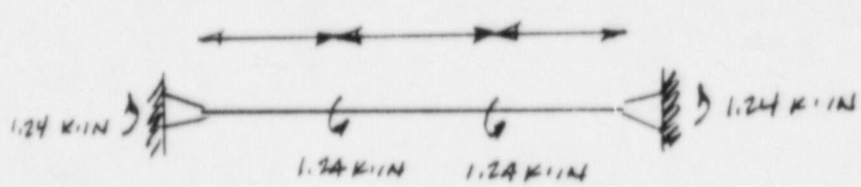
THE RESULTS IN TABLE VI COMPARE THE LOAD COMPONENTS ON THE TIER. THE SINGLE CLIP MODEL IS SHOWN TO GIVE A FAIRLY CLOSE OR CONSERVATIVE PREDICTION FOR ALL TIER LOADS EXCEPT TIER TORSION. THE TIER TORSIONAL LOADS POTENTIALLY DECREASE IN THE SINGLE CLIP MODEL BECAUSE THE TORSIONAL STIFFNESS IS RELAXED BY MODELLING THE CLIP AT THE TRAY CENTERLINE RATHER THAN CLOSER TO THE POSTS. ALTHOUGH THE TOTAL LOAD CARRIED IS RELATIVELY UNCHANGED, MORE IS CARRIED BY FLEXURAL DEFORMATION OF THE TRAY RATHER THAN TORSIONAL RESISTANCE OF THE TIERS.

THE TIER TORSIONAL MOMENT IS A SELF-LIMITING LOAD WHICH WILL BE RELIEVED BY DEFORMATION. TORSION MAY BE A SIGNIFICANT CONTRIBUTOR TO THE OVERALL STRESS INTERACTION RATIO DUE TO HIGH WARPING STRESSES. IN GENERAL, ANY DECREASE IN TORSIONAL MOMENT FOR THE SINGLE CLIP MODEL IS MORE THAN COMPENSATED FOR BY AN INCREASE IN WARPING STRESSES DUE TO THE MORE SEVERE STRESS DISTRIBUTION. THIS WILL BE DEMONSTRATED FOR THE REPRESENTATIVE CASE BY SHOWING THAT THE SINGLE CLIP MODEL YIELDS HIGHER WARPING STRESSES EVEN THOUGH THE APPLIED TORSIONAL MOMENT IS LOWER.

THE CASES SHOWN BELOW ARE COMPARED, USING THE WORST CASE DISCREPANCY LISTED IN TABLE VI. STRESSES ARE COMPUTED USING A PROCEDURE FROM REF [15], CONSISTENT WITH IMPELL DESIGN VERIFICATION PROCEDURES. TIER ENDS ARE ASSUMED FREE TO WARP BUT NOT TWIST.



SINGLE CLIP MODEL



DUAL CLIP MODEL

					CLIP MODELLING JUSTIFICATION		
					IMPELL CORPORATION	JOB NO 0210-041	PAGE 46
0	RTK	8/11/86	JCP	8/12/86		CALC NO M-28	OF 57
REV	BY	DATE	CHECKED	DATE			

FOR C4x7.25 TIER :

t_w = 0.321 in
t_f = 0.296 in
d = 4.00 in
b_w = 2.625 in
b_f = 1.721 in
E = 29×10^3 ksi
G = 11.2×10^3 ksi
K = 0.082 in^4
a = 6.19 in

W_{n0} = 1.88 in^2
W_{n2} = 1.01 in^2
S_{w1} = 0.28 in^4
S_{w2} = 0.20 in^4
S_{w3} = 0.10 in^4

CALCULATE WARPING NORMAL STRESSES :

$$\sigma_w = E W_{n0} \phi''$$

$$\phi'' = \frac{M}{GKa}\gamma$$

$$\therefore \sigma_w = \frac{E W_{n0} M \gamma}{GKa}$$

THE PARAMETER γ IS OBTAINED FROM TABLES IN REF [15] USING THE FOLLOWING PARAMETERS :

$$\frac{L}{a} = \frac{48}{6.19} = 7.75 \text{ , use } \frac{L}{a} = 6.0 \text{ CURVE}$$

THE ACTUAL CLIP LOCATION POINTS ARE AT 0.25L, 0.50 L, AND 0.75 L. THE AVAILABLE CURVES WILL BE USED FOR 0.30L, 0.50L, AND 0.70L TO APPROXIMATE WARPING STRESSES.

∴ FOR DUAL CLIP CONFIGURATION :

$\gamma_{@\ 0.30} = 0.485$

$\gamma_{@\ 0.50} = 0.150$

$\gamma_{@\ 0.70} = 0.045$

∴ FOR SINGLE CLIP CONFIGURATION :

$\gamma_{@\ 0.50} = 0.500$

SUBSTITUTING INTO THE EQUATION FOR σ_W :

DUAL CLIP : σ_W @ 0.30 = 4.65 M

σ_W @ 0.50 = 1.44 M

σ_W @ 0.70 = 0.43 M

SINGLE CLIP : σ_W @ 0.50 = 4.80 M

FOR BOTH CONFIGURATIONS, THE MAXIMUM WARPING STRESS WILL OCCUR AT A CLIP LOCATION :

DUAL CLIP : $\sigma_{W\,MAX} = 4.65M + 0.43\ M$
$= (4.65 + 0.43)(1.24) = 6.3$ ksi

SINGLE CLIP : $\sigma_{W\,MAX} = 4.80\ M$
$= (4.80)(1.48) = 7.1$ ksi

SINCE 6.3 ksi < 7.1 ksi, THE MAXIMUM WARPING NORMAL STRESS WILL OCCUR FOR THE SINGLE CLIP CONFIGURATION.

CALCULATE WARPING SHEAR STRESS:

- WARPING: $\tau_{ws} = \frac{-E S_{ws} \phi'''}{t_f}$

$\phi''' = \frac{M}{GKa^2} \gamma$

$\therefore \tau_{ws} = \frac{-E S_{ws} M \gamma}{GKa^2 t_f}$

ENTERING CURVES WITH THE SAME PARAMETERS PREVIOUSLY USED:

DUAL CLIP -

$|\gamma @ 0.30| = 0.510$

$|\gamma @ 0.50| = 0.150$

$|\gamma @ 0.70| = 0.050$

SINGLE CLIP -

$|\gamma @ 0.50| = 0.500$

USING $S_{ws} = S_{w1} = 0.28$ TO OBTAIN MAX. SHEAR -

DUAL CLIP: $\tau_w @ 0.3 = 0.40\ M$

$\tau_w @ 0.5 = 0.12\ M$

$\tau_w @ 0.7 = 0.04\ M$

SINGLE CLIP: $\tau_w @ 0.5 = 0.39\ M$

AGAIN THE MAXIMUM STRESS WILL OCCUR AT THE CLIP:

DUAL CLIP: $\tau_W = 0.40M + 0.04M$
$= (0.40+0.04)(1.24) = 0.55$ ksi

SINGLE CLIP: $\tau_W = 0.39M$
$= 0.39(1.48) = 0.58$ ksi

SINCE 0.55 ksi < 0.58 ksi, THE MAXIMUM WARPING SHEAR STRESS WILL OCCUR FOR THE SINGLE CLIP CONFIGURATION.

ALTHOUGH ONLY ONE MODEL HAS BEEN STUDIED IN DETAIL, BEHAVIORAL TRENDS ARE DEMONSTRATED WHICH ILLUSTRATE THE CONSERVATISM OF THE MODELLING PROCEDURE. THE LOCATION OF THE SINGLE CLIP AT THE TRAY CENTER MAXIMIZES STRESSES FROM BENDING MOMENT AND TORSIONAL WARPING. THE ADDED FLEXIBILITY OF THE SINGLE CLIP ALLOWS MORE OF THE MOMENT TO BE REDISTRIBUTED AS FLEXURE IN THE TRAY RATHER THAN TORSION IN THE TIER. THE POTENTIAL UNDERPREDICTION OF THE TIER TORSIONAL LOAD HAS BEEN SHOWN TO BE COMPENSATED FOR BY THE CONSERVATIVE DISTRIBUTION OF WARPING STRESSES. GIVEN THE CONSERVATISM SHOWN IN PREDICTING OTHER LOAD COMPONENTS, IT IS CONCLUDED THAT THE SINGLE CLIP MODELLING CONFIGURATION IS MORE CONSERVATIVE THAN THE DUAL CLIP CONFIGURATION.

REV	BY	DATE	CHECKED	DATE	CLIP MODELLING JUSTIFICATION		
2	RTK	7/24/86	JP	7/25/86	IMPELL CORPORATION	JOB NO 0210-041 / CALC NO M-18	PAGE 50 OF 59

I. JUSTIFICATION OF MODELLING PROCEDURES THROUGH COMPARISON TO TEST DATA

AN EXTENSIVE TESTING PROGRAM OF TYPICAL CASES CABLE TRAY CONFIGURATIONS HAS BEEN PERFORMED BY ANCO ENGINEERING, INC (REF [9]). PRELIMINARY TEST RESULTS (REF [10]), AS WELL AS IMPELL ANALYTICAL CORRELATION ANALYSES (REFS [11, 12, 35, 36, AND 7]) HAVE BEEN USED TO VALIDATE THE IMPELL MODELLING PROCEDURES.

OF THE TEST CONFIGURATIONS SPECIFIED IN REF [9], FIVE TESTS HAVE BEEN PERFORMED - TEST CASES 1, 2, 4, 6 AND 7 (REFS [11, 12, 35, 36, AND 7]) RESPECTIVELY
TEST CONFIGURATIONS HAS BEEN INSTRUMENTED TO RECORD THE RELATIVE MOVEMENT BETWEEN TRAY AND CLIP AT SELECTED FRICTION TYPE SUPPORTS. IN NO INSTANCE HAS THE RECORDED RELATIVE MOVEMENT EXCEEDED THE NOISE LEVEL ACCURACY OF THE RECORDING DEVICE (0.05") FOR DESIGN BASIS LOADS. A SAMPLE PLOT OF THE RELATIVE MOVEMENT RECORD FOR TWO LOCATIONS ON TEST CONFIGURATION 4 IS INCLUDED AS ATTACHMENT "C" TO THIS CALCULATION.

THE TEST RESULTS, COMBINED WITH THE ANALYTICAL STUDIES PRESENTED IN SECTION IV A, SHOW THAT THE ELASTIC MODELLING OF THE FRICTIONAL CLIP RESTRAINT IN THE TRAY LONGITUDINAL DIRECTION MOST CLOSELY REPRESENTS ACTUAL BEHAVIOR AND IS THE ONLY CASE REQUIRING ANALYSIS FOR DESIGN VERIFICATION.

THE TEST RESULTS IN REF [10] AND POST TEST CORRELATION DONE IN REFS [11, 12, 35, 36, 17] SHOW THAT THE ANALYTICAL MODELS PRODUCE REASONABLE RESULTS AND CONSISTENTLY OVERPREDICT THE MEASURED SYSTEM RESPONSE. TEST CONFIGURATION 7 (REF [7]) WAS THE MOST HEAVILY INSTRUMENTED OF THE TEST CASES. FOR 1.0 SSE INPUT AT 100% FILL LEVELS AND NO INSTALLED CLAMP GAPS, TRAY DISPLACEMENTS ARE OVERPREDICTED BY AN AVERAGE OF 316% AND SUPPORT DISPLACEMENTS BY 102%. FOR TESTS PERFORMED WITH INTENTIONALLY INSTALLED CLAMP GAPS, TRAY DISPLACEMENTS ARE OVERPREDICTED BY AN AVERAGE OF 270% AND SUPPORT DISPLACEMENTS BY 100%. THE AVERAGE TRAY DISPLACEMENT THEREFORE DECREASES (BUT IS STILL OVERPREDICTED) WHEN GAPS ARE INSTALLED, DUE TO THE RIGID BODY SLIDING MOTION. HOWEVER, THE AVERAGE OVERPREDICTION FOR SUPPORT DISPLACEMENT INCREASES, INDICATING THAT THE GAPS ACT TO DISSIPATE ENERGY IN THE SYSTEM AND ARE NOT CRITICAL IN THE DESIGN VERIFICATION PROCESS.

					CLIP MODELLING JUSTIFICATION		
0	RTK	7/9/86			IMPELL CORPORATION	JOB NO 0310-041 CALC NO M-23	PAGE 52 OF 59
REV	BY	DATE	CHECKED	DATE			

THE OTHER TEST CONFIGURATIONS WERE NOT TESTED WITH INTENTIONALLY INSTALLED GAPS BUT SHOW AVERAGE OVERPREDICTIONS IN THE SAME RANGE FOR DISPLACEMENTS AND ACCELERATIONS OF SYSTEMS WITH NO GAPS.

THE ANALYTICAL MODELS PREDICT ADDITIONAL MODES WHICH ARE NOT MEASURED BY TESTING. THESE MODES ARE DUE TO THE LOWER BOUND CLIP STIFFNESSES ASSUMED (PER REF [6]) FOR THE VERTICAL DIRECTION. HOWEVER, THE DOMINANT SYSTEM MODES ARE NOT AFFECTED AND CORRELATE WELL WITH TESTING. THE NET EFFECT OF THE ELASTIC STIFFNESSES USED TO MODEL CLIPS, AS SHOWN IN REFS [11, 12, 7, 35, AND 36] IS TO INCREASE THE SYSTEM MASS PARTICIPATING BELOW 33 Hz AND OVERPREDICT ACTUAL RESPONSE.

II SUMMARY

THE MAJOR ASSUMPTIONS USED IN THE MODELLING OF CABLE TRAY CLIPS HAVE BEEN EVALUATED. BOTH ANALYTICAL MODELS AND TESTING DATA HAVE BEEN USED TO STUDY THE ACCURACY AND CONSERVATISM OF THE IMPELL MODELLING PROCEDURE.

THE IMPELL MODELLING PROCEDURE ASSUMES AN ELASTIC STIFFNESS TO MODEL THE FRICTIONAL RESTRAINT BETWEEN TRAY AND TRANSVERSE CLIP FOR THE TRAY LONGITUDINAL DIRECTION. THROUGH ANALYTICAL COMPARISONS, IT HAS BEEN DEMONSTRATED THAT THIS IS THE ONLY TYPE OF BEHAVIOR WHICH WOULD REQUIRE CONSIDERATION IN DESIGN VERIFICATION. OTHER BEHAVIOR SCENARIOS (CLIP SLIPPAGE OR INTERMITTENT FRICTIONAL SLIPPAGE) HAVE BEEN SHOWN TO PRODUCE LOWER STRESSES OR STRESSES WHICH ARE WELL BELOW AISC ALLOWABLES. IN ADDITION, TESTING HAS SHOWN THAT FULL FRICTIONAL RESTRAINT IS THE ACTUAL FRICTION CLIP BEHAVIOR FOR TYPICAL CPSES CABLE TRAY SYSTEMS UNDER DESIGN SEISMIC LOADINGS.

THE ACTUAL STIFFNESSES USED TO MODEL THE CLIP MEMBERS WERE CHOSEN TO ENSURE CONSERVATIVE PREDICTION OF TRAY/CLIP INTERACTION AND OVERALL MODAL MASS PARTICIPATION. THIS

HAS BEEN SHOWN TO CONSERVATIVELY OVERPREDICT SYSTEM RESPONSE (REF [7]) WHEN COMPARED TO TEST MEASUREMENTS, PARTICULARLY FOR THE TRAY VERTICAL DIRECTION.

THE TEST CORRELATION HAS ALSO CONFIRMED THAT A LINEAR ELASTIC STIFFNESS WILL CONSERVATIVELY MODEL THE NON-LINEAR BEHAVIOR OF A CLIP WITH GAPS. THE NON-LINEAR RESPONSE OF A CLIP WITH GAPS INCREASES THE EFFECTIVE DAMPING OF THE SYSTEM, RESULTING IN A CONSERVATIVE ANALYTICAL PREDICTION OF SYSTEM RESPONSE (REF [7]).

FINALLY, THE USE OF OTHER SIMPLIFYING ASSUMPTIONS, SUCH AS USING A SINGLE ELEMENT TO MODEL A PAIR OF TRAY CLIPS, PROVIDES A SIMPLE AND CONSERVATIVE BOUNDING CASE FOR DESIGN VERIFICATION. THE LOCATION OF THE SINGLE CLIP AT THE TRAY CENTER DOES NOT SIGNIFICANTLY ALTER THE SYSTEM FREQUENCIES, YET GIVES A WORST CASE STRESS DISTRIBUTION FOR THE TIER MEMBERS.

III. REFERENCES

1. IMPELL PROJECT INSTRUCTION NO. PI-02
"DYNAMIC ANALYSIS OF CABLE TRAY SYSTEMS"
JOB NO. 0210-040 REV. 4

2. IMPELL ANALYSIS PROGRAM SUPERPIPE
VERS. 19A (CYBER VERSION)
VERS. 19.4 (VAX VERSION)

3. IMPELL CALCULATION M-27 "CABLE TRAY THERMAL EXPANSION." REV. 0.

4. TUGCO PROCEDURE TNE-FVM-CS-001, "FIELD VERIFICATION METHOD UNIT 1 CABLE TRAY HANGER AS-BUILTING AND DESIGN ADEQUACY VERIFICATION PROGRAM", REV. 4, MARCH 1986.

5. IMPELL CALCULATION M-10 REV 1
"CABLE TRAY CLIP ANGLE STIFFNESS"

6. IMPELL CALCULATION M-19 REV. 1
"CLIP STIFFNESS PRODUCTION VALUES"

7. IMPELL CALCULATION TC7-PT1 REV. 0
"TEST CONFIGURATION 7 POST TEST ANALYSIS."

8. N. ASLAM, W.G. GODDEN, D.T SCALISE
"SLIDING RESPONSE OF RIGID BODIES TO EARTHQUAKE MOTIONS" L. BERKELEY LAB REPORT, UNIV. OF CALIFORNIA, SEPTEMBER 1975 REPORT LBL-3868

9. ANCO ENGINEERING, INC. TEST PLAN
"DYNAMIC TESTING OF TYPICAL CABLE TRAY SUPPORT CONFIGURATIONS - COMANCHE PEAK STEAM ELECTRICAL STATION" REV 1 DEC 1985

10. ANCO ENGINEERING, INC PRELIMINARY DATA PACKAGES FOR COMANCHE PEAK CABLE TRAY TESTS, IN PROGRESS.

11. IMPELL CALC TC1-PT1 REV. Φ
"TEST CONFIGURATION 1 POST TEST ANALYSIS"

12. IMPELL CALC TC2-PT1 REV Φ
"TEST CONFIGURATION 2 POST TEST ANALYSIS"

13. IMPELL SUPERPIPE OUTPUT 86/08/12 17.39.24.
SINGLE CLIP MODEL

14. IMPELL SUPERPIPE OUTPUT 86/08/08 10.8.18.
DOUBLE CLIP MODEL

15. "TORSION ANALYSIS OF ROLLED STEEL SECTIONS"
PUBLICATION BY BETHLEHEM STEEL

16. BLEVINS, R.D. "FORMULAS FOR NATURAL FREQUENCY AND MODE SHAPE" VAN NOSTRAND REINHOLD © 1979

17. SUPERPIPE OUTPUT 86/08/11 04.21.59.

18. CPSES REFINED RESPONSE SPECTRA FOR SAFEGUARDS BUILDING, OBE EVENT, DATED JAN. 1982.

19 SUPERPIPE OUTPUT 3' LENGTH MODEL a 86/04/10 18.13.27.

20. —— " —— 3' LENGTH MODEL b 86/04/03 15.22.32.

21 —— " —— 3' LENGTH MODEL c 86/04/04 15.49.22.

22. —— " —— 6' LENGTH MODEL a 86/07/03 17.41.13.

23. —— " —— 6' LENGTH MODEL b 86/07/03 17.45.35

24. —— " —— 6' LENGTH MODEL c 86/07/03 17.47.16.

25. —— " —— 8' LENGTH MODEL a 86/07/02 7.37.58.

26. —— " —— 8' LENGTH MODEL b 86/07/02 17.36.50.

27. —— " —— 8' LENGTH MODEL c 86/07/02 17.34.45.

28. SUPERPIPE OUTPUT 12' LENGTH MODEL a
86/04/07 11.22.39.

29. ——— " ——— 12' LENGTH MODEL b
86/04/07 11.42.43.

30. ——— " ——— 12' LENGTH MODEL c
86/07/08 20.29.54.

31. ——— " ——— 18' LENGTH MODEL a
86/07/02 16.05.36.

32. ——— " ——— 18' LENGTH MODEL b
86/07/02 16.09.12.

33. ——— " ——— 18' LENGTH MODEL c
86/07/02 16.09.56.

34. CLOUGH, R.W. AND PENZIEN, J. "DYNAMICS OF STRUCTURES", McGRAW HILL BOOK CO., © 1975

35. IMPELL CALC TC4-PT1 Rev 0.
"TEST CONFIGURATION 4 POST TEST ANALYSIS"

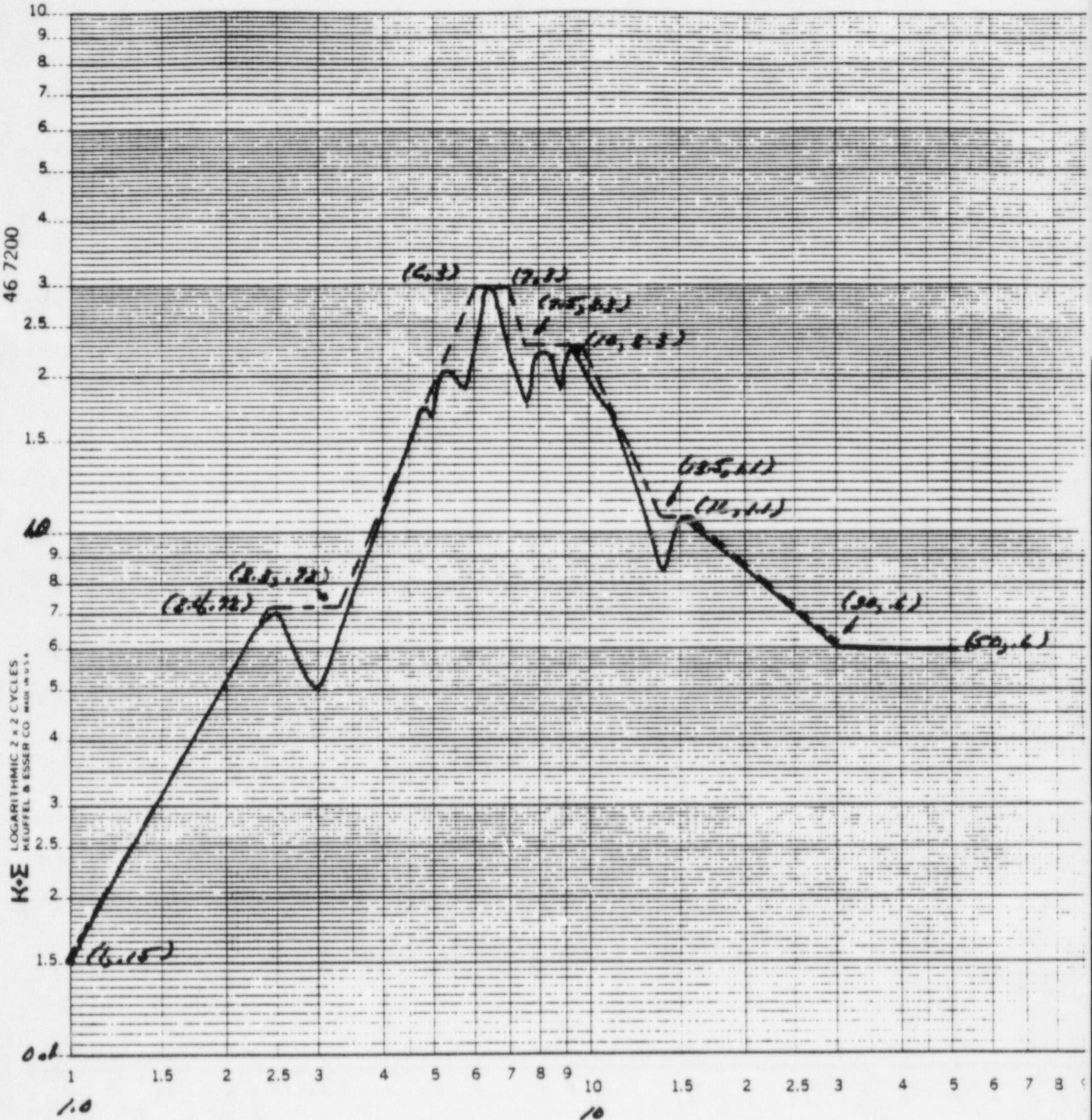
36. IMPELL CALC TC6-PT1 Rev. 0
"TEST CONFIGURATION 6 POST TEST ANALYSIS"

ATTACHMENT A

PLOTS OF ENVELOPED PLANT SPECTRA
SSE RESPONSE SPECTRUM AT 7% DAMPING
OBE RESPONSE SPECTRUM AT 4% DAMPING

ENVELOPING* FLOOR REQUIRED RESPONSE SPECTRUM
HORIZONTAL OBE - β = .04

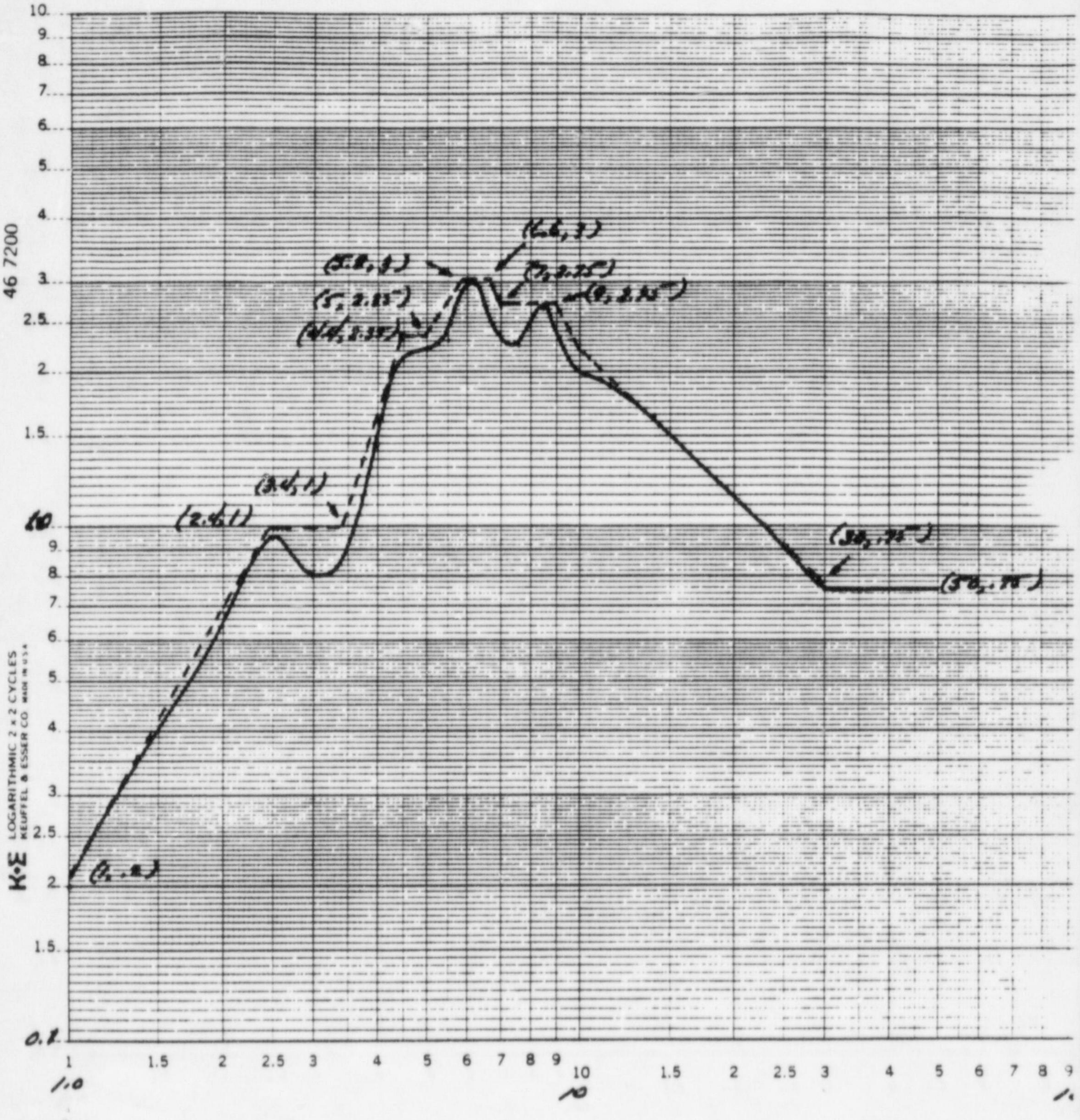
OBEX
OBEZ



*Combines lower bound, best guess and upper bound soil spring predicted floor response spectra.

ENVELOPING FLOOR REQUIRED RESPONSE SPECTRUM
HORIZONTAL SSE - β = .07

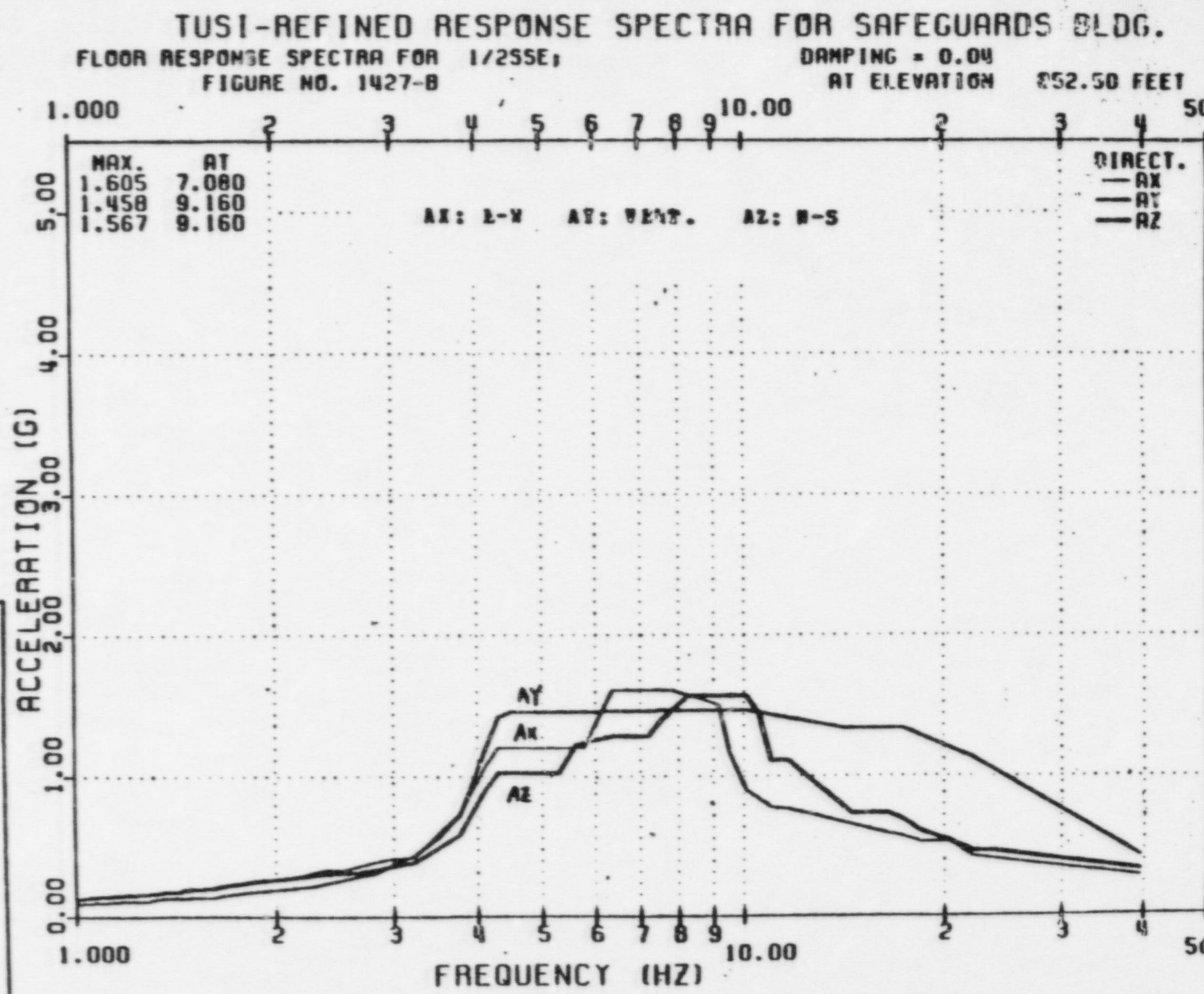
SSEx
SSEZ



ATTACHMENT "B"

OBE 4% DAMPING ELEV. 852.5'

SAFEGUARDS BUILDING SPECTRA



FSB-IC, Rev. 1

TUSI-SAFEGUARDS BLDG.

REFINED RESPONSE SPECTRA

GIBBS & HILL, INC.
ENGINEERS, DESIGNERS, CONSTRUCTORS

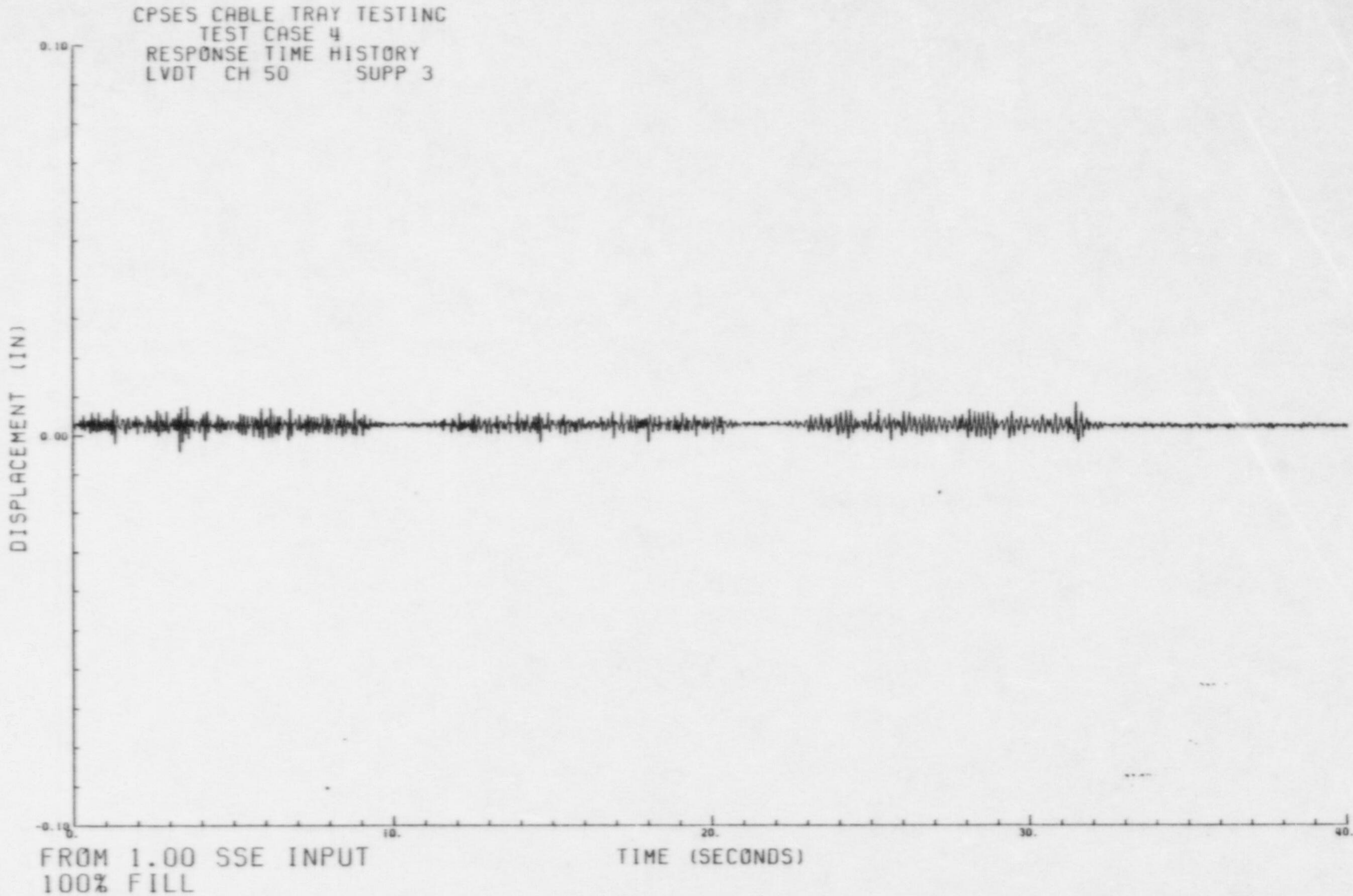
JOB NO. 2325

FIGURE-1427-B

SHEET 106 (6/14/85)

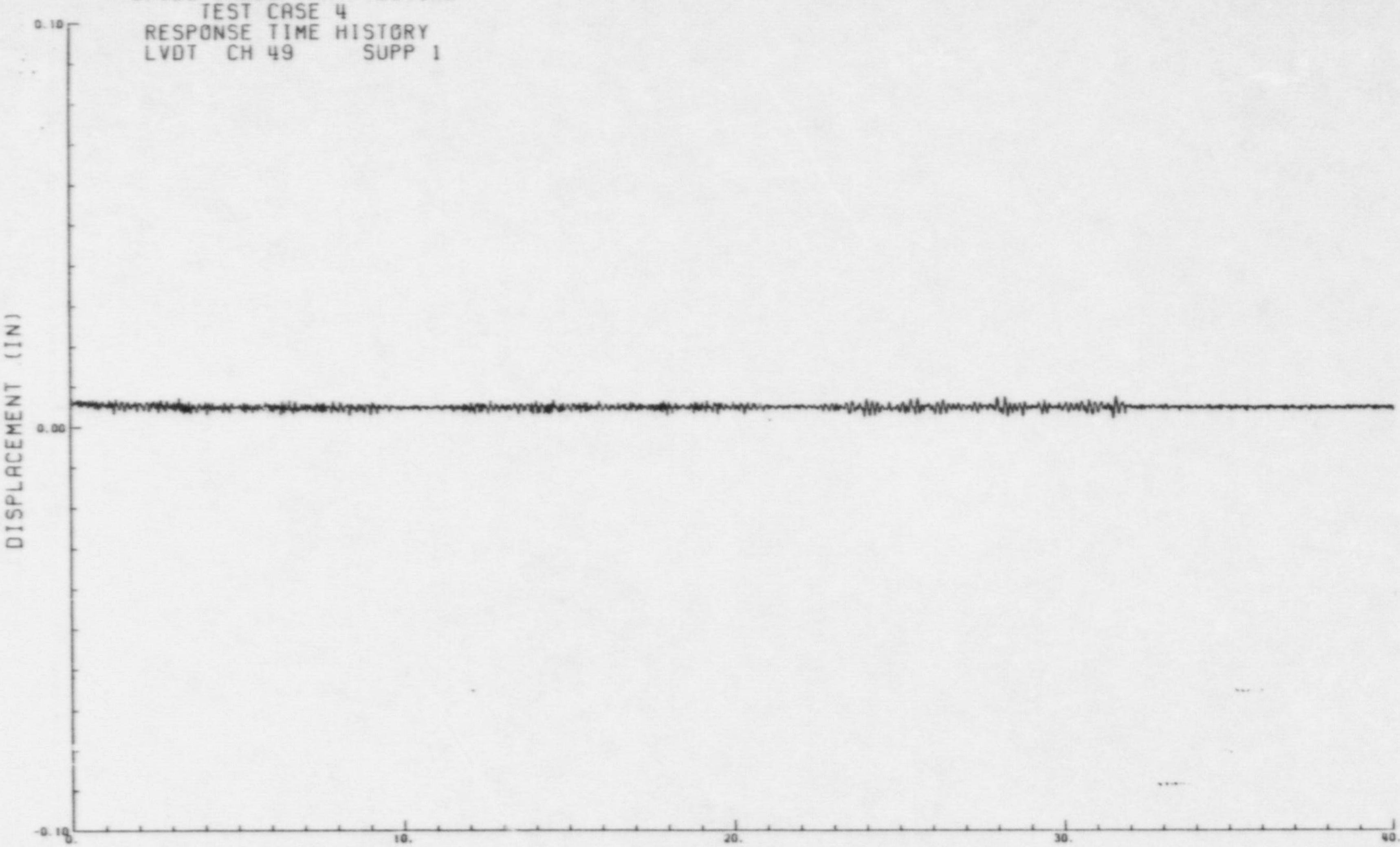
ATTACHMENT C

SAMPLE PLOTS OF LONGITUDINAL RELATIVE MOVEMENT BETWEEN TRAY AND FRICTIONAL (TRANSVERSE) CLIP DURING SEISMIC TESTING



ATTACHMENT C

CPSES CABLE TRAY TESTING
TEST CASE 4
RESPONSE TIME HISTORY
LVDT CH 49 SUPP 1

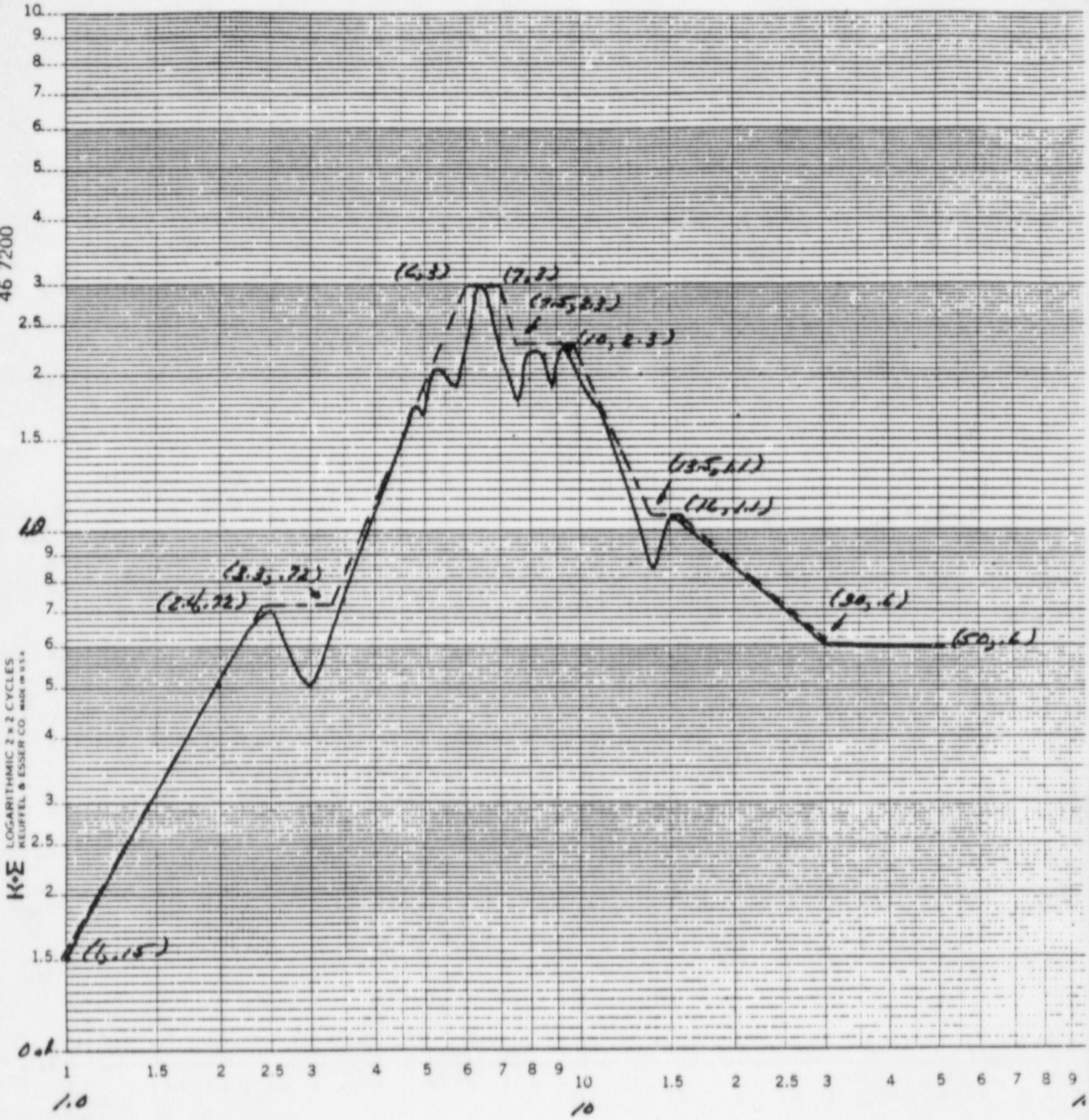


FROM 1.00 SSE INPUT
100% FILL

ATTACHMENT C
p. 2 of 2

ENVELOPING* FLOOR REQUIRED RESPONSE SPECTRUM
HORIZONTAL OBE - β = .04

OBEX
OBEZ



*Combines lower bound, best guess and upper bound soil spring predicted floor response spectra.

ENVELOPING FLOOR REQUIRED RESPONSE SPECTRUM
HORIZONTAL SSE - β = .07

SSEX
SSEZ