ORIGINAL

QA Record PAGE 1

TVA 10697 (DNE-6-86)

DNE CALCULATIONS

WCG-1-397

TITLE 2 DEGREE OF FREEDOM COMPARISON TO A COUPLED SYSTEM RESPONSE	PLANT/UNIT WATTS BAR UNIT 1
PREPARING ORGANIZATION SARGENT & LUNDY	KEY NOUNS (Consult RIMS DESCRIPTORS LIST) DYNAMIC RESPONSE, COMPONENTS, HVAC, CONDUIT, CABLE TRAY

BRANCH/PROJECT IDENTIFIERS
8.11.6-1
WCG-1-397

Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.

Rev	(for RIMS' use) (88)	RIMS accession number
R0	900322A0005	B18 900224 810
R 1 Note 1		B18 910126 994
R __		
R __		

APPLICABLE DESIGN DOCUMENT(S)
WB-DC-40-31.8
Rev. 7 & Note 2

SAR SECTION(S) N/A

UNID SYSTEM(S) N/A

Revision 0		R1	R2	R3
ECN No. (or indicate Not Applicable)	N/A	N/A		
Prepared	P.K. Agrawal for M. AMIN 2/21/90	A. Ali Dabbagh 1/25/91		
Checked	2-21-90	M. Amin 1.25.91		
Reviewed	2-21-90	M. Amin 1.25.91		
Approved	SJ Fang for S.L. Chu JAK 2/21/90	BCP FOR LCE		
Date	2-21-90	1.25.91		
List all pages added by this revision.		Note 3		
List all pages deleted by this revision.		3,4		
List all pages changed by this revision.		ia, iii & Note 4		

Use form 10534 if space required.

Safety-related? Yes ☒ No ☐

Statement of Problem

THE PURPOSE OF THIS CALCULATION IS TO CALIBRATE AN APPROXIMATE 2-DEGREES-OF-FREEDOM (2DF) APPROACH TO DETERMINE THE DYNAMIC RESPONSE OF MULTI-DEGREES-OF-FREEDOM (MDF) SYSTEMS CONSISTING OF SEVERAL SPANS OF COMPONENTS ON FLEXIBLE SUPPORTS.

Abstract See Pages 0.1 thru 0.3 of Calculation

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒

Notes

1. This Calculation is TVA Rev. 1/S&L Rev. 3
2. WB-DC-40-31.10, Rev. 4 & WB-DC-20-21.1 Rev. 5
3. 3, 4, 4a, 6a, ib, iia, iib, iic, iid, iv & [0.1 thru 0.3], [10.1 thru 10.52], [11.1 thru 11.54], [12.1 thru 12.113], [13.1 thru 13.8], [14.1 thru 14.28], [15.1 thru 15.95] & [16.1 thru 16.3] & [A.1 thru A.8].
4. ~~1, 2, 5, [5a thru 5e], & 6.~~ BCP 1-31-91 H.A.

   1, 2, 5, [5a thru 5e], & 6

9106190380 910613
PDR ADOCK 05000390
A PDR

☐ Microfilm and store calculations in RIMS Service Center.

Microfilm and destroy. ☐

☒ Microfilm and return calculations to: DCRM / B. YOUNG

Address: 113 TSOB-WBN

cc: RIMS, SL 26 C-K

WCG-1-377

PG. 2 ~~of 82~~ |R1

Title: 2 DEGREE OF FREEDOM COMPARISON TO A COUPLED SYSTEM RESPONSE

REVISION LOG

8.11.6-1

Revision No.	DESCRIPTION OF REVISION	Date Approved
0	INITIAL ISSUE	
1	Provide additional cases to show the adequacy of the calibration factors (multi-mode factors) determined in Revision 0. The additional cases resulted from the NRC comments in a meeting related to Rev. 0. These cases are further described on Page 10.3 of this calculation	1.25.91

TVA 10534 (EN DES-4-78)

WCG-1-397 R1

SARGENT & LUNDY
ENGINEERS

Calcs. For 2 DEGREE OF FREEDOM COMPARISON TO A COUPLED SYSTEM RESPONSE		Calc. No. 8.11.6-1
☒ Safety-Related	☐ Non-Safety-Related	Rev. 3 Date
		Page 3 of

Client	TVA	Prepared by	Date 1/25/91
Project	WBN	Reviewed by M. Ami	Date 1.25.91
Proj. No. 8573-03	Equip. No.	Approved by	Date 1-25-91

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	Cover sheet (TVA Form 10697)	1
	Revision Log (TVA Form 10534)	2
	Table of Contents	3, 4, 4a
	Calculation Review Summary Checklist	5, 5a thru 5.e
	Calculation Design Verification Form	6, 6a
	Analysis/Design Control, Computer Output Summary, List of Programs & Table of Contents	i, ia, ib, ii, iia, iib, iic, iid, iii, iv
0)	Abstract	0.1 – 0.3
1)	Purpose	1.1
2)	Two-Degrees-of-Freedom (2DF) Approach for Component & Support (C/S) Seismic Response.	2.1 – 2-10 2.10a, 2-10b, 2-11
3)	MDF Systems Analyzed (Component on Flexible Supports)	3.1 – 3.14
4)	2DF Analysis Results for MDF System in Figure (3-1): Component on Flexible Supports	4.1 – 4.18

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

SARGENT & LUNDY ENGINEERS	Calcs. For 2 DEGREE OF FREEDOM COMPARISON TO A COUPLED SYSTEM RESPONSE	Calc. No. 8-11-6-1
	☒ Safety-Related ☐ Non-Safety-Related	Rev. 3 Date
		Page 4a of

Client TVA		Prepared by A. Al-Dabbagh	Date 1/25/91
Project WBN		Reviewed by M. Amin	Date 1.25.91
Proj. No. 8573-03	Equip. No.	Approved by	Date 1-25-91

TABLE OF CONTENTS (CONTINUED)

SECTION	CONTENTS	PAGES
16)	Summary and Conclusions of Revision 3	16.1 – 16.3
Appendix A	Duct Section Properties	A-1 – A-8
	Total # of pages =	460

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PG. 5 ~~of 82 R~~

CALCULATION CONTROL CHECKLIST

TASK	Person Responsible for Performing Task	Initials/Date
1. Enter Calculation Identifier/Title into Calculation Log	Preparer	
2. If a computer program is to be used in the preparation of the calculation, ensures that NEP-3.8 and WBEP 5.21 are followed.	Preparer	PKA for MA/2-2
3. Determine and Implement Interface Review requirements per NEP 5.2.	Preparer	PKA for MA/2-21-
4. Ensures that (1) the "Applicable Design Document(s)" block refers to Design Documents to which the calculation applies and that the identified design documents are entered on the calculation log, (2) that the Key Nouns block contains the words "(Appropriate Discipline) Calculations" in addition to other applicable key nouns, (3) all cover sheet information blocks are completed and (4) all required information is on each sheet of the calculation.	Preparer	PKA for MA/2-21-
5. Obtains initials on revision log of the discipline LEs to which calculation was interface reviewed.	Preparer	
6. Issues approved calculation per NEP 1.3	LE or Designee	
7. Updates discipline calculation log with (1) calculation RIMS number, (2) design documents to which the calculation applies, (3) if the calculation contains unverified assumptions which require further verification.	LE or Designee	
8. If the calculation contains unverified assumptions that require later verification schedules in the project scheduling network the activities for predecessor and unverified assumption resolution activities.	LE or Designee	
9. After receipt from microfilming sends the original calculation to Engineering Records Control Section (ERCS)	LE or Designee	

Void
M.A
1-25-91

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NEP-3.1
Attachment 6
Page 1 of 1

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

WCG-1-397	0
Calculation No.	Revision

Method of design verification (independent review) used (check method used):

1. Design Review X
2. Alternate Calculation ______
3. Qualification Test ______

Justifiaction (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies include for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

Justification of the 1.2 multimode factor (equivalent static load) appears reasonable. In providing this justification, S&L used a method proposed in **Vibration Theory and Applications** by William T Thomson to calculate a combined frequency for the component and its support. TVA has in the past used the Dunkerley Equation to combine individual frequencies. The attached calculations show the equivalency of these two methods. Also, in combining modal responses, S&L used the Complete Quadric Combination (CQC) method as proposed by Wilson, deKiureghian, and Bayo for the combination of closely spaced modes. In SER 3.7.2 (section I.7), the NRC references Regulatory Guide 1.92 as providing acceptable methods for the combination of closely spaced modes. Although the CQC method is not explicitly referenced in 1.92, the Double Sum Method is and this method will yield an answer equivalent to the CQC method. This combination method for commodities should be incorporated into the FSAR at its next revision since it is used to justify a lower design basis multimode factor than the 1.5 permitted by the current NRC SER.

	2-23-90
Design Verifier (Independent Reviewer)	Date

WCG-1-511 R0 SHEET 1 OF 4

COMPARISON OF METHODS TO CALCULATE SYSTEM FREQUENCIES (ALTERNATE CALCULATION - NO CHECKING REQUIRED)

WATTS BAR N.P
UNITS 1+2
COMPUTED JDS DATE 2-23-9
CHECKED N/A DATE

PURPOSE

The purpose of this comparison is to identify (if any) differences between the two different methods used to calculate the natural frequency of a system. The two methods are: 1.) Southwell-Dunkerley Approximation (used by TVA) and 2.) the Thomson Approximation (used by Sargent & Lundy).

DESCRIPTION

Method #1 has been used by TVA in the past (and by others in the nuclear industry) but now Sargent & Lundy is basing their calculation for the 1.2 vs. 1.5 static load factor on the method #2. This comparison will show that their is little or no difference between the two methods.

Rev. 1 ⊥ P. 2 ~~[illegible]~~

WCG-1-397 R0 SHEET 2 OF 4

COMPARISON OF METHODS TO CALCULATE SYSTEM FREQUENCIES (ALTERNATE CALCULATION – NO CHECKING REQUIRED)

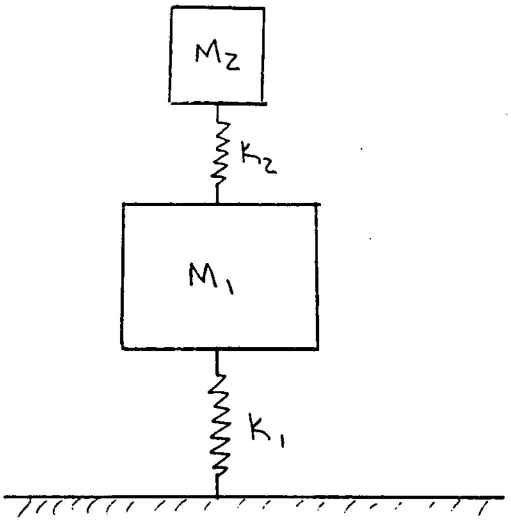
WATTS BAR N.P.

UNITS HZ

COMPUTED JDS DATE 2-23-90

CHECKED N/A DATE

Example



$$M_2 = \left(\frac{20^{\#}}{386.4\ ^{IN}/_{sec^2}}\right) = 0.05\ \frac{\#\text{-}sec^2}{IN}$$

$$K_2 = 800\ ^{\#}/_{IN}$$

$$M_1 = \left(\frac{100^{\#}}{386.4\ ^{IN}/_{sec^2}}\right) = 0.26\ \frac{\#\text{-}sec^2}{IN}$$

$$K_1 = 10{,}000\ ^{\#}/_{IN}$$

Individual Frequencies

$$f_1 = \left(\frac{1}{2\pi}\right)\sqrt{\frac{K_1}{M_1}} = \left(\frac{1}{2\pi}\right)\left(\frac{10{,}000}{0.26}\right)^{1/2} \approx 31\ Hz$$

$$f_2 = \left(\frac{1}{2\pi}\right)\sqrt{\frac{K_2}{M_2}} = \left(\frac{1}{2\pi}\right)\left(\frac{800}{0.05}\right)^{1/2} \approx 20\ Hz$$

System Frequency

$$\frac{1}{f_s^2} = \frac{1}{f_1^2} + \frac{1}{f_2^2} = \frac{1}{(31)^2} + \frac{1}{(20)^2}$$

$$\therefore f_s \approx 17\ Hz. \quad \Leftarrow \underline{\text{Dunkerley}}$$

Rev. 1 pg. 5 ~~4 of 05~~

WCG-1-397 R0 SHEET 3 OF 4

COMPARISON OF METHODS TO CALCULATE SYSTEM FREQUENCIES (ALTERNATE CALCULATION - NO CHECKING REQUIRED)

WATTS BAR N.P. UNITS 1&2

COMPUTED JDS DATE 2-23-90

CHECKED N/A DATE

Individual Frequencies

$$\omega^4 - \left[\frac{K_1+K_2}{M_1} + \frac{K_2}{M_2}\right]\omega^2 + \frac{K_1K_2}{M_1M_2} = 0$$

$$\omega^4 - \left[\frac{10{,}000+800}{0.26} + \frac{800}{0.05}\right]\omega^2 + \frac{(10{,}000)(800)}{(0.26)(0.05)} = 0$$

$$\omega^4 - 57{,}538\,\omega^2 + 615{,}384{,}615 = 0$$

$$(\omega^2 - 43{,}338.5)(\omega^2 - 14{,}199.5) \approx 0$$

$$\therefore\ \omega_1 \approx 208 \Rightarrow f_1 \approx 33\ \text{Hz.}$$

$$\omega_2 \approx 119 \Rightarrow f_2 \approx 19\ \text{Hz.}$$

System Frequency (based on individual frequencies on sheet 2)

$$\frac{f_s^2}{f_1f_2} = 0.5\left\{\left[\frac{f_1}{f_2} + (1+\mu)\left(\frac{f_2}{f_1}\right)\right] - \sqrt{\left[\frac{f_1}{f_2} + (1+\mu)\frac{f_2}{f_1}\right]^2 - 4}\right\}$$

$$\frac{f_s^2}{(31)(20)} = 0.5\left\{\left[\cancelto{1.55}{\frac{31}{20}} + \cancelto{0.769}{\left(1+\frac{0.05}{0.26}\right)\left(\frac{20}{31}\right)}\right] - \sqrt{\left[\cancelto{1.55}{\frac{31}{20}} + \cancelto{0.769}{\left(1+\frac{0.05}{0.26}\right)\frac{20}{31}}\right]^2 - 4}\right\}$$

$$f_s \approx 19\ \text{Hz.} \Longleftarrow \underline{\underline{\text{Thomson}}}$$

WCG-1-397 R0 SHEET 4 OF 4

COMPARISON OF METHODS TO CALCULATE SYSTEM FREQUENCIES (ALTERNATE CALCULATION - NO CHECKING REQUIRED)

WATTS BAR N.P.
UNITS 1+2

COMPUTED JDS DATE 2-23-90
CHECKED N/A DATE

System Frequency (based on individual frequencies on sheet 3)

$$\frac{f_s^2}{(33)(19)} = 0.5\left\{\left[\overset{1.737}{\cancel{\frac{33}{19}}} + \overset{0.686}{\cancel{\left(1+\frac{0.05}{0.26}\right)\left(\frac{19}{33}\right)}}\right] - \sqrt{\left[\overset{1.737}{\cancel{\frac{33}{19}}} + \overset{0.686}{\cancel{\left(1+\frac{0.05}{0.26}\right)\frac{19}{33}}}\right]^2 - 4}\right\}$$

$f_s \approx 18$ Hz $\Longleftarrow$ Thomson

SUMMARY

Results from Different Individual Frequencies

f_1	f_2	Dunkerly Appro. (f_s)	Sargent & Lundy (f_s)
30	10	≈ 9.5 Hz	≈ 10 Hz
30	5	≈ 5 Hz	≈ 5 Hz
20	10	≈ 9 Hz	≈ 10 Hz
20	5	≈ 5 Hz	≈ 5 Hz
10	5	≈ 4.5 Hz	≈ 5 Hz.

CONCLUSION

This example (comparison) shows that there is in fact little or no difference between the two methods, except that the Southwell - Dunkerley Approximation method is more clear.

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

8.11.6-1	0
Calculation No.	Revision

Method of design verification (independent review) used (check method used):

1. Design Review	X
2. Alternate Calculation	
3. Qualification Test	

Justification (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

THE TECHNICAL ADEQUACY OF THIS CALCULATION IS JUSTIFIED ON THE BASIS OF CONDUCTING A DETAILED DESIGN REVIEW OF THE PREPARER'S CALCULATIONS.

Design Verifier
(Independent Reviewer)

2-21-90
Date

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

8-11-6-1	3
BRANCH/PROJECT ID:/Calculation No.	Revision

Method of design verification (independent review) used (check method used):

1. Design Review X
2. Alternate Calculation ________
3. Qualification Test ________

Justification (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

DESIGN REVIEW IS APPLICABLE TO THIS CALCULATION, SINCE IT IS BASED ON STANDARD ENGINEERING HANDBOOK METHODS.

The technical adequacy of this calculation is justified on the basis of conducting a detailed review of the preparer's calculation.

M. Assi
Design Verifier
(Independent Reviewer)

1·25·91
Date

WCG-1-397

SARGENT & LUNDY
ENGINEERS

DESIGN CONTROL SUMMARY
DESIGN VERIFICATION
STRUCTURAL ANALYTICAL DIVISION
PAGE i

PROJECT NAME WATTS BAR
PROJECT NO. 8573-03 UNIT NO. 1
CLIENT TVA
CALC. NO. 8.11.6-1 FILE INDEX 8.11
CALC. FOR CALIBRATION OF 2DF APPROACH TO C/S RESPONSE
☒ SAFETY RELATED ☐ NON SAFETY RELATED

SIGNATURE & DATE FOR REV.			IDENTIFICATION OF PAGES PREPARED/REVISED/VOIDED & REVIEW METHOD	COMMENT NO.	QA SERIAL NUMBER
REV. 0 PREPARER	M. Amin	10.26.89	i, ii, iii, 1.1, 2.1 thru 2.11, 3.12 thru 3.14, 8.1 thru 8.6, 6.1 thru (6.3) 9.1 and ia.		
REVIEWER		10.26.89			
APPROVER	Shih-Lung Chu	10-26-89	REVIEW METHOD Detailed Review		✓
REV 0 PREPARER		10-26-89	3.1 thru 3.10. Page 3.11 For Reference only		✓
REVIEWER	M. Amin	10.26.89			
APPROVER	Shih-Lung Chu	10-26-89	REVIEW METHOD Detailed Review		
REV 0 PREPARER	Y. Wang	10-26-89	4.1 thru 4.18		
REVIEWER		10-26-89			
APPROVER	Shih-Lung Chu	10-26-89	REVIEW METHOD Detailed Review		
REV 0 PREPARER		10/26/89	5.1 thru 5.9		
REVIEWER		10-26-89			
APPROVER	Shih-Lung Chu	10-26-89	REVIEW METHOD Detailed Review		

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SARGENT & LUNDY
ENGINEERS

DESIGN CONTROL SUMMARY
DESIGN VERIFICATION
STRUCTURAL ANALYTICAL DIVISION
PAGE ia

PROJECT NAME WATTS BAR
PROJECT NO. 8573-03 UNIT NO. 1
CLIENT TVA
CALC. NO. 8.11.6-1 FILE INDEX 8.11
CALC. FOR CALIBRATION OF 2DF APPROACH TO C/S RESPONSE
☒ SAFETY RELATED ☐ NON SAFETY RELATED

SIGNATURE & DATE FOR REV		SIGNATURE	DATE	IDENTIFICATION OF PAGES PREPARED/REVISED/VOIDED & REVIEW METHOD	COMMENT NO.	QA SERIAL NUMBER
0	PREPARER		10-26-89	7.1 thru 7.6		✓
	REVIEWER	M. Ami	10.26.89			
	APPROVER	Shih-Lung Chu	10-26-89	REVIEW METHOD Detailed Review		
1	PREPARER	M. Ami	10-31-89	Added 2.10a & 2.10b Revised 2.10, 2.11, 8.2, 8.4, 8.5, 8.6, 9.1. and ia.		✓
	REVIEWER		10-31-89			
	APPROVER	Shih-Lung Chu	10-31-84	REVIEW METHOD Detail. Review		
2	PREPARER	S Singh	2-16-90	Revised Pages 1.1, 2.11, 3.11, 3.13, 4.1, 7.1 7.5 and 8.5 Added pages 7.4a and 7.4b		✓
	REVIEWER	M. Ami	2.16.90			
	APPROVER	Shih-Lung Chu	2-16-90	REVIEW METHOD Detail Review		
3	PREPARER	M. Ami	1.25.91	Revised ia, iii Added ib, iv, iia, iib, iic, iid 0.1 thru 0.3		
	REVIEWER	A-Al-Dabbagh	1/25/91			
	APPROVER		1-25-91	REVIEW METHOD Detailed Review		

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SARGENT & LUNDY
ENGINEERS

DESIGN CONTROL SUMMARY
DESIGN VERIFICATION
STRUCTURAL ANALYTICAL DIVISION
PAGE ib

PROJECT NAME WATTS BAR
PROJECT NO. 8573-03 UNIT NO. 1
CLIENT TVA
CALC. NO. 8-11-6-1 FILE INDEX 8.1
CALC. FOR Calibration of 2DF Approach to C/S Response
☒ SAFETY RELATED ☐ NON SAFETY RELATED

COMMENT NO.
QA SERIAL NUMBER

SIGNATURE & DATE FOR REV 3
PREPARER: See signatures on individual pages
REVIEWER: See Signatures on individual Pages
APPROVER: 1-25-91

IDENTIFICATION OF PAGES PREPARED/REVISED/VOIDED & REVIEW METHOD

Added 10-1 thru 10.52
11.1 thru 11-54
12-1 thru 12-113
13-1 thru 13.8
14-1 thru 14-28
15-1 thru 15-95
16-1 thru 16.3
& A.1 thru A.8

REVIEW METHOD Detailed

SIGNATURE & DATE FOR REV__
PREPARER
REVIEWER
APPROVER

REVIEW METHOD

SIGNATURE & DATE FOR REV__
PREPARER
REVIEWER
APPROVER

REVIEW METHOD

SIGNATURE & DATE FOR REV__
PREPARER
REVIEWER
APPROVER

REVIEW METHOD

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SARGENT & LUNDY ENGINEERS

Calcs. For	
☐ Safety-Related	☐ Non-Safety-Related

Calc. No. 8.11.6-1	
Rev. 0	Date
Page ii	of

Client	
Project	
Proj. No. 8573-03	Equip. No.

Prepared by	Date
Reviewed by	Date
Approved by	Date

TABLE OF CONTENTS FOR COMPUTER RUNS

	RUN I.D.	DATE	TITLE TVA Fiche Number	PREPARED BY	REVIEWED BY	APPROVED BY
①	AVFA	89/10/20	MDF for AA2 (SSE Spectra) TVA-F-J001483 CQC	10/24/89	M. Ami 10/25/89	10-26-89
	AWKQ	89/10/21	MDF for AA2 (Flat 1g Spectra) TVA-F-J001483 CQC	10/24/89	M. Ami 10/25/89	
②	AWYJ	89/10/21	MDF for AB2 (SSE Spectra) TVA-F-J001484 CQC	10/24/89	M. Ami 10/25/89	
	AXEU	89/10/21	MDF for AB2 (Flat 1g Spectra) TVA-F-J001484 CQC	10/24/89	M. Ami 10/25/89	
	BHGP	89/10/21	MDF for BC3 (SSE Spectra) TVA-F-J001485 CQC	10/24/89	M. Ami 10/25/89	
	ADQH	89/10/23	MDF for BC3 (Flat 1g Spectra) TVA-F-J001485 CQC	10/24/89	M. Ami 10/25/89	
④	AWYV	89/10/21	MDF for BC4 (SSE Spectra) TVA-F-J001486 CQC	10/24/89	M. Ami 10/25/89	
	ADTE	89/10/23	MDF for BC4 (Flat 1g Spectra) TVA-F-J001486 CQC	10/24/89	M. Ami 10/25/89	
⑤	ATHT	89-10-20	ONE SPAN BEAM TVA-F-J001487 CQC	10/24/89		
	ASXL	89-10-20	TWO SPAN BEAM TVA-F-J001487 CQC	10/24/89		
	ASZP	89-10-20	THREE SPAN BEAM TVA-F-J001487 CQC	10/24/89		
⑥ one fiche	AMT0	89-10-18	STIFFNESS CALC FOR CM * FACTOR (DUCT 24x36)	YWa 10/26/89	M. Ami 10/26/89	
	AMTS	89-10-18	STIFFNESS CALC FOR CM * FACTOR (DUCT 60x72)	YWa 10/26/89	M. Ami 10/26/89	10-26-89
			* TVA-F-J001488			

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

WCG-1-397

SARGENT & LUNDY
ENGINEERS

Calcs. For		Calc. No. 8011.6-1
☒ Safety-Related	☐ Non-Safety-Related	Rev. 3 · Date
		Page ii a of

Client	TVA	Prepared by	Date 1/25/91
Project	WATTS BAR	Reviewed by D. M. Lamoureux	Date 1-25-91
Proj. No.	8573-03 · Equip. No.	Approved by	Date

TABLE OF CONTENTS FOR COMPUTER RUNS

RUN I.D	DATE Ref. Page	TITLE OF FICHE TVA Fiche Number	PREPARED BY	REVIEWED BY	APPROVED BY
HNEL	11/15/90 page 11.9	MDF FOR AA2150 SSE-EW TVA-F-G097410	1/24/91	D. M. Lamoureux 1-25-91	1-25-91
JGAX	11/28/90 page 11.10	MDF FOR AA2150 FLAT 1-g TVA-F-G097424	1/25/91	D. M. Lamoureux 1-25-91	
HUAO	11/17/90 page 11.12	MDF FOR AA2200 SSE-EW TVA-F-G097436	1/25/91	D. M. Lamoureux 1-25-91	
JGIN	11/28/90 page 11.13	MDF FOR AA2200 FLAT 1-g TVA-F-G097440	1/25/91	D. M. Lamoureux 1-25-91	
HNJI	11/15/90 page 11.15	MDF FOR AB2150 SSE-EW TVA-F-G097442	1/25/91	D. M. Lamoureux 1-25-91	
JGIX	11/28/90 page 11.16	MDF FOR AB2150 FLAT 1-g TVA-F-G097444	1/25/91	D. M. Lamoureux 1-25-91	
HUBP	11/17/90 pg. 11.18	MDF FOR AB2200 SSE-EW TVA-F-G097446	1/25/91	D. M. Lamoureux 1-25-91	
JGKF	11/28/90 pg. 11.19	MDF FOR AB2200 FLAT 1-g TVA-F-G097448	1/25/91	D. M. Lamoureux 1-25-91	
JKOV	11/29/90 pg. 11.21	MDF FOR BC3150 SSE-EW TVA-F-G097450	1/25/91	D. M. Lamoureux 1-25-91	
JKUF	11/29/90 pg. 11.22	MDF FOR BC3150 FLAT 1-g TVA-F-G097452	1/25/91	D. M. Lamoureux 1-25-91	
JKPI	11/29/90 pg. 11.24	MDF FOR BC3200 SSE-EW TVA-F-G097456	1/25/91	D. M. Lamoureux 1-25-91	
JKVJ	11/29/90 pg. 11.25	MDF FOR BC3200 FLAT 1-g TVA-F-G097460	1/25/91	D. M. Lamoureux 1-25-91	
JKOB	11/29/90 pg. 11.27	MDF FOR BC4125 SSE-EW TVA-F-G097462	1/25/91	D. M. Lamoureux 1-25-91	
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JKNQ	11/29/90 pg. 11.30	MDF FOR BC4150 SSE-EW TVA-F-G097466	1/25/91	D.M. Lamoureux 1-25-91	
JLPL	11/29/90 pg. 11.31	MDF FOR BC4150 FLAT 1-9 TVA-F-G097468	1/25/91	D.M. Lamoureux 1-25-91	
JKOL	11/29/90 pg. 11.33	MDF FOR BC4200 SSE-EW TVA-F-G097470	1/25/91	D.M. Lamoureux 1-25-91	
JKTP	11/29/90 pg. 11.34	MDF FOR BC4200 FLAT 1-9 TVA-F-G097472	1/25/91	D.M. Lamoureux 1-25-91	
CBLL	12/12/90 pg. 11.36	MDF FOR AA2150F SSE-EW TVA-F-G097494	1/25/91	D.M. Lamoureux 1-25-91	
BCWL	12/07/90 pg. 11.38	MDF FOR AA2150F FLAT 1-9 TVA-F-G097476	1/25/91	D.M. Lamoureux 1-25-91	
CBWF	12/12/90 pg. 11.40	MDF FOR AA2150H SSE-EW TVA-F-G097478	1/25/91	D.M. Lamoureux 1-25-91	
AQKK	12/04/90 pg. 11.42	MDF FOR AA2150H FLAT 1-9 TVA-F-G097480	1/25/91	D.M. Lamoureux 1-25-91	
CBLZ	12/12/90 pg. 11.44	MDF FOR BC3150F SSE-EW TVA-F-G097482	1/25/91	D.M. Lamoureux 1-25-91	
AZUW	12/06/90 pg. 11.46	MDF FOR BC3150F FLAT 1-9 TVA-F-G097484	1/25/91	D.M. Lamoureux 1-25-91	
AQMK	12/04/90 pg. 11.49	MDF FOR CT33 SSE-EW TVA-F-G097486	1/25/91	D.M. Lamoureux 1-25-91	
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INDF	1/18/91 pg. 15.5	MDF FOR ELBTEE1 X-DIR TVA-F-G097418	1/25/91	A. Ah Dabbagh 1/25/91	
IPWC	1/18/91 pg. 15.13	MDF FOR ELBTEE1 Z-DIR TVA-F-G097420	1/25/91	A. Ah Dabbagh 1/25/91	
JPZL	1/23/91 pg. 15.24	MDF FOR ELBTEE2 Y-DIR TVA-F-G097422	1/25/91	A. Ah Dabbagh 1/25/91	
JOOA	1/23/91 pg. 15.52	ELBOW STUDY FOR TORQUE TVA-F-G097426	1/25/91	A. Ah Dabbagh 1/25/91	
AOXZ	12/04/90 pg. 14.7	2SP150 SSE-EW TVA-F-G097428	1/25/91	D. M. Lamoureux 1-25-91	
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AOZR	12/04/90 pg. 14.11	3SP150 SSE-EW TVA-F-G097434	1/25/91	D. M. Lamoureux 1-25-91	
APBH	12/04/90 pg. 14.12	3SP150 FLAT 1-G TVA-F-G097434	1/25/91	D. M. Lamoureux 1-25-91	
APDC	12/04/90 pg. 14.13	3SP MIX SSE-EW TVA-F-G097438	1/25/91	D. M. Lamoureux 1-25-91	
APDH	12/04/90 pg. 14.14	3SPMIX FLAT 1-G TVA-F-G097438	1/25/91	D. M. Lamoureux 1-25-91	1-25-91

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LIST OF COMPUTER PROGRAMS

1. GTSTRUDL Version 8701 CDC

2. Program for Calculating Effective Duct Properties per Appendix A of this calculation

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Appendix A A.1

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0. ABSTRACT

Initially, during October 1989 the following studies were performed to establish a multi-mode factor for use with an equivalent static analysis using a 2DOF system approach:

a. Continuous spans on flexible supports (see Sections 1 through 6 of the Calculation).

b. Continuous spans on rigid supports (see Section 7 of the Calculation)

The conclusions of this work are summarized in Section 8 of the Calculation. In summary, it was concluded that for systems with flexible supports a 1.2 multi-mode factor, and for systems with rigid supports a 1.0 multi-mode factor is adequate for use.

During the week of Nov. 10, 1990, at Watts Bar site, the details of the work summarized above

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were presented to the NRC. Based on NRC comments in the meeting, TVA agreed to supplement the existing Calculations to consider more cases to show the adequacy of the multi-mode factor of 1.2 (1.0 for rigid supports). These cases were to include straight runs and runs with elbows and tees. For straight runs, the following conditions were to be investigated:

- * greater span length variability
- * Cases including end span evaluation
- * multi-tiered systems

Results of these additional studies are presented in Sections 10 through 15 of the Calculation, Section 10 being the introduction and background for the additional work. Conclusions of these additional studies are presented in Section 16 of the Calculation. In summary, the

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additional studies confirm the Conclusions of the earlier study that the use of 1.2 multi-mode factor (1.0 for systems with rigid supports) is adequate.

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1. PURPOSE

The purpose of this calculation is to calibrate an approximate two-degrees-of-freedom (2DF) approach to determine the dynamic response of multi-degrees-of-freedom (MDF) systems consisting of several spans of components on flexible supports. The 2DF approach is described herein. The components may be conduits, HVAC ducts or cable trays. The calibration is achieved by selecting four component/support (C/S) systems] Rev2 and by comparing the MDF response to the corresponding responses obtained through the 2DF procedure

The calculation also demonstrates that for component with rigid supports, the component response is a single mode response and an equivalent static approach as stated in the text can be used.

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2. TWO-DGREES-OF-FREEDOM (2DF) APPROACH FOR COMPONENT AND SUPPORT (C/S) SEISMIC RESPONSE

Suppose either supports B or C or the span BC in Figure (2-1) is to be evaluated. The subsystem of interest is a part of a largers system. The information needed to implement the 2DF approach is also shown in Figure 2-1. To consider the response in the seismic direction s (s = x, y, z), we also need the applicable floor spectrum for that direction.

For each seismic direction, the approach is based on constructing a 2DF system such as the one shown in Figure (2-2). The three parameters of this 2DF system ($\omega_1, \omega_2, \mu = \frac{m_2}{m_1}$) are so selected as to obtain a lowest reasonable value for the fundamental frequency of the 2DF system. This frequency value is then used to select a conservative

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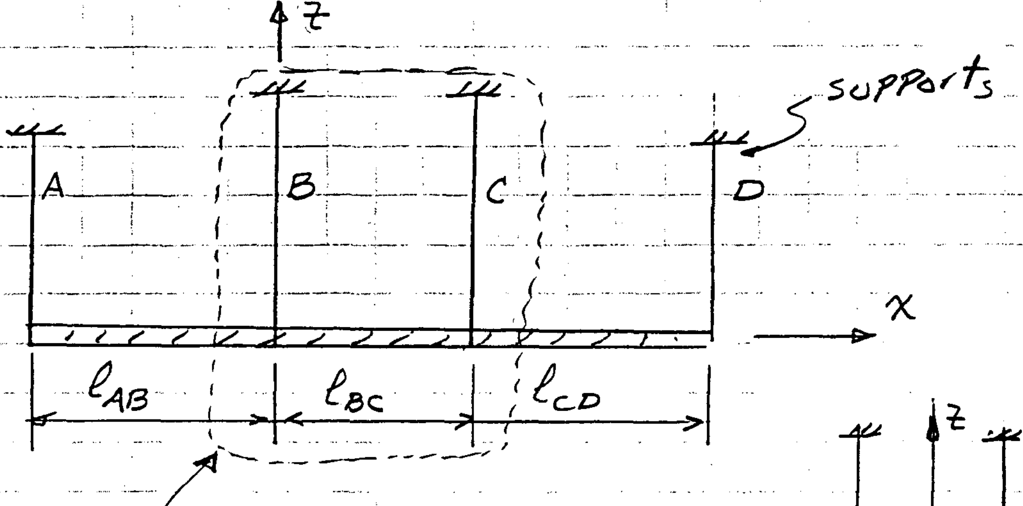
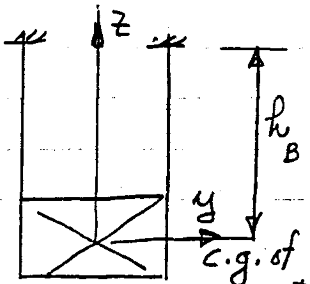
Procedure for cosidering a C/S system



SPan BC or Supports B or C are of interest



c.g. of component (i.e. duct, conduits, tiers of tray)

FIG. 2-1 - C/S-System considered

Information needed to implement (2DF) approach for supports B or C or for span BC

W_i = total weight of support i, i = B or C

l_{AB}, l_{BC}, l_{CD} = Component spans

W_{AB}, W_{BC}, W_{CD} = total weights on the span including the concentrated weights, if they exist

k_{is} = stiffness of support i at the cg of component in the seismic direction s; i = B or C
$s = x, y, z$

I_{BCs} = moment of inertia of span BC for bending related to seismic directions. Example: for seismic in y-direction, I_{BCy} = bending moment of inertia of the component BC about the z-axis.

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acceleration from the response spectrum. The supports and the span are then evaluated for this acceleration.

In the following we present the algorithm for calculations and then calibrate the results against a few MDF analysis results on specific c/s systems

2DF Frequency Equation

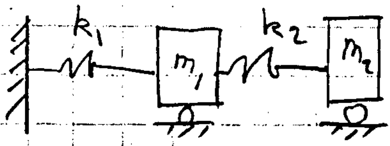

FIGURE 2-2 - 2DF System

ω_1 = uncoupled frequency of mass 1 $= \sqrt{\frac{k_1}{m_1}}$ (rad./sec.)

ω_2 = " " " " 2 $= \sqrt{\frac{k_2}{m_2}}$ (rad./sec.)

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From Reference 1, (Equation (6.2-9) with $k_2 = 0$)
$k_c = k_2$ of our case

$$\omega^4 - \left[\frac{k_1+k_2}{m_1} + \frac{k_2}{m_2}\right]\omega^2 + \frac{k_1 k_2}{m_1 m_2} = 0$$ ✓

with $k_1 = m_1\omega_1^2$, $k_2 = m_2\omega_2^2$

$$\frac{k_1+k_2}{m_1} = \frac{m_1\omega_1^2 + m_2\omega_2^2}{m_1} = \omega_1^2 + \frac{m_2}{m_1}\omega_2^2$$

Let $\mu = \frac{m_2}{m_1}$ = mass ratio.

$$\therefore \omega^4 - \left[\omega_1^2 + (1+\mu)\omega_2^2\right]\omega^2 + \omega_1^2\omega_2^2 = 0$$

$$\omega^2 = \frac{\left[\omega_1^2 + (1+\mu)\omega_2^2\right] \pm \left\{\left[\omega_1^2 + (1+\mu)\omega_2^2\right]^2 - 4\omega_1^2\omega_2^2\right\}^{1/2}}{2}$$ ✓

Therefore the fundamental frequency of the 2DF system is

$$\omega^2 = \frac{1}{2}\left\{\left[\omega_1^2 + (1+\mu)\omega_2^2\right] - \sqrt{\left[\omega_1^2 + (1+\mu)\omega_2^2\right]^2 - 4\omega_1^2\omega_2^2}\right\} \quad (1)$$

or

$$\omega^2 = \frac{\omega_1\omega_2}{2}\left\{\left[\frac{\omega_1}{\omega_2} + (1+\mu)\frac{\omega_2}{\omega_1}\right] - \sqrt{\left[\frac{\omega_1}{\omega_2} + (1+\mu)\frac{\omega_2}{\omega_1}\right]^2 - 4}\right\} \quad (1')$$

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Note that for a fixed ω_1 & ω_2 as the mass ratio, μ, increases the combined frequency decreases. This is demonstrated by following numerical examples.

For $\frac{\omega_1}{\omega_2} = 1.5$

	$\frac{\omega^2}{\omega_1 \omega_2}$
$\mu = 0.5$	0.50
$= 1$	0.41
$= 2$	0.31

as $\mu \uparrow$ $\omega^2 \downarrow$ ✓

For $\frac{\omega_1}{\omega_2} = 0.667$

	$\frac{\omega^2}{\omega_1 \omega_2}$
$\mu = 0.5$	0.40
$= 1.0$	0.30
$= 2.0$	0.20

as $\mu \uparrow$ $\omega^2 \downarrow$ ✓

Because of this behavior, when ω_1 and ω_2 are selected at their reasonably low value, to minimize ω of the combined system, the highest reasonable μ should be used.

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Calculation of 2DF system parameters (ω_1, ω_2, μ)

Need information for
- supports B & C
- spans AB, BC, and CD

} as shown in Figure (2-1)

1. Compute k_{BS}, k_{CS}

2. Compute

$$m_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$ ✓

$$m_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$ ✓

$$\omega_{1BS} = \sqrt{\frac{k_{BS}}{m_{1B}}}, \quad \omega_{1CS} = \sqrt{\frac{k_{CS}}{m_{1C}}}$$ ✓

Use $\omega_{1S} = \min(\omega_{1BS}, \omega_{1CS})$ ✓

$m_1 = \min(m_{1B}, m_{1C})$ for μ calculation ✓

3. $$k_{2S} = \frac{48 E I_{BCS}}{(\ell_{BC})^3}$$ ✓

$$m_{2BC} = \frac{W_{BC}}{2g}$$ ✓

$$\omega_{2S} = \sqrt{\frac{k_{2S}}{m_{2BC}}}$$ ✓

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$$m_{2AB} = \frac{W_{AB}}{2g}, \quad m_{2CD} = \frac{W_{CD}}{2g} \checkmark$$

$$m_2 = \text{max.}\left\{\frac{m_{2AB}+m_{2BC}}{2} \text{ or } \frac{m_{2BC}+m_{2CD}}{2}\right\}. \checkmark$$

$$\mu = \frac{m_2}{m_1} \checkmark$$

4. $$\omega_s^2 = 0.5\left\{\left[\omega_{1s}^2+(1+\mu)\omega_{2s}^2\right] - \sqrt{\left[\omega_{1s}^2+(1+\mu)\omega_{2s}^2\right]^2 - 4\omega_{1s}^2\omega_{2s}^2}\right\}. \checkmark$$

$$f_s = \frac{\omega_s}{2\pi} \checkmark$$

5. If $f_s \geq 33$ Hz, $a_s = S_a(33)$ ✓

If $f_s < 33$ Hz, a_s = { largest S_a for frequencies greater than or equal to f_s }

6. Determine design bending moment and shear of span BC by considering appropriate boundary conditions for the span (Continuous in the case shown) and by applying the acceleration a_s to the span with distributed and concentrated span loads at their appropriate location.

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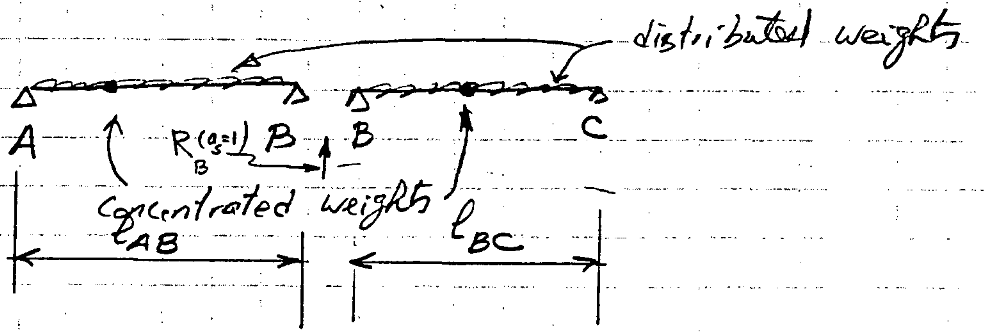
7. Determine the support force R, at location where support stiffness is calculated by doing the following. Consider, for example, support B. The adjacent spans are AB and BC. Consider these as simply supported with concentrated weights, if they exist, at their proper location within each span



$$R_B = a_s\left[R_B(a_s=1) + \frac{W_B}{2}\right]$$

A similar calculation is used to determine R_C by using spans BC and CD.

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Condition for Support Rigidity in Terms of Support Frequency

Rewrite Equation (1') in terms of frequency by simply multiplying all ω values by 2π. Clearly, the result is

$$\frac{f^2}{f_1 f_2} = 0.5\left\{\left[\frac{f_1}{f_2} + (1+\mu)\frac{f_2}{f_1}\right] - \sqrt{\left[\frac{f_1}{f_2} + (1+\mu)\frac{f_2}{f_1}\right]^2 - 4}\right\} \qquad (a)$$

It is of interest to determine a high numerical value for f_1 such that for all reasonable values of mass ratio μ and span frequency f_2, the support may be considered as rigid.

Take $\mu = 1$

$f_2 = 10$ cps, 15 cps, 20 cps, 25 cps

$f_1 = 40$ cps, 50 cps, 60 cps

The resulting values of $\frac{f^2}{f_1 f_2}$ from Equation (a) are listed below:

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values of $\frac{f^2}{f_1 f_2}$ for $\mu = 1$

f_1 \ f_2	10	15	20	25
40	0.234	0.323	0.382	0.410
50	0.192	0.273	0.338	0.382
60	0.162	0.234	0.297	0.346

frequencies in cps units

The resulting values of f for above ranges of f_1 and f_2 are

Values of f for $\mu = 1$

f_1 \ f_2	10	15	20	25
40	9.67	13.92	17.48	20.2
50	9.80	14.31	18.38	21.85
60	9.86	14.5	18.88	22.78

Rev. 1
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Per item 2 on page 2.6, the frequency f_1 is calculated by taking 1/4 of each span mass and lumping it at the support. For using the criterion of support rigidity, it is more convenient to deal with a support frequency f_1^* that is obtained by using tributary mass from each span. This means f_1^* is a frequency obtained using the same support stiffness and $\frac{1}{2}$ the mass of each span. Therefore,

$$f_1^* = \frac{f_1}{\sqrt{2}}$$

Ratio f/f_2 for $f_1 = 50$ Hz ($f_1^* = .707 \times 50 = 35.4$ Hz), $\mu = 1$

f_2	f/f_2
10	0.98
15	0.95
20	0.92
25	0.87

Ave $\frac{f}{f_2} = 0.93$

This average is well within the spectrum peak widening range of ± 15%

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Conclusion

When the support frequency f_1^* calculated on the basis of span tributary weight is 33 cps or higher, the support may be considered as rigid. Rev. 1

Under this condition value of a_s for span and support evaluation is determined as follows:

If $f_2 \geq 33$ Hz, a_s = ZPA from building Analysis Rev. 2

If $f_2 < 33$ Hz, a_s = {largest Sa for frequencies greater than or equal to f_2}

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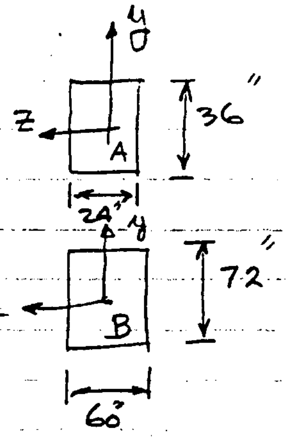
3. MDF SYSTEMS ANALYZED (Component on Flexible Supports)

Four MDF systems have been analyzed. They were intended to simulate the general seismic response of a straight run of HVAC duct, continuous on several duct supports. Supports are considered to be identical but their spacing (duct spans) vary. Figure (3-1) shows the geometry of duct-support system analyzed. This figure also shows the node numbering used in the finite element model. All members (duct and support members) are beam elements.

The following three-descriptor system identification code is used: $Q_1\ Q_2\ Q_3$

Q_1 = (duct intifier)
- A for 24 x 36 duct
- B for 60 x 72 duct



Q_2 (basic span ℓ identifier)
- A for $\ell = 8'-0"$
- B for $\ell = 10'-0"$
- C for $\ell = 12'-0"$

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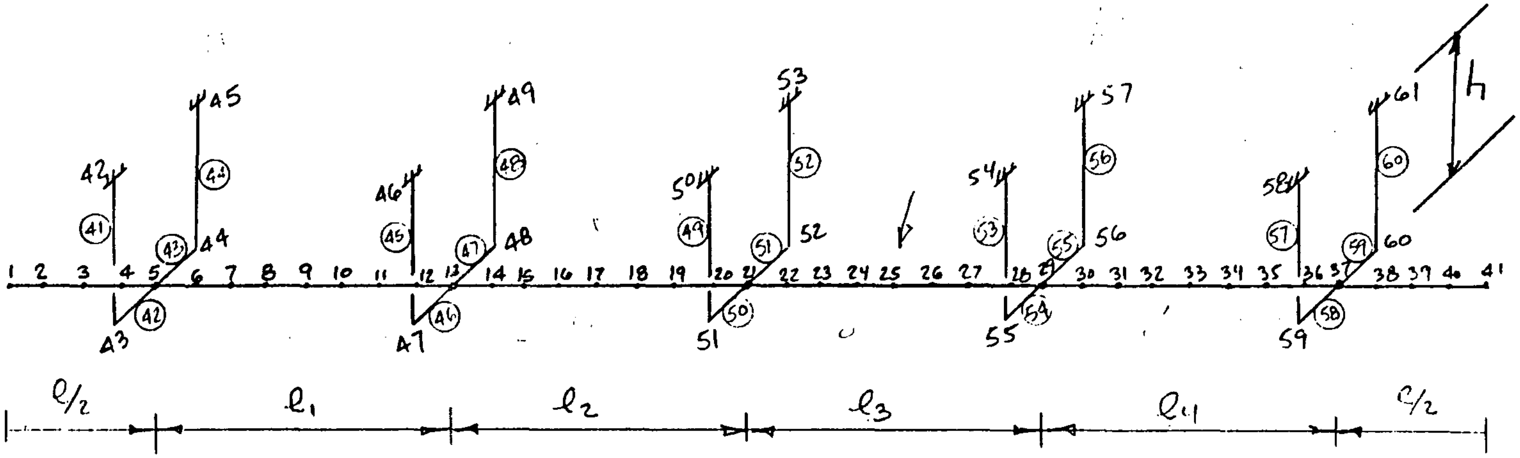
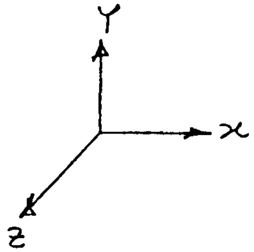


FIGURE 3-1 MDF COMPONENT SUPPORT SYSTEM ANALYZED



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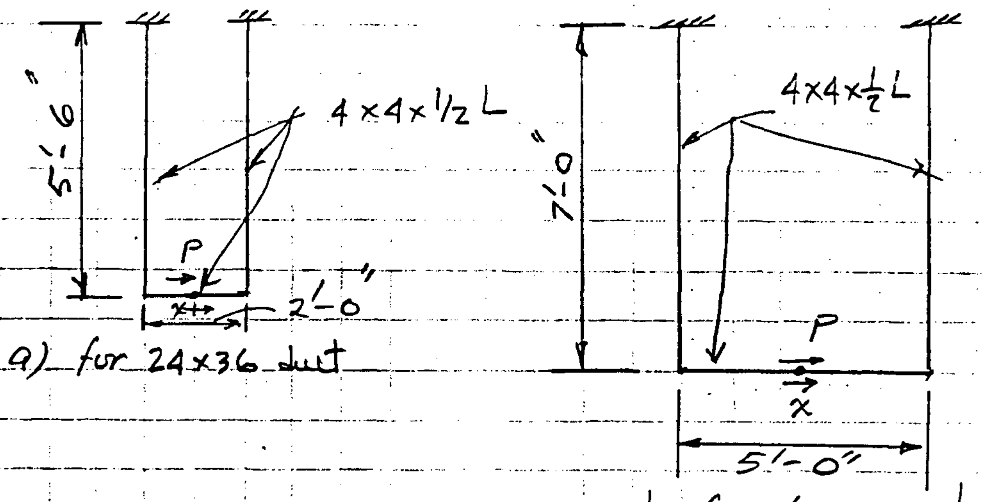
Q_3 Individual span length identifier

$$\begin{cases} 2 \rightarrow \ell_1 = \ell_3 = \ell_4 = \ell \ , \ \ell_2 = 1.25\ell \\ 3 \rightarrow \ell_1 = \ell_4 = \ell \ , \ \ell_2 = \ell_3 = 1.25\ell \\ 4 \rightarrow \ell_1 = \ell_2 = 1.25\ell \ , \ \ell_3 = \ell_4 = \ell \end{cases}$$

The supports are made of 4 x 4 x 1/2 L^s which is a common type of member size for HVAC supports. The dimension H in Figure (3-1) is

- 5'-6" for 24x36 duct
- 7'-0" for 60x72 duct

The length of the horizontal hanger member (nodes 51-50-52, for example in Figure (3-1)) is the same as the duct width supported. Therefore hangers used have the following idealized geometries



a) for 24x36 duct

b) for 60x72 duct

FIGURE 3-2 Geometry of Duct Supports

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Returning to system identification code, for example, the code BC4, has the following configuration in the yx-plane

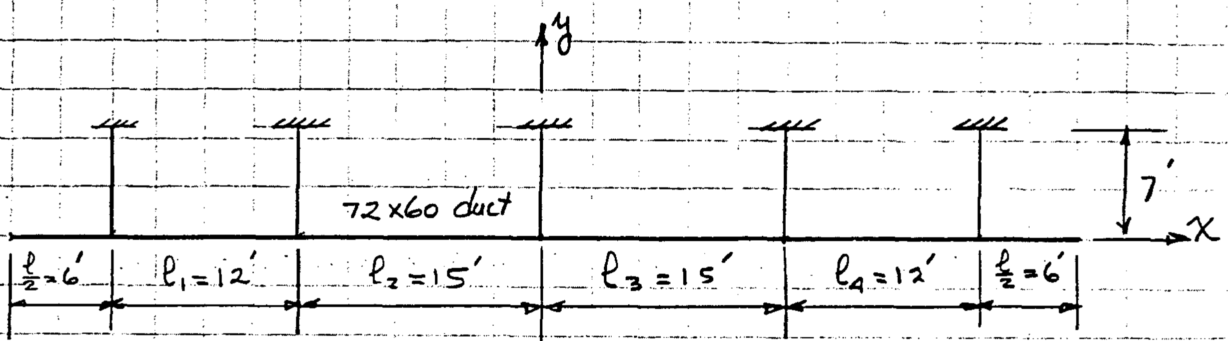

FIGURE 3-3 VIEW OF SYSTEM BC4 IN YX-plane

System Boundary Conditions

- Hanger connections fixed against rotation and translation
- System terminations at nodes 1 & 41 in Figure 3-1 free to translate, fixed against rotation ($\theta_x = \theta_y = \theta_z = 0.$)
- duct beam to horizontal support member connection [nodes (5,43), (13,47) .. etc] in Figure 3-1 are continuous (fully connected)

Unit Weights

- support members all 12.8 #/ft. (4x4x½ L)
- duct { 31 #/l for 24x36 duct (usual design weight for this size duct)
  { 101.2 #/l for 60x72 duct (same)

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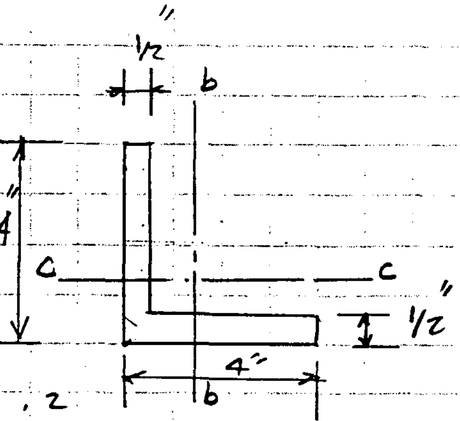
Material

– duct { $E = 29000$ ksi, $\nu = 0.3$, $F_y = 33$ ksi

– Support { $E = 29000$ ksi, $\nu = 0.3$

Member Properties

– Support



$I_{bb} = I_{cc} = 5.56\ in^4$

$I_{aa} = 0.322$

$A_{bb} = A_{cc} = \frac{1}{2} \times 4 = 2\ in^2$

$A_{aa} = 3.75\ in^2$

– Ducts

For 24×36 duct, t=0.0299" (#22 gage)
60×72 duct, t=0.0356 (#20 gage)

The values of I_{bb}, I_{bc} are evaluated by first considering the effective channel sections shown in Figure 3-4. These values are reduced by $(0.46)^2$ to account for frequency reduction observed in TVA duct

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tests of Reference 2.

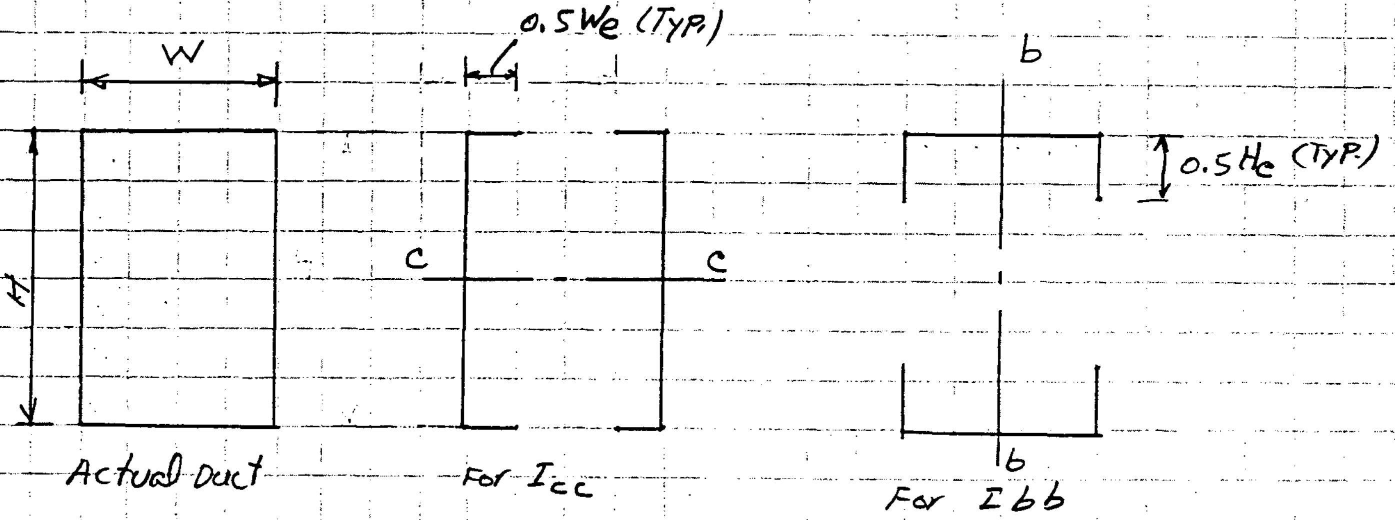

FIGURE 3-4 EFFECTIVE SECTIONS FOR MOMENT OF INERTIA CALCULATION

$$W_e = \frac{326t}{\sqrt{f}}\left(1 - \frac{64.9}{\left(\frac{W}{t}\right)\sqrt{f}}\right), \quad H_e = \frac{326t}{\sqrt{f}}\left(1 - \frac{64.9}{\left(\frac{H}{t}\right)\sqrt{f}}\right)$$

The stress f in these equations used is

$$f = 0.96 F_y = 0.96 \times 33 = 31.68 \text{ ksi}$$

$$I_{aa} = I_{bb} + I_{cc}$$

$$A_{aa} = \text{solid metal area} = 2t(W+H)$$

$$A_{bb} = 2Ht$$

$$A_{cc} = 2Wt$$

Comments on Duct Member Properties Used:

1. In Reference 2, the constant 0.46 is recommended for a double channel effective section corresponding to effective stress f that results from 1g acceleration load on the duct

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This stress will be smaller than 31.68 ksi used here. Therefore, the analysis here is using a somewhat smaller moment of inertia

2. In Reference 3, it has been concluded that for Revision 7 of criteria WB-DC-40-31.8, the duct effective sections should be defined differently so that using an allowable stress of $0.9F_y$ produces seismic capacities consistent with TVA fragility tests in Reference 2.

Since the aim of present calculation is to calibrate the ZDF results to MDF results, and since the same properties are used in the corresponding ZDF and MDF solutions, there is no reason to change the section properties that are used in this calculation.

The calculated duct properties are given in the next two pages

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DUCT 24x36

CALCULATE DUCT PROPERTIES

$F_y = 33.0\,\text{ksi}$

$F_{\text{allowable SSE}} = 0.96\,F_y = 31.68^{\text{ksi}}$

$w/t = 24/0.0299 = 802.68$

$$We_{c\text{-}c} = \frac{326\,t}{\sqrt{f}}\left(1 - \frac{64.9}{w/t\,\sqrt{f}}\right) = \frac{326 \times 0.0299}{\sqrt{31.68}}\left(1 - \frac{64.9}{802.68\sqrt{31.68}}\right) = 1.707''$$

$$I_{e\,c\text{-}c} = 0.0299\left(\frac{36^3}{12} + 1.707 \times 18^2\right) \times 2 = 265.57\ \text{in}^4$$

$$We_{b\text{-}b} = \frac{326 \times 0.0299}{\sqrt{31.68}}\left(1 - \frac{64.9}{36/0.0299 \times \sqrt{31.68}}\right) = 1.715''$$

$$I_{e\,b\text{-}b} = 0.0299\left(\frac{24^3}{12} + 1.715 \times 12^2\right) \times 2 = 83.66\ \text{in}^4$$

CORRECTION FACTOR = 0.46 PER TVA TESTING FOR FREQUENCY
REF. WB-DC-40-31.8

$\therefore$ Area $A_{aa} = 0.0299(24+36) \times 2 = 3.59\ \text{in}^2$

$A_{bb} = 0.0299(36) \times 2 = 2.15\ \text{in}^2$

$A_{cc} = 0.0299(24 \times 2) = 1.44\ \text{in}^2$

$I_{bb} = 0.46^2 \times 83.66 = 17.70\ \text{in}^4$

$I_{cc} = 0.46^2 \times 265.57 = 56.19\ \text{in}^4$

$I_{aa} = 17.7 + 56.19 = 73.89\ \text{in}^4$

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DUCT 60×72

$$W_{e\,c\text{-}c} = \frac{326 \times 0.0359}{\sqrt{31.68}}\left(1 - \frac{64.9}{\frac{60}{0.0359}\sqrt{31.68}}\right) = 2.07''$$

$$W_{e\,b\text{-}b} = \frac{326 \times 0.0359}{\sqrt{31.68}}\left(1 - \frac{64.9}{\frac{72}{0.0359} \times \sqrt{31.68}}\right) = 2.07''$$

$$I_{e\,(c\text{-}c)} = 0.0359\left[\frac{72^3}{12} + 2.07 \times 36^2\right] \times 2 = 2425.9\ \text{in}^4$$

$$I_{e\,(b\text{-}b)} = 0.0359\left[\frac{60^3}{12} + 2.07 \times 30^2\right] \times 2 = 1426.2\ \text{in}^4$$

AREA $A_a = 0.0359 \times 2\,(72 + 60) = 9.48\ \text{in}^2$

$A_b = 0.0359 \times 2 \times 72 = 5.17\ \text{in}^2$

$A_c = 0.0359 \times 2 \times 60 = 4.31\ \text{in}^2$

$I_{bb} = 0.46^2 \times 1426.2 = 301.8\ \text{in}^4$

$I_{cc} = 0.46^2 \times 2425.9 = 513.3\ \text{in}^4$

$I_{a\text{-}a} = 301.8 + 513.3 = 815.1\ \text{in}^4$

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Input Response spectra

The four MDF systems (AA2, AB2, BC3 and BC4) are evaluated for response in z-direction in Figure 3-1. Two sets of analyses are made.

1. The z-direction response spectrum corresponds the piecewise linear definition of SSE-EW at elevation 771.5' in Auxiliary-Control Building. Note that Log(frequency) is in the horizontal scale. (Figure 3-5). This will be referred to a "SSE-EW spectrum at elev. 771.5".

2. The z-direction spectrum is a flat spectrum shown in Figure 3-6. This will be referred to as "Flat spectrum"

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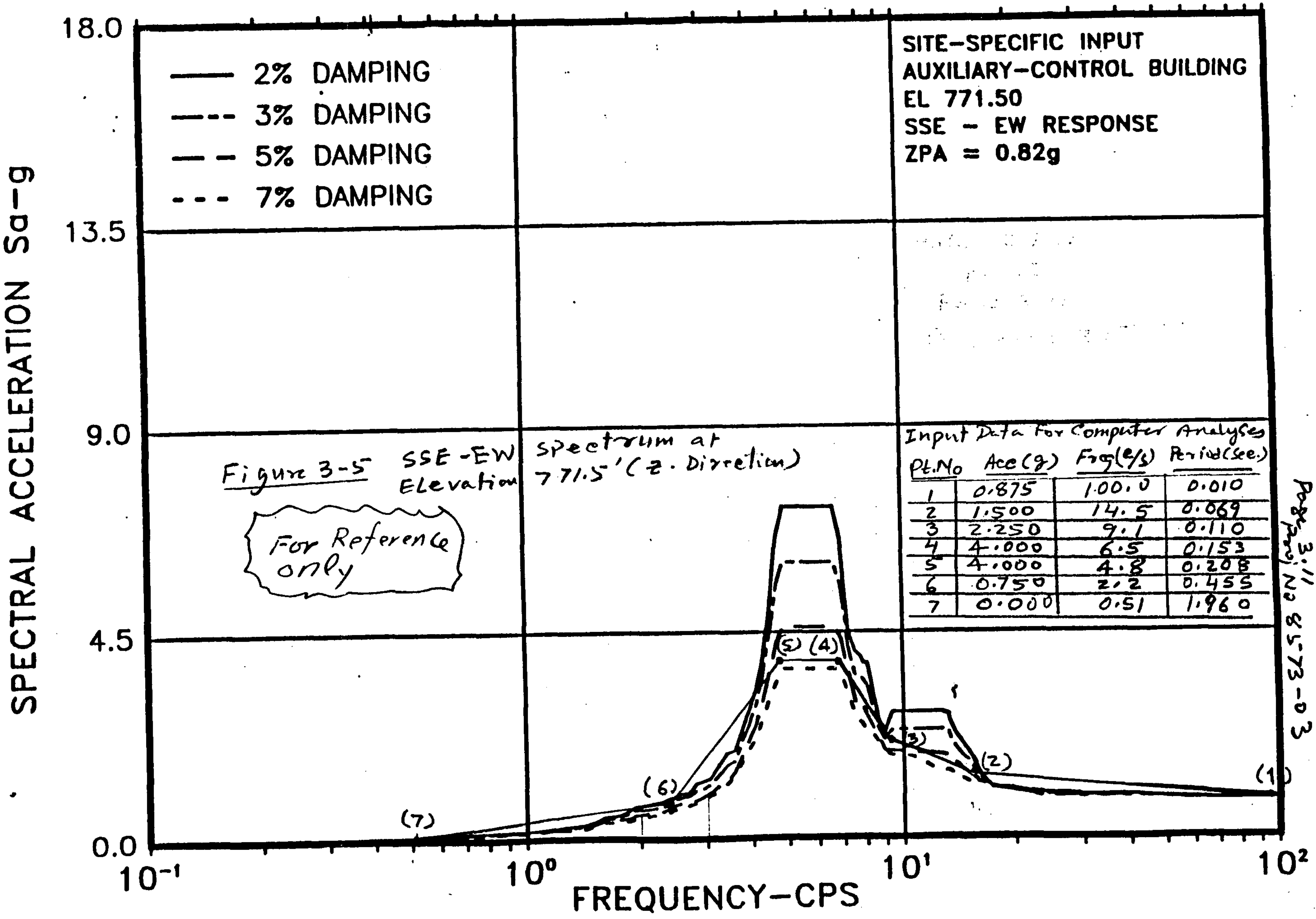

Figure 3-5 SSE-EW spectrum at Elevation 771.5' (Z. Direction)

For Reference only

Input Data For Computer Analyses

Pt.No	Acc (g)	Frq (c/s)	Period (Sec.)
1	0.875	100.0	0.010
2	1.500	14.5	0.069
3	2.250	9.1	0.110
4	4.000	6.5	0.153
5	4.000	4.8	0.208
6	0.750	2.2	0.455
7	0.000	0.51	1.960

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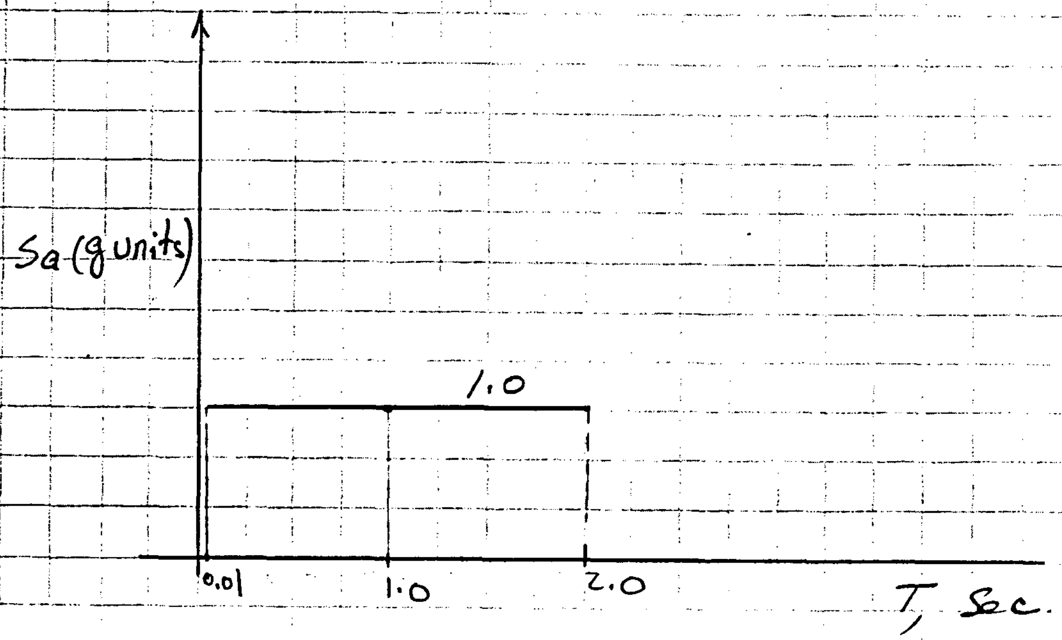

FIGURE 3-6 FLAT SPECTRUM (Z-Direction)

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Solution for MDF Response

- Program GTSTRUDL is used Rev. 2

- All modes with frequency less than or equal to 33 Hz are considered

- The complete Quadratic Combination (CQC) of the Program is used to combine the maximum modal responses to obtain the total response. The reason for using CQC is as follows:

When modal frequencies are well-separated, CQC gives the same result as the SRSS method. For well-separated frequencies the combined result thus obtained provides a reasonable approximation to the average of maximum responses calculated from making time history analyses using time histories that correspond to a design spectrum. W...

When frequencies are not well-separated, the CQC procedure gives a closer approximation to time history results than the SRSS method. (Reference 4, for example)

The systems analyzed here for the calibration study do have contributing modes with close frequencies. Since the aim is to provide a calibration constant for the 2DF system analysis that will make results in close agreement with time history result, the CQC procedure has been used in this work

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It is also noted that because of better applicability of the CQC method, this procedure is also recommended in ASCE Standard 4-86 (Reference 5) and in Section 3.3.1 of Reference 6.

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4. 2DF ANALYSIS RESULTS FOR MDF SYSTEM IN FIGURURE (3-1): COMPONENT ON FLEXIBLE SUPPORTS

The obtained results are summarized below. Detailed calculations are presented in the following pages (4.2 through 4.18). Rev. 2

MDF System Id.	Frequency from 2DF CPS	Acc. (g)	Span Mom. 'lb	Span Shear lb	Support Force Lb
For SSE-EW spectrum at Elev. 771.5					
AA2 (AA200)	15.95 ✓	1.47 ✓	456 ✓	228 ✓	532 ✓
AB2 (AB200)	13.35 ✓	1.63 ✓	790 ✓	316 ✓	704 ✓
BC3 (BC300)	5.2 ✓	4.0 ✓	9108 ✓	3036 ✓	5958 ✓
BC4 (BC400)	5.2 ✓	4.0 ✓	9108 ✓	3036 ✓	6558 ✓
For Flat spectrum					
AA2 (AA200)	15.95	1.0 ✓	310 ✓	155 ✓	362 ✓
AB2 (AB200)	13.35	1.0 ✓	485 ✓	194 ✓	432 ✓
BC3 (BC300)	5.2	1.0 ✓	2277 ✓	759	1490 ✓
BC4 (BC400)	5.2	1.0 ✓	2277 ✓	759 ✓	1640 ✓

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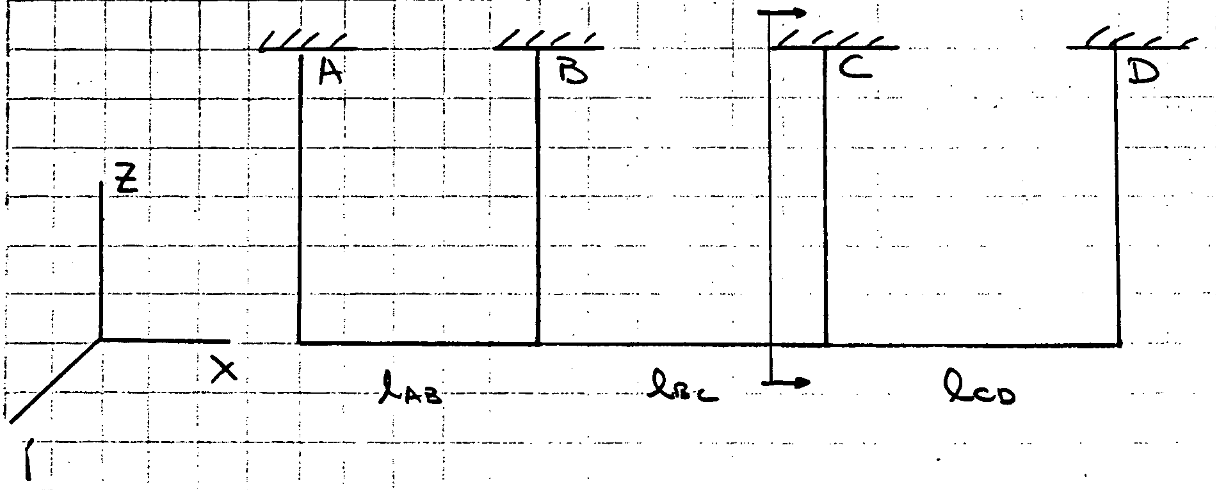
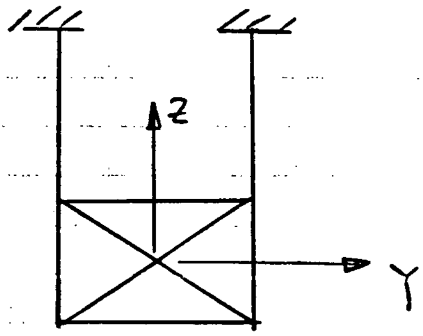
General Arrangement





Section View

Spectra Curve (Ref. Calc. 5.1)

Site - Specific Input
Auxiliary - Control Room
EL. 771.5
SSE - EW response
ZPA = 0.82g
7% damping

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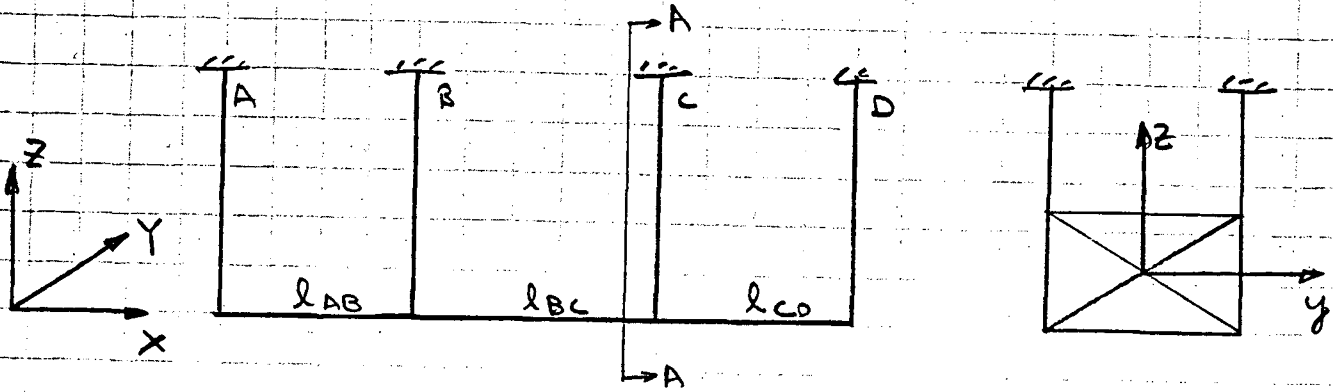
MPF System I.D = AA200

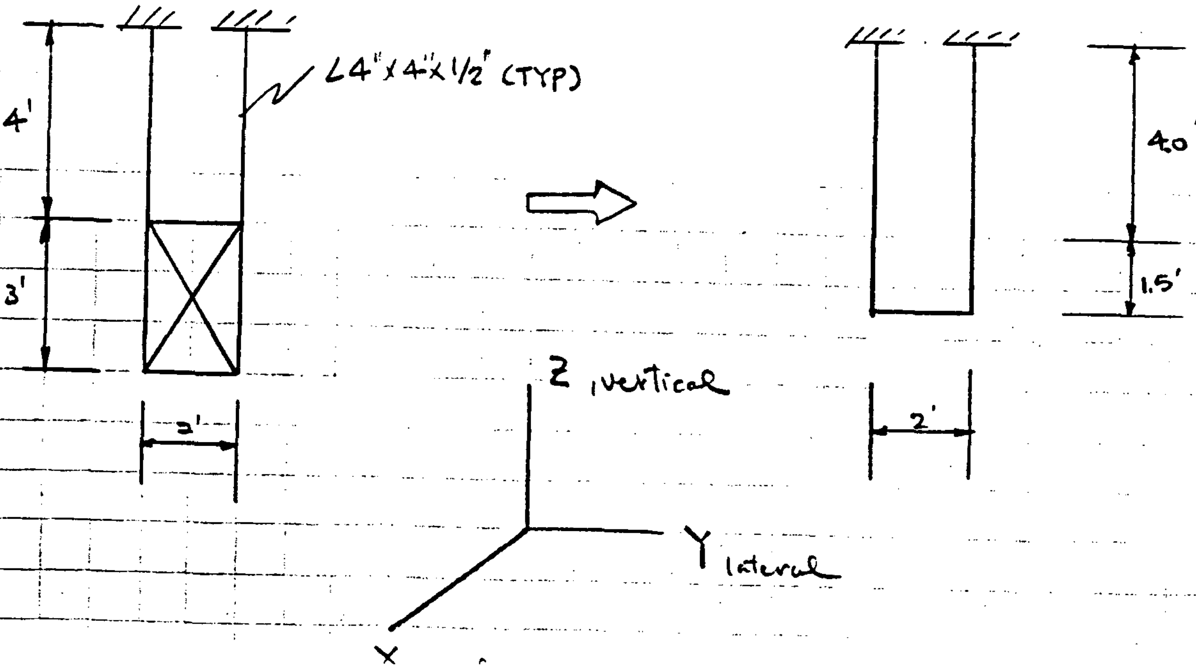
AA200



Section A-A

1: Duct Size = 24"x36"
A: Span length = 8.00'
2: $L_2 = 1.25 L_3$ ($l_{BC} = 1.25\, l_{CD}$) ⇒ $l_{AB} = l_{CD} = 8.0'$, $l_{BC} = 10.0'$
0: No additional load.
0: Without variation of support stiffness

Support Member : ∠4"x4"x1/2" ($I = 5.56 in^4$) (12.8 lb/Ft)



WCG-1-571

SARGENT & LUNDY
ENGINEERS

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AA200

W_A = Total weight of support A
$= [(4+1.5)*2. + 2.] * 12.8\ ^{\#}/ft = 166.^{\#}$ ✓

$W_B = W_C = W_D = W_A = 166.^{\#}$ ✓

$l_{AB} = l_{CD} = 8.0'$ ✓

$l_{BC} = 1.25\ l_{AB} = 10.0'$ ✓

W_{AB} = Total duct loads between supports A and B
$= 248^{\#}$

$W_{BC} = 310^{\#}$ $\quad W_{CD} = 248^{\#}$

Duct Span BC

1. k_y = Support Stiffness $= \frac{500}{0.046134} = 10838.\ ^{lbs}/in$

(Ref: GTSTRUDL (TVA) RUNID AMTφ, 10/18/89)

2. Compute m_1, ω_{1y}

$$m_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{248. + 310.}{4g} + \frac{166.}{2g} = 222.5/g$$

$$m_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$

$$= \frac{310 + 248}{4g} + \frac{166}{2g} = 222.5/g$$

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WCG-1-397

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AA200

$$\omega_{1BY} = \left(\frac{k_{1BY}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{222.5/g}\right)^{1/2} = 137.2 \text{ Rad/sec}$$

$$\omega_{1CY} = \left(\frac{k_{1CY}}{M_{1C}}\right)^{1/2} = \left(\frac{10838}{222.5/g}\right)^{1/2} = 137.2 \text{ Rad/sec}$$

$$M_1 = \min(M_{1B}, M_{1C}) = 222.5/g$$

$$\omega_{1y} = \min(\omega_{1BY}, \omega_{1CY}) = 137.2 \text{ Rad/sec}$$

3. Compute M_2, ω_{2y}

? ~~from [illegible]~~

$$k_{2BCY} = \frac{48 E I_{BCY}}{(\ell_{BC})^3} = \frac{48(29\times10^6)(17.7)}{(10\times12.)^3} = 14258 \text{ lbs/in}$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{310}{2g} = 155/g$$

$$\omega_{2BCY} = \sqrt{\frac{k_{2BCY}}{M_{2BC}}} = \left(\frac{14258}{155/g}\right)^{1/2} = 188.5 \text{ Rad/sec}$$

$$\omega_{2y} = \omega_{2BC} = 188.5 \text{ Rad/sec}$$

$$M_{2AB} = \frac{W_{AB}}{2g} = 124/g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = 124/g$$

$$M_2 = \max\left(\frac{M_{2AB}+M_{2BC}}{2}, \frac{M_{2BC}+M_{2CD}}{2}\right) =$$

$$= \frac{155+124}{2g} = 139.5/g$$

$$\mu = \frac{M_2}{M_1} = \frac{139.5}{222.5} = 0.627$$

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AA200

4. Compute f_y

$$D = \omega_{1y}^2 + (1+\mu)\,\omega_{2y}^2$$

$$= (137.2)^2 + (1+0.627)(188.5)^2 = 76633.61$$

$$\omega_y^2 = 0.5\left\{ D - (D^2 - 4\omega_{1y}^2\omega_{2y}^2)^{1/2} \right\}$$

$$= 0.5\left\{ 76633.61 - \left[(76633.61)^2 - 4(137.2)^2(188.5)^2\right]^{1/2} \right\}$$

$$= 10044.48$$

$$f_y = \omega_y / 2\pi = 15.95\ \text{Hz}$$

5. Determine a_y at $f_y = 15.95$ Hz

From site specified curve

$f_y = 100$ Hz $a_y = 0.875\ g$

$f_y = 14.5$ Hz $a_y = 1.50\ g$

$$\frac{\log 14.5 - \log 15.95}{\log 14.5 - \log 100} = \frac{1.5g - a_y}{1.5g - 0.875g}$$

$$a_y = 1.47\,g \quad \text{for} \quad f_y = 15.95\ \text{Hz}$$

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AA200

6. Determine duct span moment and shear.

$$M = 0.10\, W_{BC} \cdot l_{BC} \cdot a_y/g$$

$$= 0.10\,(310)(10.)(1.47) = 456 \text{ ft-lbs} \checkmark$$

$$V = 0.5\, W_{BC} \cdot a_y/g \checkmark$$

$$= 0.5\,(310)(1.47) = 228 \text{ lbs} \checkmark$$ ok

Moment has been calculated based on continuous beam, shear for continuous beam will be somewhat greater than .5 W_BC. But the present calculation will give larger Dynamic/static ratio hence OK.

7. Determine support load (Support B or C)

$$P = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\frac{a_y}{g}$$

$$= \frac{248 + 310 + 166}{2}(1.47) = 532 \text{ lbs} \checkmark$$

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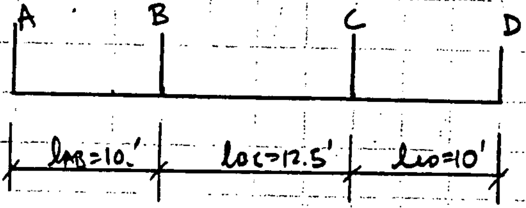
MDF System I.D. AB200



AB200

A : Duct Size 24" x 36"
B : Span length = 10.0 ft ✓
2 = $L_2 = 1.25 L_3$
0 : No additional load
0 = w/o variation of support stiffness
Support : ∠4x4x½

$W_A = W_B = W_C = W_D = 166.\#$ ✓

$l_{AB} = l_{CD} = 10.0'$ ✓

$l_{BC} = 1.25\, l_{AB} = 12.5'$ ✓

$W_{AB} = W_{CD} = 310\#$ ✓

$W_{BC} = 388\#$

Duct Span BC

1. $k_y = k_{BY} = k_{AY} = k_{CY} = k_{DY} = 10838 \text{ lbs/in}$
(See calculation for MDF system AA200)

2. Compute m_1, f_{1y}

$$m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g} = \frac{310+388}{4g} + \frac{166}{2g} = 257.5/g$$ ✓

$$m_{1C} = 257.5/g$$

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AB200

$$\omega_{1BY} = \sqrt{\frac{k_{BY}}{m_{1B}}} = \left(\frac{10838}{257.5/g}\right)^{1/2} = 127.5 \text{ Rad/sec}$$ ✓

$$W_{1cy} = \sqrt{\frac{k_{cy}}{m_{1c}}} = 127.5 \text{ Rad/sec}$$

$$m_1 = \text{Min}(m_{1B}, m_{1c}) = 257.5/g$$ ✓

$$W_{1Y} = \text{Min}(\omega_{1BY}, \omega_{1cy}) = 127.5 \text{ Rad/sec}$$

3. Compute m_2, f_{2y}

$$k_{2BCy} = \frac{48 EI_{BCy}}{(l_{BC})^3} = \frac{48(29\times10^6)(17.70)}{(12.5\times12)^3} = 7300.\ \#/\text{in}$$ ✓

$$m_{2BC} = \frac{W_{BC}}{2g} = \frac{388}{2g} = 194/g$$ ✓

$$\omega_{2y} = \sqrt{\frac{k_{2BCy}}{m_{2BC}}} = \left(\frac{7300}{194/g}\right)^{1/2} = 120.6 \text{ Rad/sec}$$ ✓

$$m_{2AB} = \frac{W_{AB}}{2g} = \frac{310}{2g} = 155/g$$

$$m_{2CD} = m_{2AB} = 155/g$$

$$m_2 = \text{Max}\left\{\frac{m_{2AB} + m_{2BC}}{2} \text{ or } \frac{m_{2BC} + m_{2CD}}{2}\right\} = \frac{194 + 155}{2g} = 174.5/g$$

$$\mu = \frac{m_2}{m_1} = \frac{174.5}{257.5} = 0.6777$$ ✓

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AB200

4. Compute w_y

$$\omega_y^2 = 0.5\left\{ D - (D^2 - 4\omega_{1y}^2\omega_{2y}^2)^{1/2} \right\}$$

$$D = \omega_{1y}^2 + (1+\mu)\omega_{2y}^2$$

40657.3 ✓

$$= (127.5)^2 + (1+0.6777)(120.6)^2 = 40656.88$$

$$\omega_y^2 = 0.5\left[40656.88 - \left[(40656.88)^2 - 4(127.5)^2(120.6)^2\right]^{1/2}\right]$$

$$= 7031.5 \checkmark$$

$$w_y = 83.85 \checkmark$$

$$f_y = \frac{w_y}{2\pi} = 13.35\,\text{Hz} \checkmark$$

5. Determine a_y @ $f_y = 13.35$ Hz

$f_y = 14.5$ Hz $a_y = 1.5g$
$f_y = 9.1$ Hz $a_y = 2.25g$

$$\frac{\log 14.5 - \log 13.35}{\log 14.5 - \log 9.1} = \frac{1.5 - a_y}{1.5 - 2.25} \qquad a_y = 1.63g$$

6. Determine M and V

$$M = \frac{1}{10} W_{BC}\, l_{BC}\, a_y/g = \frac{1}{10}(388)(12.5)(1.63) = 790^{\text{ft-lbs}} \checkmark$$

$$V = \frac{1}{2} W_{BC}\, a_y/g = \frac{1}{2}(388)(1.63) = 316^{\text{lbs}} \checkmark$$

7. Determine Support load (Support B or C) ✓

$$P = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\frac{a_y}{g} = \frac{310+388+166}{2}(1.63) = 704^{\text{lbs}}$$

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MDF system BC300

BC300

BC300 :
B : Duct Size 60 x 72 , $I_z = 301.8 \text{ in}^4$ IBey
C : Span Length 12.0'
3 : $L_1 = L_2 = 1.25 L_3$
0 : No additional load
0 : w/o variation of support stiffness

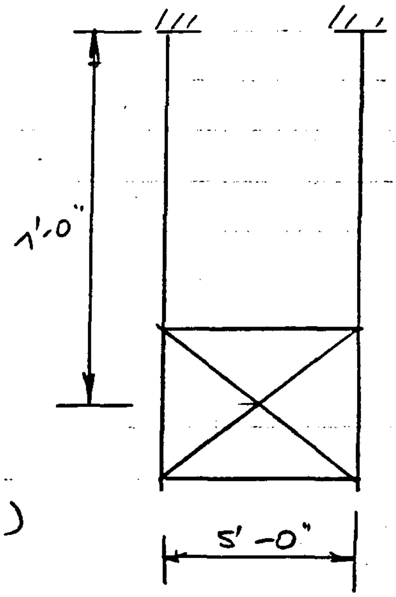
Support member ∠4 x 4 x 1/2 ($I = 5.56 \text{ in}^4$) ✓

$W_A = W_B = W_C = W_D = (7 \times 2 + 5) * 12.8$
$= 243^{\#}$ ✓

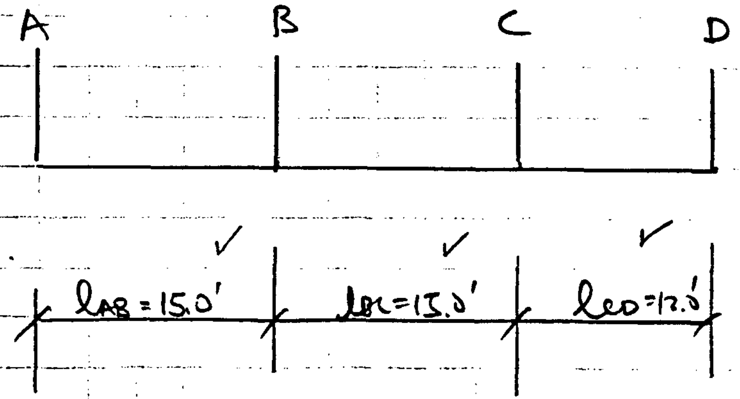
$l_{CD} = 12.0'$
$l_{AB} = l_{BC} = 1.25\, l_{CD} = 15.0'$ ✓

$W_{AB} = W_{BC} = 1518^{\#}$

$W_{CD} = 1215^{\#}$



$k_{Ay} = k_{By} = k_{Cy} = k_{Dy} = \frac{500}{0.102824} = 4863 \text{ lbs/in}$
(per GTSTRUDL RunID AMTTS, 10/18/89)



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BC300

Duct Span BC

1. $k_{BY} = k_{CY} = 4863$ lbs/in

2. Compute m_1, ω_{1Y}

$$m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g} = \frac{1518+1518}{4g} + \frac{243}{2g} = 880.5/g$$

$$m_{1C} = \frac{W_{BC}+W_{CD}}{4g} + \frac{W_C}{2g} = \frac{1518+1215}{4g} + \frac{243}{2g} = 804.75/g$$

$$\omega_{1BY} = \sqrt{\frac{k_{BY}}{m_{1B}}} = \left(\frac{4863}{880.5/g}\right)^{1/2} = 46.2 \text{ Rad/sec}$$

$$\omega_{1CY} = \sqrt{\frac{k_{CY}}{m_{1C}}} = \left(\frac{4863}{804.75/g}\right)^{1/2} = 48.3 \text{ Rad/sec}$$

$$\omega_{1Y} = \min(\omega_{1BY}, \omega_{1CY}) = 46.2 \text{ Rad/sec}$$

$$m_1 = \min(m_{1B}, m_{1C}) = 804.75/g$$

3. Compute m_2, ω_{2Y}

$$k_{2Y} = \frac{48 E I_{BCY}}{(l_{BC})^3} = \frac{48(29\times10^6)(301.8)}{(15\times12)^3} = 72034.6 \text{ lbs/in}$$

$$m_{2BC} = \frac{W_{BC}}{2g} = \frac{1518}{2g} = 759/g$$

$$\omega_{2Y} = \sqrt{\frac{k_{2Y}}{m_{2BC}}} = \left(\frac{72034.6}{759/g}\right)^{1/2} = 191.5 \text{ Rad/sec}$$

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BC300

$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1518}{2g} = 759/g$ ✓

$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1215}{2g} = 607.5/g$ ✓

$M_2 = \max\left(\frac{M_{2AB}+M_{2BC}}{2}, \frac{M_{2BC}+M_{2CD}}{2}\right) = 759/g$ ✓

$u = \frac{M_2}{M_1} = \frac{759}{804.75} = 0.9431$ ✓

4 Compute ω_y

$D = \omega_{1y}^2 + (1+u)\,\omega_{2y}^2$

$= (46.2)^2 + (1+0.9431)(191.5)^2 = \overset{73392.28}{73394.1}$ ✓ ok

$\omega_y^2 = 0.5\left\{D - (D^2 - 4\omega_{1y}^2\omega_{2y}^2)^{1/2}\right\}$

$= 0.5\left\{73394.1 - \left[(73394.1)^2 - 4(46.2)^2(191.5)^2\right]^{1/2}\right\}$

$= 1082.5$ ✓

$f_y = \omega_y / 2\pi = 5.2$ Hz ✓

5. Determine a_y for $f_y = 5.2$ Hz

$a_y = 4.0g$ for $f_y = 5.2$ Hz

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6. Determine duct span moment and shear BC300

$M = 0.1\, W_{BC}\, l_{BC}\, a_y / g$

$= 0.1\,(1518)(15.0)(4.0) = 9108$ ft-lbs ✓

$V = 0.5\, W_{BC}\, a_y / g$

$= 0.5\,(1518)(4.0) = 3036$ lbs ✓

7. Determine support load at support C

$$P = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\frac{a_y}{g}$$

$$= \left(\frac{1518 + 1215}{2} + \frac{243}{2}\right)(4.0) = \overset{5952}{5958} \text{ lbs}$$ dc

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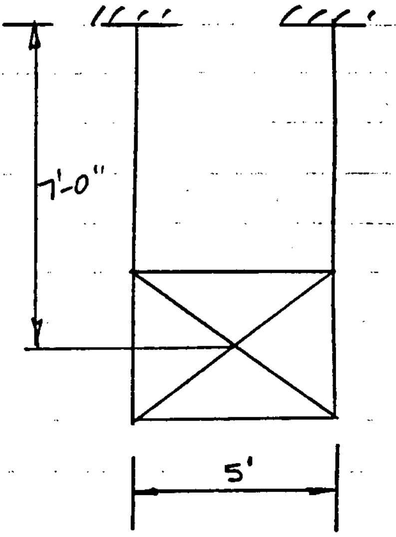
MDF SYSTEM BC400 BC400

BC400 = B : Duct Size 60"x72", $I_z = 301.8\ in^4$
C : Span Length 12'0"
4 : $L_2 = L_3 = 1.25 L_1$ ($L_1 = 12.0'$)
0 = No additional load
0 = w/o variation of support stiffness

Support Member = ∠4"x4"x½" ($I = 5.56\ in^4$)

$W_A = W_B = W_C = W_D = [(7 \times 2) + 5] * 12.8$ ✓
$= 243^{\#}$ ✓



$l_{AB} = 12.0'$

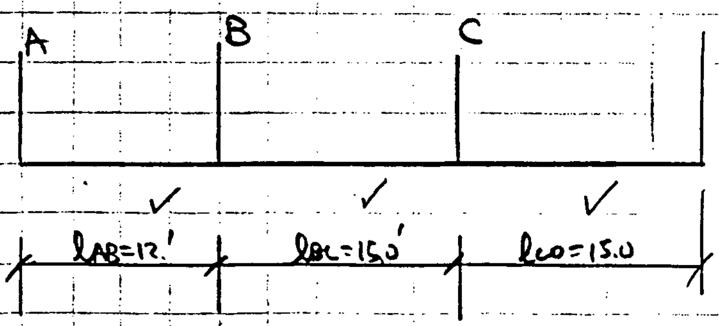
$l_{BC} = l_{CD} = 1.25\ l_{AB} = 15.0'$

$W_{AB} = 1215^{\#}$

$W_{BC} = W_{CD} = 1518^{\#}$

$k_y = \frac{500}{0.102824} = 4863\ lbs/in$

(per GTSTRUDL RUN ID AMTS, 10/18/89)



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BC400

Duct Span BC

1. $k_{BY} = 4863$ lbs/in

$k_{CY} = 4863$ lbs/in

2. Compute m_1, ω_{1Y}

$$m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g} = \frac{1215+1518}{4g} + \frac{243}{2g} = 804.75/g \checkmark$$

$$m_{1C} = \frac{W_{BC}+W_{CD}}{4g} + \frac{W_C}{2g} = \frac{1518+1518}{4g} + \frac{243}{2g} = 880.5/g \checkmark$$

$$\omega_{1BY} = \sqrt{\frac{k_{BY}}{m_{1B}}} = \left(\frac{4863}{804.75/g}\right)^{1/2} = 48.3 \checkmark$$

$$\omega_{1CY} = \sqrt{\frac{k_{CY}}{m_{1C}}} = \left(\frac{4863}{880.5/g}\right)^{1/2} = 46.2 \checkmark$$

$$\omega_{1Y} = \text{Min}(\omega_{1BY}, \omega_{1CY}) = 46.2 \text{ Rad/sec} \checkmark$$

$$m_1 = \text{Min}(m_{1B}, m_{1C}) = 804.75/g \checkmark$$

3. Compute m_2, ω_{2Y}

$$k_{2Y} = \frac{48 E I_{BCY}}{(l_{BC})^3} = \frac{48(29\times10^6)(301.8)}{(15\times12)^3} = 72034.6 \text{ lbs/in} \checkmark$$

$$m_{2BC} = \frac{W_{BC}}{2g} = \frac{1518}{2g} = 759/g \checkmark$$

$$\omega_{2Y} = \sqrt{\frac{k_{2Y}}{m_{2BC}}} = \left(\frac{72034.6}{759/g}\right)^{1/2} = 191.5 \text{ Rad/sec} \checkmark$$

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BC400

$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1215}{2g} = 607.5/g$ ✓

$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1518}{2g} = 759./g$ ✓

$M_2 = \text{Max}\left\{ \frac{M_{2AB} + M_{2BC}}{2} , \frac{M_{2BC} + M_{2CD}}{2} \right\} = 759/g$ ✓

$\mu = m_2/m_1 = 759/804.75 = 0.9431$ ✓

4. Compute ω_y

$D = \omega_{1y}^2 + (1+\mu)\,\omega_{2y}^2$

$= (46.2)^2 + (1+0.9431)(191.5)^2 = 73394.1$ ✓

$\omega_y^2 = 0.5\left\{ D - (D^2 - 4\omega_{1y}^2 \omega_{2y}^2)^{1/2} \right\}$

$= 0.5\left\{ 73394.1 - \left[(73394.1)^2 - 4(46.2)^2(191.5)^2 \right]^{1/2} \right\}$

$= 1082.5$ ✓

$W_y = 32.9$ Rad/sec

$f_y = W_y/2\pi = 5.2$ Hz ✓ Sam as BC300

5. Determine a_y @ $f_y = 5.2$ Hz

$a_y = 4.0\,g$ @ $f_y = 6.5$ Hz
$a_y = 4.0\,g$ @ $f_y = 4.8$ Hz

$a_y = 4.0\,g$ @ $f_y = 5.2$ Hz ✓

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BC400

6 Determine duct span moment and shear

$M = 0.1\, W_{BC}\, l_{BC}\, a_y / g$

$= 0.1(1518)(15.0)(4.0) = 9108^{\text{ft-lbs}}$

$V = 0.5\, W_{BC}\, a_y / g$

$= 0.5(1518)(4.0) = 3036^{\text{lbs}}$

7 Determin support load @ support C

$$P = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\frac{a_y}{g}$$

$$= \frac{1518 + 1518 + 243}{2}(4.0) = 6558^{\text{lbs}}$$

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5. MDF ANALYSIS RESULTS for SYSTEM IN FIG (3-1); COMPONENT ON FLEXIBLE SUPPORTS

The result of analyzing the four systems (AA2, AB2, BC3, and BC4) are summarized below. These were extracted from the computer runs as described on the following pages of this Section.

System Id.	Ferquency of 1st contributing mode (Hz)	Span, Note1		Ave. Acc. on support span (g) Note2	Support Force lb Note3
		Moment 'lb	Shear lb		
	For SSE-EW Spectrum				
AA2	16.7	403	231	1.55	577
AB2	14.7	634	296	1.50	660
BC3	5.6	8433	2837	3.99	5896
BC4	5.7	9708	3180	4.44	6722
	For Flat Spectrum				
AA2	16.7	276	159	1.06	396
AB2	14.7	423	198	1.01	442
BC3	5.6	2117	709	1.00	1473
BCA	5.7	2455	794	1.11	1678

Notes:

1. Maximum of nodes 13 thru 21 in Figure 3-1
2. Ave of nodes 17 thru 25 in Figure 3-1
3. Sum of Shears in members 49 & 52 in Figure 3-1
4. MDF Analysis F.E. Idealization in given in Section 3.

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MDF for AA2

1. SSE EW spectrum (Elev. 771.5')

Reference Run AVFA 89/10/20

Input File = AA200I
Output File = AA200O

Moment y, max of nodes 13 thru 21 = 4833 ✓"lb = 403 lb. ✓

Shear z " " = 231 ✓lbs

Ave. acc. of nodes (17 thru 25)

$= \text{Ave}(691.4, 681.4, 652.9, 613.6, 575.8, 558.6, 547.3, 538.1, 528.5) = 599 \text{ in/sec}^2 = 1.55g$

Support force = Shear z of members 49 & 52 = 288.3 + 288.3 = 577 lbs.

Contributing mode frequencies: {16.7 Hz, 17.5 Hz, 18.0 Hz, 21.5 Hz}

2. Flat 1g spectrum

Reference Run AWKQ 89/10/21

Input File = AA200J
Output File = AA200Q

Moment y, max. of nodes 13 thru 21 = 3309 "lb ✓ = 276 'lb ✓

(For 2DF $M = \frac{456}{1.47} = 310$ 'lb)

Shear z, max. of nodes 13 thru 21 = 159 lb

(For 2DF, $V = \frac{228}{1.47} = 155$ lb.)

Ave. acc. of nodes (17 thru 25)

$= \text{Ave}(473.9, 467.0, 447.6, 420.8, 395.1, 383.7, 376.4, 370.5, 364.3) = 411 \text{ in./sec}^2 = 1.06g$

(F 2DF, a = 1.0g)

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MDF for AA2 (Cont'd)

Support force = Shear Z of members 49 & 52 = 197.9 + 197.9
= 396 lb.

$$\left(\text{2DF supp. force} = \frac{532}{1.47} = 362 \text{ lb}\right)$$

×

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MDF for AB2

1 SSE EW spectrum (Elev. 771.5')

Reference Run AWYJ 89/10/21 Input File = AB200I
Output File = AB2000

Moment y, max. of nodes 13 thru 21 = 7611 "lb = 634.' lb ✓

Shear Z , " " " " = 296 lbs ✓

Ave. acc. of nodes (17 thru 25)

= Ave (744.3, 722.7, 666.3, 591.7, 525.6, 501.1, 493.4, 493.4, 494.4)

= 581.4 in/sec^2 = 1.50 g

Support force = Shear Z of members 49 & 52
= 330 + 330 = 660 lbs ✓

Contributing Mode Frequencies:

{14.7 Hz, 15.9 Hz, 16.1 Hz, 17.7 Hz, 22.0 Hz, 27.1 Hz}

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MDF for AB2 (cont'd)

2 Flat 1g spectrum

Reference Run AXEU 89/10/21 Input File = AB200J
Output File = AB200Q

Moment Y, max. of nodes 13 thru 21 = 5077 "-lb = 423 '-lb

Shear Z, max. of nodes 13 thru 21 = 198 lbs

Ave. acc of nodes (17 thru 25)
= Ave (496.8, 482.3, 444.8, 395.4, 352.0, 336.6, 332.6, 333.7, 335.3) = 390 IN/sec² = 1.01 g

Support Force = Shear Z of members 49 & 52
= 221 + 221 = 442 lbs.

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MDF for BC 3

1. SSE EW Spectrum (Elev. 771.5′)

Reference Run BHGP 89/10/21 Input File = BC300I
Output File = BC3000

Moment y, max. of nodes 13 thru 21 = $101200^{''lb}$ ✓ = $8433^{'lb}$ ✓

Shear Z, " " " " = 2837^{lbs} ✓

Ave. acc. of nodes (17 thru 25)

= Ave (1624, 1605, 1582, 1557, 1531, 1516,
1503, 1490, 1477)
= $1543\ in/sec^2$ = 3.99 g

Support force = Shear Z of members 49 & 52
= 2948 ✓ + 2948 ✓ = 5896^{lbs} ✓

Contributing mode frequencies:

{5.6 Hz, 6.1 Hz, 8.3 Hz, 14.5 Hz, 24.0 Hz}

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MDF for BC3 (cont'd)

2. Flat 1g Spectrum

Reference Run ADQH 89/10/23 Input File = BC300J
Output File = BC300Q

Moment y, max. of nodes 13 thru 21 = 25400 "lb = 2117 'lb

Shear Z, max. of nodes 13 thru 21 = 709 lbs

Ave. acc. of nodes (17 thru 25)
= Ave (405.4, 400.8, 395.1, 388.6, 382.3, 378.6,
375.3, 372.1, 368.9) = 385 in/sec^2 = 1.00 g

Support Force = Shear Z of members 49 & 52
= 736.3 + 736.3 = 1473 lbs.

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MDF for BC4

1. SSE EW Spectrum (Elev. 771.5')

Reference Run AWYV 89/10/21 Input File = BC400I
Output File = BC400O

moment y, max. of nodes 13 thru 21 = $116500''^{lb} = 9708'^{lb}$

Shear Z, " " " " = 3180^{lbs}

Ave. acc. of nodes (17 thru 25)

= Ave (1693, 1712, 1722, 1725, 1724, 1725, 1722, 1712, 1693)

= 1714 IN/sec^2 = 4.44 g

Support force = Shear Z of members 49 & 52

= 3361 + 3361 = 6722^{lbs}

Contributing mode frequencies:

{ 5.7 Hz, 8.3 Hz, 23.9 Hz }

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MDF for BC4 (Cont'd)

2 Flat 1g Spectrum

Reference Run ADTE 89/10/23 Input File = BC400J
Output File = BC400Q

moment y, max. of nodes 13 thru 21 = 29460 ''lb = 2455 'lb

Shear Z, max. of nodes 13 thru 21 = 794 lbs

Ave. acc. of nodes (17 thru 25)

= Ave (422.8, 427.5, 430.1, 431.0, 430.7, 431.0, 430.1, 427.5, 422.8) = 428 in/sec^2 = 1.11g

Support Force = Shear Z of members 49 & 52

= 839 + 839 = 1678 lbs

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6. COMPARISON OF RESULTS FOR SYSTEM IN FIG. (3-1): COMPONENT ON FLEXIBLE SUPPORTS

Table 1. Comparison of Frequencies

System	Frequency from ZDF P. (4.1)	Frequency of 1st contributing mode from MDF P. (5.1)
AAZ	15.95 Hz	16.7
ABZ	13.35 Hz	14.7
BC3	5.2 Hz	5.6
BC4	5.2 Hz	5.7

Conclusion: Frequencies calculated from ZDF approach are lower corresponding modal frequency from MDF analysis. Therefore a reasonable low frequency for the MDF system is being provided by the ZDF procedure

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Table 2. Comparison of Component and Support Responses For Purposes of Calibration

System	Ratio MDF/2DF (Note 1)			
	Component		Support Force	Ave Acc. in Support span
	Moment	Shear		
	For SSE-EW spectrum at elev. 771.5'			
AA2	0.88	1.01	1.08	1.05
AB2	0.80	0.94	0.94	0.92
BC3	0.93	0.93	0.99	1.00
BC4	1.07	1.05	1.03	1.11
	For Flat 1g- spectrum			
AA2	0.89	1.03	1.09	1.06
AB2	0.87	1.03	1.03	1.01
BC3	0.93	0.93	0.99	1.00
BC4	1.08	1.05	1.02	1.11

Notes:

(1). Numerator of the ratio presented is obtained from MDF results summarized on (P. 5.1); the denominator is from the 2DF result summarized on P. (4.1).

Conclusions:

1. The highest ratio calculated for component forces is: 1.08, for support force is 1.09 and for average acceleration on support span is 1.11 (See Table 2)
2. Since the 2DF approach, based on Table 1, captures frequency effect due to different span length; this 2DF approach

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can handle other variations due to span lengths being different. consequently, no span difference limitation is necessary when this simplified approach is used.

3. In view of 1 and 2 above the use of a calibration constant of 1.2 for ZDF approach when f is not in the rigid zone (≥33 Hz) is an ample factor to be used with this procedure to substitute for MDF analysis

4. In view of results for the flat spectrum analysis, the use of 1.2 factor is also an ample amplification when peak of the spectral acceleration is utilized without an system frequency analysis.

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7. SYSTEMS WITH RIGID SUPPORTS

For systems (HVAC DUCTS, CABLE TRAYS, CONDUITS) with rigid supports*, the seismic response for any direction of excitation is a single mode response i.e. the total response is mainly due to one mode, as Shown in Table 1. For such a system the design response (acceleration, moment and shear) can be obtained using an equivalent static method as described below:]Rev 2

1. Determine the fundamental frequency "f" of the longest span of the system assuming pin-pin end condition:

$$f = \frac{9.87}{2\pi}\sqrt{\frac{EIg}{w\ell^4}} \quad Hz.$$

where E is the modulus of elasticity, I is the moment of inertia of the system, w is the weight per unit length, ℓ is the span length and g is the acceleration due to gravity.

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* For condition on support rigidity See Section 2.

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2. Determine the largest acceleration "a" for frequencies greater than or equal to "f" from the applicable acceleration response spectrum

3. Determine the design moment, and shear by considering the appropriate boundary condition (single span, multispan etc.) and applying the acceleration "a" to the system.

The single mode response characteristics for such a system can be demostrated by reviewing the mode shape and modal mass participation for the system. Table 1 shows this characteristics. To further

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demonstrate this characteristics, representative problems were also analyzed using GT STRUDAL program and a flat response spectrum with 1.0 g acceleration. The results from the dynamic analysis are compared with the equivalent static method as described above. Such a comparison is shown in Table 2. A flat response spectrum has been used to make the comparison independent of the shape of the spectrum. Because the acceleration for the system is selected such that it represent the largest acceleration for frequencies greater or equal to the system fundamental frequency with pin end condition, the response obtained from the

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equivalent static approach will be equal or more conservative than the comparison shown from a study with a flat spectrum.

Based on these results, it is concluded that the equivalent static approach as stated above can be used to determine the design acceleration, moment and shear for the system.

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Modal Mass Participation for 1-span, 2-span and 3-span systems.

For modal vectors normalized with respect to mass metrix, the modal mass participation is equal to the square of the participation factor i.e.

for $\phi_i^T [M] \phi_i = 1$,

the mass participation in mode i is given by $m_i = \gamma_i^2$ where $\gamma_i = \phi_i^T [M] \{\bar{P}\}$

an $\{\bar{P}\}$ = Load vector with unity in the direction of excitation and zero otherwise

In the problems for 1-span, 2-span, 3-span systems the masses are lumped at 2'-0" appart, ie ✓

mass per node = 2 × 45/386 lbs sec²/in = .233 $\frac{\text{lbs sec}^2}{\text{in}}$ ✓

(uniformaly loaded 45 lb/ft)

Total Mass for 1-span system = 3 × .233 = .699 $\frac{\text{lbs sec}^2}{\text{in}}$ ✓

Total Mass for 2-span system = 6 × .233 = 1.398 $\frac{\text{lb sec}^2}{\text{in}}$ ✓

Total Mass for 3-span system = 9 × .233 = 2.097 $\frac{\text{lb sec}^2}{\text{in}}$

From dynamic analyses Run I.D.'s ATHT, A8XL, A5ZP dated 29-10-20 the participation factors and calculated mass participation factors are:

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1-span System

Mode i	Participation factor γ_i	Mass $m_i = \gamma_i^2$	% Modal Mass $(m_i/.699) \times 100$
1	.8242111	0.679	97%
2	0	0	0
3	.1414123	0.020	3%

2-span System

Mode i	Participation factor γ_i	Mass $m_i = \gamma_i^2$	% Modal Mass $m_i/1.398 \times 100$
1	0.	0.	0.
2	1.13199	1.2814	92%
3	0.	0	0.
4	-.18004	0.0324	2%
5	0.	0	0.
6	-.29124	0.0848	6%

3-span System

Mode i	γ_i	$m_i = \gamma_i^2$	$m_i/2.097 \times 100$
1	-.4758	.2263	11%
2	0.	0	0
3	-1.29232	1.6700	80%
4	0.	0	0
5	-.23705	.056	3%
6	0.	.0	0
7	.0816	.0066	0
8	0	.0	0
9	.37224	0.138	7%

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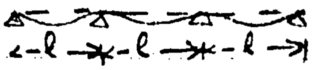
Table 1. Modal characteristics of systems with rigid support

Mode	1-span w/mode shape	Mass Part.	2 span w/mode shape	Mass Part	3 span w/mode shape	Mass Part
1	$\omega_1 = \frac{\pi^2}{\ell^2}\sqrt{\frac{EI}{m}}$  *	97%	$\omega_1 = \frac{\pi^2}{\ell^2}\sqrt{\frac{EI}{m}}$ 	0%	$\omega_1 = \frac{\pi^2}{\ell^2}\sqrt{\frac{EI}{m}}$ 	11%
2	$\omega_2 = 4\,\omega_1$ 	0%	$\omega_2 = 1.55\,\omega_1$  *	92%	$\omega_2 = 1.27\,\omega_1$ 	0%
3	$\omega_3 = 9\,\omega_1$ 	3%	$\omega_3 = 4\,\omega_1$ 	0%	$\omega_3 = 1.87\,\omega_1$  *	80%

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* Major Participating modes

Table 2 COMPARISON OF DYNAMIC MDF AND EQUIVALENT STATIC

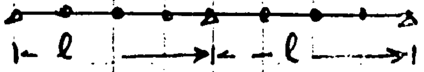
SYSTEM	MOMENT (Lb-in)			SHEAR (Lb)		
	DYN	STA	RATIO DYN/STA	DYN	STA	RATIO DYN/STA
ONE SPAN	4456.	4320.	1.03	131.	180.	0.73
TWO SPAN	3742.	4320.	0.86	153.	225.	0.68
THREE SPAN	3000.	3456.	0.87	166.	216.	0.77

STATIC

1-SPAN

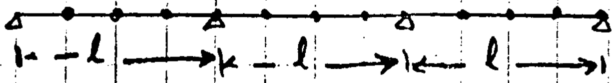
$Mom = 0.125wl^2$ Shear = .5wl

2SPAN



$Mom = .125wl^2$ Shear = .625wl

3SPAN



$Mom = 0.1wl^2$ Shear = .6wl

$E = 29 \times 10^6$ psi

$l = 8$ Ft, $I = 1.0$ in^4, $w = 45$ lbs/Ft

fundamental frequency for 1-span beam $= \frac{9.87}{2\pi}\sqrt{\frac{EIg}{wl^4}} = 9.31$ Hz

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8. SUMMARY AND CONCLUSIONS

Based on following information

- Comparisons of 2DF and MDF analyses of four component /support systems on flexible supports presented in Section 6,
- Conclusion drawn on support rigidity in terms of support frequency in Section 2, and
- Comparisons for multi span beams on rigid supports in Section 7

the results of this calculation may be summarized in the form of a criteria for equivalent static analysis of component-support systems. This criteria is presented in the following pages.

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CRITERIA FOR EQUIVALENT STATIC ANALYSIS OF COMPONENTS AND SUPPORTS

1. Scope

This criteria is applicable to equivalent static analysis of components (conduits, cable trays and HVAC ducts) supported on several supports. The supports may be either rigid, as defined herein, or flexible. Rev 1

The component may be continuous on any number of supports; for applying this criteria, a subsystem consisting of three spans and two supports will be evaluated as a unit (See Figure 8-1). The evaluation span of interest in Figure 8-1, is the span BC; and the supports of interest are the supports B or C. The condition of not having end spans (AB or CD) is acceptable if these spans are not present.

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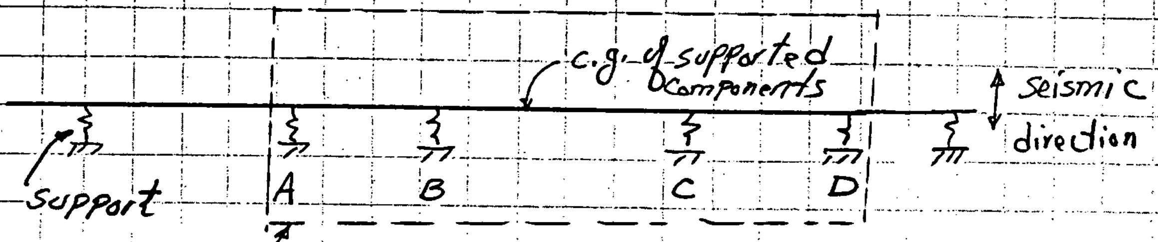

Unit to be considered for evaluating span BC or any of the supports B and C

FIGURE 8-1 COMPONENT AND SUPPORT SYSTEM FOR CRITERIA

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→ Relative to the component, the direction of seismic excitation may be in one of three directions (axial or lateral) [illegible]. Each seismic load directions, shall be treated separately and results combined according to the rule governing the seismic directional combination (absolute sum or square-root-of-sum of squares, as appropriate).

2. Rigid and Flexible Supports

The supports are considered as either flexible or rigid depending on support frequency. A support is flexible if its frequency calculated on the basis of support stiffness at the center of gravity (c.g.) of the components and the tributary mass at this node from the adjacent spans, self weight of the support and additional attached loads to the support is less than 33 Hz. Supports having frequency equal to or greater than 33 Hz are rigid. Rev. 1

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[illegible]

Rev. 1 Deleted

3. Component on Flexible Supports

The equivalent acceleration, a_s, shall be determined either by computing subsystem frequency f or by using the peak of floor spectral acceleration, a_{peak}.

When frequency is not calculated

$$a_s = 1.2 \times a_{peak}$$

When the 2DF approach of Section 2 of this calculation is used to determine f,

$$a_s = \text{ZPA from building analysis; if } f \geq 33\text{ Hz}.$$ Rev 2

$$a_s = 1.2 \{\text{largest } S_a \text{ for frequencies equal to or greater than } f\} \text{ if } f < 33\text{ Hz}.$$ Rev. 1

The component and the support design forces are determined using a_s and following a procedure similar to that described

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under items 6 and 7, respectively, of Section 2.

4. Component on Rigid Supports

This article applies when supports A through D in Figure 8-1 are rigid. [Rev. 1]

A lower bound system frequency, f, is calculated by considering each of the spans AB, BC, and CD as simply supported. The lowest of these frequencies is used as f. The equivalent acceleration, a_s, shall be determined as

$$a_s = \left\{ \begin{array}{l} \text{largest } S_a \text{ for frequencies equal to or} \\ \text{greater than } f \end{array} \right\}$$

The span BC or the supports B and C are evaluated for forces obtained by applying uniform acceleration a_s, to the continuous beam from A to D.

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9. REFERENCES

1. Thomson, W. T., "Vibration Theory and Applications", Prentice-Hall, INC., 1965

2. Summary Report for HVAC Ducts Seismic Qualification and Verification Improvement Program, Report NO. MA2-79-1, June 16, 1979

3. Calculation NO. 857303-2.3 (WCG-1-396)

4. Der Kiureghian, A., "Probabilistic Modal Combination For Earthquake Loading" Proceeding Seventh World Conference on Earthquake Engineering, September 8-13, 1980, Istanbul, Turkey, Part III, pp. 729-736. [Rev.1

5. ASCE Standard 4-86, "Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures" American Society of Civil Engineers, September 1986.

6. Philippacopoulos, A.J., "Recommendations for Resolution of Public Comments on USI A-40; Seismic Design Criteria" NUREG/CR-5347, BNL-NUREG-52191 Prepared by Brookhaven National Lab. for USNRC., June 1989

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10. INTRODUCTION TO REVISION 3

Background and Purpose of Revision 3

The material through Revision 2 of this calculation considered

*a. spans continuous on flexible supports
(Sections 1 through 6)

b. spans continuous on rigid supports (Section 7)
(For definition of rigid support see pages 2.10b and 8.4)

The conclusions of Revision 2 are summarized in Section 8.

In Revision 2, four systems on flexible supports were studied: AA2, AB2, BC3, and BC4. The evaluations compared MDF and 2DF support and span forces considering two response spectra: SSE-EW and a flat 1g spectrum. The evaluation unit in each system consisted of an interior span BC and its adjacent supports B and C. The ratio of the span length BC to one of the adjacent spans was 1.25. Based on the comparison of MDF to 2DF response ratios, it was concluded that a 1.2 calibration factor is appropriate

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for systems on flexible supports when the 2DF approach is used.

Similarly, in Revision 2, span shear and moment responses for two- and three-span beams on rigid supports were studied. These cases used 1 g flat response spectrum.

The systems considered had equal spans, i.e. no span length variation was studied. The response obtained from MDF analysis of these systems were compared to the response by applying spectral acceleration to the system at the frequency of a simply supported span with span length equal to the span in the multi-span beam. This comparison concluded the adequacy of 1.0 calibration factor for systems on rigid supports.

During the week of Nov. 10, 1990, at WBN site, a presentation was made to NRC on the logic for 1.2 factor and 2DF system approach to systems with flexible supports. Based on this meeting

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TVA prepared response to the Open Item WE0001. Th

Sargent and Lundy has been requested to supplement the existing calculations to consider more cases to show the adequacy of the factor 1.2 (1.0 for rigid supports). These cases are to include straight runs and runs with elbows and tee. For straight runs, the following conditions are to be investigated:

* more span length variability

* Cases where end span is the unit of evaluation

* multi-tiered spans

The purpose of Revision 3 is to provide comparisons for cases that include above parameters. Also, the span variability effect for beams on rigid supports is included.

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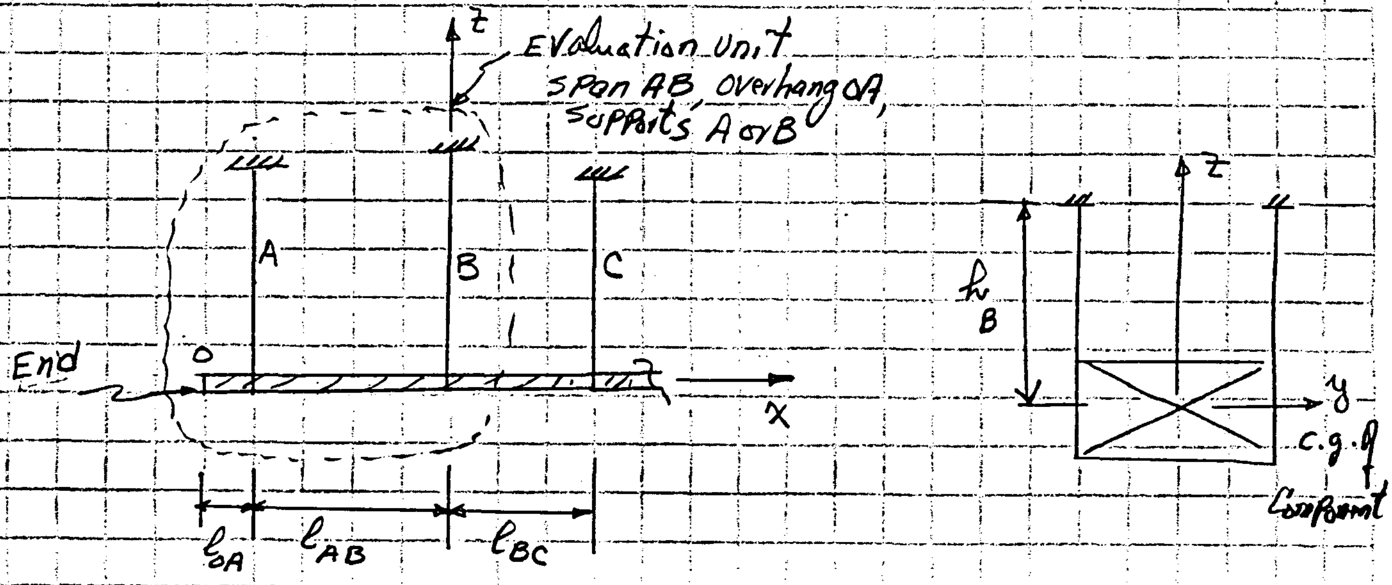
2DF Approach for Evaluation Unit Containing End Span (Straight Run)

The evaluation unit shown on Page 2.2 considers an interior span (BC). Using the same notation the procedure for an end span is as follows:



Steps are as follows

1. Compute k_{AS}, k_{BS}

2. Compute

$$m_{1A} = \frac{W_{OA}}{2g} + \frac{W_{AB}}{4g} + \frac{W_A}{2g}$$

$$m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g}$$

$$\omega_{1AS} = \left[\frac{k_{AS}}{m_{1A}}\right]^{0.5}, \quad \omega_{1BS} = \left[\frac{k_{BS}}{m_{1B}}\right]^{0.5}$$

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Use $\omega_{1S} = \min(\omega_{1AS}, \omega_{1BS})$

$m_1 = \min(m_{1A}, m_{1B})$

3. $k_{2OAS} = \frac{3EI_{OAS}}{(l_{OA})^3}$, $k_{2ABS} = \frac{48EI_{ABS}}{l_{AB}^3}$, $k_{2BCS} = \frac{48EI_{BCS}}{l_{BC}^3}$

$m_{2OA} = \frac{W_{OA}}{2g}$, $m_{2AB} = \frac{W_{AB}}{2g}$, $m_{2BC} = \frac{W_{BC}}{2g}$

$\omega_{2OA} = \left[\frac{k_{2OAS}}{m_{2OA}}\right]^{0.5}$, $\omega_{2AB} = \left[\frac{k_{2ABS}}{m_{2AB}}\right]^{0.5}$, $\omega_{2BC} = \left[\frac{k_{2BCS}}{m_{2BC}}\right]^{0.5}$

$\omega_2 = \min\left[\omega_{2OA}, \omega_{2AB}, \omega_{2BC}\right]$

$m_2 = \text{Max.}\left[\left(m_{2OA} + \frac{m_{2AB}}{2}\right), \left(\frac{m_{2AB} + m_{2BC}}{2}\right)\right]$,

$\mu = \frac{m_2}{m_1}$

Steps 4 & 5 are the same as those on page 2.7. These give the acceleration a_s

6. Determine Component & Support forces

$M_{AO} = \left[0.5 W_{OA} l_{OA}\right] a_s$

$V_{AO} = W_{OA} a_s$

$M_{AB} = \text{Max.}\left\{M_{AO}, \left(\frac{1}{8} W_{AB} l_{AB} a_s\right), \left(\frac{1}{10} W_{BC} l_{BC} a_s\right)\right\}$

$V_{AB} = 0.5 W_{AB} a_s + \frac{M_{AO}}{l_{AB}}$

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G. (Cont'd)

Support Force A = (Tributary Weight to Support) a_s

Support Force B = (Tributary Weight to Support) a_s

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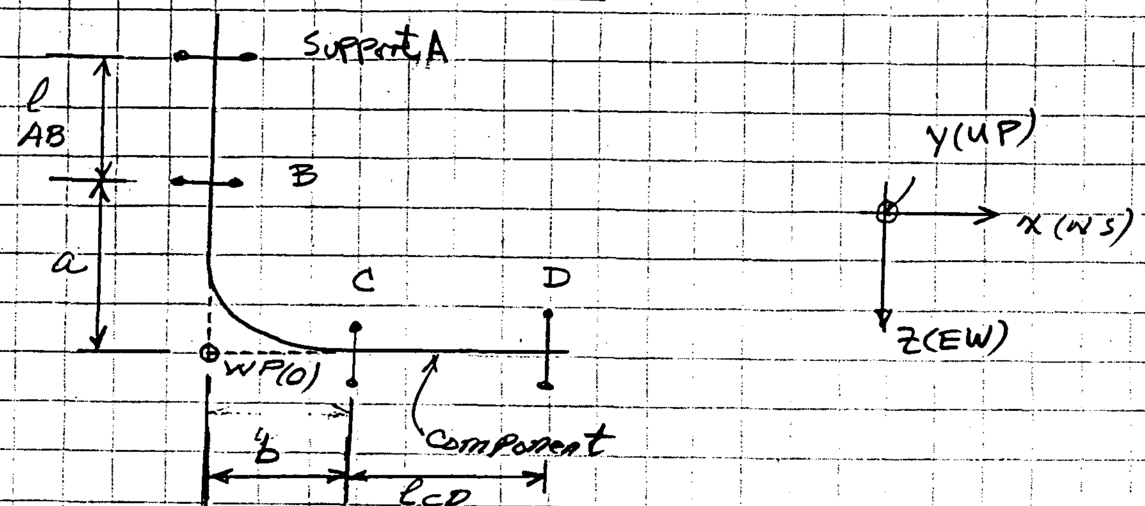
ZDF APPROAH WHEN EVALUATION UNIT CONTAINS AN ELBOW

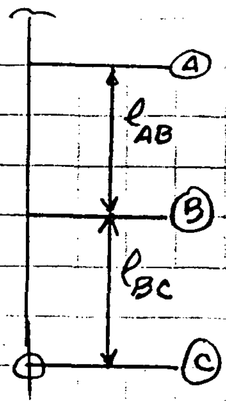


Plan view of component & supports

For x, y, and z excitations, use $l_{BC} = a+b$

Details of ZDF Procedure are described separately for each excitation direction

X- Excitation



Step 1. Compute k_{BX}, k_{CX}

Step 2. $m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g}$

$m_{1C} = \frac{W_{AB}}{4g} + \frac{W_{CD}}{2g} + \frac{W_B}{2g}$

$\omega_{1BX} = \left[\frac{k_{BX}}{m_{1B}}\right]^{0,5}$, $\omega_{1CX} = \left[\frac{k_{CX}}{m_{1C}}\right]^{0,5}$

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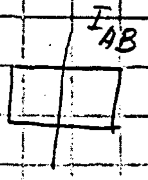
$$\omega_{1x} = \min(\omega_{1Bx}, \omega_{1Cx})$$

$$m_1 = \min(m_{1B}, m_{1C})$$



Step 3. $k_{2ABx} = \dfrac{48EI_{AB}}{(L_{AB})^3}$, $k_{2BCx} = \dfrac{48EI_{BC}}{(L_{BC})^3}$

$$m_{2AB} = \frac{W_{AB}}{2g}, \quad m_{2BC} = \frac{W_{BC}}{2g}$$

$$\omega_{2ABx} = \left(\frac{k_{2ABx}}{m_{2AB}}\right)^{0.5}, \quad \omega_{2BCx} = \left(\frac{k_{2BCx}}{m_{2AB}}\right)^{0.5}$$

$$\omega_{2x} = \min(\omega_{2ABx}, \omega_{2BCx})$$

$$m_2 = 0.5(m_{2AB} + m_{2BC})$$

$$\mu = \frac{m_2}{m_1}$$

Steps 4 and 5 are the same as those on page 2.7

This gives a_x

Step 6. Determine component and support forces

$$M_{BCx} = \text{Max.}\{(0.1 W_{AB} l_{AB} a_x), (0.1 W_{BC} l_{BC} a_x)\}$$

$$V_{BCx} = 0.5 W_{BC} a_x$$

$$N_{BCx} = \text{Axial} = V_{BCx}$$

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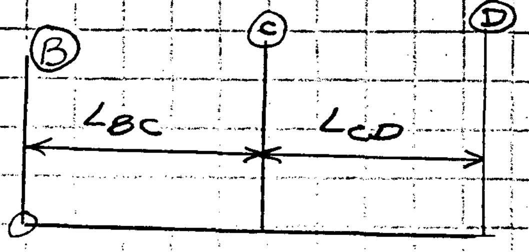
Support Force B = (Tributary Weight to support B) a_x

Support Force C = (" " " " C) a_x

Z - excitation



Step 1 Compute k_{BZ}, k_{CZ}

Step 2. $$m_{1B} = \frac{W_{AB}}{2g} + \frac{W_{BC}}{4g} + \frac{W_B}{2g}$$

$$m_{1C} = \frac{W_{BC}+W_{CD}}{4g} + \frac{W_C}{2g}$$

$$\omega_{1BZ} = \left(\frac{k_{BZ}}{m_{1B}}\right)^{0.5}, \quad \omega_{1CZ} = \left(\frac{k_{CZ}}{m_{1C}}\right)^{0.5}$$

$$\omega_{1Z} = \min(\omega_{1BZ}, \omega_{1CZ})$$

$$m_1 = \min(m_{1B}, m_{1C})$$

Step 3. $$k_{2BCZ} = k_{2BCX}, \quad k_{2CDZ} = \frac{48EI_{CD}}{(L_{CD})^3}$$

↑ Step 2 of x-excitation

$$m_{2BC} = \frac{W_{BC}}{2g}, \quad m_{2CD} = \frac{W_{CD}}{2g}.$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{m_{2BC}}\right)^{0.5}, \quad \omega_{2CDZ} = \left(\frac{k_{2CDZ}}{m_{2CD}}\right)^{0.5}$$

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$$\omega_{2z} = \min(\omega_{2BCz}, \omega_{2CDz})$$

$$m_2 = 0.5(m_{2BC} + m_{2CD})$$

$$\mu = \frac{m_2}{m_1}$$

Steps 4&5 are the same as those on Page 2.7
This gives a_z

Step 6 Determine Component and Support forces

$$M_{BCz} = \mathrm{Max}\{(0.1 W_{BC} L_{BC} a_z), (0.1 W_{CD} L_{CD} a_z)\}$$

$$V_{BCz} = 0.5 W_{BC} a_z$$

$$N_{BCz} = V_{BCz}$$

Support Force B = (Tributary weight to supp B) a_z

Support Force C = (Tributary weight to supp C) a_z

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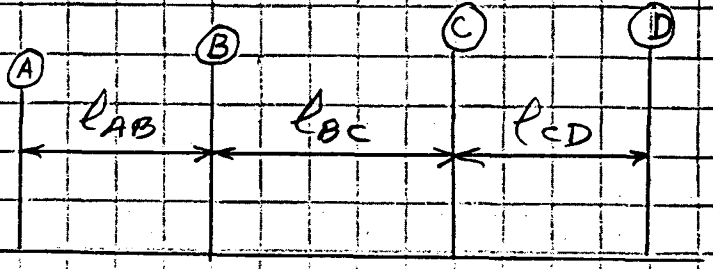


Step 1. Compute k_{1By}, k_{1Cy}

Step 2. $m_{1B} = \frac{W_{AB}+W_{BC}}{4g} + \frac{W_B}{2g}$

$m_{1C} = \frac{W_{BC}+W_{CD}}{4g} + \frac{W_C}{2g}$

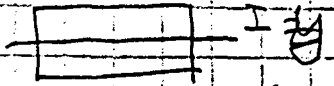
$\omega_{1By} = \left[\frac{k_{By}}{m_{1B}}\right]^{0.5}$, $\omega_{1Cy} = \left[\frac{k_{Cy}}{m_{1C}}\right]^{0.5}$

$\omega_{1y} = \min(\omega_{1By}, \omega_{1Cy})$

$m_1 = \min(m_{1B}, m_{1C})$

Step 3. $k_{2ABy} = \frac{48EI_{ABy}}{(l_{AB})^3}$, $k_{2BCy} = \frac{48EI_{BCy}}{(l_{BC})^3}$

$k_{2CDy} = \frac{48EI_{CDy}}{(l_{CD})^3}$



$m_{2AB} = \frac{W_{AB}}{2g}$, $m_{2BC} = \frac{W_{BC}}{2g}$, $m_{2CD} = \frac{W_{CD}}{2g}$

$\omega_{2ABy} = \left[\frac{k_{2ABy}}{m_{2AB}}\right]^{0.5}$, $\omega_{2BCy} = \left[\frac{k_{2BCy}}{m_{2BC}}\right]^{0.5}$

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$$\omega_{2CDy} = \left(\frac{k_{2CDy}}{m_{2CD}}\right)^{0.5}$$

$$\omega_{2y} = \min\left(\omega_{2ABy}, \omega_{2BCy}, \omega_{2CDy}\right)$$

$$m_2 = \mathrm{Max.}\left\{\left(\frac{m_{2AB} + m_{2BC}}{2}\right), \left(\frac{m_{2CD} + m_{2CD}}{2}\right)\right\}.$$

$$\mu = \frac{m_2}{m_1}$$

Steps 4&5 are the same as those on page 2.7

This gives a_y

Step 6. Determine Component & Support Forces

$$M_{BC} = \mathrm{Max}\left\{\left(0.1\, W_{AB}\, l_{AB}\, a_y\right), \left(0.1\, W_{BC}\, l_{BC}\, a_y\right), \left(0.1\, W_{CD}\, l_{CD}\, a_y\right)\right\}$$

$$V_{BC} = 0.5\, W_{BC}\, a_y$$

Torque T_{BC}: (Any where on the elbow and also on each support B & C)

Option 1 (Conservative) $T_{BC} = M_{BC}$

Option 2. $T_{BC} = \alpha_{BC} M_{BC}$

Where α_{BC} is determined by statically loading the corresponding bent in the y-direction

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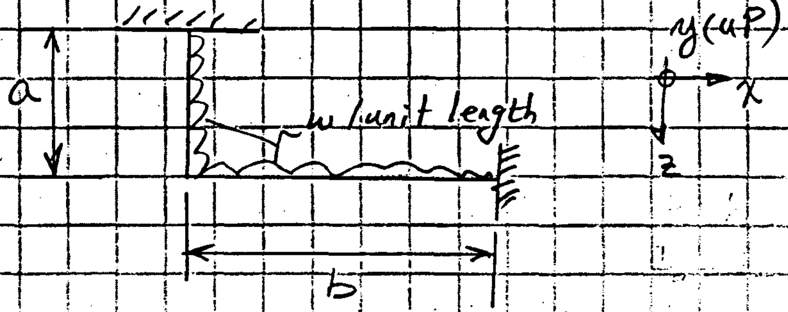

Load above frame statically along y-direction

$$\alpha_{BC} = \frac{\text{Max Torque in frame}}{\text{Maximum bending moment in frame}}$$

Support force B = (Tributary Weight to B) a_y

Support force C = (Tributary Weight to C) a_y

Note: When evaluating leg forces of support consider also effect of T_{BC} on each support

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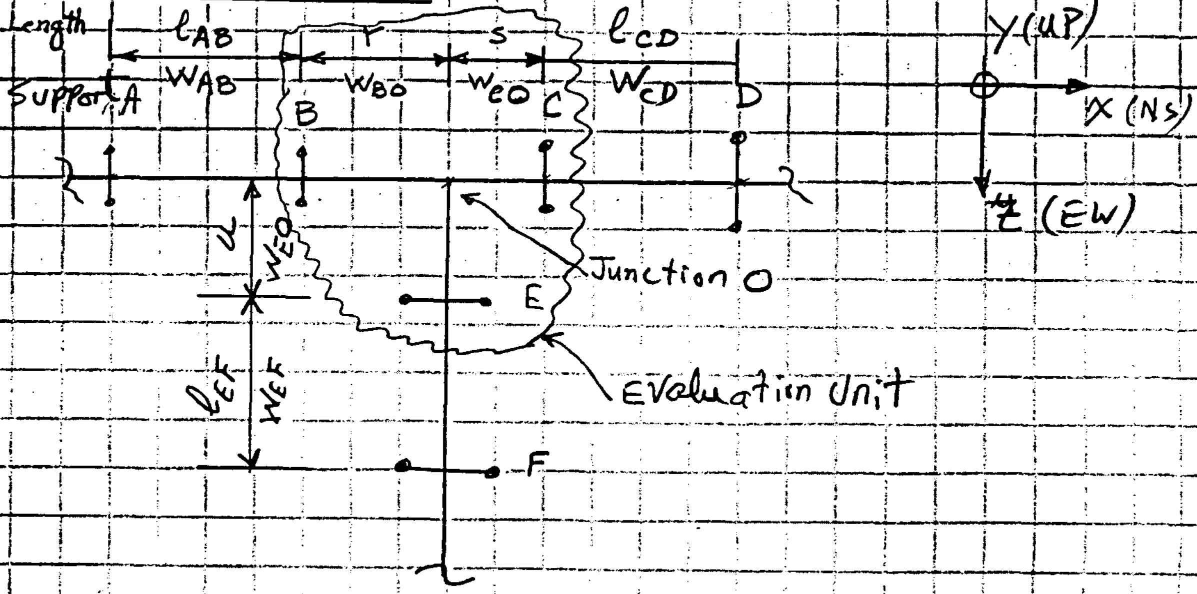
Prepared by	H-Amin	Date 1.23.91
Reviewed by	A-Al-Dabbagh	Date 1/23/91
Approved by		Date

2DF APPROACH WHEN EVALUATION UNIT CONTAINS A TEE



Plan View of Component & Supports

Notes:

1. $W_{AB}, W_{BO}, W_{CO}, W_{EO}, W_{CD}, W_{EF}$ = total weights between the centerline lengths identified

   $W_A, W_B, W_C, W_D, W_E, W_F$ = self weight of supports

2. l_T = span of Tee

   l_{Tx} = span for x-excitation
   $= \text{Max.}\{(r+u), (s+u)\}$

   l_{Ty} = span for y-excitation
   $= \text{Max.}\{(r+s), (r+u), (s+u)\}$

   l_{Tz} = span for z-excitation
   $= r+s$

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In the description below, it is assumed, for simplicity of presentation, that

$$r > u > s$$

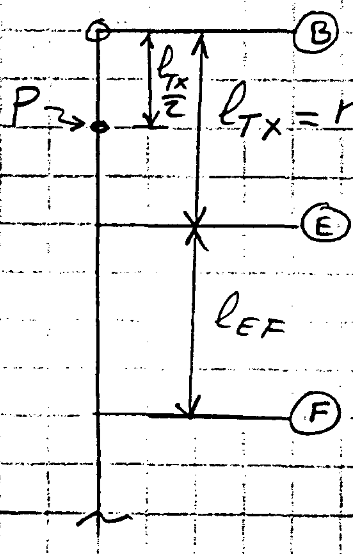
Therefore

$$l_{Tx} = r+u, \quad l_{Ty} = r+u$$

Details of the 2DF Procedure are described separately for each excitation direction

X - Excitation

P = weight of length s to stretched span $l_{TX} = \frac{Wco}{2}$



Step1. Determine k_{BX}, k_{EX} stiffnesses

Step2. $m_{1B} = \frac{W_{AB}}{2g} + \frac{W_{BO}+W_{EO}}{4g} + \frac{W_B}{2g}$

$m_{1E} = \frac{W_{BO}+W_{EO}}{4g} + \frac{W_{EF}}{4g} + \frac{W_E}{2g}$

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Prepared by	M. Ami	Date 1.23.91
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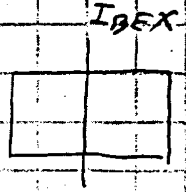
$$\omega_{1BX} = \left[\frac{k_{BX}}{m_{1B}}\right]^{0.5}, \quad \omega_{1EX} = \left[\frac{k_{EX}}{m_{1E}}\right]^{0.5}$$

$$\omega_{1X} = \min(\omega_{1BX}, \omega_{1EX})$$

$$m_1 = \text{Min}(m_{1B}, m_{1E})$$



Step 3. $$k_{2BEX} = \frac{48EI_{BEX}}{(\ell_{TX})^3}$$

$$k_{2EFX} = \frac{48EI_{EFX}}{(\ell_{EF})^3}$$

$$m_{2BEX} = \frac{W_{EO}+W_{BO}}{2g} + \frac{P}{g}$$

$$m_{2EFX} = \frac{W_{EF}}{2g}$$

$$\omega_{2BEX} = \left[\frac{k_{2BEX}}{m_{2BEX}}\right]^{0.5}, \quad \omega_{2EFX} = \left[\frac{k_{2EFX}}{m_{2EFX}}\right]^{0.5}$$

$$\omega_{2X} = \min(\omega_{2BEX}, \omega_{2EFX})$$

$$m_2 = 0.5(m_{2BEX} + m_{2EFX})$$

$$\mu = \frac{m_2}{m_1}$$

Steps 4 & 5 are the same as those on page 2.7
This gives a_x

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Step 6 Determine Component and Support Forces

$$M_{Tee} = \text{Max.}\left\{\left[0.1(W_{BO}+W_{EO})\,l_{TX}\,a_X + \frac{1}{6}P\,l_{TX}\,a_X\right],\ \left[0.1\,W_{EF}\,l_{EF}\,a_X\right]\right\}$$

$$V_{Tee} = 0.5\left[W_{BO}+W_{EO}+P\right]a_x$$

$$N_{Tee} = 0.5\left[W_{BO}+W_{CO}+\frac{W_{EO}}{2}\right]a_x$$

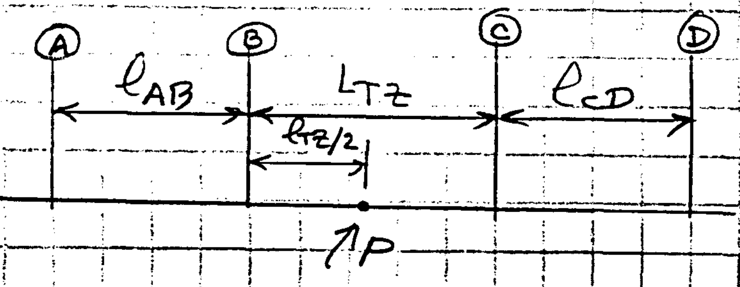
Support Force B = [Tributary Weight to B] a_x

Support Force E = [Tributary Weight to E] a_x

Support Force C = [Tributary Weight to C] a_x

Z-Excitation

P = Weight of length lumped at midspan of span l_{TZ} = W_{EO}



Step 1. Determine K_{BZ}, K_{CZ} stiffness

Step 2. $m_{1B} = \frac{W_{AB}}{4g} + \frac{W_{BO}+W_{CO}}{4g} + \frac{W_B}{2g}$

$m_{1C} = \frac{W_{CD}}{4g} + \frac{W_{BO}+W_{CO}}{4g} + \frac{W_C}{2g}$.

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Prepared by M-Aini Date 1-23-91
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$$\omega_{1BZ} = \left[\frac{k_{BZ}}{m_{1B}}\right]^{0.5}, \quad \omega_{1CZ} = \left[\frac{k_{CZ}}{m_{1C}}\right]^{0.5}$$

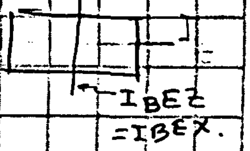
$$\omega_{1Z} = \min(\omega_{1BZ}, \omega_{1CZ})$$

$$m_1 = \min(m_{1B}, m_{1C})$$

Step 3

$$k_{zABZ} = \frac{48EI_{ABZ}}{(L_{AB})^3}, \quad k_{2BCZ} = \frac{48EI_{BCZ}}{(L_{TZ})^3}, \quad k_{2CDZ} = \frac{48EI_{CDZ}}{(L_{CD})^3}$$

$$m_{2AB} = \frac{W_{AB}}{2g}, \quad m_{2BC} = \frac{W_{BC}+W_{CD}}{2g} + \frac{P}{g}$$



$$m_{2CD} = \frac{W_{CD}}{2g}$$

$$\omega_{2ABZ} = \left[\frac{k_{2ABZ}}{m_{2AB}}\right]^{0.5}, \quad \omega_{2BCZ} = \left[\frac{k_{2BCZ}}{m_{2BC}}\right]^{0.5}$$

$$\omega_{2CDZ} = \left[\frac{k_{2CDZ}}{m_{2CD}}\right]^{0.5},$$

$$\omega_{2Z} = \min(\omega_{2ABZ}, \omega_{2BCZ}, \omega_{2CDZ})$$

$$m_2 = \mathrm{Max.}\left[\frac{m_{2AB}+m_{2BC}}{2}, \frac{m_{2BC}+m_{2CD}}{2}\right]$$

$$\mu = \frac{m_2}{m_1}$$

Steps 4 and 5 are the same as those on Page 2.7
This gives a_z

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Step 6 Determine Component and Support Forces

$$M_{Tee} = Max.\left\{\left[0.1\, W_{AB}\, L_{AB}\, a_Z\right], \left[0.1(W_{BO}+W_{CO})\,l_{TZ}\, a_Z + \frac{1}{6} P L_{TZ}\, a_Z\right], \left[0.1 W_{CD}\, L_{CD}\, a_Z\right]\right\}$$

$$V_{Tee} = 0.5\left[W_{BO}+W_{CO}+P\right] a_Z$$

$$N_{Tee} = 1P\, a_Z$$

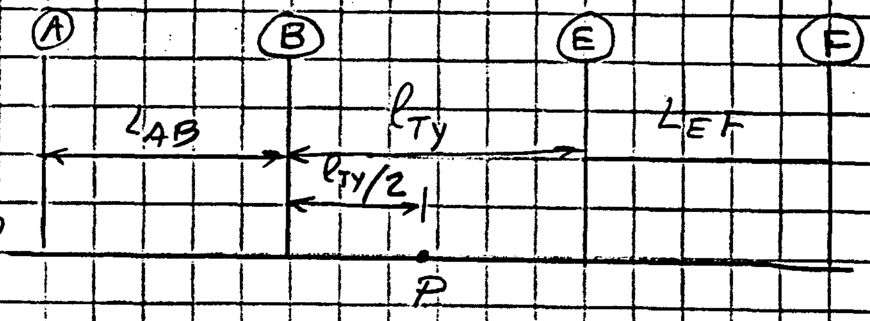
Support Force B = [Tributary Weight to B] a_Z

Support Force C = [Tributary Weight to C] a_Z

Support Force E = [Tributary Weight to E] a_Z

Y- Excitation

P = Weight of lengths concentrated on span $l_{Ty} = \frac{WCO}{2}$



Step 1. Determine k_{BY}, k_{EY} stiffness

Step 2. $m_{1B} = \frac{WAB}{4g} - \frac{WBO+WEO}{4g} + \frac{WB}{2g}$

$m_{1E} = \frac{WBO+WEO+WEF}{4} - \frac{WE}{2g}$

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$$\omega_{1BY} = \left[\frac{k_{BY}}{m_{1B}}\right]^{0.5}, \quad \omega_{1EY} = \left[\frac{k_{EY}}{m_{1E}}\right]^{0.5}$$

$$\omega_{1y} = \min(\omega_{1BY}, \omega_{1EY})$$

$$m_1 = \min(m_{1B}, m_{1C})$$

<u>Step3</u>

$$k_{2ABy} = \frac{48EI_{ABy}}{(L_{AB})^3}, \quad k_{2BEy} = \frac{48EI_{EBY}}{(L_{Ty})^3},$$

$$k_{2EFy} = \frac{48EI_{EFY}}{(L_{EF})^3}$$

$$m_{2AB} = \frac{W_{AB}}{2g}, \quad m_{2BE} = \frac{W_{BD} + W_{EO}}{2g} + \frac{P}{g}$$

$$m_{2EF} = \frac{W_{EF}}{2g}$$

$$\omega_{2ABy} = \left(\frac{k_{2ABy}}{m_{2AB}}\right)^{0.5}, \quad \omega_{2EFy} = \left(\frac{k_{2EFY}}{m_{2EF}}\right)^{0.5}$$

$$\omega_{2BEy} = \left(\frac{k_{2BEY}}{m_{2BE}}\right)^{0.5}$$

$$\omega_{2y} = \min(\omega_{2ABy}\ \omega_{2BEy}, \omega_{2EFy})$$

$$m_2 = \mathrm{MAX}\left[\frac{m_{2AB} + m_{2BE}}{2}, \frac{m_{2BE} + m_{2EF}}{2}\right]$$

$$\mu = \frac{m_2}{m_1}$$

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Steps 4 and 5 are the same as those on Page 2.7
This gives a_y

Step 6 Determine Component and Support Forces

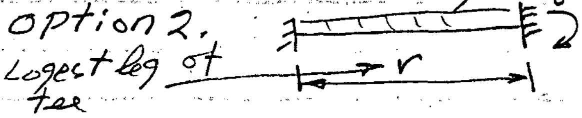
$$M_{Tee} = Max.\left\{ \left[0.1 W_{AB} L_{AB} a_y\right], \left[0.1 (W_{BO} + W_{EO}) L_{Ty} a_y + \frac{1}{6} P L_{Ty} a_y\right], \left[0.1 W_{EF} L_{EF} a_y\right] \right\}$$

$$V_{Tee} = 0.5 \left[W_{BO} + W_{EO} + P\right] a_y$$

Torque T_{Tee} (On Tee Components and all three supports)

option 1. $T = M_{Tee}$ very conservative way

option 2.



use FEM of this beam as T

Support Force B = [Tributary weight to B] a_y

Support Force E = [Tributary weight to E] a_y

Support Force C = [Tributary weight to C] a_y

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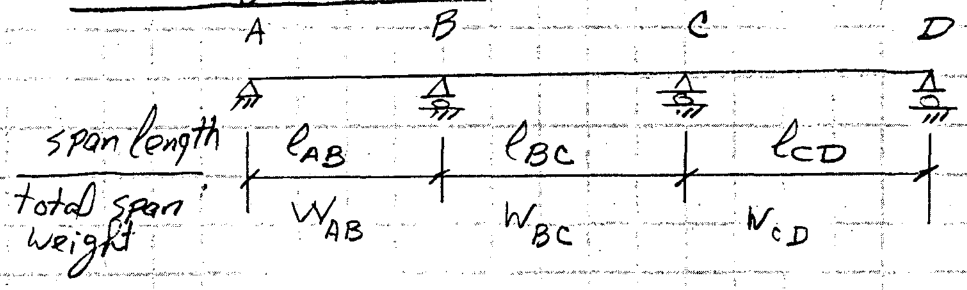
Unequal span Continuous Beam on Rigid Supports (Straight Run)



1. Calculate frequency of each span as simply supported

   Use $\omega = \min.(\omega_{AB}, \omega_{BC}, \omega_{CD})$

2. $f_s = \dfrac{\omega}{2\pi}$

   If $f_s < 33$ hz, $a_s = \{$largest S_a for frequencies greater or equal to $f_s\}$

   If $f_s \geq 33$ hz, $a_s = ZPA$ from building analysis

3. $M_{AB} = \text{Max.}\{(0.125\,W_{AB}\,l_{AB}\,a_s), (0.1\,W_{BC}\,l_{BC}\,a_s)\}$

   $M_{BC} = \text{Max.}\{(0.125\,W_{AB}\,l_{AB}\,a_s), (0.1\,W_{BC}\,l_{BC}\,a_s), (0.125\,W_{CD}\,l_{CD}\,a_s)\}$

   $M_{CD} = \text{Max.}\{(0.1\,W_{BC}\,l_{BC}\,a_s), (0.125\,W_{CD}\,l_{CD}\,a_s)\}$

   $V_{AB} = 0.5\,W_{AB}\,a_s + \dfrac{M_{BC}}{l_{AB}}$

   $V_{CD} = 0.5\,W_{CD}\,a_s + \dfrac{M_{BC}}{l_{CD}}$

   $V_{BC} = 0.5\,W_{BC}\,a_s$

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Any Support force = (Tributary Weight to support) a_s

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M3599.001 6-90

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Description of Systems Considered

For straight-run situations a total of 14 systems on flexible supports and 4 systems on rigid supports are considered in Revision 3. Additionally two variations of a system with elbows and tee is studied

Sytems on Flexible Supports (straigh-Run)

The table on the next page shows the new 14 systems and their relationship to the 4 systems previously studied and the intent of illustrative case study for the new System

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New Straight-Run Systems on Flexible Supports and their Relation to Previous Systems and the Purpose of Case Studies

Intent of Case / System in Rev. 2	New System, Rev. 3		
	More span variation	End span	Two tier system
AA2	AA2150 AA2200	AA2150F AA2150H	
AB2	AB2150 AB2200		
BC3	BC3150 BC3200	BC3150F	
BC4	BC4150 BC4200 BC4125		
—			CT33 CT13
Total	9	3	2

A total of 9 systems are analyzed for span length variation effect. These are the same as systems AA2, AB2, BC3, and BC4, except for span variation. The figures on the next four pages show the similarity

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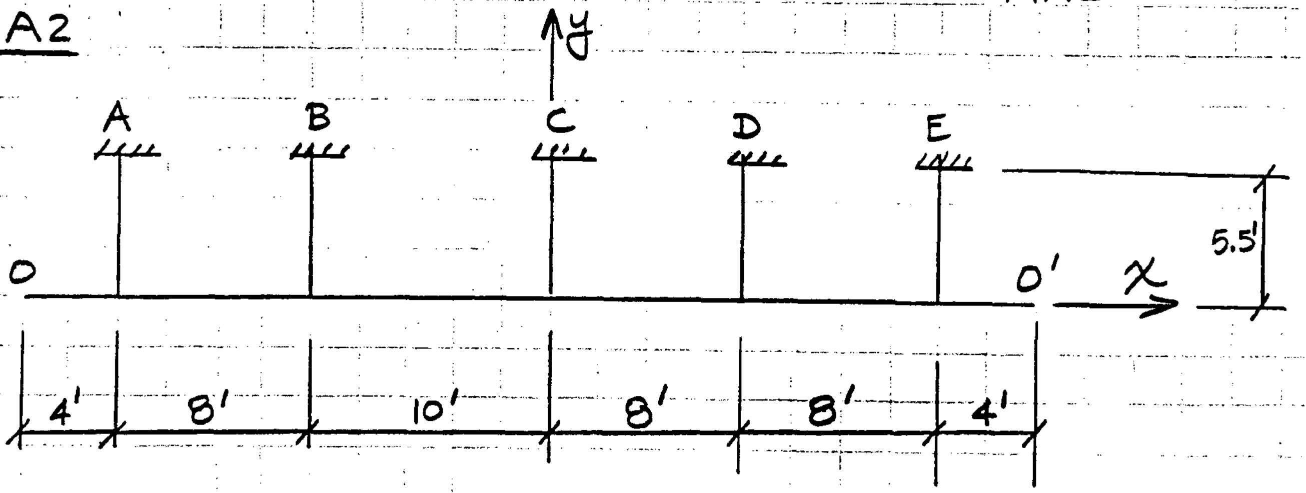
24X36 Duct

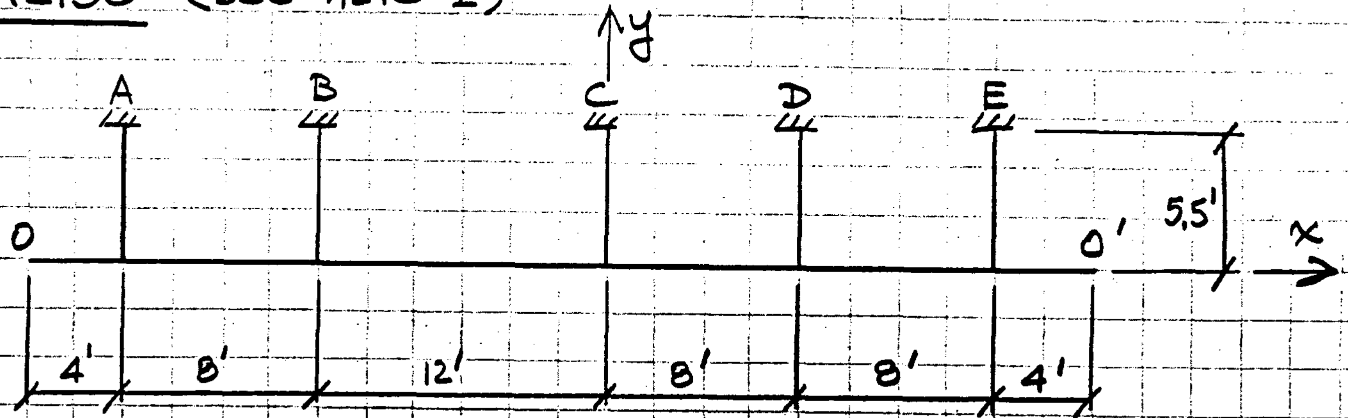
AA2

AA2

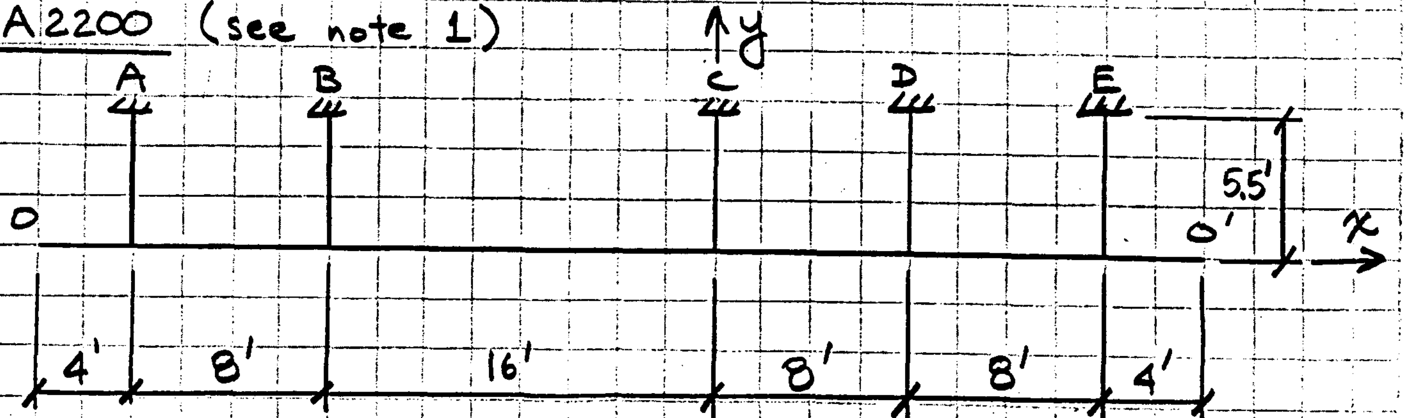


Note 1: For Z excitation, slopes are zero at 0 and 0'

AA2150 (see note 1)



AA2200 (see note 1)



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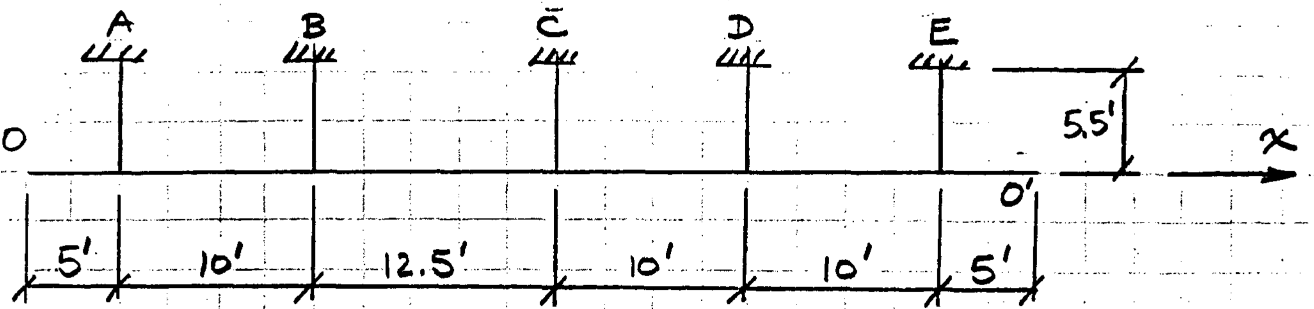
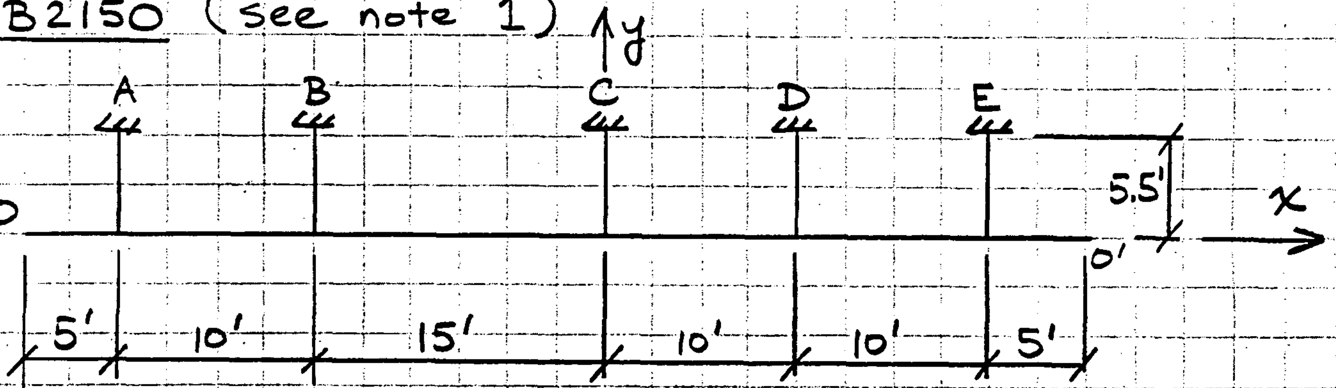
24X36 Duct AB2

AB2

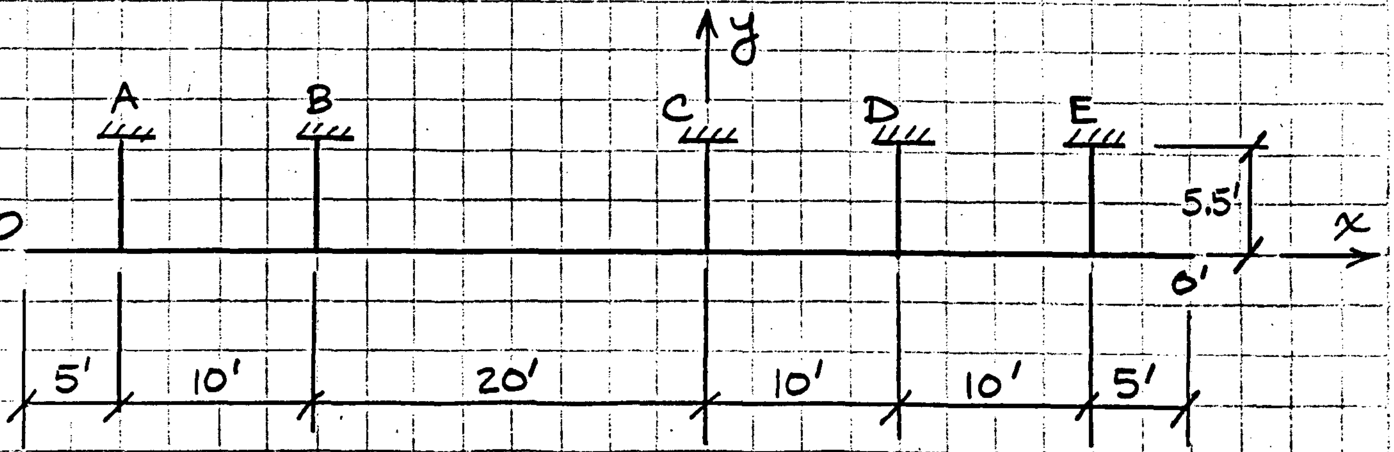
note 1: For Z excitation, slopes are zero at O and O'.



AB2150 (see note 1)



AB2200 (see note 1)



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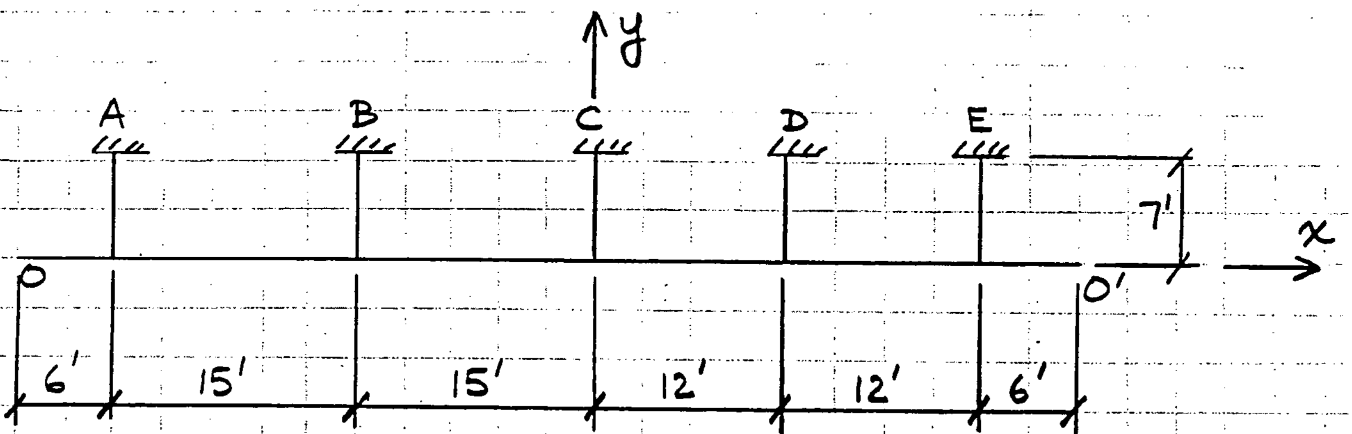
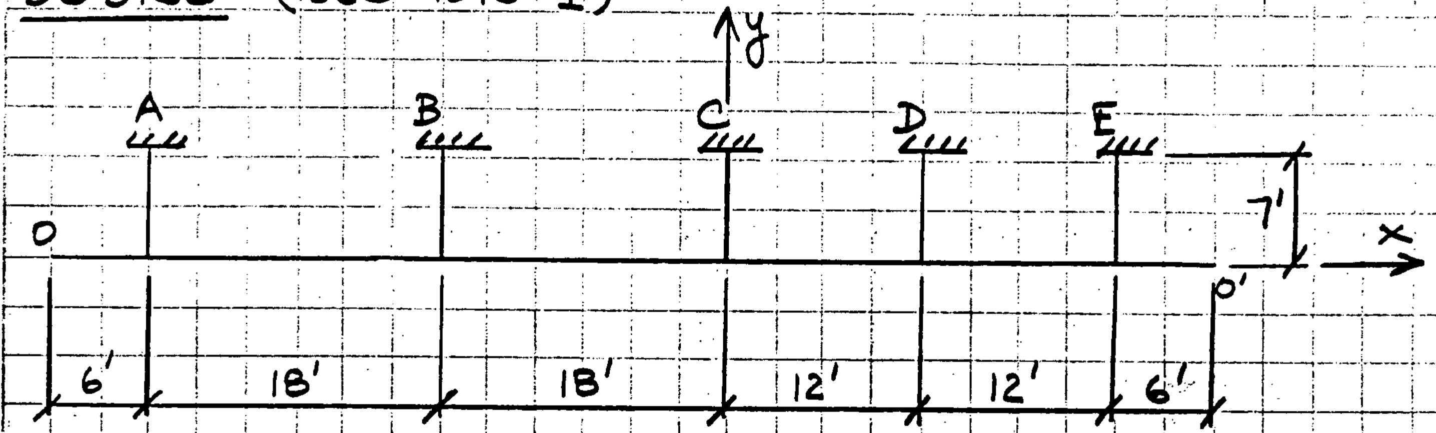
60 x 72 Duct BC3

BC3

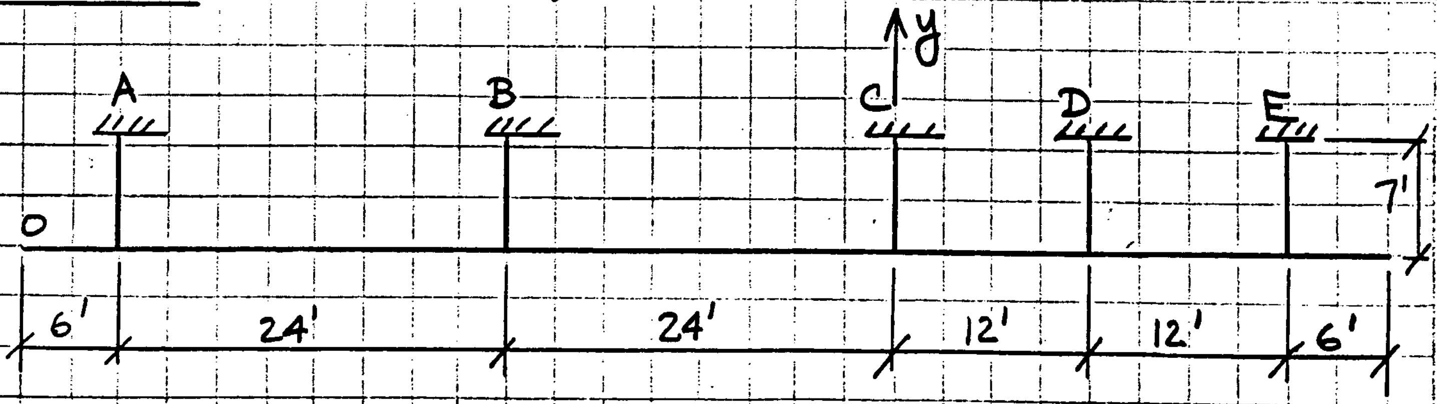
note 1: For z excitation, slopes are zero at O and O'



BC3150 (see note 1)



BC3200 (see note 1)



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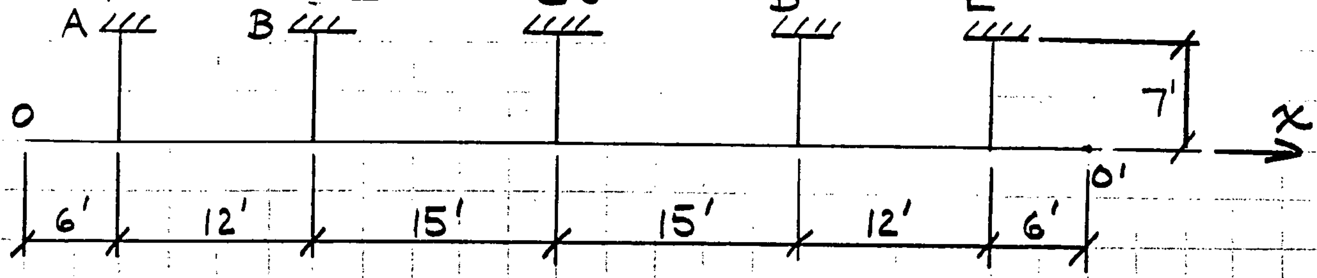
Reviewed by		Date 1.24.91
Approved by		Date

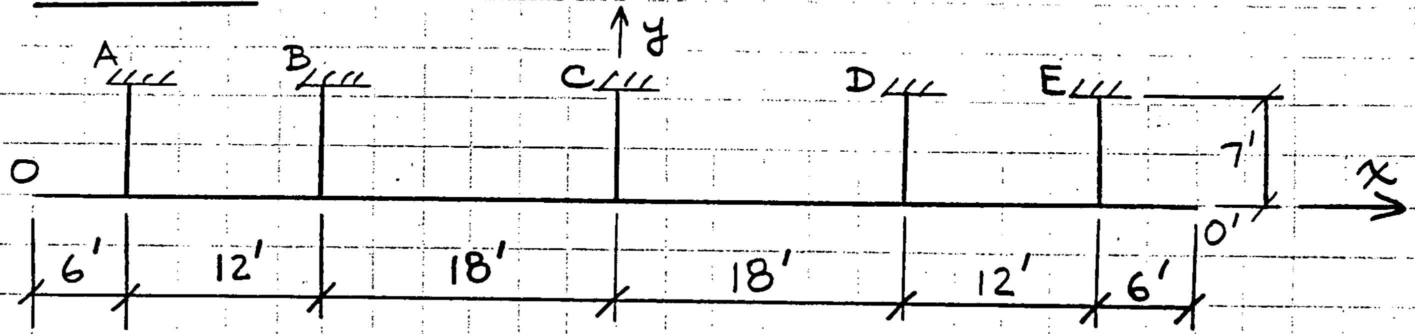
60 X 72 Duct BC4

note 1: For z excitation, slopes are zero at 0 and 0'

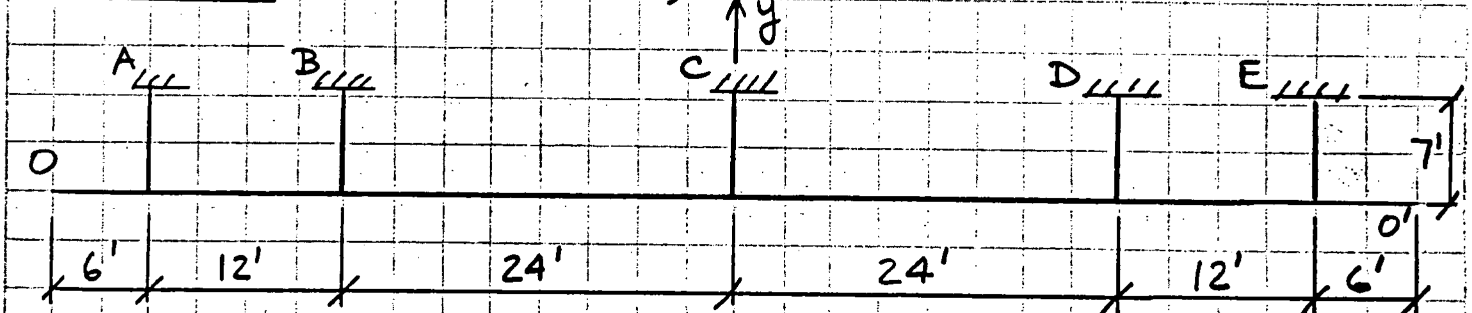
BC4125



BC 4150 (see note 1



BC 4200 (see note 1)



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and the difference. On page 10.11, for example, first, the previous system AA2 is shown. In this system, the span length of the evaluation span BC is $\frac{10}{8} = 1.25$ times (125%) of the adjacent span. The new system AA2150, also shown on page 10.11, differs from AA2 in the fact that this span ratio is $\frac{12}{8} = 1.5$. For system AA2200, the corresponding ratio is $\frac{16}{8} = 2.0$. Note that these are very high adjacent span length differences. A similar relationship exists between the new systems AB2150 and AB2200 with system AB2; the new systems BC3150 and BC3200 with system BC3; and the new systems BC4150, BC4200 with system BC4.

The horizontal member of AA2 and AB2 series weighs 31 #/ft. The corresponding weight for BC3 and BC4 series is 101.2 #/ft. (See Page 3.4). The lateral stiffness of hangers in the z-direction (the direction studied in all of these calculations) were 10838 #/in

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for AA2 and AB2 series (See Pages 4.4 and 4.18) and 4863 #/in for BC3 and BC4 series (See Pages 4.12 and 4.15). Thus, the BC3 and BC4 series analyzed in Revision 2 were very flexible systems compared to AA2 and AB2. When the span lengths were increased by 150% and 200%, the corresponding dynamic lateral directions exceeded 2" for some of BC3 and BC4 series. This was under the SSE-EW spectrum loading. This behavior is not realistic of hangers with steel members at WBN. Lateral deflections of the order 1/2" or less are more representative of the plant conditions.

For this reason the stiffness of supports is increased in Systems BC3150, BC3200, BC4150, and BC4200, by a factor 3 (New stiffness is 14589 = 3x4863), over that used for BC3 and BC4 in Rivision 2. This increase in stiffness keeps lateral deflection of these

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systems to less than 0.7 inches under the SSE-EW spectra.

Because of the increased stiffness relative to Revision 2, a new system (BC4125) is analyzed to be compared to results of BC4 in Revision 2.

Three Systems AA2150E, AA2150H, and BC3150F are analyzed to consider the end span behavior. These are shown on the next two pages. Note the following

* AA2150F and BC3150F have free boundary condition at termination points 0 and 0' instead of zero slope boundary condition for the 9 cases that considered interior span behavior. System AA2150H does not have an overhang

* The overhang length to adjacent span ratio for AA2150F is 2/8 = 0.25, and it's 6/18 = 0.33 and 4/12 = 0.33 for BC3150F

* The lateral hanger stiffness for BC3150F is the increased value over Revision 2 calculation

* Based on information from Page 6.2, System AA2 has the highest MDF/ZDF response ratio (1.09). This was a reason for selecting AA2150F for end span evaluation.

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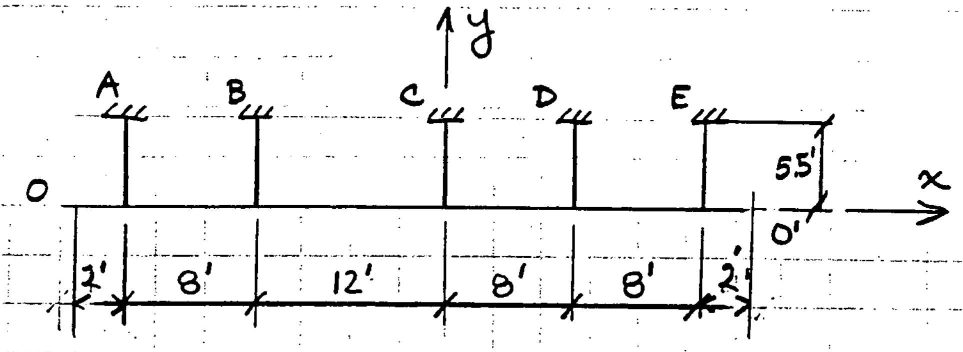
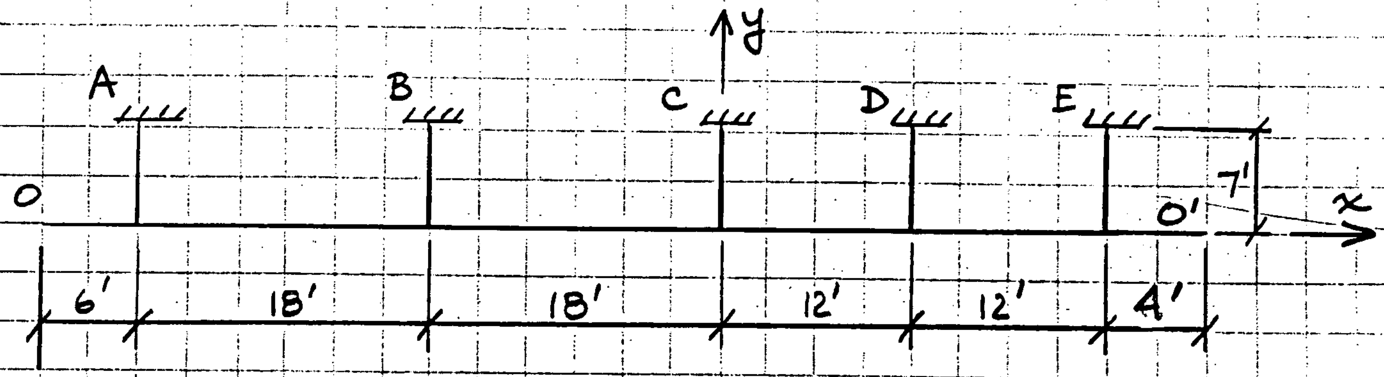
AA2150F 24 X 36 Duct



note: O and O' are free for Z excitation.

BC3150F 60 X 72 Duct



note: O and O' are free for Z excitation.

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In order to include examples for tiered systems, two examples (CT33 and CT13), patterned after cable tray and support systems are analyzed. The figure on the next page shows the configuration studied. Both systems have two tiers (Beams 1 and 2). For system CT33, each beam represents three 18" trays. For system CT13, Beam 1 represents one 18" tray; Beam 2 represents three 18" trays. Therefore, in CT33, both beams have the same properties, i.e. moment of inertia and area. For CT13, these properties are not the same.

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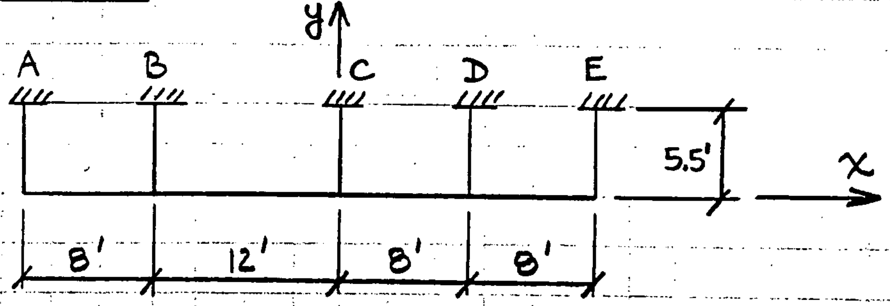
AA 2150H 24X36 Duct



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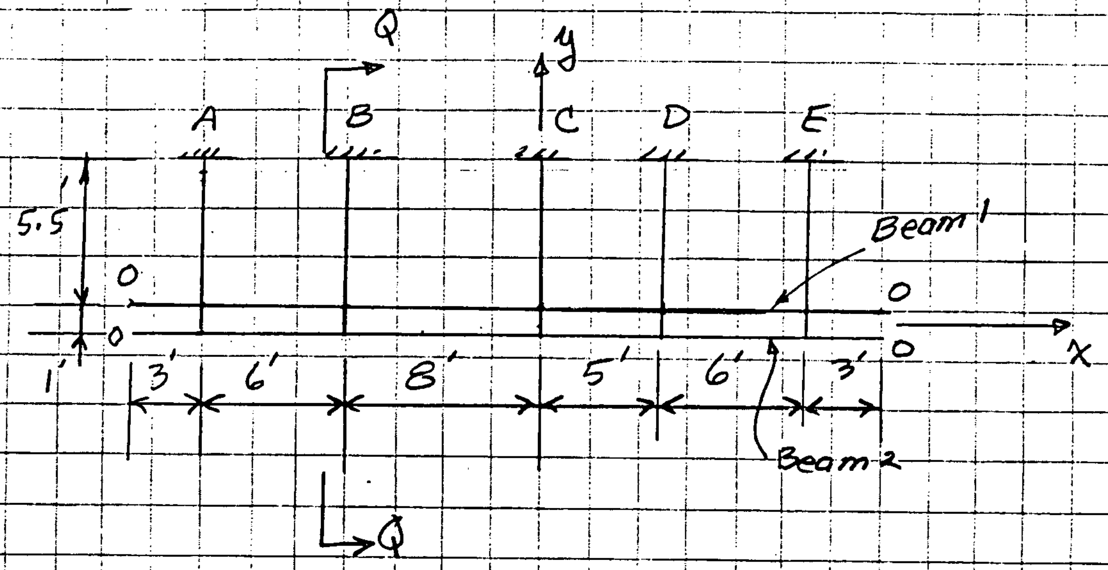
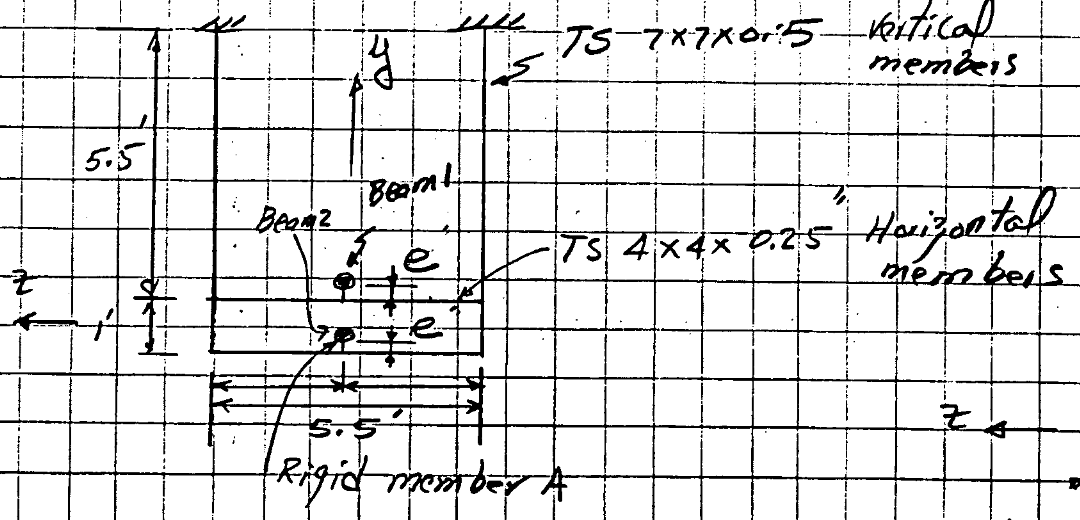
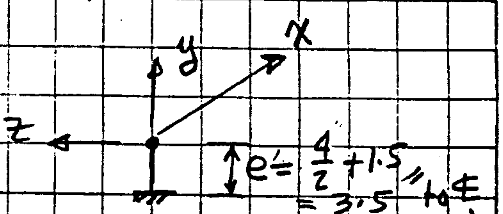
Parameters of Cable Tray Models (CT33 & CT13)







Rigid member A with moment release at beams ($M_x = M_y = M_z = 0$)

Model	No. of 18" trays for Beam 1	Beam 2
CT 33	3	3
CT 13	1	3

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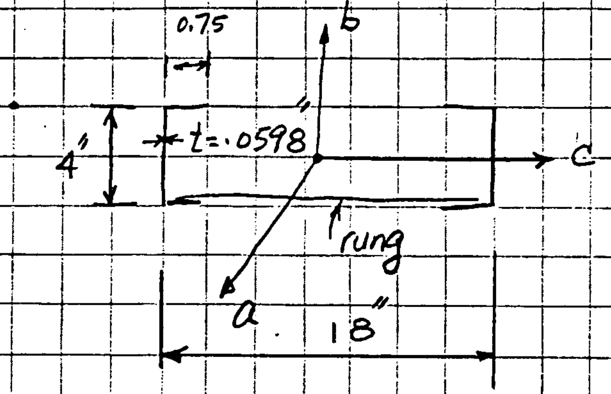
Member Properties

- For one 4" nominal depth tray 18" wide

$W = 45\ \#/ft.$ of length (WB-DC-20-21.1 Section 4.2.1)



Span	Frequency (Hz) f_V	f_H
8'	8.5	9.0
6'	15.0	11.9
5'	21.6	14.3

Reference;
Calc WB-CT-01, Rev. 1
P. 1.25, no attachment
case with 0.8 factor
included.

Use frequencies of 6' span Assume Simply supported to determine I_{cc} and I_{bb}

$$f = \frac{\pi}{2L^2}\sqrt{\frac{EI}{W}g}$$

$$I = \frac{4L^4}{\pi^2} \times \frac{W}{Eg} f^2 \quad ft^4/unit.$$

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$$E = 29\times10^{6}\ \frac{lb}{in^2}\times\frac{144\ in^2}{ft^2} = 4176\times10^{6}\ \frac{lb}{ft^2}$$

$$I = \frac{4\times(6)^4}{(3.14)^2}\times\frac{45}{4176\times10^{6}\times32.2}\times f^2 = 0.176\times10^{-6}f^2\ (ft^4)$$

$$= 0.176\times10^{-6}\times(12)^4$$

$$= 0.00365 f^2\ (in^4)$$

$$I_{cc} = 0.00365\times(15)^2 = 0.821\ in^4$$

$$I_{bb} = 0.00365\times(11.9)^2 = 0.517\ in^4$$

$$I_{aa} = I_{bb}+I_{cc} = 0.821+0.517 = 1.34\ in^4$$

$$A_{aa} = 2\,[0.75+4+0.75]\times.0598 = 0.658\ in^2$$

$$A_{cc} = 2\,[0.75+0.75]\times.0598 = 0.179\ in^4$$

$$A_{bb} = 2\,[4]\times0.0598 = 0.478\ in^4$$

- Properties for Beams 1 & 2.

Model	A_{aa} in^2	A_{bb} in^2	A_{cc} in^2	I_{aa} in^4	I_{bb} in^4	I_{cc} in^4
CT33 (Beam 1 & Beam 2)	1.974	1.434	0.537	4.02	1.551	2.463
CT13 (Beam 1)	0.658	0.478	0.179	1.34	0.517	0.821
(Beam 2)	1.974	1.434	0.537	4.02	1.551	2.463

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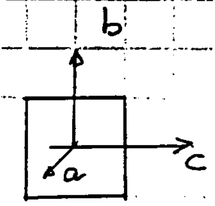
TS 7x7x0.5"

$w = 42.05\ \#/'$



GTSTRUDEL

$A_{aa} = 12.356\ in^2$

$A_{bb} = A_{cc} = 5.600\ in^2$

$I_{bb} = I_{cc} = 84.629\ in^4$

$I_{aa} = 142.213\ in^4$

TS 4x4x0.25

$w = 12.21\ \#/'$

GTSTRUDEL

$A_{aa} = 3.589\ in^2$

$A_{bb} = A_{cc} = 1.500\ in^2$

$I_{bb} = I_{cc} = 8.215\ in^4$

$I_{aa} = 13.614\ in^4$

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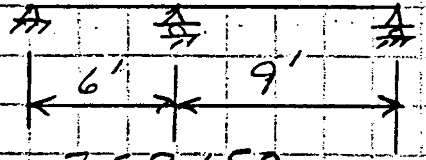
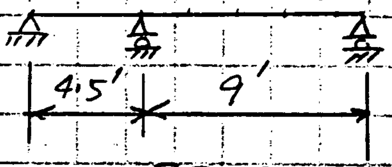
Straight-Run Systems on Rigid Supports

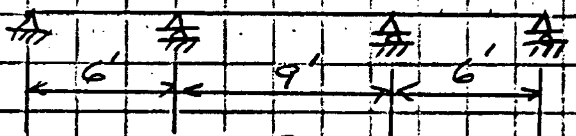
Four systems are evaluated. Two of these, 2SP150 and 2SP200, are two-span beams with unequal spans. The other two are three-span beams with with unequal spans (3SP150 and 3SPMIX). These four systems are shown below



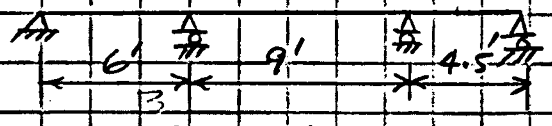
2SP150



2SP200



3SP150



3SPMIX

The beams are prismatic with weight per foot and moment inertia as given on page 7.6

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System With Elbows and Tee (ELBTEE System)

The configuration of this system is shown on the next page. The system consists of a horizontally oriented duct work with two elbows and a tee. The system rests on 18 supports, S1 through S18. The figure on the page following the next page shows typical support configuration. The supports are made of WT6x18, and they are rigidly attached to the ceiling. The duct size, through-out the system, is 36"x24" with the 36" walls being horizontal. The support member size and configuration is typical of duct supports for this size duct.

The global x, y, and z axes used to define the excitations for the duct-support system is shown on the system sketch (next page) The xz-Plane is the horizontal plane and the y-axis is vertical. The system is excitated, separately,

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Reviewed by: A. 1/23/91

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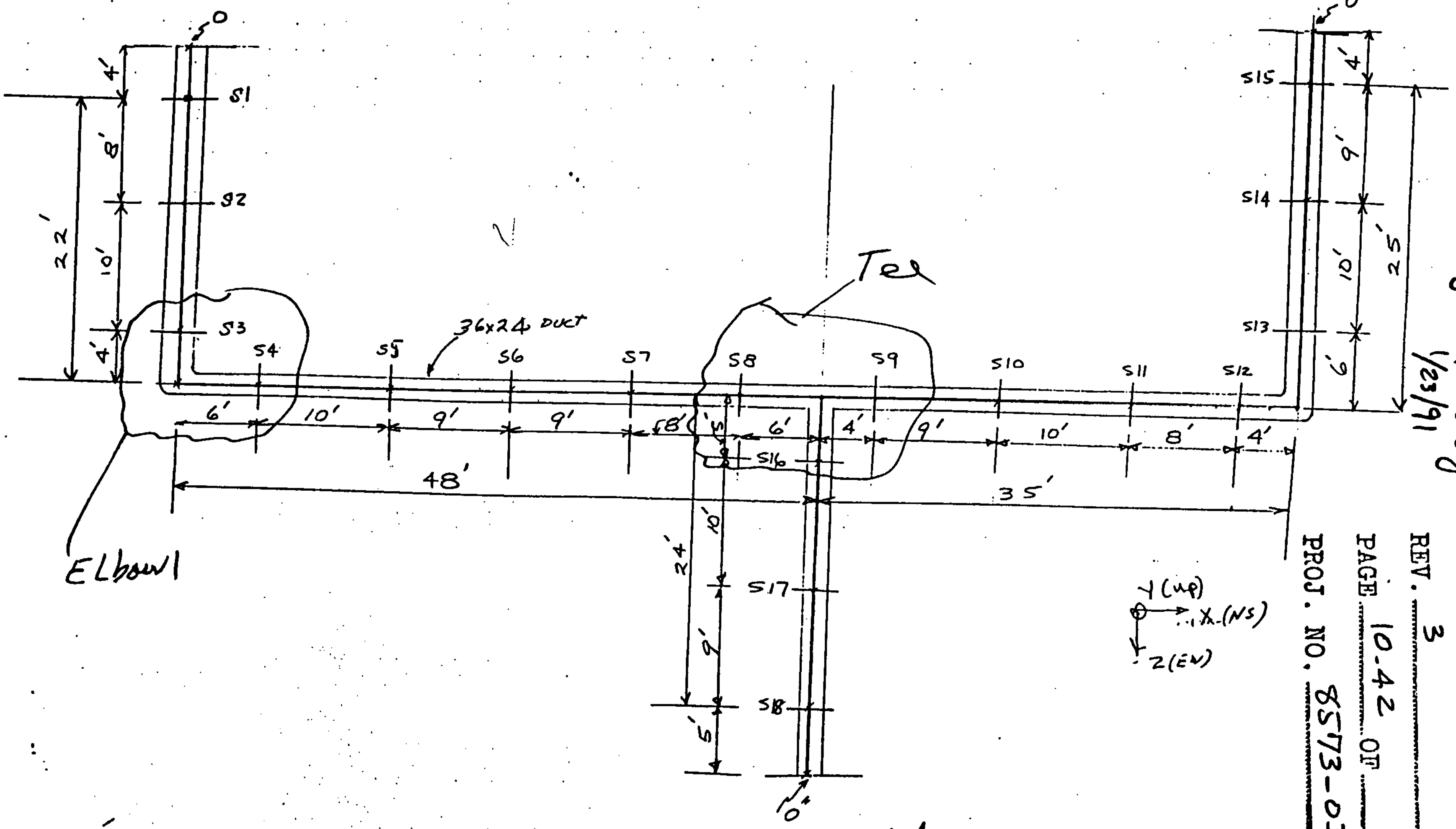

ELBTEE SYSTEM

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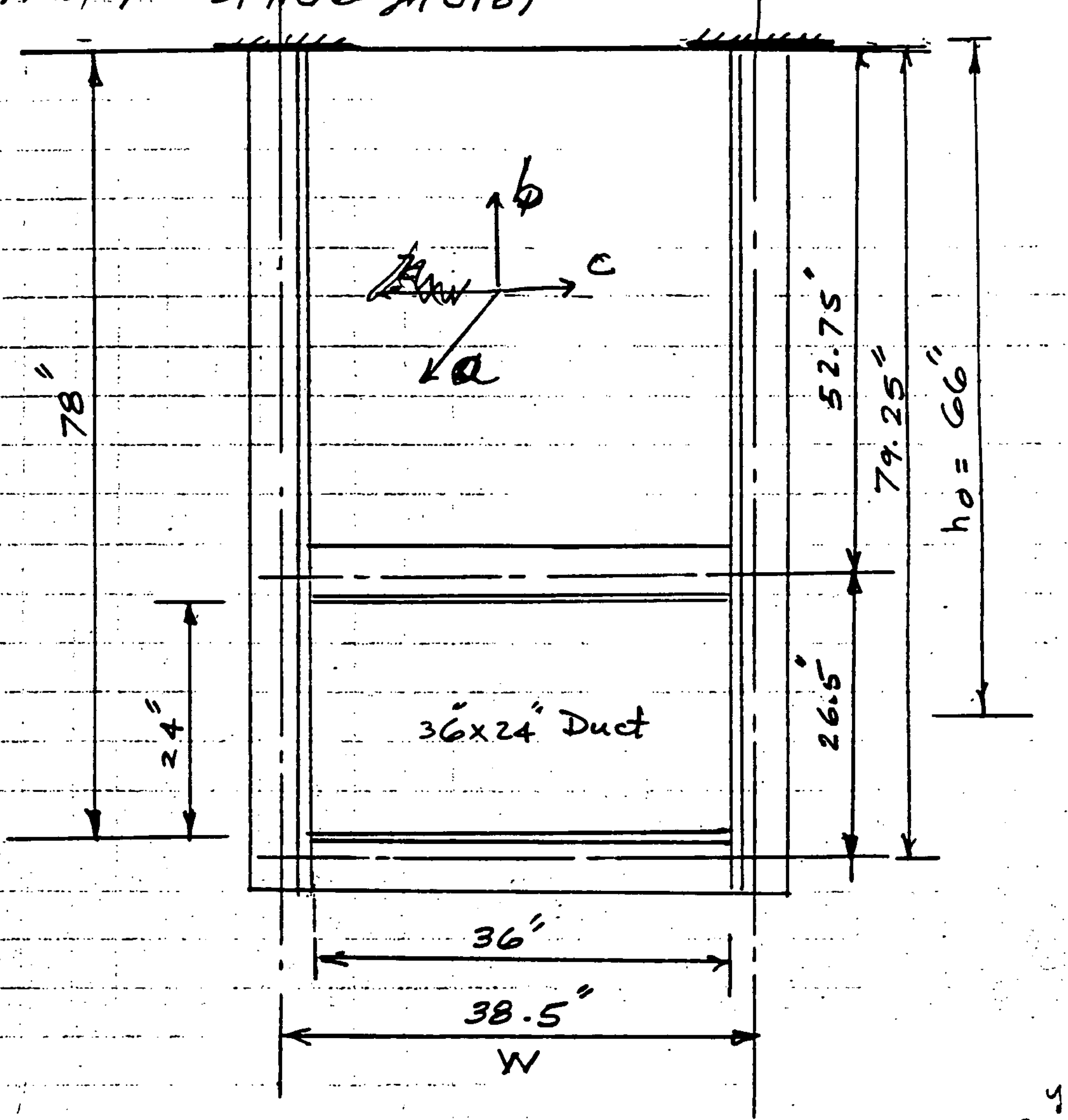
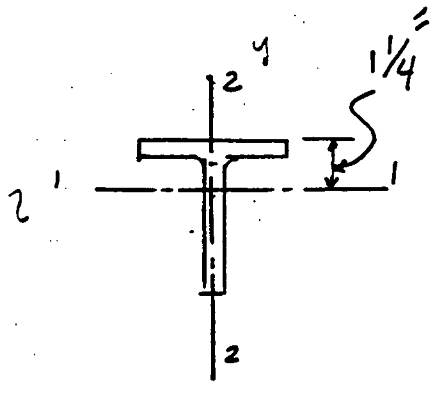
Typical Support Used In Analysis OF ELbows & Tees
(Typical for S1 through S18)





WT 6X 18

$I_1 = 15.3$

$I_2 = 12.7$

$A = 5.30$

$A_1 = 3.545$

$A_2 = 1.867$

$J = 0.397$

wt. = 1.5 #/in

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along x, y, and z-axes by inputing flat 1g spectrum. For all analyses, the boundary conditions at the system terminal points O, O', and O'' are as follows:

* $\delta_x, \delta_y, \delta_z$ free to move
* $\theta_x = \theta_y = \theta_z = 0$ (fixed)

Following are the basic parameters used for analyzing the system

A. System ELBTEE1

This system is used for x and z excitations. (In the vertical direction the system was observed to be too rigid as shown by modal frequencies and mass participation factors listed in Section 15. To obtain dynamic behavior in the vertical direction, the duct member properties and weight were modified. The resulting system is identified as ELBTEE2 and

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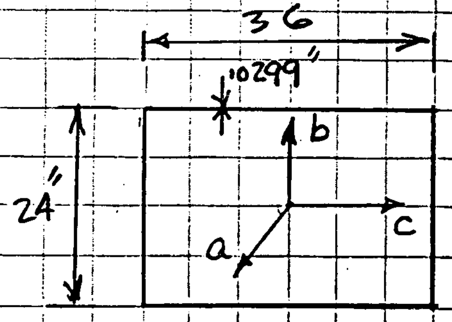
described under B below.

1. Unit Weight
   - duct 31 #/'

2. Material
   For duct and support these are the same as those listed on page 3.5

3. Duct- Support Idealization
   Duct is idealized as 3-D beam members. The effective section properties are determined for analysis following Section 3.3.1.1 of the WB-DC-40-31.8, Rev. 7. For the 36x24 duct, the application of this Procedure yields the following parameters



$A_{aa} = 1.92 \text{ in}^2$ $I_{aa} = 744 \text{ in}^4$
$A_{bb} = 1.44 \text{ in}^2$ $I_{bb} = 126.4 \text{ in}^4$
$A_{cc} = 2.15 \text{ in}^2$ $I_{cc} = 51.1 \text{ in}^4$

These properties are different than those on Page 3.8. The new properties are in accord with Rev. 7 of WB-DC-40-31.8. They were calculated using a short computer Program documented in calc. 857303-7.5, Rev. 0, Appendix A (TVA calc. No. WCG-1-403). For computer output see Appendix A of present calc.

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Support is idealized as six springs attached to the beam node where duct is connected to the support. The six spring constants for a typical support are calculated on the following three Pages

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Duct Support Stiffness

Effective Length = 52.75 ✓ + $\frac{26.5}{2}$ ✓ = 66" ✓

[illegible]) a- direction

$I = 12.7 \times 2 = 25.4 \text{ in}^4$ ✓ (two Legs)

$K_a = \frac{12EI}{L^3}$ ✓

$= \frac{12 \times 29000 \times 25.4}{(66)^3}$

$k_a = 30.75$ k/in ✓

[illegible]) c- direction

$I = 2 \times 15.3 = 30.6 \text{ in}^4$ ✓ (two legs)

$k_c = \frac{12EI}{L^3}$

$= \frac{12 \times 29000 \times 30.6}{(66)^3}$ ✓

$k_c = 37.04$ k/in

[illegible]) b- direction

Area = $2 \times 5.30 = 10.6 \text{ in}^2$ ✓ (two legs)

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$$k_b = \frac{EA}{L} = \frac{29000 \times 10.6}{66} = 4657.6 \ k/in$$ ✓

a) $$k_{\theta a} = \frac{E A W^2}{2 h_o}$$

$$= \frac{29000 \times 5.3 \times (38.5)^2}{2 \times 66}$$

$$= 1.7259 \times 10^6 \ \text{in-k / Rad.}$$ ✓

$$= \frac{1.7259 \times 10^6}{57.29578} = 30123 \ \text{in-k / degree}$$ ✓

b) $$k_{\theta b} = \frac{6 E I_z W^2}{h_o^3}$$

$$= \frac{6 \times 29000 \times 12.7 (38.5)^2}{(66)^3}$$

$$= 11393.1 \ \text{in-k / Rad.}$$ ✓

$$= \frac{11393.1}{57.29578} = 198.85 \ \text{in-k / degree}$$ ✓

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6) $k_{\theta c} = \dfrac{8EI_z}{h_o}$

$= \dfrac{8 \times 29000 \times 12.7}{66}$

$= 44642.4$ in-k / Rad.

$= 779.2$ in-k / degree

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Support effective Weight

Assume all members surrounding the duct are effective plus 1/2 the length of the legs

WT 6x18 wt. = 1.5 #/in

Effective WT Length = $2 \times 36 + 2 \times 36 + 2 \times 48 \times \frac{1}{2}$

= 192"

Effective wt. = 192 × 1.5 = 288 #

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Client	TVA	Prepared by	M. Amin	Date 1.23.91
Project	WBN	Reviewed by	A-AlDabbagh	Date 1/24/91
Proj. No.	8573-03 Equip. No.	Approved by		Date

B. System ELBTEE2

This system is used only for study of y (vertical) excitation. (System ELBTEE1 was found to be too rigid based on frequencies for y-excitation; see Section 15)

These are the basic parameters of ELBTEE2

1. Unit Weight of beam members = 45 #/'
   (same as for a 18" wide cable tray)

2. Beam area and moment of inertia properties correspond to a single 18" wide tray as listed on Page 10.38.

3. Support stiffnesses

   - Horizontal translational springs same as ELBTEE1 axes, same as ELBTEE1
   - Vertical translational spring very rigid
     vertical axis infinitely rigid
   - Rotational springs $K_{\theta c}^{t}$ (see Page 10.43) is zero (free). This is because tray connection to its support is not the same as duct connection to its support
   - Rotational springs $K_{\theta b}$ and $K_{\theta a}$ same as ELBTEE1

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ENGINEERS

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Client	TVA	Prepared by M. Ami	Date 1.23.91
Project	WBN	Reviewed by A-AliDabbagh	Date 1/24/91
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4. Translational inertias along the horizontal (x and z) axes are condensed.

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Client	TVA	Prepared by	Date 12/11/90
Project	WATTS BAR	Reviewed by S. M. Lamoureux	Date 1.24.91
Proj. No.	8573-03 Equip. No.	Approved by	Date

11. MDF Results for Systems on Flexible Supports (Straight Run Models)

The multi-degress-of-freedom (MDF) analyses were performed using the GTSTRUDL Version GTICES 3.3B (8701).

The following systems were analyzed:

1. AA2150 ✓
2. AA2200 ✓
3. AB2150 ✓
4. AB2200 ✓
5. BC3150 ✓
6. BC3200 ✓
7. BC4125 ✓
8. BC4150 ✓
9. BC4200 ✓
10. AA2150F ✓
11. AA2150H ✓
12. BC3150F ✓
13. CT33 ✓
14. CT13 ✓

The results of analyzing these systems are summarized on pages 11.2 thru 11.6. They were extracted from the GTSTRUDL computer runs as described on the following pages of this Section. For input spectra and modal combination rule see Pages 3.10 thru 3.14. ✓

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Project	WATTS BAR	Reviewed by	A. M. Lamoureux	Date	12-14-90
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SUMMARY OF RESULTS FOR COMPONENT AND SUPPORT FORCES

(SSE-EW SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE units: POUNDS
	MOMENT units: FT-POUND	SHEAR units: POUNDS	
AA2150	BC 703 ✓	BC 305 ✓	B 592 ✓ C 600 ✓
AA2200	BC 1327 ✓	BC 449 ✓	B 706 ✓ C 709 ✓
AB2150	BC 1102 ✓	BC 400 ✓	B 706 ✓ C 704 ✓
AB2200	BC 2164 ✓	BC 620 ✓	B 936 ✓ C 935 ✓
BC3150	BC 7891 ✓	BC 2358 ✓	B 5294 ✓ C 3786 ✓
BC3200	BC 16950 ✓	BC 4517 ✓	B 9598 ✓ C 5268 ✓
BC4125	BC 4983 ✓	BC 1761 ✓	B 3298 ✓ C 4112 ✓
BC4150	BC 8458 ✓	BC 2389 ✓	B 3698 ✓ C 5732 ✓
BC4200	BC 16183 ✓	BC 4516 ✓	B 4936 ✓ C 10264 ✓

SARGENT & LUNDY ENGINEERS	Calcs. For		Calc. No. 8.11.6-1
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SUMMARY OF
RESULTS FOR COMPONENT AND SUPPORT FORCES (Cont.)
(SSE-EW SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE
	MOMENT units: FT-POUNDS	SHEAR units: POUNDS	units: POUNDS
AA2150F	AO 91 ✓	AO 68 ✓	A 361 ✓
	AB 307 ✓	AB 158 ✓	B 607 ✓
	EO' 78 ✓	EO' 58 ✓	E 386 ✓
	DE 306 ✓	DE 162 ✓	D 427 ✓
AA2150H	AB 313 ✓	AB 161 ✓	A 238 ✓
			B 620 ✓
	DE 342 ✓	DE 149 ✓	E 247 ✓
			D 409 ✓
BC3150F	AO 3414 ✓	AO 1007 ✓	A 3744 ✓
	AB 8625 ✓	AB 2429 ✓	B 5762 ✓
	EO' 1751 ✓	EO' 706 ✓	E 2434 ✓
	DE 3213 ✓	DE 1103 ✓	D 2416 ✓
CT33			B 2692 ✓
			C 2964 ✓
(Tier 1)	BC 1206 ✓	BC 808 ✓	
(Tier 2)	BC 1317 ✓	BC 886 ✓	
CT13			B 1697 ✓
			C 1975 ✓
(Tier 1)	BC 362 ✓	BC 242 ✓	
(Tier 2)	BC 1163 ✓	BC 784 ✓	

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Calcs. For		
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Project	WATTS BAR	Reviewed by D. M. Lamoureux	Date 12-14-90
Proj. No. 8573-03	Equip. No.	Approved by	Date

SUMMARY OF
RESULTS FOR COMPONENT AND SUPPORT FORCES
(FLAT 1-g SPECTRUM)

SYSTEM	COMPONENT				SUPPORT FORCE units: POUNDS	
	MOMENT units: FT-POUND		SHEAR units: POUNDS			
AA2150	BC	474 ✓	BC	206 ✓	B	401 ✓
					C	405 ✓
AA2200	BC	743 ✓	BC	250 ✓	B	403 ✓
					C	402 ✓
AB2150	BC	651 ✓	BC	236 ✓	B	424 ✓
					C	422 ✓
AB2200	BC	981 ✓	BC	280 ✓	B	446 ✓
					C	449 ✓
BC3150	BC	3257 ✓	BC	951 ✓	B	2110 ✓
					C	1572 ✓
BC3200	BC	5188 ✓	BC	1364 ✓	B	2890 ✓
					C	1643 ✓
BC4125	BC	2286 ✓	BC	802 ✓	B	1510 ✓
					C	1872 ✓
BC4150	BC	3479 ✓	BC	968 ✓	B	1523 ✓
					C	2322 ✓
BC4200	BC	4867 ✓	BC	1349 ✓	B	1571 ✓
					C	3068 ✓

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Calcs. For

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Client	TVA	Prepared by	Date 12/14/90
Project	WATTS BAR	Reviewed by G. M. Lamoureux	Date 12-14-90
Proj. No.	8573-03 Equip. No.	Approved by	Date

SUMMARY OF
RESULTS FOR COMPONENT AND SUPPORT FORCES (cont.)

(FLAT 1-g SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE
	MOMENT units: FT-POUNDS	SHEAR units: POUNDS	units: POUNDS
AA2150F	AO 66 ✓	AO 49 ✓	A 258 ✓
	AB 208 ✓	AB 108 ✓	B 409 ✓
	EO' 55 ✓	EO' 42 ✓	E 274 ✓
	DE 217 ✓	DE 114 ✓	D 299 ✓
AA2150H	AB 200 ✓	AB 111 ✓	A 174 ✓
			B 418 ✓
	DE 245 ✓	DE 106 ✓	E 177 ✓
			D 287 ✓
BC3150F	AO 1484 ✓	AO 432 ✓	A 1485 ✓
	AB 3397 ✓	AB 944 ✓	B 2244 ✓
	EO' 889 ✓	EO' 359 ✓	E 1236 ✓
	DE 1268 ✓	DE 560 ✓	D 1120 ✓
CT33			B 1510 ✓
			C 1672 ✓
(Tier 1)	BC 506 ✓	BC 352 ✓	
(Tier 2)	BC 546 ✓	BC 384 ✓	
CT13			B 1010 ✓
			C 1200 ✓
(Tier 1)	BC 159 ✓	BC 111 ✓	
(Tier 2)	BC 507 ✓	BC 358 ✓	

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ENGINEERS

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Client	TVA	Prepared by	Date 12/11/90
Project	WATTS BAR	Reviewed by S. M. Lamoureux	Date 12-12-90
Proj. No.	8573-03 Equip. No.	Approved by	Date

For each system analyzed, the information is summarized as follows:

- Nodalized FEM model used
- Results for SSE-EW spectrum analysis
- Results for Flat 1-g spectrum analysis.

The fiche of the computer outputs for these analyses are included in these calulations. These systems are described in detail in Section 10.

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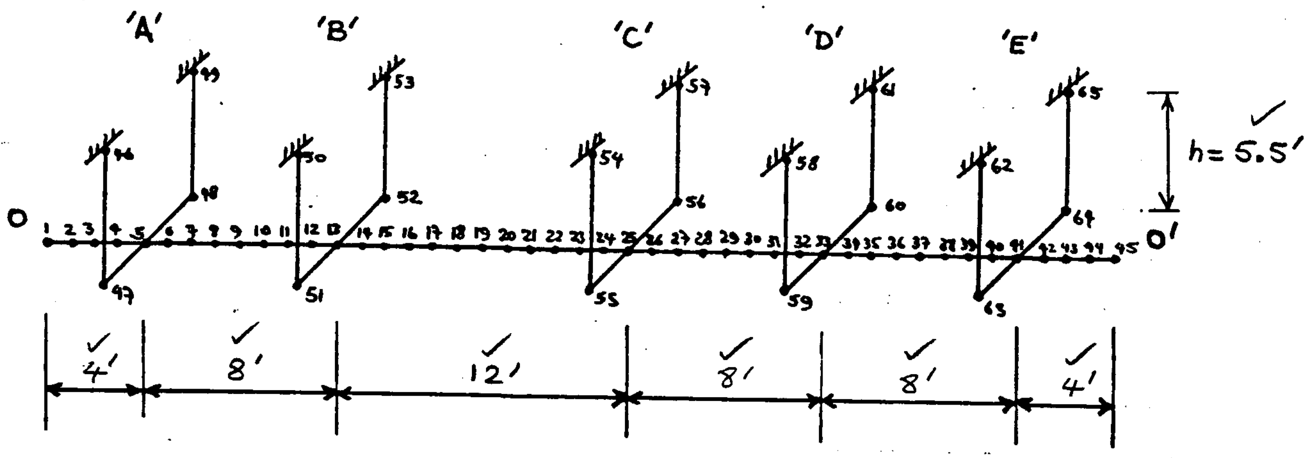
Client	TVA	**Prepared by**	[illegible]	**Date** 12/11/90
Project	WATTS BAR	**Reviewed by**	J. M. Lamoureux	**Date** 12-11-90
Proj. No.	8573-03 **Equip. No.**	**Approved by**		**Date**

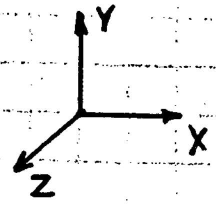
MDF for AA2150 ✓

24 x 36 DUCT ✓

Nodalized FEM Model of AA2150



Slopes are zero at O & O' for Z excitation. ✓



SARGENT & LUNDY
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Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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Client	TVA		
Project	WATTS BAR		
Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/11/90
Reviewed by	D. M. Lamoureux	Date	12-11-90
Approved by		Date	

MDF for AA2150 (Cont.)

SSE - EW SPECTRUM ANALYSIS

Reference Run : HNEL 11/15/90 ✓
Input File : AA2150I ✓
Output File : AA2150O ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 25 = 8432 ✓ in-lb = 703 ✓ ft-lb (AT 19 ✓)
SHEAR Z, max. of nodes 13 thru 25 = 305 ✓ lb. (Between 24 & 25)

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 296.2 + 296.2 = 592 lb. ✓
SUPPORT FORCE "C" (Sum of Shear Z at 54 & 57)
= 300.1 + 300.1 = 600 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)	
2	15.3	46.7	✓
3	17.5	17.6	✓
4	17.8	33.4	✓
5	20.7	2.0	✓

Σ 99.946 ✓

SARGENT & LUNDY
ENGINEERS

Calcs. For		**Calc. No.** 8.11.6-1
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Client TVA		**Prepared by**	**Date** 12/11/90
Project WATTS BAR		**Reviewed by** S. M. Lamoureux	**Date** 12-12-90
Proj. No. 8573-03	**Equip. No.**	**Approved by**	**Date**

MDF for AA2150 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JGAX ✓ 11/28/90 ✓
Input File : AA2150J ✓
Output File : AA2150Q ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 25 = 5686 in-lb = 474 ✓ ft-lb (AT 19) ✓

SHEAR Z, max. of nodes 13 thru 25 = 206 ✓ lb. (Between 24 & 25) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 200.3 + 200.3 = 401 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 54 & 57)
= 202.6 + 202.6 = 405 Lb. ✓

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SARGENT & LUNDY
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Client	TVA
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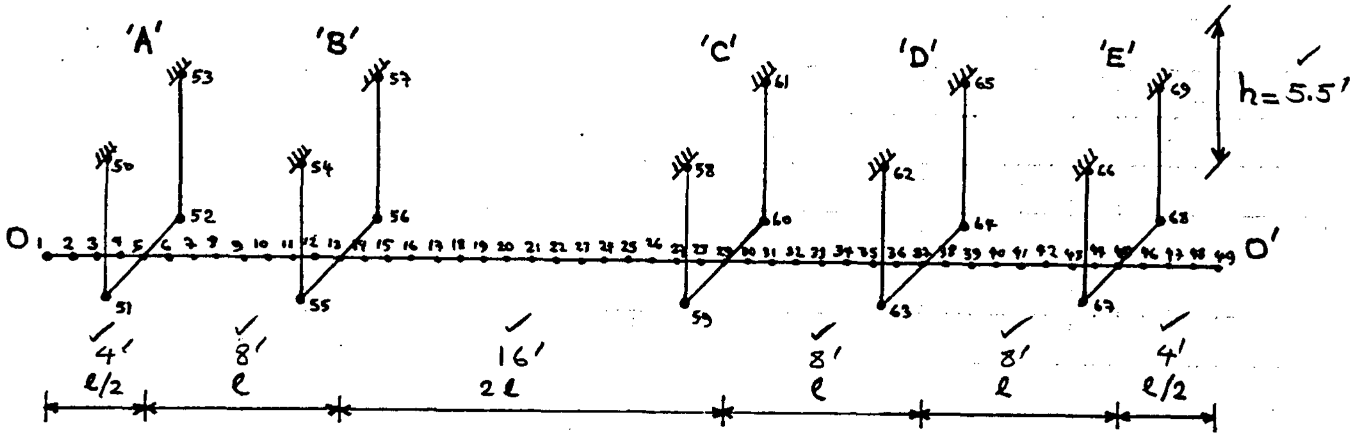
Equip. No.	
Prepared by	
Date	12/11/90
Reviewed by	D. M. Lamoureux
Date	12-11-90
Approved by	
Date	

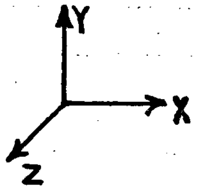
MDF for AA2200 ✓

24 x 36 DUCT

Nodalized FEM model of AA2200



Slopes are zero at O & O' for Z excitation. ✓



SARGENT & LUNDY
ENGINEERS

Calcs. For	
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Client	TVA		
Project	WATTS BAR		
Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/11/90
Reviewed by	J. M. Lamoureux	Date	12-11-90
Approved by		Date	

MDF for AA2200 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : HUAO 11/17/90 ✓
Input File : AA2200I ✓
Output File : AA2200O ✓

Results

COMPONENT SPAN "BC"
MOMENT Y, max. of nodes 13 thru 29 = 15920 in-lb = 1327 ft-lb (AT 21) ✓
SHEAR Z, max. of nodes 13 thru 29 = 449 lb. (Between 28 & 29) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57) ✓
= 353.2 + 353.2 = 706 lb.
SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 354.6 + 354.6 = 709 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)	
2	12.1	33.4	✓
3	17.4	13.7	✓
4	17.7	47.6	✓
5	19.7	4.2	✓
6	24.6	0.5	✓
8	32.3	0.5	✓

$\sum$ 99.937 ✓

SARGENT & LUNDY
ENGINEERS

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Project	WATTS BAR	Reviewed by J. M. Lamoureux	Date 12-12-90
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MDF for AA2200 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JGIN ✓ 11/28/90 ✓
Input File : AA2200J ✓
Output File : AA2200Q ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 29 = 8914 in-lb ✓ = 743 ✓ ft.lb ✓ (AT 21) ✓

SHEAR Z, max. of nodes 13 thru 29 = 250 lb. ✓ (Between 28 & 29)

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 201.4 + 201.4 = 403 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 201.2 + 201.2 = 402 Lb ✓

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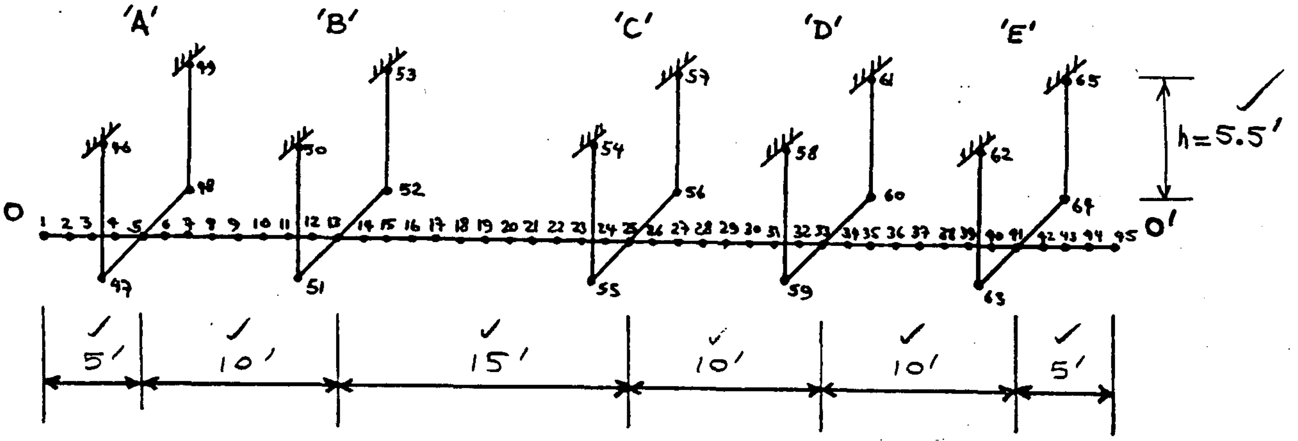
Prepared by	Date 12/11/90
Reviewed by A. M. Lamoureux	Date 12-11-90
Approved by	Date

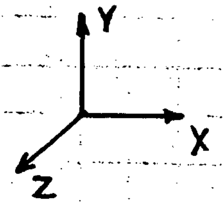
MDF for AB2150 ✓

24×36 DUCT ✓

Nodalized FEM Model of AB2150



Slopes are zero at O & O' for Z excitation. ✓



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SARGENT & LUNDY
ENGINEERS

Calcs. For			
☒	Safety-Related	☐	Non-Safety-Related

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Client	TVA		
Project	WATTS BAR		
Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/11/90
Reviewed by	D. M. Lamoureux	Date	12-11-90
Approved by		Date	

MDF for AB2150 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : HNJI 11/15/90 ✓
Input File : AB2150I ✓
Output File : AB2150O ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 25 = 13220 in-lb = 1102 ft-lb (AT 19) ✓
SHEAR Z, max. of nodes 13 thru 25 = 400 lb. (Between 24 & 25) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 353.1 + 353.1 = 706 lb. ✓
SUPPORT FORCE " " (Sum of Shear Z at &)
= 351.9 + 351.9 = 704 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	12.8	31.3 ✓
3	15.9	21.6 ✓
4	16.0	41.4 ✓
5	17.3	4.6 ✓
6	21.1	0.3 ✓
7	25.5	0.5 ✓

$\sum 99.799$

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ENGINEERS

Calcs. For		
☒ Safety-Related		☐ Non-Safety-Related

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Client	TVA	
Project	WATTS BAR	
Proj. No.	8573-03	Equip. No.

Prepared by		Date 12/11/90
Reviewed by	D. M. Lamoureux	Date 12-12-90
Approved by		Date

MDF for AB2150 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JGIX ✓ 11/28/90 ✓
Input File : AB2150J ✓
Output File : AB2150Q ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 25 = 7809 ✓ in-lb = 651 ✓ ft-lb (AT 19 ✓)

SHEAR Z, max. of nodes 13 thru 25 = 236 ✓ lb. (Between 24 & 25 ✓)

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 212.1 + 212.1 = 424 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 54 & 57)
= 211.1 + 211.1 = 422 Lb. ✓

SARGENT & LUNDY
ENGINEERS

Calcs. For		
☒ **Safety-Related**	☐ **Non-Safety-Related**	
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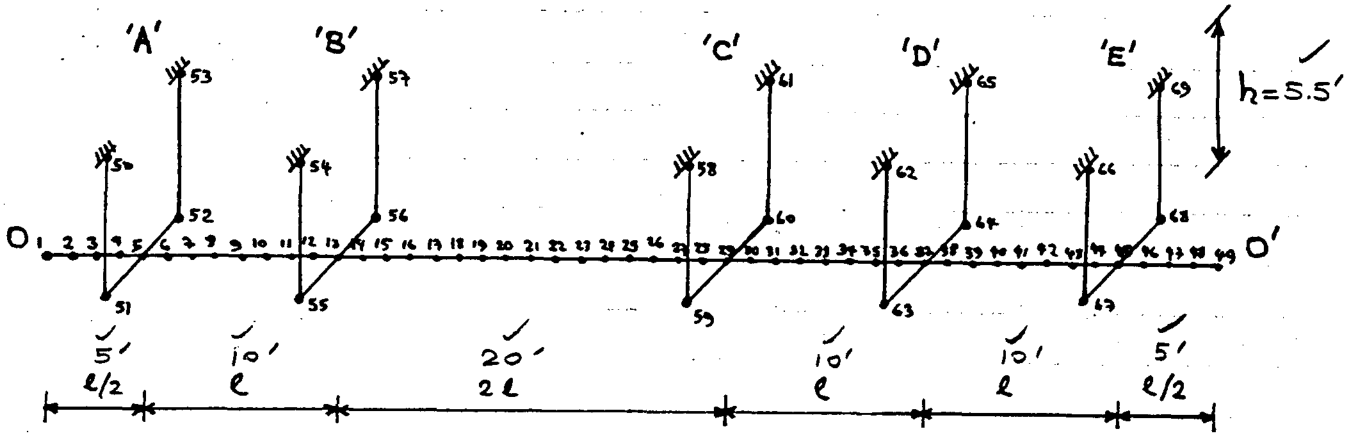
Client TVA		**Prepared by**	**Date** 12/11/90
Project WATTS BAR		**Reviewed by** D. M. Lamoureux	**Date** 12-11-90
Proj. No. 8573-03	**Equip. No.**	**Approved by**	**Date**

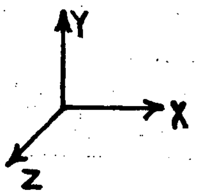
MDF for AB2200

24 x 36 DUCT ✓

Nodalized FEM model of AB2200



Slopes are zero at O & O' for z excitation. ✓



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Project	WATTS BAR	Reviewed by	J. M. Lamoureux	Date 12-11-90
Proj. No.	8573-03 Equip. No.	Approved by		Date

MDF for AB2200 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : HUBP 11/17/90 ✓
Input File : AB2200I ✓
Output File : AB2200O ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 29 = 25970 in-lb = 2164 ft-lb (AT 21) ✓
SHEAR Z, max. of nodes 13 thru 29 = 620 lb. (Between 28 & 29) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 468.1 + 468.1 = 936 lb. ✓
SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 467.3 + 467.3 = 935 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	9.3	26.4 ✓
3	15.9	12.4 ✓
4	16.0	52.4 ✓
5	16.9	6.2 ✓
6	19.4	1.1 ✓
8	23.4	1.2 ✓
10	39.0	0.1 ✓

$\sum 99.892$ ✓

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ENGINEERS

Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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Client	TVA	
Project	WATTS BAR	
Proj. No.	8573-03	Equip. No.

Prepared by		Date 12/11/90
Reviewed by	A. M. Lamoureux	Date 12-12-90
Approved by		Date

MDF for AB2200 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JGKF ✓ 11/28/90 ✓
Input File : AB2200J ✓
Output File : AB2200Q ✓

Results

COMPONENT SPAN "~~AB~~ BC"

MOMENT Y, max. of nodes 13 thru 29 = 11770 ✓ in-lb = 981 ✓ ft-lb (AT 21 ✓)

SHEAR Z, max. of nodes 13 thru 29 = 280.4 ✓ lb. (Between 28 ✓ & 29)

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 222.9 + 222.9 = 446 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 224.3 + 224.3 = 449 Lb. ✓

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ENGINEERS

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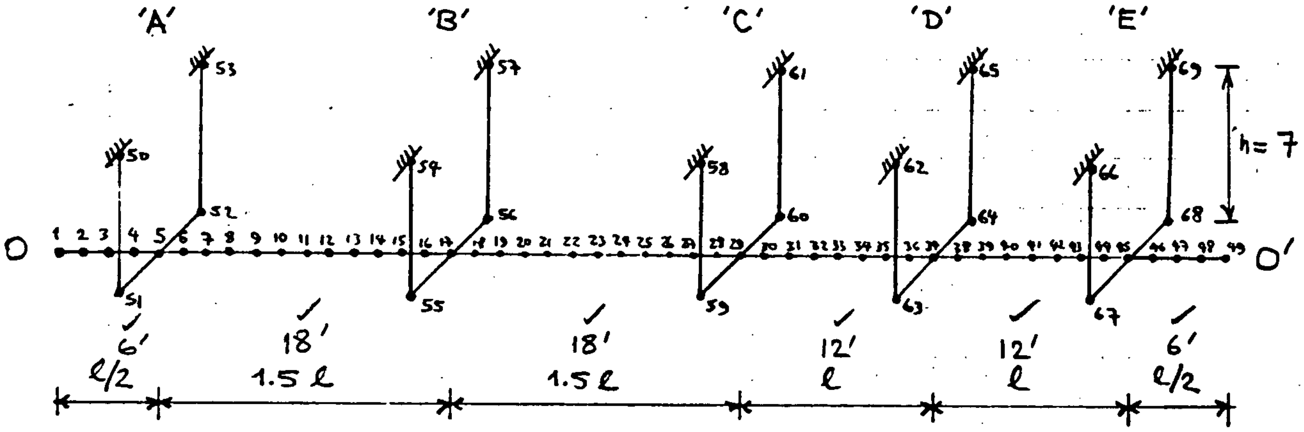
Project	WATTS BAR	Reviewed by	J. M. Lamoureux	Date 12-11-90
Proj. No.	8573-03 Equip. No.	Approved by		Date

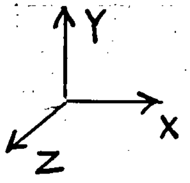
MDF for BC3150 ✓

60×72 DUCT ✓

NODALIZED FEM MODEL OF BC3150



Slopes are zero at O & O' for z excitation. ✓



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SARGENT & LUNDY
ENGINEERS

Calcs. For

☒ Safety-Related ☐ Non-Safety-Related

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Client TVA
Project WATTS BAR
Proj. No. 8573-03 Equip. No.

Prepared by Date 12/11/90
Reviewed by G. M. Lamoureux Date 12-12-90
Approved by Date

MDF for BC3150 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : JKOV ✓ 11/29/90
Input File : BC3150G ✓
Output File : BC3150X ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 17 thru 29 = 94690 in-lb = 7891 ft-lb (AT 23) ✓
SHEAR Z, max. of nodes 17 thru 29 = 2358 lb. (Between 17 & 18)

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 2647 + 2647 = 5294 lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 1893 + 1893 = 3786 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	8.7	68.3 ✓
3	9.9	18.7 ✓
4	10.7	12.6 ✓
5	15.1	0.4 ✓

$\sum$ 99.988 ✓

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Client TVA		Prepared by	Date 12/11/90
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Proj. No. 8573-03	Equip. No.	Approved by	Date

MDF for BC3150 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JKUF✓ 11/29/90✓
Input File : BC3150H ✓
Output File : BC3150Y ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 17 thru 29 = 39080 ✓ in-lb = 3257 ✓ ft-lb (AT 22 ✓)

SHEAR Z, max. of nodes 17 thru 29 = 951 ✓ lb. (Between 17 & 18 ✓)

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 1055 + 1055 = 2110 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 786 + 786 = 1572 Lb. ✓

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SARGENT & LUNDY
ENGINEERS

Calcs. For			
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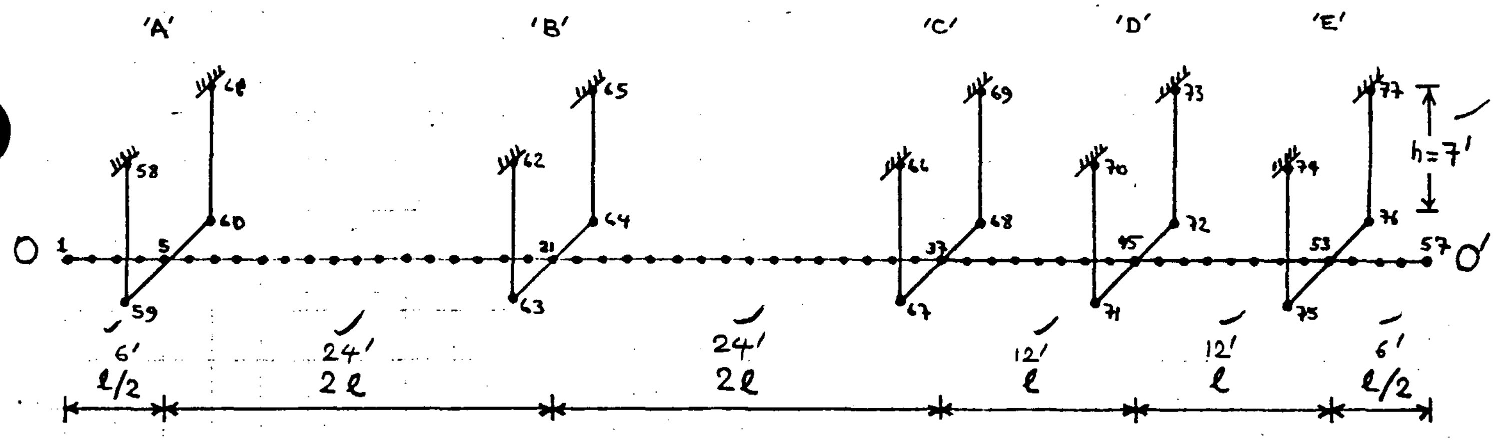
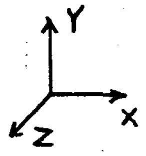
Prepared by		Date 12/11/90
Reviewed by	A. M. Lamoureux	Date 12-11-90
Approved by		Date

MDF for BC3200 ✓

60 × 72 DUCT ✓

NODALIZED FEM MODEL OF BC3200





Slopes are zero at O & O' for z excitation ✓

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Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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Client	TVA	Prepared by	Date 12/11/90
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MDF for BC3200 (Cont.)

SSE - EW SPECTRUM ANALYSIS

Reference Run : JKPI ✓ 11/29/90
Input File : BC3200G ✓
Output File : BC3200X ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 21 thru 37 = 203400 in-lb = 16950 ft-lb (AT 29) ✓
SHEAR Z, max. of nodes 21 thru 37 = 4517 lb. (Between 21 & 22) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 62 & 65)
= 4799 + 4799 = 9598 lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 66 & 69)
= 2634 + 2634 = 5268 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	7.4	66.6 ✓
3	8.6	0.1 ✓
4	10.2	32.4 ✓
5	12.9	0.7 ✓
9	24.5	0.1 ✓
10	33.6	0.1 ✓

Σ 99.986 ✓

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SARGENT & LUNDY
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Proj. No. 8573-03	Equip. No.	Approved by	Date

MDF for BC3200 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JKVJ ✓ 11/29/90 ✓
Input File : BC3200H ✓
Output File : BC3200Y ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 21 thru 37 = 62250 ✓ in-lb = 5188 ✓ ft-lb (AT 29) ✓

SHEAR Z, max. of nodes 21 thru 37 = 1364 ✓ lb. (Between 21 & 22) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 62 & 65)
= 1445 + 1445 = 2890 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 66 & 69)
= 821.4 + 821.4 = 1643 Lb. ✓

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SARGENT & LUNDY
ENGINEERS

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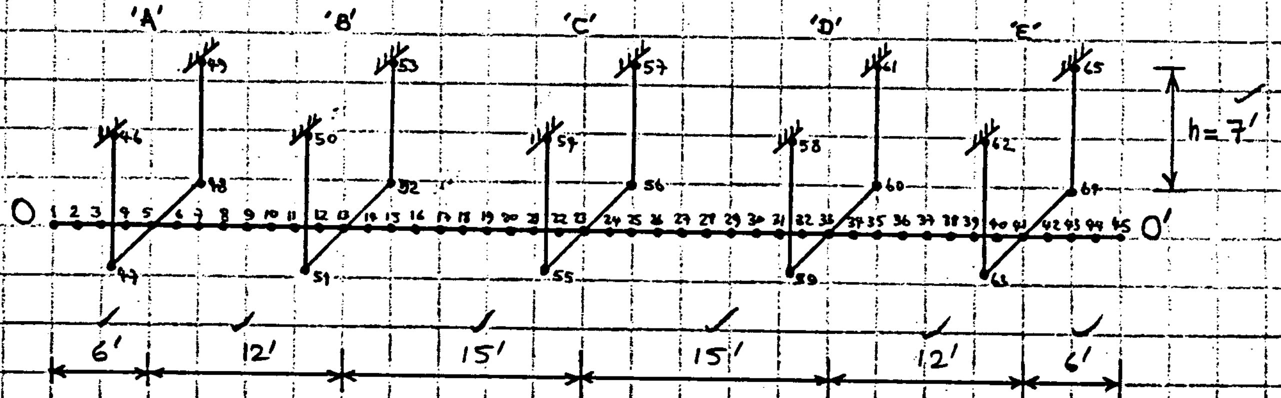
Prepared by		Date	12/11/90
Reviewed by	D. M. Lamoureux	Date	12-11-90
Approved by		Date	

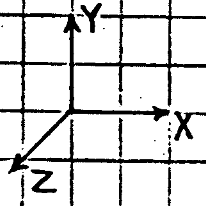
MDF for BC4125 ✓

60x72 DUCT ✓

Nodalized FEM model of BC4125



Slopes are zero @ O & O' for Z excitation. ✓



SARGENT & LUNDY ENGINEERS	Calcs. For		Calc. No. 8.11.6-1
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Client	TVA	Prepared by	Date 1.24.91
Project	WATTS BAR	Reviewed by D. M. Lamoureux	Date 1.24.91
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MDF for BC4125 (Cont.)

SSE - EW SPECTRUM ANALYSIS

Reference Run : JKOB ✓ 11/29/90
Input File : BC4125G ✓
Output File : BC4125X ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 23 = 59800 in-lb = 4983 ft-lb (AT 18) ✓
SHEAR Z, max. of nodes 13 thru 23 = 1761 lb. (Between 13 & 14)

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 1649 + 1649 = 3298 lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 54 & 57)
= 2056 + 2056 = 4112 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1*	9.5	93.6 ✓
3	11.4	6.4 ✓

Σ 99.991 ✓

* In most problems of this series, the first contributing mode number appears as 2 rather than 1 here. The reason is as follows: For BC4125, the x-displacement of nodes 0 & 0' is set to zero. The models with 1st contributing mode number 2 are those for which the x-displacement of 0 & 0' is free. This causes the 1st mode to be hanger cantilever deflection along x-axis. Such a mode has no mass participation for z-excitation being considered. To verify this BC4125 was re-run with x-displacement at 0 & 0' free. The same results were obtained as those listed here except mode numbers listed here increased by one. Ref Run: GGJN 1/8/91, Input File: BC4125I, Output File: BC41250

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SARGENT & LUNDY
ENGINEERS

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Prepared by		Date	12/11/90
Reviewed by	D. M. Lamoureux	Date	12-12-90
Approved by		Date	

MDF for BC4125 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JKSM ✓ 11/29/90 ✓
Input File : BC4125H ✓
Output File : BC4125Y ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 23 = 27430 ✓ in-lb = 2286 ✓ ft-lb (AT 18 ✓)

SHEAR Z, max. of nodes 13 thru 23 = 802 ✓ lb. (Between 13 ✓ & 14)

SUPPORT FORCE "B" (Sum of Shear Z at 50 & 53)
= 755 + 755 = 1510 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 54 & 57)
= 936 + 936 = 1872 Lb. ✓

SARGENT & LUNDY
ENGINEERS

Calcs. For

☒ Safety-Related ☐ Non-Safety-Related

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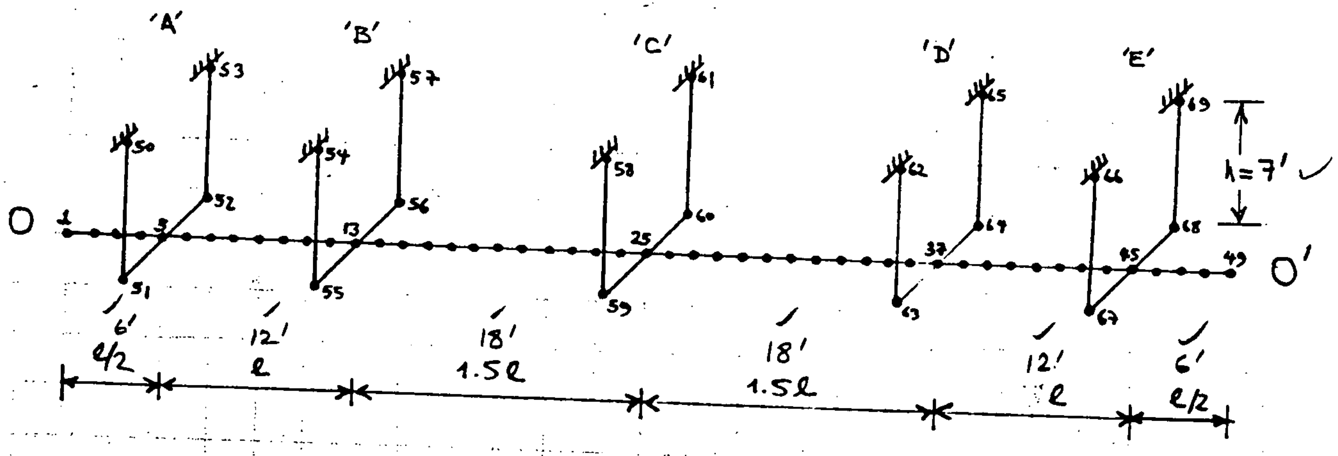
Prepared by Date 12/11/90
Reviewed by D. M. Lamoureux Date 12-11-90
Approved by Date

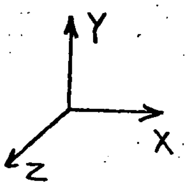
MDF for BC4150 ✓

60x72 DUCT ✓

NODALIZED FEM MODEL OF BC4150



Slopes are zero at O & O' for z excitation. ✓



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SARGENT & LUNDY
ENGINEERS

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Project	WATTS BAR	Reviewed by J. M. Lamoureux	Date 12-11-90
Proj. No.	8573-03 Equip. No.	Approved by	Date

MDF for BC4150 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : JKNQ 11/29/90 ✓
Input File : BC4150G ✓
Output File : BC4150X ✓

Results

COMPONENT SPAN "BC"
MOMENT Y, max. of nodes 13 thru 25 = 101500 in-lb = 8458 ft-lb (AT 20) ✓
SHEAR Z, max. of nodes 13 thru 25 = 2389 lb. (Between 24 & 25) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 1849 + 1849 = 3698 lb. ✓
SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 2866 + 2866 = 5732 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	8.7	80.5 ✓
4	10.9	19.5 ✓

$\sum$ 99.989 ✓

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SARGENT & LUNDY
ENGINEERS

Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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Prepared by		Date	12/11/90
Reviewed by	A. M. Lamoureux	Date	12-12-90
Approved by		Date	

MDF for BC4150 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JLPL ✓ 11/29/90 ✓
Input File : BC4150H ✓
Output File : BC4150Y ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 25 = 41750 in-lb = 3479 ft-lb (AT 20) ✓

SHEAR Z, max. of nodes 13 thru 25 = 968 lb. (Between 24 & 25) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 54 & 57)
= 761.4 + 761.4 = 1523 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 58 & 61)
= 1161 + 1161 = 2322 Lb. ✓

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ENGINEERS

☒ Safety-Related ☐ Non-Safety-Related

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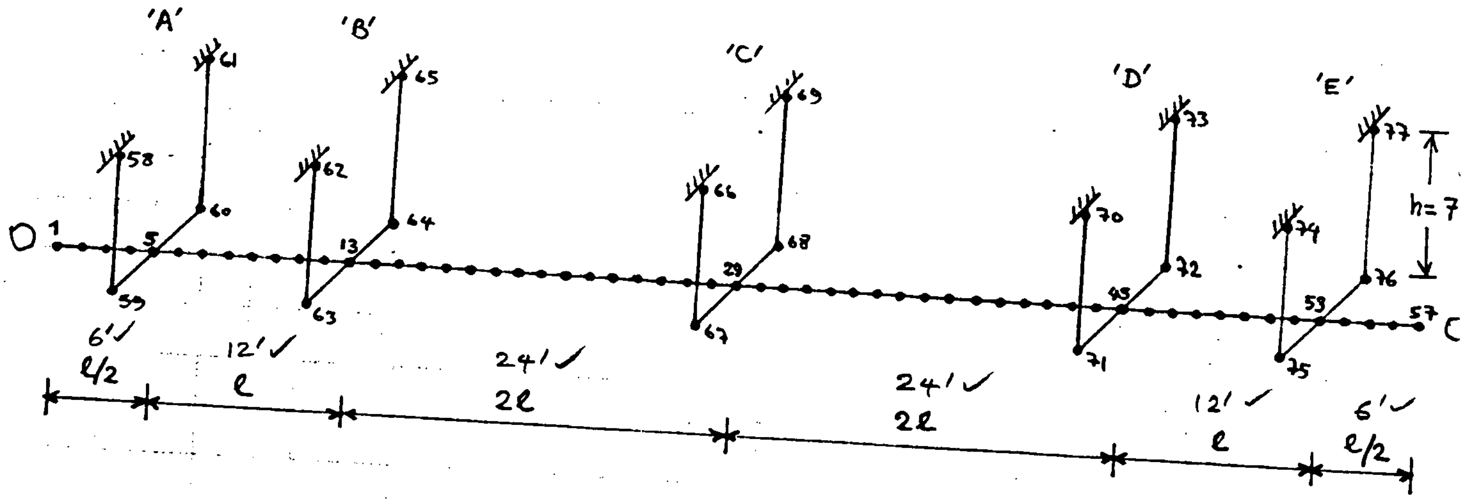
Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/11/9
Reviewed by	D. M. Lamoureux	Date	12-11-9
Approved by		Date	

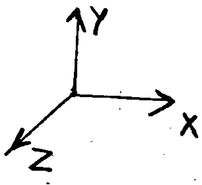
MDF for BC4200

60 x 72 DUCT ✓

Nodalized FEM model of BC4200 ✓



Slopes are zero at O & O' for Z excitation. ✓



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ENGINEERS

Calcs. For

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Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/11/90
Reviewed by	D. M. Lamoureux	Date	12-11-90
Approved by		Date	

MDF for BC4200 (Cont.)

SSE-EW SPECTRUM ANALYSIS

Reference Run : JKOL ✓ 11/29/90
Input File : BC4200G ✓
Output File : BC4200X ✓

Results

COMPONENT SPAN "BC"
MOMENT Y, max. of nodes 13 thru 29 = 194200 in-lb = 16183 ft-lb (AT 21) ✓
SHEAR Z, max. of nodes 13 thru 29 = 4516 lb. (Between 28 & 29) ✓

SUPPORT FORCE "B" (Sum of Shear Z at 62 & 65)
= 2468 + 2468 = 4936 lb. ✓
SUPPORT FORCE "C" (Sum of Shear Z at 66 & 69)
= 5132 + 5132 = 10264 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	7.4	67.9 ✓
4	10.5	31.9 ✓
7	17.7	0.1 ✓
10	33.6	0.1 ✓

Σ 99.985 ✓

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SARGENT & LUNDY
ENGINEERS

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MDF for BC4200 (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run: JKTP ✓ 11/29/90 ✓
Input File : BC4200H ✓
Output File : BC4200Y ✓

Results

COMPONENT SPAN "BC"

MOMENT Y, max. of nodes 13 thru 29 = 58400 ✓ in-lb = 4867 ✓ ft-lb (AT 21 ✓)

SHEAR Z, max. of nodes 13 thru 29 = 1349 ✓ lb. (Between 28 & 29 ✓)

SUPPORT FORCE "B" (Sum of Shear Z at 62 & 65)
= 785.4 + 785.4 ✓ = 1571 Lb. ✓

SUPPORT FORCE "C" (Sum of Shear Z at 66 & 69)
= 1534 + 1534 ✓ = 3068 Lb. ✓

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SARGENT & LUNDY
ENGINEERS

Calcs. For	
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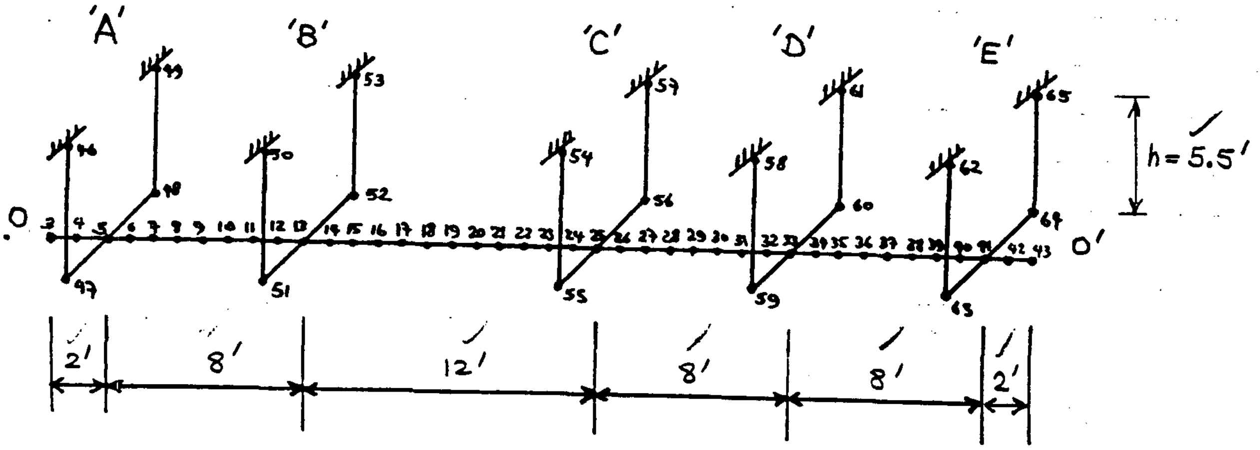
Prepared by		**Date** 12/11/90
Reviewed by	D. M. Lamoureux	**Date** 12-11-90
Approved by		**Date**

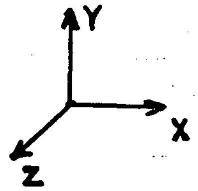
MDF for AA2150F ✓

24×36 DUCT ✓

NODALIZED FEM MODEL OF AA2150F



Note that O & O' are free for Z excitation. ✓



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Calcs. For		Calc. No.	8.11.6-1
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MDF for AA2150FC (Cont.)

SSE-EW Spectrum Analysis

Reference Run: CBLL ✓ 12/12/90 ✓

Input File: AA2150K ✓
Output File: AA2150P ✓

COMPONENT SPAN "AO"

MOMENT Y, max. of nodes 1 thru 5 = 1097 in-lb = 91 ft-lb (AT 5) ✓
SHEAR Z, max. of nodes 1 thru 5 = 68 lb (Between 4 & 5)

COMPONENT SPAN "AB"

MOMENT Y, max. of nodes 5 thru 13 = 3684 in-lb = 307 ft-lb (AT 13) ✓
SHEAR Z, max. of nodes 5 thru 13 = 158 lb ✓ (Between 12 & 13) ✓

COMPONENT SPAN "EO"

MOMENT Y, max. of nodes 41 thru 43 = 930 in-lb = 78 ft-lb (AT 41) ✓
SHEAR Z, max. of nodes 41 thru 43 = 58 lb ✓ (Between 41 & 42)

COMPONENT SPAN "DE"

MOMENT Y, max. of nodes 33 thru 41 = 3674 in-lb = 306 ft-lb (AT 37) ✓
SHEAR Z, max. of nodes 33 thru 41 = 162 lb ✓ (Between 40 & 41)

SUPPORT "A" FORCE (Sum of Shear Z at 46 & 49)
= 180.6 + 180.6 = 361 lb ✓

SUPPORT "B" FORCE (Sum of Shear Z at 50 & 53)
= 303.3 + 303.3 = 607 lb ✓

SUPPORT "D" FORCE (Sum of Shear Z at 58 & 61) ✓
= 213.7 + 213.7 = 427 lb ✓

SUPPORT "E" FORCE (Sum of Shear Z at 62 & 65)
= 193.2 + 193.2 = 386 lb ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2 ✓	15.2 ✓	49.9 ✓
3 ✓	18.1 ✓	15.5 ✓
4 ✓	19.5 ✓	33.5 ✓
5 ✓	21.5 ✓	0.2 ✓
6 ✓	26.6 ✓	0.6 ✓
7 ✓	36.1 ✓	0.2 ✓
		Σ 99.935 ✓

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Calcs. For		Calc. No. 8.11.6-1	
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MDF for AA2150F (Cont.)

It should be noted that the 1st contributing mode, i.e., Mode 2 at 15.2 Hz, is not the dominant mode for the segment EDCB.

The most contributing modes for the segment EDCB are given below (in the order of dominance):

COMPONENT SPAN "DE"
max. moment : Mode 3, mode 4 ✓
max. shear : mode 4, mode 3 ✓

COMPONENT SPAN "EO'"
max. moment : mode 4, mode 3 ✓
max. shear : mode 4, mode 3 ✓

SUPPORT FORCE "D" : Mode 3 ✓

SUPPORT FORCE "E" : Mode 4, mode 3 ✓

Therefore, the frequency of the first contributing mode is that of mode 3 at 18.1 Hz or higher for the segment EDCB.

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Prepared by	Date 12/11/90
Reviewed by S. M. Lamoureux	Date 12-12-90
Approved by	Date

MDF for AA2150F (Cont.)

FLAT 1-g SPECTRUM ANALYSIS

Reference Run : BCWL ✓ 12/07/1990 ✓
Input File : AA2150L ✓
Output File : AA2150E ✓

COMPONENT SPAN "AO" ✓
MOMENT Y, max. of nodes 3 thru 5 = 787 ✓ in-lb = 66 ✓ ft-lb (AT 5) ✓
SHEAR Z, max. of nodes 3 thru 5 = 49 lb ✓ (Between 4 & 5) ✓

COMPONENT SPAN "AB" ✓
MOMENT Y, max. of nodes 5 thru 13 = 2496 ✓ in-lb = 208 ✓ ft-lb (AT 13) ✓
SHEAR Z, max. of nodes 5 thru 13 = 108 ✓ lb (Between 12 & 13)

COMPONENT SPAN "EO'"
MOMENT Y, max. of nodes 41 thru 43 = 662 ✓ in-lb = 55 ✓ ft-lb (AT 41) ✓
SHEAR Z, max. of nodes 41 thru 43 = 42 ✓ lb (Between 41 & 42)

COMPONENT SPAN "DE"
MOMENT Y, max. of nodes 33 thru 41 = 2598 ✓ in-lb = 217 ✓ ft-lb (AT 37) ✓
SHEAR Z, max. of nodes 33 thru 41 = 114 ✓ lb (Between 40 & 41)

SUPPORT "A" FORCE (Sum of Shear Z at 46 & 49)
= 129.2 + 129.2 = 258 lb. ✓

SUPPORT "B" FORCE (Sum of Shear Z at 50 & 53)
= 204.6 + 204.6 = 409 lb ✓

SUPPORT "D" FORCE (Sum of Shear Z at 58 & 61)
= 149.3 + 149.3 = 299 lb ✓

SUPPORT "E" FORCE (Sum of Shear Z at 62 & 65)
= 136.8 + 136.8 = 274 lb ✓

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SARGENT & LUNDY
ENGINEERS

Calcs. For			
☒ Safety-Related	☐ Non-Safety-Related		
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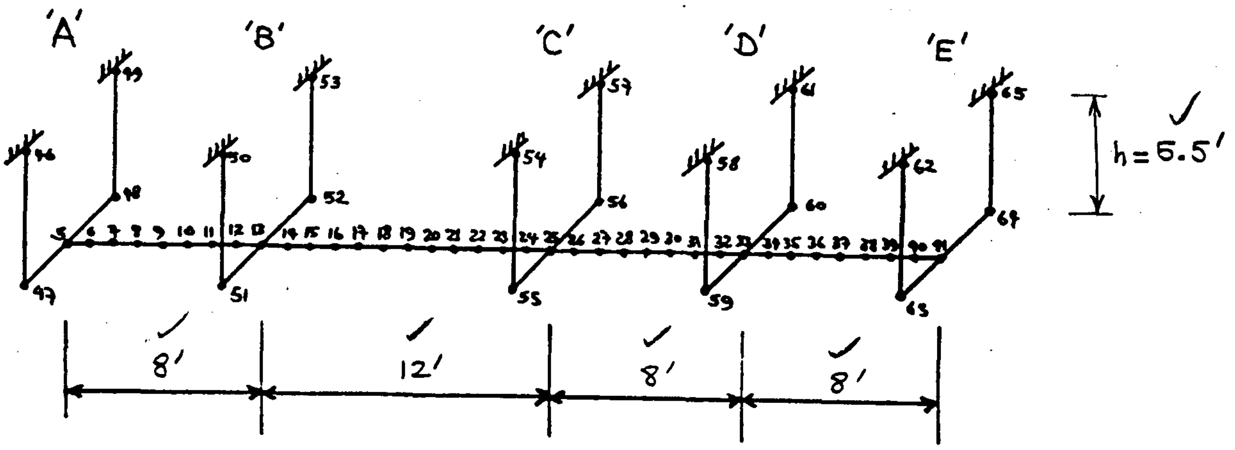
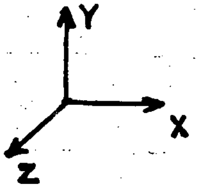
Prepared by	Date 12/11/90
Reviewed by A. M. Lamoureux	Date 12-11-90
Approved by	Date

MDF for AA2150H ✓

24×36 DUCT ✓

NODALIZED FEM MODEL OF AA2150H





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SARGENT & LUNDY
ENGINEERS

Calcs. For

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Client TVA
Project WATTS BAR
Proj. No. 8573-03 Equip. No.

Prepared by Date 12/14/90
Reviewed by D. M. Lamoureux Date 12-14-90
Approved by Date

MDF for AA2150 H (Cont.)

SSE-EW Spectrum Analysis

Reference Run : CBWF ✓ 12/12/90 ✓
Input File : AA2150 G ✓
Output File : AA2150 Z ✓

Results

COMPONENT SPAN "AB"
Moment Y, max. of nodes 5 thru 13 ✓ = 3754 in-lb = 313 ft-lb (AT 13)
Shear Z, max. of nodes 5 thru 13 = 161 lb ✓ (Between 12 & 13)

COMPONENT SPAN "DE"
Moment Y, max. of nodes 33 thru 41 = 4106 in-lb ✓ = 342 ft-lb ✓ (AT 37) ✓
Shear Z, max. of nodes 33 thru 41 = 149 lb ✓ (Between 33 & 34)

SUPPORT 'A' FORCE (Sum of Shear Z at 46 & 49)
= 119 + 119 = 238 lb. ✓

SUPPORT 'B' FORCE (Sum of Shear Z at 50 & 53)
= 310 + 310 = 620 lb ✓

SUPPORT 'D' FORCE (Sum of Shear Z at 58 & 61)
= 204.4 + 204.4 = 409 lb. ✓

SUPPORT 'E' FORCE (Sum of Shear Z at 62 & 65)
= 123.3 + 123.3 = 247 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
2	15.2	56.4 ✓
3	18.3	15.5 ✓
4	21.0	25.1 ✓
5	24.9	0.2 ✓
6	30.8	2.6 ✓
7	40.3	0.1 ✓
9	56.5	0.1 ✓

$\sum$ 99.9% ✓

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Client TVA	Prepared by [illegible] Date 12/14/90
Project WATTS BAR	Reviewed by D. M. Lamoureux Date 12-14-90
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MDF for AA2150H (cont.)

It should be noted that the 1st contribution mode, i.e., mode 2 at 15.2 Hz ✓ is not the dominant mode for the segment EDCB. ✓

The most contributing modes for the segment EDCB are given below (in the order of dominance):

COMPONENT SPAN "DE"

max. moment : mode 4, mode 3 ✓

max. shear : mode 3, mode 4 ✓

SUPPORT FORCE "D" : mode 3 ✓

SUPPORT FORCE "E" mode 4, mode 3 ✓

Therefore, in the frequency of the ✓ first contributing mode is that of mode 3 at 18.3 Hz or higher ✓ for the segment EDCB

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MDF for AA2150H (Cont.)

FLAT 1-g Spectrum Analysis

Reference Run : AQKK ✓ 12/04/90 ✓
Input File : AA2150H ✓
Output File : AA2150Y ✓

Results

COMPONENT SPAN "AB" ✓
Moment y, max. of nodes 5 thru 13 = 2405 ✓ in-lb = 200 ✓ ft-lb (AT 9) ✓
Shear z, max. of nodes 5 thru 13 = 111 ✓ lb (Between 12 & 13)

COMPONENT SPAN "DE" ✓
Moment y, max. of nodes 33 thru 41 = 2936 ✓ in-lb = 245 ✓ ft-lb (AT 37) ✓
Shear z, max. of nodes 33 thru 41 = 106 lb (Between 33 & 34)

SUPPORT 'A' FORCE (Sum of Shear Z at 46 & 49) ✓
= 86.8 + 86.8 ✓ = 174 lb ✓
SUPPORT 'B' FORCE (Sum of Shear Z at 50 & 53)
= 209.1 + 209.1 ✓ = 418 lb ✓
SUPPORT 'D' FORCE (Sum of Shear Z at 58 & 61)
= 143.3 + 143.3 ✓ = 287 lb ✓
SUPPORT 'E' FORCE (Sum of Shear Z at 62 & 65)
= 88.7 + 88.7 ✓ = 177 lb. ✓

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SARGENT & LUNDY ENGINEERS

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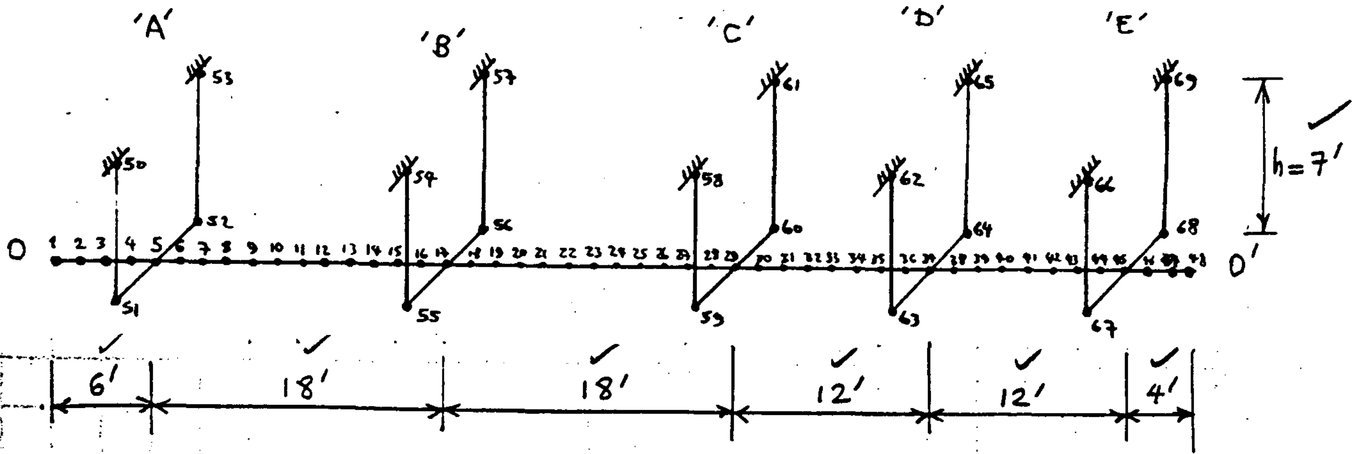
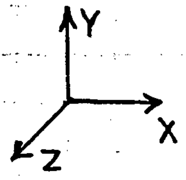
MDF for BC3150F ✓

60 x 72 DUCT ✓

Nodalized FEM model for BC3150F



Note that O & O' are free for Z-excitation ✓



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Calcs. For		Calc. No.	80106-1
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MDE for BC3150F (Cont.)

SSE-EW Spectrum Analysis

Reference Run : CBLZ ✓ 12/12/90 ✓
Input File : BC3150A ✓
Output File : BC3150F ✓

Results

COMPONENT SPAN "AO" ✓
Moment Y, max. of nodes 1 thru 5 = 40970 in-lb = 3414 ft-lb (AT 5)
Shear Z, max. of nodes 1 thru 5 = 1007 lb (Between 4 & 5)

COMPONENT SPAN "AB" ✓
Moment Y, max. of nodes 5 thru 17 = 103500 in-lb = 8625 ft-lb (AT 11)
Shear Z, max. of nodes 5 thru 17 = 2429 lb. (Between 16 & 17)

COMPONENT SPAN "EO'" ✓
Moment Y, max. of nodes 45 thru 48 = 21010 in-lb = 1751 ft-lb (AT 45)
Shear Z, max. of nodes 45 thru 48 = 706 (Between 45 & 46)

COMPONENT SPAN "DE"
Moment Y, max. of nodes 37 thru 45 = 38560 in-lb = 3213 ft-lb (AT 37)
Shear Z, max. of nodes 37 thru 45 = 1103 lb (Between 44 & 45)

SUPPORT 'A' FORCE (Sum of Shear Z at 50 & 53)
= 1872 + 1872 ✓ = 3744 lb ✓

SUPPORT 'B' FORCE (Sum of Shear Z at 54 & 57)
= 2881 + 2881 ✓ = 5762 lb ✓

SUPPORT 'D' FORCE (Sum of Shear Z at 62 & 65)
= 1208 + 1208 ✓ = 2416 lb ✓

SUPPORT 'E' FORCE (Sum of Shear Z at 66 & 69)
= 1217 + 1217 ✓ = 2434 lb ✓

CONTRIBUTION OF MODES

Mode No	Frequency (Hz)	Mass Participation (%)
2 ✓	8.6 ✓	69.6 ✓
3 ✓	9.5 ✓	0.5 ✓
4 ✓	10.8 ✓	29.9 ✓
		Σ 99.984 ✓

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MDF for BC3150F (Cont.)

It should be noted that the 1st contributing mode, i.e., mode 2 at 8.6 Hz, ✓ is not the dominant mode for the segment EDCB. ✓

The most contributing modes for the segment EDCB are given below (in the order of dominance):

COMPONENT SPAN "DE"
  max. moment : mode 2 ✓
  max. shear : mode 4 ✓

COMPONENT SPAN "EO"
  max. moment : mode 4 ✓
  max. shear : mode 4 ✓

SUPPORT FORCE "D" : Mode 4, Mode 2 ✓
SUPPORT FORCE "E" : Mode 4 ✓

Therefore for Segment EDCB, the first contributing mode is that of mode 2 at 8.6 Hz. However, most responses are dominated by mode 4 at 10.8 Hz. EDCB.

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MDF for BC3150F (Cont.)

Flat 1-g Spectrum Analysis

Reference Run : AZUW ✓ 12/06/90 ✓
Input File : BC3150B ✓
Output File : BC3150Z ✓

Results

COMPONENT SPAN "AO" ✓
Moment Y, max. of nodes 1 thru 5 = 17810 ✓ in-lb = 1484 ✓ ft-lb (AT 5) ✓
Shear Z, max. of nodes 1 thru 5 = 432 ✓ lb (Between 4 & 5) ✓

COMPONENT SPAN "AB" ✓
Moment Y, max. of nodes 5 thru 17 = 40760 ✓ in-lb = 3397 ✓ ft-lb (AT 11) ✓
Shear Z, max. of nodes 5 thru 17 = 944 ✓ lb (Between 16 & 17)

COMPONENT SPAN "EO" ✓
Moment Y, max. of nodes 45 thru 48 = 10670 ✓ in-lb = 889 ✓ ft-lb (AT 45) ✓
Shear Z, max. of nodes 45 thru 48 = 359 lb (Between 45 & 46)

COMPONENT SPAN "DE" ✓
Moment Y, max. of nodes 37 thru 45 = 15210 ✓ in-lb = 1268 ✓ ft-lb (AT 37) ✓
Shear Z, max. of nodes 37 thru 45 = 560 ✓ lb (Between 44 & 45)

SUPPORT 'A' FORCE (Sum of Shear Z at 50 & 53)
= 742.4 + 742.4 = 1485 lb ✓

SUPPORT 'B' FORCE (Sum of Shear Z at 54 & 57)
= 1122 + 1122 = 2244 lb ✓

SUPPORT 'D' FORCE (Sum of Shear Z at 62 & 65)
= 560 + 560 = 1120 lb ✓

SUPPORT 'E' FORCE (Sum of Shear Z at 66 & 69)
= 618 + 618 = 1236 lb ✓

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Client TVA
Project WATTS BAR
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Calcs. For MDF FOR CT33

☒ Safety-Related ☐ Non-Safety-Related

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Prepared by Date 12/11/90
Reviewed by S. M. Lamoureux Date 12-11-90
Approved by Date

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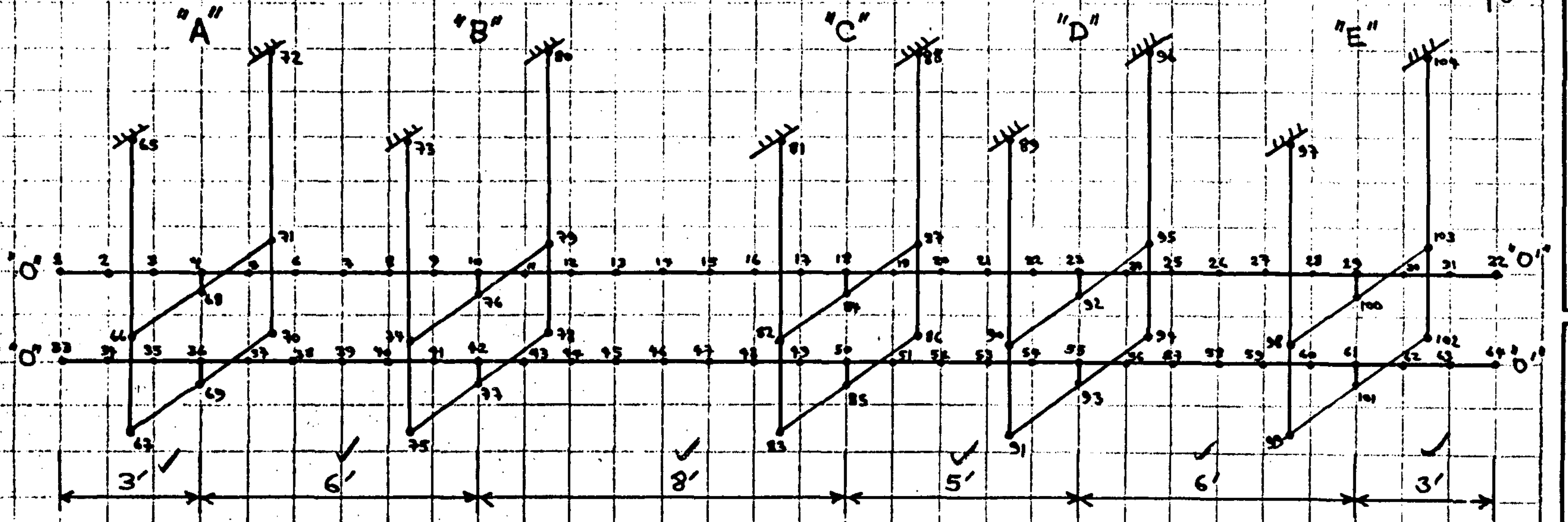
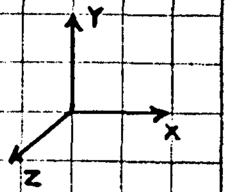
Nodalized FEM model of CT33



Slopes are zero at O & O' for Z excitation



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Calcs. For		Calc. No.	8.11.6-1
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Client	TVA		Prepared by	Date 12/11/90
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MDF for CT33 (Cont.)

Reference Run: AQMK 90/12/04
Input file: CT33SI
Output file: CT33SO

CONTRIBUTION OF MODES

mode No.	Frequency (Hz)	Mass Participation (%)
1 ✓	8.8 ✓	10.5 ✓
2 ✓	9.4 ✓	0.1 ✓
5 ✓	12.5 ✓	0.4 ✓
6 ✓	12.7 ✓	2.4 ✓
9 ✓	14.8 ✓	22.6 ✓
10 ✓	14.9 ✓	28.5 ✓
13 ✓	17.1 ✓	29.3 ✓
17 ✓	21.7 ✓	0.3 ✓
18 ✓	23.1 ✓	0.1 ✓
23 ✓	27.2 ✓	0.3 ✓
24	27.6	0.8

$\sum$ 95.200 ✓

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Project	WATTS BAR	Reviewed by A. M. Lamoureux	Date 12-11-90
Proj. No.	8573-03 Equip. No.	Approved by	Date

MDF FOR CT 33 (Cont.)

1. SSE EW SPECTRUM (ELEV 771.5')

REFERENCE RUN: AQMK 90/12/04
INPUT FILE: CT33SI
OUTPUT FILE: CT33S0

SUMMARY OF RESULTS:

BEAM 1:
MOMENT Y, max of nodes 10 thru 18 = 14470 in-lbs (AT 14)
= 1206 ft-lbs
SHEAR Z, max of nodes 10 thru 18 = 808 lbs.
(BETWEEN 17 & 18)

BEAM 2:
MOMENT Y, max of nodes 42 thru 50 = 15800 in-lb (AT 46)
= 1317 ft-lb
SHEAR Z, max of nodes 42 thru 50 = 886 lbs.
(BETWEEN 49 & 50)

SUPPORT FORCE 'B' (sum of shear Z at 73 & 80)
= 1346 + 1346 = 2692 lbs.

SUPPORT FORCE 'C' (sum of shear Z at 81 & 88)
= 1482 + 1482 = 2964 lbs.

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Calcs. For

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Prepared by Date 12/11/90
Reviewed by A. M. Lamoureux Date 12-11-90
Approved by Date

MDF FOR CT 33 (Cont.)

2. FLAT 1 G SPECTRUM

REFERENCE RUN: ASUN 90/12/05
INPUT FILE: CT33SJ
OUTPUT FILE: CT33SQ

SUMMARY OF RESULTS:

BEAM 1:

MOMENT Y, max of nodes 10 thru 18 = 6068 in-lbs (AT 14)
= 506 ft-lbs

SHEAR Z, max of nodes 10 thru 18 = 352 lbs.
(BETWEEN 17 & 18)

BEAM 2:

MOMENT Y, max of nodes 42 thru 50 = 6557 in-lb (AT 46)
= 546 ft-lb

SHEAR Z, max of nodes 42 thru 50 = 384 lbs.
(BETWEEN 49 & 50)

SUPPORT FORCE 'B' (sum of shear Z at 73 & 80)
= 755 + 755 = 1510 lbs.

SUPPORT FORCE 'C' (sum of shear Z at 81 & 88)
= 836 + 836 = 1672 lbs.

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Client TVA
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MDF for CT13

Calcs. For
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Prepared by
Date 12/11/90
Reviewed by S. M. Lamoureux
Date 12-11-90
Approved by
Date

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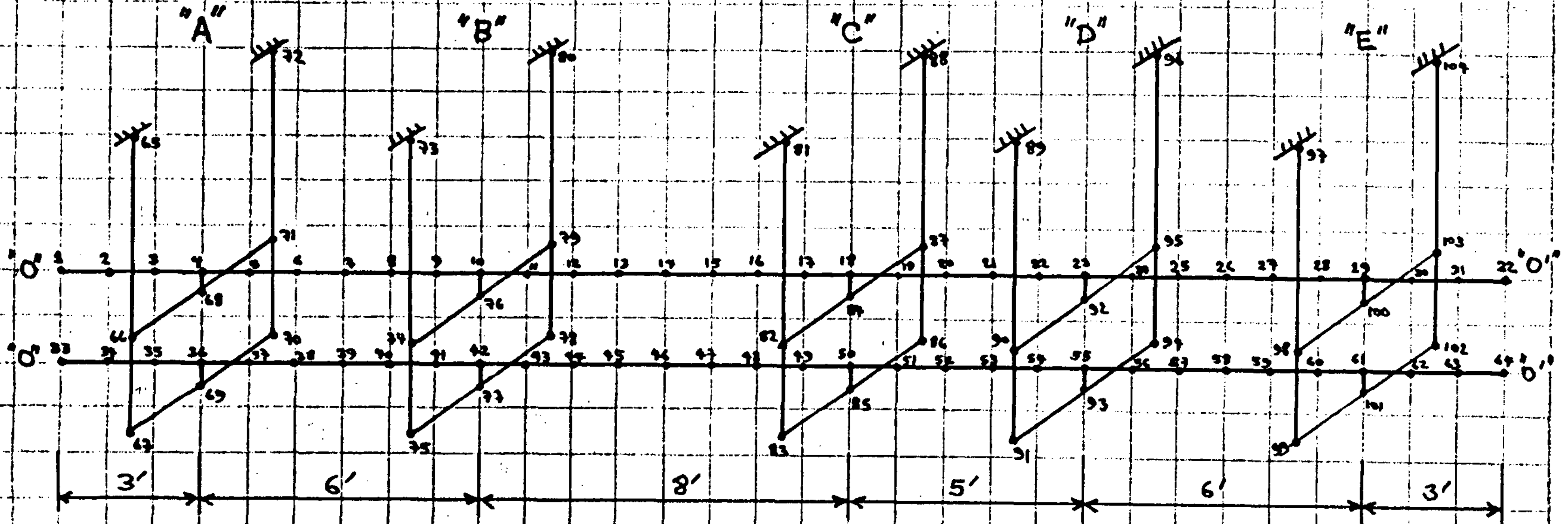
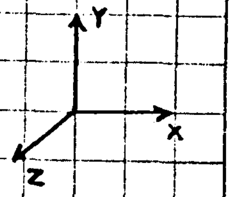
Nodalized FEM model of CT13



Slopes are zero at O & O' for Z excitation.



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MDF for CT13 (Cont.)

Reference Run: ASTD 90/12/05
Input file: CT13SI
Output file: CT13SO

om

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1 ✓	9.0 ✓	8.6 ✓
5 ✓	12.7 ✓	0.3 ✓
6 ✓	13.1 ✓	2.5 ✓
9 ✓	16.1 ✓	20.1 ✓
10 ✓	16.3 ✓	24.0 ✓
15 ✓	18.5 ✓	34.8 ✓
17 ✓	23.1 ✓	0.2 ✓
22 ✓	27.4 ✓	0.2 ✓
25 ✓	28.9 ✓	0.9 ✓

Σ 91.855 ✓

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MDF FOR CT 13

1. SSE EW SPECTRUM (ELEV 771.5')

REFERENCE RUN: ASTD 90/12/05
INPUT FILE: CT13SI
OUTPUT FILE: CT13S0

SUMMARY OF RESULTS:

BEAM 1:
MOMENT Y, max of nodes 10 thru 18 = 4345 in-lbs (AT 14)
= 362 ft-lbs
SHEAR Z, max of nodes 10 thru 18 = 242 lbs.
(BETWEEN 17 & 18)

BEAM 2:
MOMENT Y, max of nodes 42 thru 50 = 13950 in-lb (AT 46)
= 1163 ft-lb
SHEAR Z, max of nodes 42 thru 50 = 784 lbs.
(BETWEEN 49 & 50)

SUPPORT FORCE 'B' (sum of shear Z at 73 & 80)
= 848.5 + 848.5 = 1697 lbs.

SUPPORT FORCE 'C' (sum of shear Z at 81 & 88)
= 987.6 + 987.6 = 1975 lbs.

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Calcs. For	
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Reviewed by	A. M. Lamoureux	Date	12-11-90
Approved by		Date	

MDF FOR CT 13

2. FLAT 1 g SPECTRUM

REFERENCE RUN: ASWP 90/12/05
INPUT FILE: CT13SJ
OUTPUT FILE: CT13SQ

SUMMARY OF RESULTS:

BEAM 1:

MOMENT Y, max of nodes 10 thru 18 = 1908 in-lbs (AT 14)
= 159 ft-lbs

SHEAR Z, max of nodes 10 thru 18 = 111 lbs.
(BETWEEN 17 & 18)

BEAM 2:

MOMENT Y, max of nodes 42 thru 50 = 6082 in-lb (AT 46)
= 507 ft-lb

SHEAR Z, max of nodes 42 thru 50 = 358 lbs.
(BETWEEN 49 & 50)

SUPPORT FORCE 'B' (sum of shear Z at 73 & 80)
= 505 + 505 = 1010 lbs.

SUPPORT FORCE 'C' (sum of shear Z at 81 & 88)
= 600 + 600 = 1200 lbs.

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Client	TVA	Prepared by A. M. Lamoureux	Date 1.24.91
Project	WATTS BAR	Reviewed by	Date 1.24.91
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12.) 2DF CALCULATIONS AND RESULTS FOR SYSTEMS ON FLEXIBLE SUPPORTS (Straight-Run Models)

For all systems identified on page 10.10, this section contains the corresponding 2DF system calculations. The results of this section are summarized in the tables below and on the next 4 pages. Detailed calculations for each case follow the tables.

SUMMARY OF SYSTEM FREQUENCIES FROM 2DF EVALUATION:

SYSTEM	FREQUENCY (Hz)
AA2150	14.2
AA2200	10.2
AB2150	11.0
AB2200	7.0
BC3150	7.9
BC3200	6.4
BC4125	8.9
BC4150	7.9
BC4200	6.4
AA2150F (OAB End)	13.4
" (DEO' End)	16.8
AA2150H (AB End)	12.8
" (DE End)	16.1
BC3150F (OAB End)	7.9
" (DEO' End)	9.9
CT33	6.4
CT13	6.5

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Client	TVA
Project	WATTS BAR
Proj. No.	8573-03 Equip. No.

Prepared by D. M. Lamoureux	Date 12-13-90
Reviewed by	Date 12/14/90
Approved by	Date

RESULTS FOR COMPONENT AND SUPPORT FORCES
(SSE-EW SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE units: POUNDS
	MOMENT units: FT-POUND	SHEAR units: POUNDS	
AA2150	BC 684	BC 285	B 602 C 602
AA 2200	BC 1644	BC 514	B 943 C 943
AB 2150	BC 1357	BC 452	B 916 C 916
AB 2200	BC 4470	BC 1118	B 1976 C 1976
BC3150	BC 9745	BC 2707	B 5775 C 4873
BC3200	BC 23318	BC 4858	B 10202 C 7773
BC4125	BC 5351	BC 1784	B 3496 C 3853
BC4150	BC 9738	BC 2705	B 4869 C 5771
BC4200	BC 23318	BC 4858	B 7773 C 10202

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RESULTS FOR COMPONENT AND SUPPORT FORCES CONTINUED
(SSE-EW SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE units: POUNDS
	MOMENT units: FT-POUNDS	SHEAR units: POUNDS	
AA2150F	AO 101	AO 101	A 439
	AB 728	AB 215	B 641
	EO' 90	EO' 90	E 390
	DE 360	DE 191	D 480
AA2150H	AB 759	AB 211	A 352
			B 668
	DE 363	DE 182	E 303
			D 485
BC3150F	AO 5410	AO 1803	A 4870
	AB 12176	AB 3006	B 5772
	EO' 1717	EO' 858	E 2404
	DE 3864	DE 1431	D 2833
CT33			B 8922
			C 8382
(Tier 1)	BC 3456	BC 2160	
(Tier 2)	BC 3456	BC 2160	
CT13			B 6402
			C 6042
(Tier 1)	BC 1152	BC 720	
(Tier 2)	BC 3456	BC 2160	

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RESULTS FOR COMPONENT AND SUPPORT FORCES (1g, FLAT SPECTRUM)

SYSTEM	COMPONENT		SUPPORT FORCE units: POUNDS
	MOMENT units: FT-POUND	SHEAR units: POUNDS	
AA2150	BC 446	BC 186	B 393 C 393
AA2200	BC 794	BC 248	B 455 C 455
AB2150	BC 698	BC 233	B 471 C 471
AB2200	BC 1240	BC 310	B 548 C 548
BC3150	BC 3279	BC 911	B 1943 C 1640
BC3200	BC 5830	BC 1215	B 2551 C 1943
BC4125	BC 2277	BC 759	B 1488 C 1640
BC4150	BC 3279	BC 911	B 1640 C 1943
BC4200	BC 5830	BC 1215	B 1943 C 2551

Calcs. For

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RESULTS FOR COMPONENT AND SUPPORT FORCES CONTINUED
(1g FLAT SPECTRUM)

SYSTEM	COMPONENT MOMENT units: FT-POUNDS	COMPONENT SHEAR units: POUNDS	SUPPORT FORCE units: POUNDS
AA2150F	AO 62	AO 62	A 269
	AB 446	AB 132	B 393
	EO' 62	EO' 62	E 269
	DE 248	DE 132	D 331
AA2150H	AB 446	AB 124	A 207
			B 393
	DE 248	DE 124	E 207
			D 331
BC3150F	AO 1822	AO 607	A 1640
	AB 4100	AB 1012	B 1944
	EO' 810	EO' 405	E 1134
	DE 1823	DE 675	D 1337
CT33			B 2231
			C 2096
(Tier 1)	BC 864	BC 540	
(Tier 2)	BC 864	BC 540	
CT13			B 1601
			C 1511
(Tier 1)	BC 288	BC 180	
(Tier 2)	BC 864	BC 540	

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DETAILED 2DF CALCULATIONS

The figures on the next four pages summarize the symbols used in 2 DF calculations of this section.

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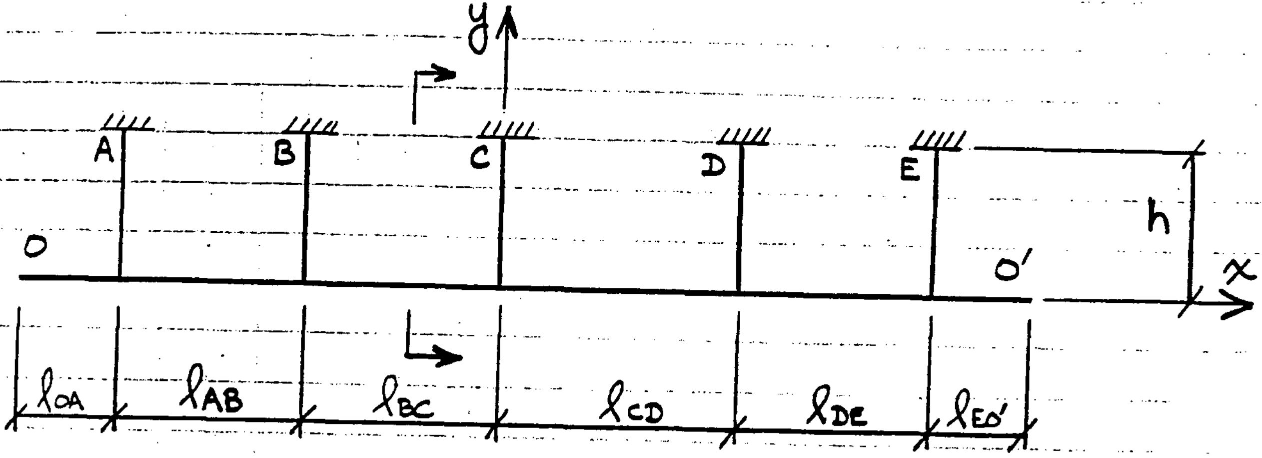
DEFINITION OF TERMS FOR THE FOLLOWING SYSTEMS:

AA2150 and AA2200

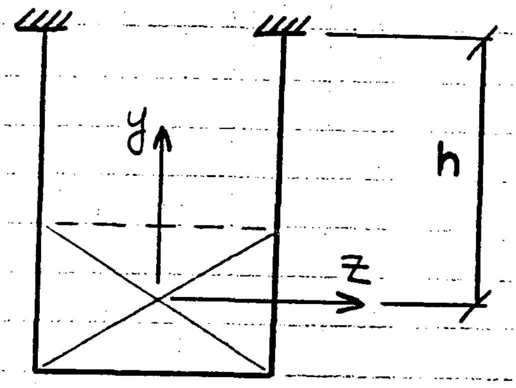
AB2150 and AB2200

BC3150 and BC3200

BC4125, BC4150 and BC4200.



note: for Z excitation, slopes are zero at O and O'.



SECTION VIEW

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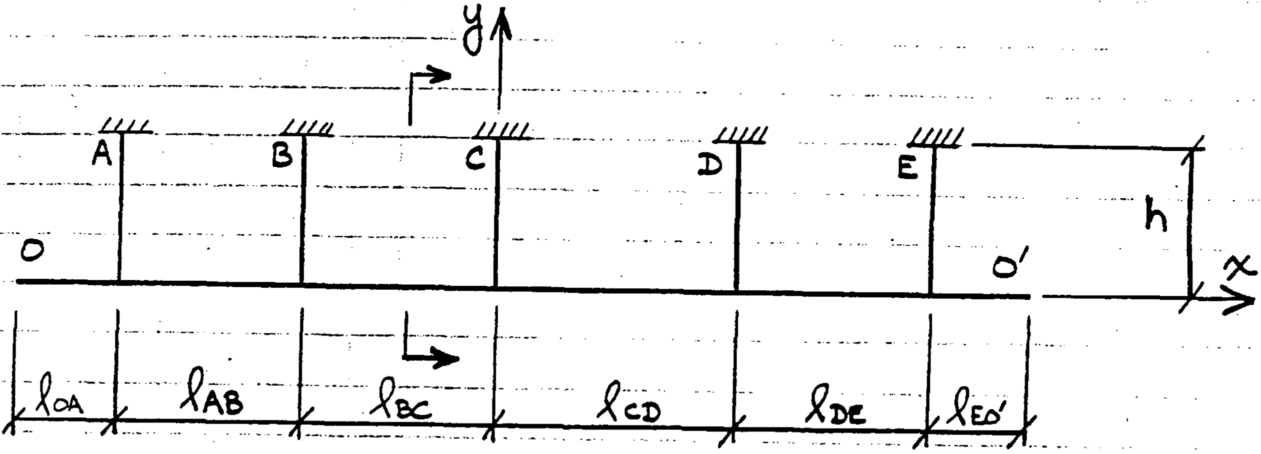
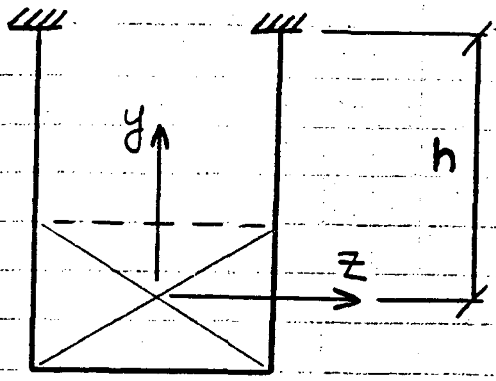
DEFINITION OF TERMS FOR THE FOLLOWING SYSTEMS:
AA2150F
BC3150F

Note: O and O' are free for z excitation





SECTION VIEW

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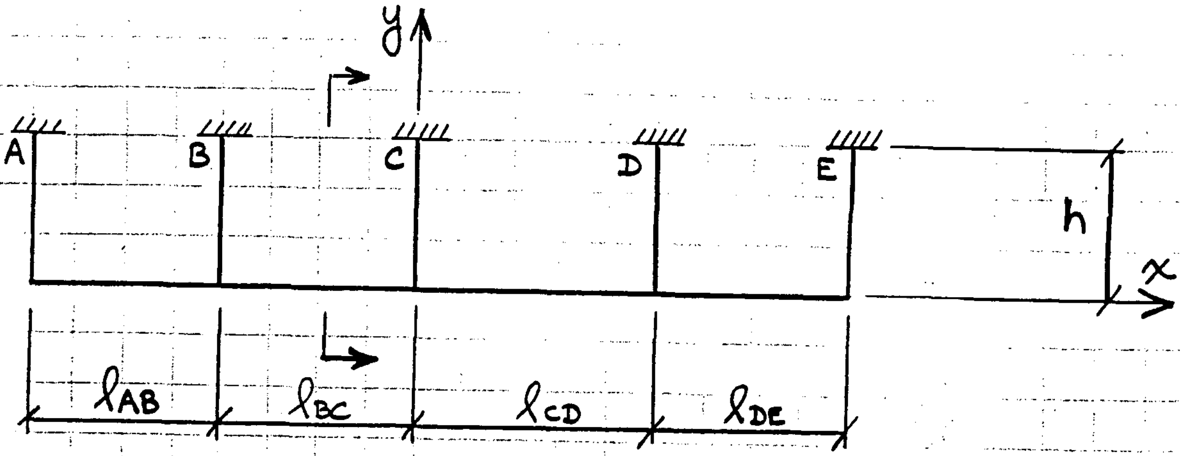
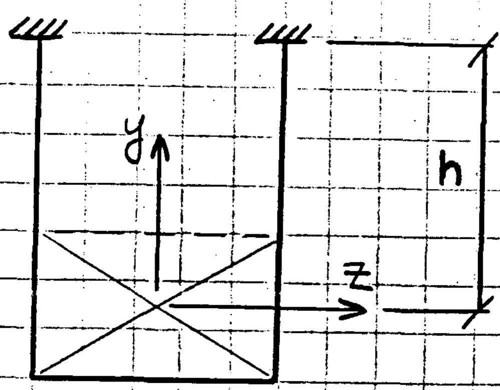
DEFINITION OF TERMS FOR THE FOLLOWING SYSTEM:
AA2150H





SECTION VIEW

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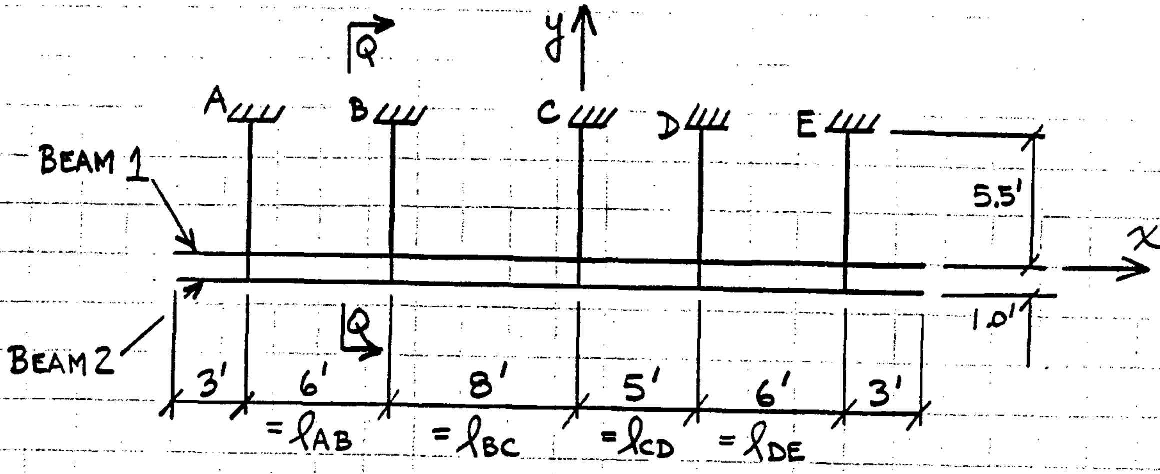
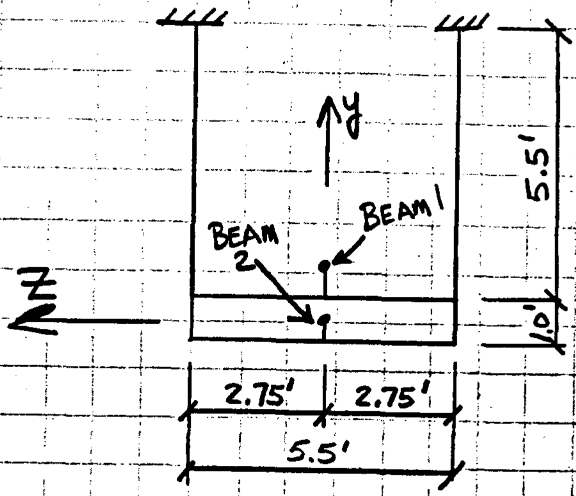
DEFINITION OF TERMS FOR
CABLE TRAY MODELS CT33 AND CT 13





SECTION Q-Q

Vertical members:
TS 7X7X1/2
42.05 #/ft

Horizontal members
TS 4X4X1/4
12.21 #/ft

l_{AB} = 6 ft
l_{BC} = 8 ft
l_{CD} = 5 ft
l_{DE} = 6 ft

SYSTEM CT33
BEAM 1 = 3 TRAYS
BEAM 2 = 3 TRAYS
SYSTEM CT 13
BEAM 1 = 1 TRAY
BEAM 2 = 3 TRAYS

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AA2150

SYSTEM ID = AA2150

$l_{OA} = l_{EE'} = 4$ ft
$l_{AB} = l_{CD} = l_{DE} = 8$ ft
$l_{BC} = 1.5 \times l_{AB} = 12$ ft
$h = 5.5$ ft

} see page 12.7 for definition of terms

PARAMETERS OF AA2150

1.) Duct Size 24 X 36 Weight = 31 #/FT (see page 3.4)

2.) Support Members ∠4 X 4 X ½

$W_A = W_B = W_C = W_D = W_E = 166^{\#}$ (see page 4.4)

$l_{AB} = l_{CD} = 8.0$ ft "

$l_{BC} = 12.0$ ft

W_{ij} = Weight of Duct between supports i and j

$W_{AB} = (31\ \text{lb/ft}) \times (8.0\ \text{ft}) = 248^{\#}$
↖ per page 3.4

$W_{BC} = (31\ \text{lb/ft}) \times (12.0\ \text{ft}) = 372^{\#}$

$W_{CD} = 248^{\#}$

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AA2150

DUCT SPAN BC

1.) K_z = Support Stiffness = 10838 #/in (per page 4.4) ✓

2.) COMPUTE M_1 and ω_{1z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{248 + 372}{4g} + \frac{166}{2g} = 238/g \quad ✓$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$

$$= \frac{372 + 248}{4g} + \frac{166}{2g} = 238/g \quad ✓$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{238/g}\right)^{1/2}$$

$$= \left(\frac{10838\ \#/\text{in}}{[238\#]/[32.2\ \text{ft/sec}^2 \times 12\ \text{in/ft}]}\right)^{1/2} = 132.6\ \text{RAD/SEC} \quad ✓$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{10838}{238/g}\right)^{1/2} = 132.6\ \text{RAD/SEC} \quad ✓$$

M_1 = MINIMUM OF (M_{1B} & M_{1C}) = 238#/g ✓

ω_{1Z} = MINIMUM OF (ω_{1BZ} & ω_{1CZ}) = 132.6 RAD/SEC ✓

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SARGENT & LUNDY
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AA2150

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48 E I_{BCZ}}{(l_{BC})^3} = \frac{48(29 \times 10^6 \ \#/in^2)(17.70 \ in^4)}{(12ft \times 12 \ in/ft)^3} = 8251 \ \#/in \ ✓$$

note: $I_{BCZ} = I_{bb} = 17.70 \ in^4$ per page 3.8 ✓
for 24 X 36 Duct

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{372}{2g} = 186/g$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{8251 \ \#/in}{[186\#]/[32.2 \ ft/sec^2 \times 12 \ in/ft]}\right)^{1/2} = 130.9 \ RAD/SEC \ ✓$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{248}{2g} = 124/g \ ✓$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{248}{2g} = 124/g \ ✓$$

$$M_2 = \text{maximum of} \left(\frac{M_{2AB} + M_{2BC}}{2} \ \text{OR} \ \frac{M_{2BC} + M_{2CD}}{2}\right)$$

$$= \frac{124/g + 186/g}{2} = 155/g$$

$$\mu = \frac{M_2}{M_1} = \frac{155/g}{238/g} = 0.651$$

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AA2150

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= (132.6)^2 + (1+0.651)(130.9)^2 = 45872 \checkmark$$

$$\omega_z^2 = 0.5\left[D_z - \left(D_z^2 - 4\,\omega_{1z}^2\,\omega_{2z}^2\right)^{1/2}\right]$$

$$= 0.5\left\{45872 - \left[(45872)^2 - 4(132.6)^2(130.9)^2\right]^{1/2}\right\}$$

$$= 7943 \checkmark$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{7943}}{2\pi} = 14.18 \text{ Hz} \checkmark$$

5.) DETERMINE a_z at $f_z = 14.18$ Hz
FROM SITE SPECIFIED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz $\quad a_z = 1.50\,g$
$f_z = 9.1$ Hz $\quad a_z = 2.25\,g$

Interpolate

$$\frac{\log 14.5 - \log 14.18}{\log 14.5 - \log 9.1} = \frac{1.50g - a_z}{1.50g - 2.25g}$$

$$+a_z = -\left[\left(\frac{\log 14.5 - \log 14.18}{\log 14.5 - \log 9.1}\right)(1.50g - 2.25g) - 1.50g\right]$$

$$a_z = \begin{matrix}1.533\,g\\ 1.536\,g\end{matrix} \quad @ \quad f_z = 14.18 \text{ Hz} \checkmark$$

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SYSTEM AA2150 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.533$ g, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(l_{BC})(a_z/g)$$

$$= 0.1\,(372\,\#)(12\ ft)(1.533\ g/g) = 684\ ft\text{-}lbs\ \checkmark$$

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(372\,\#)(1.533\ g/g) = 285\ lbs\ \checkmark$$

7.) DETERMINE SUPPORT FORCES
using $a_z = 1.533$ g, ~~(see page)~~
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{248\,\# + 372\,\#}{2} + \frac{166\,\#}{2}\right)(1.533\ g/g) = 602\ lbs$$

✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{372\,\# + 248\,\#}{2} + \frac{166\,\#}{2}\right)(1.533\ g/g) = 602\ lbs$$

✓

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SYSTEM AA2150 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00\ g$, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(372\ \#)(12\ \text{ft})(1.00\ g/g) = 446\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(372\ \#)(1.00\ g/g) = 186\ \text{lbs}$$ ✓

9.) DETERMINE SUPPORT FORCES

using $a_z = 1.00\,g$, from flat 1g spectra

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{248\ \# + 372\ \#}{2} + \frac{166\ \#}{2}\right)(1.00\ g/g) = 393\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{372\ \# + 248\ \#}{2} + \frac{166\ \#}{2}\right)(1.00\ g/g) = 393\ \text{lbs}$$ ✓

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AA2200

SYSTEM ID = AA2200

same as MDF System ID = AA2150 (see page 12.11)
except:

$\ell_{BC} = 2.0 \times \ell_{AB} = 2.0 \times 8\ ft = 16.0\ ft$

$W_A = W_B = W_C = W_D = 166^{\#}$ (see page 4.4) ✓

$\ell_{AB} = \ell_{CD} = 8.0\ ft$ ✓ "

$\ell_{BC} = 16.0\ ft$ ✓

$W_{AB} = (31\ ^{\#}/ft) \times (8.0\ ft) = 248^{\#}$ ✓

$W_{BC} = (31\ ^{\#}/ft) \times (16.0\ ft) = 496^{\#}$ ✓

$W_{CD} = 248^{\#}$ ✓

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AA2200

DUCT SPAN BC

1.) k_z = Support Stiffness = 10838 #/in (per page 4.4)

2.) COMPUTE M_1 AND ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{248 + 496}{4g} + \frac{166}{2g} = 269/g$$ ✓

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$

$$= \frac{496 + 248}{4g} + \frac{166}{2g} = 269/g$$ ✓

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{269/g}\right)^{1/2}$$

$$= \left(\frac{10838\ \#/\text{in}}{[269\ \#] / [32.2\ \text{ft/sec}^2 \times 12\ \text{in/ft}]}\right)^{1/2} = 124.8\ \text{RAD/SEC}$$ ✓

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{10838}{269/g}\right)^{1/2} = 124.8\ \text{RAD/SEC}$$ ✓

M_1 = MINIMUM OF (M_{1B} & M_{1C}) = 269 #/g ✓

ω_{1Z} = MINIMUM OF (ω_{1BZ} & ω_{1CZ}) = 124.8 RAD/SEC ✓

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SARGENT & LUNDY ENGINEERS

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AA2200

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48 E I_{BCZ}}{(l_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(17.70\ in^4)}{(16\ ft\times12\ in/ft)^3} = 3481\ \#/in$$ ✓

note: $I_{BCZ} = I_{bb} = 17.70\ in^4$ per page 3.8 for 24x36 Duct ✓

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{496}{2g} = 248/g$$ ✓

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{3481\ \#/in}{[248\#]/[32.2\ ft/sec^2\times12\ in/ft]}\right)^{1/2} = 73.6\ RAD/SEC$$ ✓

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{248}{2g} = 124/g$$ ✓

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{248}{2g} = 124/g$$ ✓

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB}+M_{2BC}}{2} \text{ OR } \frac{M_{2BC}+M_{2CD}}{2}\right)$$ ✓

$$= \frac{124/g + 248/g}{2} = 186/g$$ ✓

$$\mu = \frac{M_2}{M_1} = \frac{186/g}{269/g} = 0.691$$ ✓

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AA2200

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [124.8]^2 + (1+0.691)[73.6]^2 = 24735$$ ✓

$$[\omega_z]^2 = 0.5\left\{D_z - \left[D_z^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{24735 - \left[(24735)^2 - 4(124.8)^2(73.6)^2\right]^{1/2}\right\}$$

$$= 4086$$ ✓

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{4086}}{2\pi} = 10.17\ Hz$$ ✓

5.) DETERMINE a_z at 10.17 Hz
FROM SITE SPECIFIED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz $\quad a_z = 1.50\,g$
$f_z = 9.1$ Hz $\quad a_z = 2.25\,g$

Interpolate $$\frac{a_z - 2.25g}{1.50g - 2.25g} = \frac{\log 10.17 - \log 9.1}{\log 14.50 - \log 9.1}$$

$$a_z = \left(\frac{\log 10.17 - \log 9.1}{\log 14.50 - \log 9.1}\right)(1.50g - 2.25g) + 2.25g$$

$$a_z = 2.072\,g \text{ at } 10.17\ Hz$$ ✓

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SYSTEM AA2200 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 2.072\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(496^{\#})(16\ \text{ft})(2.072\ g/g) = 1644\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(496^{\#})(2.072\ g/g) = 514\ \text{lbs}$$ ✓

7.) DETERMINE SUPPORT FORCES

using $a_z = 2.072\ g$, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{248^{\#} + 496^{\#}}{2} + \frac{166^{\#}}{2}\right)(2.072\ g/g) = 943\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{496^{\#} + 248^{\#}}{2} + \frac{166^{\#}}{2}\right)(2.072\ g/g) = 943\ \text{lbs}$$ ✓

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SYSTEM AA2200 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00\ g$, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(496\,\#)(16\ ft)(1.00\ g/g) = 794\ ft\text{-}lbs$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(496\,\#)(1.00\ g/g) = 248\ lbs$$ ✓

9.) DETERMINE SUPPORT FORCES
using $a_z = 1.00\,g$, from flat 1g spectra
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{248\,\# + 496\,\#}{2} + \frac{166\,\#}{2}\right)(1.00\ g/g) = 455\ lbs$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{496\,\# + 248\,\#}{2} + \frac{166\,\#}{2}\right)(1.00\ g/g) = 455\ lbs$$ ✓

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AB 2150

SYSTEM ID = AB2150

Same as system AA 2150 (see page 12.11) except:

$\ell_{OA} = \ell_{EO'} = 5 \text{ ft}$ ✓

$\ell_{AB} = \ell_{CD} = \ell_{DE} = 10 \text{ ft}$ ✓

$\ell_{BC} = 1.5\, \ell_{AB} = 15 \text{ ft}$ ✓

$W_A = W_B = W_C = W_D = W_E = 166^{\#}$ (see page 4.4)

$W_{AB} = W_{CD} = W_{DE} = (31\ ^{\#}/_{ft})(10 \text{ ft}) = 310^{\#}$ ✓

$W_{BC} = (31\ ^{\#}/_{ft})(15 \text{ ft}) = 465^{\#}$ ✓

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AB2150

DUCT SPAN BC

1.) $k_z = 10838$ #/in (see page 4.4)

2.) COMPUTE M_1 and ω_{1z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{310 + 465}{4g} + \frac{166}{2g} = 276.75/g \checkmark$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$

$$= \frac{465 + 310}{4g} + \frac{166}{2g} = 276.75/g \checkmark$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{276.75/g}\right)^{1/2}$$

$$= \left(\frac{10838 \text{ \#/in}}{[276.75 \text{ \#}] / [32.2 \text{ ft/sec}^2 \times 12 \text{ in/ft}]}\right)^{1/2} = 123.0 \text{ RAD/SEC} \checkmark$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = 123.0 \text{ RAD/SEC} \checkmark$$

$$M_1 = \text{MINIMUM OF } (M_{1B} \text{ \& } M_{1C}) = 276.75/g \checkmark$$

$$\omega_{1Z} = \text{MINIMUM OF } (\omega_{1BZ} \text{ \& } \omega_{1CZ}) = 123.0 \text{ RAD/SEC} \checkmark$$

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AB2150

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48 E I_{BCZ}}{(l_{BC})^3} = \frac{48(29 \times 10^6 \,\#/in^2)(17.70\,in^4)}{(15 ft \times 12\, in/ft)^3} = 4225\,\#/in \quad ✓$$

note : $I_{BCZ} = I_{bb} = 17.70\,in^4$ per page 3.8
for 24X36 Duct

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{465}{2g} = 232.5/g \quad ✓$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{4225\,\#/in}{[232.5\#]/[32.2 \times 12\, in/sec^2]}\right)^{1/2} = 83.8\, RAD/SEC \quad ✓$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{310}{2g} = 155/g \quad ✓$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{310}{2g} = 155/g \quad ✓$$

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB} + M_{2BC}}{2} \text{ OR } \frac{M_{2BC} + M_{2CD}}{2}\right)$$

$$= \frac{155/g + 232.5/g}{2} = 193.75/g \quad ✓$$

$$\mu = \frac{M_2}{M_1} = \frac{193.75/g}{276.75/g} = 0.700 \quad ✓$$

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AB2150

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [123.0]^2 + (1+0.700)[83.8]^2 = 27067$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(27067) - \left[(27067)^2 - 4(123.0)^2(83.8)^2\right]^{1/2}\right\}$$

$$= 4763$$ ✓

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{4763}}{2\pi} = 10.98 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 10.98 Hz
FROM SITE SPECIFIED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz $a_z = 1.50$ g
$f_z = 9.1$ Hz $a_z = 2.25$ g

INTERPOLATE: $$\frac{a_z - 2.25g}{1.50g - 2.25g} = \frac{\log 10.98 - \log 9.1}{\log 14.50 - \log 9.1}$$

$$a_z = \left(\frac{\log 10.98 - \log 9.1}{\log 14.50 - \log 9.1}\right)(1.50g - 2.25g) + 2.25g$$

$a_z = 1.946$ g at 10.98 Hz ✓

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SYSTEM AB2150 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.946$ g, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(465\,\#)(15\ \text{ft})(1.946\ g/g) = 1357\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(465\,\#)(1.946\ g/g) = 452\ \text{lbs}$$ ✓

7.) DETERMINE SUPPORT FORCES

using $a_z = 1.946$ g, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{310\,\# + 465\,\#}{2} + \frac{166\,\#}{2}\right)(1.946\ g/g) = 916\ \text{lbs}$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{465\,\# + 310\,\#}{2} + \frac{166\,\#}{2}\right)(1.946\ g/g) = 916\ \text{lbs}$$

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SYSTEM AB2150 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00\ g$, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(465\ \#)(15\ ft)(1.00\ g/g) = 698\ ft\text{-}lbs$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(465\ \#)(1.00\ g/g) = 233\ lbs$$

9.) DETERMINE SUPPORT FORCES

using $a_z = 1.00\,g$, from flat 1g spectra

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{310\ \# + 465\ \#}{2} + \frac{166\ \#}{2}\right)(1.00\ g/g) = 471\ lbs$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{465\ \# + 310\ \#}{2} + \frac{166\#}{2}\right)(1.00\ g/g) = 471\ lbs$$

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AB2200

SYSTEM ID = AB2200

same as MDF SYSTEM ID = AB2150 (see page 12.23)
except:

~~$\ell_{BC} = 2.0 \times \ell_{AB} = 2.0 \times 10\text{ ft} = 20.0\text{ ft}$~~

$W_A = W_B = W_C = W_D = W_E = 166\#$ (see page 4.4)

$\ell_{AB} = \ell_{CD} = 10.0\text{ ft}$

$\ell_{BC} = 2 \times 10.0\text{ft} = 20.0\text{ ft}$

$W_{AB} = W_{CD} = (31\#/\text{ft}) \times (10.0\text{ ft}) = 310\#$ ✓

$W_{BC} = (31\#/\text{ft}) \times (20.0\text{ ft}) = 620\#$ ✓

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AB2200

DUCT SPAN BC

1.) $k_Z = 10838\ \#/\text{in}$ (see page 4.4)

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{310 + 620}{4g} + \frac{166}{2g} = 315.5/g \checkmark$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4g} + \frac{W_C}{2g}$$

$$= \frac{620 + 310}{4g} + \frac{166}{2g} = 315.5/g \checkmark$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{315.5/g}\right)^{1/2}$$

$$= \left(\frac{10838\ \#/\text{in}}{[315.5\#]/[32.2 \times 12\ \text{in}/\text{sec}^2]}\right)^{1/2} = 115.2\ \text{RAD}/\text{SEC} \checkmark$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = 115.2\ \text{RAD}/\text{SEC} \checkmark$$

$$M_1 = \text{MINIMUM OF } (M_{1B}\ \&\ M_{1C}) = 315.5/g \checkmark$$

$$\omega_{1Z} = \text{MINIMUM OF } (\omega_{1BZ}\ \&\ \omega_{1CZ}) = 115.2\ \text{RAD}/\text{SEC} \checkmark$$

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AB2200

3.) COMPUTE M_2 and ω_{2z}

$$k_{2BCz} = \frac{48 E I_{BCz}}{(l_{BC})^3} = \frac{48(29\times10^6 \ \#/in^2)(17.70 \ in^4)}{(20\times12 \ in)^3} = 1782 \ \#/in$$ ✓

note: $I_{BCz} = I_{bb} = 17.70 \ in^4$ per page 3.8
for 24x36 Duct

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{620}{2g} = 310/g$$ ✓

$$\omega_{2BCz} = \left(\frac{k_{2BCz}}{M_{2BC}}\right)^{1/2} = \left(\frac{1782 \ \#/in}{[310\#]/[32.2\times12 \ in/sec^2]}\right)^{1/2} = 47.1 \ RAD/SEC$$ ✓

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{310}{2g} = 155/g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{310}{2g} = 155/g$$

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB}+M_{2BC}}{2} \ \text{OR} \ \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= \frac{155/g + 310/g}{2} = 232.5/g$$ ✓

$$\mu = \frac{M_2}{M_1} = \frac{232.5/g}{315.5/g} = 0.737$$ ✓

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AB2200

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [115.2]^2 + (1+0.737)[47.1]^2 = 17124$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(17124) - \left[(17124)^2 - 4(115.2)^2(47.1)^2\right]^{1/2}\right\}$$

$$= 1939$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{1939}}{2\pi} = 7.008\ Hz \checkmark$$

5) DETERMINE a_z at 7.008 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 9.1\ Hz$ $\quad a_z = 2.25\,g$
$f_z = 6.5\ Hz$ $\quad a_z = 4.00\,g$

INTERPOLATE: $$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 7.008 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 7.008 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

$$a_z = 3.605g \checkmark \text{ at } 7.008\ Hz \checkmark$$

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SYSTEM AB2200 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 3.605\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(620\,\#)(20\ ft)(3.605\,g/g) = 4470\ ft\text{-}lbs$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(620\,\#)(3.605\,g/g) = 1118\ lbs$$ ✓

7.) DETERMINE SUPPORT FORCES

using $a_z = 3.605\,g$, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{310\,\# + 620\,\#}{2} + \frac{166\,\#}{2}\right)(3.605\,g/g) = 1976\ lbs$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{620\,\# + 310\,\#}{2} + \frac{166\,\#}{2}\right)(3.605\,g/g) = 1976\ lbs$$ ✓

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SYSTEM AB2200 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00$ g, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(l_{BC})(a_z/g)$$

$$= 0.1\,(620\,\#)(20\text{ ft})(1.00\ g/g) = 1240\text{ ft-lbs} \checkmark$$

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(620\,\#)(1.00\ g/g) = 310\text{ lbs} \checkmark$$

9.) DETERMINE SUPPORT FORCES
using $a_z = 1.00g$, from flat 1g spectra
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{310\,\# + 620\,\#}{2} + \frac{166\,\#}{2}\right)\left(1.00\ g/g\right) = 548\text{ lbs} \checkmark$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{620\,\# + 310\,\#}{2} + \frac{166\,\#}{2}\right)\left(1.00\ g/g\right) = 548\text{ lbs} \checkmark$$

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BC3150

~~MDF~~ SYSTEM ID = BC3150 $k = 4863 \#/in \times 3 = 14589 \#/in$

$l_{OA} = 6'$ see page 12.7 for definition of terms

$l_{AB} = 18'$

$l_{BC} = 18'$

$l_{CD} = 12'$

$l_{DE} = 12'$

$l_{EO'} = 6'$

$h = 7 ft$,

Support weights = 243#

$W_A = W_B = W_C = W_D = W_E = 243\#$

Duct Size: 60 x 72

Weight = 101.2 #/ft (see page 3.4)

$I_{BCz} = I_{bb} = 301.8 \ in^4$ (see page 3.9)

$W_{OA} = (101.2 \#/ft) \times (6 ft) = 607.2 \#$ ✓

$W_{AB} = (101.2) \times (18) = 1821.6 \#$ ✓

$W_{BC} = (101.2) \times (18) = 1821.6 \#$ ✓

$W_{CD} = (101.2) \times (12) = 1214.4 \#$ ✓

$W_{DE} = (101.2) \times (12) = 1214.4 \#$ ✓

$W_{EO'} = (101.2) \times (6) = 607.2 \#$ ✓

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BC 3150

DUCT SPAN BC

1.) $k_{BZ} = 14589$ #/in

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1821.6 + 1821.6}{4g} + \frac{243}{2g} = 1032/g$$ ✓

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{1821.6 + 1214.4}{4\cancel{2}g} + \frac{243}{2g} = 880.75/g$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589\ \#/in}{[1032\#]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 73.9\ \frac{RAD}{SEC}$$ ✓

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{14589\ \#/in}{[880.75\#]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 80.0\ \frac{RAD}{SEC}$$ ✓

$$M_1 = \text{MINIMUM OF } (M_{1B}\ \&\ M_{1C}) = 880.75/g$$ ✓

$$\omega_{1Z} = \text{MINIMUM OF } (\omega_{1BZ}\ \&\ \omega_{1CZ}) = 73.9\ RAD/SEC$$ ✓

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BC3150

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48EI_{BCZ}}{(\ell_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(301.8\ in^4)}{(18\times12\ in)^3} = 41687\ \#/in$$ ✓

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{1821.6}{2g} = 911\ /g$$ ✓

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{41687\ \#/in}{[911\ \#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 133.0\ \frac{RAD}{SEC}$$ ✓

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1821.6}{2g} = 911\ /g$$ ✓

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1214.4}{2g} = 607.2/g$$ ✓

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB}+M_{2BC}}{2}\ \text{OR}\ \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= 911/g$$ ✓

$$\mu = \frac{M_2}{M_1} = \frac{911\ /g}{880.75/g} = 1.034$$ ✓

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BC3150

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [73.9]^2 + (1 + 1.034)[133.0]^2 = 41441$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(41441) - \left[(41441)^2 - 4(73.9)^2(133.0)^2\right]^{1/2}\right\}$$

$$= 2479$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{2479}}{2\pi} = 7.92 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 7.92 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 9.1$ Hz $\quad a_z = 2.25g$
$f_z = 6.5$ Hz $\quad a_z = 4.00g$

Interpolate:

$$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

$a_z = 2.972g$ at 7.92 Hz ✓

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SYSTEM BC3150 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 2.972\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(1821.6^{\#})(18\ \text{ft})(2.972\ g/g) = 9745\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(1821.6^{\#})(2.972\ g/g) = 2707\ \text{lbs}$$

7.) DETERMINE SUPPORT FORCES
using $a_z = \quad g$, ~~(see page)~~
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1821.6^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.972\ g/g\right) = 5775\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1821.6^{\#} + 1214.4^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.972\ g/g\right) = 4873\ \text{lbs}$$ ✓

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SYSTEM BC3150 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00\ g$, from flat 1g spectra

$$M_{BC} = 0.1 (W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1 (1821.6^{\#})(18\ ft)(1.00\ g/g) = 3279\ ft\text{-}lbs$$ ✓

$$V_{BC} = 0.5 (W_{BC})(a_z/g)$$ ✓

$$= 0.5 (1821.6^{\#})(1.00\ g/g) = 911\ lbs$$

9.) DETERMINE SUPPORT FORCES

using $a_z = 1.00g$, from flat 1g spectra

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{1821.6^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)(1.00\ g/g) = 1943\ lbs$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$ ✓

$$= \left(\frac{1821.6^{\#} + 1214.4^{\#}}{2} + \frac{243^{\#}}{2}\right)(1.00\ g/g) = 1640\ lbs$$

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~~MDF~~ SYSTEM ID = BC3200   BC3200 $k = 4863\ \#/in \times 3 = 14589\ \#/in$

l_{OA} = 6 ft   see page 12.7 for definition of terms.
l_{AB} = 24
l_{BC} = 24
l_{CD} = 12
l_{DE} = 12
$l_{EO'}$ = 6

h = 7 ft ,

Support weights = 243#
$W_A = W_B = W_C = W_D = W_E = 243\#$

Duct Size: 60x72
Weight = 101.2 #/ft (see page 3.4)
$I_{BCZ} = I_{bb} = 301.8\ in^4$ (see page 3.9)

$W_{OA} = (101.2\ \#/ft) \times (6\ ft) = 607.2\ \#$ ✓

$W_{AB} = (101.2) \times (24) = 2429\ \#$ ✓

$W_{BC} = (101.2) \times (24) = 2429\ \#$ ✓

$W_{CD} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{DE} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{EO'} = (101.2) \times (6) = 607.2\ \#$ ✓

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BC3200

DUCT SPAN BC

1.) $k_{BZ} = 14589$ #/in

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{2429 + 2429}{4g} + \frac{243}{2g} = 1336/g$$ ✓

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{2429 + 1214.4}{4\cancel{2}g} + \frac{243}{2g} = 1032/g$$ ✓

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[1336\#]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 65.0 \frac{\text{RAD}}{\text{SEC}}$$ ✓

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[1032\#]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 73.9 \frac{\text{RAD}}{\text{SEC}}$$ ✓

M_1 = MINIMUM OF (M_{1B} & M_{1C}) = 1032/g ✓

ω_{1Z} = MINIMUM OF (ω_{1BZ} & ω_{1CZ}) = 65.0 RAD/SEC ✓

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BC 3200

3.) COMPUTE M_2 and ω_{2z}

$$k_{2BCz} = \frac{48EI_{BCz}}{(\ell_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(301.8\ in^4)}{(24\times 12\ in)^3} = 17587\ \#/in \quad ✓$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{2429}{2g} = 1214.5/g \quad ✓$$

$$\omega_{2BCz} = \left(\frac{k_{2BCz}}{M_{2BC}}\right)^{1/2} = \left(\frac{17587\ \#/in}{[1214.5\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 74.8\ \frac{RAD}{SEC} \quad ✓$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{2429}{2g} = 1214.5/g \quad ✓$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1214.4}{2g} = 607.2/g \quad ✓$$

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB}+M_{2BC}}{2} \text{ OR } \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= 1214.5/g \quad ✓$$

$$\mu = \frac{M_2}{M_1} = \frac{1214.5/g}{1032/g} = 1.176 \quad ✓$$

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BC3200

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [65.0]^2 + (1+1.176)[74.8]^2 = 16400$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(16400) - \left[(16400)^2 - 4(65.0)^2(74.8)^2\right]^{1/2}\right\}$$

$$= 1597$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{1597}}{2\pi} = 6.36 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 6.36 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

PEAK ACCELERATION OCCURS BETWEEN
FREQUENCIES 4.8 Hz AND 6.5 Hz
PEAK ACCEL = 4.0 g

use $a_z = 4.0g$ at 6.36 Hz ✓

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SYSTEM BC3200 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 4.00\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(2429^{\#})(24\ \text{ft})(4.00\ g/g) = 23318\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(2429^{\#})(4.00\ g/g) = 4858\ \text{lbs}$$ ✓

7.) DETERMINE SUPPORT FORCES

using $a_z = 4.00\ g$, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{2429^{\#} + 2429^{\#}}{2} + \frac{243^{\#}}{2}\right)(4.00\ g/g) = 10202\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{2429^{\#} + 1214.4^{\#}}{2} + \frac{243^{\#}}{2}\right)(4.00\ g/g) = 7773\ \text{lbs}$$ ✓

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SYSTEM BC3200 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00\ g$, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(2429^{\#})(24\ \text{ft})(1.00\ g/g) = 5830\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(2429^{\#})(1.00\ g/g) = 1215\ \text{lbs}$$ ✓

9.) DETERMINE SUPPORT FORCES

using $a_z = 1.00\,g$, from flat 1g spectra

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{2429^{\#} + 2429^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(1.00\ g/g\right) = 2551\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{2429^{\#} + 1214.4^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(1.00\ g/g\right) = 1943\ \text{lbs}$$ ✓

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BC4125

~~MDF~~ SYSTEM ID = BC4125 $k = 4863 \#/in \times 3 = 14589 \#/in$

l_{OA} = 6 ft

l_{AB} = 12

l_{BC} = 15

l_{CD} = 15

l_{DE} = 12

$l_{EO'}$ = 6

See page 12.7 for definition of terms

h = 7 ft,

Support weights = 243 lb ✓

$W_A = W_B = W_C = W_D = W_E = 243$ lb

Duct Size 60 x 72

Weight = 101.2 #/ft (see page 3.4)

$I_{BCZ} = I_{bb} = 301.8\ in^4$ (see page 3.9)

$W_{OA} = (101.2 \#/ft) \times (6\ ft) = 607.2\ \#$ ✓

$W_{AB} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{BC} = (101.2) \times (15) = 1518\ \#$ ✓

$W_{CD} = (101.2) \times (15) = 1518\ \#$ ✓

$W_{DE} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{EO'} = (101.2) \times (6) = 607.2\ \#$ ✓

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BC4125

DUCT SPAN BC

1.) $k_{BZ} = 14589$ #/in

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1214.4 + 1518}{4g} + \frac{243}{2g} = 804.6/g$$ ✓

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{1518 + 1518}{4\cancel{2}g} + \frac{243}{2g} = 880.5/g$$ ✓

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[804.6\#]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 83.7 \ \frac{\text{RAD}}{\text{SEC}}$$ ✓

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[880.5\#]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 80.0 \ \frac{\text{RAD}}{\text{SEC}}$$ ✓

M_1 = MINIMUM OF $(M_{1B}$ & $M_{1C})$ = 804.6/g ✓

ω_{1Z} = MINIMUM OF $(\omega_{1BZ}$ & $\omega_{1CZ})$ = 80.0 RAD/SEC ✓

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BC 4125

3.) COMPUTE M_2 and ω_{2z}

$$k_{2BCz} = \frac{48EI_{BCz}}{(l_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(301.8\ in^4)}{(15\times12\ in)^3} = 72035\ \#/in$$ ✓

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{1518}{2g} = 759\ /g$$ ✓

$$\omega_{2BCz} = \left(\frac{k_{2BCz}}{M_{2BC}}\right)^{1/2} = \left(\frac{72035\ \#/in}{[759\ \#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 191.5\ \frac{RAD}{SEC}$$ ✓

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1214.4}{2g} = 607.2/g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1518}{2g} = 759\ /g$$

$$M_2 = \text{MAXIMUM OF}\left(\frac{M_{2AB}+M_{2BC}}{2}\ \text{OR}\ \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= 759/g$$ ✓

$$\mu = \frac{M_2}{M_1} = \frac{759\ /g}{804.6/g} = 0.943$$ ✓

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BC4125

4.) COMPUTE f_z

$$D_z = \left[\omega_{1z}\right]^2 + (1+\mu)\left[\omega_{2z}\right]^2$$

$$= \left[80.0\right]^2 + (1+0.943)\left[191.5\right]^2 = 77654$$

$$\left[\omega_z\right]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(77654) - \left[(77654)^2 - 4(80.0)^2(191.5)^2\right]^{1/2}\right\}$$

$$= 3150$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{3150}}{2\pi} = 8.93\text{ Hz}$$ ✓

5.) DETERMINE a_z at 8.93 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 9.1$ Hz $\quad a_z = 2.25$ g
$f_z = 6.5$ Hz $\quad a_z = 4.00$ g

Interpolate:

$$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 8.93 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 8.93 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

$$a_z = 2.35g \quad \text{at} \quad 8.93\text{ Hz}$$ ✓

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SYSTEM BC4125 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 2.35\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(1518^{\#})(15\ \text{ft})(2.35\ g/g) = 5351\ \text{ft-lbs}\ \checkmark$$

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(1518^{\#})(2.35\ g/g) = 1784\ \text{lbs}\ \checkmark$$

7.) DETERMINE SUPPORT FORCES
using $a_z = 2.35\ g$, ~~(see page)~~
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1214.4^{\#} + 1518^{\#}}{2} + \frac{243^{\#}}{2}\right)(2.35\ g/g) = 3496\ \text{lbs}\ \checkmark$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{1518^{\#} + 1518^{\#}}{2} + \frac{243^{\#}}{2}\right)(2.35\ g/g) = 3853\ \text{lbs}\ \checkmark$$

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SYSTEM BC4125 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00$ g, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(1518\,\#)(15\text{ ft})(1.00\text{ g}/g) = 2277\text{ ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(1518\,\#)(1.00\text{ g}/g) = 759\text{ lbs}$$ ✓

9.) DETERMINE SUPPORT FORCES
using $a_z = 1.00$g, from flat 1g spectra
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1214.4\,\# + 1518\,\#}{2} + \frac{243\,\#}{2}\right)\left(1.00\text{ g}/g\right) = 1488\text{ lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1518\,\# + 1518\,\#}{2} + \frac{243\,\#}{2}\right)\left(1.00\text{ g}/g\right) = 1640\text{ lbs}$$ ✓

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BC4150

~~MDF~~ SYSTEM ID = BC4150 $k = 4863\ \#/\text{in} \times 3 = 14589\ \#/\text{in}$

$\ell_{OA} = 6$ ft see page 12.7 for definition of terms

$\ell_{AB} = 12$

$\ell_{BC} = 18$

$\ell_{CD} = 18$

$\ell_{DE} = 12$

$\ell_{EO'} = 6$

$h = 7$ ft

Support weights = 243 #

$W_A = W_B = W_C = W_D = W_E = 243$ #

Duct Size: 60 x 72

Weight = 101.2 #/ft (see page 3.4)

$I_{BCZ} = I_{bb} = 301.8$ in^4 (see page 3.9)

$W_{OA} = (101.2\ \#/\text{ft}) \times (6\ \text{ft}) = 607.2$ # ✓

$W_{AB} = (101.2) \times (12) = 1214.4$ # ✓

$W_{BC} = (101.2) \times (18) = 1821.6$ # ✓

$W_{CD} = (101.2) \times (18) = 1821.6$ # ✓

$W_{DE} = (101.2) \times (12) = 1214.4$ # ✓

$W_{EO'} = (101.2) \times (6) = 607.2$ # ✓

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BC 4150

DUCT SPAN BC

1.) $k_{BZ} = 14589\ ^{\#}/_{in}$

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1214.4 + 1821.6}{4g} + \frac{243}{2g} = 880.75/g \ ✓$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{1821.6 + 1821.6}{4\cancel{2}g} + \frac{243}{2g} = 1032.5\ /g \ ✓$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589\ ^{\#}/_{in}}{[880.75^{\#}]/[32.2 \times 12\ ^{in}/_{sec^2}]}\right)^{1/2} = 80.0\ \frac{RAD}{SEC} \ ✓$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{14589\ ^{\#}/_{in}}{[1032.5^{\#}]/[32.2 \times 12\ ^{in}/_{sec^2}]}\right)^{1/2} = 73.9\ \frac{RAD}{SEC} \ ✓$$

$$M_1 = \text{MINIMUM OF } (M_{1B}\ \&\ M_{1C}) = 880.75/g \ ✓$$

$$\omega_{1Z} = \text{MINIMUM OF } (\omega_{1BZ}\ \&\ \omega_{1CZ}) = 73.9 \ ✓\ ^{RAD}/_{SEC}$$

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BC 4150

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48EI_{BCZ}}{(\ell_{BC})^3} = \frac{48(29\times10^6\ \#/\text{in}^2)(301.8\ \text{in}^4)}{(18\times12\ \text{in})^3} = 41687\ \#/\text{in}$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{1821.6}{2g} = 911\ /g$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{41687\ \#/\text{in}}{[911\ \#]/[32.2\times12\ \text{in}/\text{sec}^2]}\right)^{1/2} = 133.0\ \frac{\text{RAD}}{\text{SEC}}$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1214.4}{2g} = 607.2\ /g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{1821.6}{2g} = 911\ /g$$

$$M_2 = \text{MAXIMUM OF}\left(\frac{M_{2AB}+M_{2BC}}{2}\ \text{OR}\ \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= 911\ /g \checkmark$$

$$\mu = \frac{M_2}{M_1} = \frac{911\ /g}{880.75\ /g} = 1.034 \checkmark$$

BC4150

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [73.9]^2 + (1+1.034)[133.0]^2 = 41441$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(41441) - \left[(41441)^2 - 4(73.9)^2(133.0)^2\right]^{1/2}\right\}$$

$$= 2479$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{2479}}{2\pi} = 7.92 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 7.92 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

f_z = 9.1 Hz $\quad$ a_z = 2.25 g
f_z = 6.5 Hz $\quad$ a_z = 4.00 g

Interpolate:

$$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

a_z = 2.97 g at 7.92 Hz ✓

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SYSTEM BC4150 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 2.97\ g$, ~~(see page)~~

$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$

$= 0.1\,(1821.6^{\#})(18\ ft)(2.97\ g/g) = 9738\ ft\text{-}lbs$ ✓

$V_{BC} = 0.5\,(W_{BC})(a_z/g)$

$= 0.5\,(1821.6^{\#})(2.97\ g/g) = 2705\ lbs$ ✓

7.) DETERMINE SUPPORT FORCES

using $a_z = \quad g$, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1214.4^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.97\ g/g\right) = 4869\ lbs$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1821.6^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.97\ g/g\right) = 5771\ lbs$$ ✓

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SYSTEM BC4150 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00 \; g$, from flat 1g spectra

$$M_{BC} = 0.1 (W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1(1821.6^{\#})(18 \text{ ft})(1.00 \; g/g) = 3279 \text{ ft-lbs} \checkmark$$

$$V_{BC} = 0.5 (W_{BC})(a_z/g)$$

$$= 0.5(1821.6^{\#})(1.00 \; g/g) = 911 \text{ lbs} \checkmark$$

9.) DETERMINE SUPPORT FORCES

using $a_z = 1.00 g$, from flat 1g spectra

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1214.4^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)(1.00 \; g/g) = 1640 \text{ lbs} \checkmark$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{1821.6^{\#} + 1821.6^{\#}}{2} + \frac{243^{\#}}{2}\right)(1.00 \; g/g) = 1943 \text{ lbs} \checkmark$$

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BC4200

~~MDF~~ SYSTEM ID = BC4200 $k = 4863 \#/in \times 3 = 14589 \#/in$

$\ell_{OA} = 6$ ft see page 12.7 for definition of terms.
$\ell_{AB} = 12$
$\ell_{BC} = 24$
$\ell_{CD} = 24$
$\ell_{DE} = 12$
$\ell_{EO'} = 6$

$h = 7$ ft ,

Support weights = 243
$W_A = W_B = W_C = W_D = W_E = 243$

Duct Size: 60 x 72
Weight = 101.2 #/ft (see page 3.4)
$I_{BCz} = I_{bb} = 301.8$ in^4 (see page 3.9)

$W_{OA} = (101.2 \#/ft) \times (6\ ft) = 607.2\ \#$ ✓

$W_{AB} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{BC} = (101.2) \times (24) = 2429\ \#$ ✓

$W_{CD} = (101.2) \times (24) = 2429\ \#$ ✓

$W_{DE} = (101.2) \times (12) = 1214.4\ \#$ ✓

$W_{EO'} = (101.2) \times (6) = 607.2\ \#$ ✓

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BC 4200

DUCT SPAN BC

1.) $k_{BZ} = 14589$ #/in

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1214.4 + 2429}{4g} + \frac{243}{2g} = 1032.5/g \quad ✓$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{2429 + 2429}{4\cancel{2}g} + \frac{243}{2g} = 1336/g \quad ✓$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[1032.5\text{\#}]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 73.9 \frac{\text{RAD}}{\text{SEC}} \quad ✓$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{14589 \text{ \#/in}}{[1336\text{\#}]/[32.2 \times 12 \text{ in/sec}^2]}\right)^{1/2} = 65.0 \frac{\text{RAD}}{\text{SEC}} \quad ✓$$

M_1 = MINIMUM OF $(M_{1B} \,\&\, M_{1C}) = 1032.5/g$ ✓

ω_{1Z} = MINIMUM OF $(\omega_{1BZ} \,\&\, \omega_{1CZ}) = 65.0$ RAD/SEC ✓

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BC4200

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2BCZ} = \frac{48 E I_{BCZ}}{(l_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(301.8\ in^4)}{(24\times12\ in)^3} = 17587\ \#/in \quad \checkmark$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{2429}{2g} = 1214.5\ /g$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{17587\ \#/in}{[1214.5\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 74.8\ \frac{RAD}{SEC} \quad \checkmark$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1214.4}{2g} = 607.2\ /g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{2429}{2g} = 1214.5\ /g$$

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB}+M_{2BC}}{2} \text{ OR } \frac{M_{2BC}+M_{2CD}}{2}\right)$$

$$= 1214.5\ /g \quad \checkmark$$

$$\mu = \frac{M_2}{M_1} = \frac{1214.5\ /g}{1032.5\ /g} = 1.176 \quad \checkmark$$

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BC4200

4.) COMPUTE f_z

$$D_z = \left[\omega_{1z}\right]^2 + (1+\mu)\left[\omega_{2z}\right]^2$$

$$= \left[65.0\right]^2 + (1+1.176)\left[74.8\right]^2 = 16400$$

$$\left[\omega_z\right]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(16400) - \left[(16400)^2 - 4(65.0)^2(74.8)^2\right]^{1/2}\right\}$$

$$= 1597$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{1597}}{2\pi} = 6.36 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 6.36 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

PEAK ACCELERATION OCCURS BETWEEN
FREQUENCIES 4.8 Hz AND 6.5 Hz
PEAK ACCEL = 4.0 g

use $a_z = 4.0$ g at 6.36 Hz ✓

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SYSTEM BC4200 CONTINUED

6.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 4.00\ g$, ~~(see page)~~

$$M_{BC} = 0.1\,(W_{BC})(\ell_{BC})(a_z/g)$$

$$= 0.1\,(2429\ \#)(24\ ft)(4.00\ g/g) = 23318\ ft\text{-}lbs \quad ✓$$

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(2429\ \#)(4.00\ g/g) = 4858\ lbs \quad ✓$$

7.) DETERMINE SUPPORT FORCES

using $a_z = 4.00\ g$, ~~(see page)~~

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1214.4\ \# + 2429\ \#}{2} + \frac{243\ \#}{2}\right)(4.00\ g/g) = 7773\ lbs \quad ✓$$

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{2429\ \# + 2429\ \#}{2} + \frac{243\ \#}{2}\right)(4.00\ g/g) = 10202\ lbs \quad ✓$$

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SYSTEM BC4200 CONTINUED

8.) DETERMINE DUCT MOMENT AND SHEAR

using $a_z = 1.00$ g, from flat 1g spectra

$$M_{BC} = 0.1\,(W_{BC})(l_{BC})(a_z/g)$$

$$= 0.1\,(2429\,\#)(24\ \text{ft})(1.00\ g/g) = 5830\ \text{ft-lbs}$$ ✓

$$V_{BC} = 0.5\,(W_{BC})(a_z/g)$$

$$= 0.5\,(2429\,\#)(1.00\ g/g) = 1215\ \text{lbs}$$ ✓

9.) DETERMINE SUPPORT FORCES
using $a_z = 1.00$g, from flat 1g spectra
SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1214.4\,\# + 2429\,\#}{2} + \frac{243\,\#}{2}\right)(1.00\ g/g) = 1943\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{2429\,\# + 2429\,\#}{2} + \frac{243\,\#}{2}\right)(1.00\ g/g) = 2551\ \text{lbs}$$ ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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AA2150F

SYSTEM ID = AA2150F

$\ell_{OA} = 1/4\ \ell_{AB} = 1/4\ (8\ ft) = 2\ ft$

$\ell_{EO'} = 1/4\ \ell_{DE} = 1/4\ (8\ ft) = 2\ ft$

see page 12.8 for definition of terms

$\ell_{AB} = \ell_{CD} = \ell_{DE} = 8\ ft$ ✓

$\ell_{BC} = 1.5 \times \ell_{AB} = 12\ ft$ ✓

$h = 5.5\ ft$ ✓

Duct Size: 24" x 36"

Weight = 31 #/ft (see page 3.4)

$I_z = I_{bb} = 17.70\ in^4$ (see page 3.8)

Supports: ∠4x4x½

weight = 166 # (see page 4.4)

Stiffness = 10838 #/in (see page 4.4)

$W_A = W_B = W_C = W_D = W_E = 166\#$ ✓

$W_{OA} = W_{EO'} = (31\ \#/ft) \times (2\ ft) = 62\ \#$ ✓

$W_{AB} = W_{CD} = W_{DE} = 31 \times 8 = 248\#$ ✓

$W_{BC} = 31 \times 12 = 372\#$ ✓

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AA2150F

DUCT SPANS OA & AB

1.) $k_{AZ} = k_{BZ} = 10838\ \#/in$

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1A} = \frac{W_{OA}}{2g} + \frac{W_{AB}}{4g} + \frac{W_A}{2g}$$

$$= \frac{62}{2g} + \frac{248}{4g} + \frac{166}{2g} = 176/g \quad ✓$$

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{248 + 372}{4g} + \frac{166}{2g} = 238/g \quad ✓$$

$(k_{1AZ} = k_{AZ})$

$$\omega_{1AZ} = \left(\frac{k_{1AZ}}{M_{1A}}\right)^{1/2} = \left(\frac{10838\ \#/in}{[176\ \#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 154.3\ RAD/SEC$$

$(k_{1BZ} = k_{BZ})$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838}{[238]/[32.2\times12]}\right)^{1/2} = 132.6\ RAD/SEC \quad ✓$$

M_1 = MINIMUM OF $(M_{1A}, M_{1B}) = 176./g$ ✓

ω_{1Z} = MINIMUM OF $(\omega_{1AZ}, \omega_{1BZ}) = 132.6$ RAD/SEC. ✓

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2OAZ} = \frac{3EI_{OAZ}}{(l_{OA})^3} = \frac{3(29\times10^6\ \#/in^2)(17.70\ in^4)}{(2\times12\ in)^3} = 111\,393\ \#/in$$

$$k_{2ABZ} = \frac{48EI_{ABZ}}{(l_{AB})^3} = \frac{48(29\times10^6)(17.70)}{(8\times12)^3} = 27848\ \#/in$$

$$k_{2BCZ} = \frac{48EI_{BCZ}}{(l_{BC})^3} = \frac{48(29\times10^6)(17.70)}{(12\times12)^3} = 8251\ \#/in$$

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$$M_{2OA} = \frac{W_{OA}}{2g} = \frac{62}{2g} = 31/g$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{248}{2g} = 124/g$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{372}{2g} = 186/g$$

$$\omega_{2OAZ} = \left(\frac{k_{2OAZ}}{M_{2OA}}\right)^{1/2} = \left(\frac{111393\ \#/in}{[31\#]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 1178\ RAD/SEC$$

$$\omega_{2ABZ} = \left(\frac{k_{2ABZ}}{M_{2AB}}\right)^{1/2} = \left(\frac{27848}{[124]/[32.2 \times 12]}\right)^{1/2} = 295\ RAD/SEC$$

$$\omega_{2BCZ} = \left(\frac{k_{2BCZ}}{M_{2BC}}\right)^{1/2} = \left(\frac{8251}{[186]/[32.2 \times 12]}\right)^{1/2} = 130.9\ RAD/SEC$$

$$\omega_2 = \text{MINIMUM OF} \left(\omega_{2OAZ}, \omega_{2ABZ}, \omega_{2BCZ}\right) = 130.9\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF} \left[\left(M_{2OA} + \frac{M_{2AB}}{2}\right) \text{ and } \left(\frac{M_{2AB} + M_{2BC}}{2}\right)\right]$$

$$= 31/g + \frac{124/g}{2} = 93/g$$

$$\text{OR} = \left(\frac{124/g + 186/g}{2}\right) = \underline{155/g = M_2} \checkmark$$

$$\mu = \frac{M_2}{M_1} = \frac{155/g}{176/g} = 0.881 \checkmark$$

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AA2150F

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [132.6]^2 + (1+0.881)[130.9]^2 = 49813 \quad ✓$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{49813 - \left[(49813)^2 - 4(132.6)^2(130.9)^2\right]^{1/2}\right\}$$

$$= 7044 \quad ✓$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{7044}}{2\pi} = 13.36 \text{ Hz} \quad ✓$$

5.) DETERMINE a_z at $f_z = 13.36$ Hz
FROM SITE SPECIFIED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz	$a_z = 1.50$ g
$f_z = 9.1$ Hz	$a_z = 2.25$ g

Interpolate: $$\frac{a_z - 1.50g}{2.25g - 1.50g} = \frac{\log 13.36 - \log 14.5}{\log 9.1 - \log 14.5}$$

$$a_z = \left(\frac{\log 13.36 - \log 14.5}{\log 9.1 - \log 14.5}\right)(2.25 - 1.50) + 1.50$$

$$a_z = 1.631 \text{ g} \quad \text{at} \quad f_z = 13.36 \text{ Hz} \quad ✓$$

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AA2150F

SPANS EO' AND DE

6.) $k_{DZ} = k_{EZ} = 10838\ \#/\text{in}$

7.) COMPUTE M_1 and ω_{1Z}

$$M_{IE} = \frac{W_{EO'}}{2g} + \frac{W_{DE}}{4g} + \frac{W_E}{2g}$$

$$= \frac{62}{2g} + \frac{248}{4g} + \frac{166}{2g} = 176\ /g$$ ✓

$$M_{ID} = \frac{W_{CD} + W_{DE}}{4g} + \frac{W_D}{2g}$$

$$= \frac{248 + 248}{4g} + \frac{166}{2g} = 207/g$$ ✓

$$\omega_{IEZ} = \left(\frac{k_{IEZ}}{M_{IE}}\right)^{1/2} = \left(\frac{10838\ \#/\text{in}}{[176\#]/[32.2\times 12\ \text{in/sec}^2]}\right)^{1/2} = 154.3\ \text{RAD/SEC}$$ ✓

$$\omega_{IDZ} = \left(\frac{k_{IDZ}}{M_{ID}}\right)^{1/2} = \left(\frac{10838\ \#/\text{in}}{[207\#]/[32.2\times 12\ \text{in/sec}^2]}\right)^{1/2} = 142.2\ \text{RAD/SEC}$$ ✓

M_1 = MINIMUM OF (M_{IE} , M_{ID}) = 176 /g ✓

ω_{1Z} = MINIMUM OF (ω_{IEZ}, ω_{IDZ}) = 142.2 RAD/SEC ✓

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8.) COMPUTE M_2 and ω_{2Z}

$$k_{2EO'Z} = \frac{3EI_{EO'Z}}{(\ell_{EO'})^3} = \frac{3(29\times10^6\,\#/in^2)(17.70\,in^4)}{(2\times12\,in)^3} = 111393\,\#/in$$

$$k_{2DEZ} = \frac{48EI_{DEZ}}{(\ell_{DE})^3} = \frac{48(29\times10^6)(17.70)}{(8\times12)^3} = 27848\,\#/in$$

$$k_{2CDZ} = \frac{48EI_{CDZ}}{(\ell_{CD})^3} = \frac{48(29\times10^6)(17.70)}{(8\times12)^3} = 27848\,\#/in$$

$$M_{2EO'} = \frac{W_{EO'}}{2g} = \frac{62}{2g} = 31/g$$

$$M_{2DE} = \frac{W_{DE}}{2g} = \frac{248}{2g} = 124/g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{248}{2g} = 124/g$$

$$\omega_{2EO'Z} = \left(\frac{k_{2EO'Z}}{M_{2EO'}}\right)^{1/2} = \left(\frac{111393\,\#/in}{[31\#]/[32.2\times12\,in/sec^2]}\right)^{1/2} = 1178\ RAD/SEC$$

$$\omega_{2DEZ} = \left(\frac{k_{2DEZ}}{M_{2DE}}\right)^{1/2} = \left(\frac{27848\,\#/in}{[124\#]/[32.2\times12\,in/sec^2]}\right)^{1/2} = 294.6\ RAD/SEC$$

$$\omega_{2CDZ} = \left(\frac{k_{2CDZ}}{M_{2CD}}\right)^{1/2} = 294.6\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF}\left[\left(M_{2EO'} + \frac{M_{2DE}}{2}\right) \text{ and } \left(\frac{M_{2DE} + M_{2CD}}{2}\right)\right]$$

$$= \text{MAX OF}\left[\left(31/g + \frac{124/g}{2} = 93/g \text{ and } \left(\frac{124/g}{2} + \frac{124/g}{2} = 124/g\right)\right]$$

$M_2 = 124/g$ ✓ $\omega_2 = 294.6$ RAD/SEC ✓

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$$\mu = \frac{M_2}{M_1} = \frac{124/g}{176/g} = 0.705 \checkmark$$

9.) COMPUTE f_z

$$D_z = \left[\omega_{1z}\right]^2 + (1+\mu)\left[\omega_{2z}\right]^2$$

$$= \left[142.2\right]^2 + (1+.705)\left[294.6\right]^2 = 168196$$

$$\left[\omega_z\right]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(168196) - \left[(168196)^2 - 4(142.2)^2(294.6)^2\right]^{1/2}\right\}$$

$$= 11177$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{11177}}{2\pi} = 16.83 \text{ Hz} \checkmark$$

10.) DETERMINE a_z at $f_z = 16.83$ Hz

FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 100$ Hz $\quad a_z = 0.875$ g

$f_z = 14.5$ Hz $\quad a_z = 1.50$ g

Interpolate:

$$\frac{a_z - 0.875g}{1.50g - 0.875g} = \frac{\log 16.83 - \log 100}{\log 14.5 - \log 100}$$

$$a_z = \left(\frac{\log 16.83 - \log 100}{\log 14.5 - \log 100}\right)(1.50g - 0.875g) + 0.875g$$

$a_z = 1.451g$ at 16.83 Hz ✓

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SYSTEM AA2150F CONTINUED.

SUMMARY: at OAB END $a_z = 1.631\ g$
at O'ED END $a_z = 1.451\ g$

11.) DETERMINE MOMENT AND SHEAR

A.) OAB END, use $a_z = 1.631\ g$

$M_{OA} = 0.5(W_{OA})(l_{OA})(a_z/g)$

$= 0.5(62\#)(2\ ft)(1.631\ g/g) = 101\ ft\text{-}lbs.$

$V_{OA} = (W_{OA})(a_z/g) = (62\#)(1.631\ g/g) = 101\ lbs.$

$V_{AB} = 0.5(W_{AB})(a_z/g) + (M_{OA}/l_{AB})$

$= 0.5(248\#)(1.631\ g/g) + (101\ ft\cdot lb/8\ ft) = 215\ lb$

$\frac{1}{8}(W_{AB})(l_{AB})(a_z/g) = \frac{1}{8}(248\#)(8\ ft)(1.631\ g/g) = 404\ ft\text{-}lbs$

$\frac{1}{10}(W_{BC})(l_{BC})(a_z/g) = \frac{1}{10}(372\#)(12\ ft)(1.631\ g/g) = 728\ ft\text{-}lbs$

$M_{AB} = \text{MAXIMUM OF} \left\{ M_{OA} ; \frac{1}{8}(W_{AB})(l_{AB})(a_z/g) ; \frac{1}{10}(W_{BC})(l_{BC})(a_z/g) \right\}$

$= \text{MAXIMUM OF} \{ 101 ; 404 ; 728 \}$

$= 728\ ft\text{-}lbs.$

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SYSTEM AA2150F CONTINUED

DETERMINE MOMENT AND SHEAR (CONTINUED)

B.) O'ED END, use $a_z = 1.451\ g$

$$M_{EO'} = 0.5 (W_{EO'})(\ell_{EO'})(a_z/g)$$
$$= 0.5 (62\ \#)(2\ ft)(1.451\ g/g) = 90\ ft\text{-}lbs. \checkmark$$

$$V_{EO'} = (W_{EO'})(a_z/g) = (62\ \#)(1.451\ g/g) = 90\ lbs. \checkmark$$

$$V_{DE} = 0.5 (W_{DE})(a_z/g) + (M_{EO'}/\ell_{DE})$$
$$= 0.5 (248\ \#)(1.451\ g/g) + (90\ ft\text{-}lb/8\ ft) = 191\ lbs \checkmark$$

$$\tfrac{1}{8}(W_{DE})(\ell_{DE})(a_z/g) = \tfrac{1}{8}(248\ \#)(8\ ft)(1.451\ g/g) = 360\ ft\text{-}lbs \checkmark$$

$$\tfrac{1}{10}(W_{CD})(\ell_{CD})(a_z/g) = \tfrac{1}{10}(248\ \#)(8\ ft)(1.451\ g/g) = 288\ ft\text{-}lbs \checkmark$$

$$M_{DE} = \text{MAXIMUM OF} \left\{ M_{EO'} ; \tfrac{1}{8}(W_{DE})(\ell_{DE})(a_z/g) ; \tfrac{1}{10}(W_{CD})(\ell_{CD})(a_z/g) \right\}$$
$$= \text{MAXIMUM OF} \left\{ 90 ; 360 ; 288 \right\}$$
$$= 360\ ft\text{-}lbs \checkmark$$

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SYSTEM AA2150F CONTINUED

12.) DETERMINE SUPPORT LOADS:

at A & B, $a_z = 1.631\ g$
at D & E, $a_z = 1.451\ g$

SUPPORT A:

$$P_A = \left(W_{OA} + \frac{W_{AB}}{2} + \frac{W_A}{2} \right) \left(a_z / g \right)$$

$$= \left(62\ \# + \frac{248\ \#}{2} + \frac{166\ \#}{2} \right) \left(1.631\ g/g \right) = 439\ \text{lbs}$$

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2} \right) \left(a_z / g \right)$$

$$= \left(\frac{248\ \# + 372\ \#}{2} + \frac{166\ \#}{2} \right) \left(1.631\ g/g \right) = 641\ \text{lbs}$$

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2} \right) \left(a_z / g \right)$$

$$= \left(\frac{248\ \# + 248\ \#}{2} + \frac{166\ \#}{2} \right) \left(1.451\ g/g \right) = 480\ \text{lbs.} \checkmark$$

SUPPORT E:

$$P_E = \left(W_{ED'} + \frac{W_{DE}}{2} + \frac{W_E}{2} \right) \left(a_z / g \right)$$

$$= \left(62\ \# + \frac{248\ \#}{2} + \frac{166\ \#}{2} \right) \left(1.451\ g/g \right) = 390\ \text{lbs.} \checkmark$$

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SYSTEM AA2150F CONTINUED.

SUMMARY: at OAB END $a_z = 1.0\ g$
at O'ED END $a_z = 1.0\ g$

13.) DETERMINE MOMENT AND SHEAR

A.) OAB END, use $a_z = 1.0\ g$

$$M_{OA} = 0.5(W_{OA})(\ell_{OA})(a_z/g)$$
$$= 0.5(62\#)(2\ ft)(1.0\ g/g) = 62\ ft\text{-}lbs.$$

$$V_{OA} = (W_{OA})(a_z/g) = (62\#)(1.0\ g/g) = 62\ lbs.$$

$$V_{AB} = 0.5(W_{AB})(a_z/g) + (M_{OA}/\ell_{AB})$$

$$= 0.5(248\#)(1.0\ g/g) + (62\ ft\text{-}lb/8\ ft) = 132\ lb$$

$$\tfrac{1}{8}(W_{AB})(\ell_{AB})(a_z/g) = \tfrac{1}{8}(248\#)(8\ ft)(1.0\ g/g) = 248\ ft\text{-}lbs$$

$$\tfrac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) = \tfrac{1}{10}(372\#)(12\ ft)(1.0\ g/g) = 446\ ft\text{-}lbs$$

$$M_{AB} = \text{MAXIMUM OF} \left\{ M_{OA}\ ;\ \tfrac{1}{8}(W_{AB})(\ell_{AB})(a_z/g)\ ;\ \tfrac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) \right\}$$
$$= \text{MAXIMUM OF} \{ 62\ ;\ 248\ ;\ 446 \}$$
$$= 446\ ft\text{-}lbs.$$

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SYSTEM AA2150F CONTINUED

DETERMINE MOMENT AND SHEAR (CONTINUED)

B.) O'ED END, use $a_z = 1.0\ g$

$M_{EO'} = 0.5\,(W_{EO'})(\ell_{EO'})(a_z/g)$

$= 0.5\,(62\ \#)(2\ ft)(1.0\ g/g) = 62\ ft\text{-}lbs.$

$V_{EO'} = (W_{EO'})(a_z/g) = (62\ \#)(1.0\ g/g) = 62\ lbs.$

$V_{DE} = 0.5\,(W_{DE})(a_z/g) + (M_{EO'}/\ell_{DE})$

$= 0.5\,(248\ \#)(1.0\ g/g) + (62\ ft\text{-}lb/8\ ft) = 132\ lbs$

$1/8\,(W_{DE})(\ell_{DE})(a_z/g) = 1/8\,(248\ \#)(8\ ft)(1.0\ g/g) = 248\ ft\text{-}lbs$

$1/10\,(W_{CD})(\ell_{CD})(a_z/g) = 1/10\,(248\ \#)(8\ ft)(1.0\ g/g) = 198\ ft\text{-}lbs$

$M_{DE} = \text{MAXIMUM OF} \left\{ M_{EO'}\,;\ 1/8(W_{DE})(\ell_{DE})(a_z/g)\,;\ 1/10(W_{CD})(\ell_{CD})(a_z/g) \right\}$

$= \text{MAXIMUM OF} \left\{ 62\,;\ 248\,;\ 198 \right\}$

$= 248\ ft\text{-}lbs$

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SYSTEM AA2150F CONTINUED

14.) DETERMINE SUPPORT LOADS:

at A & B, $a_z = 1.0\ g$
at D & E, $a_z = 1.0\ g$

SUPPORT A:

$$P_A = \left(W_{OA} + \frac{W_{AB}}{2} + \frac{W_A}{2}\right)\left(a_z/g\right)$$

$$= \left(62\# + \frac{248\#}{2} + \frac{166\#}{2}\right)\left(1.0\ g/g\right) = 269\ \text{lbs}$$

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248\# + 372\#}{2} + \frac{166\#}{2}\right)\left(1.0\ g/g\right) = 393\ \text{lbs}$$

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248\# + 248\#}{2} + \frac{166\#}{2}\right)\left(1.0\ g/g\right) = 331\ \text{lbs.}$$ ✓

SUPPORT E:

$$P_E = \left(W_{EO'} + \frac{W_{DE}}{2} + \frac{W_E}{2}\right)\left(a_z/g\right)$$

✓

$$= \left(62\# + \frac{248\#}{2} + \frac{166\#}{2}\right)\left(1.0\ g/g\right) = 269\ \text{lbs.}$$

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AA2150H

SYSTEM ID = AA2150H

See page 12.9 for definition of terms.

$l_{AB} = l_{CD} = l_{DE} = 8\ ft$
$l_{BC} = 1.5\ l_{AB} = 12\ ft$
$h = 5.5\ ft$

Duct Size 24X36
Weight = 31 #/ft (see page 3.4)
$I_z = I_{bb} = 17.70\ in^4$ (see page 3.8)

Supports: ∠4X4X½
Weight = 166 # (see page 4.4)
Stiffness = 10838 #/in (see page 4.4)

$W_A = W_B = W_C = W_D = W_E = 166\#$ ✓

$W_{AB} = (31\#/ft)(8\ ft) = 248\#$ ✓

$W_{BC} = 31 \times 12 = 372\#$ ✓

$W_{CD} = 31 \times 8 = 248\#$ ✓

$W_{DE} = 31 \times 8 = 248\#$ ✓

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AA2150H

DUCT SPAN AB

1.) $k_{AZ} = k_{BZ} = 10838\ \#/in$

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1A} = \frac{W_{AB}}{4g} + \frac{W_B}{2g} = \frac{248}{4g} + \frac{166}{2g} = 145/g \checkmark$$

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_C}{2g} = \frac{248+372}{4g} + \frac{166}{2g} = 238/g \checkmark$$

$$\omega_{1AZ} = \left(\frac{k_{1AZ}}{M_{1A}}\right)^{1/2} = \left(\frac{10838\ \#/in}{[145\#]/[32.2\times 12\ in/sec^2]}\right)^{1/2} = 169.9\ RAD/SEC$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{10838\ \#/in}{[238\#]/[32.2\times 12\ in/sec^2]}\right)^{1/2} = 132.6\ RAD/SEC$$

$$M_1 = \text{MINIMUM OF } (M_{1A}, M_{1B}) = 145/g \checkmark$$

$$\omega_{1Z} = 132.6\ RAD/SEC \checkmark$$

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AA2150H

AB SIDE CONTINUED

3.) COMPUTE M_2 and ω_{2z}

$$k_{2ABz} = \frac{48EI_{ABz}}{(l_{AB})^3} = \frac{48(29\times10^6\ \#/in^2)(17.70\ in^4)}{(8\times12\ in)^3} = 27848\ \#/in$$

$$k_{2BCz} = \frac{48EI_{BCz}}{(l_{BC})^3} = \frac{48(29\times10^6)(17.70)}{(12\times12)^3} = 8251\ \#/in$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{248}{2g} = 124/g$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{372}{2g} = 186/g$$

$$\omega_{2ABz} = \left(\frac{k_{2ABz}}{M_{2AB}}\right)^{1/2} = \left(\frac{27848\ \#/in}{[124\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 295\ RAD/SEC$$

$$\omega_{2BCz} = \left(\frac{k_{2BCz}}{M_{2BC}}\right)^{1/2} = \left(\frac{8251}{[186]/[32.2\times12]}\right)^{1/2} = 130.9\ RAD/SEC$$

$$\omega_2 = \text{MINIMUM OF } (\omega_{2ABz}, \omega_{2BCz}) = 130.9\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF } \left(\left[M_{2AB}/2\right] \text{ and } \left[\frac{M_{2AB}+M_{2BC}}{2}\right]\right)$$

$$= \frac{124/g + 186/g}{2} = 155/g \checkmark$$

$$\mu = \frac{M_2}{M_1} = \frac{155/g}{145/g} = 1.069 \checkmark$$

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AA2150H

AB SIDE CONTINUED

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [132.6]^2 + (1+1.069)[130.9]^2 = 53035$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(53035) - \left[(53035)^2 - 4(132.6)^2(130.9)^2\right]^{1/2}\right\}$$

$$= 6470$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{6470}}{2\pi} = 12.80\ Hz$$ ✓

5.) DETERMINE a_z at $f_z = 12.80\ Hz$ FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz $a_z = 1.50\ g$

$f_z = 9.1$ Hz $a_z = 2.25\ g$

Interpolate:

$$\frac{a_z - 1.50\ g}{2.25\ g - 1.50\ g} = \frac{\log 12.80 - \log 14.5}{\log 9.1 - \log 14.5}$$

$$a_z = \left(\frac{\log 12.80 - \log 14.5}{\log 9.1 - \log 14.5}\right)(2.25\ g - 1.50\ g) + 1.50\ g$$

$a_z = 1.700\ g$ at $F_z = 12.80\ Hz$ ✓

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AA2150H

DUCT SPAN DE

6.) $k_{EZ} = k_{DZ} = 10838\ ^{\#}/_{in}$

7.) COMPUTE M_1 and ω_{1Z}

$$M_{1E} = \frac{W_{DE}}{4g} + \frac{W_E}{2g} = \frac{248}{4g} + \frac{166}{2g} = 145/g$$

$$M_{1D} = \frac{W_{DE} + W_{CD}}{4g} + \frac{W_D}{2g} = \frac{248 + 248}{4g} + \frac{166}{2g} = 207/g$$

$$\omega_{1EZ} = \left(\frac{k_{1EZ}}{M_{1E}}\right)^{1/2} = \left(\frac{10838\ ^{\#}/_{in}}{[145^{\#}]/[32.2 \times 12\ ^{in}/_{sec^2}]}\right)^{1/2} = 169.9\ ^{RAD}/_{SEC}\ \checkmark$$

$$\omega_{1DZ} = \left(\frac{k_{1DZ}}{M_{1D}}\right)^{1/2} = \left(\frac{10838\ ^{\#}/_{in}}{[207^{\#}]/[32.2 \times 12\ ^{in}/_{sec^2}]}\right)^{1/2} = 142.2\ ^{RAD}/_{SEC}$$

$$M_1 = \text{MINIMUM OF } (M_{1E}, M_{1D}) = 145/g$$

$$\omega_{1Z} = \text{MINIMUM OF } (\omega_{1EZ}, \omega_{1DZ}) = 142.2\ ^{RAD}/_{SEC}$$

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AA2150H

DE SIDE CONTINUED

8.) COMPUTE M_2 and ω_{2Z}

$$k_{2DEZ} = \frac{48\,E\,I_{DEZ}}{(l_{DE})^3} = \frac{48(29\times10^6\ \#/in^2)(17.70\ in^4)}{(8\times12\ in)^3} = 27848\ \#/in$$

$$k_{2CDZ} = \frac{48\,E\,I_{CDZ}}{(l_{CD})^3} = 27848\ \#/in$$

$$M_{2DE} = W_{DE}/2g = 248/2g = 124/g$$

$$M_{2CD} = W_{CD}/2g = 248/2g = 124/g$$

$$\omega_{2DEZ} = \left(\frac{k_{2DEZ}}{M_{2DE}}\right)^{1/2} = \left(\frac{27848\ \#/in}{[124\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 294.6\ RAD/SEC$$

$$\omega_{2CDZ} = \left(\frac{k_{2CDZ}}{M_{2CD}}\right)^{1/2} = 294.6\ RAD/SEC$$

$$\omega_2 = \text{MINIMUM OF } (\omega_{2DEZ} \text{ and } \omega_{2CDZ}) = 294.6\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF } \left(\left[M_{2DE}/2\right] \text{ and } \left[\frac{M_{2DE}+M_{2CD}}{2}\right]\right)$$

$$= \frac{124/g + 124/g}{2} = 124/g$$

$$\mu = \frac{M_2}{M_1} = \frac{124/g}{145/g} = 0.855$$

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AA2150H

DE SIDE CONTINUED

9~~4~~.) COMPUTE f_z

$$D_z = \left[\omega_{1z}\right]^2 + (1+\mu)\left[\omega_{2z}\right]^2$$

$$= \left[142.2\right]^2 + (1+0.855)\left[294.6\right]^2 = 181215$$

$$\left[\omega_z\right]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(181215) - \left[(181215)^2 - 4(142.2)^2(294.6)^2\right]^{1/2}\right\}$$

$$= 10266$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{10266}}{2\pi} = 16.13\ Hz$$

10 ~~5~~.) DETERMINE a_z at $f_z = 16.13\ Hz$
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 100\ Hz$ $\quad a_z = 0.875g$
$f_z = 14.5\ Hz$ $\quad a_z = 1.50g$

Interpolate:

$$\frac{a_z - 0.875\,g}{1.50\,g - 0.875\,g} = \frac{\log 16.13 - \log 100}{\log 14.5 - \log 100}$$

$$a_z = \left(\frac{\log 16.13 - \log 100}{\log 14.5 - \log 100}\right)(1.50\,g - 0.875\,g) + 0.875\,g$$

$a_z = 1.465\,g$ at $F_z = 16.13\ Hz$ ✓

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AA2150H

Summary : at AB END $a_z = 1.700\,g$
at DE END $a_z = 1.465\,g$

II.) DETERMINE MOMENT AND SHEAR

A.) AB END $a_z = 1.700\,g$

$$V_{AB} = 0.5(W_{AB})(a_z/g) = 0.5(248^{\#})(1.700) = 211^{\#}$$

$$1/8(W_{AB})(\ell_{AB})(a_z/g) = 1/8(248)(8)(1.700) = 422 \text{ ft-lbs}$$

$$1/10(W_{BC})(\ell_{BC})(a_z/g) = 1/10(372)(12)(1.700) = 759 \text{ ft-lbs} \checkmark$$

$$M_{AB} = \text{MAXIMUM OF} \left\{ 1/8[W_{AB}][\ell_{AB}](a_z/g) \,;\, 1/10[W_{BC}][\ell_{BC}](a_z/g) \right\}$$

$$= 759 \text{ ft-lbs.} \checkmark$$

B.) DE END $a_z = 1.465\,g$

$$V_{DE} = 0.5(W_{DE})(a_z/g) = 0.5(248)(1.465) = 182^{\#}$$

$$1/8(W_{DE})(\ell_{DE})(a_z/g) = 1/8(248)(8)(1.465) = 363 \text{ ft-lbs}$$

$$1/10(W_{CD})(\ell_{CD})(a_z/g) = 1/10(248)(8)(1.465) = 291 \text{ ft-lbs}$$

$$M_{DE} = \text{MAXIMUM OF} \left\{ 1/8(W_{DE})(\ell_{DE})(a_z/g) \,;\, 1/10(W_{CD})(\ell_{CD})(a_z/g) \right\}$$

$$= 363 \text{ ft-lbs.} \checkmark$$

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AA2150H

12.) SUPPORT LOADS

at A & B $a_z = 1.700\,g$

at D & E $a_z = 1.465\,g$

Support A:

$$P_A = \left(\frac{W_{AB}}{2} + \frac{W_A}{2}\right)\left(a_z/g\right) = \left(\frac{248}{2} + \frac{166}{2}\right)(1.700) = 352^{\#}$$ ✓

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248 + 372}{2} + \frac{166}{2}\right)(1.700) = 668^{\#}$$ ✓

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248 + 248}{2} + \frac{166}{2}\right)(1.465) = 485^{\#}$$ ✓

SUPPORT E:

$$P_E = \left(\frac{W_{DE}}{2} + \frac{W_E}{2}\right)\left(a_z/g\right) = \left(\frac{248}{2} + \frac{166}{2}\right)(1.465) = 303^{\#}$$ ✓

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AA2150H

13.) DETERMINE MOMENT AND SHEAR

using $a_z = 1.0\ g$ from flat 1-g spectra

$V_{AB} = 0.5\,(W_{AB})(a_z/g) = 0.5(248^{\#})(1.0) = 124$ lbs

$\frac{1}{8}(W_{AB})(\ell_{AB})(a_z/g) = \frac{1}{8}(248^{\#})(8\text{ ft})(1.0) = 248$ ft-lbs.

$\frac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) = \frac{1}{10}(372^{\#})(12\text{ ft})(1.0) = 446$ ft-lbs.

$M_{AB} = \text{MAXIMUM OF} \left\{ \frac{1}{8}(W_{AB})(\ell_{AB})(a_z/g)\ ;\ \frac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) \right\}$

$= 446$ ft-lbs. ✓

$V_{DE} = 0.5\,(W_{DE})(a_z/g) = 0.5\,(248^{\#})(1.0) = 124^{\#}$

$\frac{1}{8}(W_{DE})(\ell_{DE})(a_z/g) = \frac{1}{8}(248^{\#})(8\text{ ft})(1.0) = 248$ ft-lbs.

$\frac{1}{10}(W_{CD})(\ell_{CD})(a_z/g) = \frac{1}{10}(248^{\#})(8\text{ ft})(1.0) = 198$ ft-lbs.

$M_{DE} = \text{MAXIMUM OF} \left\{ \frac{1}{8}(W_{DE})(\ell_{DE})(a_z/g)\ ;\ \frac{1}{10}(W_{CD})(\ell_{CD})(a_z/g) \right\}$

$= 248$ ft-lbs. ✓

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AA2150H

14.) DETERMINE SUPPORT LOADS

using $a_z = 1.0g$ from flat 1-g spectra

SUPPORT A:

$$P_A = \left(\frac{W_{AB}}{2} + \frac{W_A}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248}{2} + \frac{166}{2}\right)(1.0) = 207 \text{ lbs.}$$

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248 + 372}{2} + \frac{166}{2}\right)(1.0) = 393 \text{ lbs.}$$

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248 + 248}{2} + \frac{166}{2}\right)(1.0) = 331 \text{ lbs.}$$

SUPPORT E:

$$P_E = \left(\frac{W_{DE}}{2} + \frac{W_E}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{248}{2} + \frac{166}{2}\right)(1.0) = 207 \text{ lbs.}$$

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BC3150F

SYSTEM ID = BC3150F

$\ell_{OA} = 6$ ft $\quad \ell_{EO'} = 4$ ft

$\ell_{CD} = \ell_{DE} = 12$ ft

$\ell_{AB} = \ell_{BC} = 1.5 \times \ell_{CD} = 18$ ft

$h = 7$ ft

see page 12.8 for definition of terms.

Duct Size: 60" x 72"

Weight = 101.2 #/ft (see page 3.4)

$I_z = I_{bb} = 301.8$ in^4 (see page 3.9)

SUPPORTS:

WEIGHT = 243# (see page 4.11)

STIFFNESS = 3 x 4863 #/in = 14589 #/in

$W_A = W_B = W_C = W_D = W_E = 243\#$

$W_{OA} = (101.2\ \#/ft) \times (6\ ft) = 607.2\ \#$ ✓

$W_{AB} = W_{BC} = (101.2) \times (18) = 1822\#$ ✓

$W_{CD} = W_{DE} = (101.2) \times (12) = 1215\#$ ✓

$W_{EO'} = (101.2)(4) = 404.8\#$ ✓

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BC3150F

DUCT SPANS OA & AB

1.) $k_{AZ} = k_{BZ} = 14589\ ^{\#}/in$

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1A} = \frac{W_{OA}}{2g} + \frac{W_{AB}}{4g} + \frac{W_A}{2g}$$

$$= \frac{607.2}{2g} + \frac{1822}{4g} + \frac{243}{2g} = 880.6/g \quad ✓$$

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1822 + 1822}{4g} + \frac{243}{2g} = 1032/g \quad ✓$$

$$\omega_{1AZ} = \left(\frac{k_{1AZ}}{M_{1A}}\right)^{1/2} = \left(\frac{14589\ ^{\#}/in}{[880.6^{\#}]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 80.0\ RAD/SEC \quad ✓$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{14589\ ^{\#}/in}{[1032^{\#}]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 73.9\ RAD/SEC \quad ✓$$

$$M_1 = \text{MINIMUM OF}\left(M_{1A}, M_{1B}\right) = 880.6/g \quad ✓$$

$$\omega_{1Z} = \text{MINIMUM OF}\left(\omega_{1AZ}, \omega_{1BZ}\right) = 73.9\ RAD/SEC \quad ✓$$

BC3150F

3.) COMPUTE M_2 and ω_{2Z}

$$k_{2OAZ} = \frac{3EI_{OAS}}{(l_{OA})^3} = \frac{3(29\times10^6\ \#/in^2)(301.8\ in^4)}{(6\times12\ in)^3} = 70346\ \#/in$$

$$k_{2ABZ} = \frac{48EI_{ABZ}}{(l_{AB})^3} = \frac{48(29\times10^6\ \#/in^2)(301.8\ in^4)}{(18\times12)^3} = 41687\ \#/in$$

$$k_{2BCZ} = \frac{48EI_{BCZ}}{(l_{BC})^3} = \frac{48(29\times10^6)(301.8)}{(18\times12)^3} = 41687\ \#/in$$

$$M_{2OA} = \frac{W_{OA}}{2g} = \frac{607.2}{2g} = 303.6/g$$

since $W_{AB} = W_{BC}$

$$M_{2AB} = M_{2BC} = \frac{W_{AB}}{2g} = \frac{1822}{2g} = 911/g$$

$$\omega_{2OAZ} = \left(\frac{k_{2OAZ}}{M_{2OA}}\right)^{1/2} = \left(\frac{70346\ \#/in}{[303.6\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 299.2\ RAD/SEC$$

since $k_{2ABZ} = k_{2BCZ}$ and $M_{2AB} = M_{2BC}$:

$$\omega_{2AB} = \omega_{2BC} = \left(\frac{k_{2ABZ}}{M_{2AB}}\right)^{1/2} = \left(\frac{41687\ \#/in}{[911\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 133.0\ RAD/SEC$$

$$\omega_2 = \text{MINIMUM OF } (\omega_{2OAZ}, \omega_{2AB}, \omega_{2BC}) = 133.0\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF}\left[\left(M_{2OA} + \frac{M_{2AB}}{2}\right) \text{ and } \left(\frac{M_{2AB}+M_{2BC}}{2}\right)\right]$$

$$= 303.6/g + [911/g]/2 = 759/g \text{ OR } = \frac{911/g + 911/g}{2} = \underline{\underline{911/g}} = M_2$$

$$\mu = \frac{M_2}{M_1} = \frac{911/g}{\quad} = 1.035$$

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BC3150F

4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [73.9]^2 + (1+1.035)[133.0]^2 = 41458$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(41458) - \left[(41458)^2 - 4(73.9)^2(133.0)^2\right]^{1/2}\right\}$$

$$= 2478$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{2478}}{2\pi} = 7.92 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 7.92 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 9.1$ Hz $\quad a_z = 2.25$ g
$f_z = 6.5$ Hz $\quad a_z = 4.00$ g

Interpolate:

$$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 7.92 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

$a_z = 2.97$ g at 7.92 Hz ✓

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ENGINEERS

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BC3150F

SPANS EO' and DE

6.) $k_{DZ} = k_{EZ} = 14589\ \#/in$

7.) COMPUTE M_1 and ω_{1Z}

$$M_{1E} = \frac{W_{EO'}}{2g} + \frac{W_{DE}}{4g} + \frac{W_E}{2g}$$

$$= \frac{404.8}{2g} + \frac{1215}{4g} + \frac{243}{2g} = 628\ /g$$

$$M_{1D} = \frac{W_{CD} + W_{DE}}{4g} + \frac{W_D}{2g}$$

$$= \frac{1215 + 1215}{4g} + \frac{243}{2g} = 729/g$$

$$\omega_{1EZ} = \left(\frac{k_{1EZ}}{M_{1E}}\right)^{1/2} = \left(\frac{14589\ \#/in}{[628\#]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 94.8\ RAD/SEC$$

$$\omega_{1DZ} = \left(\frac{k_{1DZ}}{M_{1D}}\right)^{1/2} = \left(\frac{14589\ \#/in}{[729\#]/[32.2 \times 12\ in/sec^2]}\right)^{1/2} = 87.9\ RAD/SEC$$

M_1 = MINIMUM OF $(M_{1E}, M_{1D}) = 628/g$

ω_{1Z} = MINIMUM OF $(\omega_{1EZ}, \omega_{1DZ}) = 87.9$ RAD/SEC

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BC315OF

SPAN DE

8.) COMPUTE M_2 and ω_{2Z}

$$k_{2EO'Z} = \frac{3EI_{EO'Z}}{(\ell_{EO'})^3} = \frac{3(29\times10^6\ \#/in^2)(301.8\ in^4)}{(4\times12\ in)^3} = 237419\ \#/in$$

$$k_{2DEZ} = \frac{48EI_{DEZ}}{(\ell_{DE})^3} = \frac{48(29\times10^6)(301.8)}{(12\times12)^3} = 140693\ \#/in$$

$$k_{2CDZ} = \frac{48EI_{CDZ}}{(\ell_{CD})^3} = \frac{48(29\times10^6)(301.8)}{(12\times12)^3} = 140693\ \#/in$$

$$M_{2EO'} = \frac{W_{EO'}}{2g} = 404.8/2g = 202.4/g$$

$$M_{2DE} = \frac{W_{DE}}{2g} = 1215/2g = 607.5/g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = 1215/2g = 607.5/g$$

$$\omega_{2EO'Z} = \left(\frac{k_{2EO'Z}}{M_{2EO'}}\right)^{1/2} = \left(\frac{237419\ \#/in}{[202.4\#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 673\ RAD/SEC$$

$$\omega_{2DEZ} = \left(\frac{k_{2DEZ}}{M_{2DE}}\right)^{1/2} = \left(\frac{140693}{[607.5]/[32.2\times12]}\right)^{1/2} = 299\ RAD/SEC$$

$$\omega_{2CDZ} = (k_{2CDZ}/M_{2CD})^{1/2} = 299\ RAD/SEC$$

$$\omega_2 = \text{MINIMUM OF } (\omega_{2EO'Z}, \omega_{2DEZ}, \omega_{2CDZ}) = 299\ RAD/SEC$$

$$M_2 = \text{MAXIMUM OF } \left[\left(M_{2EO'} + \frac{M_{2DE}}{2}\right) \text{ and } \left(\frac{M_{2DE}+M_{2CD}}{2}\right)\right]$$

$$= 607.5/g$$

$$\mu = \frac{M_2}{M_1} = \frac{607.5/g}{628/g} = 0.967$$

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BC3150F

9.) COMPUTE f_z SPAN DE

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [87.9]^2 + (1+0.967)[299]^2 = 183578$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(183578) - \left[(183578)^2 - 4(87.9)^2(299)^2\right]^{1/2}\right\}$$

$$= 3843$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{3843}}{2\pi} = 9.87\ Hz$$

10.) Determine a_z at $f_z = 9.87$ Hz FROM SITE SPECIFIED SPECTRA CURVE (see page 3.11)

$f_z = 14.5$ Hz $\qquad a_z = 1.50g$

$f_z = 9.1$ Hz $\qquad a_z = 2.25g$

Interpolate: $\dfrac{a_z - 2.25g}{1.50g - 2.25g} = \dfrac{\log 9.87 - \log 9.1}{\log 14.5 - \log 9.1}$

$$a_z = \left(\frac{\log 9.87 - \log 9.1}{\log 14.5 - \log 9.1}\right)(1.50g - 2.25g) + 2.25g$$

$a_z = 2.120\ g$ at 9.87 Hz ✓

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SYSTEM BC3150F CONTINUED.

SUMMARY: at OAB END $a_z = 2.97\ g$
at O'ED END $a_z = 2.12\ g$

II.) DETERMINE MOMENT AND SHEAR

A.) OAB END, use $a_z = 2.97\ g$

$$M_{OA} = 0.5(W_{OA})(\ell_{OA})(a_z/g)$$

$$= 0.5(607.2\#)(6\ \text{ft})(2.97\ g/g) = 5410\ \text{ft-lbs.}$$ ✓

$$V_{OA} = (W_{OA})(a_z/g) = (607.2\#)(2.97\ g/g) = 1803\ \text{lbs.}$$ ✓

$$V_{AB} = 0.5(W_{AB})(a_z/g) + (M_{OA}/\ell_{AB})$$

$$= 0.5(1822\#)(2.97\ g/g) + (5410\ \text{ft-lb}/18\ \text{ft}) = 3006\ \text{lb}$$ ✓

$$\tfrac{1}{8}(W_{AB})(\ell_{AB})(a_z/g) = \tfrac{1}{8}(1822\#)(18\ \text{ft})(2.97\ g/g) = 12176\ \text{ft-lbs}$$ ✓

$$\tfrac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) = \tfrac{1}{10}(1822\#)(18\ \text{ft})(2.97\ g/g) = 9740\ \text{ft-lbs}$$ ✓

$$M_{AB} = \text{MAXIMUM OF} \left\{ M_{OA}\ ;\ \tfrac{1}{8}(W_{AB})(\ell_{AB})(a_z/g)\ ;\ \tfrac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) \right\}$$

$$= \text{MAXIMUM OF} \left\{ 5410\ ;\ 12176\ ;\ 9740 \right\}$$

$$= 12176\ \text{ft-lbs.}$$ ✓

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SYSTEM BC3150F CONTINUED

DETERMINE MOMENT AND SHEAR (CONTINUED)

B.) O'ED END, use $a_z = 2.12\ g$

$M_{EO'} = 0.5(W_{EO'})(\ell_{EO'})(a_z/g)$
$= 0.5(404.8^{\#})(4\ ft)(2.12\ g/g) = 1717\ ft\text{-}lbs.$

$V_{EO'} = (W_{EO'})(a_z/g) = (404.8^{\#})(2.12\ g/g) = 858\ lbs.$

$V_{DE} = 0.5(W_{DE})(a_z/g) + (M_{EO'}/\ell_{DE})$
$= 0.5(1215^{\#})(2.12\ g/g) + (1717\ ft\text{-}lb/12\ ft) = 1431\ lbs$

$1/8(W_{DE})(\ell_{DE})(a_z/g) = 1/8(1215^{\#})(12\ ft)(2.12\ g/g) = 3864\ ft\text{-}lbs$

$1/10(W_{CD})(\ell_{CD})(a_z/g) = 1/10(1215^{\#})(12\ ft)(2.12\ g/g) = 3091\ ft\text{-}lbs$

$M_{DE} = \text{MAXIMUM OF}\left\{M_{EO'};\ 1/8(W_{DE})(\ell_{DE})(a_z/g);\ 1/10(W_{CD})(\ell_{CD})(a_z/g)\right\}$
$= \text{MAXIMUM OF}\left\{1717;\ 3864;\ 3091\right\}$
$= 3864\ ft\text{-}lbs$ ✓

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SYSTEM BC3150F CONTINUED

12.) DETERMINE SUPPORT LOADS:

$$\text{at A \& B}, \ a_z = 2.97\,g$$

$$\text{at D \& E}, \ a_z = 2.12\,g$$

SUPPORT A:

$$P_A = \left(W_{OA} + \frac{W_{AB}}{2} + \frac{W_A}{2}\right)\left(a_z/g\right)$$

$$= \left(607.2^{\#} + \frac{1822^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.97\, g/g\right) = 4870 \text{ lbs.}$$ ✓

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1822^{\#} + 1822^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.97\, g/g\right) = 5772 \text{ lbs}$$ ✓

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{1215^{\#} + 1215^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.12\, g/g\right) = 2833 \text{ lbs.}$$ ✓

SUPPORT E:

$$P_E = \left(W_{ED'} + \frac{W_{DE}}{2} + \frac{W_E}{2}\right)\left(a_z/g\right)$$

$$= \left(404.8^{\#} + \frac{1215^{\#}}{2} + \frac{243^{\#}}{2}\right)\left(2.12\, g/g\right) = 2404 \text{ lbs.}$$ ✓

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SYSTEM BC3150F CONTINUED.

SUMMARY: at OAB END $a_z = 1.0\ g$
at O'ED END $a_z = 1.0\ g$

13.) DETERMINE MOMENT AND SHEAR

A.) OAB END, use $a_z = 1.0\ g$

$M_{OA} = 0.5(W_{OA})(\ell_{OA})(a_z/g)$

$= 0.5(607.2^{\#})(6\ ft)(1.0\ g/g) = 1822$ ft-lbs. ✓

$V_{OA} = (W_{OA})(a_z/g) = (607.2^{\#})(1.0\ g/g) = 607$ lbs. ✓

$V_{AB} = 0.5(W_{AB})(a_z/g) + (M_{OA}/\ell_{AB})$

$= 0.5(1822^{\#})(1.0\ g/g) + (1822\ ft\text{-}lb/18\ ft) = 1012$ lb ✓

$\frac{1}{8}(W_{AB})(\ell_{AB})(a_z/g) = \frac{1}{8}(1822^{\#})(18\ ft)(1.0\ g/g) = 4100$ ft-lbs ✓

$\frac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) = \frac{1}{10}(1822^{\#})(18\ ft)(1.0\ g/g) = 3280$ ft-lbs ✓

$M_{AB} = \text{MAXIMUM OF} \left\{ M_{OA};\ \frac{1}{8}(W_{AB})(\ell_{AB})(a_z/g);\ \frac{1}{10}(W_{BC})(\ell_{BC})(a_z/g) \right\}$

$= \text{MAXIMUM OF} \left\{ 1822;\ 4100;\ 3280 \right\}$ ✓

$= 4100$ ft-lbs. ✓

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SYSTEM BC315OF CONTINUED

DETERMINE MOMENT AND SHEAR (CONTINUED)

B.) O'ED END, use $a_z = 1.0\ g$

$M_{EO'} = 0.5 (W_{EO'})(\ell_{EO'})(a_z/g)$
$= 0.5(404.8\#)(4\ ft)(1.0\ g/g) = 810\ ft\text{-}lbs.$ ✓

$V_{EO'} = (W_{EO'})(a_z/g) = (404.8\#)(1.0\ g/g) = 405\ lbs.$ ✓

$V_{DE} = 0.5(W_{DE})(a_z/g) + (M_{EO'}/\ell_{DE})$
$= 0.5(1215\#)(1.0\ g/g) + (810\ ft\text{-}lb/12\ ft) = 675\ lbs$ ✓

$1/8\,(W_{DE})(\ell_{DE})(a_z/g) = 1/8(1215\#)(12\ ft)(1.0\ g/g) = 1823\ ft\text{-}lbs$ ✓

$1/10\,(W_{CD})(\ell_{CD})(a_z/g) = 1/10(1215\#)(12\ ft)(1.0\ g/g) = 1458\ ft\text{-}lbs$ ✓

$M_{DE} = \text{MAXIMUM OF} \left\{ M_{EO'} ; 1/8(W_{DE})(\ell_{DE})(a_z/g) ; 1/10(W_{CD})(\ell_{CD})(a_z/g) \right\}$
$= \text{MAXIMUM OF} \{ 810 ; 1823 ; 1458 \}$ ✓
$= 1823\ ft\text{-}lbs$

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SYSTEM BC3150F CONTINUED

14.) DETERMINE SUPPORT LOADS:

at A & B , $a_z = 1.0\ g$
at D & E , $a_z = 1.0\ g$

SUPPORT A:

$$P_A = \left(W_{OA} + \frac{W_{AB}}{2} + \frac{W_A}{2}\right)\left(a_z/g\right)$$

✓

$$= \left(607.2\# + \frac{1822\#}{2} + \frac{243\#}{2}\right)\left(1.0\ g/g\right) = 1640\ \text{lbs.}$$

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)\left(a_z/g\right)$$

✓

$$= \left(\frac{1822\# + 1822\#}{2} + \frac{243\#}{2}\right)\left(1.0\ g/g\right) = 1944\ \text{lbs}$$

SUPPORT D:

$$P_D = \left(\frac{W_{CD} + W_{DE}}{2} + \frac{W_D}{2}\right)\left(a_z/g\right)$$

✓

$$= \left(\frac{1215\# + 1215\#}{2} + \frac{243\#}{2}\right)\left(1.0\ g/g\right) = 1337\ \text{lbs.}$$

SUPPORT E:

$$P_E = \left(W_{ED'} + \frac{W_{DE}}{2} + \frac{W_E}{2}\right)\left(a_z/g\right)$$

✓

$$= \left(404.8\# + \frac{1215\#}{2} + \frac{243\#}{2}\right)\left(1.0\ g/g\right) = 1134\ \text{lbs.}$$

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SYSTEM: CT33 CT33

see page 12.10 for definition of terms

W_A = TOTAL WEIGHT OF SUPPORT A

$$= 2 \times (5.5 + 1.0 \text{ ft}) \times (42.05 \text{ \#/ft}) + 2 \times (5.5 \text{ ft}) \times (12.21 \text{ \#/ft})$$

$$= 681 \text{\#}$$

$$W_B = W_C = W_D = W_E = 681 \text{\#}$$

W_{AB} = TOTAL CABLE TRAY WEIGHT BETWEEN A & B

$$= \left[\left(\overset{\text{BEAM 1}}{3} \times 45 \text{ \#/ft}\right) + \left(\overset{\text{BEAM 2}}{3} \times 45 \text{ \#/ft}\right) \right] (6 \text{ ft})$$

$$= (270 \text{ \#/ft})(6 \text{ ft}) = 1620 \text{\#}$$

$$W_{BC} = (270 \text{ \#/ft})(8 \text{ ft}) = 2160 \text{\#}$$

$$W_{CD} = (270)(5) = 1350 \text{\#}$$

$$W_{DE} = (270)(6) = 1620 \text{\#}$$

CABLE TRAY I_Z

$$I_Z = \underbrace{(3 \times 0.517)}_{\text{BEAM 1}} + \underbrace{(3 \times 0.517)}_{\text{BEAM 2}} = 3.102 \text{ in}^4$$

SUPPORT STIFFNESS

per GTSTRUDL Run IGIG 90/11/20

input file: CTSUPI output file: CTSUPO

$$k = (4 \times 250 \text{\#}) / \left[(.01382 + .01682) \times 2/4 \right] = 65274 \text{ \#/in}$$

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CABLE TRAY SPAN BC CT33

1.) $k_{BZ} = 65274 \ \#/in$

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1620 + 2160}{4g} + \frac{681}{2g} = 1286 \ /g \quad ✓$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{2160 + 1350}{4\cancel{2}g} + \frac{681}{2g} = 1218 \ /g \quad ✓$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{65274 \ \#/in}{[1286\#]/[32.2 \times 12 \ in/sec^2]}\right)^{1/2} = 140.0 \ \frac{RAD}{SEC} \quad ✓$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{65274 \ \#/in}{[1218 \ \#]/[32.2 \times 12 \ in/sec^2]}\right)^{1/2} = 143.9 \ \frac{RAD}{SEC} \quad ✓$$

M_1 = MINIMUM OF (M_{1B} & M_{1C}) = 1218 /g ✓

ω_{1Z} = MINIMUM OF (ω_{1BZ} & ω_{1CZ}) = 140.0 RAD/SEC ✓

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4.) COMPUTE f_z

$$D_z = [\omega_{1z}]^2 + (1+\mu)[\omega_{2z}]^2$$

$$= [140.0]^2 + (1+0.776)[41.8]^2 = 22703$$

$$[\omega_z]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(22703) - \left[(22703)^2 - 4(140.0)^2(41.8)^2\right]^{1/2}\right\}$$

$$= 1625$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{1625}}{2\pi} = 6.41 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 6.41 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

PEAK ACCELERATION OCCURS BETWEEN
FREQUENCIES 4.8 Hz and 6.5 Hz
WITH PEAK ACCEL = 4.00g

∴ a_z = 4.00g at 6.41 Hz ✓

WCG-1-371

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CT33

6) DETERMINE CABLE TRAY MOMENT AND SHEAR

TIER 1 (3 TRAYS)

$M = 0.1\,(\text{NUMBER OF TRAYS})(w\ \#/\text{ft per tray})(\ell_{BC})^2(a_z/g)$

$= 0.1\,(3)(45\ \#/\text{ft})(8\text{ ft})^2(4.00) = 3456\text{ ft-lbs}$ ✓

$V = 0.5\,(\text{NUMBER OF TRAYS})(w\ \#/\text{ft per tray})(\ell_{BC})(a_z/g)$

$= 0.5\,(3)(45)(8)(4.00) = 2160\ \#$ ✓

TIER 2 (3 TRAYS)

BECAUSE TIER 2 IS IDENTICAL TO TIER 1

$M = 3456\text{ ft-lbs}$ ✓
$V = 2160\ \#$ ✓

7.) DETERMINE SUPPORT LOADS

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1620 + 2160}{2} + \frac{681}{2}\right)(4.00) = 8922\ \#$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{2160 + 1350}{2} + \frac{681}{2}\right)(4.00) = 8382\ \#$$ ✓

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8.) DETERMINE CABLE TRAY MOMENT AND SHEAR, $a_z = 1.0\,g$

TIER 1 (3 TRAYS)

$M = 0.1\,(\text{Number of Trays})(\omega\ \#/\text{ft per tray})(l_{BC})^2(a_z/g)$

$= 0.1\,(3)(45\ \#/\text{ft})(8\ \text{ft})^2(1.0\ g/g) = 864\ \text{ft-lbs}$ ✓

$V = 0.5\,(\text{Number of Trays})(\omega\ \#/\text{ft per tray})(l_{BC})(a_z/g)$

$= 0.5\,(3)(45\ \#/\text{ft})(8\ \text{ft})(1.0\ g/g) = 540\ \text{lbs}$ ✓

TIER 2 (3 TRAYS)

BECAUSE TIER 1 IS IDENTICAL TO TIER 2

$M = 864\ \text{ft-lbs}$ ✓
$V = 540\ \text{lbs}$ ✓

9.) DETERMINE SUPPORT LOADS:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1620\# + 2160\#}{2} + \frac{681\#}{2}\right)(1.0\ g/g) = 2231\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{2160\# + 1350\#}{2} + \frac{681\#}{2}\right)(1.0\ g/g) = 2096\ \text{lbs.}$$ ✓

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SYSTEM: CT 13 CT13

see page 12.10 for definition of terms

$W_A = W_B = W_C = W_D = W_E = 681^{\#}$

W_{AB} = TOTAL CABLE TRAY WEIGHT BETWEEN A & B

$$= \left[\left(\overset{\text{Beam 1}}{1} \times 45^{\#}/ft \right) + \left(\overset{\text{Beam 2}}{3} \times 45^{\#}/ft \right) \right] (6 ft)$$

$$= (180^{\#}/ft)(6 ft) = 1080^{\#} \checkmark$$

$W_{BC} = 180 \times 8 = 1440^{\#}$ ✓

$W_{CD} = 180 \times 5 = 900^{\#}$ ✓

$W_{DE} = 180 \times 6 = 1080^{\#}$ ✓

CABLE TRAY I_z

$$I_z = (1 \times 0.517) + (3 \times 0.517) = 2.068 \text{ in}^4$$

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CT13

CABLE TRAY SPAN BC

1.) $k_{BZ} = 65274$ #/in

2.) COMPUTE M_1 and ω_{1Z}

$$M_{1B} = \frac{W_{AB} + W_{BC}}{4g} + \frac{W_B}{2g}$$

$$= \frac{1080 + 1440}{4g} + \frac{681}{2g} = 970.5/g \checkmark$$

$$M_{1C} = \frac{W_{BC} + W_{CD}}{4\cancel{2}g} + \frac{W_C}{2g}$$

$$= \frac{1440 + 900}{4\cancel{2}g} + \frac{681}{2g} = 925.5/g$$

$$\omega_{1BZ} = \left(\frac{k_{1BZ}}{M_{1B}}\right)^{1/2} = \left(\frac{65274 \text{ #/in}}{[970.5\text{#}]/[32.2\times 12 \text{ in/sec}^2]}\right)^{1/2} = 161.2 \frac{\text{RAD}}{\text{SEC}} \checkmark$$

$$\omega_{1CZ} = \left(\frac{k_{1CZ}}{M_{1C}}\right)^{1/2} = \left(\frac{65274 \text{ #/in}}{[925.5\text{#}]/[32.2\times 12 \text{ in/sec}^2]}\right)^{1/2} = 165.1 \frac{\text{RAD}}{\text{SEC}} \checkmark$$

M_1 = MINIMUM OF (M_{1B} & M_{1C}) = 925.5 /g ✓

ω_{1Z} = MINIMUM OF (ω_{1BZ} & ω_{1CZ}) = 161.2 RAD/SEC ✓

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3.) COMPUTE M_2 and ω_{2z}

$$k_{2BCz} = \frac{48EI_{BCz}}{(l_{BC})^3} = \frac{48(29\times10^6\ \#/in^2)(2.068\ in^4)}{(8 \times 12\ in)^3} = 3254\ \#/in$$

$$M_{2BC} = \frac{W_{BC}}{2g} = \frac{1440}{2g} = 720\ /g$$

$$\omega_{2BCz} = \left(\frac{k_{2BCz}}{M_{2BC}}\right)^{1/2} = \left(\frac{3254\ \#/in}{[720\ \#]/[32.2\times12\ in/sec^2]}\right)^{1/2} = 41.8\ \frac{RAD}{SEC}$$

$$M_{2AB} = \frac{W_{AB}}{2g} = \frac{1080}{2g} = 540\ /g$$

$$M_{2CD} = \frac{W_{CD}}{2g} = \frac{900}{2g} = 450\ /g$$

$$M_2 = \text{MAXIMUM OF} \left(\frac{M_{2AB} + M_{2BC}}{2} \text{ OR } \frac{M_{2BC} + M_{2CD}}{2}\right)$$

$$= \frac{540/g + 720/g}{2} = 630/g \quad ✓$$

$$\mu = \frac{M_2}{M_1} = \frac{630\ /g}{925.5\ /g} = 0.681 \quad ✓$$

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4.) COMPUTE f_z

$$D_z = \left[\omega_{1z}\right]^2 + (1+\mu)\left[\omega_{2z}\right]^2$$

$$= \left[161.2\right]^2 + (1+0.681)\left[41.8\right]^2 = 28923$$

$$\left[\omega_z\right]^2 = 0.5\left\{D_z - \left[(D_z)^2 - 4(\omega_{1z})^2(\omega_{2z})^2\right]^{1/2}\right\}$$

$$= 0.5\left\{(28923) - \left[(28923)^2 - 4(161.2)^2(41.8)^2\right]^{1/2}\right\}$$

$$= 1666$$

$$f_z = \frac{\omega_z}{2\pi} = \frac{\sqrt{1666}}{2\pi} = 6.50 \text{ Hz}$$ ✓

5.) DETERMINE a_z at 6.50 Hz
FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

PEAK ACCELERATION OCCURS BETWEEN
FREQUENCIES 4.8 Hz and 6.5 Hz
WITH PEAK ACCEL = 4.00 g

$\therefore$ $a_z = 4.00g$ at 6.50 Hz ✓

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CT13

6.) DETERMINE CABLE TRAY SPAN MOMENT AND SHEAR

TIER 1 (1 TRAY)

$$M = 0.1(\text{NUMBER OF TRAYS})(w\ \#/\text{ft per tray})(l_{BC})^2(a_z/g)$$

$$= 0.1(1)(45\ \#/\text{ft})(8\ \text{ft})^2(4.00) = 1152\ \text{ft-lbs}$$ ✓

$$V = 0.5(\text{NUMBER OF TRAYS})(w\ \#/\text{ft per tray})(l_{BC})(a_z/g)$$

$$= 0.5(1)(45)(8)(4.00) = 720\#$$ ✓

TIER 2 (3 TRAYS)

$$M = 3 \times (M_{\text{TIER1}}) = 3 \times 1152 = 3456\ \text{ft-lbs}$$ ✓

$$V = 3 \times (V_{\text{TIER1}}) = 3 \times 720 = 2160\#$$ ✓

7.) DETERMINE SUPPORT LOADS

SUPPORT B:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1080 + 1440}{2} + \frac{681}{2}\right)(4.00) = 6402\#$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{1440 + 900}{2} + \frac{681}{2}\right)(4.00) = 6042\#$$ ✓

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CT13

8.) DETERMINE CABLE TRAY MOMENT AND SHEAR, $a_z = 1.0\,g$

TIER 1 (1 TRAY)

$M = 0.1(\text{Number of Trays})(\omega\ \#/\text{ft per tray})(l_{BC})^2(a_z/g)$

$= 0.1(1)(45\ \#/\text{ft})(8\ \text{ft})^2(1.0\ g/g) = 288\ \text{ft-lbs}$ ✓

$V = 0.5(\text{Number of Trays})(\omega\ \#/\text{ft per tray})(l_{BC})(a_z/g)$

$= 0.5(1)(45\ \#/\text{ft})(8\ \text{ft})(1.0\ g/g) = 180\ \text{lbs.}$ ✓

TIER 2 (3 TRAYS)

$M = 3 \times (M_{\text{TIER 1}}) = 3 \times 288 = 864\ \text{ft-lbs}$ ✓

$V = 3 \times (V_{\text{TIER 1}}) = 3 \times 180 = 540\ \text{lbs.}$ ✓

9.) DETERMINE SUPPORT LOADS:

$$P_B = \left(\frac{W_{AB} + W_{BC}}{2} + \frac{W_B}{2}\right)(a_z/g)$$

$$= \left(\frac{1080\,\# + 1440\,\#}{2} + \frac{681\,\#}{2}\right)(1.0\ g/g) = 1601\ \text{lbs}$$ ✓

SUPPORT C:

$$P_C = \left(\frac{W_{BC} + W_{CD}}{2} + \frac{W_C}{2}\right)(a_z/g)$$

$$= \left(\frac{1440\,\# + 900\,\#}{2} + \frac{681\,\#}{2}\right)(1.0\ g/g) = 1511\ \text{lbs.}$$ ✓

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13. COMPARISON OF MDF AND 2DF RESULTS FOR SYSTEMS ON FLEXIBLE SUPPORTS

(Straight-Run-Models)

The MDF and 2DF results for the systems on flexible supports are given in Sections 11 and 12, respectively.

The following comparisons were made:

Table 13.1. Comparison of Frequencies.

Table 13.2. Comparison of Component and Support Forces for SSE-EW Spectrum

Table 13.3. Comparison of Component and Support Forces for FLAT 1-g Spectrum.

These comparison tables are given on the following pages of this Section.

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Table 13.1
COMPARISON OF FREQUENCIES

SYSTEM		FREQUENCY from 2DF (Hz)	FREQUENCY 1st contributing mode (Hz)
AA2150		14.2	15.3
AA2200		10.2	12.1
AB2150		11.0	12.8
AB2200		7.0	9.3
BC3150		7.9	8.7
BC3200		6.4	7.4
BC4150		7.9	8.7
BC4200		6.4	7.4
BC4125		8.9	9.5
BC4		5.2 (1)	5.7 (2)
AA2150F	From ABCD	13.8	15.2
	From EDCB	17.4	18.1)^3
AA2150H	From ABCD	12.8	15.2
	From EDCB	16.1	18.3^3
BC3150F	From ABCD	7.9	8.6
	From EDCB	~~10.2~~ 9.9	8.6, (10.8)^3
CT 33		6.4	8.8
CT 13		6.5	9.0

Notes:

(1) From Page 6.1

(2) " " 5.8

BC4 results are listed to show the effect of changing support stiffness 3 times. Compare BC4 to BC4125.

(3) This is the frequency of next contributing mode. Most of the responses in the EDCB part of the system are dominated by this mode

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Conclusion from Frequency Comparison

The 2DF approach provided frequencies lower than the first contributing mode in all cases except the end EDCB of BC 3150F. In this case the 2DF frequency is slightly less than the frequency of system mode that dominates most of the responses in this part of the structure

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TABLE 13.2
COMPARISON OF COMPONENT & SUPPORT FORCES FOR CALIBRATION
(SSE - EW SPECTRUM)

SYSTEM	RATIO MDF/2DF					
	COMPONENT				SUPPORT FORCE	
	MOMENT		SHEAR			
AA2150	BC	1.03	BC	1.07	B	0.98
					C	1.00
AA2200	BC	0.81	BC	0.87	B	0.75
					C	0.75
AB2150	BC	0.81	BC	0.88	B	0.77
					C	0.77
AB2200	BC	0.48	BC	0.55	B	0.47
					C	0.47
BC3150	BC	0.81	BC	0.87	B	0.92
					C	0.78
BC3200	BC	0.73	BC	0.93	B	0.94
					C	0.68
BC4125	BC	0.93	BC	0.99	B	0.94
					C	1.07
BC4150	BC	0.87	BC	0.88	B	0.76
					C	0.99
BC4200	BC	0.69	BC	0.93	B	0.64
					C	1.01
AA2150F	AD	0.91	AD	0.67	A	0.82
	AB	0.42	AB	0.73	B	0.95
	EO'	0.86	EO'	0.64	E	0.99
	DE	0.85	DE	0.85	D	0.89

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Table 13.2 (Cont.)

COMPARISON OF COMPONENT & SUPPORT FORCES FOR CALIBRATION (Cont.)
(SSE-EW SPECTRA)

SYSTEM	RATIO MDF/2DF					
	COMPONENT				SUPPORT FORCE	
	MOMENT		SHEAR			
AA2150H	AB	0.41	AB	0.76	A	0.68
					B	0.93
	DE	0.94	DE	0.82	E	0.82
					D	0.84
BC3150F	AO	0.63	AD	0.56	A	0.77
	AB	0.71	AB	0.81	B	1.00
	EO'	1.02	EO'	0.82	E	1.01
	DE	0.83	DE	0.77	D	0.85
CT33					B	0.30
					C	0.35
(Tier 1)	BC	0.35	BC	0.37		
(Tier 2)	BC	0.38	BC	0.41		
CT13					B	0.27
					C	0.33
(Tier 1)	BC	0.31	BC	0.34		
(Tier 2)	BC	0.34	BC	0.36		

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Table 13.3

COMPARISON OF COMPONENT & SUPPORT FORCES FOR CALIBRATION
(1-g FLAT SPECTRUM)

SYSTEM	RATIO MDF/2DF		
	COMPONENT		SUPPORT FORCE
	MOMENT	SHEAR	
AA2150	BC 1.06	BC 1.11	B 1.02
			C 1.03
AA2200	BC 0.94	BC 1.01	B 0.89
			C 0.88
AB2150	BC 0.93	BC 1.02	B 0.90
			C 0.90
AB2200	BC 0.79	BC 0.90	B 0.81
			C 0.82
BC3150	BC 0.99	BC 1.04	B 1.09
			C 0.96
BC3200	BC 0.89	BC 1.12	B 1.13
			C 0.85
BC4125	BC 1.00	BC 1.06	B 1.01
			C 1.14
BC4150	BC 1.06	BC 1.06	B 0.93
			C 1.20
BC4200	BC 0.83	BC 1.11	B 0.81
			C 1.20
AA2150F	AD 1.06	AD 0.79	A 0.96
	AB 0.47	AB 0.82	B 1.04
	EO' 0.89	EO' 0.68	E 1.02
	DE 0.88	DE 0.86	D 0.90

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Table 13.3 (cont.)

COMPARISON OF COMPONENT & SUPPORT FORCES FOR CALIBRATION (cont.)
(1-g FLAT SPECTRUM)

SYSTEM	RATIO MDF/2DF		
	COMPONENT		SUPPORT FORCE
	MOMENT	SHEAR	
AA2150H	AB 0.45	AB 0.90	A 0.84
			B 1.06
	DE 0.99	DE 0.85	E 0.86
			D 0.87
BC3150F	AO 0.81	AO 0.71	A 0.91
	AB 0.83	AB 0.93	B 1.15
	EO' 1.10	EO' 0.89	E 1.09
	DE 0.70	DE 0.83	D 0.84
CT33			B 0.68
			C 0.80
(Tier 1)	BC 0.59	BC 0.65	
(Tier 2)	BC 0.63	BC 0.71	
CT13			B 0.63
			C 0.79
(Tier 1)	BC 0.55	BC 0.62	
(Tier 2)	BC 0.59	BC 0.66	

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Conclusion Based on MDF/2DF Response Ratio Comparison

If support and component forces from the 2DF approach are calculated as stated in straigh-run Sections 2, and 10 of this calculation, the comparisons for the 14 systems considered here show that the maximum MDF/2DF response ratio is

- * 1.07 for SSE EW spectium
- * 1.20 for the flat 1g spectium

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14. Results for Straight-Run Systems on Rigid Supports

The following additional systems were analyzed:

- 2SP150
- 2SP200
- 3SP150
- 3SPMIX

These systems are described in detail in Section 10.

The results for systems on rigid supports are summarized as follows:

- Comparison of MDF to Simplified Analysis Results for Systems on Rigid Supports.
- MDF Analysis Results for Systems on Rigid Supports.
- Simplified Analysis Calculations for Systems on Rigid Supports.

The MDF analyses were performed using the GTSTRUDL Version GTICES 3.3B (8701). The simplified analysis is per Section 10.

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Comparison of MDF to Simplified Analysis

Results

Table 14.1 Comparison of System Frequency

SYSTEM	Frequency from Simplified Analysis (Hz)	Frequency from MDF 1st Contributing mode (Hz)
2SP150	7.36 ✓	9.0 ✓
2SP200	7.36 ✓	9.4 ✓
3SP150	7.36 ✓	10.4 ✓
3SPMIX	7.36 ✓	10.9 ✓

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- COMPARISON of MDF to Simplified Analysis Results

Table 14.2 Comparision of Component and Support Forces.
(SSE-EW spectrum)

SYSTEM	RATIO MDF/~~EDF~~ Simplified Analysis		
	COMPONENT		SUPPORT FORCE
	MOMENT	SHEAR	
2SP150	AB 0.29 ✓	AB 0.24 ✓	A 0.37 ✓
	BC 0.40 ✓	BC 0.37 ✓	B 0.34 ✓
			C 0.35 ✓
2SP200	AB 0.36 ✓	AB 0.23 ✓	A 0.46 ✓
	BC 0.42 ✓	BC 0.42 ✓	B 0.45 ✓
			C 0.38 ✓
3SP150	AB 0.23 ✓	AB 0.27 ✓	A 0.28 ✓
	BC 0.24 ✓	BC 0.25 ✓	B 0.27 ✓
	CD 0.23 ✓	CD 0.27 ✓	C 0.27 ✓
			D 0.28 ✓
3SPMIX	AB 0.22 ✓	AB 0.25 ✓	A 0.30 ✓
	BC 0.26 ✓	BC 0.29 ✓	B 0.24 ✓
	CD 0.22 ✓	CD 0.17 ✓	C 0.24 ✓
			D 0.30 ✓

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Client TVA	Prepared by	Date 1.24.91
Project WATTS BAR	Reviewed by S. M. Lamoureux	Date 1.24.91
Proj. No. 8573-03 Equip. No.	Approved by	Date

Table 14.3 . Comparison of Component and Support Forces
(Flat 1-g Spectrum)

SYSTEM	RATIO MDF/~~EDF~~ Simplified Analysis		
	COMPONENT		SUPPORT FORCE
	MOMENT	SHEAR	
2SP150	AB 0.48 ✓ BC 0.59 ✓	AB 0.58 ✓ BC 0.55 ✓	A 0.75 ✓ B 0.61 ✓ C 0.54 ✓
2SP200	AB 0.57 ✓ BC 0.65 ✓	AB 0.40 ✓ BC 0.66 ✓	A 0.80 ✓ B 0.75 ✓ C 0.60 ✓
3SP150	AB 0.51 ✓ BC 0.51 ✓ CD 0.51 ✓	AB 0.66 ✓ BC 0.50 ✓ CD 0.66 ✓	A 0.67 ✓ B 0.64 ✓ C 0.64 ✓ D 0.67 ✓
3SPMIX	AB 0.48 ✓ BC 0.46 ✓ CD 0.39 ✓	AB 0.61 ✓ BC 0.54 ✓ CD 0.41 ✓	A 0.67 ✓ B 0.56 ✓ C 0.47 ✓ D 0.68 ✓

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Prepared by		Date 1.24.91
Reviewed by	S. M. Lamoureux	Date 1.24.91
Approved by		Date

Conclusions for Systems on Rigid Supports

If support and component forces are calculated from simplified analysis as stated in Section 10 of this calculation, the comparison for the 4 straight-run systems considered here show that the maximum of MDF/simplified analysis response ratio is well below 1.0 for both SSE-EW and flat 1g spectra.

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Project	WATTS BAR	Reviewed by J. M. Lamoureux	Date 12-12-90
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MDF for Systems on Rigid Supports

Summary of Results (MDF) for Systems on Rigid Supports (SSE-EW Spectrum)

SYSTEM	COMPONENT		SUPPORT FORCE (Lb)
	MOMENT (ft-lb)	SHEAR (Lb.)	
2SP150	AB 446 ✓	AB 169 ✓	A 169 ✓
	BC 613 ✓	BC 311 ✓	B 381 ✓
			C 241 ✓
2SP200	AB 555 ✓	AB 156 ✓	A 156 ✓
	BC 645 ✓	BC 356 ✓	B 463 ✓
			C 259 ✓
3SP150	AB 278 ✓	AB 175 ✓	A 129 ✓
	BC 288 ✓	BC 172 ✓	B 306 ✓
	CD 278 ✓	CD 175 ✓	C 306 ✓
			D 129 ✓
3SPMIX	AB 273 ✓	AB 163 ✓	A 134 ✓
	BC 317 ✓	BC 194 ✓	B 275 ✓
	CD 267 ✓	CD 102 ✓	C 245 ✓
			D 102 ✓

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ENGINEERS

Calcs. For	
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Prepared by	Date 12/12/90
Reviewed by A. M. Lamoureux	Date 12-12-90
Approved by	Date

Summary of Results (MDF) for Systems on Rigid Supports (FLAT 1-g Spectrum)

	COMPONENT		SUPPORT FORCE (Lb)
SYSTEM	MOMENT (ft-lb)	SHEAR (Lb.)	
2SP150	AB 218 ✓ BC 267 ✓	AB 122 ✓ BC 139 ✓	A 101 ✓ B 205 ✓ C 110 ✓
2SP200	AB 259 ✓ BC 295 ✓	AB 81 ✓ BC 167 ✓	A 81 ✓ B 228 ✓ C 121 ✓
3SP150	AB 185 ✓ BC 185 ✓ CD 185 ✓	AB 130 ✓ BC 102 ✓ CD 130 ✓	A 90 ✓ B 216 ✓ C 216 ✓ D 90 ✓
3SPMIX	AB 175 ✓ BC 167 ✓ CD 144 ✓	AB 120 ✓ BC 109 ✓ CD 75 ✓	A 91 ✓ B 189 ✓ C 144 ✓ D 69 ✓

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Client	TVA	Prepared by		Date 12/12/90
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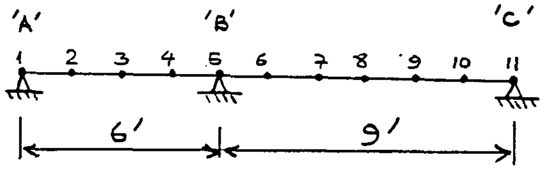
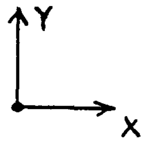
MDF for 2SP150

Nodalized FEM model:





SSE-EW Spectrum Analysis Results

Reference Run : AOXZ ✓ 12/04/90 ✓
Input File : 2SP150I ✓
Output File : 2SP150O ✓

Span "AB"

Moment Z, max. of nodes 1 thru 5 = 5355 ✓ in-lb = 446 ✓ ft-lb (AT 5 ✓)
Shear Y, max. of nodes 1 thru 5 = 169 ✓ lb (BETWEEN 1 & 2 ✓)

Span "BC"

Moment Z, max. of nodes 5 thru 11 = 7357 ✓ in-lb = 613 ✓ ft-lb (AT 8 ✓)
Shear Y, max. of nodes 5 thru 11 = 311 ✓ lb (BETWEEN 5 & 6 ✓)

SUPPORT FORCE 'A' at Node 1 = 169 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 381 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 241 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1	9.0	34.4 ✓
2	20.6	48.0 ✓
3	34.3	6.0 ✓
4	65.7	2.5 ✓
5	79.3	5.4 ✓
6	118.9	0.1 ✓
7	146.8	2.1 ✓

Σ 98.562 % ✓

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Client	TVA
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Prepared by		Date 12/12/90
Reviewed by	D. M. Lamoureux	Date 12-12-90
Approved by		Date

MDF for 2SP150 (cont.)

FLat 1-g Spectrum Analysis Results

Reference Run : AMNP ✓ 12/03/90 ✓
Input File : 2SP150J ✓
Output File : 2SP150Q ✓

Span "AB"

Moment Z, max. of nodes 1 thru 5 = 2610 in-lb = 218 ✓ ft-lb (AT 5 ✓)
Shear Y, max. of nodes 1 thru 5 = 122 ✓ lb (BETWEEN 4 & 5 ✓)

Span "BC"

Moment Z, max. of nodes 5 thru 11 = 3198 in-lb = 267 ✓ ft-lb (AT 8 ✓)
Shear Y, max. of nodes 5 thru 11 = 139 ✓ Lb (BETWEEN 5 & 6 ✓)

SUPPORT FORCE 'A' at Node 1 = 101 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 205 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 110 lb. ✓

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Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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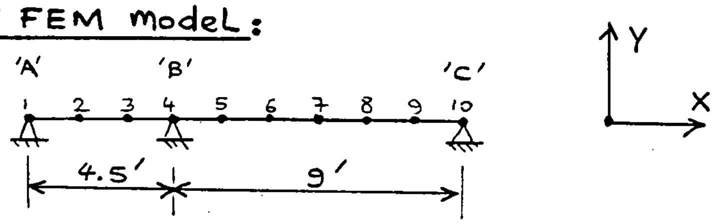
Prepared by		Date 12/12/90
Reviewed by	D. M. Lamoureux	Date 12-12-90
Approved by		Date

MDF for 2SP200

Nodalized FEM model:



SSE-EW Spectrum Analysis Results

Reference Run : AOYQ ✓ 12/04/90 ✓
Input File : 2SP200I ✓
Output File : 2SP200O ✓

Span "AB"
Moment Z, max. of nodes 1 thru 4 = 6661 in-lb = 555 ✓ ft-lb (AT 4 ✓)
Shear Y, max. of nodes 1 thru 4 = 156 ✓ lb (BETWEEN 1 & 2 ✓)

Span "BC"
Moment Z, max. of nodes 4 thru 10 = 7737 in-lb = 645 ✓ ft-lb (AT 7 ✓)
Shear Y, max. of nodes 4 thru 10 = 356 ✓ lb (BETWEEN 4 & 5 ✓)

SUPPORT FORCE 'A' at Node 1 = 156 lb. ✓
SUPPORT FORCE 'B' at Node 4 = 463 lb. ✓
SUPPORT FORCE 'C' at Node 10 = 259 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1	9.4	53.7 ✓
2	29.4	9.5 ✓
3	41.0	22.4 ✓
4	71.6	11.8 ✓
6	130.6	1.4 ✓
7	166.3	1.1 ✓

Σ 100.000 %

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Calcs. For	
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Project	WATTS BAR	
Proj. No.	8573-03	Equip. No.

Prepared by	Date 12/12/90
Reviewed by S. M. Lamoureux	Date 12-12-90
Approved by	Date

MDF for 2SP200 (cont.)

Flat 1-g Spectrum Analysis Results

Reference Run : AMOB ✓ 12/03/90 ✓

Input File : 2SP200J ✓

Output File : 2SP200Q ✓

Span "AB"

Moment Z, max. of nodes 1 thru 4 = 3102 in-lb = 259 ✓ ft-lb (AT 4 ✓)

Shear Y, max. of nodes 1 thru 4 = 81 ✓ lb (BETWEEN 1 & 2 ✓)

Span "BC"

Moment Z, max. of nodes 4 thru 10 = 3544 in-lb = 295 ✓ ft-lb (AT 7 ✓)

Shear Y, max. of nodes 4 thru 10 = 167 ✓ Lb (BETWEEN 4 & 5 ✓)

SUPPORT FORCE 'A' at Node 1 = 81 lb. ✓

SUPPORT FORCE 'B' at Node 4 = 228 lb. ✓

SUPPORT FORCE 'C' at Node 10 = 121 lb. ✓

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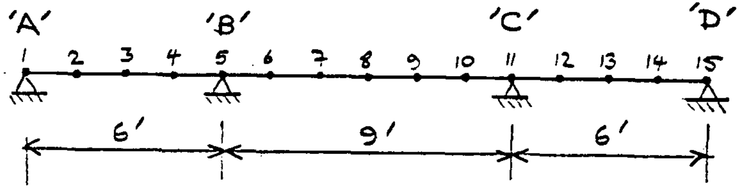
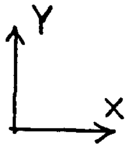
Project	WATTS BAR		
Proj. No.	8573-03	Equip. No.	

Prepared by		Date	12/12/90
Reviewed by	D. M. Lamoureux	Date	12-12-90
Approved by		Date	

MDF for 3SP150

Nodalized FEM model:





SSE-EW Spectrum Analysis Results

Reference Run : A02R ✓ 12/04/90 ✓
Input File : 3SP150I ✓
Output File : 3SP150O ✓

Span "AB"

Moment Z, max. of nodes 1 thru 5 = 3332 in-lb = 278 ✓ ft-lb (AT 5 ✓)
Shear Y, max. of nodes 1 thru 5 = 175 ✓ lb (BETWEEN 4 & 5 ✓)

Span "BC"

Moment Z, max. of nodes 5 thru 11 = 3451 in-lb = 288 ✓ ft-lb (AT 8 ✓)
Shear Y, max. of nodes 5 thru 11 = 172 ✓ lb (BETWEEN 5 & 6 ✓)

Span "CD"

Moment Z, max. of nodes 11 thru 15 = 3332 in-lb = 278 ✓ ft-lb (AT 11 ✓)
Shear Y, max. of nodes 11 thru 15 = 175 ✓ lb (BETWEEN 11 & 12 ✓)

SUPPORT FORCE 'A' at Node 1 = 129 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 306 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 306 lb. ✓
SUPPORT FORCE 'D' at Node 15 = 129 Lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1	10.4	9.5 ✓
3	22.9	77.2 ✓
5	65.7	1.3 ✓
7	85.1	7.3 ✓

Σ 95.279 % ✓

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ENGINEERS

Calcs. For	
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Reviewed by	D. M. Lamoureux	Date	12-12-90
Approved by		Date	

MDF for 3SP150 (cont.)

FLat 1-g Spectrum Analysis Results

Reference Run : APBH ✓ 12/04/90 ✓
Input File : 3SP150J ✓
Output File : 3SP150Q ✓

Span "AB"
Moment Z, max. of nodes 1 thru 5 = 2216 in-lb = 185 ✓ ft-lb (AT 5 ✓)
Shear Y, max. of nodes 1 thru 5 = 130 ✓ lb (BETWEEN 4 & 5 ✓)

Span "BC"
Moment Z, max. of nodes 5 thru 11 = 2216 in-lb = 185 ✓ ft-lb (AT 5 ✓)
Shear Y, max. of nodes 5 thru 11 = 102 ✓ Lb (BETWEEN 5 & 6)

Span "CD"
Moment Z, max. of nodes 11 thru 15 = 2216 in-lb = 185 ✓ ft-lb (AT 11 ✓)
Shear Y, max. of nodes 11 thru 15 = 130 ✓ lb. (BETWEEN 11 & 12 ✓)

SUPPORT FORCE 'A' at Node 1 = 90 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 216 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 216 lb. ✓
SUPPORT FORCE 'D' at Node 15 = 90 lb ✓

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Calcs. For	
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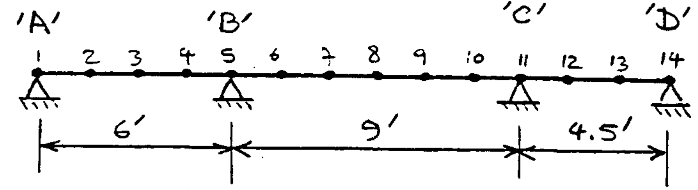
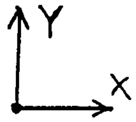
Reviewed by	D. M. Lamoureux	Date 12-12-90
Approved by		Date

MDF for 3SPMIX

Nodalized FEM model:





SSE-EW Spectrum Analysis Results

Reference Run : APDC ✓ 12/04/90 ✓
Input File : 3SPMIXI ✓
Output File : 3SPMIXO ✓

Span "AB"
Moment Z, max. of nodes 1 thru 5 = 3271 in-lb = 273 ✓ ft-lb (AT 3 ✓)
Shear Y, max. of nodes 1 thru 5 = 163 ✓ lb (BETWEEN 4 & 5)

Span "BC"
Moment Z, max. of nodes 5 thru 11 = 3809 in-lb = 317 ✓ ft-lb (AT 8 ✓)
Shear Y, max. of nodes 5 thru 11 = 194 ✓ lb (BETWEEN 10 & 11)

Span "CD"
Moment Z, max. of nodes 11 thru 14 = 3208 in-lb = 267 ✓ ft-lb (AT 11 ✓)
Shear Y, max. of nodes 11 thru 14 = 102 ✓ lb (BETWEEN 13 & 14)

SUPPORT FORCE 'A' at Node 1 = 134 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 275 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 245 lb. ✓
SUPPORT FORCE 'D' at Node 14 = 102 lb. ✓

CONTRIBUTION OF MODES

Mode No.	Frequency (Hz)	Mass Participation (%)
1	10.9	16.9 ✓
2	21.0	34.6 ✓
3	32.4	27.1 ✓
4	43.1	6.1 ✓
5	68.8	2.7 ✓
6	82.0	8.4 ✓
7	117.1	0.2 ✓

Σ 96.061 ✓ %

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Reviewed by D. M. Lamoureux	Date 12-12-90
Approved by	Date

MDF for 3SPMIX (cont.)

FLat 1-g Spectrum Analysis Results

Reference Run : APDH ✓ 12/04/90 ✓
Input File : 3SPMIXJ ✓
Output File : 3SPMIXQ ✓

Span "AB"
Moment Z, max. of nodes 1 thru 5 = 2100 in-lb = 175 ✓ ft-lb (AT 3 ✓)
Shear Y, max. of nodes 1 thru 5 = 120 ✓ lb (BETWEEN 4 & 5 ✓)

Span "BC"
Moment Z, max. of nodes 5 thru 11 = 2007 in-lb = 167 ✓ ft-lb (AT 8 ✓)
Shear Y, max. of nodes 5 thru 11 = 109 ✓ Lb (BETWEEN 10 & 11 ✓)

Span "CD"
Moment Z, max. of nodes 11 thru 14 = 1733 in-lb = 144 ✓ ft-lb (AT 11 ✓)
Shear Y, max. of nodes 11 thru 14 = 75 ✓ lb (BETWEEN 11 & 12)

SUPPORT FORCE 'A' at Node 1 = 91 lb. ✓
SUPPORT FORCE 'B' at Node 5 = 189 lb. ✓
SUPPORT FORCE 'C' at Node 11 = 144 lb. ✓
SUPPORT FORCE 'D' at Node 14 = 69 Lb. ✓

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Calcs. For	
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Client TVA	Prepared by A. M. Lamoureux	Date 12-12-90
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Simplified Analysis Calculations for Systems on Rigid Supports

Summary of Results for Systems on Rigid Supports (Simplified Analysis)
(SSE-EW Spectrum)

SYSTEM	COMPONENT MOMENT (ft-lb)	COMPONENT SHEAR (Lb.)	SUPPORT FORCE (Lb)
2SP150	AB 1528 BC 1528	AB 707 BC 848	A 453 B 1132 C 679
2SP200	AB 1528 BC 1528	AB 677 BC 848	A 339 B 1018 C 679
3SP150	AB 1222 BC 1222 CD 1222	AB 657 BC 681 CD 657	A 453 B 1132 C 1132 D 453
3SPMIX	AB 1222 BC 1222 CD 1222	AB 657 BC 679 CD 610	A 453 B 1132 C 1018 D 339

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Summary of Results for Systems on Rigid Supports
(Simplified Analysis)
(Flat 1-g Spectrum)

	COMPONENT		SUPPORT FORCE (Lb)
SYSTEM	MOMENT (ft-lb)	SHEAR (Lb.)	
2SP150	AB 456 BC 456	AB 211 BC 253	A 135 B 338 C 203
2SP200	AB 456 BC 456	AB 202 BC 253	A 101 B 304 C 203
3SP150	AB 365 BC 365 CD 365	AB 196 BC 203 CD 196	A 135 B 338 C 338 D 135
3SPMIX	AB 365 BC 365 CD 365	AB 196 BC 203 CD 182	A 135 B 338 C 304 D 101

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Calcs. For		Calc. No. 8.11.6-1	
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FUNDAMENTAL FREQUENCY FOR ONE-SPAN BEAM.

$$f = \frac{9.87}{2\pi}\sqrt{\frac{EIg}{\omega \ell^4}}$$ where ω = uniform distributed load

$$f = \frac{9.87}{2\pi}\sqrt{\frac{(29\times10^6\ \text{psi})(1.0\ \text{in}^4)(32.2\times12\ \text{in/sec}^2)}{(45/12\ \#/\text{in})(9\times12\,\text{in})^4}} = 7.36\ \text{Hz}$$

DETERMINE a_z at $f_z = 7.36$ Hz

FROM SITE SELECTED SPECTRA CURVE (see page 3.11)

$f_z = 9.1$ Hz	$a_z = 2.25\,g$
$f_z = 6.5$ Hz	$a_z = 4.00\,g$

Interpolate: $$\frac{a_z - 4.00g}{2.25g - 4.00g} = \frac{\log 7.36 - \log 6.5}{\log 9.1 - \log 6.5}$$

$$a_z = \left(\frac{\log 7.36 - \log 6.5}{\log 9.1 - \log 6.5}\right)(2.25g - 4.00g) + 4.00g$$

$a_z = 3.353\,g$ at $f_z = 7.36$ Hz

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Calcs. For		Calc. No.	8.11.6-1
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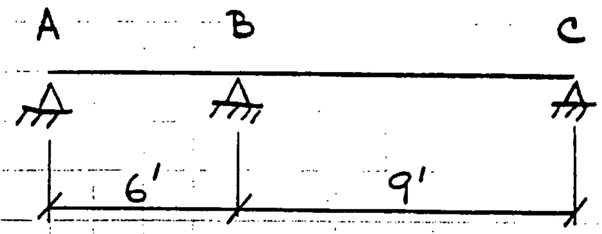
2SP150

CASE : 2SP 150



$\omega = 45 \,\#/ft$

$M_{BC} = 0.125\, \omega\, l_{BC}^2 = 1/8(45\,\#/ft)(9\,ft)^2 = 455.6$ ft-lbs.

$V_{AB} = 0.5\, \omega\, l_{AB} + M_{BC}/l_{AB}$

$= 0.5(45)(6) + (455.6)/6 = 211\,\#$

$V_{BC} = 0.5\, \omega\, l_{BC} + M_{BC}/l_{BC}$

$= 0.5(45)(9) + (455.6)/9 = 253\,\#$

APPLY $a_z = 3.353g$

$M_{AB} = M_{BC} = 455.6 \times 3.353 = 1528$ ft-lbs

$V_{AB} = 211 \times 3.353 = 707\,\#$

$V_{BC} = 253 \times 3.353 = 848\,\#$

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

Calcs. For		Calc. No. 8.11.6-1	
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2SP150 Continued

DETERMINE SUPPORT LOADS:

A.) $a_z = 1.0g$

SUPPORT A:

$$P_A = \left(\frac{w\,l_{AB}}{2}\right)\left(a_z/g\right) = \left(\frac{45^{\#}/ft \times 6\ ft}{2}\right)\left(1.0\ g/g\right) = 135\ lbs.$$

SUPPORT B:

$$P_B = \left(\frac{w\,l_{AB}}{2} + \frac{w\,l_{BC}}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{45 \times 6}{2} + \frac{45 \times 9}{2}\right)\left(1.0\ g/g\right) = 338\ lbs.$$

SUPPORT C:

$$P_C = \left(\frac{w\,l_{BC}}{2}\right)\left(a_z/g\right) = \left(\frac{45 \times 9}{2}\right)\left(1.0\ g/g\right) = 203\ lbs.$$

B.) $a_z = 3.353g$

Same method as above

SUPPORT A:

$$P_A = \left(\frac{45 \times 6}{2}\right)\left(3.353\right) = 453\ lbs.$$

SUPPORT B:

$$P_B = \left(\frac{45 \times 6}{2} + \frac{45 \times 9}{2}\right)\left(3.353\right) = 1132\ lbs.$$

SUPPORT C:

$$P_C = \left(\frac{45 \times 9}{2}\right)\left(3.353\right) = 679\ lbs.$$

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ENGINEERS

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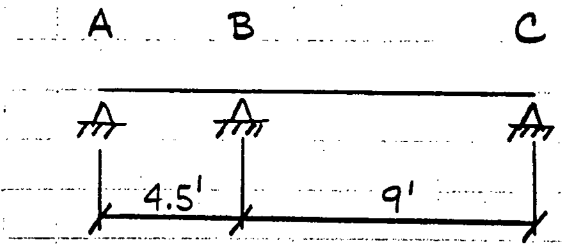
2SP200

CASE : 2SP200



$\omega = 45\,\#/ft$

$M_{BC} = 0.125\,\omega \ell_{BC}^2 = 1/8\,(45\,\#/ft)(9\,ft)^2 = 455.6$ ft-lbs.

$V_{AB} = 0.5\,\omega \ell_{AB} + M_{BC}/\ell_{AB}$

$= 0.5(45)(4.5) + (455.6)/4.5 = 202\#$

$V_{BC} = 0.5\,\omega \ell_{BC} + M_{BC}/\ell_{BC}$

$= 0.5(45)(9) + (455.6)/9 = 253\#$

APPLY $a_z = 3.353\,g$

$M_{BC} = 455.6 \times 3.353 = 1528$ ft-lbs

$V_{AB} = 202 \times 3.353 = 677\#$

$V_{BC} = 253 \times 3.353 = 848\#$

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2SP200 Continued

DETERMINE SUPPORT LOADS:

A.) $a_z = 1.0\,g$

SUPPORT A:

$$P_A = \left(\frac{\omega\, l_{AB}}{2}\right)\left(a_z/g\right) = \left(\frac{45\,\#/ft \times 4.5\,ft}{2}\right)\left(1.0\ g/g\right) = 101\ lbs.$$

SUPPORT B:

$$P_B = \left(\frac{\omega\, l_{AB}}{2} + \frac{\omega\, l_{BC}}{2}\right)\left(a_z/g\right)$$

$$= \left(\frac{45 \times 4.5}{2} + \frac{45 \times 9}{2}\right)\left(1.0\ g/g\right) = 304\ lbs.$$

SUPPORT C:

$$P_C = \left(\frac{\omega\, l_{BC}}{2}\right)\left(a_z/g\right) = \left(\frac{45 \times 9}{2}\right)\left(1.0\ g/g\right) = 203\ lbs.$$

B.) $a_z = 3.353\,g$

Same method as above

SUPPORT A:

$$P_A = \left(\frac{45 \times 4.5}{2}\right)(3.353) = 339\ lbs.$$

SUPPORT B:

$$P_B = \left(\frac{45 \times 4.5}{2} + \frac{45 \times 9}{2}\right)(3.353) = 1018\ lbs.$$

SUPPORT C:

$$P_C = \left(\frac{45 \times 9}{2}\right)(3.353) = 679\ lbs.$$

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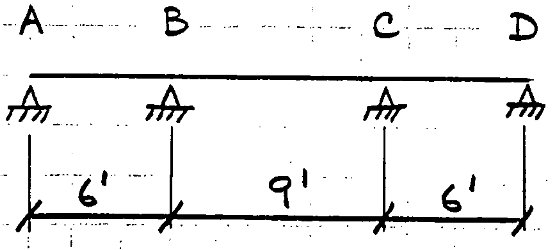
3SP150

CASE: 3SP150



$\omega = 45$ #/ft

$V_{BC} = 0.5\,\omega\,l_{BC} = 0.5(45)(9) = 203$#

$M_{BC} = .1\,\omega\,l_{BC}^2 = .1(45)(9)^2 = 364.5$ ft-lbs.

$V_{AB} = 0.5\,\omega\,l_{AB} + M_{BC}/l_{AB}$

$= 0.5(45)(6) + (364.5)/6 = 196$#

$M_{AB} = \text{Maximum}\left\{.125\,\omega\,l_{AB}^2\ ;\ .1\,\omega\,l_{BC}^2\right\}$

$= \text{maximum}\left\{1/8(45)(6)^2 = 202.5\ ;\ 364.5\right\}$

$= 364.5$ ft-lbs.

$V_{CD} = V_{AB} = 196$# (due to symmetry)

$M_{CD} = M_{AB} = 364.5$ ft-lbs (due to symmetry)

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3SP150

SUMMARY For $a_z = 3.353\,g$

$M_{AB} = 364.5 \times 3.353 = 1222$ ft-lbs

$M_{BC} = 364.5 \times 3.353 = 1222$ ft-lbs

$M_{CD} = 364.5 \times 3.353 = 1222$ ft-lbs

$V_{AB} = 196 \times 3.353 = 657$#

$V_{BC} = 203 \times 3.353 = 681$#

$V_{CD} = 196 \times 3.353 = 657$#

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3SP150 CONTINUED

DETERMINE SUPPORT LOADS:

A.) $a_z = 1.0g$

SUPPORT A:

$$P_A = (\omega)\left(\frac{l_{AB}}{2}\right)\left(a_z/g\right) = \left(45\ \#/ft\right)\left(\frac{6\ ft}{2}\right)\left(1.0g/g\right) = 135\ lbs.$$

SUPPORT B:

$$P_B = (\omega)\left(\frac{l_{AB}+l_{BC}}{2}\right)\left(a_z/g\right) = 45\left(\frac{6+9}{2}\right)\left(1.0\,g/g\right) = 338\ lbs.$$

SUPPORT C:

$$P_C = (\omega)\left(\frac{l_{BC}+l_{CD}}{2}\right)\left(a_z/g\right) = 45\left(\frac{9+6}{2}\right)\left(1.0g/g\right) = 338\ lbs$$

SUPPORT D:

$$P_D = (\omega)\left(\frac{l_{CD}}{2}\right)\left(a_z/g\right) = 45\left(\frac{6}{2}\right)\left(1.0g/g\right) = 135\ lbs.$$

B.) $a_z = 3.353g$ Same method as above

SUPPORT A:

$$P_A = 45\left(\frac{6}{2}\right)(3.353) = 453\ lbs$$

SUPPORT B:

$$P_B = 45\left(\frac{6+9}{2}\right)(3.353) = 1132\ lbs.$$

SUPPORT C:

$$P_C = 45\left(\frac{9+6}{2}\right)(3.353) = 1132\ lbs.$$

SUPPORT D:

$$P_D = 45\left(\frac{6}{2}\right)(3.353) = 453\ lbs.$$

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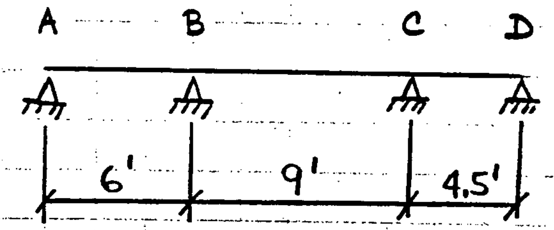
3SPMIX

CASE : 3SPMIX



$w = 45\ \#/ft$

$V_{BC} = 0.5\, w\, \ell_{BC} = 0.5\,(45)(9) = 202.5\#$

$M_{BC} = 0.1\, w(\ell_{BC})^2 = 0.1\,(45)(9)^2 = 364.5$ ft-lb

$V_{AB} = 0.5\, w\, \ell_{AB} + \frac{.1\, w(\ell_{BC})^2}{\ell_{AB}}$

$= 0.5\,(45)(6) + (364.5)/6 = 195.75\#$

$V_{CD} = 0.5\, w\, \ell_{CD} + \frac{.1\, w(\ell_{BC})^2}{\ell_{CD}}$

$= 0.5\,(45)(4.5) + (364.5)/4.5 = 182.25\#$

$\frac{1}{8} w(\ell_{AB})^2 = \frac{1}{8}(45)(6)^2 = 202.5$ ft-lb

$\frac{1}{8} w(\ell_{CD})^2 = \frac{1}{8}(45)(4.5)^2 = 113.9$ ft-lb

$.1\, w(\ell_{BC})^2 = 364.5$ ft-lbs

$M_{AB} = \text{MAXIMUM}\left\{\frac{1}{8} w(\ell_{AB})^2 ; .1\, w(\ell_{BC})^2\right\} = 364.5$ ft-lbs

$M_{CD} = \text{MAXIMUM}\left\{\frac{1}{8} w(\ell_{CD})^2 ; .1\, w(\ell_{BC})^2\right\} = 364.5$ ft-lbs

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3SPMIX

SUMMARY for $a_z = 3.353$ g

$M_{AB} = 364.5 \times 3.353 = 1222$ ft-lbs

$M_{BC} = 364.5 \times 3.353 = 1222$ ft-lbs

$M_{CD} = 364.5 \times 3.353 = 1222$ ft-lbs

$V_{AB} = 196 \times 3.353 = 657$#

$V_{BC} = 202.5 \times 3.353 = 679$#

$V_{CD} = 182 \times 3.353 = 610$#

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3SPMIX CONTINUED

DETERMINE SUPPORT LOADS:

A.) $a_z = 1.0\,g$

SUPPORT A:

$$P_A = (w)\left(\frac{\ell_{AB}}{2}\right)\left(a_z/g\right) = \left(45\,\#/ft\right)\left(\frac{6\ ft}{2}\right)\left(1.0g/g\right) = 135\ lbs.$$

SUPPORT B:

$$P_B = (w)\left(\frac{\ell_{AB}+\ell_{BC}}{2}\right)\left(a_z/g\right) = 45\left(\frac{6+9}{2}\right)\left(1.0\,g/g\right) = 338\ lbs.$$

SUPPORT C:

$$P_C = (w)\left(\frac{\ell_{BC}+\ell_{CD}}{2}\right)\left(a_z/g\right) = 45\left(\frac{9+4.5}{2}\right)\left(1.0\,g/g\right) = 304\ lbs$$

SUPPORT D:

$$P_D = (w)\left(\frac{\ell_{CD}}{2}\right)\left(a_z/g\right) = 45\left(\frac{4.5}{2}\right)\left(1.0\,g/g\right) = 101\ lbs.$$

B.) $a_z = 3.353\,g$ Same method as above

SUPPORT A:

$$P_A = 45\left(\frac{6}{2}\right)(3.353) = 453\ lbs$$

SUPPORT B:

$$P_B = 45\left(\frac{6+9}{2}\right)(3.353) = 1132\ lbs.$$

SUPPORT C:

$$P_C = 45\left(\frac{9+4.5}{2}\right)(3.353) = 1018\ lbs.$$

SUPPORT D:

$$P_D = 45\left(\frac{4.5}{2}\right)(3.353) = 339\ lbs.$$

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15. CALCULATIONS AND DISCUSSION OF RESULTS FOR SYSTEMS WITH ELBOWS AND TEE FITTINGS

This section is arranged as follows:

A. MDF Solutions for Systems ELBTEE1 and ELBTEE2.

B. 2DF Solutions for Systems ELBTEE1 and ELBTEE2

C. Comparison of Results

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A. MDF SOLUTIONS FOR

SYSTEMS

ELBTEE1 & ELBTEE2

- Response spectrum method of analysis is used for all MDF results. Program GTSTRUDL Vers.8701CDC
- 1g- flat spectrum of Page 3.12 used to excite system separately in x, y, and z directions.
- ELBTEE1 analyzed for x & z (horizontal) directions. ELBTEE2 is analyzed for y (vertical) direction.
- CQC method is used to combine maximum modal responses.
- Detailed results are Presented for each direction of excitation
- Characteristics of finite element model are summarized on next two pages

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A.1 MDF for ELBTEE1

MDF Analysis was performed using GTSTRUDL Vers. 8701CDC

SECTION PROPERTIES OF 36" x 24" DUCT

$A_x = 1.92\ in^2$ ✓

$A_y = 1.44\ in^2$ ✓

$A_z = 2.15\ in^2$ ✓

$I_x = 744\ in^4$ ✓

$I_y = 126.4\ in^4$ ✓

$I_z = 51.1\ in^4$ ✓

SUPPORT STIFFNESSES (modeled as linear springs)

For $S_1, S_2, S_3, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}$:

$K_{Fx} = 37.04$ k/in ✓ $K_{Fy} = 4658$ k/in ✓ $K_{Fz} = 30.75$ k/in ✓

$K_{mx} = 779.2$ in-k/deg ✓ $K_{my} = 198.9$ in-k/deg ✓ $K_{mz} = 30120$ in-k/deg ✓

For $S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}$:

$K_{Fx} = 30.75$ k/in ✓ $K_{Fy} = 4658$ k/in $K_{Fz} = 37.04$ k/in ✓

$K_{mx} = 30120$ in-k/deg ✓ $K_{my} = 198.9$ in-k/deg $K_{mz} = 779.2$ ✓

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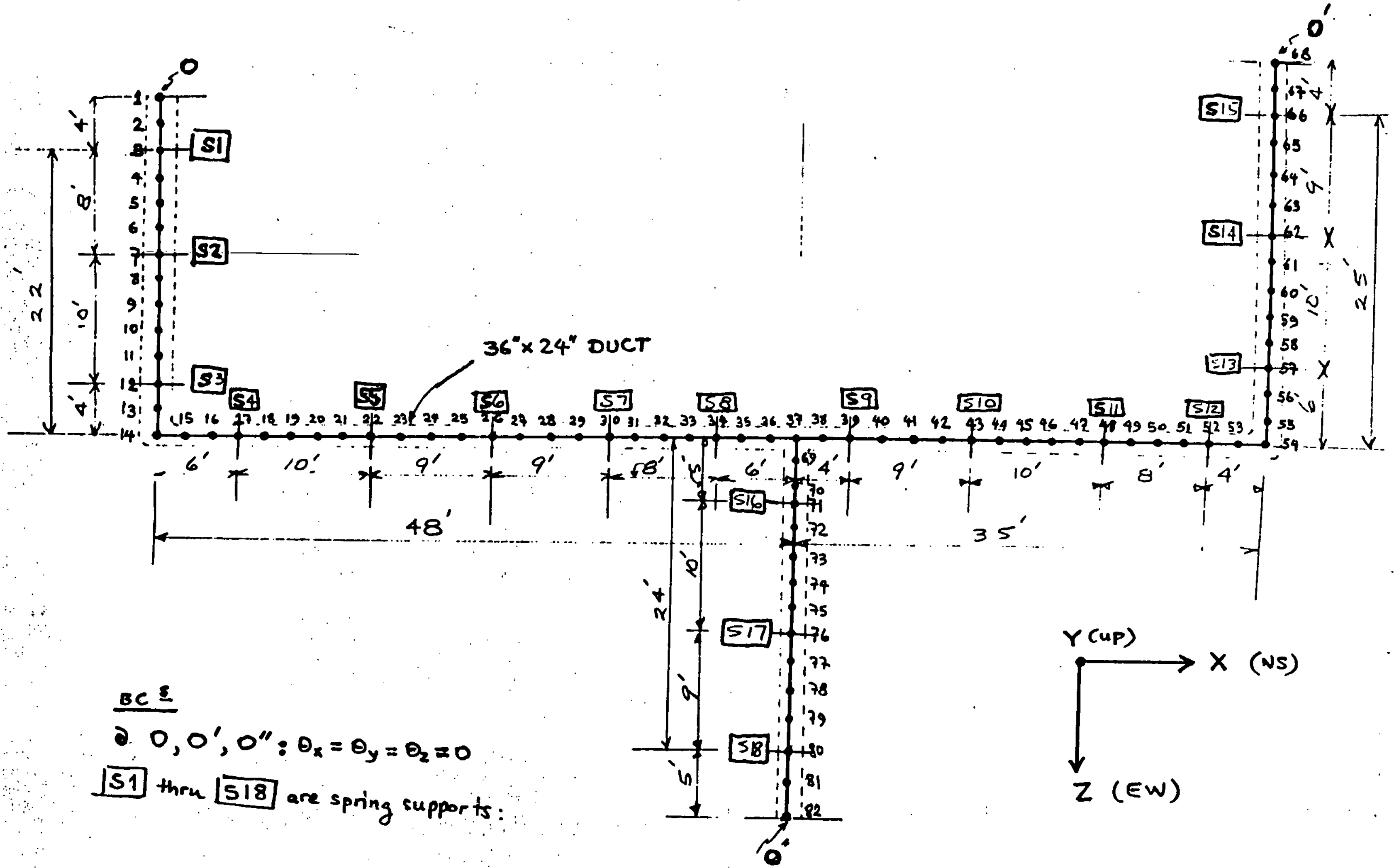
Nodalized FEM model for ELBTEE1



BC's
@ 0, 0', 0": $\theta_x = \theta_y = \theta_z = 0$

S1 thru S18 are spring supports:

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A.2 ELBTEE1

X-DIRECTION RESPONSE TO FLAT 1-g EXCITATION

REFERENCE RUN: INDF 1/18/91

Input File = DT2FXI
Output File = DT2FX

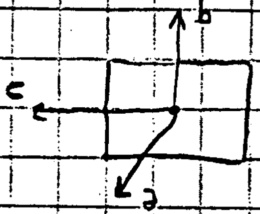
1st Contributing Mode No = 1

freq. = 23.1 cps

% of X-Direction Mass Participation $\left(\sum_x \gamma_i^2\right)$ = 99.985 %
for 18 modes
f_{18} = 48.6 CPS

Left Elbow

DUCT FORCES



(max. of nodes 12 thru 17)

F_a = 0.0862 ✓ (Between 16 & 17)

F_b = 0 ✓

F_c = 0.172 ✓ (Between 12 & 13)

M_a = 0 ✓

M_b = 3.68 ✓ (at 14)

M_c = 0 ✓

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S_3 (@ Node 12)

	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 12	0.0161	0	0.00160	0	0.00451	0
Support Stiffnesses	37.04	4658	30.75	779.2	198.9	30123
	F_c	F_b	F_a	M_a	M_b	M_c
Support Forces	0.596	0	0.0492	0	0.897	0

Support Leg Forces

$$R_x = \frac{F_c}{2} = \frac{0.596}{2} = 0.298 \text{ k}$$

$$M_z = R_x \times \frac{66}{2} = 9.83 \text{ in-k}$$

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Approved by		Date

S_4 (@ Node 17)

	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 17	0.01894	0	0.0021	0	0.00129	0
Support Stiffness	30.75	4658	37.04	30123	198.9	779.2
	F_a	F_b	F_c	M_a	M_b	M_c
Support Forces (= Kδ)	0.582	0	0.0778	0	0.257	0

Support Leg Forces

$$R_x = \frac{F_a}{2} + \frac{M_b}{W} = \frac{0.582}{2} + \frac{0.257}{38.5} = 0.298 \text{ k}$$

$$M_z = R_x \times l_e = 0.298 \times \frac{66}{2} = 9.83 \text{ in-k}$$

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Reviewed by	A-Ali Dabbagh	Date 1/24/91
Approved by		Date

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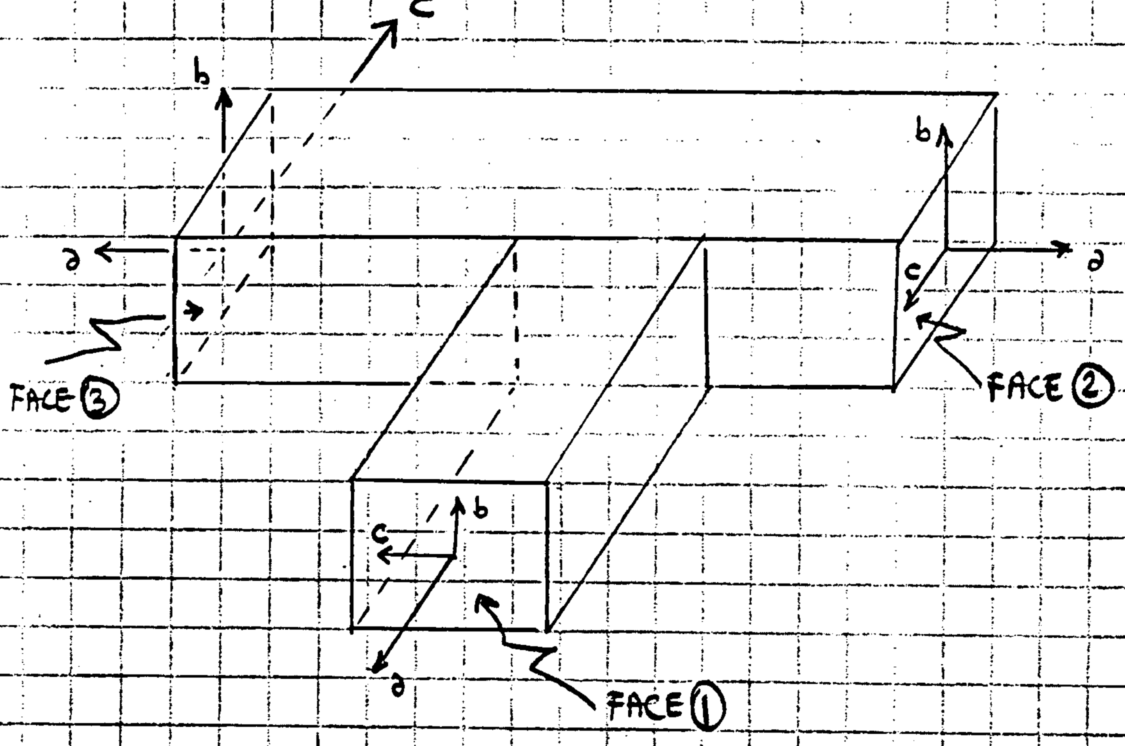

Face		Fa	Fb	Fc	Ma	Mb	Mc
1	(max. of 37, 62, 70, 71)	0.00776 ✓ (@ 37)	0 ✓	0.178 ✓ (70 & 71)	0 ✓	4.43 ✓ (@37)	0 ✓
2	(max. of 37, 38, 39)	0.0982 ✓ (@39)	0 ✓	0.0226 ✓ (@ 39)	0 ✓	2.07 ✓ (@37)	0 ✓
3	(max. of 34 thru 37)	0.111 ✓ (@34)	0 ✓	0.0232 ✓ (@ 34)	0 ✓	2.44 ✓ (@37)	0 ✓

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Approved by		Date

S_8 (@ Node 34)

	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 34	0.01886 ✓	0	0.001204	0 ✓	0.000397	0 ✓
Support Stiffness	30.75	4658	37.04	30123.	198.9	779.2
	(F_a)	(F_b)	(F_c)	(M_a)	(M_b)	(M_c)
Support Forces	0.580 ✓	0 ✓	0.0446	0 ✓	0.079	0 ✓

Support Leg Forces

$$R_x = \frac{F_a}{2} + \frac{M_b}{W} = \frac{0.580}{2} + \frac{0.079}{38.5} = 0.292 \text{ k}$$

$$M_z = R_x \cdot \ell_e = 0.292 \times \frac{66}{2} = 9.64 \text{ in-k}$$

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S_9 (@ Node 39)

	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 39	0.01887 ✓	0 ✓	0.000929 ✓	0 ✓	0.00098 ✓	0 ✓
Support Stiffness	30.75	4658	37.04	30123	198.9	779.2
	(F_a)	(F_b)	(F_c)	(M_a)	(M_b)	(M_c)
Support Forces	0.580 ✓	0 ✓	0.034 ✓	0 ✓	0.195 ✓	0 ✓

Support Leg Forces

$$R_x = \frac{F_a}{2} + \frac{M_b}{W} = \frac{0.580}{2} + \frac{0.195}{38.5} = 0.295 \text{ k}$$

$$M_z = R_x \cdot l_e = 0.295 \times \frac{66}{2} = 9.74 \text{ in-k}$$

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Reviewed by	A-Al Dabbagh	Date	1/24/91
Approved by		Date	

Support S_{16} (@ Node 71)

	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 71	0.01612 ✓	0 ✓	0.000256 ✓	0 ✓	0.00331 ✓	0
Support Stiffness	37.04 ✓	4658	30.75 ✓	779.2 ✓	198.9	30123. ✓
	(F_c)	(F_b)	(F_a)	(M_c)	(M_b)	(M_a)
Support Forces	0.597 ✓	0 ✓	0.0079 ✓	0 ✓	0.658 ✓	0

Leg Forces

$$R_x = \frac{F_c}{2} = \frac{0.597}{2} = 0.299 \text{ k} \checkmark$$

$$\checkmark$$

$$M_z = R_x \cdot l_e = 0.299 \times \frac{66}{2} = 9.85 \text{ in-k}$$

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MDF RESULTS (ELBTEE1)

EXCITATION DIRECTION : X

INPUT SPECTRUM : FLAT 1-g

Fitting	Component in Fitting	RESPONSES [inch, kips units]					
		DUCT				SUPPORT LEG	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.0862 ✓	0.172 ✓	3.68 ✓	0	—	—
	Support S3	—	—	—	—	0.298 ✓	9.83 ✓
	Support S4	—	—	—	—	0.298 ✓	9.83
Tee	Duct Face 1	0.00776 ✓	0.178 ✓	4.43 ✓	0	—	—
	Duct Face 2	0.0982 ✓	0.0226 ✓	2.07 ✓	0	—	—
	Duct Face 3	0.111 ✓	0.0272 ✓	2.44 ✓	0		
	Support S 8	—	—	—	—	0.292 ✓	9.64 ✓
	Support S9	—	—	—	—	0.295 ✓	9.74 ✓
	Support S16	—	—	—	—	0.299 ✓	9.85 ✓

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A.3 ELBTEE1

Z - DIRECTION RESPONSE TO FLAT 1-g EXCITATION

Reference Run : IPWC ✓ 1/18/91 ✓

Input File : DT2FZI

Output File : DT2FZ

1st Contributing Mode No = 2

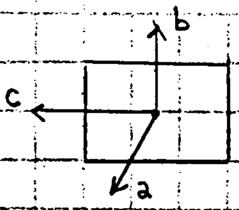
Freq. = 23.3 cps

% of Z-Direction Mass Participation $(\Sigma \gamma_i^2)$ = 99.964 %
for 18 modes

$f_{18} = 48.6$ cps

Left Elbow

DUCT FORCES



(max. of Nodes 12 thru 17)

$F_a = 0.104^k$ ✓ (Between 12 & 13)

$F_b = 0$ ✓

$F_c = 0.148^k$ ✓ (Between 16 & 17)

$M_a = 0$ ✓

$M_b = 3.903$ ✓ (at 17)

$M_c = 0$ ✓

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Reviewed by	A-Al-Dabbagh	Date 1/24/91
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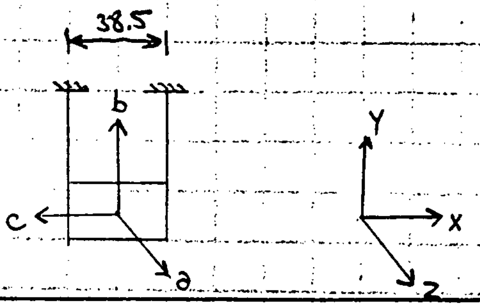
Support S_3 (@ NODE 12)



	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 12	0.00162 ✓	0 ✓	0.0189 ✓	0 ✓	0.00120 ✓	0 ✓
Support Stiffness	37.04 ✓	4658 ✓	30.75 ✓	779.2 ✓	198.9 ✓	30123 ✓
	F_c	F_b	F_a	M_c	M_b	M_a
Support Forces	0.06 ✓	0	0.581 ✓	0	0.239 ✓	0

Leg Forces

$$R_2 = \frac{0.581}{2} + \frac{0.239}{38.5} = 0.297 \text{ k} ✓$$

$$M_x = 0.297 \times \frac{66}{2} = 9.79 \text{ in-k} ✓$$

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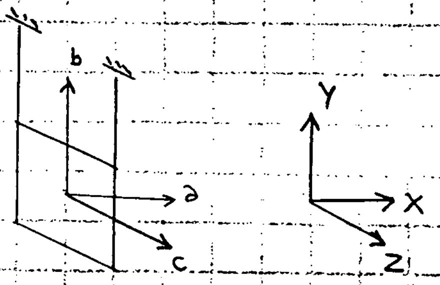
Support S_4 (@ NODE 17)



	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacements of Node 17	0.000168 ✓	0 ✓	0.0156 ✓	0 ✓	0.00421 ✓	0 ✓
Support Stiffness	30.75 ✓	4658	37.04 ✓	30123	198.9 ✓	779.2

	F_a	F_b	F_c	M_a	M_b	M_c
Support Forces $(= K \cdot \delta)$	0.005 ✓	0	0.578 ✓	0	0.837 ✓	0

Support Leg Forces

$$R_z = \frac{0.578}{2} = 0.289 \text{ k} ✓$$

$$M_x = 0.289 \times \frac{66}{2} = 9.54 \text{ in-k} ✓$$

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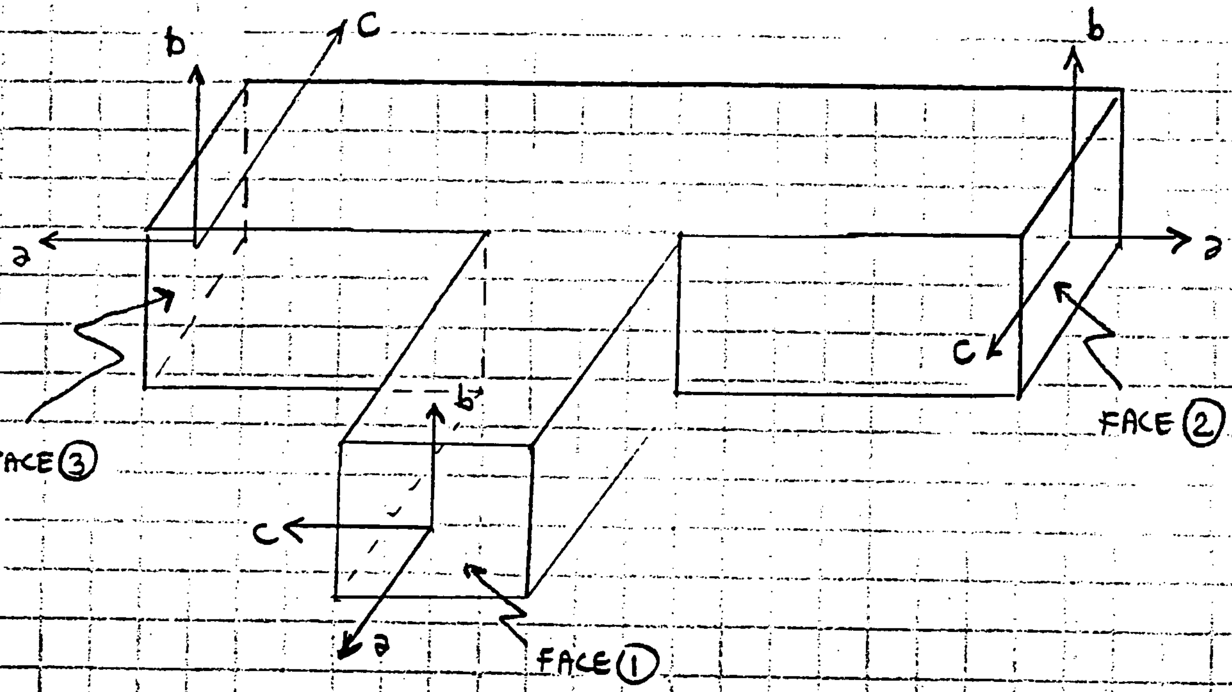
"T" (@ NODE 37) (Z-DIR)



DUCT FORCES (inch, kips units)

Face	F_a	F_b	F_c	M_a	M_b	M_c
① (max. of 37,69,70,71)	0.131 ✓ (@37-69)	0 ✓	0.006 ✓ (@70-71)	0 ✓	0.534 ✓ (@Node 37)	0 ✓
② (max. of 37,38,39)	0.0342 ✓ (@37-38)	0 ✓	0.214 ✓ (@38-39)	0 ✓	7.468 ✓ (@Node 37)	0 ✓
③ (max. of 34 thru 37)	0.0342 ✓ (@34-35)	0 ✓	0.197 ✓ (@34-35)	0 ✓	7.343 ✓ (@NODE 37)	0 ✓

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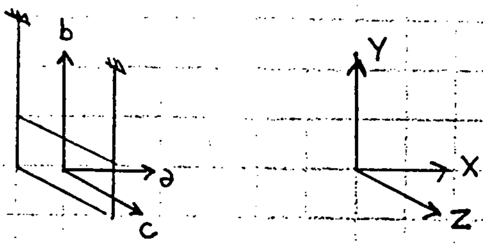
Support S_8 (@ NODE 34)



	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 34	0.000209 ✓	0 ✓	0.0156 ✓	0 ✓	0.00393 ✓	0 ✓
Support Stiffness	30.75 ✓	4658	37.04 ✓	30123	198.9 ✓	779.2
	F_a	F_b	F_c	M_a	M_b	M_c
Support Forces (= K.δ)	0.006 ✓	0	0.578 ✓	0	0.782 ✓	0

Support Leg Forces

$$R_z = \frac{0.578}{2} = 0.289 \text{ k} \checkmark$$

$$M_x = 0.289 \times \frac{66}{2} = 9.54 \text{ in-k} \checkmark$$

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Approved by	
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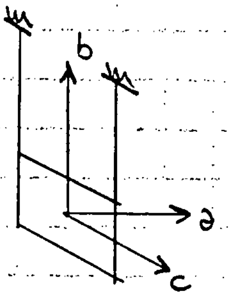
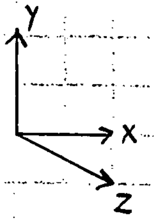
Support S_9 (@NODE 39)





	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacements of Node 39 (δ)	0.000262 ✓	0 ✓	0.0173 ✓	0 ✓	0.00299 ✓	0 ✓
Support Stiffnesses (k)	30.75 ✓	4658	37.04 ✓	30123	198.9 ✓	779.2
	F_a	F_b	F_c	M_a	M_b	M_c
Support Forces ($= k\delta$)	0.008 ✓	0	0.641 ✓	0	0.595 ✓	0

Support Leg Forces

$$R_z = \frac{0.641}{2} = 0.321 \text{ k} \checkmark$$

$$M_x = 0.321 \times \frac{66}{2} = 10.6 \checkmark \text{ in-k}$$

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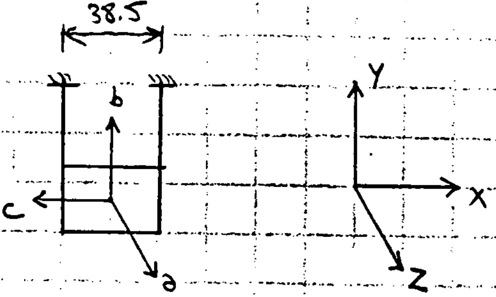
Support S_{16} (@ Node 71)



	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Displacement of Node 71 (δ)	0.000276 ✓	0 ✓	0.0191 ✓	0 ✓	0.000228 ✓	0 ✓
Support Stiffnesses (K)	37.04 ✓	4658	30.75 ✓	779.2	198.9 ✓	30123
	F_a	F_b	F_c	M_a	M_b	M_c
Support Forces (= K δ)	0.0102 ✓	0	0.587 ✓	0	0.0453 ✓	0

Support Leg Forces

$$R_z = \frac{0.587}{2} + \frac{0.0453}{38.5} = 0.295 \text{ k} \checkmark$$

$$M_x = 0.295 \times \frac{66}{2} = 9.72 \text{ in-k} \checkmark$$

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MDF RESULTS (ELBTEE1)

EXCITATION DIRECTION: Z

INPUT SPECTRUM: FLAT 1-8

Fitting	Component in Fitting	RESPONSES [inch, kips units]					
		DUCT				SUPPORT LEG	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.104 ✓	0.148 ✓	3.903 ✓	0	–	–
	Support S3					0.297 ✓	9.79 ✓
	Support S4					0.289 ✓	9.54 ✓
Tee	Duct Face1	0.131 ✓	0.006 ✓	0.534 ✓	0	–	–
	Duct Face2	0.0342 ✓	0.214 ✓	7.408 ✓	0	–	–
	Duct Face3	0.0342 ✓	0.197 ✓	7.343 ✓	0	–	–
	Support S8					0.289 ✓	9.54 ✓
	Support S9					0.321 ✓	10.60 ✓
	Support S16					0.295 ✓	9.72 ✓

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A.4 ELBTEE1

Y- DIRECTION Response

For this system first mode frequency, $f_1 = 23.1$ cps

frequency of mode 18 = 48.6 cps.

The mass participation factor in

y-direction $= \sum_{i=1}^{18} \gamma_i^2 = 0.1$

This shows the system is rigid in the y(vertical) response. For this reason System ELBTEE2 with characteristics of a cable tray as described in Section 10 and farther detailed in the following pages was analyzed to show the behavior of a system with elbows and tee under vertical dynamic excitation.

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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A.5 MDF for ELBTEE2

MDF Analysis was performed using GTSTRUDL Vers. 8701CDC

SECTION PROPERTIES OF 18" CABLE TRAY

$A_x = 0.658$ in² ✓

$A_Y = 0.478$ in² ✓

$A_Z = 0.179$ in² ✓

$IX = 1.34$ in⁴ ✓

$IY = 0.517$ in⁴ ✓

$IZ = 0.821$ in⁴ ✓

Weight = 45 lbs/ft ✓

Support Stiffnesses

For $S_1, S_2, S_3, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}$:

$K_{FX} = 37.04$ k/in ✓ K_{FY} = RIGID ✓ $F_{FZ} = 30.75$ k/in ✓

$K_{MX} = 0$ (FREE) ✓ $K_{MY} = 198.9$ in-k/degree ✓ $K_{MZ} = 30120$ in-k/deg. ✓

For $S_4, S_5, S_6, S_7, S_9, S_{10}, S_{11}, S_{12}$:

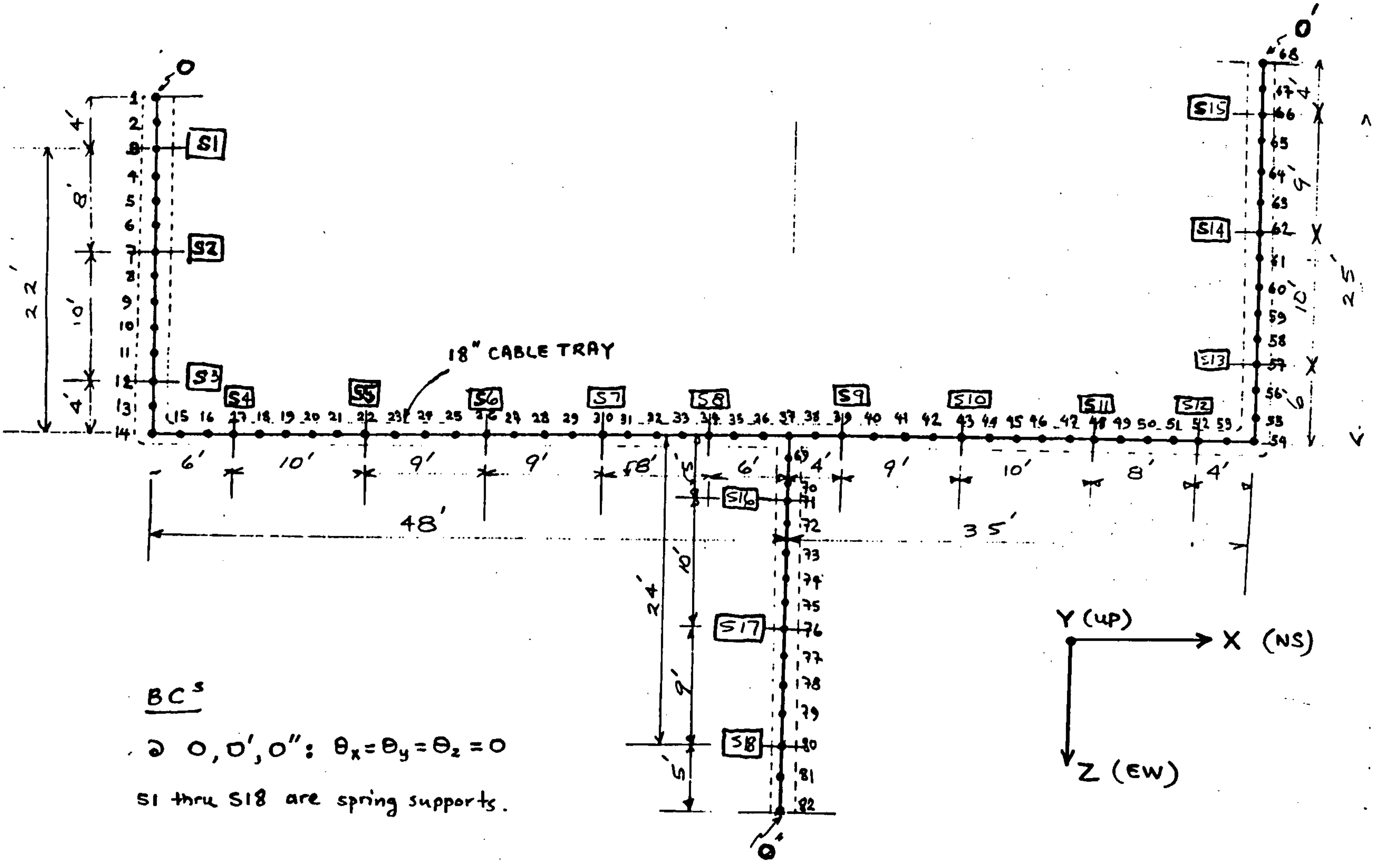
$K_{FX} = 30.75$ k/in ✓ K_{FY} = RIGID ✓ $F_{FZ} = 37.04$ k/in ✓

$K_{MX} = 30120$ in-k/deg ✓ $K_{MY} = 198.9$ in-k/deg ✓ $K_{MZ} = 0$ (FREE) ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

Form GO-3.08.1 Rev. 2

Nodalized FEM model for ELBTEE2



BCs

@ 0,0',0": $\theta_x = \theta_y = \theta_z = 0$

S1 thru S18 are spring supports.

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A.6 ELBTEE2

Y-DIRECTION RESPONSE TO FLAT 1-g EXCITATION

Reference Run : JPZL ✓ 1/23/91 ✓

Input File = CT2FYJ
Output File = CT2FY

1st Contributing Mode No = 1
Frequency = 4.64 ✓ cps

Last Contributing Mode No = 58 ✓

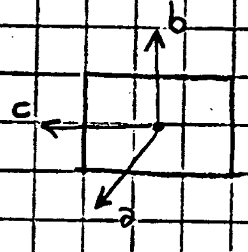
Frequency = 77.7 cps ✓

% OF Y DIRECTION MASS PARTICIPATION

$(\sum \gamma_i^2) = 99.517\ \%$ ✓

LEFT ELBOW

DUCT FORCES (max of nodes 12 thru 17)



$F_a = 0$

$F_b = 0.102^k$ ✓ (Between 12 & 13)

$F_c = 0$ ✓

$M_a = 0.666$ in-k ✓ (between 14–17)

$M_b = 0$ ✓

$M_c = 3.483$ in-k ✓ (@ NODE 12)

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M3599.001 6-90

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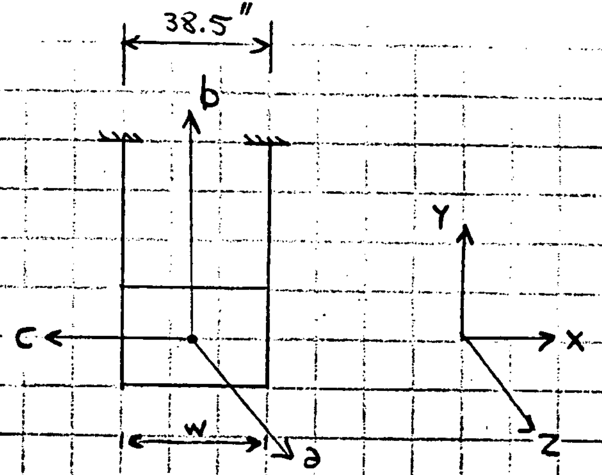
SUPPORT S_3 (@ NODE 12)

Support Forces



$F_a = F_z = 0$

$F_b = F_y = 0.229^k$ ✓

$F_c = F_x = 0$

$M_a = M_z = 0.566$ in-k ✓

$M_b = M_y = 0$

$M_c = M_x = 0$ in-k

SUPPORT LEG FORCES

$R_y = \left((\text{weight of support}) + F_b \right) / \overset{\text{two legs}}{2} + \left(\frac{M_a}{w} \right)$

$= (0.288 + 0.229)/2 + \frac{0.566}{38.5} = 0.273\,k$ ✓

$M_x = \frac{0}{2}$

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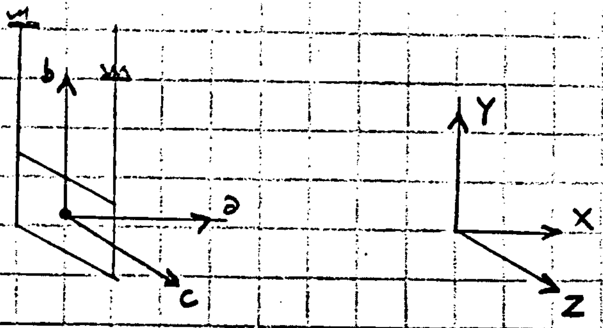
Approved by **Date**

Support S_4 (@ NODE 17)



Support Forces

$F_a = F_x = 0$ $M_a = M_x = 0.666$ in-k ✓

$F_b = F_y = 0.176$ k ✓ $M_b = M_y = 0$

$F_c = F_z = 0$ $M_c = M_z = 0$

Support Leg Forces

$$R_y = \left((\text{Weight of Supp}) + F_b\right)/2 + \frac{M_a}{38.5}$$

$$= (0.288 + 0.176)/2 + \frac{0.666}{38.5} = 0.249 \text{ k}$$ ✓

$$M_z = \frac{M_c}{2} = 0$$

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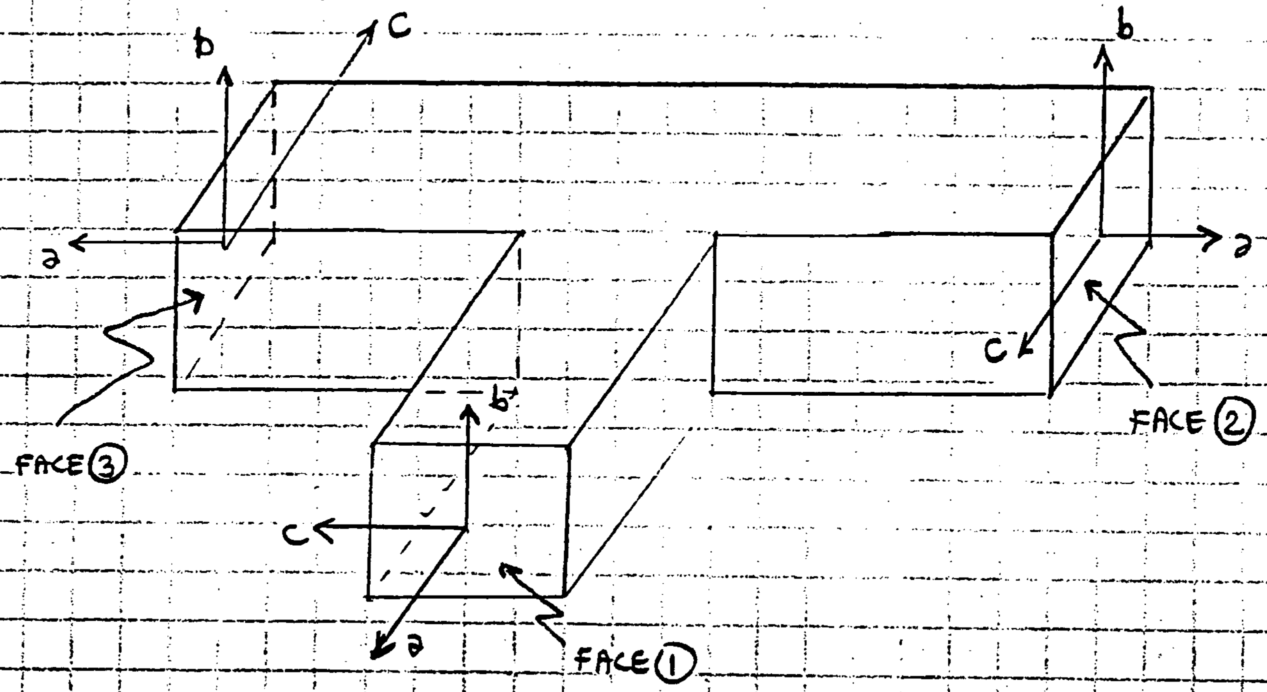
"T" (@ NODE 37)

CT2EY



DUCT FORCES

Face	F_a	F_b	F_c	M_a	M_b	M_c
① (max. of 37,69,70,71)	0 ✓	0.077 ✓ (@70-71)	0 ✓	0.226 ✓ (all)	0 ✓	2.47 ✓ (@71)
② (max. of 37,38,39)	0 ✓	0.125 ✓ (@38-39)	✓ 0	0.402 ✓ (all)	✓ 0	3.08 ✓ (@39)
③ (max. of 34 thru 37)	0	0.097 ✓ (@34-35)	0	0.268 ✓ (all)	0	3.21 ✓ (@34)

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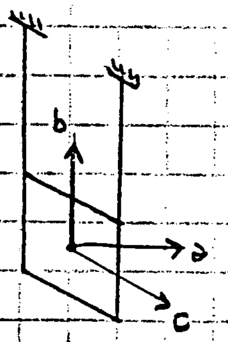
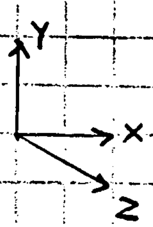
Support S_8 (@ NODE 34)





Support Forces

$F_a = F_x = 0$

$F_b = F_y = 0.272$ k

$F_c = F_z = 0$

$M_a = M_x = 0.268$ in-k

$M_b = M_y = 0$

$M_c = M_z = 0$

Support Leg Forces

$$R_y = (0.288 + 0.272)/2 + \frac{0.268}{38.5} = 0.287 \text{ k}$$

$$M_z = \frac{M_c}{2} = 0$$

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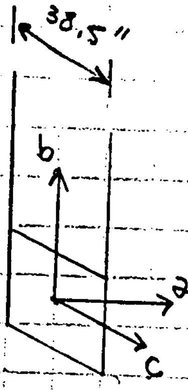
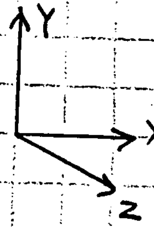
Support S_9 (@ NODE 39)





Support Forces

$F_a = F_x = 0$

$F_b = F_y = 0.256$ k ✓

$F_c = F_z = 0$

$M_a = M_x = 0.402$ in-k ✓

$M_b = M_y = 0$

$M_c = M_z = 0$

Support Leg Forces

$$R_y = (0.288 + 0.256)/2 + \frac{0.402}{38.5} = 0.282 \text{ k}$$ ✓

$$M_z = \frac{M_c}{2} = 0$$

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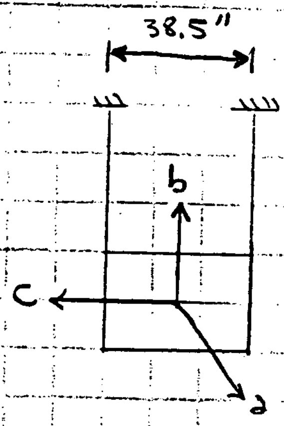
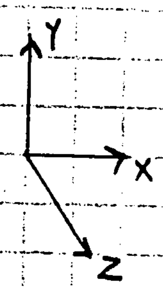
Support S_{16} (@ NODE 71)





Support Forces

$F_a = F_z = 0$

$M_a = M_z = 0.226$ in-k ✓

$F_b = F_Y = 0.178$ k ✓

$M_b = M_y = 0$

$F_c = F_x = 0$

$M_c = M_x = 0$

Support Leg Forces

$$R_y = (0.288 + 0.178)/2 + \frac{0.226}{38.5} = 0.239 \text{ k}$$ ✓

$$M_x = \frac{M_c}{2} = 0$$

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MDF RESULTS (ELBTEE2)

EXCITATION DIRECTION : Y

INPUT SPECTRUM : FLAT 1-g

Fitting	Component in Fitting	RESPONSES [inch, kips units]					
		DUCT				SUPPORT LEG	
		Axial	Shear	Moment	Torque	Axial	Moment
Elbow 1	Duct	0	0.102 ✓	3.48 ✓	0.666 ✓	—	—
	Support S3	—	—	—	—	0.273 ✓	0
	Support S4	—	—	—	—	0.249 ✓	0
Tee	Duct Face 1	0	0.077 ✓	2.47 ✓	0.226 ✓	—	—
	Duct Face 2	0	0.125 ✓	3.08 ✓	0.402 ✓	—	—
	Duct Face 3	0	0.097 ✓	3.21 ✓	0.268 ✓	—	—
	Support S 8	—	—	—	—	0.287 ✓	0
	Support S9	—	—	—	—	0.282 ✓	0
	Support S16	—	—	—	—	0.239 ✓	0

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B. 2DF CALCULATIONS FOR SYSTEMS ELBTEE1 & ELBTEE2

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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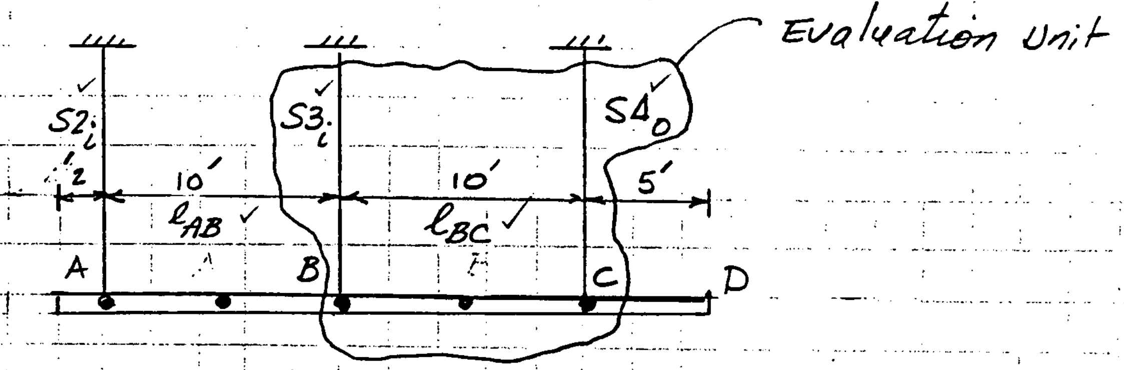
B.1 SYSTEM ELBTEE1

Elbow 1; X-Excitation



Support Effective Wt.

[illegible] 288 # [illegible]

Wt. of Duct / Foot

For 36"x24" Duct = 31 #/foot (insulated)

Support stiffness

$K_A = K_{S2i} = 37.04$ k/in

$K_B = K_{S3i} = 37.04$ k/in

$K_C = K_{S4o} = 30.75$ k/in

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Masses

$$m_{1B} = \frac{\left(\frac{10}{4} + \frac{10}{4}\right) .031 + .288}{g} = \frac{0.443}{g} ✓$$

$$m_{1C} = \frac{\left(\frac{10}{4} + \overset{✓}{5}\right) .031 + .288}{g} = \frac{0.521}{g} ✓$$

Frequencies

$$\omega_{1BS} = \sqrt{\frac{k_B}{m_{1B}}} = \sqrt{\frac{37.04 \times 386.4}{0.443}} = 179.74 \ R/S ✓$$

$$\omega_{1CS} = \sqrt{\frac{k_C}{m_{1C}}} = \sqrt{\frac{30.75 \times 386.4}{0.521}} = 151.0 \ R/S$$

$$\omega_{1S} = \min(\omega_{1BS}, \omega_{1CS}) = 151.0 \ R/S ✓$$

$$m_1 = \min(m_{1B}, m_{1C}) = \frac{0.443}{g} ✓$$

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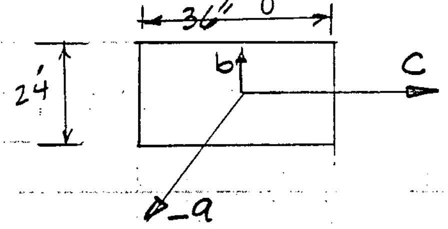
Duct Frequencies



Analysis Section properties per WB-DC-31.8 Rev. 7

$I_{aa} = 744.0\ in^4$ $A_{aa} = 1.92\ in^2$

$I_{bb} = 126.4\ in^4$ $A_{bb} = 1.44\ in^2$

$I_{cc} = 51.1\ in^4$ $A_{cc} = 2.15\ in^2$

$$K_{AB} = \frac{48EI}{(L_{AB})^3} = \frac{48 \times 29000 \times 126.4}{(120)^3} = 101.8\ k/in$$

$$K_{BC} = \frac{48EI}{(L_{BC})^3} = \text{''} = 101.8\ k/in$$

Duct masses

$$m_{AB} = \frac{5 \times .031}{g} = \frac{0.155}{g}$$

$$m_{BC} = \frac{5 \times .031}{g} = \frac{0.155}{g}$$

$$\omega_{BC} = \sqrt{\frac{k_{BC}}{m_{BC}}} = \sqrt{\frac{101.8 \times 386.4}{0.155}} = 503.8\ R/s$$

$$\omega_2 = 503.8\ R/S$$

$$m_2 = \frac{W_{AB} + W_{BC}}{2g} = \frac{0.155}{g}$$

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mass Ratio.

$$\mu = \frac{m_2}{m_1} = \frac{0.155}{0.443} = 0.35$$

System Frequency

$$\omega_s^2 = 0.5\left\{\left[\omega_1^2 + (1+\mu)\omega_2^2\right] - \sqrt{\left[\omega_1^2 + (1+\mu)\omega_2^2\right]^2 - 4\omega_1^2\omega_2^2}\right\}$$

$$\omega_1^2 + (1+\mu)\omega_2^2 = (151.0)^2 + 1.35(503.8)^2 = 3.6545 \times 10^5$$

$$\omega_s^2 = 0.5\left\{3.6545 \times 10^5 - \sqrt{(3.6545 \times 10^5)^2 - 4(151.0)^2(503.8)^2}\right\}$$

$\omega_s^2 = 16589$ $f = 9.0$ $a = 2.63$

$\omega_s = 128.8$ R/S $f = 20.0$ $a = 2.16$

$$f = \frac{\omega_s}{2\pi} = 20.5 \text{ cps}$$

$$\frac{\log 33.3 - \log 20.5}{\log 33.3 - \log 20.0} = \frac{1.20 - a}{1.20 - 2.16}$$

$$0.9516(-0.96) - 1.20 = -a$$

$a = 2.11$ g (see next page)

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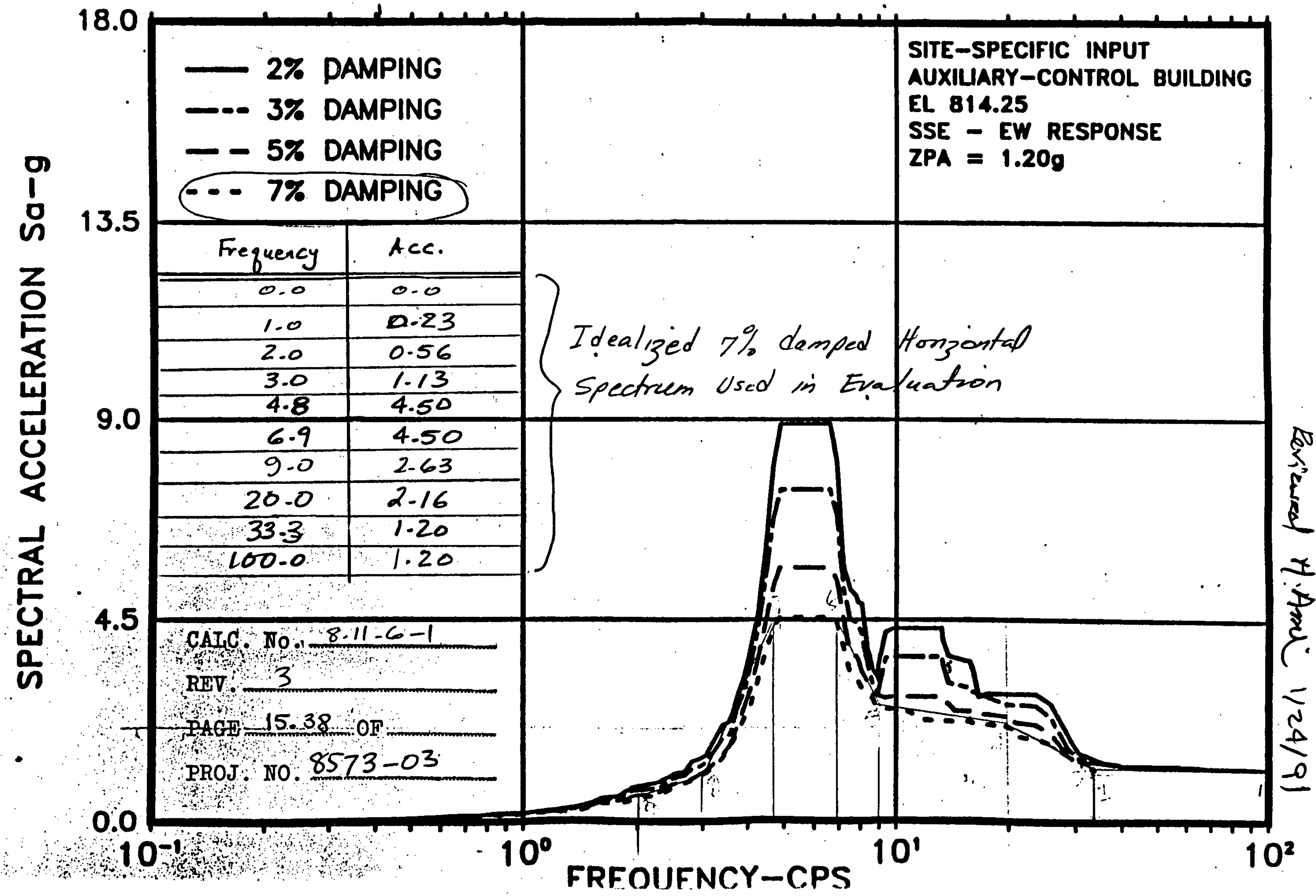
Spectra Used in Evaluation

1. For the horizontal acceleration, the EW spectrum (7% damped) for Elev. 814.25' of the Aux-Control building is idealized as shown on the next page.

2. For the Vertical acceleration, the Vertical Spectrum (7% damped) for the same elvation as above. The idealized values are show on the page following the next page.

Since Final MDF solutions are presented for 1g flat spectrum, the spectrum specific results here are for general information only,

TVA WATTS BAR UNIT 1 EVALUATION ARS



Frequency	Acc.
0.0	0.0
1.0	0.23
2.0	0.56
3.0	1.13
4.8	4.50
6.9	4.50
9.0	2.63
20.0	2.16
33.3	1.20
100.0	1.20

Idealized 7% damped Horizontal Spectrum Used in Evaluation

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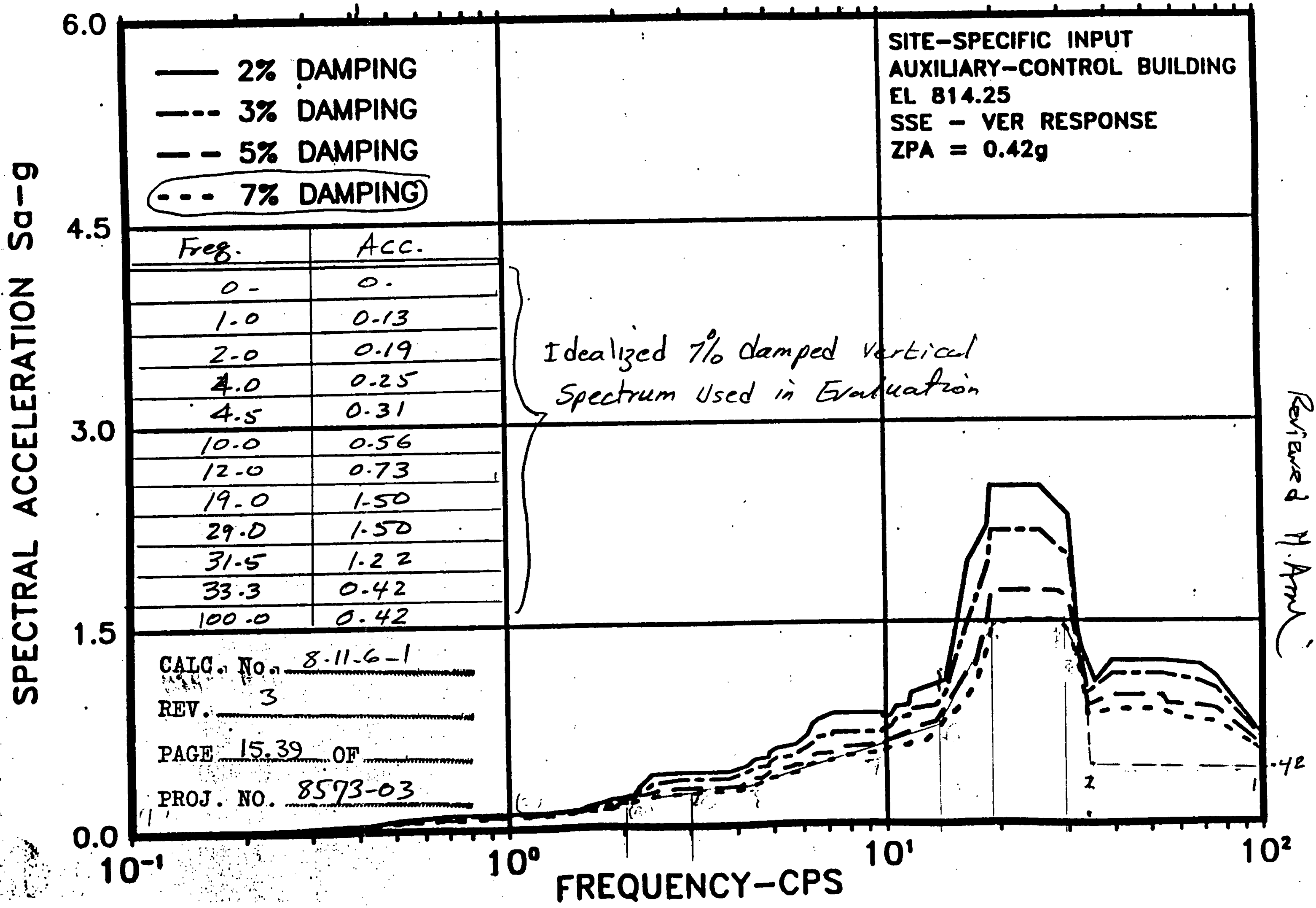
Reviewed H. Amir 1/24/91

TVA WATTS BAR UNIT 1 EVALUATION ARS



Freq.	Acc.
0.	0.
1.0	0.13
2.0	0.19
4.0	0.25
4.5	0.31
10.0	0.56
12.0	0.73
19.0	1.50
29.0	1.50
31.5	1.22
33.3	0.42
100.0	0.42

Idealized 7% damped vertical Spectrum Used in Evaluation

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QIR-CEB-WBN-89-345 R0

Prepared by: A. Abdullah 11/15/91

Reviewed M. Ami

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Determine Forces

Duct Bending $= 0.1\, w\, a\, l^2$

$= 0.10 \times .031 \times 2.11\,(120)(10)$

$= 7.85$ in-k ✓ $(3.72 \text{ in-k})^*$ ✓

Duct shear $= 0.5\, w\, a\, l$

$= 0.5 \times .031 \times 2.11\,(10)$

$= 0.327\,k$ ✓ $(0.155^k)^*$ ✓

Duct axial Force $= 0.5\,(10 \times .031)\,2.11$

$= 0.327\,k$ ✓ $(0.155^k)^*$ ✓

Support S_3 Force $= \left[\dfrac{W_{AB} + W_{BC}}{2} + W_{S3}\right] a$

$= \left[\left(\dfrac{10+10}{2}\right).031 + 0.288\right] 2.11$

$= 1.262\,k \quad (0.598^k)^*$

Support S_4 Force $= \left[\left(\dfrac{W_{BC}+W_{CD}}{2}\right) + W_{S4}\right] a$

$= \left[\left(\dfrac{10}{2}+5\right).031 + .288\right] 2.11$

$= 1.262\,k \quad (0.598)^{k*}$

* These are values corresponding to acceleration of 1.0g

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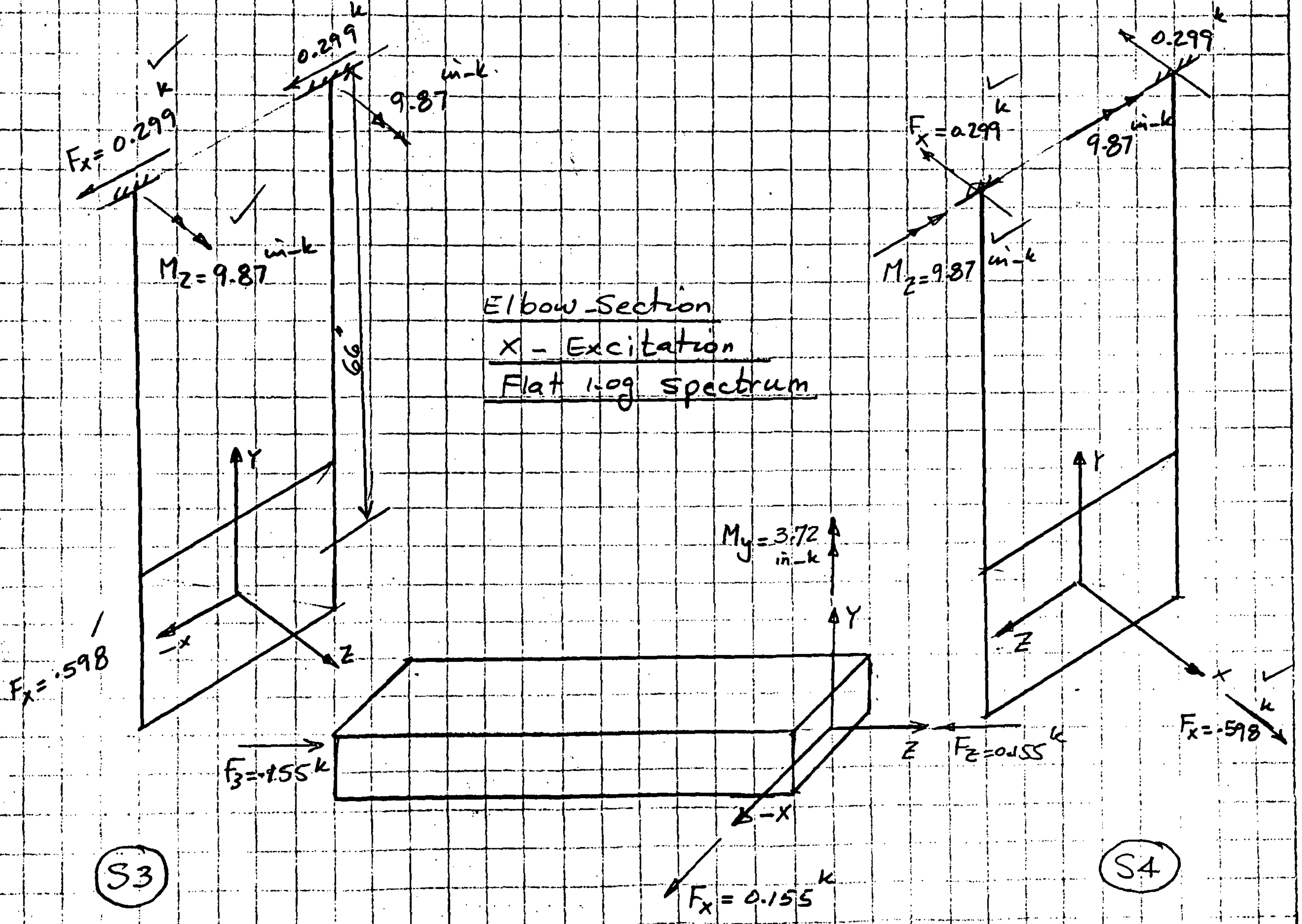
Elbow Section

X - Excitation

Flat 1.0g spectrum



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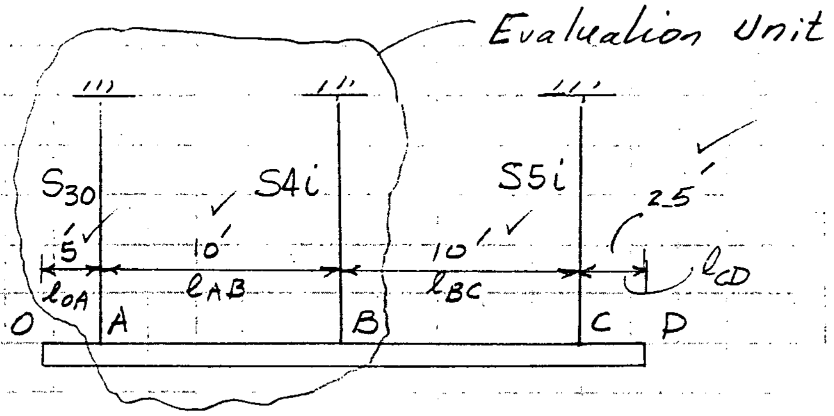
Elbow 1, Z-Excitation



Support Stiffness

$K_A = K_{S30} = 30.75$ k/in

$K_B = K_{S4i} = 37.04$ k/in

$K_C = K_{S5i} = 37.04$ k/in

masses

$$m_{1A} = \frac{\left(5 + \frac{10}{4}\right)0.031 + 0.288}{g} = \frac{0.521}{g}$$

$$m_{1B} = \frac{\left(\frac{10}{4} + \frac{10}{4}\right).031 + 0.288}{g} = \frac{0.443}{g}$$

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Support Frequencies 7

$$\omega_{1AS} = \sqrt{\frac{k_A}{m_{1A}}} = \left[\frac{30.75 \times 386.4}{0.521}\right]^{1/2} = 151.0 \ R/S$$ ✓

$$\omega_{1BS} = \sqrt{\frac{k_B}{m_{1B}}} = \left[\frac{37.04 \times 386.4}{0.443}\right]^{1/2} = 179.74 \ R/S$$ ✓

$$\omega_{1S} = \min\left(\omega_{1AS}, \omega_{1BS}\right) = 151.0 \ R/S$$ ✓

$$m_1 = \min\left(m_{1A}, m_{1B}\right) = \frac{0.443}{g}$$ ✓

Duct masses

$$m_{AB} = \left(\frac{10}{2}\right)\frac{.031}{g} = \frac{0.155}{g}$$ ✓

$$m_{BC} = \left(\frac{10}{2}\right)\frac{.031}{g} = \frac{0.155}{g}$$ ✓

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Duct Stiffness

$$k_{AB} = \frac{48EI}{\ell_{AB}^3} = \frac{48 \times 29000 \times 126.4}{(120)^3} = 101.8 \text{ k/in}$$

$$k_{BC} = \frac{48EI}{\ell_{BC}^3} = \text{''} = 101.8 \text{ k/in}$$

Duct Frequencies

$$\omega_{AB} = \sqrt{\frac{K_{AB}}{m_{AB}}} = \sqrt{\frac{101.8 \times 386.4}{0.155}} = 503.8 \text{ R/s}$$

$$\omega_2 = 503.8 \text{ R/s}$$

$$m_2 = \frac{W_{AB} + W_{BC}}{2g} = \frac{0.155}{g}$$

Frequencies & mass Ratio

$$\omega_1 = 151.0 \text{ R/s} \qquad \omega_2 = 503.8 \text{ R/s}$$

$$\mu = \frac{m_2}{m_1} = \frac{0.155}{0.443} = 0.35$$

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\,\omega_2^2 = (151.0)^2 + 1.35\,(503.8)^2 = 3.6545 \times 10^5$$

$$\omega_s^2 = 0.5 \left\{ \alpha - \sqrt{\alpha^2 - 4\,\omega_1^2\,\omega_2^2} \right\}$$

$$= 0.5 \left\{ 3.6545 \times 10^5 - \sqrt{(3.6545 \times 10^5)^2 - 4(151.0)^2(503.8)^2} \right\}$$

$$\omega_s^2 = 16589$$

$$\omega_s = 128.8 \text{ R/s}$$

$$f_s = 20.5 \text{ cps}$$

$$a = 2.11\,g$$

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10

Determine Forces

Duct Bending $= 0.1\,wa\ell^2 = 0.1 \times .031 \times 2.11\,(120)(10)$

$= 7.85$ in-k $\quad (3.72 \text{ in-k})^*$

Duct shear $= 0.5\,wa\ell$

$= 0.5 \times .031 \times 2.11 \times 10 = 0.327^k, \ (0.155^k)^*$

Duct Axial Force $= \frac{1}{2}(0.031 \times 10')\,2.11$

$= 0.327^k \quad (0.155^k)^*$

Support S_4 Force $= \left[\frac{W_{AB} + W_{BC}}{2} + W_{S4}\right] a$

$= [10 \times .031 + .288]\,2.11 = 1.262^k, \ (0.598^k)^*$

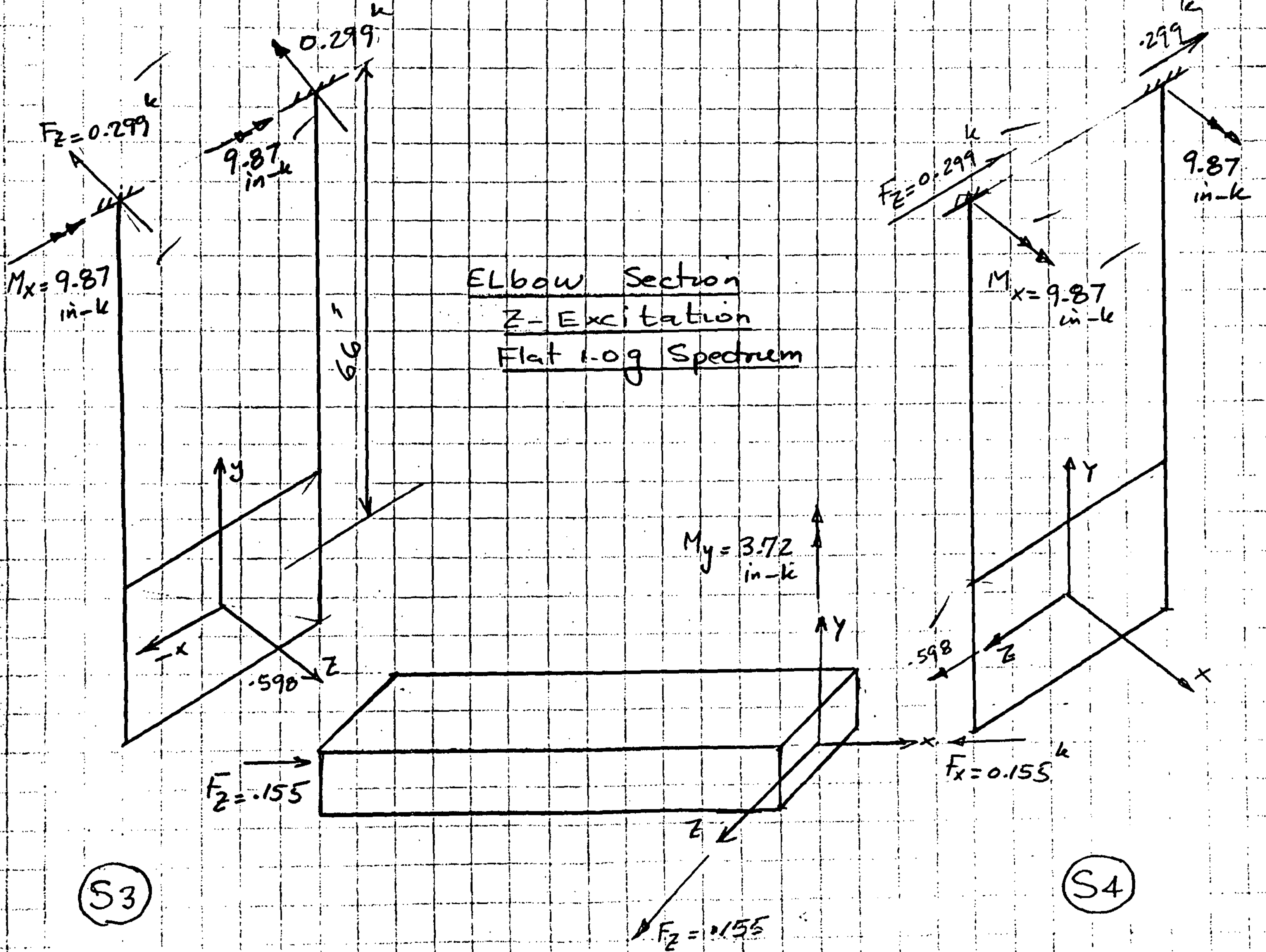
Support S_3' Force $= \left[W_{OA} + \frac{W_{AB}}{2} + W_{S3}\right] a$

$= [10 \times .031 + 0.288]\,2.11$

$= 1.262$ k $\quad (.598^k)^*$

* These values correspond to acceleration of 1.0g

Elbow Section
Z-Excitation
Flat 1.0g Spectrum



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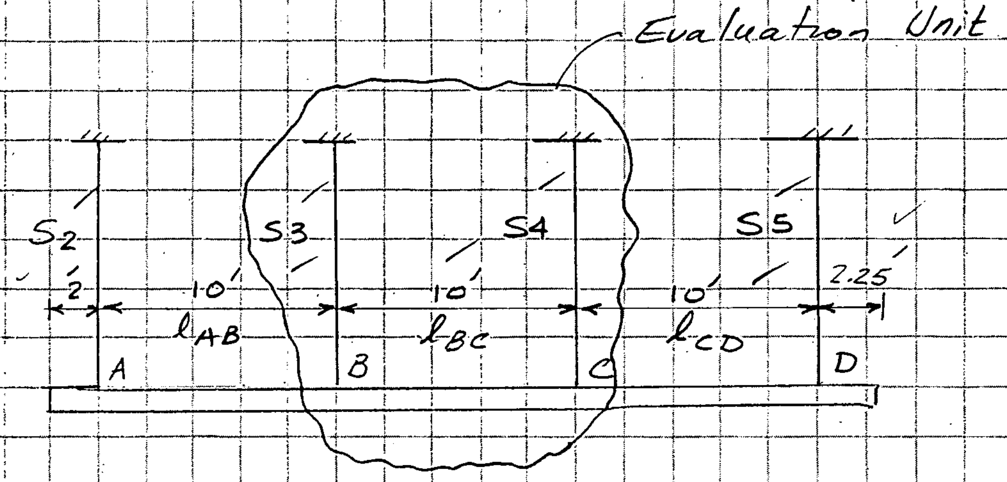
Elbow 1 - Y-Excitation



Support Stiffness

$$k_B = k_C = 4657.6 \text{ k/in}$$

Support Masses

$$m_{1B} = m_{1C} = \left[\left(\frac{10}{4}+\frac{10}{4}\right).031+.288\right]/g = \frac{0.443}{g}$$

WCG-1-397

SARGENT & LUNDY ENGINEERS

Calcs. For

☒ Safety-Related ☐ Non-Safety-Related

Calc. No. 8-11-6-1

Rev. 3 Date

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Client	TVA	Prepared by A-AlDabbagh	Date 1/16/91
Project	WBN	Reviewed by M-Amir	Date 1/23/91
Proj. No. 8573-03	Equip. No.	Approved by	Date

1-2

Support Frequencies

$$\omega_{1BS} = \;\; = \left[\frac{4657.6 \times 386.4}{0.443}\right]^{1/2} = 2015.6 \text{ R/s}$$ ✓

$$\omega_{1CS} = \;\; = \left[\frac{4657.6 \times 386.4}{\cancel{0.435}\ 0.493}\right]^{1/2} = \cancel{2034.0}\ 2015.6 \text{ R/s}$$

$$\omega_1 = 2015.6 \text{ R/s}$$ ✓

$$m_1 = 0.443/g$$ ✓

Duct Masses

$$m_{AB} = m_{BC} = m_{CD} = \left(\frac{10}{2}\right).031/g = \frac{0.155}{g}$$ ✓

Duct Stiffness

$$I = 51.1 \text{ in}^4$$ ✓

$$k_{AB} = k_{BC} = k_{CD} = \frac{48EI}{l^3} = \frac{48 \times 29000 \times 51.1}{(120)^3} = 41.16 \text{ k/in}$$ ✓

Duct Frequency

$$\omega_{BC} = \sqrt{\frac{41.16 \times 386.4}{0.155}} = 320.34 \text{ R/s}$$ ✓

$$\omega_2 = 320.34 \text{ R/s} \quad , \quad m_2 = 0.155/g$$

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SARGENT & LUNDY
ENGINEERS

Calcs. For		Calc. No. 8-11-6-1
X Safety-Related	☐ Non-Safety-Related	Rev. 3 | Date
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Client TVA		Prepared by A-Al-Dabbagh	Date 1/16/91
Project WBN		Reviewed by M-Amr	Date 1/23/91
Proj. No. 8573-03	Equip. No.	Approved by	Date

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Frequencies & Mass Ratio

$\omega_1 = 2015.6$ R/s $\qquad \omega_2 = 320.34$ R/s

$$\mu = \frac{m_2}{m_1} = \frac{0.155}{0.443} = 0.35 \checkmark$$

System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\omega_2^2$$

$$= (2015.6)^2 + 1.35\,(320.34)^2 = 4.201177\times10^6$$

$$\omega_s^2 = 0.5\left\{\alpha - \sqrt{\alpha^2 - 4\omega_1^2\omega_2^2}\right\}$$

$$= \frac{1}{2}\left\{4.201177\times10^6 - \left[(4.201177\times10^6)^2 - 4(2015.6)^2(320.34)^2\right]^{1/2}\right\}$$

$$\omega_s^2 = 101696 \checkmark$$

$$\omega_s = 318.9 \checkmark \text{ R/s}$$

$$f_s = 50.75 \checkmark \text{ cps}$$

$$a = 0.42\,g \checkmark$$

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SARGENT & LUNDY
ENGINEERS

Calcs. For		Calc. No. 8-11-6-1	
☒ Safety-Related	☐ Non-Safety-Related	Rev. 3	Date
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Client	TVA	Prepared by A. Al-Dabbagh	Date 1/16/91
Project	WBN	Reviewed by M. Amin	Date 1/23/91
Proj. No. 8573-03	Equip. No.	Approved by	Date

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Forces

Duct Bending = $0.1\, w\, a\, l^2$

= $0.1 \times .031 \times 0.42\,(120)(10)$ ✓

= 1.56 in-k ✓ $(3.72^{\text{in-k}})^*$

Duct shear = $0.5\, w\, a\, l$

= $0.5 \times .031 \times 0.42 \times 10$

= 0.065 k ✓ $(0.155^{k})^*$

Duct Torsion = $\overset{**}{0.47}\,(1.56)$ [option 2 issued]

= 0.733 in-k $(1.746^{\text{in-k}})^*$

Support S_3 Force

$$= \left[\frac{W/_{AB} + W_{BC}}{2r} + W_{S3}\right] a$$

$$= \left[\left(\frac{10+10}{2}\right).031 + 0.288\right] 0.42$$

= 0.251 k ✓ $(0.598^{k})^*$

Support S_4 Force

= 0.251 k ✓ $(0.598^{k})^*$

* These values correspond to acceleration of 1.0 g

** See next page

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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SARGENT & LUNDY
ENGINEERS

Calcs. For		Calc. No.	8.11.6-1
☒ Safety-Related	☐ Non-Safety-Related	Rev. 3	Date
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Client	TVA	Prepared by		Date	1/24/91
Project	WATTS BAR	Reviewed by	A - Al Dabbagh	Date	1/24/91
Proj. No.	8573-03	Equip. No.	Approved by	Date	

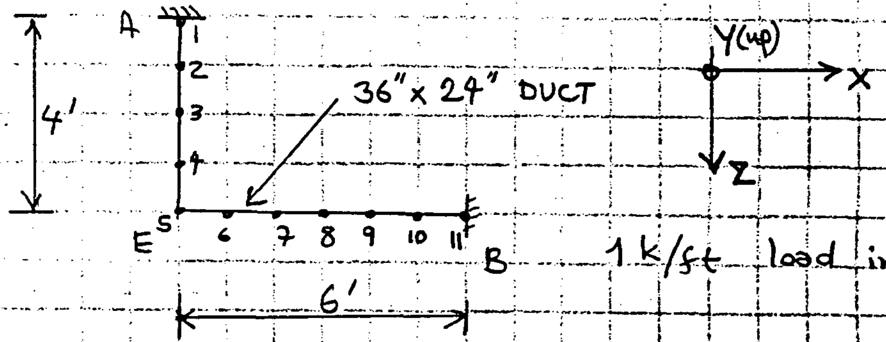
ELBOW CASE STUDY FOR DUCT MOMENT & TORQUE

Reference Run : JΦΦA dated 1/23/91

Input File : ELB64AI

Output File : ELB64A

NODALIZED FEM Model



1 k/ft load in Y-Dir.

Results (inch, kips units)

	AE SIDE (1 thru 5)	BE SIDE (5 thru 11)
SHEAR	5.46	4.54
MOMENT	113.3	93.7
TORQUE	17.5	52.6

$$\frac{\text{Max. Torque}}{\text{Max. Moment}} = \frac{52.6}{113.3} = 0.47$$

```
@ED,R Z.START-TVA
READ-ONLY MODE
CASE UPPER ASSUMED
ED 16R1D TUE-01/15/91-16:04:21-(22,)
EDIT
       1:@RUN,G/R PROP,233/051463,DEV007200,10,500  ALDABBAGH,X7286
       2:@PROG HVA20724100D
       3:@Q
       4:XEROX=1,
       5:RTO1=1-ALDABBAGH(X7286),
       6:FICHE=1,LOC=24D48,LABEL=SAD S/R QUAD 8827-25   8.20.2-2 RO ,
       7:@EOF
       8:@ASG,AZ NCB*GEN.
       9:@USE Z.,NCB*GEN.
      10:@ED,R Z.START-TVA
      11:LNP!
      12:@ED,R Z.TVA-DUCT
      13:LNP!
      14:@PRT,TLC Z.
      15:@XQT Z.ABSOL
      16:@ADD,P Z.TVA-DUCT
      17:@END
EOF:17
```

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REV.: 3
PAGE A.3 OF
PROJ. NO. 8573-03
Prepared by: A. AlDabbagh 1/15/91
Reviewed by: M. [illegible] 1-24-91

SARGENT & LUNDY

```
@ED,R Z.TVA-DUCT
END ED. NO CORRECTIONS APPLIED
READ-ONLY MODE
CASE UPPER ASSUMED
ED 16R1D TUE-01/15/91-16:04:22-(34,)
EDIT
  1: 36.0 24.0    0.0299                                     120.0120.0
  2:
EOF:2
END ED. NO CORRECTIONS APPLIED
```

input

```
@PRT,TLC Z.
FURPUR  29R2E-01      (880511 1229:45) 1991 Jan 15 Tue 1604:23

NCB*GEN(1)  ELEMENT TABLE

D  NAME          VERSION       TYPE         DATE        TIME      SEQ #  SIZE-PRE,TEXT (CYCLE WORD) PSRMODE  LOCATION
   SAP           FREQ          ELT SYMB     20 FEB 89   15:41:03    1           19    5  42    5               1792
   YGN           ELB-1         ELT SYMB     23 MAY 89   10:24:54    2           21    5  52    5               1811
   YGN           ELB-2         ELT SYMB     23 MAY 89   11:02:58    3           21    5  53    5               1832
   YGN           ELB-3         ELT SYMB     23 MAY 89   11:07:49    4           20    5  55    5               1853
   YGN           ELB-4         ELT SYMB     23 MAY 89   11:12:38    5           28    5  54    5               1873
   YGN           ELB-5         ELT SYMB     23 MAY 89   11:15:39    6           28    5  54    5               1901
   YGN           ELB-6         ELT SYMB     23 MAY 89   11:18:37    7           25    5  57    5               1929
   YGN           OFF-1         ELT SYMB     23 MAY 89   11:23:52    8           30    5  55    5               1954
   YGN           OFF-2         ELT SYMB     24 MAY 89   14:39:52    9           32    5  56    5               1984
   YGN           OFF-3         ELT SYMB     24 MAY 89   14:42:16   10           24    5  59    5               2016
   YGN           ELB-DAP       ELT SYMB     24 MAY 89   15:26:09   11           18    5  62    5               2040
   YGN           ELB-DAP-1     ELT SYMB     24 MAY 89   15:28:08   12           29    5  60    5               2058
   YGN           OFF-DAP       ELT SYMB     24 MAY 89   15:46:50   13           42    5  60    5               2087
   HVA-VALID     REC-OBE       ELT SYMB     05 JUN 89   09:00:58   14           19    5   5    5               2129
   HVA-VALID     REC-SSE       ELT SYMB     05 JUN 89   09:47:16   15           20    5   6    5               2148
   HVA-VALID     ROU-OBE       ELT SYMB     05 JUN 89   09:49:24   16           21    5   7    5               2168
   HVA-VALID     ROU-SSE       ELT SYMB     05 JUN 89   09:56:46   17           10    5   8    5               2189
   E32           TRIAL-RUN     ELT SYMB     14 JUN 89   14:54:12   18           15    5  24    5               2199
   RCTBL                       FOR SYMB     11 APR 89   15:07:39   19          208    5  30    5               2214
   RCTBL                       RELOCATABLE  11 APR 89   15:07:53   20      5   264                             2422
   CONALP                      FOR SYMB     11 APR 89   15:08:07   21           63    5  26    5               2691
   CONALP                      RELOCATABLE  11 APR 89   15:08:11   22      3    76                             2754
   SECRCT                      FOR SYMB     19 OCT 88   13:55:53   23           72    5   4    5               2833
   SECRCT                      RELOCATABLE  19 OCT 88   13:55:56   24      2    96                             2905
   MAIN                        FOR SYMB     26 OCT 88   10:57:52   25           37    5  20    5               3003
   MAIN                        RELOCATABLE  26 OCT 88   10:57:54   26      4    53                             3040
   WEIGHT                      RELOCATABLE  11 APR 89   15:08:40   27      2    51                             3097
   STFCHK                      FOR SYMB     18 NOV 88   10:46:12   28           86    5  10    5               3150
   STFCHK                      RELOCATABLE  18 NOV 88   10:46:15   29      1    91                             3236
   WEIGHT                      FOR SYMB     19 JUN 89   13:04:20   30           35    5  19    5               3328
   CON-4                       ELT SYMB     20 JUN 89   09:46:52   31           90    5  42    5               3363
   LB20                        ELT SYMB     20 JUN 89   11:34:17   32           91    5  42    5               3453
   SSE-CON-1                   ELT SYMB     20 JUN 89   11:34:45   33          103    5  43    5               3544
   RT-HORI-OBE   P3-6          ELT SYMB     21 JUN 89   16:31:22   34           90    5  42    5               3647
   RT-HORI-SSE   P3-6          ELT SYMB     21 JUN 89   16:50:25   35          156    5  43    5               3737
   RT-HORI-OBE   P10           ELT SYMB     21 JUN 89   17:02:46   36           94    5  43    5               3893
   RT-HORI-SSE   P10           ELT SYMB     21 JUN 89   16:50:25   37          156    5  43    5               3987
   RT-VERT-OBE   P3-6          ELT SYMB     22 JUN 89   15:42:48   38           92    5  44    5               4143
   RD-HORI-OBE   P3-6          ELT SYMB     22 JUN 89   16:49:54   39           94    5  43    5               4235
   RD-VERT-OBE   P3-6          ELT SYMB.    23 JUN 89   09:28:04   40           96    5  44    5               4329
```

Prepared by: A. AbdelRabbogh
1/15/90

Reviewed by: M-Amr
1-24-91

NCG-1-37/

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SARGENT & LUNDY

```
RT-VERT-OBE   P10      ELT SYMB      26 JUN 89  08:50:57  41       96  5  45  5        4425
MAINS                  ELT SYMB      20 JUL 89  08:36:59  42      129  5   8  5        4521
FIX3                   FOR SYMB      20 JUL 89  09:28:16  43      129  5  10  5        4650
FIX                    FOR SYMB      20 JUL 89  09:28:35  44      129  5  10  5        4779
MEMBER                 FOR SYMB      20 JUL 89  09:29:12  45      129  5  10  5        4908
STORE                  FOR SYMB      20 JUL 89  09:29:36  46      129  5  10  5        5037
NCB           HVAC     FOR SYMB      21 JUL 89  08:17:36  47      129  5  11  5        5166
ROTA                   FOR SYMB      21 JUL 89  08:22:30  48      129  5  11  5        5295
CHOLES                 FOR SYMB      21 JUL 89  08:24:26  49      129  5  11  5        5424
NCB           HVAC     RELOCATABLE   21 JUL 89  08:26:33  50   2   85                  5553
FIX3                   RELOCATABLE   21 JUL 89  08:26:46  51   1    5                  5640
FIX                    RELOCATABLE   21 JUL 89  08:27:05  52   1   10                  5646
ROTA                   RELOCATABLE   21 JUL 89  08:27:26  53   1   13                  5657
MEMBER                 RELOCATABLE   21 JUL 89  08:27:47  54   1   12                  5671
STORE                  RELOCATABLE   21 JUL 89  08:28:18  55   1    6                  5684
CHOLES                 RELOCATABLE   21 JUL 89  08:28:38  56   1   25                  5691
SAP           STATIC   ELT SYMB      25 JUL 89  13:55:49  57       26  5  44  5        5717
PROP                   ELT SYMB      16 DEC 89  15:41:07  58        7  5   2  3        5743
ZETA                   ELT SYMB      16 DEC 89  15:41:51  59       13  5   6  5        5750
RO                     ELT SYMB      16 DEC 89  15:50:35  60       13  5   5  5        5763
MAIN1                  ELT SYMB      19 DEC 89  11:19:48  61       24  5   9  5        5776
ABSOL                  ELT SYMB      31 JAN 90  09:39:50  62        1  5   2  3        5800
MAIN1                  RELOCATABLE   31 JAN 90  10:38:49  63   3   31             QTR  5801
RO                     RELOCATABLE   31 JAN 90  10:38:51  64   2   15             QTR  5835
PROP                   RELOCATABLE   31 JAN 90  10:38:52  65   2   21             QTR  5852
ZETA                   RELOCATABLE   31 JAN 90  10:38:54  66   2   14             QTR  5875
ABSOL                  ABSOLUTE      31 JAN 90  10:38:59  67      263             QTR  5891
DRES-DATA              ELT SYMB      14 FEB 90  10:23:32  68       79  5  10  5        6154
R589-N-01     OBE      ELT SYMB -Q   14 FEB 90  16:09:12  69       24  5   3  4        6233
R589-E-01     OBE      ELT SYMB -Q   14 FEB 90  16:10:26  70       25  5   2  3        6257
R589-N-01     SSE      ELT SYMB -Q   14 FEB 90  16:11:38  71       24  5   2  3        6282
R589-E-01     SSE      ELT SYMB -Q   14 FEB 90  16:12:21  72       25  5   2  3        6306
ABS-DRES               ELT SYMB      14 FEB 90  16:24:43  73        1  5   0  1        6331
MAIN-DRES              ELT SYMB      14 FEB 90  16:48:48  74        3  5   4  5        6332
MAIN-DRES              RELOCATABLE   14 FEB 90  16:49:03  75   2    7             QTR  6335
ABS-DRES               ABSOLUTE      14 FEB 90  16:49:46  76      198             QTR  6344
OBE-NS                 ELT SYMB -Q   14 FEB 90  16:55:11  77       24  5   0  1        6542
OBE-EW                 ELT SYMB -Q   14 FEB 90  16:57:54  78       24  5   0  1        6566
SSE-NS                 ELT SYMB -Q   14 FEB 90  16:59:13  79       24  5   0  1        6590
SSE-EW                 ELT SYMB -Q   14 FEB 90  17:01:24  80       24  5   0  1        6614
DRES-OBE      NS       ELT SYMB      15 FEB 90  10:48:34  81       77  5  18  5        6638
DRES-STIFF             ELT SYMB      17 FEB 90  13:13:23  82       10  5   0  1        6715
DRES-START             ELT SYMB      17 FEB 90  13:14:35  83        5  5   5  5        6725
DRES-START-S           ELT SYMB      17 FEB 90  13:22:42  84        6  5   6  5        6730
DRES-DATA-T            ELT SYMB      17 FEB 90  13:27:02  85       69  5  12  5        6736
DRES-START-T           ELT SYMB      17 FEB 90  13:28:51  86        5  5   6  5        6805
DRES-OBE      EW       ELT SYMB      19 FEB 90  13:15:13  87        7  5  20  5        6810
DRES-DATA-S            ELT SYMB      21 FEB 90  11:13:08  88       19  5   2  3        6817
DRES-SSE      EW       ELT SYMB      28 FEB 90  11:55:18  89        7  5  27  5        6836
DRES-SSE      NS       ELT SYMB      28 FEB 90  11:56:14  90        8  5  29  5        6843
DRE-MESHG              ELT SYMB      28 FEB 90  18:20:56  91      258  5   9  5        6851
DRE-DATA      SEIS     ELT SYMB      28 FEB 90  18:30:21  92      222  5  18  5        7109
DRES-DEAD              ELT SYMB      28 FEB 90  18:47:16  93      172  5  41  5        7331
FASG                   ELT SYMB      23 APR 90  16:10:47  94        5  5   8  5        7503
FFASG                  ELT SYMB      25 APR 90  11:47:49  95        2  5  12  5        7508
TVA-SEC-DATA           ELT SYMB      23 MAY 90  13:45:50  96       23  5  27  5        7510
START-GEN              ELT SYMB      11 JUN 90  10:21:58  97        7  5   9  5        7533
START-PROP             ELT SYMB      11 JUN 90  10:38:46  98        7  5  10  5        7540
```

Prepared by: A. AlDabbagh 1/15/91

Reviewed by: M-Amr 1-28-91

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SARGENT & LUNDY

```
   KKJ               ELT SYMB   24 JUL 90   14:43:09    99     98   5   9   5    7547
   YHK               ELT SYMB   24 JUL 90   14:47:28   100     85   5   2   3    7645
   START-ULJIN       ELT SYMB   24 JUL 90   14:55:02   101      3   5   3   4    7730
   FANG              ELT SYMB   27 SEP 90   09:24:36   102      4   5   1   2    7733
   TVA-TP3-PROP      ELT SYMB   17 OCT 90   09:44:03   103      7   5   1   2    7737
   TVA-START-1       ELT SYMB   15 NOV 90   13:49:56   104      6   5   0   1    7744
   TVA-STIF-SPA      ELT SYMB   17 NOV 90   13:13:05   105     42   5  22   5    7750
   TYPE-3            ELT SYMB   17 NOV 90   13:14:39   106     42   5  24   5    7792
   TYPE-4            ELT SYMB   17 NOV 90   13:16:45   107     42   5  24   5    7834
   TYPE-3-1          ELT SYMB   17 NOV 90   13:17:49   108     13   5  27   5    7876
   TYPE-4-1          ELT SYMB   17 NOV 90   13:19:00   109     13   5  26   5    7889
   TVA-START-2       ELT SYMB   19 NOV 90   15:15:04   110      7   5   1   2    7902
   DATA1             ELT SYMB   20 NOV 90   09:07:04   111      7   5   3   4    7909
   AMA-DATA          ELT SYMB   20 NOV 90   09:46:59   112     10   5  30   5    7916
   DRES-185          ELT SYMB   20 NOV 90   15:56:37   113     60   5   1   2    7926
   START-COOPER      ELT SYMB   07 DEC 90   08:47:28   114      8   5  12   5    7986
   LAFD              ELT SYMB   07 DEC 90   08:49:40   115      1   5   0   1    7994
   START-DUCTPR      ELT SYMB   15 DEC 90   11:03:55   116      5   5  18   5    7995
   RASG              ELT SYMB   17 DEC 90   07:27:57   117      6   5   8   5    8000
*  START-PROPQC      ELT SYMB   28 DEC 90   09:31:49   118      4   5  18   5    8006
   QC-STIFFENER      ELT SYMB   28 DEC 90   10:42:26   119      6   5  11   5    8010
   QC-PROP           ELT SYMB   28 DEC 90   15:40:31   120      4   5  33   5    8016
*  NCB-START-1       ELT SYMB   31 DEC 90   10:42:41   121      4   5   0   1    8020
   TVA-MEM-PROP      ELT SYMB   31 DEC 90   12:53:17   122    238   5  10   5    8024
   NCB-START         ELT SYMB   31 DEC 90   12:59:04   123      5   5   3   4    8262
   START-PROPQC      ELT SYMB   15 JAN 91   15:48:08   124      4   5  19   5    8267
*  START-TVA         ELT SYMB   15 JAN 91   15:48:08   125      4   5  19   5    8271
*  START-TVA         ELT SYMB   15 JAN 91   15:53:50   126      5   5  20   5    8275
*  START-TVA         ELT SYMB   15 JAN 91   15:58:33   127      5   5  21   5    8280
   TVA-DUCT          ELT SYMB   15 JAN 91   15:55:35   128      5   5  34   5    8285
   START-TVA         ELT SYMB   15 JAN 91   16:04:04   129      5   5  22   5    8290
NEXT AVAILABLE LOCATION-                                                         8295

ASSEMBLER PROCEDURE TABLE EMPTY

COBOL PROCEDURE TABLE EMPTY

FORTRAN PROCEDURE TABLE EMPTY

ENTRY POINT TABLE EMPTY

@XQT Z.ABSOL

@ADD,P Z.TVA-DUCT
```

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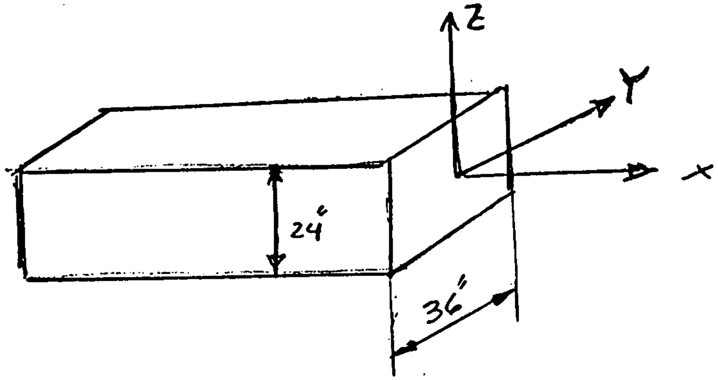
PAGE A.6 OF
PROJ. NO. 8573-03
Prepared by: A. [illegible]
1/15/91
Reviewed by: M. A[illegible]
1-24-91

SARGENT & LUNDY

3306

```
 SIZE    THICK    FY      E        OBE    SSE    AKF    AKW     AX     AY     AZ     IX      SX     IY     SY     IZ     SZ

36.X24. .0299  33.0  29000.0    .6     .9    4.0    40.0    .34   2.15   1.44   744.0   51.7   71.8    6.0  180.1   10.0
36.X24. .0299  33.0  29000.0    .6     .9    4.0    40.0    .24   2.15   1.44   744.0   51.7   60.1    5.0  148.7    8.3
36.X24. .0299  33.0  29000.0    .6     .9    4.0    40.0   1.92   2.15   1.44   744.0     .0   51.1     .0  126.4     .0

        NOTE

        THE VALUES ON THESE LINES ARE FOR:
        (1) DESIGN (OBE)
        (2) DESIGN (SSE)
        (3) ANALYSIS

@END
@END IGNORED - IN CONTROL MODE
```

Section properties used in the evaluation



WCG-1-397

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REV. 3
PAGE A7 OF
PROJ. NO. 8573-03
Prepared by: D. Al-Dabbagh 1/15/91
Reviewed by: M. Amri 1.24.91

SARGENT & LUNDY

3306

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SARGENT & LUNDY ENGINEERS
CHICAGO, ILLINOIS

* * R U N  T I M E  S U M M A R Y  I N  S U P S * *


   RUNID: PROP      ACCT: 233           PROJECT: DEV007200

   TIME:     TOTAL: 00:00:25.113     CBSUPS:     3102727

             CPU:   00:00:00.025     I/O:  00:00:03.418

             CC/ER: 00:00:21.669     WAIT: 00:00:00.050

   IMAGES  READ:         19     PAGES:        8

   START:     16:04:16 JAN 15,1991     FIN:  16:04:26 JAN 15,1991
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WCG-1-397

CALC. No. 8.11-6-1
REV. 3
PAGE A-8 OF Final
PROJ. NO. 8573-03

SARGENT & LUNDY

Prepared by: A.Akdabeg
1/15/91

Reviewed by: M.Azar
1-24-91

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Calcs. For

☒ Safety-Related ☐ Non-Safety-Related

Client	TVA		
Project	WBN		
Proj. No.	8573-03	Equip. No.	
Prepared by	A-AbDubbagh	Date	1/17/91
Reviewed by	M. Amé	Date	1.24.91
Approved by		Date	

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Calc. No. 8.11.6-1

Rev. 3 Date

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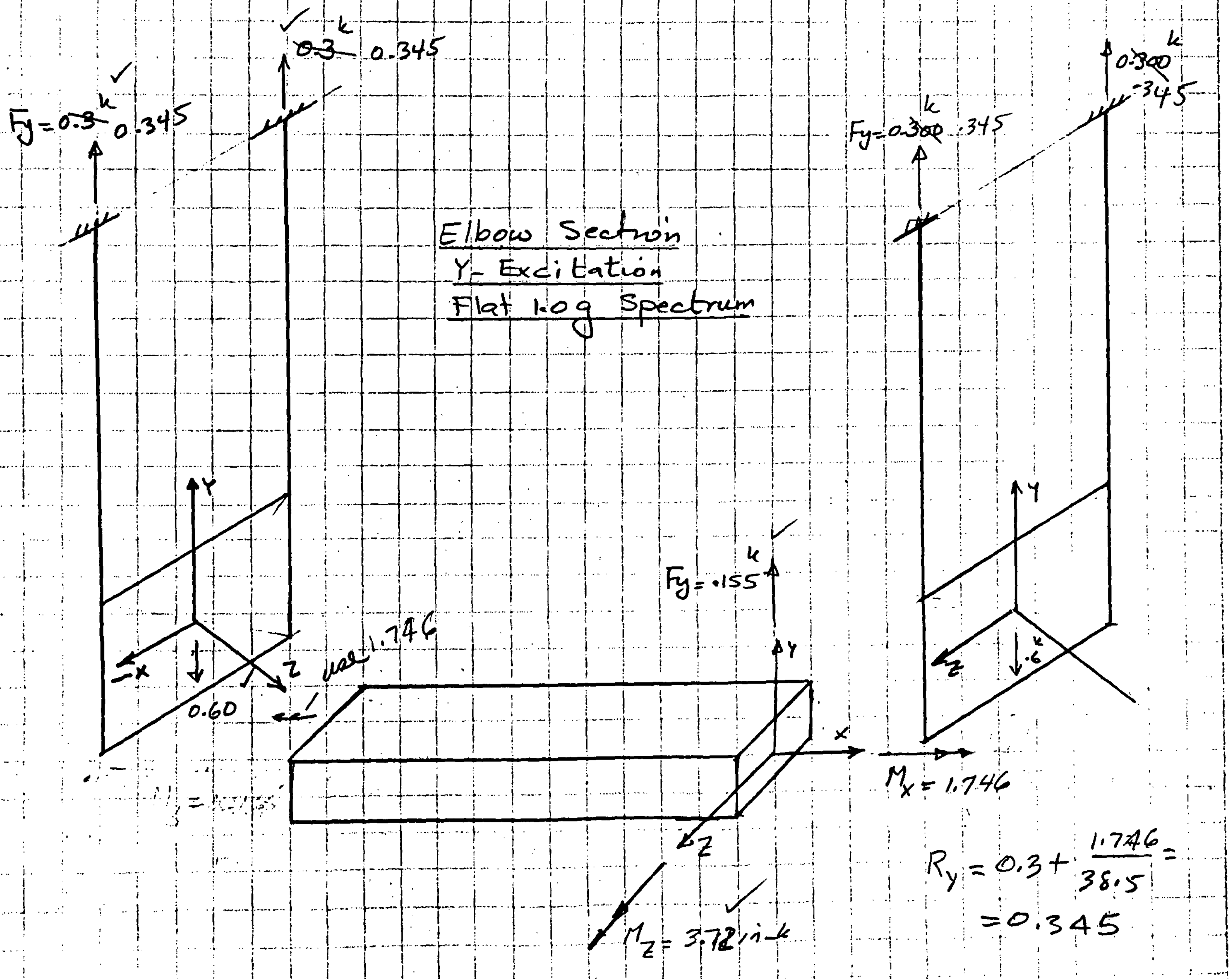
Elbow Section
Y- Excitation
Flat 1.0g Spectrum



$$R_y = 0.3 + \frac{1.746}{38.5} = 0.345$$

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Calcs. For	
☒ Safety-Related	☐ Non-Safety-Related

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Prepared by	A-Al Dabbagh	Date 1/16/91
Reviewed by	M. Amri	Date 1/23/91
Approved by		Date

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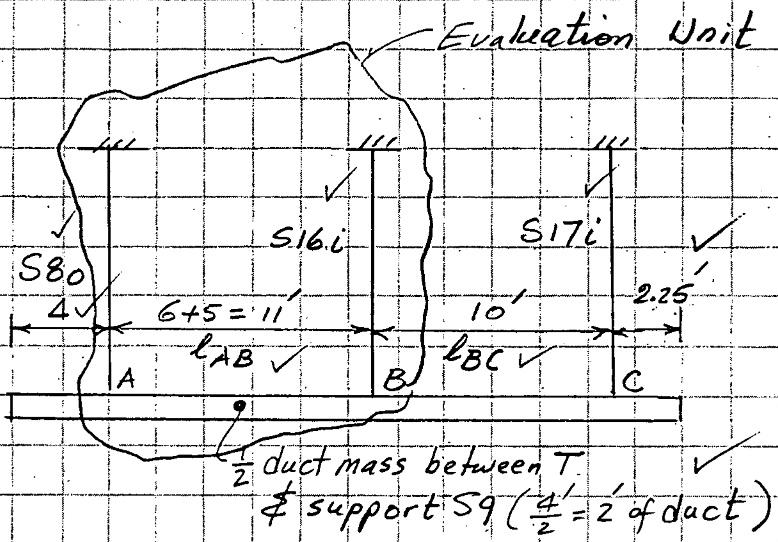
T Section - X Excitation



Support Stiffness

$k_A = k_{S80} = 30.75$ k/in

$k_B = k_C = 37.04$ k/in

Support Masses

$$m_{1A} = \Big[\frac{8}{2} + \frac{11}{4}\Big).031 + 0.288\Big]/g = \frac{0.497}{g}$$

$$m_{1B} = \Big[\Big(\frac{11}{4} + \frac{10}{4}\Big).031 + 0.288\Big]/g = \frac{0.451}{g}$$

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Support Frequencies

$$\omega_{1A} = \sqrt{\frac{k_A}{m_{1A}}} = \sqrt{\frac{30.75 \times 386.4}{0.497}} = 154.62 \text{ R/S}$$ ✓

$$\omega_{1B} = \sqrt{\frac{k_B}{m_{1B}}} = \sqrt{\frac{37.04 \times 386.4}{0.451}} = 178.14 \text{ R/S}$$ ✓

$$\omega_{1S} = 154.62 \text{ R/S}$$ ✓

$$m_1 = \frac{0.451}{g}$$ ✓

Duct Masses

$$m_{AB} = \left[\frac{6+5}{2} + \frac{4}{2}\right] .031/g = \frac{0.233}{g}$$ ✓

$$m_{BC} = \left(\frac{10}{2}\right) 0.031/g = \frac{0.155}{g}$$ ✓

Duct Stiffness

$$k_{AB} = \frac{48EI}{\ell_{AB}^3} = \frac{48 \times 29000 \times 126.4}{(11 \times 12)^3} = 76.5 \text{ k/in}$$ ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Duct Frequency

$$\omega_{AB} = \sqrt{\frac{K_{AB}}{m_{AB}}} = \sqrt{\frac{76.5 \times 386.4}{0.233}} = 356.18 \ R/s$$

$$\omega_2 = 356.18 \ R/s$$

$$m_2 = 0.5\left[\frac{0.233}{g} + \frac{0.155}{g}\right] = \frac{0.194}{g}$$

Frequencies & Mass Ratio

$$\omega_1 = 154.62 \ R/s \qquad \omega_2 = 356.18 \ R/s$$

$$\mu = \frac{m_2}{m_1} = \frac{\overset{0.194}{\cancel{0.233}}}{0.451} = \overset{0.430}{\cancel{0.517}}$$

System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\omega_2^2 = (154.62)^2 + \overset{1.43}{\cancel{1.517}}(356.18)^2 = \overset{2.05323}{\cancel{2.16313}} \times 10^5$$

$$\omega_s^2 = \frac{1}{2}\left\{\alpha - \left(\alpha^2 - 4\omega_1^2\omega_2^2\right)^{1/2}\right\}$$

$$= \frac{1}{2}\left\{\overset{2.05323}{\cancel{2.16313}} \times 10^5 - \left[\left(\overset{2.05323}{\cancel{2.16313}} \times 10^5\right)^2 - 4(154.62)^2(356.18)^2\right]^{1/2}\right\}$$

$$\omega_s^2 = \overset{16022}{\cancel{15071}}$$

$$\omega_s = \overset{126.6 \ R/S}{\cancel{122.77}} \ R/s \qquad f_s = \overset{20.2}{\cancel{19.54}} \ CPS$$

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$$\frac{\log 20-\log 19.54^{*}}{\log 20-\log 9} = \frac{2.16-a}{2.16-2.63} = 0.0292$$

f	a
20	2.16
9	2.63

$$a = .0292 \times .47 + 2.16 = 2.174\,g$$

Forces

$$\text{Duct Bending} = 0.1\,w a\,l_{AB}^2 + 2 w a \frac{l_{AB}}{6}$$

$$= 0.1 \times .031 \times 2.174 (11)(132) + 2 \times .031 \times 2.174 \times \frac{132}{6}$$

$$= 9.786 + 2.965 = 12.751 \text{ in-k.}$$

$$\text{Axial Force} = \left(\frac{6+4+2.5}{2}\right) w a = 6.25 \times .031 \times 2.174$$

$$= 0.421 \text{ k}$$

$$\text{Duct Shear} = \frac{1}{2} w a\, l_{AB} + \frac{1}{2}(2') w a$$

$$= \frac{1}{2} \times .031 \times 2.174 \times 11 + \frac{1}{2} \times 2 \times .031 \times 2.174$$

$$= 0.371 + 0.067$$

$$= 0.438 \text{ k}$$

$$\text{Support S8 Force} = \left\{\left[4 + \frac{11}{2} + \frac{2}{2}\right] w + W_{S8}\right\} a$$

$$= \{10.5 \times 0.031 + 0.288\}\, 2.174 = 1.334 \text{ k}$$

$$\text{Support S9 Force} = \left[\left\{\frac{9}{2} + \frac{10}{2} + \frac{5}{4}^{**}\right\} w + W_{S9}\right] a \underset{\text{approx.}}{\approx} (11 w + W_{S9})\, a$$

$$= (11 \times .031 + 0.288)\, 2.174 = 1.367 \text{ k}$$

$$\text{Support } S_{16} \text{ Force} = \left[\left\{\frac{11}{2} + \frac{2}{2} + \frac{10}{2}\right\} w + W_{S16}\right] a$$

$$= \{11.5 \times .031 + 0.288\}\, 2.174 = 1.401 \text{ k}$$

* the frequency calculated on previous page is 20.2 instead of 19.54. Since later results for comparison are based on flat 4g spectrum, accept the 2.174 g acceleration here. Because it is acting as a scaling factor from this point onward.

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Support Leg Forces

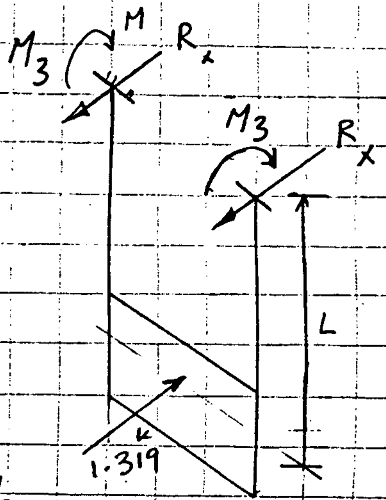
S8

out-of-plane shear Force = 1.334^k ✓

$R_x = \frac{1.334}{2} = 0.667k$ ✓

$M_3 = \frac{R_x L}{2} = \frac{0.667 \times 66}{2}$

$M_3 = 22.01$ in-k ✓



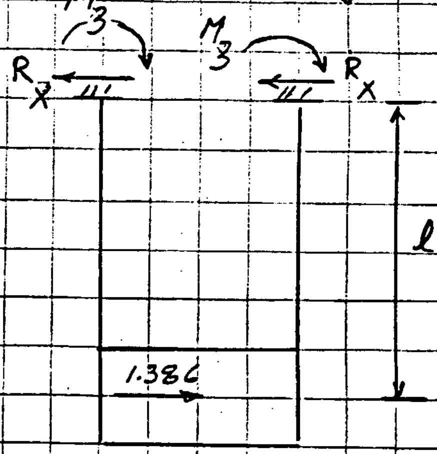
S16

In-plane shear Force = 1.401^k ✓

$R_x = \frac{1.401}{2} = 0.701$ k ✓

$M_3 = \frac{R_Z L}{2} = \frac{0.701 \times 66}{2}$

$= 23.133$ in-k ✓



S9

out-of-plane shear Force of 1.367^k ✓

$R_x = \frac{1.367}{2} = 0.684$ k ✓

$M_3 = 0.684 \times \frac{66}{2} = 22.57$ in-k

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Client TVA
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Calcs. For
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Prepared by A. AbuDabbagh Date 1/17/91
Reviewed by M. Amri Date 1/23/91
Approved by Date

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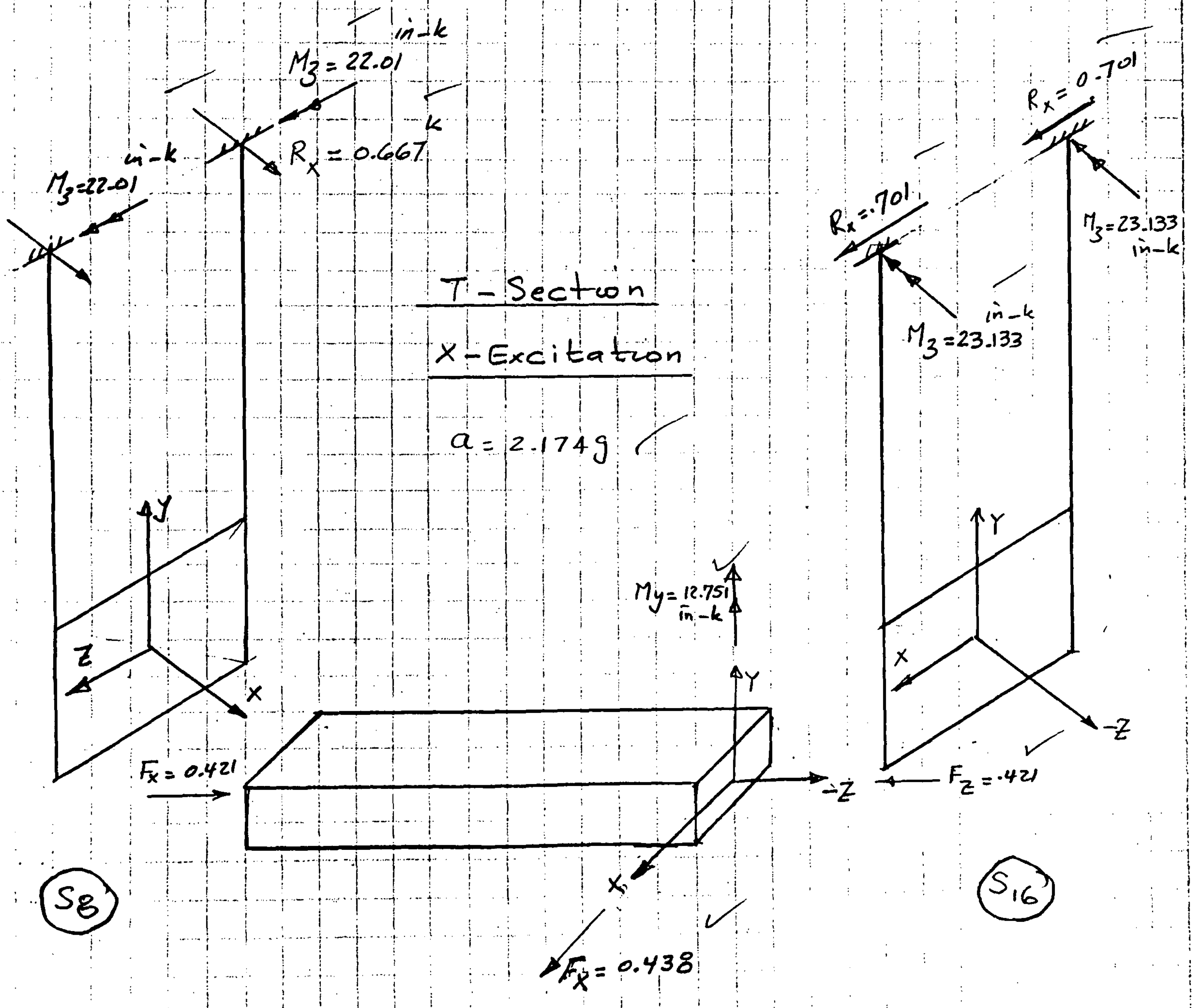
T - Section

X - Excitation

a = 2.174g



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Client	TVA
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Prepared by	A. Al-Dabbagh	Date	1/17/91
Reviewed by	M. Amr	Date	1/23/91
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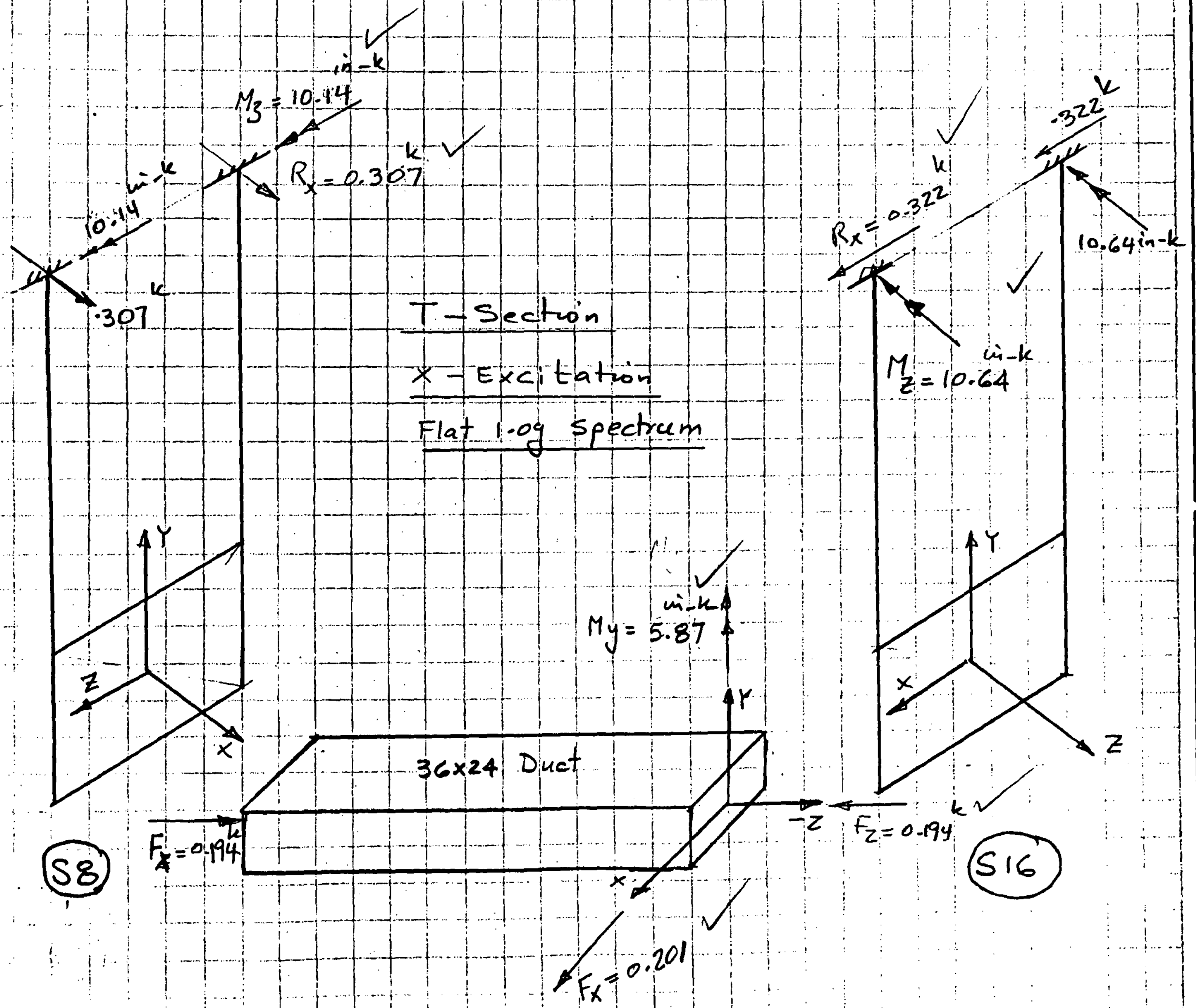
T-Section

X-Excitation

Flat 1.0g Spectrum



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Client TVA		Prepared by A-Al Dakkagh	Date 1/17/91
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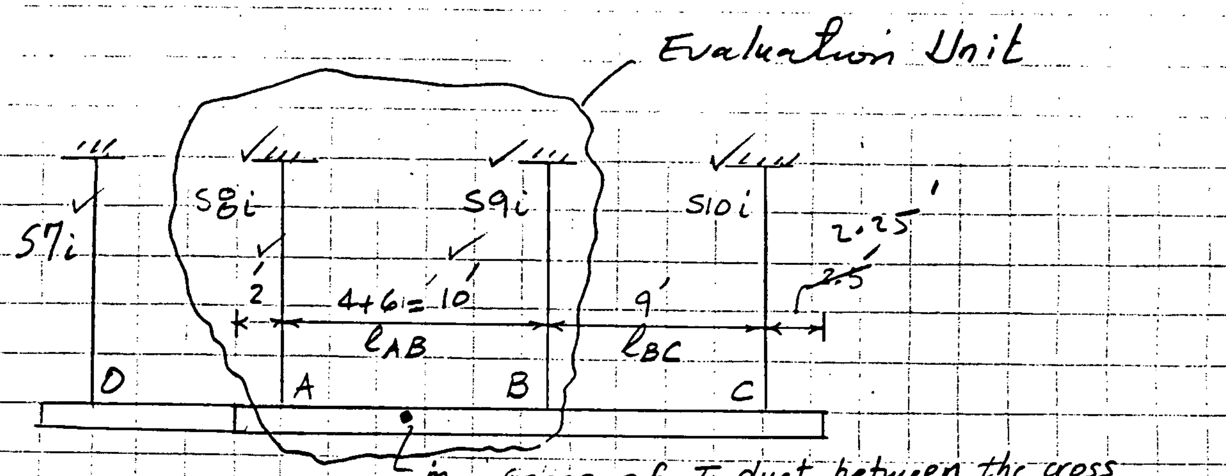
T Section – Z Excitation



m = mass of T duct between the cross of the tee and support S16 = 5' of duct ✓

Support Stiffness

$$K_A = K_B = 37.04 \text{ k/in}$$ ✓

Support Masses

$$m_{1A} = \left[\left(\frac{8}{4} + \frac{10}{4}\right) .031 + 0.288\right] / g = \frac{0.428}{g}$$ ✓

$$m_{1B} = \left[\left(\frac{10}{4} + \frac{9}{4}\right) .031 + 0.288\right] / g = \frac{0.435}{g}$$ ✓

Support Frequencies

$$\omega_{1A} = \sqrt{\frac{K_A}{m_A}} = \sqrt{\frac{37.04 \times 386.4}{0.428}} = 182.87 \text{ R/s}$$ ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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$$\omega_{1B} = \omega_{1C} = \sqrt{\frac{37.04 \times 386.4}{0.435}} = 181.39 \text{ R/s} \checkmark$$

$$\omega_{1S} = 181.39 \text{ R/s} \checkmark$$

$$m_1 = \frac{0.428}{g} \checkmark$$

Duct Masses

$$m_{AB} = \left(\frac{10}{2}\right)\frac{.031}{g} + \frac{.155}{g} = \frac{0.310}{g} \checkmark$$

$$m_{BC} = \frac{9}{2} \times \frac{.031}{g} = \frac{0.140}{g} \checkmark$$

$$m_{DA} = \frac{8}{2} \times \frac{.031}{g} = \frac{0.124}{g} \checkmark$$

Duct Stiffness

$$k_{AB} = \frac{48EI}{l_{AB}^3} = \frac{48 \times 29000 \times 126.4}{(120)^3} = 101.8 \text{ k/in} \checkmark$$

spans DA & BC will have higher stiffness

Duct Frequency

$$\omega_{AB} = \sqrt{\frac{k_{AB}}{m_{AB}}} = \sqrt{\frac{101.8 \times 386.4}{0.31}} = 356.21 \text{ R/s} \checkmark$$

$$\omega_2 = 385.27 \checkmark \qquad m_2 = \frac{0.310 + .140}{2g} = \frac{0.225}{g} \checkmark \quad \left[\text{This gives max. } m_2\right]$$

Frequencies & Mass Ratio

$$\omega_1 = 181.39 \text{ R/s} \checkmark \qquad \omega_2 = 356.21 \text{ R/s} \checkmark$$

$$\mu = \frac{m_2}{m_1} = \frac{0.225}{0.428} = 0.526 \checkmark$$

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Client TVA		Prepared by A. Ali Rabbagh	Date 1/17/91
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System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\omega_2^2 = (181.39)^2 + 1.526(356.21)^2 = 2.2653\times10^5$$ ✓

$$\omega_s^2 = \frac{1}{2}\left\{\alpha - \left(\alpha^2 - 4\omega_1^2\omega_2^2\right)^{1/2}\right\}$$

$$= \frac{1}{2}\left\{2.2653\times10^5 - \left[(2.2653\times10^5)^2 - 4(181.39)^2(356.21)^2\right]^{1/2}\right\}$$

$$\omega_s^2 = 20237.5$$ ✓

$$\omega_s = 142.26 \text{ R/S}$$ ✓

$$f_s = 22.64 \text{ cps}$$ ✓

$f_1 = 20$ ✓ $\quad a_1 = 2.16$ ✓

$f_2 = 33.3$ ✓ $\quad a_2 = 1.20$ ✓

$$\frac{\log 33.3 - \log 22.64}{\log 33.3 - \log 20} = \frac{1.20 - a}{1.20 - 2.16} = 0.757$$ ✓

$$(1.20 - a) = -0.96 \times 0.757$$

$$a = 1.20 + 0.73$$

$$a = 1.93\,g$$ ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Forces

Duct bending $= 0.1\,w a\, l_{AB}^2 + 5\,w a \times \frac{1}{6}$

$= [0.1(10) + 0.833]\, w a\, l_{AB}$

$= 1.833 \times .031 \times 1.93 \times 120''$

$= 13.163$ in-k $\quad (6.82$ in-k$)^*$

Duct Shear $= \frac{1}{2} w a\, l_{AB} + \frac{5 w a}{2}$

$= 0.5\, w a (10 + 5) = 7.5\, w a$

$= 7.5 \times .031 \times 1.93 = 0.449^k \quad (0.233^k)^*$

Duct Axial Force $= 5 \times w a = 5 \times .031 \times 1.93 = 0.299^k, \quad (0.155^k)^*$

Support S 8 Force $= \left\{\left[4 + \frac{10}{2}\right] w + \frac{5w}{2} + W_{S8}\right\} a$

$= \{11.5 \times .031 + 0.288\}\, 1.93$

$= 1.244^k \quad (0.645^k)^*$

Support S9 Force $= \left\{\left(\frac{10}{2} + \frac{9}{2}\right) w + \frac{5w}{2} + W_{S9}\right\} a$

$= (12 \times .031 + 0.288)\, 1.93$

$= 1.274^k \quad (0.66^k)^*$

Support S_{16} Force $= \left\{\left(\frac{10+5+10}{2}\right) w + W_{S16}\right\} a$

$= \{12.5 \times .031 + .288\}\, 1.933 = 1.304$ k $\quad (0.676^k)^*$

* Values corresponding to acceleration of 1.0 g

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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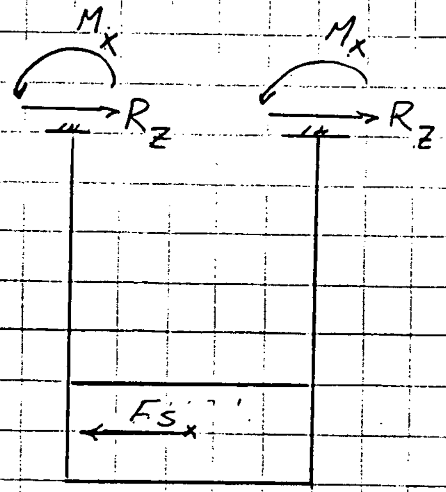
Support Leg Forces



S8

$F_S = 1.244^k$ ✓

$R_Z = \frac{1.244}{2} = 0.622^k$ ✓ $(0.322^k)^*$ ✓

$M_x = \frac{R_x L}{2} = \frac{0.622 \times 66}{2} = 20.526$ in-k ✓ $(10.64^{in\text{-}k})^*$ ✓

S9

$F_S = 1.274^k$ ✓

$R_Z = \frac{1.274}{2} = 0.637^k$ ✓ $(0.330^k)^*$ ✓

$M_x = \frac{R_x L}{2} = \frac{.637 \times 66}{2} = 21.02$ in-k ✓ $(10.89^{in\text{-}k})^*$ ✓

S16

$F_s = 1.304^k$ ✓

$R_Z = \frac{1.304}{2} = 0.652^k$ ✓ $(0.338^k)^*$ ✓

$M_x = 0.652 \times \frac{66}{2} = 21.52$ in-k ✓ $(11.15^{in\text{-}k})^*$ ✓

* Values corresponding to acceleration of 1.0 g

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Client TVA
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Calcs. For
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Prepared by A. Abdulbagh Date 1/17/91
Reviewed by M. Amin Date 1/23/91
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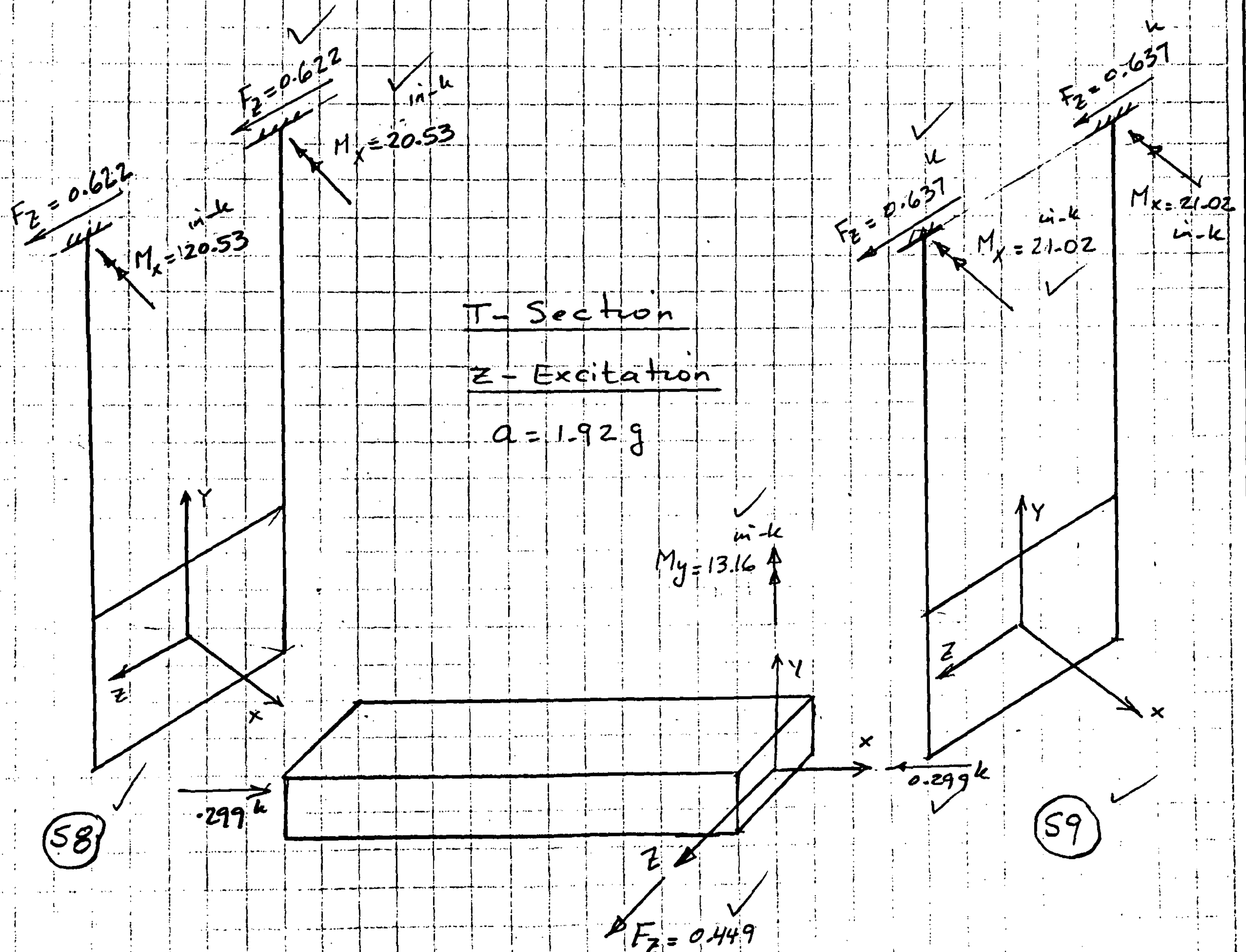
T-Section

Z-Excitation

a = 1.92 g



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Client TVA
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Prepared by A. [illegible] Date 1/17/91
Reviewed by M. Ami Date 1/23/91
Approved by Date

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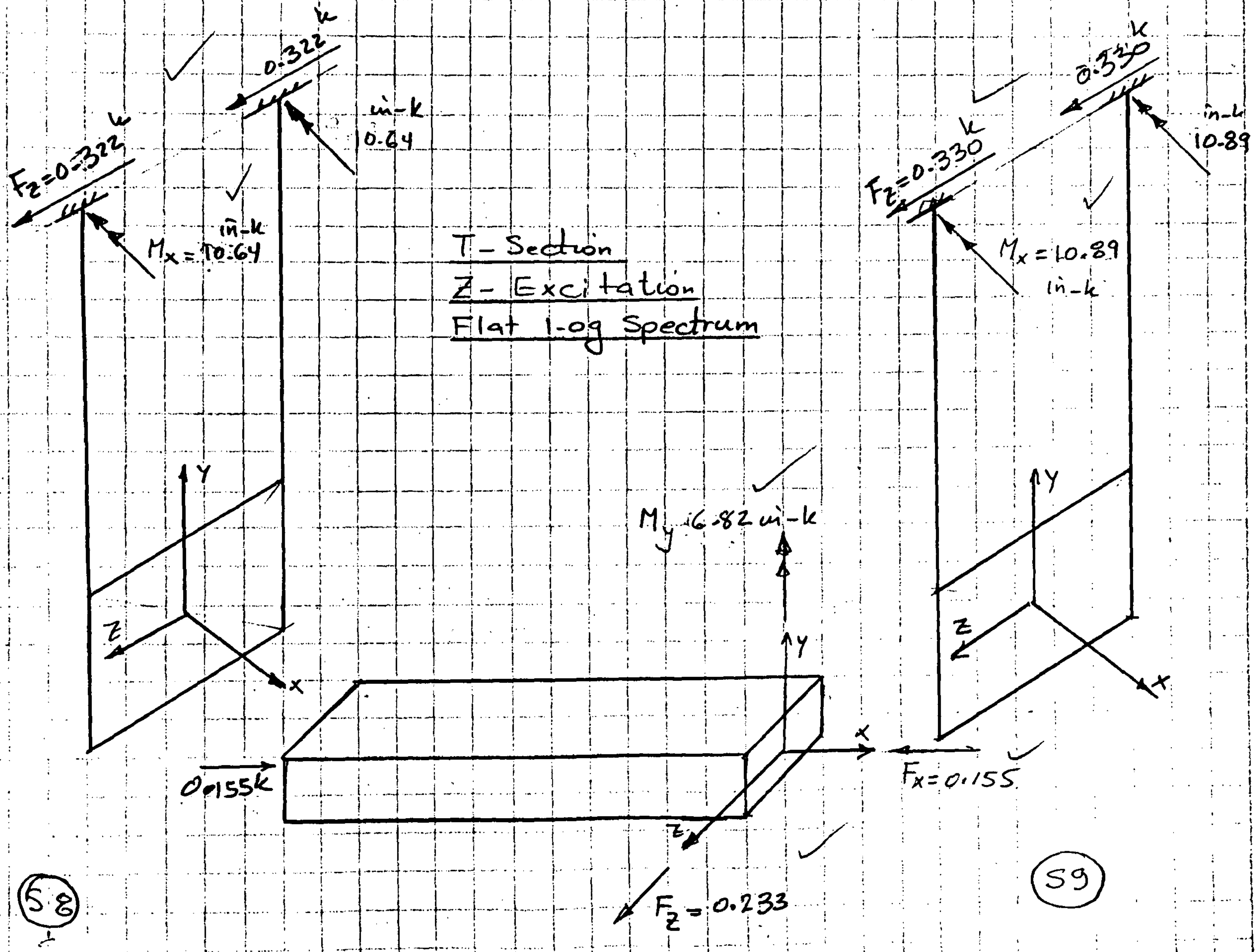
T - Section
Z - Excitation
Flat 1-og Spectrum



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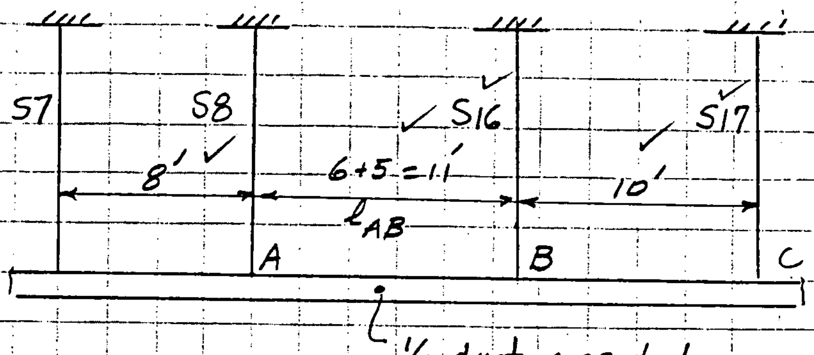
T Section, Y-Excitation



1/2 duct mass between T & support S9 $(\frac{4}{2} = 2'$ of duct) ✓

Support stiffness

$$k_A = k_B = 4657.6 \ \text{k/in}$$ ✓

Support masses

$$m_{1A} = \left[\left\{\frac{8}{4} + \frac{11}{4}\right\} .031 + 0.288\right] / g = \frac{0.435}{g}$$ ✓

$$m_{1B} = \left[\left(\frac{11}{4} + \frac{10}{4}\right) .031 + 0.288\right] / g = \frac{0.451}{g}$$ ✓

Support Frequencies

$$\omega_{1A} = \sqrt{\frac{k_A}{m_{1A}}} = \left[\frac{4657.6 \times 386.4}{0.435}\right]^{1/2} = 2034.0 \ \text{R/s}$$ ✓

$$\omega_{1B} = \sqrt{\frac{k_B}{m_{1B}}} = \left[\frac{4657.6 \times 386.4}{0.451}\right]^{1/2} = 1997.6 \ \text{R/s}$$ ✓

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Prepared by	A. AliDabbagh	Date 1/17/91
Reviewed by	M. Ami	Date 1/27/91
Approved by		Date

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$\omega_1 = 19976$ R/s ✓

$m_1 = \frac{0.435}{g}$ ✓

Duct mass

$m_{AB} = \left(\frac{11}{2} + \frac{4}{2}\right)\frac{0.031}{g} = \frac{0.233}{g}$ ✓

$M_{BC} = \frac{10}{2} \times \frac{.031}{g} = \frac{0.155}{g}$ ✓

Duct Stiffness

$k_{AB} = \frac{48EI}{l_{AB}^3} = \frac{48 \times 29000 \times 51.1}{(132)^3} = 30.927$ k/in ✓

This span will give smallest frequency

Duct Frequency

$\omega_{AB} = \sqrt{\frac{k_{AB}}{m_{AB}}} = \left[\frac{30.927 \times 386.4}{0.233}\right]^{1/2} = 226.71$ R/s ✓

$\omega_2 = 226.71$ R/s

$m_2 = \frac{0.233 + 0.155}{2g} = \frac{0.194}{g}$ ✓ [lagest m_2 used]

Frequencies & Mass Ratio.

$\omega_1 = 1997.6$ R/s ✓ $\omega_2 = 226.71$ R/s ✓

$\mu = \frac{m_2}{m_1} = \frac{0.194}{0.435} = 0.446$ ✓

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SARGENT & LUNDY
ENGINEERS

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System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\omega_2^2 = (1997.6)^2 + 1.446(226.71)^2 = 4.06473\times10^6 \checkmark$$

$$\omega_s^2 = \frac{1}{2}\left[\alpha - \left(\alpha^2 - 4\omega_1^2\omega_2^2\right)^{1/2}\right]$$

$$= \frac{1}{2}\left[4.06473\times10^6 - \left\{(4.06473\times10^6)^2 - 4(1997.6)^2(226.71)^2\right\}^{1/2}\right]$$

$$\omega_s^2 = 51100 \checkmark$$

$$\omega_s = 226.05 \text{ R/S} \checkmark$$

$$f_s = 35.98 \text{ cps} > 33 \text{ cps}$$

$$a = 0.42\,g \checkmark$$

Forces

$$\text{Duct Bending} = 0.1\,\omega a\, l_{AB}^2 + \frac{4'}{2}\omega a \frac{l_{AB}}{6}$$

$$= \left[0.1(11) + \frac{1}{3}\right]\omega a\, l_{AB}$$

$$= 1.433\times0.031\times0.42\times132 = 2.46 \text{ in-k} \checkmark$$

$(5.87 \text{ in-k})^*$

$$\text{Duct Shear} = \frac{1}{2}\omega a\, l_{AB} + \frac{4'}{2}\omega a \times \frac{1}{2}$$

$$= \left(\frac{11}{2} + 1\right)\omega a = 6.5\times.031\times0.42 = 0.085^k \checkmark$$

$(0.202^k)^*$

* Values for 1g flat spectrum

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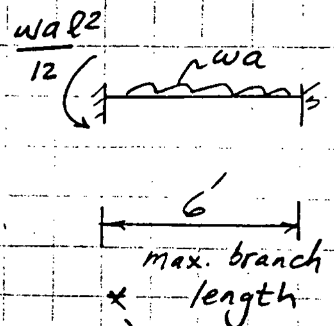
Duct Torsion



$$= \frac{wal^2}{12}$$

$$= \frac{.031 \times .42(6)(72)}{12}$$

$$= 0.469 \text{ in-k} \quad (1.117 \text{ in-k})$$

[option 2 is used]

* corresponding to acceleration of 1.0 g

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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Support S8 Force ✓ ✓ ✓

$$= \left\{\left[4+\frac{11}{2}+\frac{2}{2}\right]w + W_{S8}\right\}a$$

$$= \left\{10.5 \times .031 + 0.288\right\} 0.42$$

$$= 0.258\ k \qquad \left(0.614^{k}\right)^{*}$$

Support S16 Force

$$= \left\{\left[\frac{11}{2}+\frac{2}{2}+\frac{10}{2}\right]w + W_{S16}\right\}a$$

$$= \left[11.5 \times .031 + 0.288\right] 0.42$$

$$= 0.271\ k \qquad \left(0.645^{k}\right)^{*}$$

Support Leg Reaction

S8 & S9

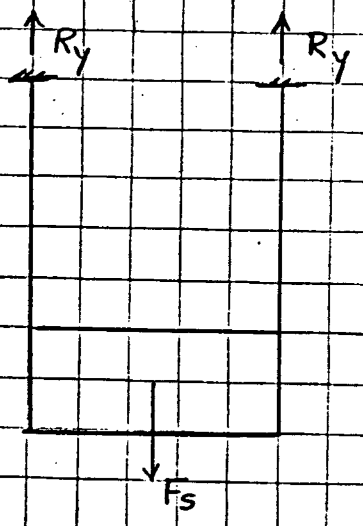
$$R_y = \frac{0.258}{2} + \frac{0.469}{38.5}$$

$$= 0.141^{k} \qquad \left(0.336^{k}\right)^{*}$$

S16

$$R_y = \frac{0.271}{2} + \frac{0.469}{38.5}$$

$$= 0.148^{k} \qquad \left(0.352^{k}\right)^{*}$$



* Values corresponding to acceleration of 1.0 g

SARGENT & LUNDY
ENGINEERS

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☐ Non-Safety-Related

Prepared by	R. Al-Dabbagh	Date	1/17/91
Reviewed by	M-Amin	Date	1-24-91
Approved by		Date	

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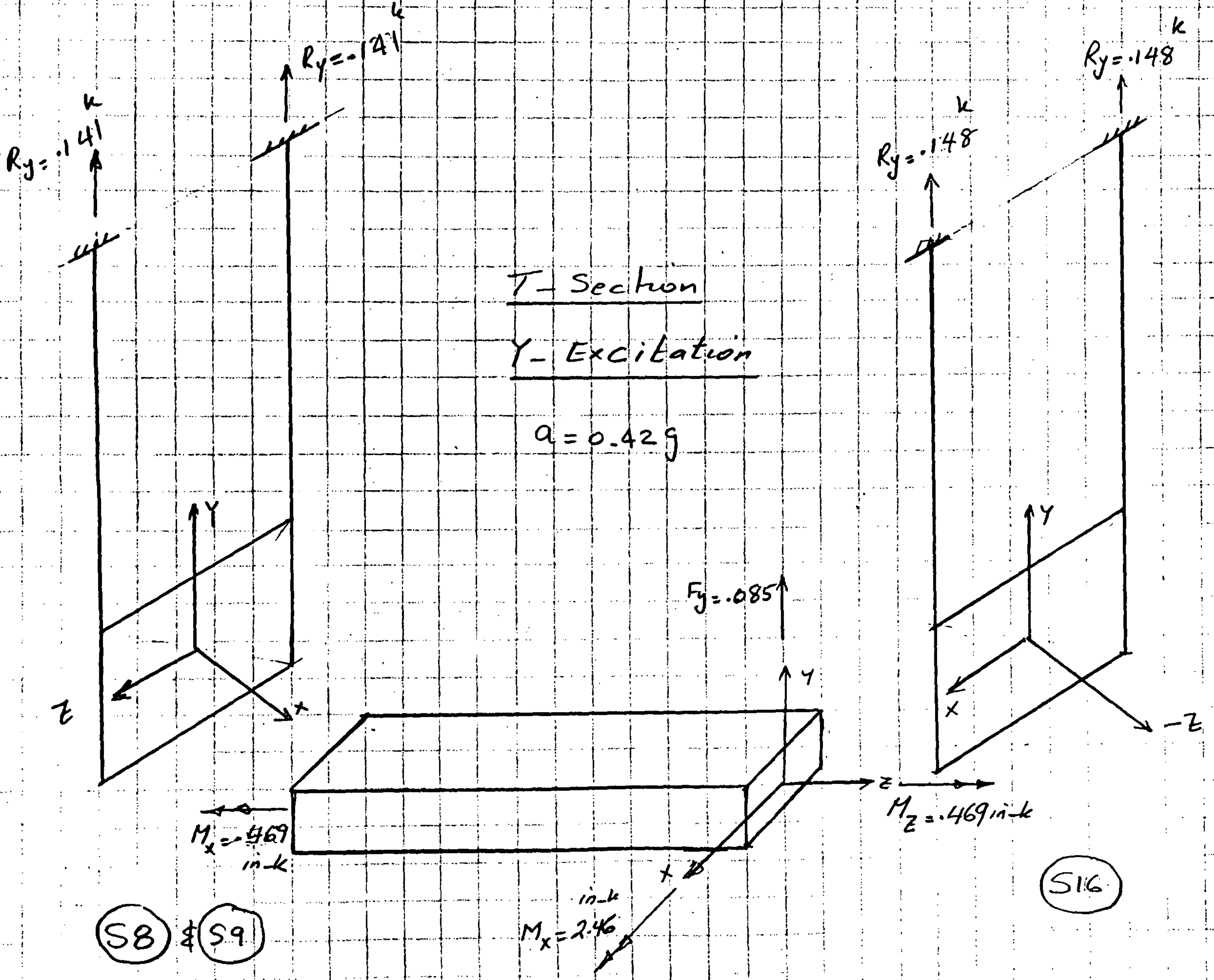
T- Section

Y- Excitation

a = 0.42g



S8 & S9

S16

SARGENT & LUNDY ENGINEERS

Client TVA
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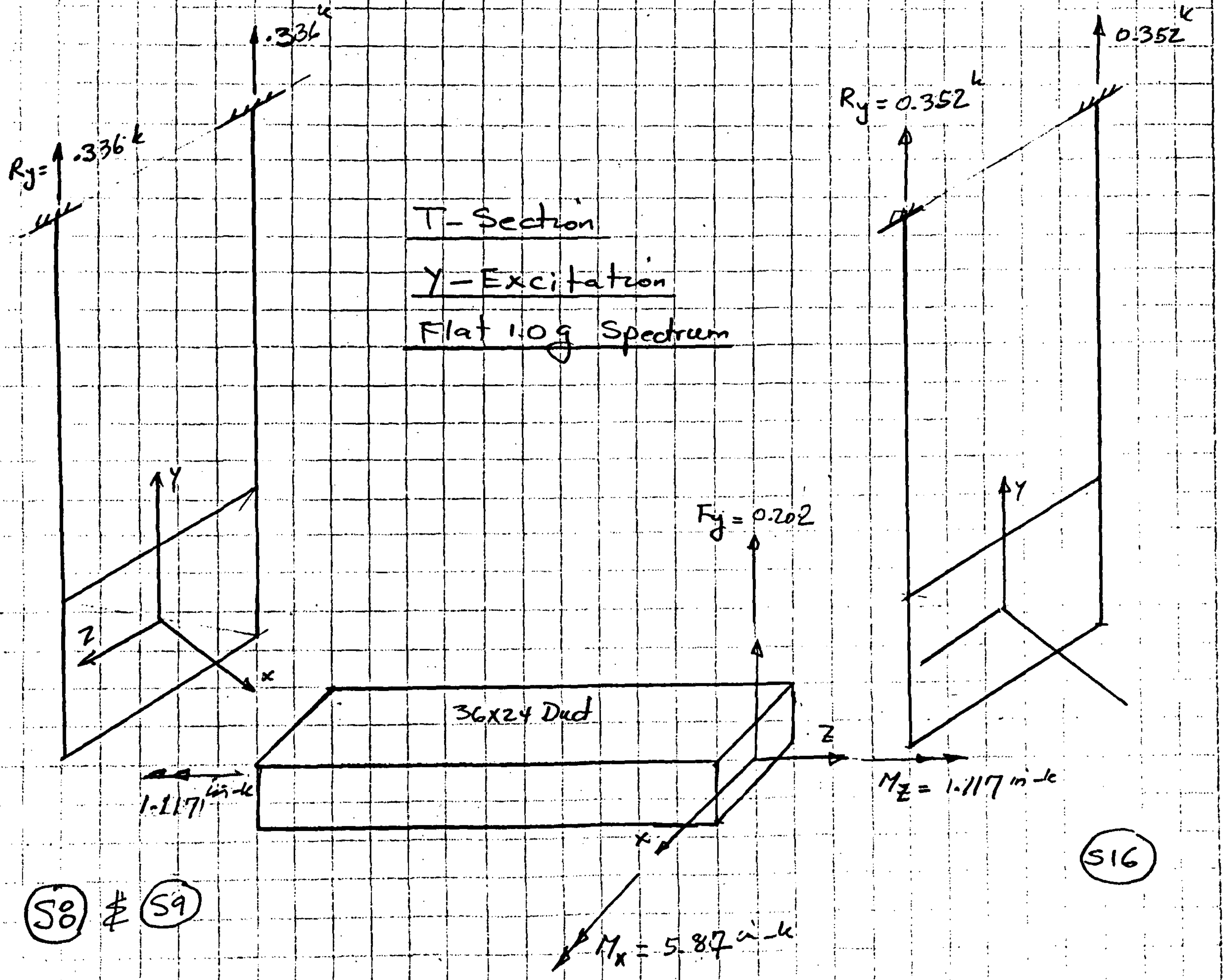
T-Section

Y-Excitation

Flat 1.0g Spectrum



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2DF RESULTS

EXCITATION DIRECTION : X

INPUT SPECTRUM : FLAT 1.0G

SYSTEM ELBTEE1

Fitting	Component in Fitting	Responses in, kip Units					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.155	0.155	3.72			
	Support S_3					0.299	9.87
	Support S_4					0.299	9.87
Tee	Duct	0.194	0.201	5.87			
	Support S8					0.307	10.14
	Supp. S_9					0.314	10.38
	Supp. S_{16}					0.322	10.64

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SARGENT & LUNDY
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2DF RESULTS

EXCITATION DIRECTION : Z

INPUT SPECTRUM : FLAT 1.0G

SYSTEM ELBTEE1

Fitting	Component in Fitting	Responses in, kip Units					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.155	0.155	3.72	—		
	Support S_3					0.299	9.87
	Support S_4					0.299	9.87
Tee	Duct	0.155	0.233	6.82	—		
	Support S8					0.322	10.64
	Supp. S_9					0.330	10.89
	Supp. S_{16}					0.338	11.15

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2DF RESULTS

EXCITATION DIRECTION : Y

INPUT SPECTRUM : FLAT 1.0G

SYSTEM ELBTEE 1

Fitting	Component in Fitting	Responses in, kip Units					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Axial	Moment
Elbow 1	Duct	——	0.155	3.72	1.75		
	Support S_3					0.345	——
	Support S_4					0.345	——
Tee	Duct	——	0.202	5.87	1.12		
	Support S8					0.336	——
	Supp. S9					0.336	——
	Supp. S_{16}					0.352	——

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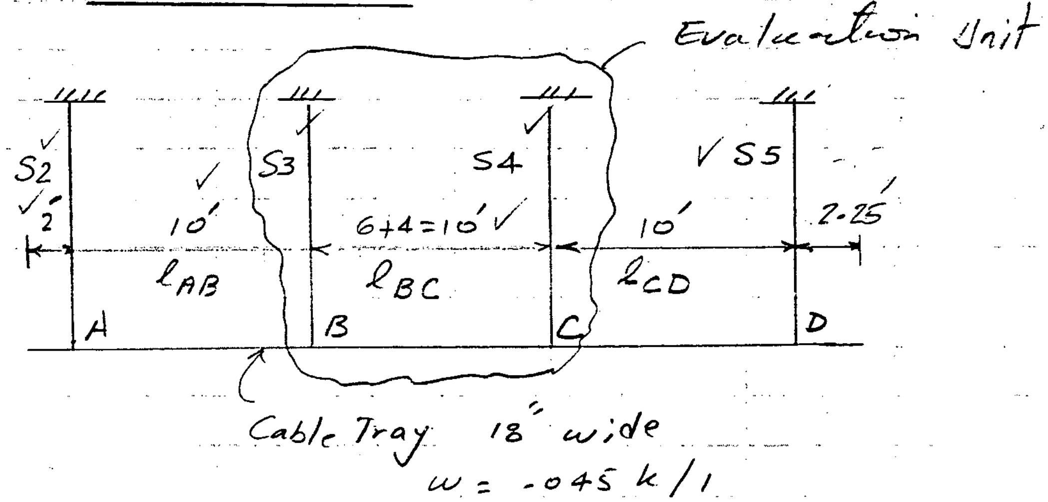
B.2 SYSTEM ELBTEE 2

Elbow OF Cable Tray System

Y- Excitation



$w = .045\ k/l$

$I_z = 0.821\ in^4$

Support Stiffness

$$k_A = k_B = k_C = k_D = 4657.6\ k/in$$

Support Masses

$$m_{1B} = \left[\left(\frac{10}{4}+\frac{10}{4}\right).045 + .288\right]/g = \frac{0.513}{g}$$

$$m_{1C} = m_{1B} = \frac{0.513}{g}$$

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$$\omega_{1BS} = \sqrt{\frac{k_B}{m_{1B}}} = \left[\frac{4567.6}{.513} \times 386.4\right]^{1/2} = 1854.83 \ R/s$$ ✓

$$\omega_{1CS} = 1854.83 \ R/s$$

$$\omega_1 = 1854.83 \ R/s$$ ✓

$$m_1 = \frac{0.513}{g}$$ ✓

Tray masses

$$m_{AB} = m_{BC} = m_{CD} = \frac{10}{2} \times .045/g = \frac{0.225}{g}$$ ✓ ✓ ✓

Tray stiffness

$$k_{AB} = k_{BC} = k_{CD} = \frac{48EI}{\ell^3} = \frac{48 \times 29000 \times 0.821}{(120)^3} = 0.6614 \ k/in$$ ✓ ✓ ✓ ✓ ✓

Tray frequency

$$\omega_{AB} = \left[\frac{0.6614 \times 386.4}{0.225}\right]^{1/2} = 33.70 \ R/s$$ ✓

$$\omega_2 = 33.70 \ R/s$$ ✓

$$m_2 = 0.225/g$$ ✓

Frequencies & mass Ratio

$\omega_1 = 1854.83 \ R/s$ ✓ $\qquad \omega_2 = 33.70 \ R/s$

$$\mu = m_2/m_1 = 0.225/0.513 = 0.44$$ ✓

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System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\,\omega_2^2$$

$$= (1854.83)^2 + 1.44(33.7)^2 = 3.44203\times10^6 \checkmark$$

$$\omega_s^2 = 0.5\left\{\alpha - \left(\alpha^2 - 4\omega_1^2\omega_2^2\right)^{1/2}\right\}$$

$$= \frac{1}{2}\left\{3.44203\times10^6 - \left[(3.44203\times10^6)^2 - 4(1854.83)^2(33.7)^2\right]^{1/2}\right\}$$

$$\omega_s^2 = 1135.5 \checkmark$$

$$\omega_s = 33.7 \text{ R/S} \checkmark$$

$$f_s = 5.363 \text{ cps} \checkmark$$

Since this frequency is located on the left of spectral peak ~~part of the spectrum~~, use Peak acceleration of spetrum

$$a = 1.50\,g \checkmark$$

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Forces:

Tray bending = $0.1\,\omega\, a\, l^2$

$= 0.1 \times .045 \times 1.50\,(120)(10)$

$= 8.1$ in-k $\qquad (5.4$ in-k$)^*$

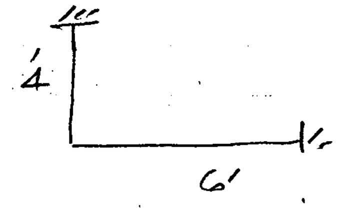
Tray Shear = $0.5\,\omega\, a\, l$

$= 0.5 \times .045 \times 1.50 \times 10$

$= 0.338^k \qquad (0.225^k)^*$

Tray Torsion

$\alpha = 0.47$ for the duct shown



(Run ID JØØA dated 1/23/91 shows α = Maximum torque over max. moment in duct, to be 0.47)

$T = 0.47 \times 8.1 = 3.81$ in-k $\qquad (2.54''^k)^*$

[option 2 is used]

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Support S_3 Force

$$= \left[\frac{W_{AB}+W_{BC}}{2} + W_{S3}\right] a$$

$$= \left[\left(\frac{10}{2}+\frac{10}{2}\right).045+0.288\right] a$$

$$= 0.738 \times 1.50 = 1.107^{k} \qquad (0.738^{k})^{*}$$

Torque on support S3 = $T = 3.81$ $\qquad (2.54''^{k})^{*}$

Support S_4 Force

$$= 1.107^{k} \qquad (0.738^{k})^{*}$$

$$T = 3.81''^{k} \qquad (2.54''^{k})^{*}$$

* in all above calc. these values correspond to acceleration of 1.0 g

Support Leg Force (1.0g)

Axial Force in leg for S_3 & S_4 $= \frac{0.738}{2} + \frac{2.54}{38.5} = 0.435^{k}$

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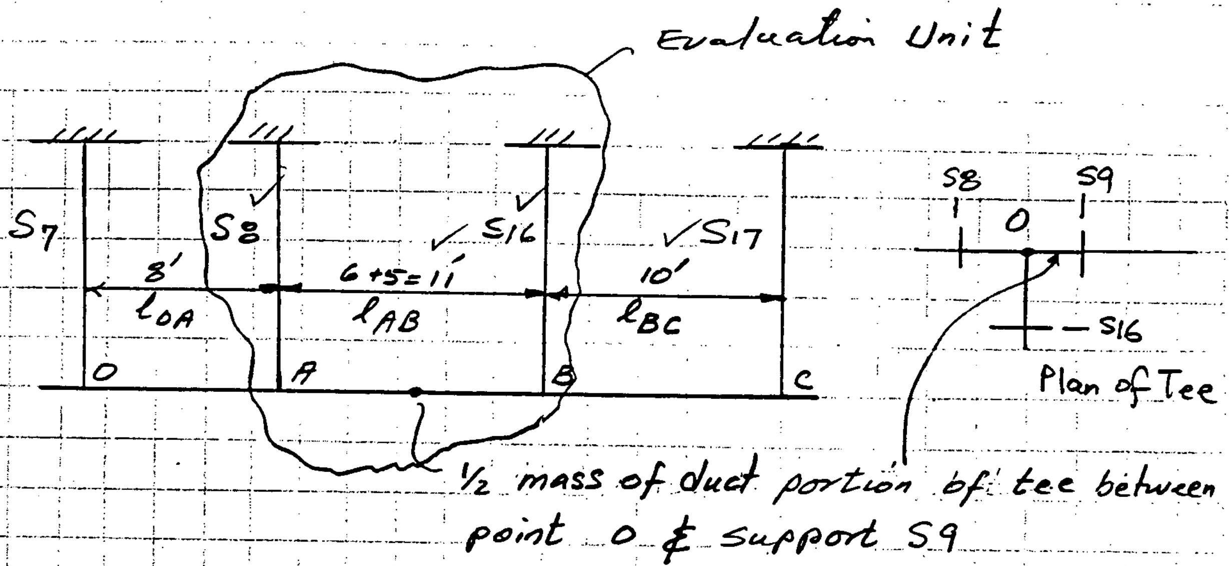
T - Section of Cable Tray System

Y- Excitation



Support Stiffness

$$k_A = k_B = 4657.6 \ k/in$$

Support masses

$$m_{1A} = \left[\left(\frac{8}{4}+\frac{11}{4}\right).045 + 0.288\right]/g = \frac{0.502}{g}$$

$$m_{1B} = \left[\left(\frac{11}{4}+\frac{10}{4}\right).045 + .288\right]/g = \frac{0.524}{g}$$

Support frequencies

$$\omega_{1A} = \sqrt{\frac{k_A}{m_{1A}}} = \left[\frac{4657.6 \times 386.4}{0.502}\right]^{1/2} = 1893.42 \ R/S$$

$$\omega_{1B} = \sqrt{\frac{k_B}{m_{1B}}} = \left[\frac{4657.6 \times 386.4}{.524}\right]^{1/2} = 1853.25 \ R/S$$

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$\omega_1 = 1853.25$ R/S ✓

$m_1 = 0.502/g$ ✓

Tray masses

$$m_{OA} = \left[\frac{8}{2} \times .045 + .288\right]/g = \frac{0.468}{g}$$

$$m_{AB} = \left[\left(\frac{11}{2} + \frac{4}{2}\right).045 + .288\right]/g = \frac{0.626}{g}$$ ✓

$$m_{BC} = \left[\left(\frac{10}{2}\right).045 + .288\right]/g = \frac{0.513}{g}$$ ✓

Tray Stiffness

$$k_{AB} = \frac{48EI}{L_{AB}^3} = \frac{48 \times 29000 \times 0.821}{(132)^3} = 0.497 \text{ k/in}$$ ✓

Tray Frequency

$$\omega_{AB} = \sqrt{\frac{k_{AB}}{m_{AB}}} = \sqrt{\frac{0.497 \times 386.4}{0.626}} = 17.513 \text{ R/s}$$ ✓

$\omega_2 = 17.513$ R/s ✓

$$m_2 = \frac{0.626 + 0.513}{2g} = \frac{0.570}{g}$$ [maximum m_2 used]

Frequencies & mass Ratio

$\omega_1 = 1853.25$ R/s ✓ $\omega_2 = 17.513$ R/s ✓

$$\mu = \frac{m_2}{m_1} = \frac{0.570}{0.502} = 1.134$$ ✓

$(1 + \mu) = 2.134$ ✓

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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System Frequency

$$\alpha = \omega_1^2 + (1+\mu)\,\omega_2^2$$

$$= (1853.25)^2 + 2.134\,(17.513)^2 = 3.43519 \times 10^6$$ ✓

$$\omega_s^2 = \frac{1}{2}\left[\alpha - \left(\alpha^2 - 4\omega_1^2\omega_2^2\right)^{1/2}\right]$$

$$= \frac{1}{2}\left\{3.43519 \times 10^6 - \left[(3.43519 \times 10^6)^2 - 4(1853.25)^2(17.513)^2\right]^{1/2}\right\}$$

$$\omega_s^2 = 306.675$$ ✓

$$\omega_s = 17.51 \text{ R/s}$$ ✓

$$f_s = 2.79 \text{ cps}$$ ✓

Use peak acceleration

$$a = 1.50g$$ ✓

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Forces

Tray Bending $= 0.1 w a l_{AB}^2 + \frac{4}{2} w a \frac{l_{AB}}{6}$

$= \left(0.1 l_{AB} + \frac{1}{3}\right) w a l_{AB}$

$= \left(0.1 \times 11 + \frac{1}{3}\right) .045 \times 1.5 \times 132$

$= 12.771$ in-k $\qquad (8514 \text{ in-k})^*$

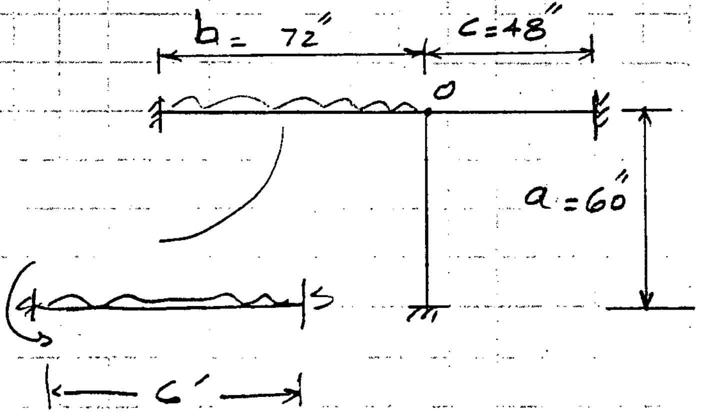
Tray shear $= \frac{1}{2} w a l_{AB} + \frac{4}{2} w a \times \frac{1}{2}$

$= (0.5 l_{AB} + 1) w a$

$= (0.5 \times 11 + 1) .045 \times 1.5$

$= 0.439^k \qquad (0.293^k)^*$

Tray Torsion :



$T = \frac{w l^2}{12}$

$= \frac{0.045 \times 1.5 (6)(72)}{12}$

$= 2.43$ in-k

$(1.62^{\text{in-k}})^*$

* in this page & the next two pages, these values correspond to acceleration of 1.0 g

SARGENT & LUNDY
ENGINEERS

Calcs. For	
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Prepared by	A-Ali Dakbagh	Date 1/24/91
Reviewed by	M-Amin	Date 1/24/91
Approved by		Date

Support S8 Force

$$= \left\{ \left[4 + \frac{11}{2} + \frac{2}{2} \right] w + W_{S8} \right\} a$$

$$= \left\{ 10.5 \times .045 + 0.288 \right\} 1.50$$ ✓

$$= 1.141^k \qquad (0.761^k)^* \checkmark$$

$$\text{Torque} = 2.43 \text{ in-k} \qquad (1.62^{\text{in-k}})^*$$

Axial Force per leg

$$= \frac{1.141}{2} + \frac{2.43}{38.5}$$ ✓

$$= 0.634^k \checkmark \qquad (0.422^k)^*$$

Support S9 Force

$$= \left\{ \left(\frac{9}{2} + \frac{11}{2} + \frac{2}{2} \right) w + W_{S9} \right\} a$$

$$= \left\{ 11 \times .045 + .288 \right\} 1.5$$

$$= 1.175^k \qquad (0.783^k)^*$$

$$\text{Torque} = 2.43 \text{ in-k} \qquad (1.62 \text{ in-k})^*$$

Axial Force per Leg

$$= \frac{1.175}{2} + \frac{2.43}{38.5}$$

$$= 0.651^k \qquad (0.434^k)^*$$ ✓

Torsion on S_{16} = 2.43 ok $(1.62^{k})^{*}$

Support S16 Force

$$= \left\{\left(\frac{11}{2} + \frac{2}{2} + \frac{10}{2}\right)\omega + W_{S16}\right\} a$$

$$= \left\{11.5 \times .045 + 0.288\right\} 1.5$$

$$= 1.208\ ^{k} \qquad (0.806^{k})^{*}$$

$$\text{Axial Force per Leg} = \frac{1.208}{2} + \frac{2.43}{38.5}$$

$$= 0.604^{k} + .0631 = 0.667^{k} \qquad \overset{0.444}{(0.444^{k})^{*}}$$

* Values corresponding to acceleration of 1.0 g.

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2DF RESULTS

EXCITATION DIRECTION : Y

INPUT SPECTRUM : FLAT 1.0G

~~SYSTEM - ELBTEE2~~

Fitting	Component in Fitting	Responses in, kip Units					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Axial	Moment
Elbow 1	Duct	—	0.225	5.40	2.54		
	Support S_3					0.435	—
	Support S_4					0.435	—
Tee	Duct	—	0.293	8.51	1.62		
	Support S8					0.422	—
	Supp. S9					0.434	—
	Supp. S_{16}					0.444	—

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C. Comarison of Results of 2DF and MDF Analyses for ELBTEE1 & ELBTEE2

1. Frequency Comparison for ELBTEE1

Portion of System	Frequency by 2DF	1st contributing mode frequency by MDF
Elbow	X-Excitation, f=20.5 cps	23.1 cps
	Z-Excitation, f=20.5 cps	23.2 cps
Tee	X-Excitation, f=20.2 cps	23.1 cps
	Z-Excitation, f=22.6 cps	23.3 cps

For above condition 2DF frequencies were less than first contributing mode frequency from MDF analysis

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2. Frequency Comparison for ELBTEE2

Portion of System	By 2DF	BY MDF 1st Contributing mode
Elbow1	Y-Excitation, f= 5.36 cps	4.64 cps
Tee	Y-Excitation, f= 2.79 cps	4.64 cps

In this case 2DF frequency was less than MDF frequency when 2DF model of Tee was evaluated.

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3. MDF/2DF Response Ratios for Major Responses

This Comparison is shown on the next three pages for X, Z and Y excitations. The excitation in all cases is a flat 7 g spectrum. The tables show that for horizontal excitation (X and Z) when supports are flexible, the response ratio is well below 1.2. For the Y-excitation, support are rigid. In this case, all response ratios are well below 1.0.

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COMPARISON OF MAJOR RESPOSE RATIOS

EXCITATION DIRECTION : X

INPUT SPECTRUM : FLAT 1.0G

SYSTEM - ELBTEE1

Fitting	Component in Fitting	RATIO MDF/2DF					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.56 ✓	1.11 ✓	0.99 ✓	—		
	Support S_3					1.00 ✓	1.00 ✓
	Support S_4					1.00 ✓	1.00 ✓
Tee	Duct	0.57 ✓	0.89 ✓	0.75 ✓			
	Support S8					0.95 ✓	0.95 ✓
	Supp. S_9					0.94 ✓	0.94 ✓
	Supp. S_{16}					0.93 ✓	0.93 ✓

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Denominator from Page 15.75

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COMPARISON OF MAJOR RESPOSE RATIOS

EXCITATION DIRECTION : Z

INPUT SPECTRUM : FLAT 1.0G

~~SYSTEM~~ – ELBTEE1

Fitting	Component in Fitting	RATIO MDF/2DF					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Shear	Moment
Elbow 1	Duct	0.67 ✓	0.95 ✓	1.05 ✓	—		
	Support S3					0.99 ✓	0.99 ✓
	Support S4					0.97 ✓	0.97 ✓
Tee	Duct	0.85 ✓	0.92 ✓	1.09 ✓	—		
	Support S8					0.90 ✓	0.90 ✓
	Supp. S9					0.97 ✓	0.97 ✓
	Supp. S16					0.87 ✓	0.87 ✓

Numerator from Page 15.20

Denominator from Page 15.76

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COMPARISON OF MAJOR RESPOSE RATIOS

EXCITATION DIRECTION : Y

INPUT SPECTRUM : FLAT 1.0G

SYSTEM - ELBTEE 2

Fitting	Component in Fitting	RATIO MDF/2DF					
		Duct				Support Leg	
		Axial	Shear	Moment	Torque	Axial	Moment
Elbow 1	Duct	—	0.45 ✓	0.64 ✓	0.26 ✓		
	Support S_3					0.63 ✓	—
	Support S_4					0.57 ✓	—
Tee	Duct	—	0.43 ✓	0.38 ✓	0.25 ✓		
	Support S8					0.68 ✓	—
	Supp. S_9					0.65 ✓	—
	Supp. S_{16}					0.54 ✓	—

Numerator from page 15.31
Denominator from page 15.77

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16. Summary and Conclusions of Revision 3

Revision 3 was undertaken to provide additional demonstration of the adequacy of the following calibration factors:

- 1.2 for systems on flexible supports using 2-DF approach
- 1.0 for systems on rigid supports where frequency is estimated from a simple span evaluation

The additional effort was to include straight run of components and components with elbows and tee. For straight run following parameters were to be addressed

* More span length variability
* Cases where the end span is in the evaluation unit
* Multi tiered systems

In Revision 3, following systems were evaluated

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– For straight Runs

a. 14 systems on flexible supports each using two spectra (SSE-EW and 1g flat)

b. 4 systems on rigid supports, each using two spectra (SSE-EW and 1g flat)

The excitation direction in straight run model was always lateral to the axis of the run.

– For Systems with Elbows and Tee.

a. One System was evaluated for two separate horizontal excitations: one in north-south and the other in east-west direction. This system had 18 supports and it involved two elbows and a tee.

The excitation was 1g flat spectrum in each direction

b. Another system of the Same plan configuration as above but with different member and support Properties was investigated for vibration normal to the plane of elbows and tee. Again 1g-flat spectrum was used. Parameters were selected to excite the system dynamically in this direction.

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Prepared by	M. Amin	Date 1.24.91
Reviewed by	A. Al-Dabbagh	Date 1/24/91
Approved by		Date

For straight-run systems on flexible support, the maximum ratio of MDF/2DF was 1.07 for SSE-~~E~~W Spectrum and 1.2 for flat 1g spectrum. (Note that a flat spectrum is conservative in campturing the effects of higher modes.)

For straigh-run systems on rigid supports, the maximum ratio of MDF/Simplified analysis was well below 1.0

For systems with elbow and tee, the maximum ratio of MDF/2DF analysis was well below 1.2 for horizontal response and well below 1.0 for vertical response. (Supports were basically rigid in the vertical direction).

Considering the above additional results and provided the component and support forces are calculated as stated in Sections 2 and 10 of this calculation, we conclude that the calibration factors of 1.2 for flexible supports and 1.0 for rigid support conditions are adequate.

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Prepared by A-AliDabbagh	Date 1/23/91
Reviewed by M. Amri	Date 1-24-91
Approved by	Date

APPENDIX A

DUCT SECTION PROPERTIES

The duct section properties used in the calculations are obtained using specific purpose computer program. The detail of this program are documented in S&L calculation 857303-7.5 Appendix A, Rev. 0 (TVA Calculation no. WCG-1403).

The basic input to this program consists of duct size and plate thickness.

The 36"x24" x 22 gage (t=.0299") was analyzed for this purpose. RUN SPROP dated 1/15/91 Contains the input & output for this duct. Listing of this output is part of this appendix. The output also indicates that the program absolute element was created on Jan. 31, 1990.

Form GQ-3.08.1 Rev. 2 SL-F647 10-85 KPS

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1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890**SEQ NO. 00


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                         SSSSSSSSSS       PPPPPPPPPPP       RRRRRRRRRRR        0000000000       PPPPPPPPPPP
                        SS        SS      PP        PP      RR        RR      00        00      PP        PP
                        SSS       SS      PP        PP      RR        RR      00        00      PP        PP
                          SSS             PP        PP      RR        RR      00        00      PP        PP
                            SSS           PPPPPPPPPPP       RRRRRRRRRRR       00        00      PPPPPPPPPPP
                              SSS         PPPPPPPPPP        RRRRRRRRRR        00        00      PPPPPPPPPP
                                SSS       PP                RR    RR          00        00      PP
                        SS        SS      PP                RR     RR         00        00      PP
                        SS        SS      PP                RR      RR        00        00      PP
                         SSSSSSSSSS       PP                RR       RR        0000000000       PP
                          SSSSSSSS        PP                RR        RR        00000000        PP


*  *  *  *  *  *  UNISYS 1100 TIME/SHARING EXEC --- MULTI-PROCESSOR SYSTEM --- LEV. 40R3A        SITE *      S&L-D*  *  *  *  *  *


    RUNID * SPROP          USER ID * 051463          PART NUMBER *          INPUT DEVICE * @@@@@@          OUTPUT DEVICE * XEROX1
      FILE NAME * RSI$SPROP   011591160427 CREATED AT:    16:04:16 JAN 15,1991                PRINTED AT:    16:38:38 JAN 15,1991


1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890**SEQ NO. 00
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Reviewed by: [illegible] 1-24-91

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