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TO: Mr. Edson G. Case

FROM: Indiana & Michigan Power Co.
New York, NY 10004
G. P. Maloney

DATE OF DOCUMENT: 02/27/78

DATE RECEIVED: 03/02/78

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DESCRIPTION

Response to NRC's ltr dtd 02/07/78 ...Furnishing addl info on the analysis of the Steam Generator Subcompartment Pressure Response... Notorized 02/27/78...

1p + 1/8".

PLANT NAME: DONALD C. COOK UNITS 1 & 2
jcm 03/02/78

ENCLOSURE

1 ENCL

FOR ACTION/INFORMATION

ASSIGNED AD: (LTR)	VASSALLO
BRANCH CHIEF:	KNIEL
PROJECT MANAGER:	MLYNCZAK
LICENSING ASST: (LTR)	J. LEE
	SCHWENCER (3)

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INDIANA & MICHIGAN POWER COMPANY

P. O. BOX 18
BOWLING GREEN STATION
NEW YORK, N. Y. 10004

February 27, 1978

Donald C. Cook Nuclear Plant Units 1 & 2
Docket Nos. 50-315 and 50-316
DPR Nos. 58 and 74
Steam Generator Subcompartment Pressure Response Analysis

Mr. Edson G. Case, Acting Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Case:

In his letter dated February 7, 1978, Mr. Kniel of the Division of Project Management requested additional information on the above cited analysis. An item by item response to Mr. Kniel's request is enclosed herein.

Very truly yours,

G. P. Maloney
Vice President

Sworn and subscribed to before me this 27th day of February, 1978 in New York County, New York

Kathleen Barry
Notary Public

KATHLEEN BARRY
NOTARY PUBLIC, State of New York
No. 41-4606792
Qualified in Queens County
Certificate filed in New York County
Commission Expires March 30, 1979

cc: R. C. Callen
G. Charnoff
P. W. Steketee
R. J. Vollen
R. Walsh
D. V. Shaller - Bridgman
R. W. Jurgensen

7806100042

1. Provide drawings which indicate the manner in which the net free volume within the steam generator enclosure was subdivided to formulate the five node and seventeen node models which were part of the nodalization sensitivity studies.

Response:

The nodalization schemes for the five and seventeen node models are given in Fig. 1 and Fig. 2, respectively. The flow parameters used in these nodalizations are listed on the following pages.

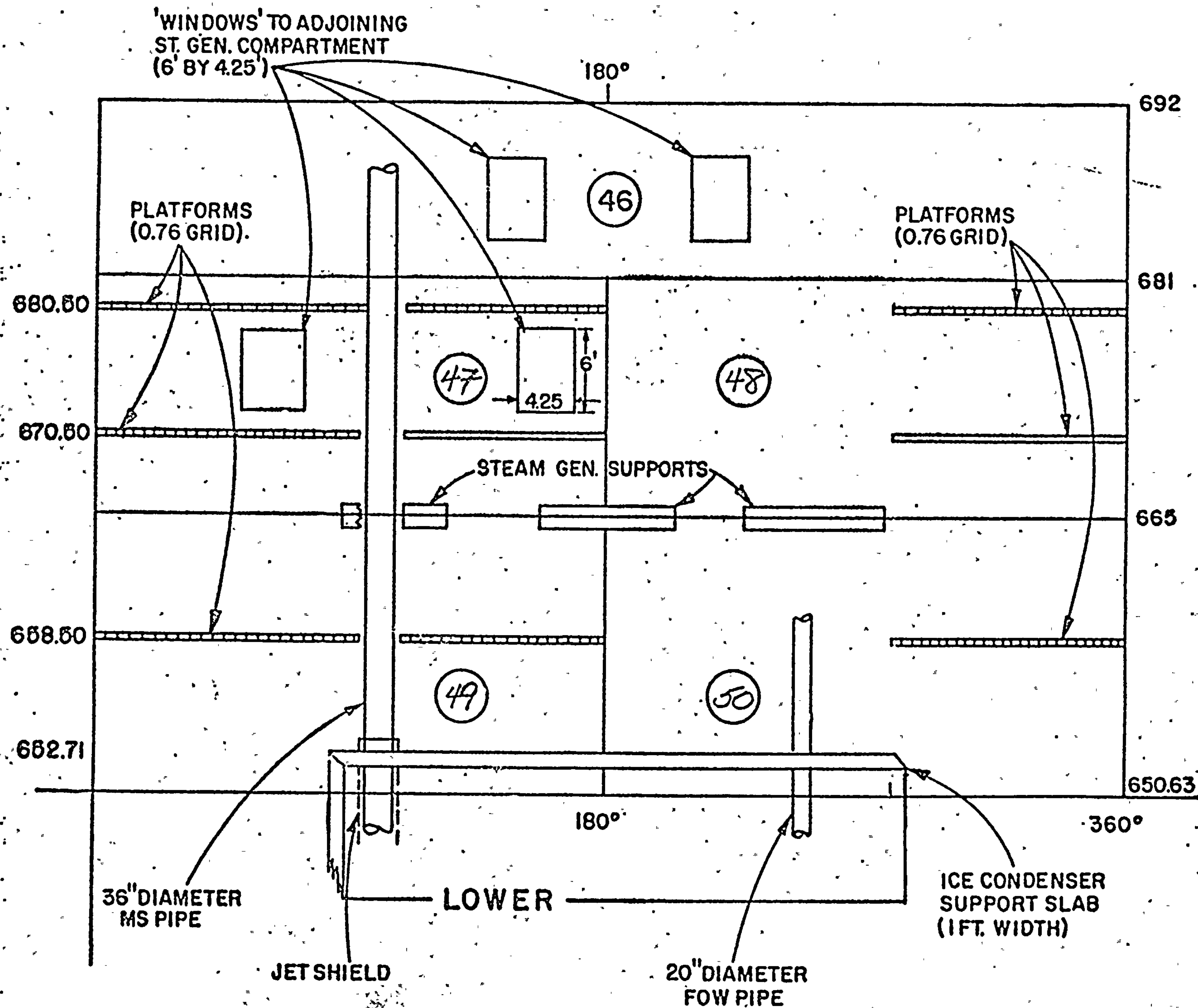


Figure 1. Five Node Model.

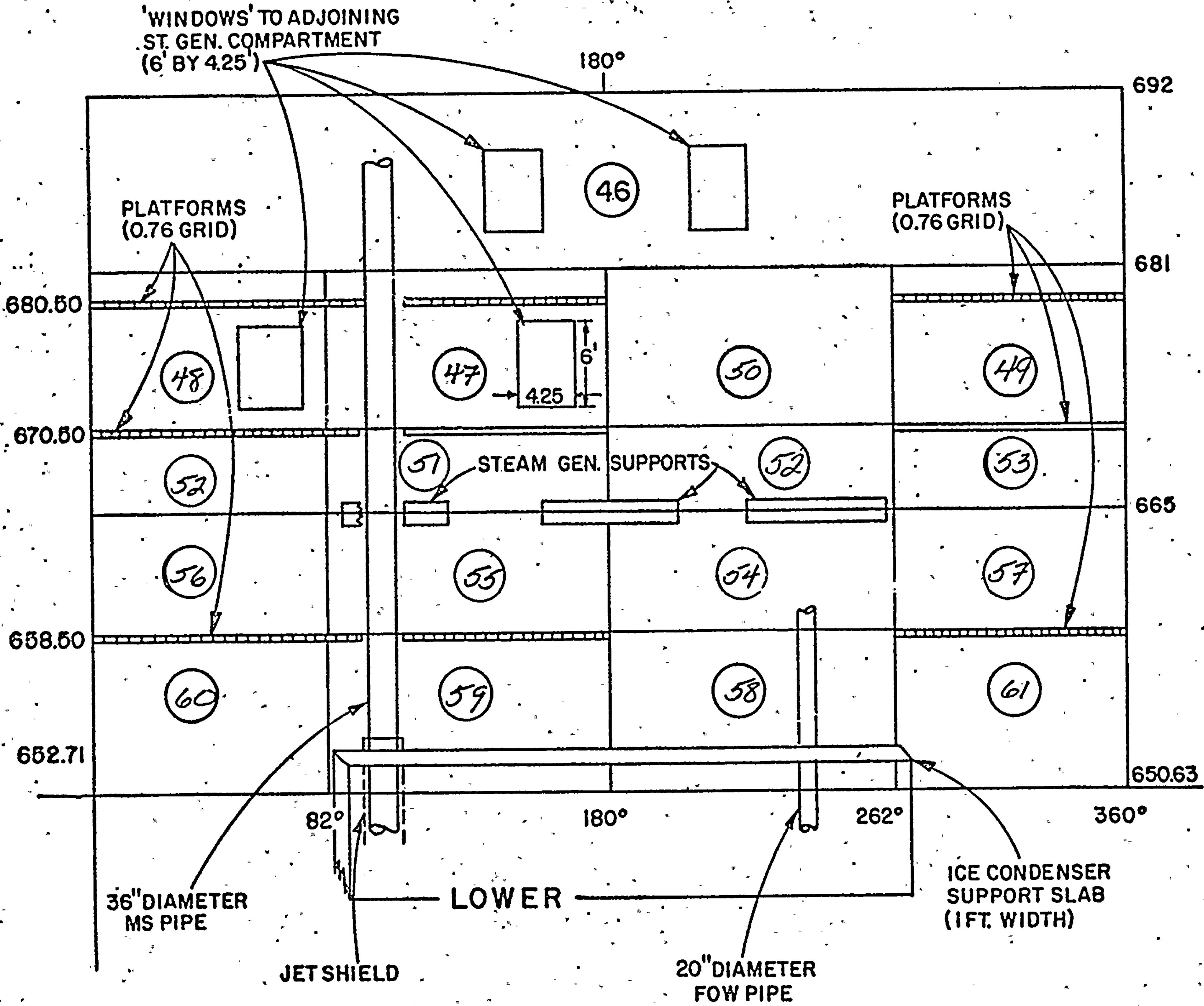


Figure 2. Seventeen Node Model.

5 NODE TMD MODEL - VOLUME AND FLOWPATH DATA

TMD NODE	VOLUME (CUBIC FEET)
46,51	4196.83
47,52	1752.33
48,53	1712.45
49,54	1766.77
50,55	1657.21

OUTLET NOZZLE (TOP) BREAK

FLOWPATH	K	F	L_I (ft)	D_H (ft)	L_{EQ} (ft)	A_T (ft^2)	A_T/A_U
46-47	0.84	0.03	10.99	5.98	10.11	90.68	0.449
46-48	0.47	0.03	10.98	7.03	9.94	100.01	0.502
47-49	1.32	0.03	14.75	5.93	14.75	90.63	0.836
48-50	0.32	0.03	14.52	6.25	13.58	81.09	0.758
49-2	1.08	0.03	6.67	6.06	7.00	113.71	0.886
50-1	1.09	0.03	6.61	6.38	6.51	104.85	1.00
47-48	1.51	0.04	24.97	5.50	31.65	154.0	0.478
49-50	1.55	0.04	25.77	6.64	31.70	96.01	0.538
47-47	1.49	0.03	10.49	4.98	10.76	51.0	0.250

SIDE BREAK*

FLOWPATH	K	F	L_I	D_H	L_{EQ}	A_T	A_T/A_U
46-47	0.84	0.03	10.99	5.98	10.11	90.68	0.836
46-48	0.84	0.03	10.98	7.03	9.94	100.01	0.8934

* All other Flowpath Data is the same for the Side Break as it is for the outlet Nozzle (Top) Break.

17 NODE TMD MODEL - VOLUME AND FLOWPATH DATA

TMD NODE	VOLUME (CUBIC FT)
46,63	4196.83
47,64	762.96
48,65	386.56
49,66	386.56
50,67	736.81
51,68	400.10
52,69	202.71
53,70	202.71
54,71	386.37
55,72	462.90
56,73	244.53
57,74	244.53
58,75	418.35
59,76	692.54
60,77	366.80
61,78	366.80
62,79	627.53

17 NODE TMD MODEL - HORIZONTAL FLOW PATHS for OUTLET NOZZLE (TOP) or SIDE BREAK

FLOWPATH	K	F	L_I (ft)	L_{EQ} (ft)	D_H (ft)	A_T (ft^2)	A_T/A_U
47-48	0.62	0.03	10.26	10.26	5.67	29.74	1.00
48-49	0.27	0.03	13.0	13.0	5.67	29.74	1.00
49-50	0.62	0.03	12.26	12.26	5.67	29.74	1.00
50-47	1.00	0.03	14.36	14.36	6.00	31.49	1.00
51-52	0.63	0.03	10.26	10.26	5.67	15.59	1.00
52-53	0.29	0.03	13.0	13.0	5.67	15.59	1.00
53-54	0.63	0.03	12.26	12.26	5.67	15.59	1.00
54-51	1.01	0.03	14.36	14.36	6.00	16.51	1.00
55-56	0.61	0.03	10.26	10.26	5.67	18.13	1.00
56-57	0.27	0.03	13.0	13.0	5.67	18.13	1.00
57-58	0.61	0.03	12.26	12.26	5.67	18.13	1.00
58-55	0.97	0.03	14.36	14.36	6.00	19.20	1.00
59-60	0.64	0.03	9.68	9.68	7.57	30.20	1.00
60-61	0.33	0.03	12.27	12.27	7.57	30.20	1.00
61-62	0.64	0.03	11.57	11.57	7.57	30.20	1.00
62-59	1.03	0.03	13.42	13.42	7.90	31.52	1.00

17 NODE TMD MODEL - VERTICAL FLOW PATHS - SIDE BREAK

FLOWPATH	K	F	L_I (ft)	L_{EQ} (ft)	D_H (ft)	A_T (ft^2)	A_T/A_U
46-47	0.82	0.03	8.21	7.38	6.16	60.87	0.837
46-48	0.88	0.03	7.58	6.60	5.67	29.81	0.809
46-49	0.80	0.03	7.58	6.60	5.67	29.81	0.809
46-50	0.38	0.03	8.16	7.10	7.83	70.20	1.00
47-51	0.69	0.03	8.00	8.00	6.07	60.54	0.845
48-52	0.66	0.03	8.00	8.00	5.67	30.09	0.817
49-53	0.60	0.03	8.00	8.00	5.67	28.89	0.784
50-54	0.0	0.03	8.00	8.00	7.83	70.20	1.00
51-55	0.0	0.03	6.00	6.00	6.07	71.64	1.00
52-56	0.01	0.03	6.00	6.00	5.67	28.83	0.783
53-57	0.08	0.03	6.00	6.00	5.67	28.83	0.783
54-58	0.13	0.03	6.00	6.00	6.62	52.20	0.744
55-59	0.67	0.03	6.71	6.29	6.07	60.54	0.661
56-60	0.74	0.03	6.46	5.87	5.67	30.09	0.563
57-61	0.69	0.03	6.46	5.87	5.67	28.89	0.540
58-62	0.06	0.03	7.07	6.95	6.62	50.02	0.713
59-2	1.03	0.03	3.63	3.38	7.10	76.88	0.840
60-2	1.09	0.03	3.93	3.93	9.09	53.49	1.00
61-1	1.09	0.03	3.93	3.93	9.09	53.49	1.00
62-1	1.08	0.03	3.70	3.49	8.17	75.93	0.864

TOP BREAK*

FLOWPATH	K	F	L_I	L_{EQ}	D_H	A_T	A_T/A_U
46-47	.82	.022	11.21	10.38	6.16	60.87	0.495
46-48	.88	.022	10.58	9.60	5.67	29.81	0.378
46-49	.88	.022	10.58	9.60	5.67	29.81	0.378
46-50	.38	.021	11.16	10.10	7.83	70.20	0.583

* All other flow data is the same for the side break as it is for the outlet nozzle (top) break.

2. Provide figures which (a) identify the peak forces and moments acting upon the steam generator for each of the models used in the sensitivity studies (i.e., five, nine and seventeen node models) and (b) demonstrate that the loads transmitted to the steam generator supports are maximized by the nine node model.

Response:

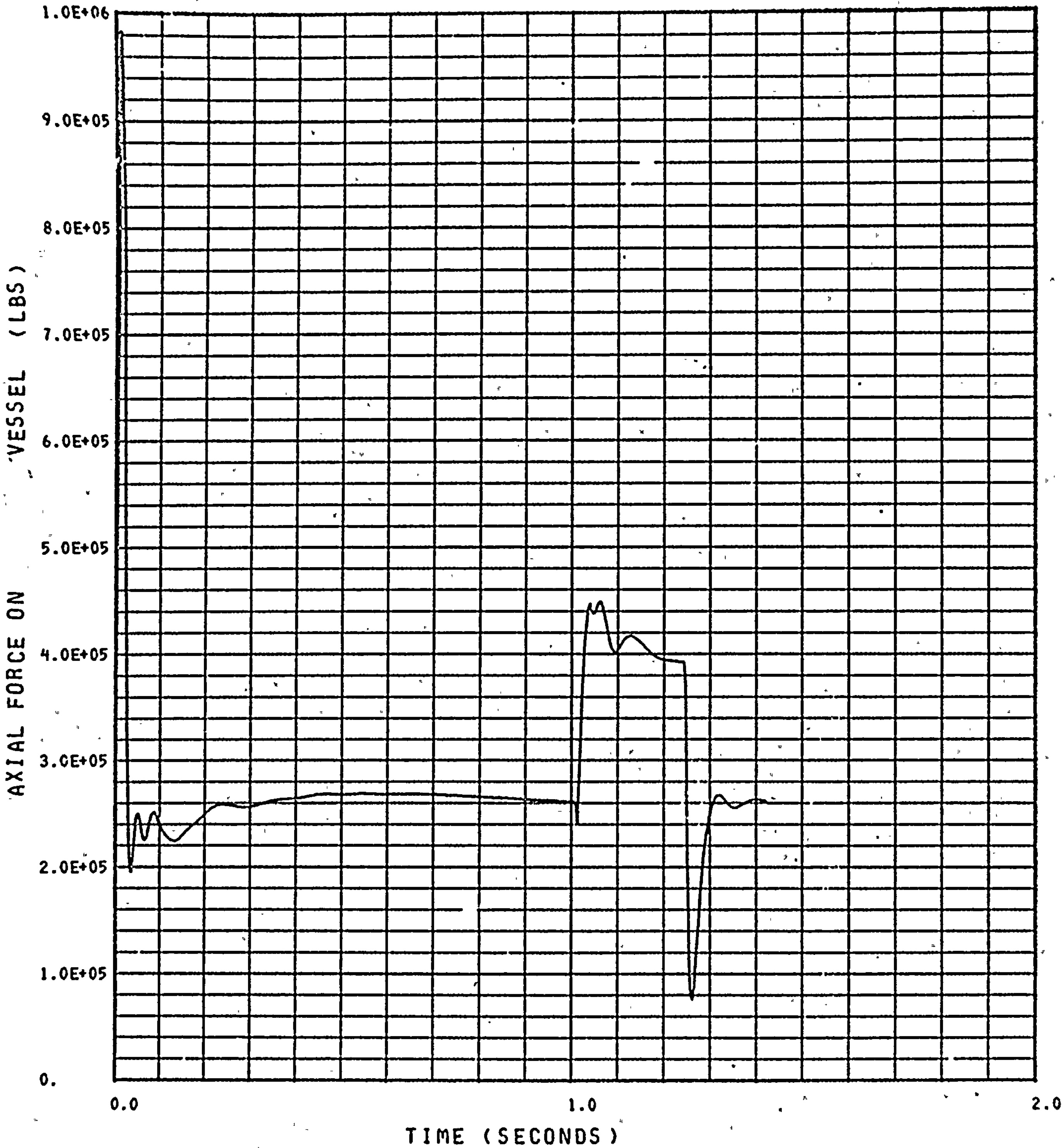
(a) Table A presents the peak steam generator loads and the time of occurrence for the five, nine and seventeen node models. Figures 2.1 through 2.9 present the horizontal (same as axial) force time history, the vertical force time history, and the moment time history for each of the three models evaluated in the nodal study.

(b) Only the peak inertial negative moment for the five and seventeen node models were slightly higher than the peak inertial negative moment for the nine node model. The calculations of the steam generator support loads were made by combining the forces and moments without consideration of time phasing. This conservatism would result in the nine node model submitted encompassing the resultant support loads using a time phase analysis with the other 2 models. This can be seen by noting from the attached information that the peaks are quite narrow and do not occur at the same time.

TABLE A

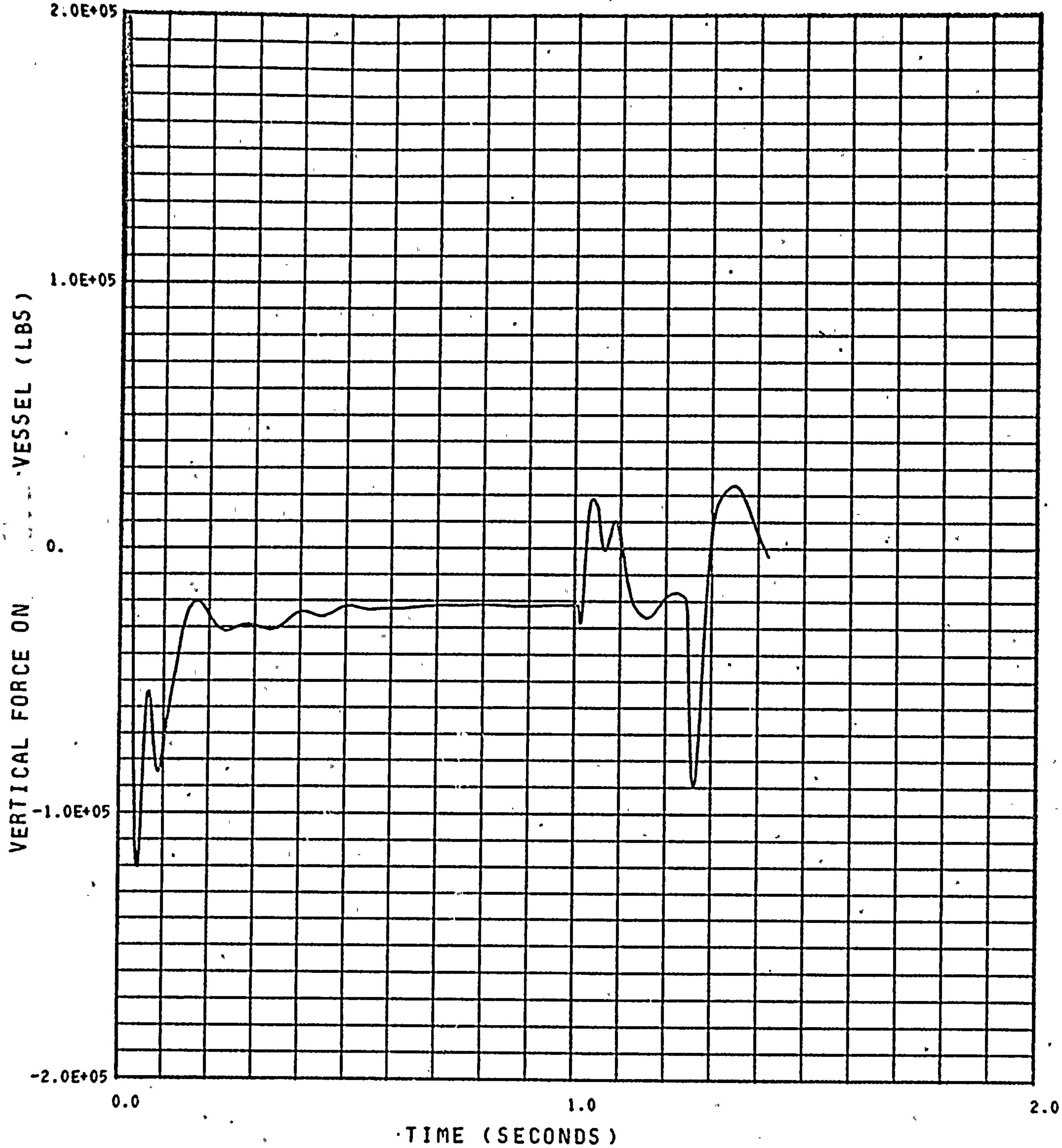
Model	F_H Peak Horizontal Force (kips)	Time of F_H (Secs)	M+ Peak Positive Moment (Ft-lbs)	Time of M+ (Secs)	M- Peak Negative Moment (Ft-lbs)	Time of M- (Secs)
5 node	982	0.01015	7.67×10^5	0.03194	$- 4.85 \times 10^6$	0.01310
9 node	982	0.00822	2.64×10^6	0.03019	$- 4.57 \times 10^6$	0.01232
17 node	800	0.00991	2.37×10^6	0.03228	$- 6.85 \times 10^6$	0.01477

FIGURE 2.1



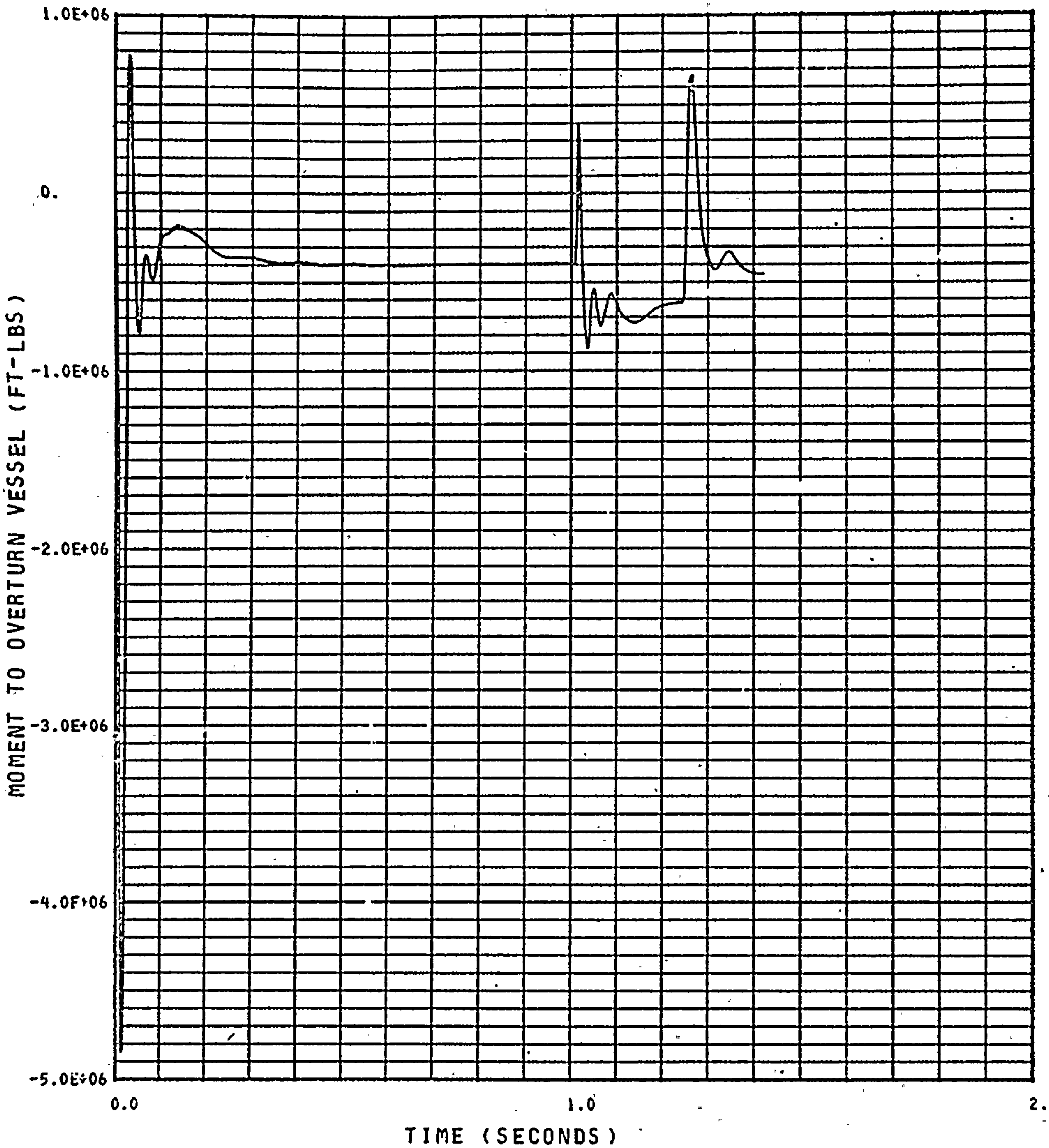
AMP STEAM GENERATOR STEAM GENERATOR MODELED AS 5 NODES

FIGURE 2.2



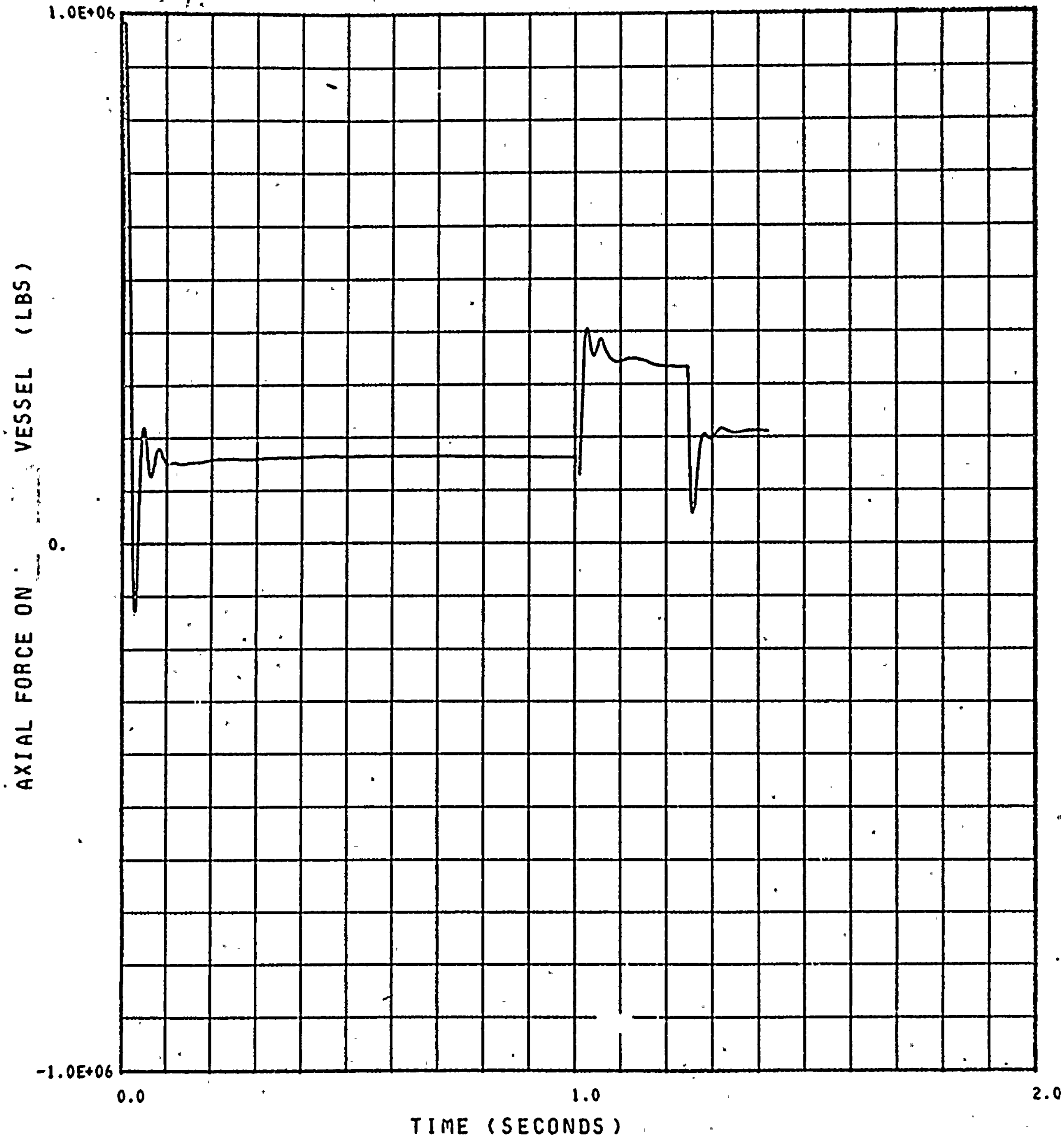
AMP STEAM GENERATOR STEAM GENERATOR MODELED AS 5 NODES

FIGURE 2.3



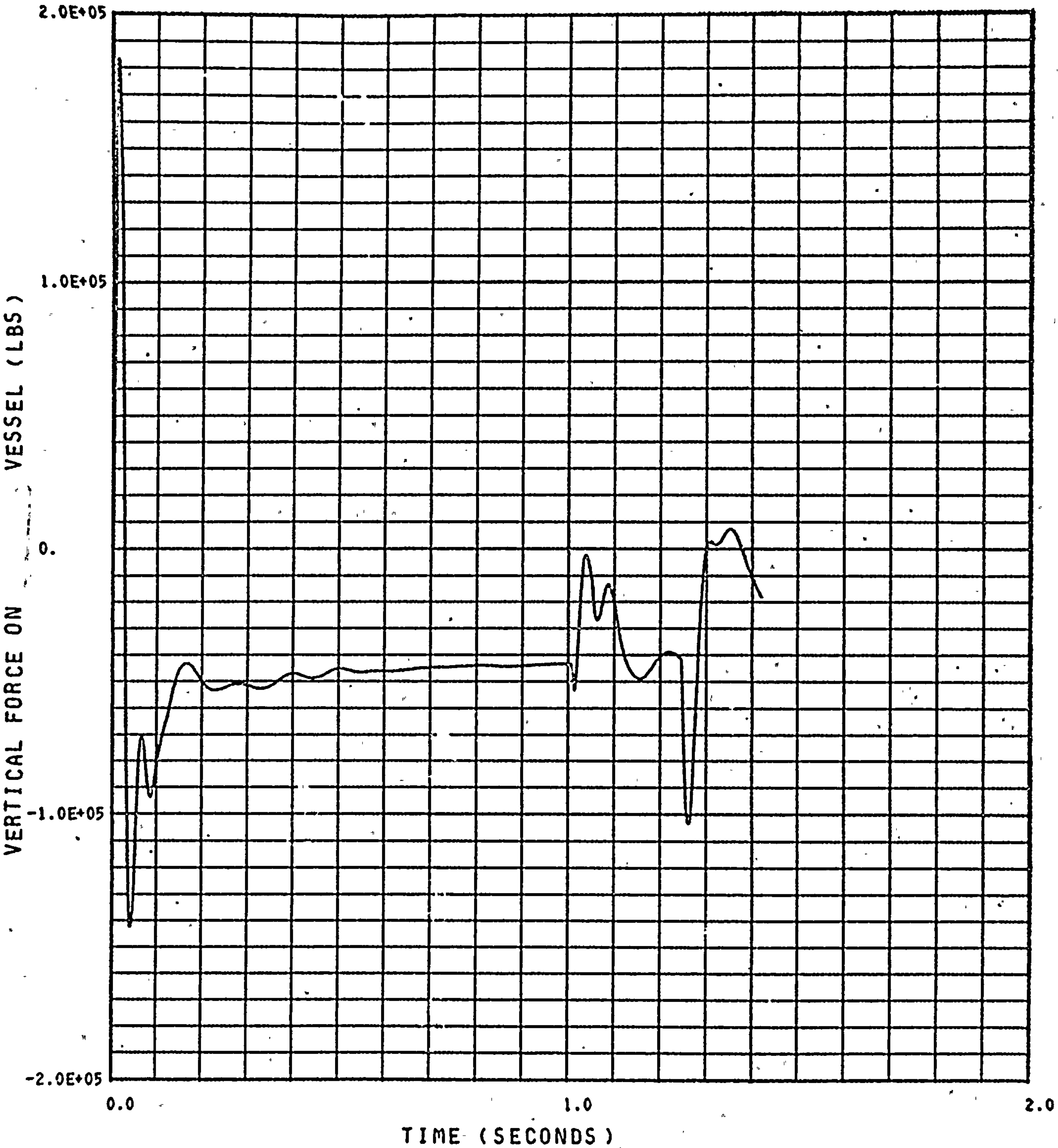
AMP STEAM GENERATOR   STEAM GENERATOR MODELED AS 5 NODES

FIGURE 2.4



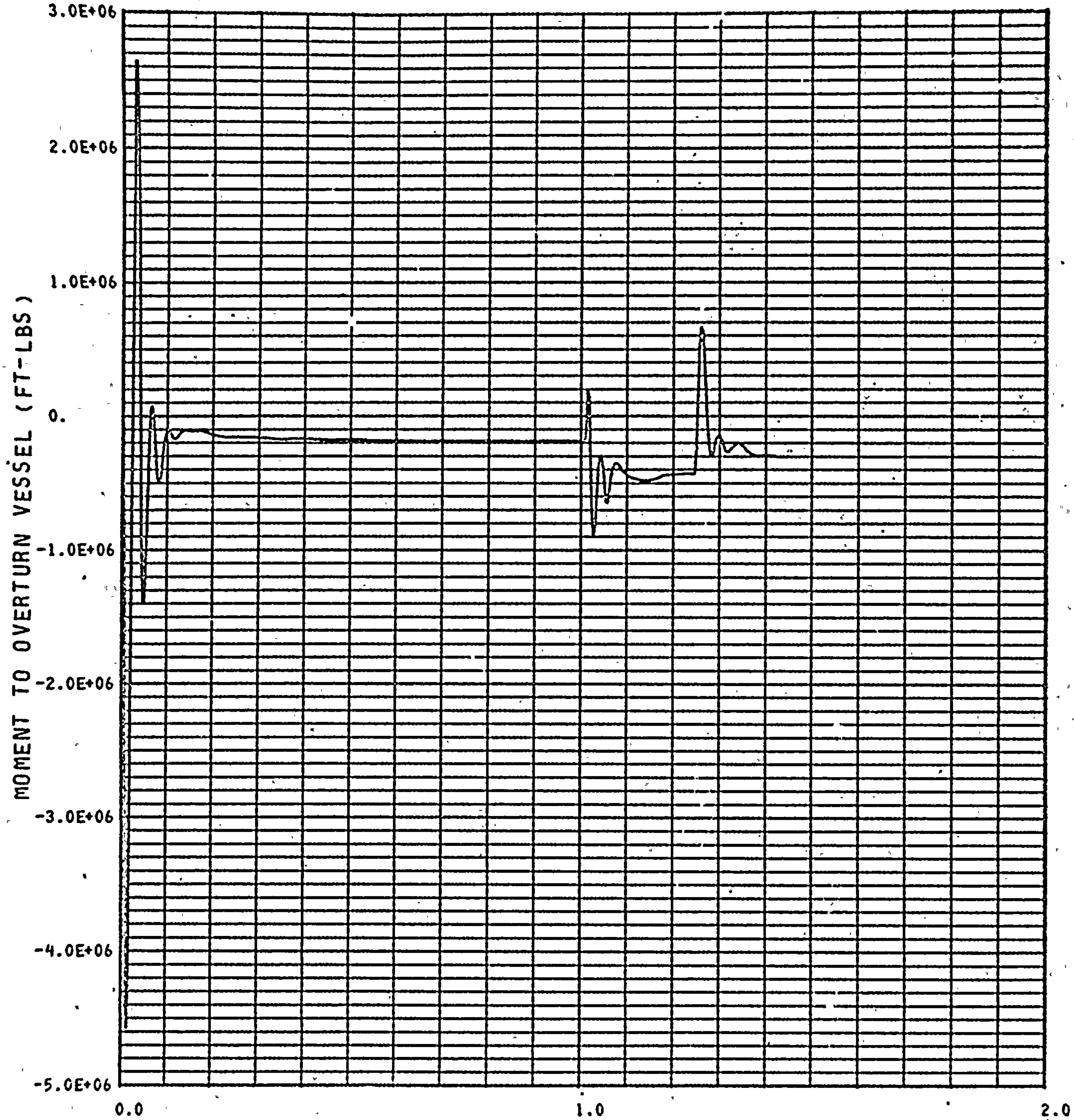
AMP STEAM GENERATOR   STEAM GENERATOR MODELED AS 9 NODES

FIGURE 2.5



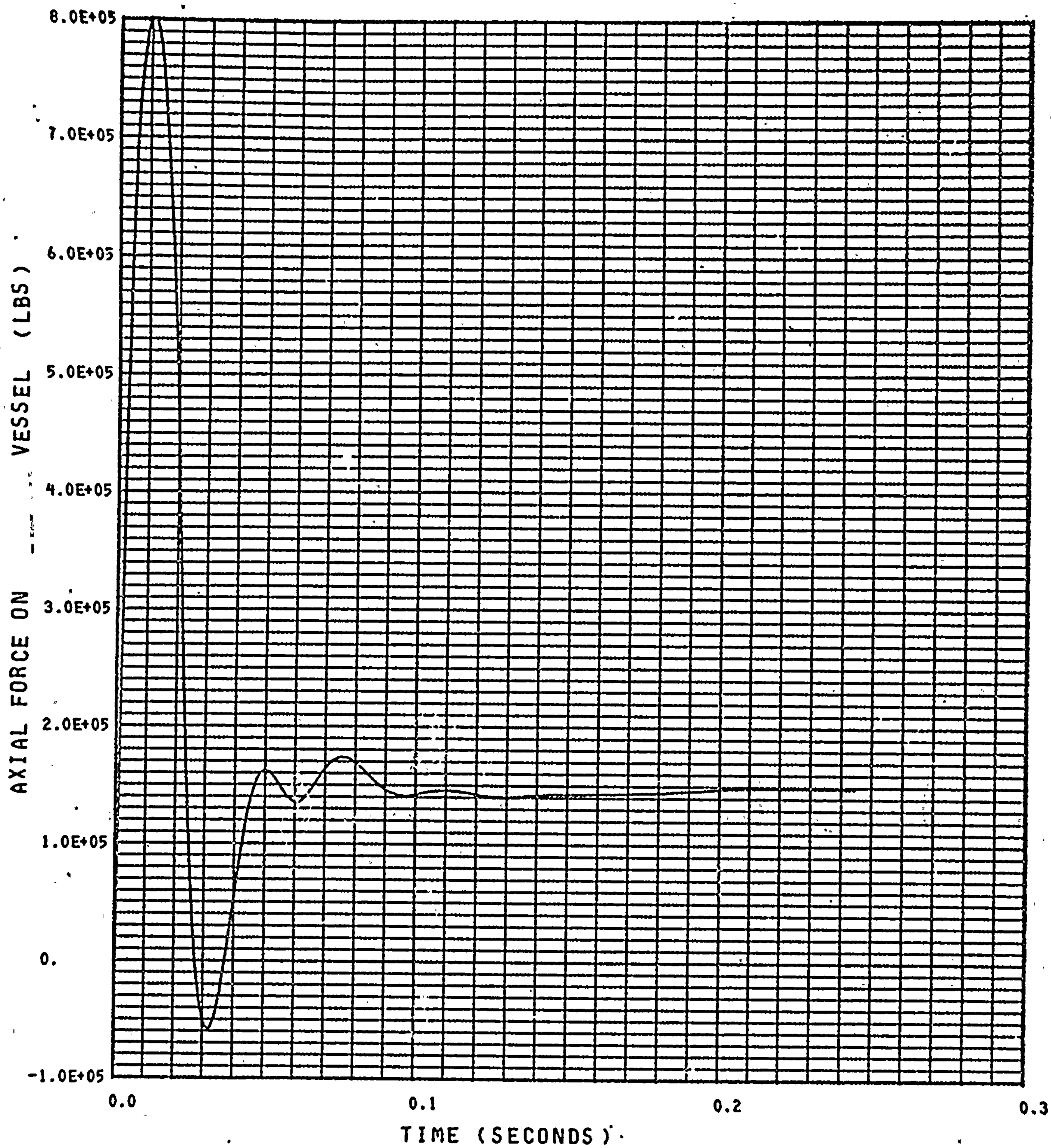
AMP STEAM.GENERATOR STEAM GENERATOR MODELED AS 9 NODES

FIGURE 2.6



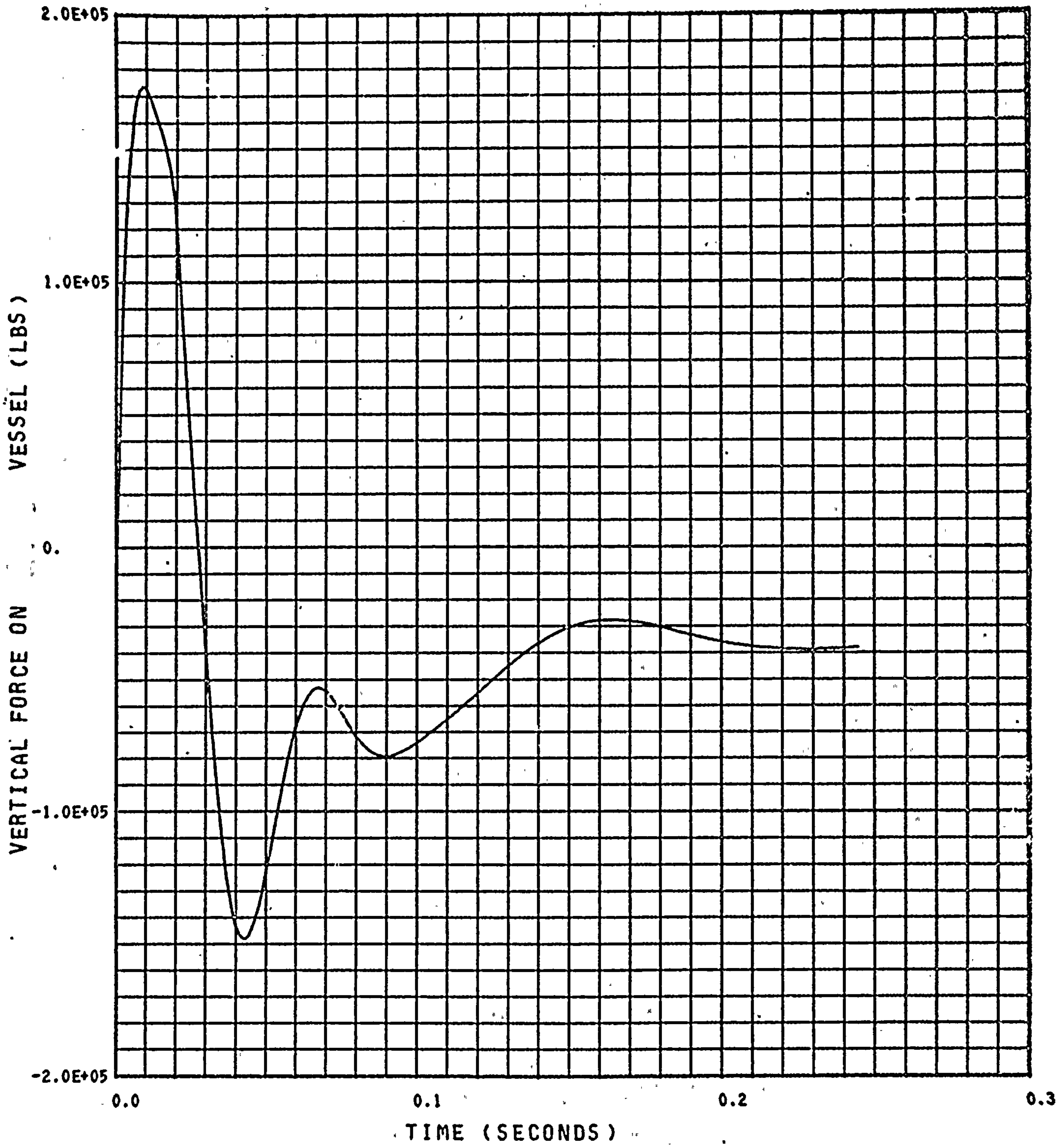
AMP STEAM GENERATOR   STEAM GENERATOR MODELED AS 9 NODES

FIGURE 2.7



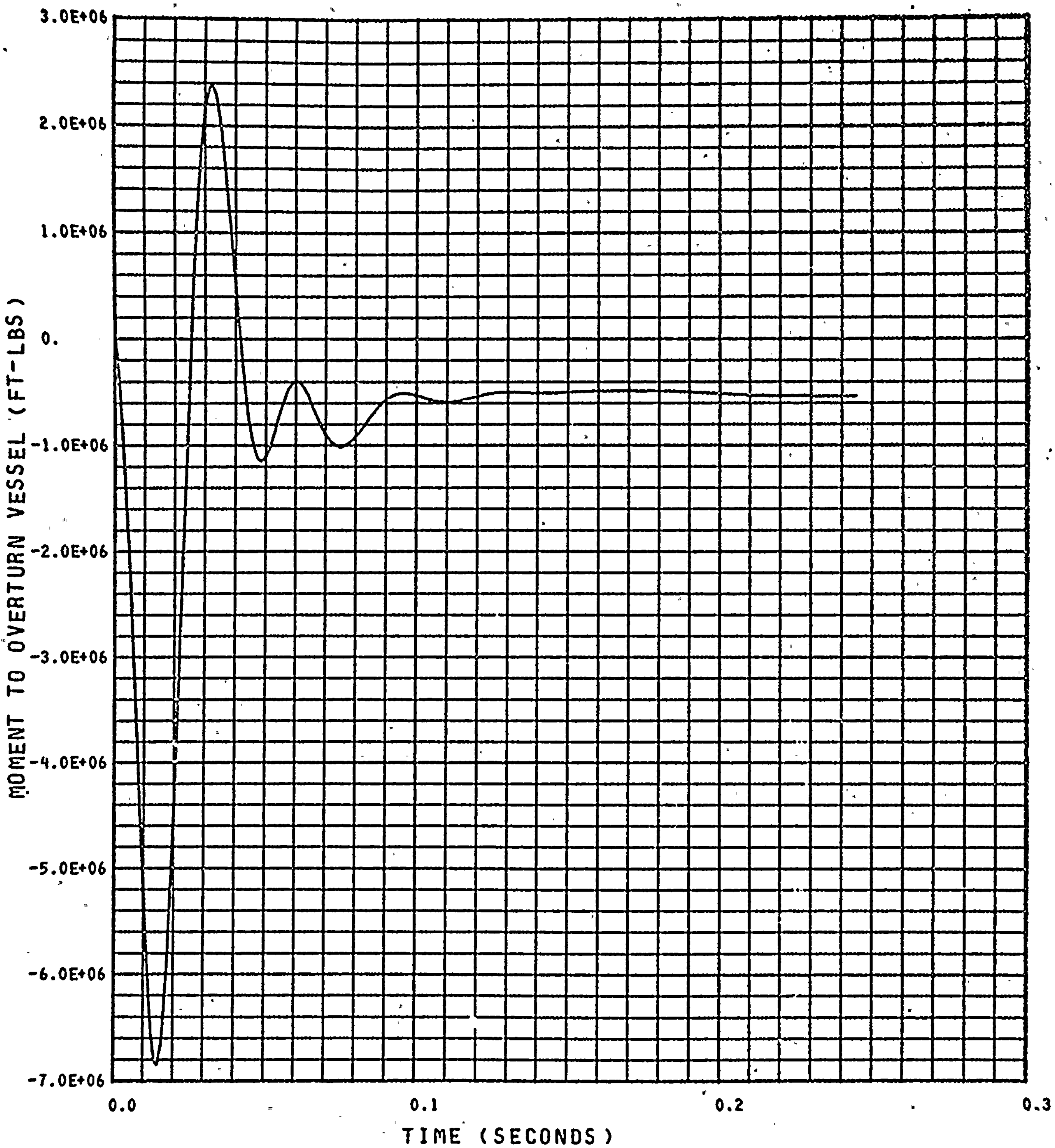
AMP STEAM GENERATOR   STEAM GENERATOR MODELED AS 17 NODES

FIGURE 2.8



AMP STEAM GENERATOR STEAM GENERATOR MODELED AS 17 NODES

FIGURE 2.9



AMP STEAM GENERATOR   STEAM GENERATOR MODELED AS 17 NODES

3. Provide the criteria including any limitations on component buckling used for determining the design load capacity of the critical elements in the vertical column support systems and the upper lateral support structure. In addition, identify the materials and the minimum specified properties for these support members.

Response:

The allowable stresses for each load condition and a description of the loading conditions themselves are provided in the following paragraphs.

Normal Condition

Thermal, weight, and pressure forces obtained from the RCL analysis acting on the support structures are combined algebraically. The combined load component vector is multiplied by member influence coefficient matrices to obtain all force components at each end of each member. The interaction equations of AISC-69 are used with allowable specified limits which include stability and secondary bending effects.

Upset Condition

OBE support forces are assigned all possible sign combinations and, in each case, are added algebraically to normal condition forces. The interaction and stress equations of AISC-69 are used with allowable specified limits.

Emergency Condition

DBE loads are assigned all possible sign combinations, combined with normal loads, and are used in the above stress and interaction equations. For this loading condition, limiting values of 1.5 times allowables are used. This limit represents a stress of about 0.9 yield and provides a margin against buckling from 10 percent for short stocky members whose buckling mode is highly inelastic to a margin of 30 percent for members that buckle elastically.

Faulted Condition

DBE (all possible sign combinations assigned) and pipe break loads are combined with normal operating loads. The stress equations of AISC-69 are used and are adjusted such that the stresses in the supports are limited to yield.

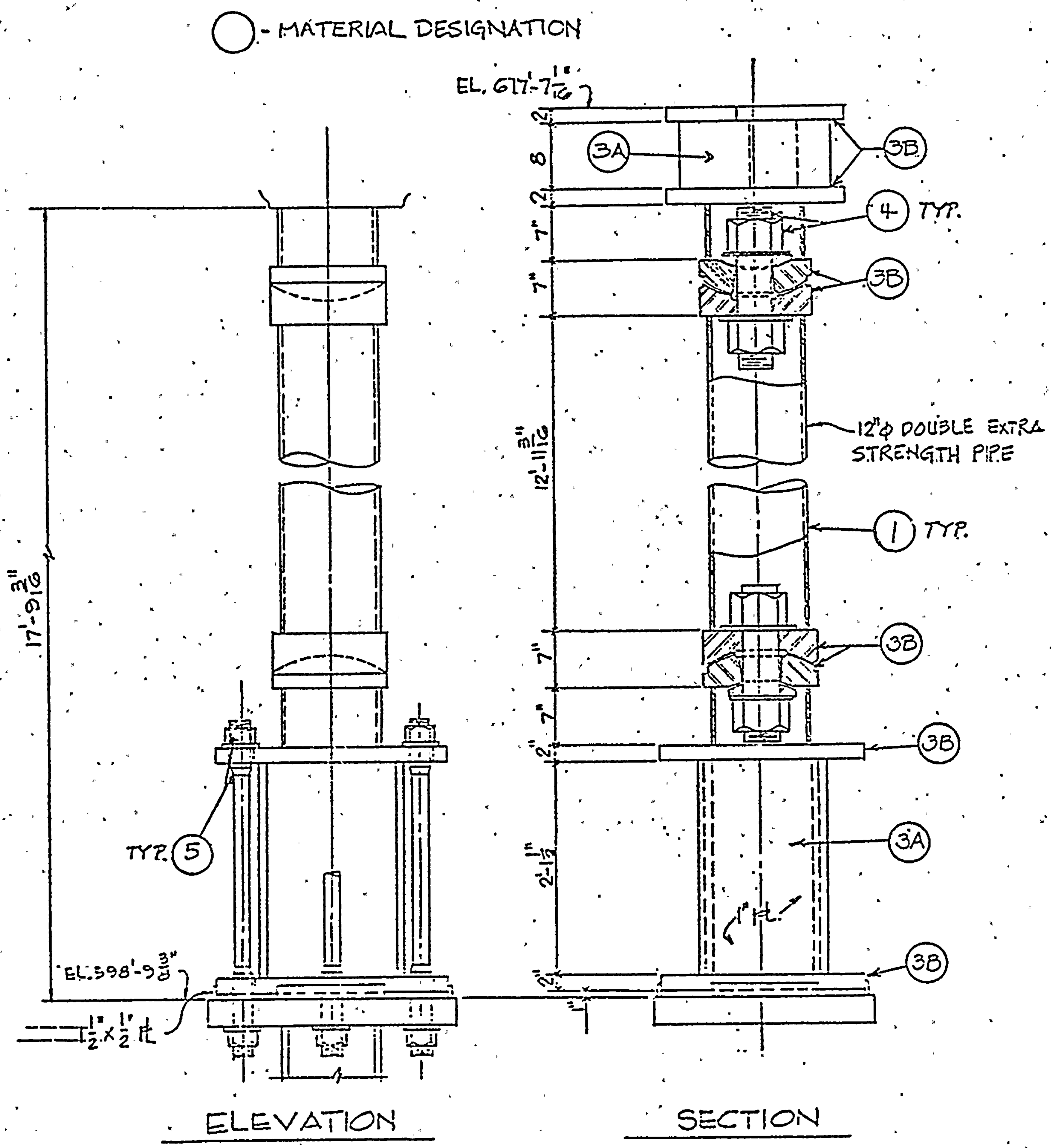
The critical load for the vertical supports is compressive under the combination of normal loads, DBE, pipe break, and steam generator compartment pressurization. Determination of the design load capacity of the columns is based on the AISC-69 stress equations fectored for the faulted condition.

Under the main steam line break at the side of the steam generator and the Design Basis Earthquake the critical element of the upper support is the belly band. As the steam generator is supported by the belly band through one-way acting bumpers (compression only), placed between the band and the steam generator shell, the band will always carry applied loads in tension and bending. The design criteria for the band was that the combined stress due to bending and tension produced by the design load must not exceed the material yield stress. This is a very conservative evaluation of the support capacity since the development of partial yielding at the extreme fibers in no way impairs the function of the support. Stresses for this support are determined from influence coefficients developed by finite element analysis.

The material used for the steam generator upper lateral support is designated 3A. Provided in Table 1 are the material type, minimum properties and testing required for this designation. The material designation for the vertical supports is given in Figure 1 and the material type, minimum properties, and testing required are given in Table 1.

TABLE 1

Material Designation		Yield Point KSI		Material and Material Thickness Group	Charpy Impact	Material Testing Required
No. on Dwg.	ASTM Spec. No.	Max.	Min.			
1	A618 Gr. 11		50	Tubing		A618 Requirements
3A	A588 Gr. 8		50	Plate (to 5")	Yes	A588 Requirements; also, 2 tension tests and 2 bend tests for each plate from which material is fabricated.
3B	A588 Gr. 8		50	Plate (to 5")	Yes	A588 Requirements; also, for each 10 sq. ft. of plate used for fabrication make 2 tension tests transverse to thickness and testing to 2/3 of specified yield, and make 1 ultrasonic test for each finished plate after fabrication.
4	A193 Gr. 87		75 to 105	Bolts and Pins	Yes	A193 Requirements.
	A194 Gr. 7			Nuts	No	A194 Requirements.
5	A588 Gr. 8	55	50	Rods	Yes	A588 Requirements; also, 2 tension tests for each finished fabricated rod.
	A194 Gr. 7			Nuts	No	A194 Requirements.



STEAM GENERATOR COLUMNS

FIGURE 1

4. Describe briefly (a) the capability of the FELAP computer program; (b) how FELAP was utilized in the analysis; (c) the mathematical model and assumptions made; and (d) how the FELAP results were verified.

Response:

(a) FELAP is a general purpose computer program developed by the Franklin Research Laboratories for the analysis of complex three-dimensional, elastic structures composed of shells, plates, and straight or curved beams. The program computes the dynamic and static response to distributed, thermal and concentrated loads.

(b) FELAP was used to perform a linear elastic analysis of the structure for the spatially varying and dynamically applied transient pressure loading.

The results from the program are the joint deflections, mid-panel stresses and stress resultants, and joint moments and forces (shear and in-plane).

The mid-panel stresses were integrated across the panel thickness to yield the in-plane forces and the mid-panel moments. These were checked against the forces and moments at the joints.

The forces and moments at the locations on the structure indicated on Fig. 1, were used in the capability analysis of the steam generator enclosure.

(c) The steam generator enclosure was modeled as a series of quadrilateral finite elements with constant Modulus of Elasticity (E) and constant Plate Moment of Inertia (D).

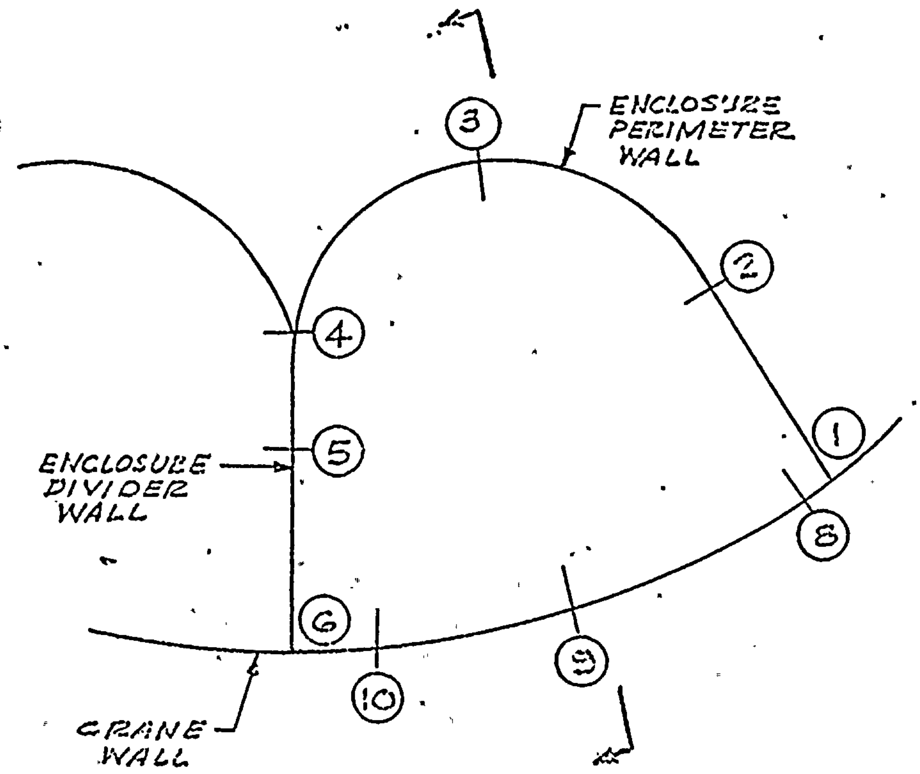
The stiffness and modal methods of analysis were employed coupled with the finite element method and the assumption of small deflection, linear-elastic structural theory.

The enclosure was considered to be laterally restrained at its base along the perimeter wall by the containment operating deck slab at El. 652' - 7 1/2" and supported along the crane wall segment by the lower inlet door piers. The crane wall segment of the model was carried beyond the limits of the perimeter wall and considered fixed by the balance of the crane wall.

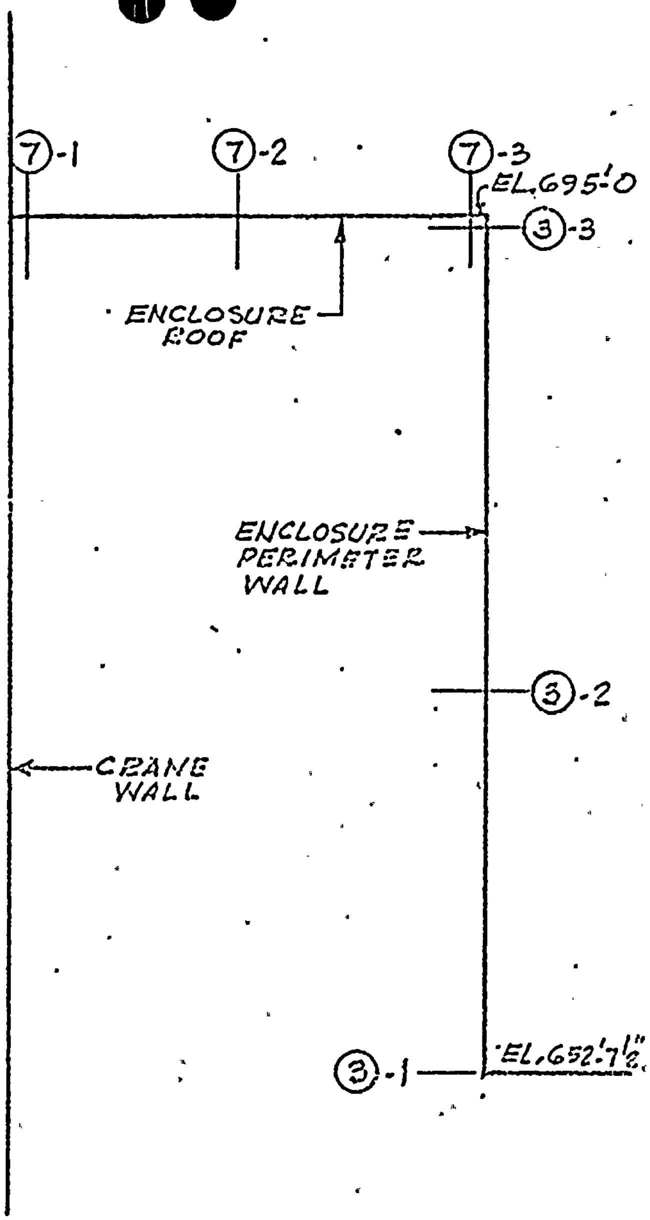
(d) The results of FELAP have been confirmed according to ASME program verification requirement (1). Furthermore, verification and acceptance tests of FELAP were performed by the Computer Application Division in A.E.P.'s IBM System/370.

The FELAP results for this particular model were verified by making internal and external force equilibrium checks. Input modeling geometry was verified by diagnostic plotting to insure the accuracy of the geometry.

Reference (1) American Society of Mechanical Engineers, Pressure Vessel and Piping, 1972 Computer Program Verification, No. I-24, 1972



PLAN



SECTION

NOTE:

CIRCLED NUMBER INDICATES LOCATION.
SUFFIX NUMBER INDICATES ELEVATION.

STEAM GENERATOR ENCLOSURE - FIG. 1

5. Since the compartment pressure load is transient and dynamic in nature, explain how the load was used as input in the FELAP program.

Response:

The FELAP program is capable of performing both static and dynamic analysis. The time load was input as pressure - time histories (9 separate loadings - 1 for each subcompartment) and a dynamic analysis made. All loads are applied simultaneously.

6. Indicate the loads and load combinations used in the design and analysis of the subcompartment walls and slabs.

Response:

The dynamic transient pressure loads acting simultaneously with the design basis earthquake were considered to act together with the operating load condition.

Load factors were not used with the individual loads because the overall factor of safety with reference to the ultimate section capacities was desired in the analysis.

7. Provide sample calculations for ultimate moment and ultimate shear respectively at sections where the factors of safety are the lowest.

Response:

Sample manual computations are on the attached design sheets.

FORM GE-8

ENGINEERING DEPT. [redacted]
AMERICAN ELECTRIC POWER S[redacted]ICE CORP.
2 BROADWAY
NEW YORK

SHEET 1 OF 12
DATE [redacted]Y Kao CK.
COMPANY G.O.
PLANT

SUBJECT

Summary of Ultimate strength of Moments, Shear & Factor of Safe.

Ultimate strength / Critical Location	Moments				Shear				Remarks
	1	2	3	4	5	6	7	8	
	N=0 Mu	N=N Mu'	APPLIED Mmax	S.F	N=0 M=0 Vu	N=N M=M Vu'	APPLIED Vmax	S.F.	
	1-K/1	1-K/1	1-K/1	1/3 / 2/3	K/1	K/1	K/1	5/7 / 6/7	
6-2 M	124.6	53.7	26.6	4.7 / 2.0	68.3	33.3	21.2	3.2 / 1.57	
10-2 M	128.7	94.5	53.4	2.4 / 1.8	81.9	38.2	4.3	19. / 8.8	
3-2 H	117.5	100.4	23.7	5.0 / 4.2	49.7	26.1	17.2	2.9 / 1.51	
3-3 H	117.5	98.2	58.3	2.0 / 1.70	49.7	24.2	12.9	3.8 / 1.9	

Note

1. M_u = Ultimate Resisting Moment for Concrete.
2. M_u' = ultimate Resisting Moment for Combined With axial Tension.
5. V_u = Ultimate strength shear for Concrete.
6. V_u' = ultimate strength of Shear for Combined With Moments & Axial Tension.

7-2

b= 12"

Location	Depth (inches) D	Comp. Face Reinf. (in²/ft.) ASC	Tension Face Reinf. (in²/ft.) AST	Stirrups (in²/ft.) ASV	Spacing (inches) S	Mom./ft. (ft-k) M	Axial Tens./ft. (k) N	Shear/ft. (k) V
[illegible]-2 M	27.5	1.56	1.56	0.	0.	26.6	65.1	21.2
[illegible]-2 M	33.0	1.33	1.33	0.	0.	53.4	25.9	4.3
3-2 H	20.0	2.08	2.08	0.	0.	23.7	23.0	17.2
3-3 H	20.0	2.08	2.08	0.	0.	58.8	25.9	12.9

Comments

1- Ultimate Moment, Ultimate Shear

2- Factor of Safety on Ult. Mom. & Ult. Shear.

FORM GE-8

ENGINEERING D

AMERICAN ELECTRIC POWER SERVICE CORP.
2 BROADWAY
NEW YORK

SHEET 1. OF ____
DATE ____ BY ____ CK. ____
COMPANY ____ G.O. ____
PLANT ____

SUBJECT *Ultimate strength of Steam Generator Enclosure.*

1) Ultimate resisting Moments : M_u (No Axial Tension).

A). Location 6-2 M

Depth $d = 27.5$ in.

Area of Compress Reinf. $A_s' = 1.56$ in².

Area of Tension Reinf. $A_s = 1.56$ in²

Width of Compression face of Flexural member : $b = 12$ in.

$$a = \frac{A_s f_y}{.85 f_c' b} = \frac{1.56(40)}{.85 \times 3.5 \times 12} = 1.75 \text{ in.}$$

$$M_u = \phi (A_s f_y)(d - \frac{a}{2})$$

$$= .9(1.56 \times 40)(27.5 - \frac{1.75}{2})$$

$$= 1495.3 \text{ in-kips/ft} = 124.6 \text{ 1-k/1}$$

B). Location 10-2 M

$d = 33$ in.

$A_s = 1.33$ in² $A_s' = 1.33$ in².

$$a = \frac{1.33 \times 40}{.85 \times 3.5 \times 12} = 1.49 \text{ in.}$$

$$M_u = .9(1.33 \times 40)(33 - \frac{1.49}{2})$$

$$= 1,544.4 \text{ in-k/1.} = 128.7 \text{ 1-k/1}$$

SUBJECT ____

C, Location 3-2 H

$d = 20$ in

$A_s = 2.08$ in^2 $\quad A_s' = 2.08$ in^2

$$a = \frac{2.08 \times 40}{.85 \times 3.5 \times 12} = 2.33 \text{ in.}$$

$$M_u = .9(2.08 \times 40)\left(20 - \frac{2.33}{2}\right)$$

$$= 1410.35 \ ^{in\text{-}k}/_{ft} = \underline{\underline{117.5 \ ^{1\text{-}k}/_{1}}}$$

D. Location 3-3 H.

$d = 20$ in.

$A_s = 2.08$ in^2 $\quad A_s' = 2.08$ in^2

$$a = \frac{2.08 \times 40}{.85 \times 3.5 \times 12} = 2.33$$

$$M_u = .9(2.08 \times 40)\left(20 - \frac{2.33}{2}\right)$$

$$= 1410.35 = \underline{\underline{117.5 \ ^{1\text{-}k}/_{1}}}$$

FORM GE-8

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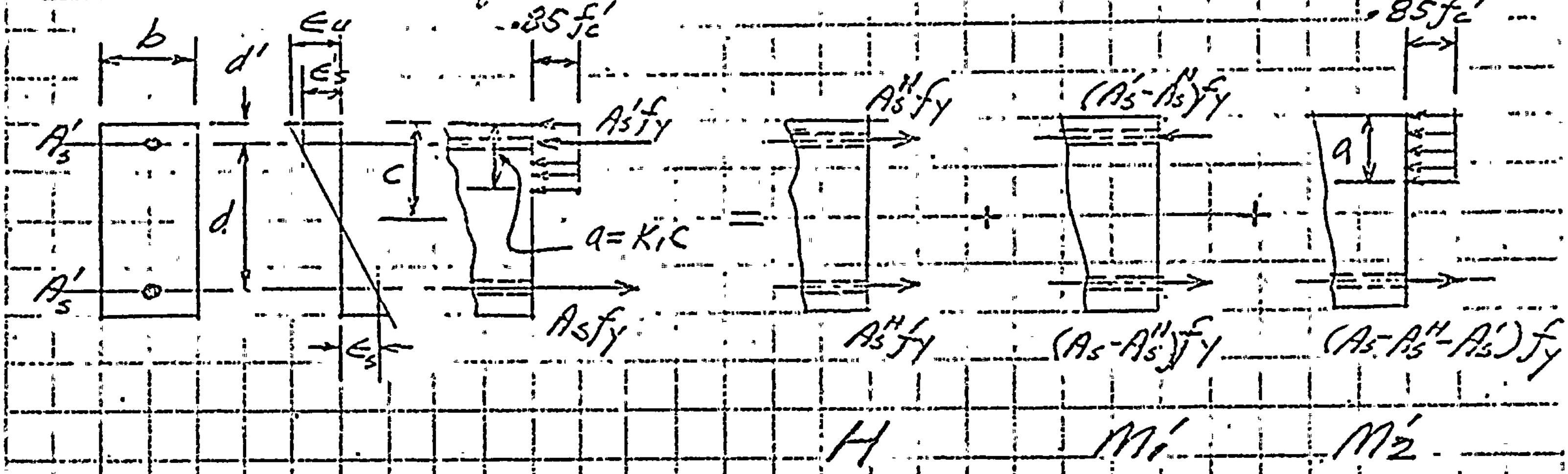
SUBJECT

2. Ultimate resisting Moments: M_u (Combined with Axial Tension)



Resisting Moments

a) Axial Tension.

$$N = 2 (A_s'' f_y)$$

b). M_1' (provided by the couple consisting of the force in the compresion steel A_s' & force in an equal area of tension steel)

$$M_1' = (A_s' - A_s'') f_y$$

c) M_2' (The contribution of the remaining tension steel $(A_s - A_s'' - A_s')$ acting with compression concrete:

$$M_2' = (A_s - A_s'' - A_s') f_y \left(d - \frac{a}{2}\right)$$

$$a = \frac{(A_s - A_s'' - A_s') f_y}{.85 f_c' b}$$

SUBJECT ______

Total Resisting Moment: M_u'

$$M_u' = M_2' + M_1'$$

$$= (A_s - A_s^N - A_s') f_y \left(d - \frac{a}{2}\right) + (A_s' - A_s^N)(d - d')$$

Ultimate Moment Capacity. (ACI 318-63)

$$M_u = \phi M_u' = \phi \left[(A_s - A_s^N - A_s') f_y \left(d - \frac{a}{2}\right) + (A_s' - A_s^N)(d - d') \right]$$

A). Location 6-2 M

Max. Moment : $M_{max} = 26.6$ '-k/'

Axial Tension $N = 65.1$ k/ft.

A-1) Axial Tension Reinf.

$$A_s^N = \frac{N}{2 \phi f_y} = \frac{65.1}{2(.9)(40)} = .9 \text{ in}^2$$

A-2) Ultimate Moment Capacity.

$$a = \frac{(A_s - A_s^N) f_y}{.85 f_c' b}$$

$$= \frac{(1.56 - .9) 40}{.85 \times 3.5 \times 12} = .74 \text{ in.}$$

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$$M_u = \phi\left[(A_s - A_s^N) f_y \left(d - \frac{a}{2}\right)\right]$$

$$= .9\left[(1.56 - .9)40\left(27.5 - \frac{.74}{2}\right)\right]$$

$$= 644.6 \ {}^{\prime\prime\text{-}K}/_{Ft} = \underline{\underline{53.72 \ {}^{\prime\text{-}K}/_{\prime}}}$$

A-3) Safety Factor.

$$S.F. = \frac{M_u}{M_{max}} = \frac{53.72}{26.6} = \underline{\underline{2.0}}$$

B. Location 10-2 M

$M_{max} = 53.4 \ {}^{\prime\text{-}K}/_{\prime}$ $N = 25.9 \ {}^{K}/_{\prime}$ $V = 4.3 \ {}^{K}/_{\prime}$

B-1) Axial Tension Reinf.

$$A_s^N = \frac{25.9}{2(.9 \times 40)} = .36 \ in^2$$

B-2) Ultimate Moment Capacity

$$a = \frac{(1.33 - .36)40}{.85(3.5 \times 12)} = 1.09$$

$$M_u = .9(1.33 - .36)40\left(33 - \frac{1.09}{2}\right)$$

$$= 1133.4 = \underline{\underline{94.5 \ {}^{\prime\text{-}K}/_{\prime}}}$$

B-3). Safety of Factor

$$S.F. = \frac{94.5}{53.4} = \underline{1.77}$$

SUBJECT

c) Location 3-2 H

$M_{max} = 23.7\ ^{\prime\text{-}k}/_{1}$ $N = 23.0\ ^{k}/_{1}$ $V = 17.2\ ^{k}/_{1}$

c-1). Axial Tension.

$$A_s^N = \frac{23.0}{2(.9 \times 40)} = .32\ in^2$$

c-2) Ultimate Moment Capacity.

$$a = \frac{\overset{1.76}{(2.08-.32)}40}{.85(3.5 \times 12)} = 1.97$$

$$M_u = .9(2.08-.32)40\left(20 - \frac{1.97}{2}\right)$$

$$= 1204.7 = 100.4\ ^{\prime\text{-}k}/_{1}$$

c-3) Safety of Factor.

$$S.F. = \frac{100.4}{23.7} = 4.24$$

SUBJECT

D. Location 3-3 H.

$M_{max} = 58.8\ ^{l-k}/_{l}$ $N = 25.9\ ^{k}/_{l}$ $V = 12.9\ ^{k}/_{l}$

D-1) Axial Tension Rienf.

$$A_s^N = \frac{25.9}{2(.9 \times 40)} = .36\ in^2$$

D-2) ultimate Moment Capacity

$$a = \frac{\overset{1.72}{(2.08 - .36)}40}{.85(3.5 \times 12)} = 1.93$$

$$M_u = .9(2.08 - .36)40\left(20 - \frac{1.93}{2}\right)$$

$$= 1178.7 = 98.2\ ^{l-k}/_{l}$$

D-3) Safety of factor

$$S.F. = \frac{98.2}{58.8} = 1.67$$

SUBJECT

3. Ultimate shear capacity.

Shear stress : v_c

$$v_c = \phi\left(1.9\sqrt{f_c'} + 2500\frac{\rho_w V d}{M}\right) < 3.5\phi\sqrt{f_c'(1+0.002N/A_g)}$$

For the members subjected to axial load in addition to shear & flexure.

$$M' = M - N\left(\frac{4t-d}{8}\right)$$

A). Location 6-2 M.

$M_{max} = 26.6\ ^{1\text{-}k}/_1 \quad N = 65.1\ ^{k}/_1 \quad V = 21.2\ ^{k}/_1$

$$M' = (26.6\times 12) - (-65.1)\left(\frac{4\times 30 - 27.5}{8}\right)$$

$$= 319.2 + 752.72 = +1{,}071.92$$

$$\rho_w = \frac{A_s}{bd} = \frac{1.56}{12\times 27.5} = .00473$$

$$v_c = .85\left(1.7\sqrt{3{,}500} + 2{,}500\,\frac{.00473\times 21.2\times 27.5}{1{,}071.92}\right)$$

$$= .85(112.4 + 6.43) = \underline{101} < 140.8 \quad \text{o.k}$$

$$3.5\phi\sqrt{f_c'(1+.002N/A_g)} = 3.5(.85)\sqrt{3{,}500(1+.002\frac{65.1}{12\times 30})}$$

.36

$$= 140.8$$

SUBJECT

<u>Ultimate Shear capacity</u>

$$V_u = \nu_c (bd) = 101 (12 \times 27.5)$$

$$= 33,330 \text{ lbs} = \underline{\underline{33.33 \text{ K/ft.}}}$$

$$S.F. = \frac{V_u}{V} = \frac{33.33}{21.2} = \underline{\underline{1.57}}$$

<u>B) Location 10-2 M</u>

$$M = 53.4 \quad N = 25.9 \quad V = 4.3$$

$$M' = (53.4 \times 12) - (-25.9)\left(\frac{4 \times 35.5 - 33}{8}\right)$$

$$= 640.8 + 352.9 = 993.7$$

$$P_w = \frac{1.33}{12 \times 33} = .00336$$

$$\nu_c = .85\left(1.9\sqrt{3,500} + 2,500 \frac{.00336 \times 4.3 \times 33}{993.7}\right)$$

$$= .85 (112.4 + 1.2) = \underline{\underline{96.56}} < 3.5(.85)\sqrt{3500} = 165$$

O.K.

<u>Ultimate shear & S.F.</u>

$$V_u = 96.56 (12 \times 33) = 38,237 = \underline{\underline{38.23 \text{ K/'}}}$$

$$S.F. = \frac{38.23}{4.3} = \underline{\underline{8.8}}$$

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c) Location 3-2 H

$M = 23.7\ ^{1\text{-}K}/_{1}$ $N = 23\ ^{K}/_{1}$ $V = 17.2\ ^{K}/_{1}$

$M' = (23.7 \times 12) - (23)\left(\frac{4 \times 22.5 - 20}{8}\right)$

$= 284.4 + 201.3 = 485.7$

$P_w = \frac{2.08}{12 \times 20} = .00867$

$v_c = .85\left(1.9\sqrt{3{,}500} + 2500 \times \frac{.00867 \times 17.2 \times 20}{485.7}\right)$

$= .85(112.4 + 15.35) = 108.6 < 219$ O.K.

$3.5\phi\sqrt{f_c'(1 + .002N/A_g)} = 3.5(.85)\sqrt{3{,}500(1 - .19)} = 219$

Ultimate Shear & S.F.

$V_u = 108.6(12 \times 20) = 26061 = \underline{\underline{26.06\ ^{K}/_{1}}}$

$S.F. = \frac{26.06}{17.2} = \underline{\underline{1.5}}$

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D. Location 3-3 H.

$M = 58.8\ ^{1\text{-}K}/_{1}\quad N = 25.9\ ^{K}/_{1}\quad V = 12.9\ ^{K}/_{1}$

$P_W = \dfrac{2.08}{12 \times 20} = .00867$

$M' = (58.8 \times 12) - (-25.9)\left(\dfrac{4 \times 22.5 - 20}{8}\right)$

$= 705.6 + 226.6 = 932.2$

$V_c = \phi\left(1.9\sqrt{f_c'} + 2500\dfrac{P_W V d}{M'}\right)$

$= .85\left(1.9\sqrt{3{,}500} + 2500\dfrac{.00867 \times 12.9 \times 20}{932.2}\right)$

$= .85(112.4 + 6) = \underline{100.64}\ psi < 158.2$ O.K

$3.5\phi\sqrt{f_c'(1 + .002\, N/A_g)} = 3.5(.85)\sqrt{3{,}500\left(1 + .002\dfrac{(25.9)10}{12 \times 22.5}\right)}$

$= 158.2$

Ultimate shear & S.F.

$V_u = 100.64(12 \times 20) = 24{,}153.6$ Lbs

$= \underline{24.15\ \text{Kips}/_1}$

$S.F. = \dfrac{24.15}{12.9} = \underline{1.87}$