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EG&G INTERNAL REPORT TR-593, AM-63 Rev. 2

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**LOFT PRIMARY COOLANT ADDITION AND
CONTROL PIPING SYSTEM STRESS ANALYSIS**

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RESEARCH, ENGINEERING AND CONSTRUCTION REPORT ENGINEERING ANALYSIS DIVISION

APPLIED MECHANICS BRANCH

LOFT PRIMARY COOLANT ADDITION AND CONTROL PIPING SYSTEM STRESS ANALYSIS

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LOFT TECHNICAL REPORT LOFT PROGRAM

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SUMMARY

A stress analysis was performed on the Primary Coolant Addition and Control Piping System to determine if it met the conditions of the ASME Code, Section III, for Class 2 components. Results indicate that the Addition and Control System does not meet Section III criteria as the system is now installed. Only hanger (support) modifications are required to bring the stresses within the limits set forth in the Code. A design temperature of 450°F was assumed for the analysis. The specified design temperature of 650°F has been revised by ECRA's L-5713 and L-5714.

RECOMMENDATIONS

- Hangers 3, 9, and 10 should be removed.
- Hangers 1, 2, 4, 5, and 6 should be replaced with flat bar, 1/2" x 2" having a minimum yield strength of 50,000 psi. In addition, hangers 1 and 2 should be 10" in length, and hangers 4, 5, and 6 should be 13" in length. Lengths may be $\pm 1/2"$.
- A unibal type hanger, similar to hanger H-1 in the Coolant Purification System, should be placed equidistant between the present location of hangers 9 and 10 of the Addition and Control System. This unibal hanger should be secured vertically above the pipe at any convenient location and be 6 inches to 10 inches in length. It must allow the pipe to move axially (ie, parallel to tracks).
- Valves CV-P-128-105, CV-P-128-106, and CV-P-128-109 should be supported at a distance not less than 30 inches from their respective pipe connections. The valve supports may be attached to the valves by any standard means.
- Hanger 11 should be replaced with flat bar 3/8" x 2" and length as shown on LOFT Dwg. 204345. A material having a yield strength of 50,000 psi (minimum) will be adequate.
- With the addition of valve V-6474-CC, a hanger should be added to provide horizontal support perpendicular to the pipe. The support should be placed on the side of the valve near the containment wall.

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1.0 INTRODUCTION

This analysis was performed to demonstrate the structural integrity of the LOFT Primary Coolant Addition and Control Piping System^[1] shown in Figure 1. Section III, Subsections NC (Class 2) and NF, of the ASME Boiler and Pressure Vessel Code establishes the criteria for this analysis and was used to define the allowable stress limits for the Addition and Control System. Consideration of design pressure, system dead weight, thermal expansion, safe shutdown earthquake (SSE), operating basis earthquake (OBE)^(a), loss-of-coolant experiment (LOCE), and loss-of-coolant accident (LOCA) for both the piping and piping supports is required by the Code and was included in this analysis.

The design conditions used in the analysis are as follows:

- (1) System temperature equal to 450°F^[2]
- (2) System pressure equal to 2500 psia^[3]
- (3) System stress free temperature equal to 70°F.

All pipe in the Addition and Control Piping System is 1-1/2 inch Sch. 160. Effects due to insulation of the pipe were not considered^[4].

2.0 METHOD OF ANALYSIS

SAP IV^[5], a structural analysis program for the static and dynamic response of linear systems, was used to determine the forces and moments in the piping system and piping supports for the various loading conditions. Once these forces and moments were known, the procedure outlined in Section III of the Code was followed to determine if the piping and supports were structurally adequate.

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^(a) This case was not analyzed since meeting the requirements of SSE satisfies OBE - see Appendix A (calculations).

2.1 Piping System

2.1.1 Computer Model

For convenience, the piping system was split into two sections, as shown in Figures 2 and 3. Also shown in these two figures are the nodes and elements developed for input to SAP IV. The dashed lines of Figure 2 (Section 1) show two of the piping systems that are connected to the Addition and Control System and included on the model to the first encountered hanger or valve of the connecting system. |2

Three separate computer runs were needed to determine the behavior of the pipe. One static response run calculated dead weight, X-Y and Y-Z SSE, and thermal loads. Two dynamic response runs, using the response spectra technique, were employed; one for LOCE, the other for LOCA.

The dead weight load case considered only the weight of the pipe and water in the pipe. This was done by simply inserting a -1.00 (ie, gravity in minus Y direction) for the Y-direction load case multiplier and allowing the Code to determine the forces and moments from pipe and water input properties.

The SSE loading condition involved some preliminary calculations to convert this dynamic case into a static equivalent (see Appendix A, pp A-21 - A-23). Load case multipliers equal to 6.3 for X-direction and Z-direction and 5.2 for Y-direction were used. The 5.2 Y-direction multiplier includes 4.2 for SSE static equivalent plus 1.00 for gravity.

Thermal loading was calculated by SAP IV from input design nodal temperatures, stress free temperatures, and coefficients of thermal expansion. Thermal displacements for nodes 21 (connected to 4" ECC-75-VA) and 70 (connected to 4" ECC-69-VA) in piping Section 1, and node 1 (connected to 4" ECC-69-VA) in piping Section 2 were incorporated in the thermal loading case |2

FIGURE 2
SECTION 1 COMPUTER MODEL

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Numbers are Nodal Points
○ = Pipe Elements
□ = Beam Elements

FIGURE 3 - Section 2 Computer Model

by means of boundary elements. These thermal displacements are given in Table I^[6]. Only these externally connected nodes were given free-end thermal displacements since they are connected to pipe of much larger diameter. Nodes 32 and 52 of Section 1 were modeled out to the first hanger or valve of the connecting system, in lieu of incorporating free end displacements, since the connecting pipe is of the same size or only slightly larger at these points. When connecting pipe was incorporated into the model, the actual size of the pipe was used. |2

TABLE I
FREE END THERMAL DISPLACEMENTS

<u>Node</u>	<u>Section</u>	<u>X</u>	<u>Y</u>	<u>Z</u>	
21	1	-0.336 in.	-0.010 in.	-0.148 in.	2
70	1	0.040 in.	0.008 in.	0.036 in.	2
1	2	-0.013 in.	0.032 in.	-0.088 in.	

The dynamic response spectra computer runs for LOCE and LOCA were performed using the SAP IV dynamic option. Acceleration versus frequency input data for these two loading conditions are shown in Figures 4 and 5^[7]. |2

All input to SAP IV for Section 2, including both the static and dynamic cases, may be found in Appendix B. The microfiche output for Section 1 may be found in Appendix D. |2

2.1.2 ASME Code Section III Analysis

Subsection NC-3650 of Section III, ASME Boiler and Pressure Vessel Code, outlines the allowable stress values for a piping system analysis. Equation 8 of Subsection NC-3650 accounts for internal pressure plus dead weight; Equation 10 deals with thermal stresses only, while Equation

MULTIPLIER X - -0.67
Y - 1.00
Z - 1.00

FIGURE 4 - RESPONSE SPECTRUM - LOCE

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ACCELERATION (IN/SEC²)

Multiplier X = -0.80

Y = 1.00

Z = 1.00

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FIGURE 5 RESPONSE SPECTRUM - LOCA

11 considers thermal stresses plus internal pressure plus dead weight. Equation 8 must be satisfied as does either Equation 10 or 11 (but not both 10 and 11). Equation 11 was used in this analysis.

Equation 9 of NC-3650 must be satisfied for three loading conditions; occasional, emergency, and faulted. The occasional loading condition includes internal pressure plus dead weight plus LOCE, the emergency condition considers internal pressure plus dead weight plus SSE, and the faulted condition handles internal pressure plus dead weight plus SSE plus LOCA. All three loading conditions of Equation 9 have different allowable stress limits. Complete details of the Section III piping analysis (Equations 8 through 11) are contained in Appendix A of this report (pp A-1 - A-6).

2.2 Supports

2.2.1 Computer Model

The piping supports were originally as shown in Figures A-1 and A-2, page A-7, (see LOFT Dwg. 204345) and positioned in the piping system as shown in Figure 1. All supports were constructed with strong axis parallel to pipe run except support hanger 7, which had strong axis perpendicular to pipe run. All hangers were modeled as beam type elements for SAP IV coding.

The unibal type supports attached to connecting lines 1-1/2"-CP-15-VA and 2"-CP-8-VA at nodes 33 and 54, respectively, of Section 1 were modeled for SAP IV coding as boundary elements.

Since support modification is easier and less costly than piping changes, support changes were the only means by which stresses were reduced in this analysis. Their addition, removal, or geometric alteration in the SAP IV code provided this means of stress modification in the various loading conditions.

Since SAP IV allows several types of geometric elements (pipes, beams, plates, etc) to be used in one computer model, the pipe, beam type supports, and boundary element supports used in this analysis were contained in one complete model. Load conditions used are described in Section 2.1.1 of this report. |2

2.2.2 ASME Code Section III Analysis

Subsection NF-3230 of ASME Code Section III provides the stress limits for the piping supports used in the Addition and Control System. Allowable stresses presented in Appendix XVII are used in NF-3230 for design, normal, and upset conditions and may be increased by a factor of 3.00 for combined mechanical loads and effects which result from constraint of free-end displacements (thermal loads). In addition, the allowable stresses of Appendix XVII may be increased by a factor of 1.33 for emergency conditions (SSE). For faulted conditions (LOCA), NF-3230 allows the stress limits of Appendix F-1370 to be used. These stresses, too, are as in Appendix XVII and may be increased by a factor of 1.2 (S_y/F_t) or .7 (S_u/F_t), whichever is less, over those presented in Appendix XVII. However, Appendix F-1370 states that in no case may the faulted condition allowable stresses exceed .67 times the critical buckling stress of the material.

The allowable stresses of Appendix XVII provide for the independent analysis of tensile, shear, compressive, bending, combined bending and tensile, and combined bending and compressive stress. Appendix A of this report contains the piping support calculations as outlined in Appendix XVII of the Code.

3.0 RESULTS AND CONCLUSIONS

An initial SAP IV run showed that some sections of pipe and some of the original pipe supports exceeded the stress limits provided by NC-3650 and NF-3230 of the Code. Thermal and SSE load cases caused these excessive stresses. To reduce these stresses, pipe support geometries and locations were changed as provided by the SAP IV code. After several of these trial runs, hanger geometry and location were such that all the pipe and pipe supports (except H-11) met the Code standards. The final changes included:

- (1) Removal of hangers 3, 9, and 10.
- (2) Changing hangers 1, 2, 4, 5, and 6 from the present 1/4" x 1" flat bar to 1/2" flat bar. Length of hangers 1 and 2 was set at 10.00" and the length of hangers 4, 5, and 6 was set at 13.00".
- (3) Addition of a vertical unibal hanger 40" (toward "A-end") from original hanger 9. (This hanger was modeled as Spherical Rod End Bearing, assembly D, in LOFT Dwg. 204352 with length of 4.5 in.). Support of pipe is from above.

Hanger 11 met stress limits for all load cases except LOCE. In the response spectrum LOCE computer results, this hanger experienced only slightly larger stresses than the limits provided for in NF-3230. This problem was corrected by changing Hanger 11 to a 3/8" x 2" flat bar hanger. With this change, only thermal and SSE loadings were further investigated since only these load cases could increase the hanger stresses. These stresses did not exceed the allowable stresses for the two load cases after the geometry change, and LOCE stresses were assumed to be below the limits of NF-3230.

Valves CV-P-128-105, CV-P-128-106, and CV-P-127-109 were originally modeled as beam elements for SAP IV coding, with support at 16.48 inches from

the pipe-valve connections. However, this support configuration produced piping induced thermal expansion stresses in the valve housings greater than allowable stresses provided by the Code. This problem was alleviated by supporting the valves 30 inches from the pipe-valve connection in the computer model. Details of the valve analysis appear in Appendix C of this report.

The addition of valve V-6474-CC creates the need to add one support. The additional support should be located on the penetration side of the valve mounted horizontally and perpendicular to the pipe. The following axial loads will be applied to the support:

- (1) Load Case I - 296 lbs
- (2) Load Case II - 869 lbs
- (3) Load Case III - 771 lbs
- (4) Faulted conditions - 535 lbs.

The revisions made in the computer model, to meet the stress limits of NC-3650 and Appendix XVII, should also be made in the actual Addition and Control Piping System. One exception could be the length of the added uni-bal hanger, which may be from 6 inches to 10 inches in length.

All valves should be secured so that no displacement of the valve end opposite its pipe connection will occur under any loading condition. The computer model showed that zero valve end displacement was necessary.

Hangers welded to MTA supports and pipe clamps must be such that^[7]

$$2A_t \geq A_s$$

where

A_t = throat area of weld

A_s = cross sectional area of hanger.

Although stress limits are presented in this report (Appendix a), actual stress calculations from computer output of pipe and hanger forces and moments are not given. Once the stress limits had been computed, the computer output was checked in detail to determine if the pipe system met the Code requirements. With the changes presented in this report, the Addition and Control Piping System does meet the ASME Code requirements for Class 2 components.

Computer output is too voluminous to list in this report, but may be obtained from the Applied Mechanics Branch upon request.

4.0 REFERENCES

1. LOFT Dwg's 650-P-128, 204290, 204291, and 204345.
2. ECRA L-5713 and ECRA L-5714.
3. Line Designation Tables, Specification P-1, Revision 2, 1-17-73.
4. LOFT Dwg. 204290.
5. K. J. Bathe, et al, "SAP IV, A Structural Analysis Program for Static and Dynamic Response of Linear Systems", Earthquake Engineering Research Center, Berkeley, California, June 1973. | 2
6. General Dynamics, Electric Boat Division, report "Engineering Calculations", enclosures 2, 3, and 4 for LOFT, August 22, 1973, calculated by Dan McCarthy, checked by Jack Crespín, Thermal 205.
7. B. F. Saffell, Jr. personal communication, 1/13/75.

APPENDIX A
CALCULATIONS

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According to NC-3650 of Section III of the ASME Boiler and Pressure Vessel Code, the following criteria must be met to assure structural integrity of a Class 2 piping system;

1) Equation 8 Pressure + Dead Weight

2) Equation 10 Thermal Only

Equation 11 Pressure + Dead Weight + Thermal

Either equation 10 or 11 may be satisfied, but not both.

3) Equation 9

(a) Occasional

1) Pressure + Dead Weight + OBE $< 1.2 S_h$

2) Pressure + Dead Weight + LUCE $< 1.2 S_h$

(b) Emergency

1) Pressure + Dead Weight + SSE $< 1.8 S_h$

(c) Faulted

1) Pressure + Dead Weight + SSE + LUCA $< 2.4 S_h$

OBE = Operating Basis Earthquake

SSE = Safe Shutdown Earthquake

LUCE = Loss of Coolant Experiment

LUCA = Loss of Coolant Accident

The two materials used in the Addition and Control piping system are

1) Pipe - SST TP-316 - SA376

2) Fittings - SST TP-316 - SA403

From Table 1-7.2, Appendix I, of Section III of the Code (1974), the temperature dependent allowable stresses are;

	Allowable Stress (psi)			
	100°F	200°F	450°F	650°F
Pipe	18.8×10^3	18.8×10^3	18.05×10^3	16.7×10^3
Fittings	18.7×10^3	18.7×10^3	18.05×10^3	16.7×10^3

The design conditions call for $T = 450^\circ\text{F}$, and therefore an allowable stress of 18.05×10^3 psi will be used.

- Equation 8 Pressure + Dead Weight

$$S_{sh} = \frac{PD_o}{4t_n} + \frac{.75i M_A}{Z} \leq 1.0 S_h$$

where

- P = internal design pressure, psi (= 2500 psi)
 D_o = outside diameter of pipe, in. (= 1.90 in.)
 t_n = nominal wall thickness, in. (= .281 in.)
 M_A = resultant moment loading on cross section due to weight and other sustained loads, in-lb (NC-3652.4)
 Z = section modulus of pipe, in³ (NC-3652.4)
 i = stress intensification factor, (NC-3673.2(b))
 S_h = basic material allowable stress at design temperature.

Notes; (1) Design Pressure = 2500 psi from Line Designation Tables, Spec. P-1, Rev. 2

(2) Design Temp. = 450°F , ECRA II L-5713, L-5714

(3) All pipe and fittings are 1 1/2" Sch. 160.

From NC 3652.4 ;

- (a) For straight through components, curved pipe, or welding elbows,

$$m_j = (m_{xj}^2 + m_{yj}^2 + m_{zj}^2)^{1/2}$$

where $j = A, B, C$, which are the subscripts for m_A , m_B , or m_C as defined in NC 3652.1, NC 3652.2 and NC 3652.3 (equations 8-11).

- (b) For full outlet branch connections, calculate the resultant moment of each branch separately (at the junction) in accordance with (a) above.

- (c) the section modulus for equations 8-11 for straight through components, curved pipe, welding elbows, and full outlet branch connections is defined as

$$Z = \pi r^2 t_n$$

where

r = mean cross sectional radius, in

t_n = nominal wall thickness, in

then, for 1 1/2" Sch 160 pipe

$$r = \frac{1.337 + (1.281 \times 2)}{2} = .809"$$

$$t_n = .281"$$

and $Z = \pi (.809)^2 (.281) = \underline{\underline{.578 \text{ in}^3}}$

From NC 3673.2(b)-1, the stress intensification factor, i , is as follows,

Type	$R^{(a)}$	t_n	$r^{(b)}$	$h = t_n R / r^2$	$i = \frac{9}{h^{2/3}}$	$i^{(d)}$	$.75i^{(e)}$
elbow	2.25"	.281"	.809"	.9660	.921	1.00	1.00
bend	7.50"	.281"	.809"	3.2201	.413	1.00	1.00
tee	—	.281"	.809"	1.5283 ^(c)	.678	1.00	1.00

(a) radius of bend or elbow

(b) mean radius

(c) $h = 4.4 t_n / r$ for tee's

(d) $i \geq 1.00$ (NC-3673.2(b)-1, note (2))

(e) $.75i \geq 1.00$ (NC-3652.1)

Now,

$$\frac{PD_o}{4t_n} = \frac{(2500 \text{ lb/in}^2)(1.90 \text{ in})}{4(.281 \text{ in})}$$

$$= 4226 \text{ psi}$$

Then equation 8 may be written,

$$\frac{PD_o}{4t_n} + \frac{.75i M_A}{Z} \leq 1.0 S_h$$

$$4226 \text{ psi} + \frac{(1.0)(M_A)}{.578 \text{ in}^3} \leq 1.0(18.05 \times 10^3 \text{ psi})$$

or

$$\underline{\underline{M_A \leq 7990 \text{ in-lb}}} \quad (8)$$

Equation 9

$$S_{oh} = \frac{P_{max} D_o}{4t_n} + .75i \left(\frac{M_A + M_B}{Z} \right) \leq \begin{cases} 1.25 S_h & \text{Occasional} \\ 1.8 S_h & \text{Emergency} \\ 2.4 S_h & \text{Faulted} \end{cases}$$

where

P_{max} = design pressure, psi.
 M_B = resultant moment due to occasional, emergency, or faulted conditions (NC 3652.4)

All other variables as in Equation 8

Then

$$4226 \text{ psi} + 1.00 \left(\frac{M_A + M_B}{.578} \right) \leq \begin{cases} 1.2 (18.05 \times 10^3 \text{ psi}) \\ 1.8 (18.05 \times 10^3 \text{ psi}) \\ 2.4 (18.05 \times 10^3 \text{ psi}) \end{cases}$$

or

$$M_A + M_B \leq \begin{cases} 10,077 \text{ in-lb} & \text{Occasional} \\ 16,337 \text{ in-lb} & \text{Emergency} \\ 22,596 \text{ in-lb} & \text{Faulted} \end{cases} \quad (9)$$

Equation 11

Equation 11 (Pressure + Dead Weight + Thermal) will be used in lieu of Equation 10.

$$S_{TE} = \frac{PD_0}{4E_n} + .75i \left(\frac{M_A}{Z} \right) + i \left(\frac{M_C}{Z} \right) \leq (S_h + S_A)$$

where M_C = resultant moment due to thermal loading (NC 3652.4)

All other variables as in Equations 8 and 9

and

S_A = allowable stress range for expansion stresses given by NC-3611.2

From NC-3611.2

$$S_A = f(1.25S_c + .25S_h)$$

where f = stress range reduction factor =

.9 for LOPT (Table NC-3611.2(c)-1) - LTR 10-11A

S_c = basic material allowable stress at min. temp. (use 100°F)

S_h = basic material allowable stress at max temp. (450°F)

then

$$\begin{aligned} S_A &= .9 [1.25(18.7 \times 10^3 \text{ psi}) + .25(18.05 \times 10^3 \text{ psi})] \\ &= 25,099 \text{ psi} \end{aligned}$$

and Equation 11 may be written

$$4226 \text{ psi} + 1.00\left(\frac{M_A}{.578}\right) + 1.00\left(\frac{M_C}{.578}\right) \leq 2.5099 \times 10^4 + 18.05 \times 10^3 \text{ psi}$$

or

$$\underline{\underline{M_A + M_C \leq 22,497 \text{ in-lb} \quad (11)}}$$

Figure A-1

Type 1

Type 2

Type 3

Support (Hanger #)	Type	Length (in)	Strong Axis of Hanger wrt Pipe Axis
1	1	7.3	(parallel)
2	1	7.3	
3	1	7.3	
4	1	10.3	
5	1	10.3	
6	1	10.3	
7	2	18.0	⊥ (perpendicular)
8	2	18.0	
9	2	16.5	
10	2	16.5	
11	1	9.2	
12	1	5.7	
12	3	20.0	N/A

Figure A-2

Strong Axis
Parallel to
Pipe Axis

Strong Axis
Perpendicular
to Pipe Axis

Hanger 12

1)

$$I_{xx} = \frac{bh^3}{12} = \frac{2(3/8)^3}{12} = .008789 \text{ in}^4$$

$$I_{yy} = \frac{bh^3}{12} = \frac{3/8(2)^3}{12} = .250000 \text{ in}^4$$

$$J = \sum \frac{bt^3}{3} = \frac{2(3/8)^3}{3} = .035156 \text{ in}^4$$

$$Z_{xx} = \frac{I_{xx}}{c_{xx}} = \frac{.008789}{(1/2)(3/8)} = .046875 \text{ in}^3$$

$$Z_{yy} = \frac{I_{yy}}{c_{yy}} = \frac{.250000}{1/2(2)} = .250000 \text{ in}^3$$

2)

$$I_{xx} = \frac{1(1/4)^3}{12} = .001302 \text{ in}^4$$

$$I_{yy} = \frac{1/4(1)^3}{12} = .020833 \text{ in}^4$$

$$J = \sum \frac{bt^3}{3} = \frac{1(1/4)^3}{3} = .005208 \text{ in}^4$$

$$Z_{xx} = \frac{I_{xx}}{c_{xx}} = \frac{.001302}{(1/2)(1/4)} = .010416 \text{ in}^3$$

$$Z_{yy} = \frac{I_{yy}}{c_{yy}} = \frac{.020833}{(1/2)(1)} = .041666 \text{ in}^3$$

3)

$$I_{xx} = I_{yy} = .70 \text{ in}^4$$

(Intro to Mech. of Solids, E.P. Popov, 1968).

$$J = \sum \frac{bt^3}{3} = \frac{2.5(1.25)^3}{3} + \frac{2.25(1.25)^3}{3} = .024740 \text{ in}^4$$

$$Z_{xx} = Z_{yy} = .39 \text{ in}^3$$

(Mech. Eng. Design, J.E. Shigley, 2nd ed., 1972).

Materials used (or proposed) in hanger construction in A-C System

ASTM A 242

A 575

A 441 (replaced by A 588, ECRA # L-2074)

A 537

Material (ASTM)	$E^{(a)}$ (psi)	S_y (psi)	S_u (psi)
A 242	27.8×10^6	$50 \times 10^3^{(b)}$	$70 \times 10^3^{(b)}$
A 537	27.8×10^6	$60 \times 10^3^{(c)}$	$80 \times 10^3^{(c)}$
A 575	27.8×10^6	assume same props as A 242, 588	
A 588	27.8×10^6	$50 \times 10^3^{(d)}$	$70 \times 10^3^{(d)}$

(a) Section III, subsection NA, Table 1-6.0

(b) Manual of Steel Construction, AISC, 7th edition, p. 5-212

(c) Section III, subsection NA, Table 1-7.1

(d) Manual of Steel Construction, AISC, 7th edition, p. 5-216

All values are at approx. 70°F, the expected hanger temperature.

- Hanger analysis follows NF 3230

- Design, Normal, Upset Conditions, and Emergency Condition

- 1) Stress in Tension

$$\left. \begin{array}{l} F_t = .60 S_y \\ \text{or } F_t = .50 S_u \end{array} \right\} \text{whichever is less} \\ \text{(from XVII-2000)}$$

For the materials of this analysis, $.60 S_y$ is always the least value of F_t .

For A 242, 575, 588, $F_t = .60 (50 \times 10^3) = 30,000 \text{ psi}$

For A 537, $F_t = .60 (60 \times 10^3) = 36,000 \text{ psi}$

From Section III, NF-3231 the following factors may be used for the allowable stress limits for the given conditions,

Case I - Design, Normal, and Upset Conditions - allowable stresses are as given in XVII-2000

Case II - Combined Mechanical Loads & Constraint of Free End Displacements (thermal) - allowable stresses are 3.00 times those given in XVII-2000

Case III - Emergency Conditions - allowable stresses are 1.33 times those given in XVII-2000

Case I

$$S_y = 50,000 \text{ psi}$$

$$S_y = 60,000 \text{ psi}$$

$$F_t = .6(50,000) = 30,000 \text{ psi}$$

$$F_t = .6(60,000) = 36,000 \text{ psi}$$

Case II

$$S_y = 50,000 \text{ psi}$$

$$S_y = 60,000 \text{ psi}$$

$$F_t = 3(30,000) = 90,000 \text{ psi}$$

$$F_t = 3(36,000) = 108,000 \text{ psi}$$

Case III

$$S_y = 50,000 \text{ psi}$$

$$S_y = 60,000 \text{ psi}$$

$$F_t = 1.33(30,000) = 39,900 \text{ psi}$$

$$F_t = 1.33(36,000) = 47,880 \text{ psi}$$

2) Stress in Shear $F_y = .40 S_y$

Material	F_y (psi) Case I	F_y (psi) Case II	F_y (psi) Case III
ASTM A242, 575, 588 ($S_y=50,000$)	20,000	60,000	26,600
A537 ($S_y=60,000$)	24,000	72,000	31,900

3) Stress in Compression

(Use end condition $K=1.2$ - Manual of Steel Construction - AISC - 7th edition, Table C1.8.1)

Hanger	r	e/r	K^2/r	(e)
1	.1445"	$69.2 \times 1.2 =$	83.0	10.0 in
2	.1445	69.2	83.0	10.0 in
4	.1445	90.0	108.0	13.0 in
5	.1445	90.0	108.0	13.0 in
6	.1445	90.0	108.0	13.0 in
7	.1083	166.2	199.4	18.0
8	.1083	166.2	199.4	18.0
11	.1083	84.9	101.9	9.2
12	.0723	78.8	94.6	5.7
12L	.7615	26.3	31.5	20.0

r = radius of gyration about weak axis, in.
 l/k = slenderness ratio where l = column (hanger) length

Hangers 1, 2, 4, 5, 6 are $\frac{1}{2} \times 2$ " bar

Hangers 7, 8, 11 are $\frac{3}{8} \times 2$ " bar

Hanger 12 is $\frac{1}{4} \times 1$ " bar

Hanger 12 L is $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ " angle

From XVII-2213

For ASTM A242, A575, and A588 ($S_y = 50,000$ psi.)

$$C_c = \left[\frac{2\pi^2 (27.8 \times 10^6 \text{ psi})}{50 \times 10^3 \text{ psi}} \right]^{1/2} = 104.8$$

For ASTM A537 ($S_y = 60,000$ psi.)

$$C_c = \left[\frac{2\pi^2 (27.8 \times 10^6 \text{ psi})}{60 \times 10^3 \text{ psi}} \right]^{1/2} = 95.6$$

Then for Hangers 1, 2, 11, 12, 12L, since $kl/r < C_c$ for their respective materials, then F_a is given as follows

$$F_a = \frac{\left[1 - \frac{(kl/r)^2}{2C_c^2} \right] S_y}{\frac{5}{3} + \frac{3(kl/r)}{8C_c} - \frac{(kl/r)^3}{8C_c^3}} \quad (4) \quad \text{XVII-2213.1}$$

For Hangers 1 & 2

$$F_a = \frac{\left[1 - \frac{(83.0)^2}{2(104.8)^2} \right] (50 \times 10^3 \text{ psi})}{\frac{5}{3} + \frac{3(83.0)}{8(104.8)} - \frac{(83.0)^3}{8(104.8)^3}}$$

$$= \underline{\underline{18,000 \text{ psi}}}$$

For Hanger 12

$$F_a = \frac{\left[1 - \frac{(94.6)^2}{2(104.8)^2} \right] (50 \times 10^3 \text{ psi})}{\frac{5}{3} + \frac{3(94.6)}{8(104.8)} - \frac{(94.6)^3}{8(104.8)^3}}$$

$$= \underline{15,460 \text{ psi}}$$

A similar calculation for H-11 gives $F_a = \underline{13,700 \text{ psi}}$

For the angle portion of Hanger 12

$$F_a = \frac{\left[1 - \frac{(31.5)^2}{2(104.8)^2} \right] (50 \times 10^3 \text{ psi})}{\frac{5}{3} + \frac{3(31.5)}{8(104.8)} - \frac{(31.5)^3}{8(104.8)^3}}$$

$$= \underline{26,831 \text{ psi}}$$

For Hangers 4, 5, 6, 7, and 8 $C_c < K/r$ and F_a is given as follows,

$$F_a = \frac{12 \pi^2 E}{23 (K/r)^2} \quad (5) \quad \text{XVII-2213.2}$$

For Hangers 4, 5, 6

$$F_a = \frac{12 \pi^2 (27.8 \times 10^6 \text{ psi})}{23 (108.0)^2}$$

$$= \underline{12,300 \text{ psi}}$$

For Hangers 7, 8

$$F_a = \frac{12 \pi^2 (27.8 \times 10^6 \text{ psi})}{23 (199.4)^2}$$

$$= \underline{3600 \text{ psi}}$$

The previous calculations for allowable stress in compression have been based on

$$S_y = 50,000 \text{ psi}$$

for all materials.

From XVII-2213.3 when $\frac{1}{r} > 120$, F_{as} is defined as follows;

$$F_{as} = \frac{F_a \text{ (Eq. 4 or Eq. 5)}}{1.6 - \frac{1}{200} \left(\frac{1}{r} \right)} \quad (6) \quad \text{XVII-2213.3}$$

Then, for hanger 7 and 8, which have $\frac{1}{r} = 199.4$,

$$\begin{aligned} F_{as} &= \frac{3600 \text{ psi}}{1.6 - \frac{1}{200} (199.4)} \\ &= \underline{\underline{4680 \text{ psi}}} \end{aligned}$$

In addition to the above allowable limits for design, normal, and upset conditions (Case I), the values may be increased by a factor of 3.00 for combined mechanical loads and constraint of free-end displacements (thermal); and increased by a factor of 1.33 for emergency conditions. The following table summarizes these results,

Hanger	F_a (or F_{as}) psi Case I	F_a (psi) Case II	F_a (psi) Case III
1	18,000	54,000	23,900
2	18,000	54,000	23,900
4	12,360	36,900	16,400
5	12,360	36,900	16,400
6	12,360	36,900	16,400
7	4680	14,000	6220
8	4680	14,000	6220
11	13,760	41,100	18,200
12	15,460	46,400	20,600
12 L	26,830	80,500	35,700

where

Case I = Design, Normal and Upset Conditions

Case II = Combined mechanical loads and constraint of free-end displacement (thermal)

Case III = emergency conditions.

4) Stress in Bending

Hangers 1, 2, 4, 5, 6, 7, 8, 11, 12 meet the requirements of XVII-2214.3 and XVII 2214.5 (a) or

$$F_b = .75 S_y \quad (12) \text{ XVII-2214.3 weak axis}$$

$$F_b = .60 S_y \quad (14) \text{ XVII-2214.5 strong axis}$$

Hanger 12' angle meets the requirements of XVII-2214.5;

$$F_b = .60 S_y \quad (14) \text{ XVII-2214.5}$$

The following table summarizes the allowable bending stresses as defined by XVII-2214 and Section III, subsection NF for Design, Normal and Upset conditions and Emergency Conditions

Hanger (Material)	F_b (a) (weak) psi	F_b (b) (strong) psi	F_b (c) (weak) psi	F_b (d) (strong) psi	F_b (Emer) (e) (weak) psi	F_b (Emer) (f) (strong) psi
1 (537)	37.5×10^3	30×10^3	112.5×10^3	90×10^3	49.9×10^3	39.9×10^3
2 (537)	↓	↓	↓	↓	↓	↓
4 (537)	↓	↓	↓	↓	↓	↓
5 (537)	↓	↓	↓	↓	↓	↓
6 (537)	↓	↓	↓	↓	↓	↓
7 (575)	↓	↓	↓	↓	↓	↓
8 (575)	↓	↓	↓	↓	↓	↓
11 (242)	↓	↓	↓	↓	↓	↓
12 (242)	↓	↓	↓	↓	↓	↓
12L (588)	30×10^3	↓	90×10^3	↓	39.9×10^3	↓

(a) Eq. 12 XVII-2214.3 } Case I

(b) Eq. 14 XVII-2214.5 }

(c) $3 \times$ Eq. 12 XVII-2214.3 (NF 3231) } Case II

(d) $3 \times$ Eq. 14 XVII-2214.5 (NF 3231) }

(e) $1.33 \times$ Eq. 12 XVII-2214.3 (NF 3231) } Case III

(f) $1.33 \times$ Eq. 14 XVII-2214.5 (NF 3231) }

5) Combined Stresses - Axial Compression and Bending

From XVII-2215 - compression + bending must meet the following;

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \quad (20) \text{ XVII-2215.1}$$

$$\text{and } \frac{f_a}{F_a} \leq .15$$

where the subscripts x and y indicate the axis (weak or strong) about which the bending stress applies.

Faulted Conditions

Section III - Appendix F, F-1370

According to F-1370, the allowable stress values are as follows;

F 1370 (a) allowable stresses may be increased by a factor of $1.2 (S_y / F_t)$ but not to exceed $.7 (S_u / F_t)$, over those given in XVII-1000.

(c) Loads shall not exceed .67 times the critical buckling strength of the supports.

(a) 1) Stress in Tension

From XVII-2000

$$\left. \begin{array}{l} F_t = .60 S_y \\ \text{or } F_t = .50 S_u \end{array} \right\} \text{whichever is less.}$$

let $K = 1.2 S_y / F_t$, then

$K F_t = \text{allowable stress}$

$$\text{or } K = 1.2 S_y / F_t = 1.2 \frac{S_y}{.60 S_y} = 2.00$$

$$\text{let } C = .7 S_u / F_t, \text{ then}$$

$C F_t = \text{allowable stress}$

Since for all the materials of this analysis have $.6 S_y < .50 S_u$, then

$$\left. \begin{aligned} K F_t &= 2 F_t = 2(.6 S_y) = \underline{1.2 S_y} \\ C F_t &= \left(\frac{.7 S_u}{F_t} \right) F_t = \underline{.7 S_u} \end{aligned} \right\} \text{whichever is less}$$

Since all the materials of this analysis have $.7 S_u < 1.2 S_y$, then

$$F_t = .7 S_u$$

Then, for faulted conditions,

$$S_y = 50,000 \quad \text{ASTM A242, 575, 588,} \quad F_t = .7(70 \times 10^3) = \underline{49,000 \text{ psi}}$$

$$S_y = 60,000 \quad \text{A 537,} \quad F_t = .7(80 \times 10^3) = \underline{56,000 \text{ psi}}$$

2) Stress in Shear

$$\begin{aligned} F_y &= .40 S_y \\ &= \frac{2}{3}(.60 S_y) \\ &= \frac{2}{3}(F_t) \end{aligned}$$

$$\text{A242, 575, 588, } F_y = \frac{2}{3}(49,000) = \underline{32,667 \text{ psi}}$$

$$\text{A 537, } F_y = \frac{2}{3}(56,000) = \underline{37,333 \text{ psi}}$$

3) Stress in Compression

From F-1370 (c) loads should not exceed .67 times the critical buckling load of the member, where

$$\frac{P_{cr}}{A} = \frac{n\pi^2 E}{(e/r)^2}$$

(This is equation 3-43 in Mech. Eng. Design by J.E. Shigley, McGraw-Hill, 2nd edition, 1972.)

This equation may be rewritten

$$P_{cr} = \frac{n\pi^2 EA}{(e/r)^2}$$

and according to F-1370 (d),

$$F_a' = .67P_{cr} = \frac{.67n\pi^2 EA}{(e/r)^2}$$

With $n=1.2$ (end condition for this analysis as specified in Manual of Steel Construction, AISC, 7th edition, Table C1.8.1), the following table summarizes the allowable stress in compression F_a for each support member,

Member (Hanger #)	E (psi)	A (in ²)	$e/r^{(a)}$	P_c (lbf)	F_a' (lbf)	$F_a = F_a'/A$ (psi)
1	27.8×10^6	1.00	69.2	68,750	46,070	46,070
2			69.2	68,750	46,070	46,070
4			90.0	40,650	27,230	27,230
5			90.0	40,650	27,230	27,230
6		↓	90.0	40,650	27,230	27,230
7		.75	166.2	8940	5990	7990
8		.75	166.2	8940	5990	7990
11		.75	84.9	34,260	22,950	30,600
12		.25	78.8	13,260	8880	35,530
12 L		1.19	26.3	566,450	379,520	318,930

(a) values taken from calculations for stress in compression for Design, Normal, and upset conditions, thermal, and emergency.

4) Stress in Bending

For Hangers 1, 2, 4, 5, 6, 7, 8, 11, 12,

$$F_b = .75 S_y \text{ (12) XVII-2214.3 weak axis}$$

$$F_b = .60 S_y \text{ (14) XVII-2214.5 Strong axis}$$

then,

$$F_b = .75 S_y = 1.25 (.60 S_y)$$

$$= \underline{1.25 (F_t)} \text{ weak axis}$$

$$F_b = .60 S_y = \underline{F_t} \text{ strong axis}$$

For angle portion of Hanger 12,

$$F_b = .60 S_y \text{ (14) XVII-2214.5}$$

$$= \underline{F_t}$$

The following table summarizes the allowable bending stresses for faulted conditions

Hanger	F_t (psi)	F_b (psi.) weak axis	F_b (psi.) strong axis
1	49,000	61,250	49,000
2	↓	↓	↓
4			
5			
6			
7			
8			
11			
12		↓	
12L	↓	49,000	↓

5) Combined Stresses - Axial Compression and Bending

From XVII-2215 - compression + bending must meet the following:

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \quad (20) \text{ XVII-2215.1}$$

$$\text{and } \frac{f_a}{F_a} \leq .15$$

where the subscripts x and y indicate the axis (weak or strong) about which the bending stress applies.

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From LTR 10-7, page 5

For SSE (Safe Shutdown Earthquake)

Horizontal Ground Acceleration = $0.35g$ Vertical Ground Acceleration = $\frac{2}{3}(0.35g) = .23g$

For OBE (Operating Basis Earthquake)

Horizontal Ground Acceleration = $.18g$ Vertical Ground Acceleration = $\frac{2}{3}(.18g) = .12g$

From Figure 5.2 (LTR 10-7)

For $1g$ input, the maximum
response acceleration is

$$S_a = \begin{cases} 2.8g & \text{OBE} & (1\% \text{ damping}) \\ 2.25g & \text{SSE} & (2\% \text{ damping}) \end{cases}$$

Applying this to the LOFT SSE and OBE
gives,

SSE

$$H = .35(2.25) = .79g$$

$$V = .23(2.25) = .52g$$

OBE

$$H = .18(2.8) = .50$$

$$V = .12(2.8) = .34$$

Since response spectra of the support points has not been determined, Equation (2) on page 11 of RDT F9-2T will be utilized to compute the equivalent static force;

$$F = 8.0 W A_g$$

where W = Weight of system or components, including liquid contents,

A_g = Peak acceleration from ground response spectrum for the system

SSE

$$A_{gH} = .79 g$$

$$A_{gV} = .52 g$$

OBE $A_{gH} = .50 g$

$$A_{gV} = .34 g$$

therefore;

SSE

$$F_H = 8.0 W (.79 g) = \underline{\underline{6.32 W}}$$

$$F_V = 8.0 W (.52 g) = \underline{\underline{4.16 W}}$$

OBE

$$F_H = 8.0 W (.50 g) = \underline{\underline{4.00 W}}$$

$$F_V = 8.0 W (.34 g) = \underline{\underline{2.72 W}}$$

Note; Class 1 and Class 2 analysis requires consideration of SSE as an emergency condition.

For this analysis, OBE will be neglected, since satisfying SSE automatically satisfies OBE. This can be shown as follows;

Eq. 9 (NC3050)

$$\text{Pressure} + \text{Dead Wt.} + \text{OBE} \leq 1.2 S_h$$

$$\text{Pressure} + \text{Dead Wt.} + \text{SSE} \leq 1.8 S_h$$

if Pressure + Dead Wt. is constant for both, then

$$\text{OBE}' \leq 1.2 S_h$$

$$\text{SSE}' \leq 1.8 S_h$$

where $\text{SSE}' = \text{Pressure} + \text{Dead Wt.} + \text{SSE}$

$\text{OBE}' = \text{Pressure} + \text{Dead Wt.} + \text{OBE}$

then

$$\frac{\text{OBE}'}{\text{SSE}'} = \frac{1.2 S_h}{1.8 S_h} \quad (\text{Equal Sign at most severe loading})$$

or $\text{OBE}' = .67 \text{SSE}'$

or $\underline{\underline{\sigma_{\text{Allowable OBE}} = .67 \sigma_{\text{Allowable SSE}}}}$

but

$$\frac{F_{H \text{ OBE}}}{F_{H \text{ SSE}}} = \frac{4.00 \text{ W}}{6.32 \text{ W}} \Rightarrow \underline{\underline{F_{H \text{ OBE}} = .63 F_{H \text{ SSE}}}}$$

and $\frac{F_{V \text{ OBE}}}{F_{V \text{ SSE}}} = \frac{2.72 \text{ W}}{4.16 \text{ W}} \Rightarrow \underline{\underline{F_{V \text{ OBE}} = .65 F_{H \text{ SSE}}}}$

therefore, allowable stresses for OBE are greater than corresponding forces, when compared to SSE.

APPENDIX B
COMPUTER INPUT FOR SECTION 2

SAP IV INPUT DATA

The following pages contain the input to the SAP IV runs for the static and dynamic cases. Pages B-1 through B-12 contain static data (dead weight, SSE, thermal) for Section 2 of the model. The response spectrum analysis for LOCE is found on page B-13 for Section 2. LOCA response spectrum input is found on page B-14 for Section 2. The response spectrum runs, both LOCE and LOCA, had nodal point and element data as in the static runs, with pages B-13 and B-14 representing only that additional input required for dynamic analysis. Structure load case force combinations, required for static analysis, were omitted in the response spectrum input.

2

PRIMARY CELL ACC-CONTROL PIPING ANALYSIS, CEAD WT-SEISMIC-THERMAL, SEC 2

CONTROL INFORMATION

NUMBER OF NODAL POINTS = 14
 NUMBER OF ELEMENT TYPES = 3
 NUMBER OF LOAD CASES = 4
 NUMBER OF FREQUENCIES = 0
 ANALYSIS CODE (NDYN) = 0
 EQ.C, STATIC
 EQ.1, NODAL EXTRACTION
 EQ.2, FORCED RESPONSE
 EQ.3, RESPONSE SPECTRUM
 SOLUTION CODE (NOEX) = 0
 EQ.C, EXECUTION
 EQ.1, DATA CHECK

NODAL POINT INPUT DATA

NODE NUMBER	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES				
	X	Y	Z	XX	YY	ZZ	X	Y	Z	T	
1	0	C	0	1	1	1	84.790	0.0	0.0	0	450.000
2	0	C	0	0	0	0	11.420	0.0	0.0	0	450.000
3	1	1	1	1	1	1	11.420	-7.730	5.000	0	450.000
4	0	C	0	0	0	0	7.500	0.0	0.0	0	450.000
5	0	C	0	0	0	0	0.0	0.980	-7.440	0	450.000
6	0	C	0	0	0	0	0.0	4.000	-30.380	0	450.000
7	0	C	0	0	0	0	0.0	4.000	-78.380	0	450.000
8	0	C	0	0	0	0	-4.680	4.000	-89.690	0	450.000
9	0	C	0	0	0	0	-8.520	4.000	-98.950	0	450.000
10	0	C	0	0	0	0	-11.390	11.500	-105.880	0	450.000
11	0	C	0	0	0	0	-11.390	29.560	-105.880	0	450.000
12	0	C	0	0	0	0	-12.000	31.810	-108.050	0	450.000
13	1	1	1	1	1	1	-14.710	31.810	-117.680	0	450.000
14	1	1	1	1	1	1	-30.000	11.500	-105.880	0	450.000

GENERATED NODAL DATA

NODE NUMBER	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES			
	X	Y	Z	XX	YY	ZZ	X	Y	Z	T
1	0	C	0	1	1	1	84.790	0.0	0.0	450.000
2	0	C	0	0	0	0	11.420	0.0	0.0	450.000
3	1	1	1	1	1	1	11.420	-7.730	5.000	450.000
4	0	C	0	0	0	0	7.500	0.0	0.0	450.000
5	0	C	0	0	0	0	0.0	0.980	-7.440	450.000
6	0	C	0	0	0	0	0.0	4.000	-30.380	450.000
7	0	C	0	0	0	0	0.0	4.000	-78.380	450.000
8	0	C	0	0	0	0	-4.680	4.000	-89.690	450.000
9	0	C	0	0	0	0	-8.520	4.000	-98.950	450.000
10	0	C	0	0	0	0	-11.390	11.500	-105.880	450.000
11	0	C	0	0	0	0	-11.390	29.560	-105.880	450.000
12	0	C	0	0	0	0	-12.000	31.810	-108.050	450.000
13	1	1	1	1	1	1	-14.710	31.810	-117.680	450.000
14	1	1	1	1	1	1	-30.000	11.500	-105.880	450.000

EQUATION NUMBERS

N	X	Y	Z	XX	YY	ZZ
1	1	2	3	0	0	0
2	4	5	6	7	8	9
3	C	C	C	C	C	C

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B-1

2	4	5	6	7	8	9
3	0	0	0	0	0	0
4	0	11	12	13	14	15
5	0	17	18	19	20	21
6	22	23	24	25	26	27
7	28	29	30	31	32	33
8	34	35	36	37	38	39
9	40	41	42	43	44	45
10	46	47	48	49	50	51
11	52	53	54	55	56	57
12	58	59	60	61	62	63
13	0	0	0	0	0	0
14	0	0	0	0	0	0

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.....TH(DIMENSIONAL BEAM ELEMENTS (

NUMBER OF BEAMS = 1
NUMBER OF GEOMETRIC PROPERTY SETS = 1
NUMBER OF FIXED END FORCE SETS = 0
NUMBER OF MATERIALS = 1

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MATERIAL	LAG S POISSON S	POISSON S RATIO	MASS DENSITY
1	27860000.	0.30000	0.00073

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6-4

BEAM GEOMETRIC PROPERTIES

ELEMENT	AREA	AREA	AREA	INERTIA	INERTIA	INERTIA
TYPE	X	Y	Z	X	Y	Z
1	0.750	0.0	0.0	0.035	0.250	0.009

ELEMENT LOAD MULTIPLIERS

	A	B	C	D
X-DIR	0.0	0.1000000 01	0.0	0.0
Y-DIR	-0.1000000 01	0.0	0.0	0.0
Z-DIR	0.0	0.0	0.1000000 01	0.0

BEAM		NODES			MATL GEOM			ELEM LOADS				END CODES	
NO		I	J	K	NO	NO	A	B	C	D	I	J	
1		2	3	4	1	1	0	0	0	0	0	0	

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...BCU RY ELEMENTS...

ELEMENT TYPE.....= 7

NUMBER OF ELEMENTS...= 3

NODE ..NODES DEFINING CONSTRAINT DIRECTION..

CODES

DISPL

ROTATION

STIFF

N

NI

NJ

NK

NL

KD

KR

KN

D

R

S

1

6

5

6

7

1

C

0

-1.300-02

0.0

1.000 10

1

7

8

7

6

1

C

0

3.200-02

0.0

1.000 10

1

10

11

10

14

1

0

0

-8.800-02

0.0

1.000 10

ELEMENT LOAD MULTIPLIERS

A

B

C

D

0.0

0.0

0.0

1.0000

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PIPE ELEMENT INPUT DATA

CONTROL INFORMATION

NUMBER OF PIPE ELEMENTS = 11

NUMBER OF MATERIAL SETS = 1

MAXIMUM NUMBER OF MATERIAL
TEMPERATURE INPUT POINTS = 5

NUMBER OF SECTION PROPERTY SETS = 1

NUMBER OF BRANCH POINT NODES = 0

MAXIMUM NUMBER OF TANGENTS
COMMON TO A BRANCH POINT = 4

FLAG FOR NEGLECTING AXIAL
DEFORMATIONS IN BEND ELEMENTS = 0
(EQ.1, NEGLECT)

MATERIAL PROPERTY TABLES

MATERIAL NUMBER = (1)

NUMBER OF
TEMPERATURE POINTS = (5)

IDENTIFICATION = (PROPERTIES OF 316 STAINLESS STEEL)

POINT NUMBER	TEMPERATURE	YOUNG'S MODULUS	POISSON'S RATIO	THERMAL EXPANSION
1	70.00	28300000.0	0.300	0.911D-05
2	150.00	27900000.0	0.300	0.939D-05
3	580.00	25500000.0	0.300	0.104D-04
4	650.00	25100000.0	0.300	0.105D-04
5	700.00	24800000.0	0.300	0.107D-04

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SECTION I PROPERTY TABLE

SECTION NUMBER	OUTSIDE DIAMETER	WALL THICKNESS	SHAPE FACTOR FOR SHEAR	WEIGHT/ UNIT LENGTH	MASS/ UNIT LENGTH	DESCRIPTION
1	1.900	0.2810	0.0	0.45620 00	0.11810-02	316 1.5 IN SCH160

ELEMENT LOAD CASE MULTIPLIERS

	CASE A	CASE B	CASE C	CASE D
X-DIRECTION GRAVITY	0.0	1.000	0.0	0.0
Y-DIRECTION GRAVITY	-1.000	0.0	0.0	0.0
Z-DIRECTION GRAVITY	0.0	0.0	1.000	0.0
THERMAL DISTORTION	0.0	0.0	0.0	1.000
PRESSURE DISTORTION	0.0	0.0	0.0	0.0

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PIPE ELEMENT INPUT DATA

ELEMENT NUMBER	ELEMENT TYPE	NODE -I	NODE -J	MATL. NUMBER	SECTION NUMBER	REFERENCE TEMPERATURE (BEND RADIUS)	INTERNAL PRESSURE (THIRD POINT)	DIRECTION COSINES A(YX) (X3- ORDINATE)	A(YY) (Y3- ORDINATE)	A(YZ) (Z3- ORDINATE)	NODE INCREMENT (WALL FRACTION)	INPUT TAG
1	TANGENT	1	2	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
2	TANGENT	2	4	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
3	BEND	4	5	1	1	70.00	2500.00					IC
						(7.500)	(II)	(0.0)	(0.0)	(0.0)	(0.1000)	
4	TANGENT	5	6	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
5	TANGENT	6	7	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
6	TANGENT	7	8	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
7	TANGENT	8	9	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
8	BEND	9	10	1	1	70.00	2500.00					IC
						(7.500)	(II)	(-11.390)	(4.000)	(-105.880)	(0.1000)	
9	TANGENT	10	11	1	1	70.00	2500.00	0.0	0.0	0.0	1	II
10	BEND	11	12	1	1	70.00	2500.00					IC
						(2.250)	(II)	(-11.390)	(31.810)	(-105.880)	(0.1000)	
11	TANGENT	12	13	1	1	70.00	2500.00	0.0	0.0	0.0	1	II

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EQUATION PARAMETERS

TOTAL NUMBER OF EQUATIONS = 63
 BANDWIDTH = 12
 NUMBER OF EQUATIONS IN A BLOCK = 63
 NUMBER OF BLOCKS = 1

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..... ACDA(FORCES/MOMENTS

NODE NUMBER	LOAD CASE	X-AXIS FORCE	Y-AXIS FORCE	Z-AXIS FORCE	X-AXIS MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
8	1	0.0	-0.150000 02	0.0	0.0	0.0	0.0
8	2	0.945000 02	-0.780000 02	0.0	0.0	0.0	0.0
8	3	0.0	-0.780000 02	0.945000 02	0.0	0.0	0.0
8	4	0.0	0.0	0.0	0.0	0.0	0.0

STRUCTURE LOAD CASE	ELEMENT A	LOAD B	MULTIPLIERS C	D
1	1.000	0.0	0.0	0.0
2	5.200	6.300	0.0	0.0
3	5.200	0.0	6.300	0.0
4	0.0	0.0	0.0	1.000

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RESPONSE SPECTRUM ANALYSIS

DIRECTION FACTORS

X = -0.6700 Y = 1.0000 Z = 1.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT
EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	0.3368D 00	0.1072D-01	-0.9914D-01
2	0.2080D-01	0.2662D 00	0.2226D 00
3	-0.1963D-01	-0.9130D-01	0.1267D 00
4	0.8074D-01	-0.4382D-01	0.3212D 00
5	0.3787D-01	0.1732D-01	-0.2607D-01
6	-0.7199D-01	-0.4304D-01	-0.2631D-01
7	-0.5118D-01	0.1338D 00	-0.4066D-01
8	0.8120D-02	0.7825D-02	-0.4525D-01
9	-0.2268D-02	-0.2038D 00	0.1182D-01
10	-0.1232D 00	-0.1602D-02	0.3693D-01

SPECTRUM TABLE (LOCAL RESPONSE SPECTRUM ACCELERATION VS PERIOD)

NUMBER OF POINTS = 10
SCALE FACTOR = 0.10000D 01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	0.5000D-02	0.3000D 04
2	0.1000D-01	0.3000D 04
3	0.1176D-01	0.4550D 04
4	0.1493D-01	0.3625D 04
5	0.1786D-01	0.4625D 04
6	0.2105D-01	0.4625D 04
7	0.4000D-01	0.1125D 04
8	0.1000D 00	0.1000D 04
9	0.1333D 00	0.7000D 03
10	0.1000D 01	0.7000D 03

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RESPONSE SPECTRUM ANALYSIS

DIRECTION FACTORS

X = -0.8000 Y = 1.0000 Z = 1.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT
EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	0.3368D 00	0.1072D-01	-0.9914D-01
2	0.2080D-01	0.2662D 00	0.2226D 00
3	-0.1963D-01	-0.9130D-01	0.1267D 00
4	0.8074D-01	-0.4382D-01	0.3212D 00
5	0.3787D-01	0.1732D-01	-0.2607D-01
6	-0.7199D-01	-0.4304D-01	-0.2631D-01
7	-0.5118D-01	0.1338D 00	-0.4066D-01
8	0.8120D-02	0.7825D-02	-0.4525D-01
9	-0.2268D-02	-0.2038D 00	0.1182D-01
10	-0.1232D 00	-0.1602D-02	0.3693D-01

SPECTRUM TABLE (LOCA RESPONSE SPECTRUM ACCELERATION VS PERIOD

NUMBER OF PGINTS = 10
SCALE FACTOR = 0.10000D 01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	0.5000D-02	0.4000D 04
2	0.1000D-01	0.4000D 04
3	0.1064D-01	0.5625D 04
4	0.1198D-01	0.5500D 04
5	0.1724D-01	0.3750D 04
6	0.1818D-01	0.2750D 04
7	0.2105D-01	0.2750D 04
8	0.2353D-01	0.3500D 04
9	0.3448D-01	0.1250D 04
10	0.1000D 01	0.1250D 04

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APPENDIX C
VALVE STRESS CALCULATIONS

The weakest points of valves CV-P-128-105, CV-P-128-106, and CV-P-128-109 in the Addition and Control Piping System are two pieces of cast iron as follows;

$$\begin{aligned}
 I_{xx} &= I(\text{entire area}) - I(\text{hollow area}) \\
 &= (3.5)(5.5)^3/12 - 3.5(2.5)^3/12 \\
 &= \underline{\underline{12.07 \text{ in}^4}}
 \end{aligned}$$

$$\begin{aligned}
 I_{yy} &= 5.5(3.5)^3/12 - 5(2.5)^3/12 \\
 &= \underline{\underline{1.79 \text{ in}^4}}
 \end{aligned}$$

$$\sigma_{xx} = \frac{M_{xx} C_{xx}}{I_{xx}} = \frac{M_{xx} (2.75")}{12.07 \text{ in}^4} = .2278 M_{xx} \quad (\text{psi if } M_{xx} \text{ is in-lb})$$

$$\sigma_{yy} = \frac{M_{yy} C_{yy}}{I_{yy}} = \frac{M_{yy} (1.75")}{1.79 \text{ in}^4} = .9777 M_{yy} \quad (\text{psi if } M_{yy} \text{ is in-lb})$$

The worst loading condition for any of the 3 valves occurs in valve CV-P-128-105 during thermal expansion. These loads are

$$M_{\text{weak}} = M_{yy} = 7937 \text{ in-lb}$$

$$M_{\text{strong}} = M_{xx} = 19730 \text{ in-lb}$$

$$\text{Axial Force} = 1005 \text{ lbf (compression)}$$

Therefore,

$$\sigma_{xx} = .2278(19730) = 4494 \text{ psi}$$

$$\sigma_{yy} = .9777(7937) = 7760 \text{ psi}$$

And, for the axial compressive force,
with cross-sectional area of

$$A = 2(3.5)(.25) = 1.75 \text{ in}^2$$

the compressive stress is

$$\sigma_c = P/A = 1005 \text{ lbf} / 1.75 \text{ in}^2 = 574 \text{ psi}$$

The corresponding worst stress case is

$$\begin{array}{rcl} \sigma_{xx} & = & 4494 \\ \sigma_{yy} & = & 7760 \\ \sigma_c & = & + 574 \\ \hline & & 12828 \text{ psi} \end{array}$$

A typical allowable stress for cast
ferritic steel is

$$S_A = 15,000 \text{ psi} \quad \begin{array}{l} 100^\circ\text{F} \Rightarrow 650^\circ\text{F} \\ \text{(Sec III, App I,} \\ \text{Table I-7.1, 1971} \\ \text{Code.} \end{array}$$

Therefore, the worst loading condition
is well within the Code limitations.

Note; The worst case loading conditions, as
well as the loading conditions for
all 3 valves, were determined
for valve support 30" from pipe
connection.

APPENDIX D
MICROFICHE OUTPUT
FOR SECTION 1