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MASTER

LOFT SUPPRESSION TANK SPRAY SYSTEM PIPING - HEAT EXCHANGER BS-H-31 PIPING MODIFICATIONS

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DEPARTMENT OF ENERGY

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APPLIED MECHANICS BRANCH

LOFT SUPPRESSION TANK SPRAY SYSTEM PIPING - HEAT EXCHANGER BS-H-31 PIPING MODIFICATIONS

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EG&G Idaho, Inc.

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ABSTRACT

A stress analysis of the piping modification, resulting from relocation of heat exchanger BS-H-31 of the LOFT Blowdown Suppression Tank Spray System, was performed. The piping, fittings, and supports were found to comply with the criteria of Section III of the ASME Boiler and Pressure Vessel Code, 1974.

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1.0 INTRODUCTION

The heating heat exchanger, designated BS-H-31, of the LOFT Blowdown Suppression Tank Spray System[1] was relocated outside of the tank shielding wall and off of the floor. An analysis of the spray system piping affected by this relocation was conducted to determine the structural adequacy of the pipe and pipe supports for LOFT design loads. A schematic of the subject piping is shown in Figure 1. A detailed description can be found in Reference 1.

2.0 METHOD OF ANALYSIS

2.1 General Approach

The structural integrity of the modified spray system piping can be assured by demonstrating that it complies with Section III of the ASME Boiler and Pressure Vessel Code.

SAP IV[2], a structural analysis computer program for the static and dynamic analysis of linear systems, was used to determine internal forces and bending moments in the piping system and supports. The results of the computer program were used with classical linear elastic analysis techniques to compute stresses. Allowable stresses and moments were established using the criteria of Section III, Subsection NC (Class 2 Piping) and NF (Component Supports) of the ASME Boiler and Pressure Vessel Code[3]. A comparison of calculated moments and stresses to Code allowables was used to verify the structural adequacy of the system.

Computer program FLANGE[4] was used to determine stresses in the flanges with moments from the SAP run being used for input. Allowable flange stresses were calculated using ASME Code criteria.

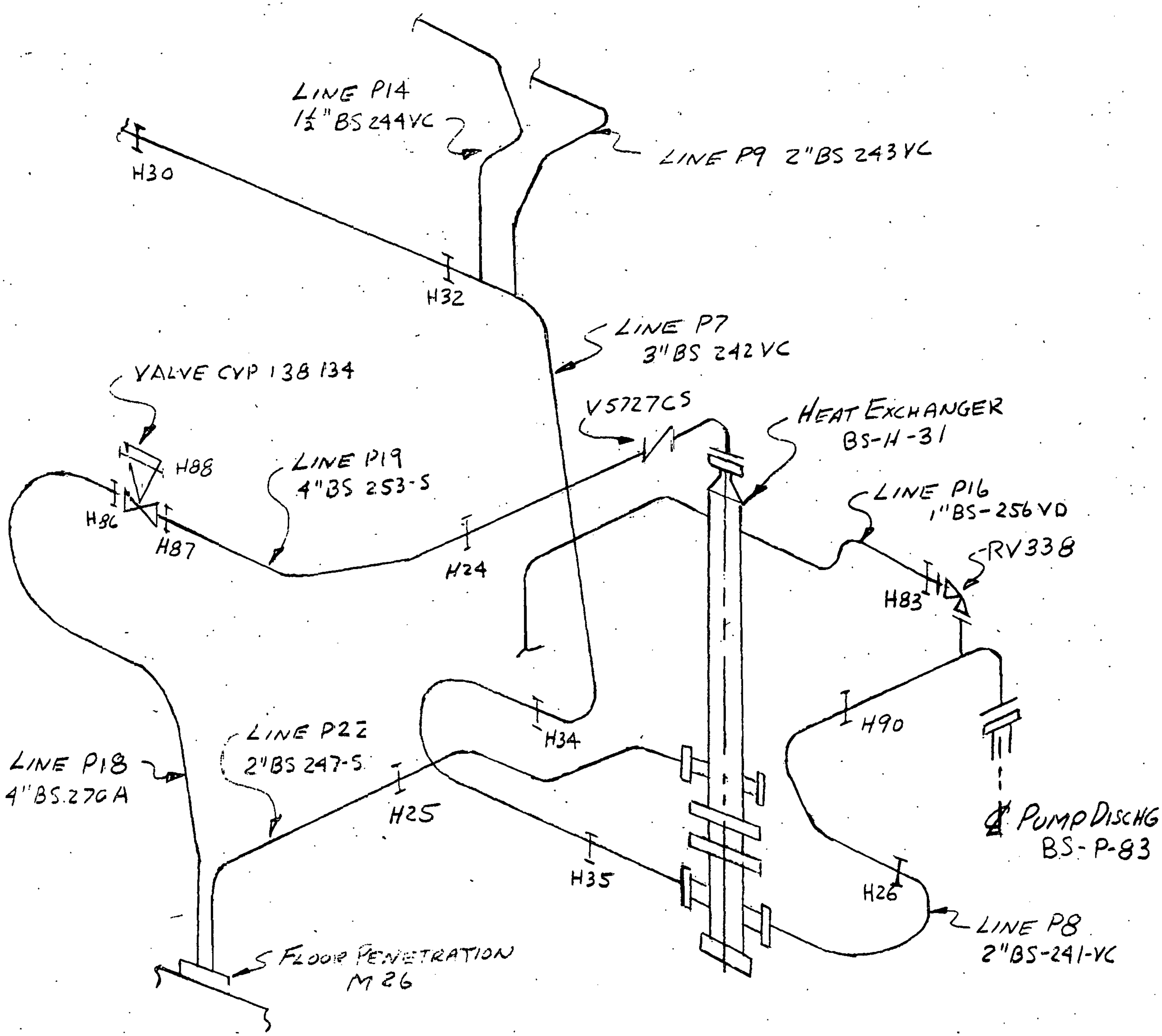


FIGURE 1

MODIFIED PIPING

LTR 112-123

Isometric sketches of the SAP IV models used to simulate the piping system and its supports are shown in Figures 2 thru 5. Model geometry was defined by Drawing 208185, Rev. A[1]. To minimize the influence of one system on another, interfaces between models and adjoining piping were chosen such that the actual constraint at the interface point could be effectively modeled as a point fixed in both rotation and translation. When such a point was not available, models were extended beyond the area of interest sufficient distance to minimize the effect of end point fixity.

2.2 Loading Conditions

In considering Code requirements for design, normal, upset, and emergency conditions, the following loadings were investigated: design pressure, system dead weight, thermal expansion and anchor movement, loads associated with the Safe Shutdown Earthquake (SSE), and the Operating Basis Earthquake (OBE)[a]. LOCE loads, which are introducted to the suppression tank spray system through the tank penetrations as a result of dynamic loadings on the tank, were not considered in this analysis. It was assumed that sufficient isolation from the tank penetrations existed for the subject piping that the effects of a LOCE could be neglected. The Loss-of-Coolant Accident (LOCA), a faulted condition, was not analyzed since the suppression tank spray system is isolated from the primary system. A LOCA in the primary system would result in negligible loading of the spray system. Anchor movements resulting from thermal expansion of the heat exchanger BS-H-31 are calculated in Appendix B.

Piping line designations and design conditions for the suppression tank spray system are given in Table I. Design temperatures and pressures were obtained from Reference 5. Load conditions applied to each model included:

[a] Meeting the requirements for SSE satisfies OBE - see Appendix A calculations.

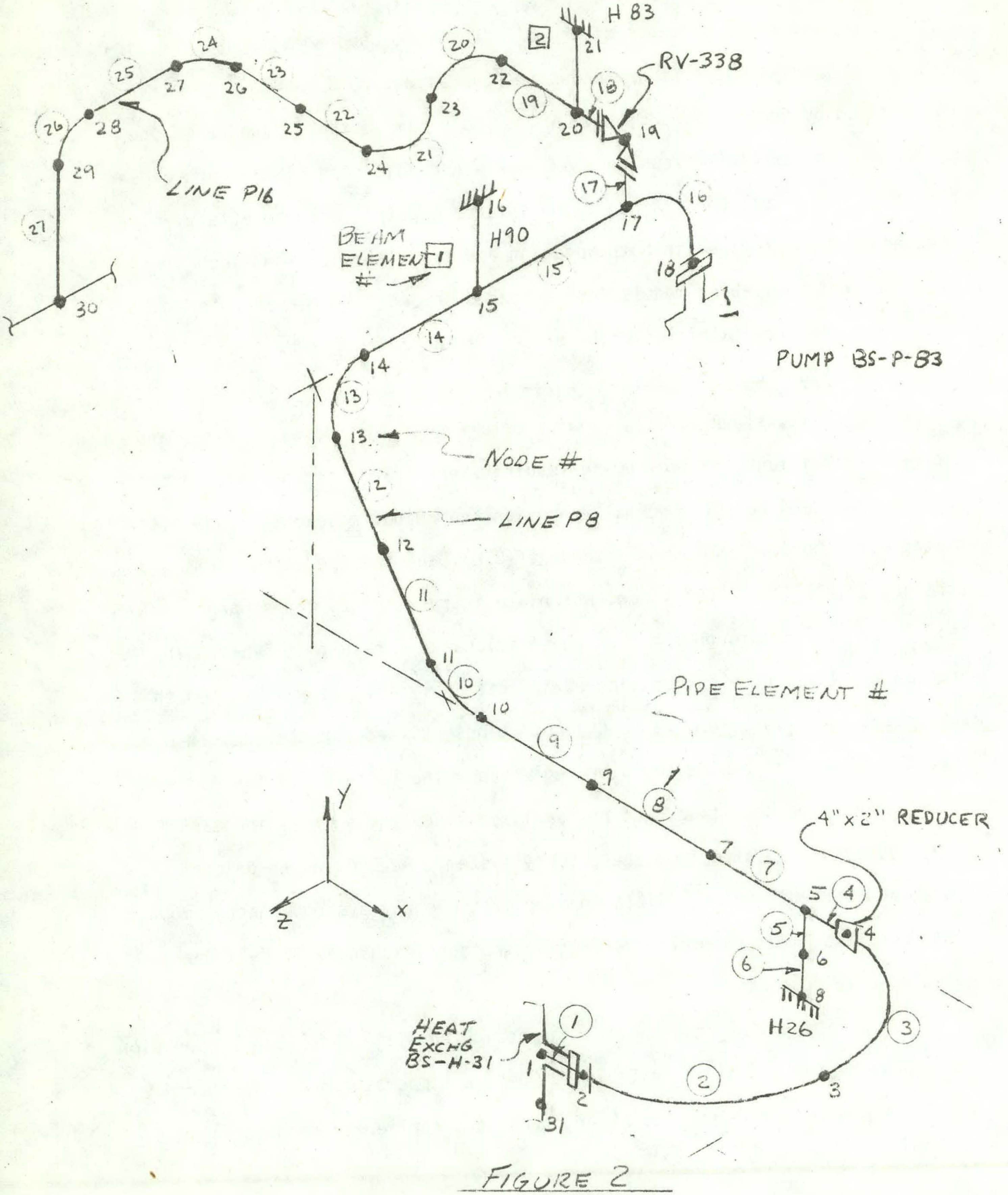


FIGURE 2

MODEL 1

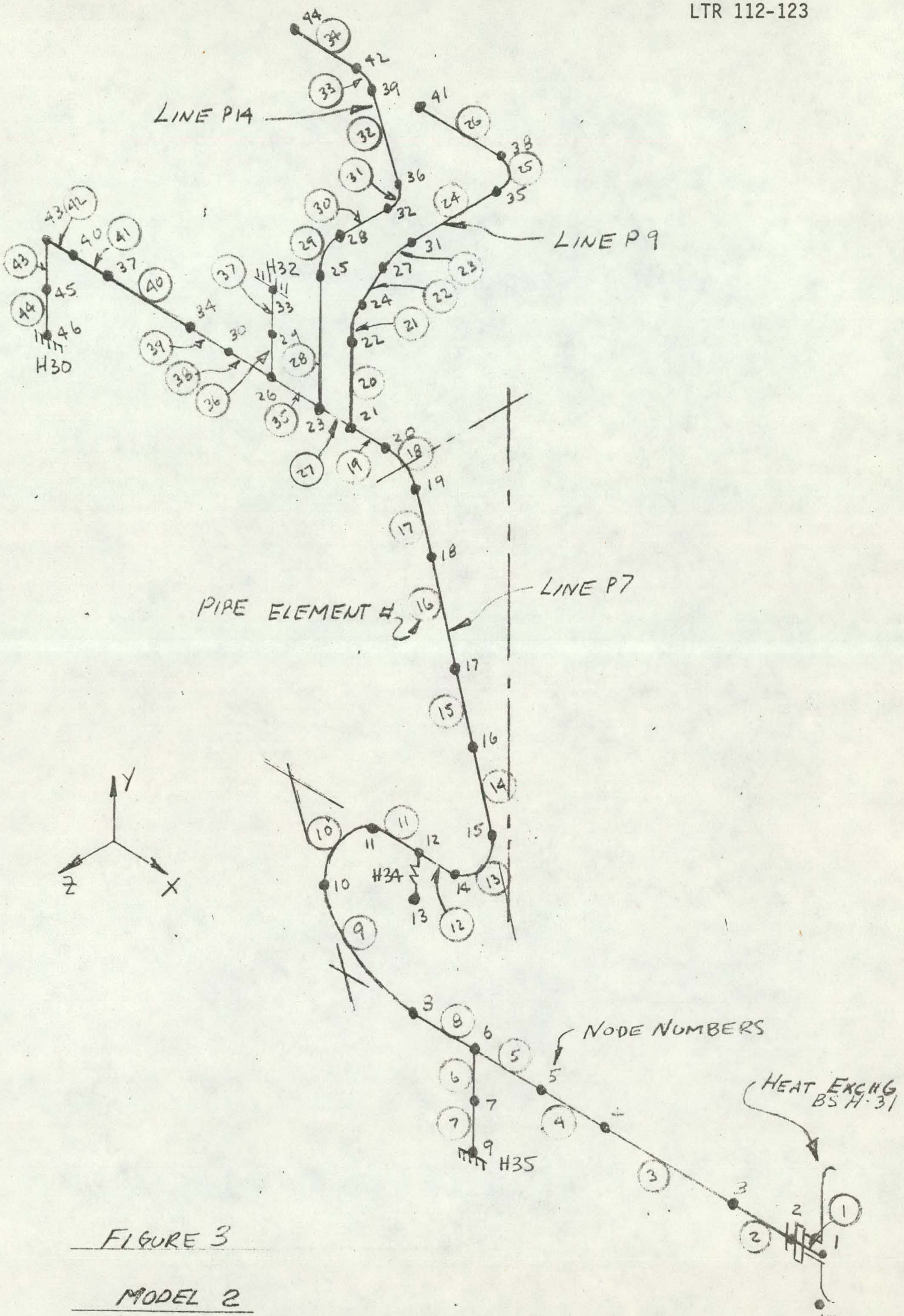


FIGURE 3

MODEL 2

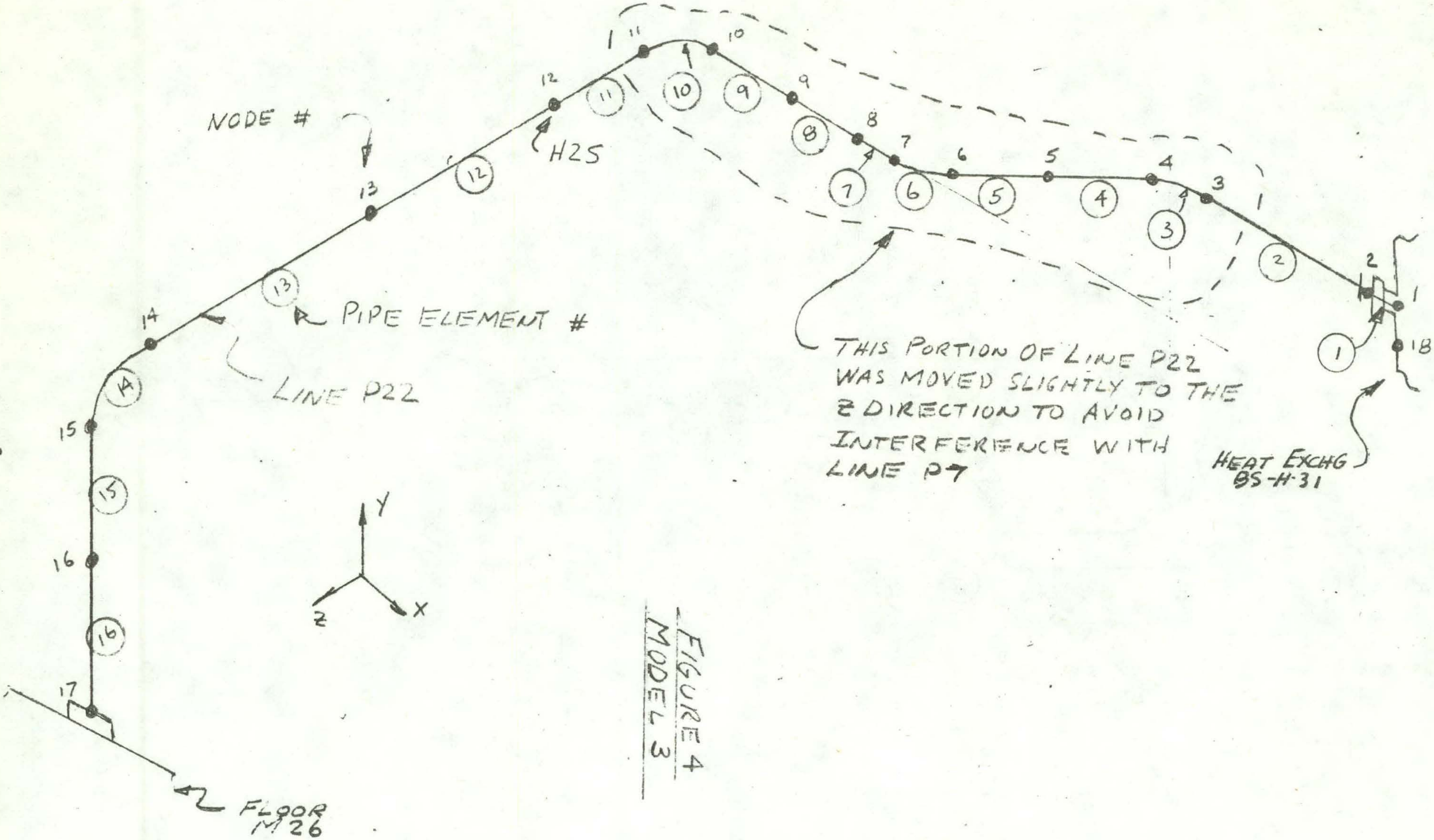


FIGURE 4
MODEL 3

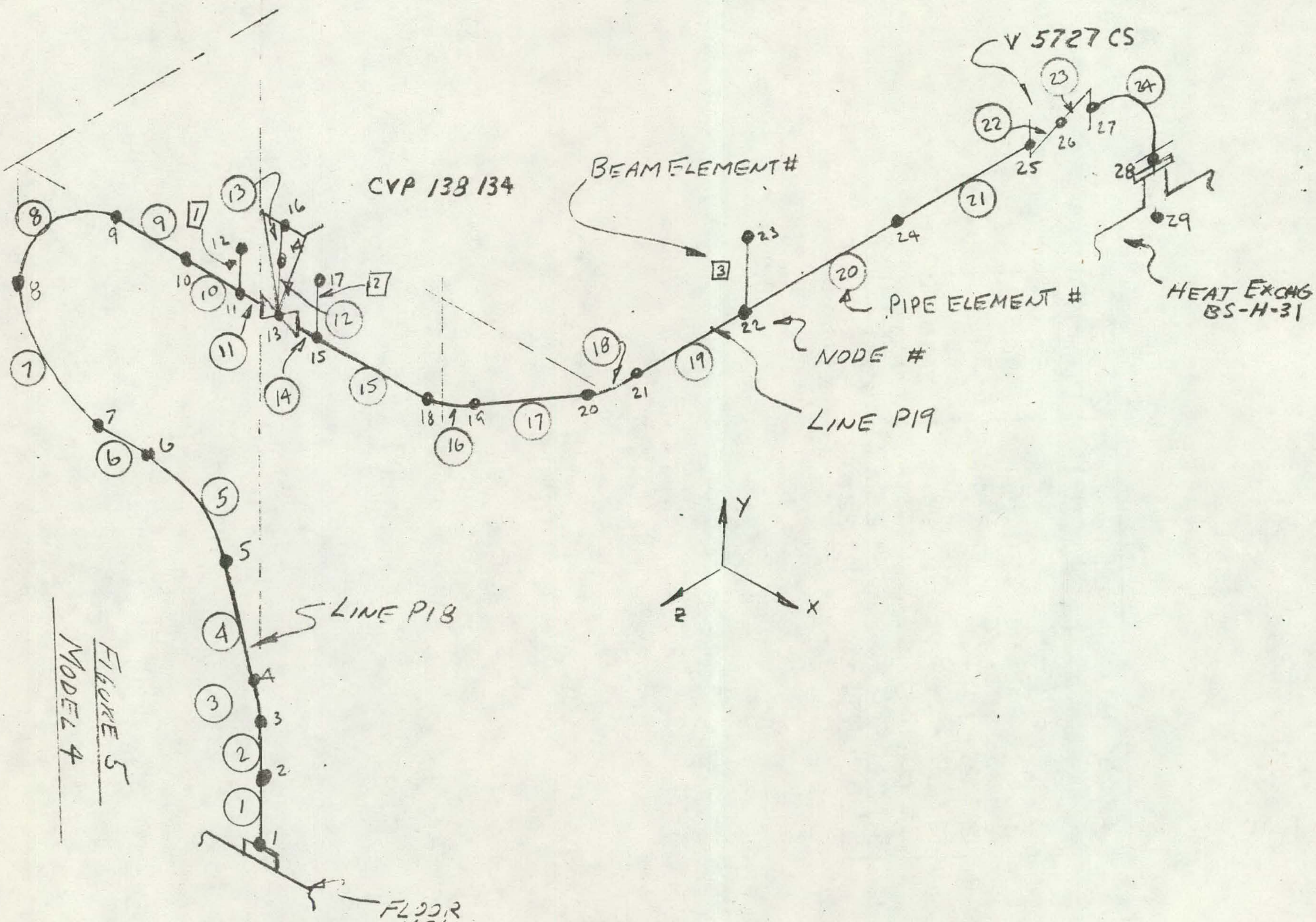


FIGURE 5
MODEL 4

TABLE I

DESIGN CONDITIONS

LINE DESIGNATION	DESIGN T (oF)	DESIGN P (PSI)
2" BS-241-VC	300	300
1" BS-256-VD	300	300
3" BS-242-VC	300	300
2" BS-243-VC	300	300
1½" BS-244-VC	300	300
2" BS-247-S	250	300
4" BS-270-A	250	150
4" BS-253-S	250	300

(1) Design pressure and system dead weight

(2) Thermal expansion and anchor movements

(3) Design pressure, deadweight, and SSE loads.

2.3 ASME Code Analysis

2.3.1 Class 2 Pipe

Analysis of the suppression tank spray system piping modifications followed the requirements of Article NC-3650 of the 1974 ASME Code, Section III, for Class 2 Piping. Equations 8 thru 11 of that article were used to evaluate allowable resultant moments on the piping cross sections for the load conditions described in Paragraph 2.2. The allowable moments were compared directly to the pipe bending moments predicted by the computer analysis to determine if Code requirements had been met. Calculation of allowable moments per Article NC-3650 are presented in Appendix C. Predicted pipe bending moments for the loadings discussed can be found in Appendix E.

Stress due to internal pressure and deadweight loads were accounted for using Equation 8 of Article NC-3650. LOFT design pressures were used as input. Pipe and pipe fitting weight, valve and valve operator weight, fluid weight, and insulation were included as deadweight loads.

Thermal expansion loads were determined using SAP IV and inputing material coefficients of thermal expansion, LOFT design temperatures, and a stress free temperature of 70^{o}F. In addition, thermal growth was accounted for at those anchor points which experience substantial movement as the system is brought up to temperature. In particular, significant thermal growth occurs at the heat exchanger BS-H-31 ports. Movements at these points are calculated in Appendix B and summarized in Table II.

TABLE II

THERMAL ANCHOR MOVEMENT

MODEL #	NODE #	DIRECTION	δ (IN)
1	1	-Y	.037
2	1	-Y	.037
3	1	-Y	.013
4	28	+Y	.116

Either Equation 10 of Article NC-3650, which deals with thermal stresses only, or Equation 11 which deals with both thermal stresses and pressure plus deadweight stresses may be used to satisfy the Code requirements for thermal loads. Equation 11 was used for this analysis.

Analysis for the dynamic earthquake loads associated with the SSE and OBE was conducted using static equivalent loads in SAP IV. Static equivalent loads were determined following the guidelines of Reference 6. Calculation of these equivalent loads can be found in Appendix A. Equation 9 of Article NC-3650 was used to satisfy the SSE plus pressure and deadweight loads for the Emergency condition. Equation 9 must also be satified for the occasional loading condition using pressure, deadweight, and OBE loads. However, as shown in Appendix A, this condition is automatically satisfied if the SSE Emergency condition satisfies the requirements of Equation 9.

2.3.2 Pipe Flanges

The pipe flanges involved in the spray system piping modifications were analyzed per Article NC-3647 of the Code. Computer program FLANGE[4] was used to compute bolt and flange stresses for comparison to Code allowables.

2.3.3 Pipe Supports

Pipe supports were analyzed per Subsection NF of Section III of the 1974 ASME Code for the loading condition previously discussed. Most of the hangers involved in the piping modifications were not changed significantly from the original support system and were analyzed simply by comparing the new hanger loads with those reported in Reference 7. For the remaining supports, appropriate stress-load relationships were used to establish hanger stresses from the SAP IV program load output. These stresses were then compared to allowable stresses calculated per Article

XVII-2000, Equations 1 thru 23, for linear elastic supports to determine the structural adequacy of the hangers. Hanger analysis can be found in Appendix D.

3.0 RESULTS AND CONCLUSIONS

Details of the ASME Section III Code analysis for the LOFT Suppression Tank Spray System Heat Exchanger BS-H-31 piping modifications can be found in Appendices C and D. The piping and supports described were found to comply with the requirements of the 1974 ASME Code.

When installing the subject piping, an interference between Lines P22 and P7 near the heat exchanger ports was discovered. Line P22 was modified slightly, as shown in Figure 4, to correct this problem. The change made to Line P22 was judged satisfactory without reanalysis of the entire line.

4.0 REFERENCES

1. EG&G Idaho, Inc. Dwg. 208185, "LOFT Modification Blowdown System Suppression Tank Spray System Piping", Rev. A, July 27, 1977.

2. R. C. Guenzler, "SAP IV, A Structural Analysis Program for Static and Dynamic Response of Linear Systems", TR-775, January 1, 1976.

3. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, "Nuclear Components", Section III, 1974.

4. E. C. Rodabaugh, F. M. O'Hara, Jr., S. E. Moore, "FLANGE: A Computer Program for the Analysis of Flanged Joints with Ring-Type Gaskets", Oak Ridge National Laboratory, ORNL-5035, January 1976.

5. SDD 1.1.2, Blowdown System, Volume 1, Appendix A, Blowdown Suppression Tank Spray System, January 1975.

6. RDT F9-2T, Seismic Requirements for Design of Nuclear Power Plants and Test Facilities, January 1974.

7. R. K. Blandford, "LOFT Blowdown Suppression System - Suppression Tank Spray System Structural Analysis", LTR 112-100, April 2, 1976.

APPENDIX A

SEISMIC LOAD CALCULATIONS

SUPPRESSION TANK SPRAY SYSTEM

SEISMIC LOADS

SAFE SHUTDOWN EARTHQUAKE (SSE)

THE EQUIVALENT STATIC LOADS USED FOR ANALYSIS OF THE SUPPRESSION TANK SPRAY SYSTEM PIPING SUBJECTED TO SSE INDUCED ACCELERATIONS WERE DETERMINED PER RDT F 9-2T [1].

$$F_{HEQ} = 1.5 \times W_c \times S_a / g$$

$$F_{VEQ} = 0.667 \times F_{HEQ}$$

WHERE:

F_{HEQ} = EQUIVALENT HORIZONTAL STATIC LOAD
W_c = COMPONENT WEIGHT
S_a = PEAK BEDROCK DESIGN RESPONSE SPECTRAL ACCELERATION (LTR 10-19)
g = ACCELERATION DUE TO GRAVITY
F_{VEQ} = EQUIVALENT VERTICAL STATIC LOAD

FOR 1% CRITICAL DAMPING

$$S_a = 43.5 \text{ ft/sec}^2$$

THUS:

$$F_{HEQ} = 1.5 \times W_c \times \frac{43.5}{32.2} = 2.03\, W_c$$

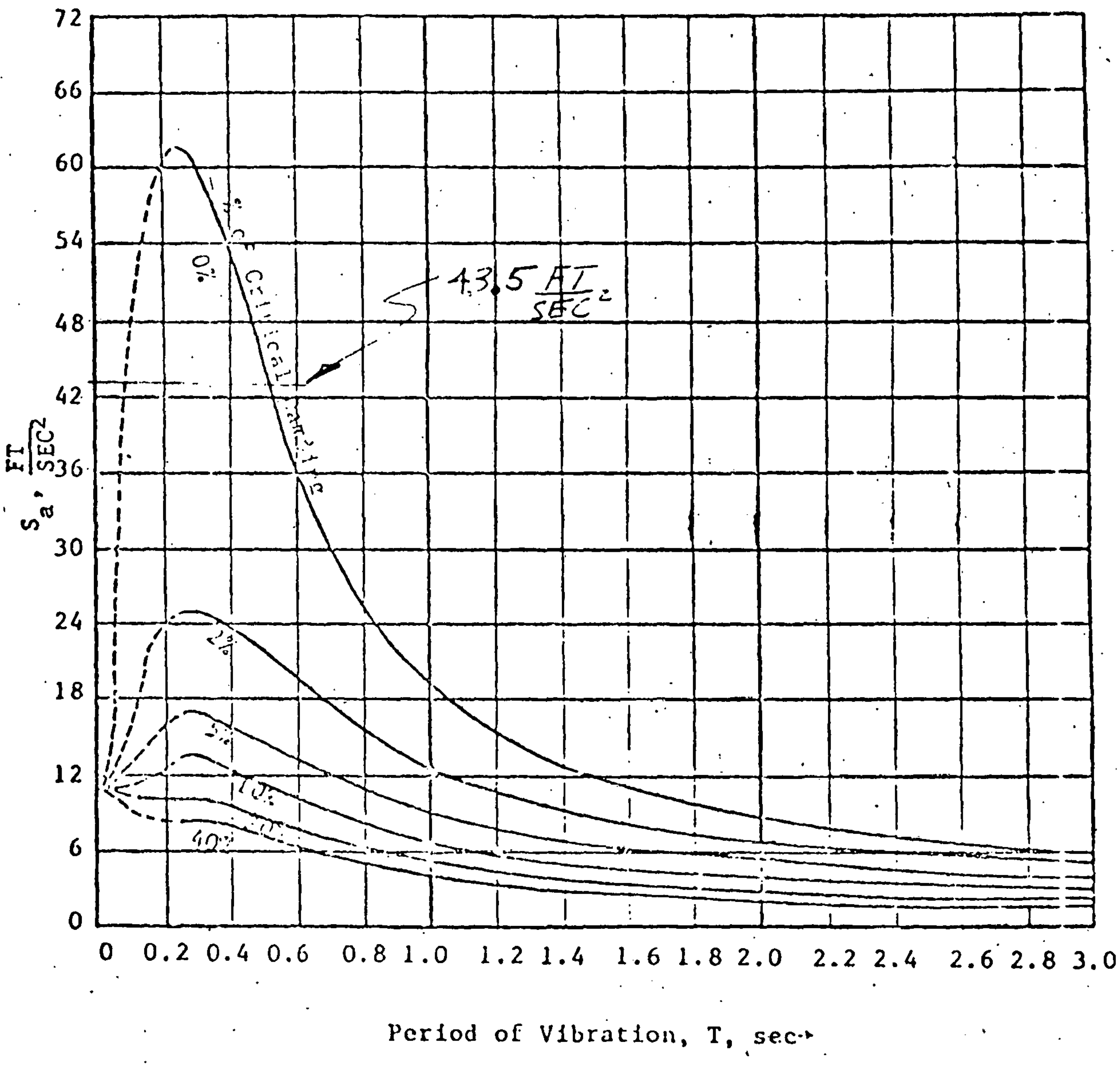
$$F_{VEQ} = 0.667 \times 2.03\, W_c = 1.35\, W_c$$

INCLUDING DEAD WEIGHT IN THE VERTICAL DIRECTION

$$F_{VEQ} = 1.35\, W_c + W_c = 2.35\, W_c$$

THE COEFFICIENTS MULTIPLYING THE WEIGHT PARAMETER ARE

$$G_H = 2.03$$
$$G_V = 2.35$$



LOFT Bedrock Design Response Spectra

SUPPRESSION TANK SPRAY SYSTEM

SEISMIC LOADS

OPERATING BASIS EARTHQUAKE (OBE)

ACCELERATIONS ASSOCIATED WITH OBE ARE HALF OF THOSE ASSOCIATED WITH SSE (LTR-10-7). THE CORRESPONDING EQUIVALENT STATIC LOADS ARE,

$$F_{HEQ} = 1.5 \times W_c \times \frac{S_a}{g} = 1.02\, W_c$$

$$F_{VEQ} = 0.667 \times 1.02 \times W_c = 0.68 \times W_c$$

INCLUDING DEADWEIGHT IN THE VERTICAL DIRECTION

$$F_{VEQ} = 0.68 \times W_c + W_c = 1.68\, W_c$$

THE COEFFICIENTS FOR OBE ARE:

$$G_H = 1.02$$
$$G_V = 1.68$$

THE TOTAL LOAD FACTOR FOR OBE + WEIGHT IS

$$G_1 = (G_H^2 + G_V^2)^{\frac{1}{2}} \Big|_{OBE + W_c} = 1.97$$

SIMILARLY FOR SSE

$$G_2 = (G_H^2 + G_V^2)^{\frac{1}{2}} \Big|_{SSE + W_c} = 3.11$$

THE RATIO OF G_1 TO G_2 IS

$$\frac{G_1}{G_2} = \frac{1.97}{3.11} = 0.63$$

THIS INDICATES THAT THE LOADS ASSOCIATED WITH OBE + WEIGHT ARE 63% OF THOSE ASSOCIATED WITH SSE + WEIGHT.

SUPPRESSION TANK SPRAY SYSTEM

SEISMIC LOADS

THE RATIO OF ALLOWABLE STRESSES FOR PIPING COMPONENTS FOR OBE + WEIGHT TO THOSE FOR SSE + WEIGHT IS:

$$\frac{\sigma_{AOBE}}{\sigma_{ASSE}} = \frac{1.2 \times S_H}{1.8 \times S_H} = 0.67$$

SIMILARLY THE RATIO OF ALLOWABLE STRESSES FOR SUPPORTS FOR OBE + WEIGHT TO THOSE FOR SSE + WEIGHT IS:

$$\left.\frac{\sigma_{AOBE}}{\sigma_{ASSE}}\right/_{SUPPORT} = \frac{\eta \times S_y}{1.33\,\eta \times S_y} = 0.75$$

SINCE THE RATIO OF LOAD COEFFICIENTS FOR OBE + WEIGHT TO SSE + WEIGHT IS LOWER THAN THE ALLOWABLE STRESS RATIOS FOR PIPING COMPONENTS AND SUPPORTS, MEETING THE REQUIREMENTS FOR SSE + WEIGHT AUTOMATICALLY SATISFIES THE REQUIREMENTS FOR OBE + WEIGHT.

REFERENCE:

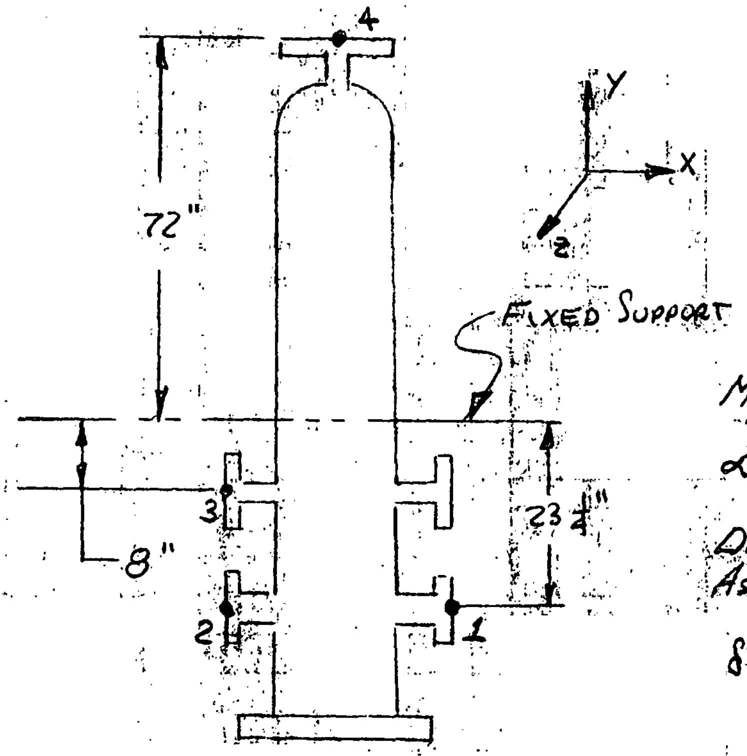
1 RDT STANDARD F-9-2T, "SEISMIC REQUIREMENTS FOR DESIGN OF NUCLEAR POWER PLANTS AND TEST FACILITIES," JAN 1974

APPENDIX B

THERMAL ANCHOR MOVEMENTS

SUPPRESSION TANK SPRAY SYSTEM
ANCHOR MOVEMENTS
HEAT EXCHANGER BS-H-31

REF: DWG 206896-1



MATL: CARBON STEEL

$\alpha = 7.10 \times 10^{-6}$ IN/IN/°F

DESIGN TEMP = 300°F
ASSUME 70°F REFERENCE

$\delta = \alpha \Delta T l$

$\Delta T = 300 - 70 = 230$

$\delta y_1 = (7.10 \times 10^{-6})(230)(23.25) = .037$ IN

$\delta y_2 = (7.10 \times 10^{-6})(230)(23.25) = .037$ IN

$\delta y_3 = (7.10 \times 10^{-6})(230)(8) = .013$ IN

$\delta y_4 = (7.10 \times 10^{-6})(230)(72) = .116$ IN

APPENDIX C

CLASS 2 PIPE ANALYSIS

CLASS 2 PIPE ANALYSIS

MATERIAL PROPERTIES ~ ALLOWABLE STRESS, Sh

MATERIAL *	TEMPERATURE (°F)				
	70	100	200	300	400
A376	18800	18800	18800	19400	19100
A53	15000	15000	15000	15000	15000
A106	15000	15000	15000	15000	15000
A234	15000	15000	15000	15000	15000

* TABLE I-7.2 APPENDIX I SECTION III, 1974 CODE

CLASS 2 PIPE ANALYSIS

CRITERIA

PER ARTICLE NC-3650 OF SECTION III OF THE ASME BOILER AND PRESSURE VESSEL CODE, 1974, A CLASS 2 PIPING SYSTEM MUST SATISFY THE FOLLOWING CRITERIA:

1) EQUATION 8 (NC 3652.1)
   a) PRESSURE + DEADWEIGHT LOADS

2) EQUATION 9 (NC3652.2)
   a) OCCASIONAL LOADS
      1) PRESSURE + DEAD WEIGHT + OBE $< 1.2\,S_h$
   b) EMERGENCY LOADS
      1) PRESSURE + DEAD WEIGHT + SSE $< 1.8\,S_h$

   OBE ~ OPERATING BASIS EARTHQUAKE
   SSE ~ SAFE SHUTDOWN EARTHQUAKE

3) EQUATION 10* (NC-3652.3)
   a) THERMAL LOADS ONLY

4) EQUATION 11*
   a) PRESSURE + DEADWEIGHT + THERMAL

   * EITHER EQUATION 10 OR 11 MAY BE SATISFIED

CLASS 2 PIPE ANALYSIS

DESIGN CONDITIONS

LINE #	LINE DESIGNATION	DESIGN T (°F)	DESIGN P (PSI)
P8	2" BS -241- VC	300	300
P16	1" BS -256- VD	300	300
P7	3" BS - 242 - VC	300	300
P9	2" BS - 243 - VC	300	300
P14	1½" BS-244 - VC	300	300
P22	2" BS - 247- S	250	300
P18	4" BS - 270 - A	250	150
P19	4" BS - 253 - S	250	300

CLASS 2 PIPE ANALYSIS

CALCULATION OF MOMENTS & SECTION MODULUS

a) FOR PURPOSES OF EQUATIONS 8, 9, 10 & 11 THE RESULTANT MOMENT FOR STRAIGHT THROUGH COMPONENTS, CURVED PIPE OR WELDING ELBOWS MAY BE CALCULATED AS FOLLOWS:

$$M_j = \left[M_{x_j}^2 + M_{y_j}^2 + M_{z_j}^2 \right]^{\frac{1}{2}}$$

where
j = A, B, or C WHICH ARE THE SUBSCRIPTS OF M_A, M_B, M_C DEFINED IN NC 3652.1, NC 3652.2 & NC 3652.3

b) FOR PURPOSES OF EQUATIONS 8, 9, 10 & 11 THE SECTION MODULUS FOR STRAIGHT THROUGH COMPONENTS, CURVED PIPE, WELDED ELBOWS OR FULL OUTLET BRANCH CONNECTIONS MAY BE CALCULATED AS FOLLOWS:

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

where
r = MEAN CROSS SECTIONAL RADIUS, IN
t_n = NOMINAL WALL THICKNESS, IN

c) FOR FULL OUTLET BRANCH CONNECTIONS, CALCULATE THE RESULTANT MOMENT OF EACH LEG SEPARATELY IN ACCORDANCE WITH (a). MOMENTS ARE TO BE TAKEN AT THE JUNCTURE POINT OF THE LEGS.

d) FOR REDUCED OUTLETS, CALCULATE THE RESULTANT MOMENT OF EACH LEG SEPARATELY IN ACCORDANCE WITH (a). MOMENTS ARE TO BE TAKEN AT THE JUNCTION POINT OF THE LEGS.

FOR THE REDUCED OUTLET:

$$M_A, M_B, M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

$$Z = \pi (r_m')^2 t_s$$

r_m' = BRANCH MEAN CROSS SECTIONAL RADIUS, IN
t_s = EFFECTIVE BRANCH WALL THICKNESS
= LESSOR OF T_r OR T_h
T_r = NOMINAL BRANCH WALL THICKNESS, IN
T_h = NOMINAL WALL THICKNESS OF RUN PIPE, IN

CLASS 2 PIPE ANALYSIS

PIPE SECTION MODULUS (Z)

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

r = MEAN CROSS SECTIONAL RADIUS (IN)
t_n = NOMINAL WALL THICKNESS (IN)

$$r = (t_n + D_i)/2$$

D_i = PIPE INSIDE DIAMETER (IN)

PIPE & SCHEDULE		D_i	t_n	r	r^2	Z
2" BS-241-VC	SCH 40	2.067	.154	1.1105	1.2332	.5966
1" BS-256-VD	SCH 40	1.049	.133	.5910	.7288	.3045
3" BS-242 VC	SCH 40	3.068	.216	1.6420	2.6962	1.8296
2" BS-243 VC	SCH 40	2.067	.154	1.1105	1.2332	.5966
1½" BS-244 VC	SCH 40	1.610	.145	.8775	.7700	.3508
2" BS-247-S	SCH 40	2.067	.154	1.1105	1.2332	.5966
4" BS-270 A	SCH 40	4.026	.237	2.1315	4.5433	3.3827
4" BS-253-S	SCH 40	4.026	.237	2.1315	4.5433	3.3827

CLASS 2 PIPE ANALYSIS

EQUATION 8 ~ PRESSURE + DEAD WEIGHT

$$S_{SL} = \frac{P D_o}{4 t_n} + \frac{.75\, i\, M_A}{Z} \leq 1.0\, S_h$$

P = INTERNAL DESIGN PRESSURE
D_o = OUTSIDE DIA OF PIPE
t_n = NOMINAL PIPE WALL THICKNESS
Z = PIPE SECTION MODULUS
i = STRESS INTENSIFICATION FACTOR
S_h = BASIC MATERIAL ALLOWABLE STRESS AT DESIGN TEMPERATURE
M_A = RESULTANT MOMENT LOADING ON PIPE CROSS SECTION DUE TO WEIGHT AND OTHER SUSTAINED LOADS

SOLVING FOR M_A:

$$\left\{ S_h - \frac{P D_o}{4 t_n} \right\} \left\{ \frac{Z}{.75 i} \right\} = M_A$$

EQ 8 ~ STRAIGHT PIPE SECTIONS ~ ALLOWABLE MOMENT, MA

PRESSURE PLUS DEAD WEIGHT

MODEL No

MODEL No	LINE NUMBER	DESCRIPTION SIZE	MATL	SCH	DESIGN T	Sh	DESIGN P	Do	tn	Z	.75i	PDo / 4tn	Z / .75i	MA (in/lb)
1	2"BS-241-VC	2	A376	40	350	18400	300	2.375	.154	.597	1.0	1157	.597	4085
1	1"BS-256-VD	1	A376	40	300	18400	300	1.315	.133	.305	1.0	742	.305	5386
2	3"BS 242 VC	3	A376	40	300	18400	300	3.50	.216	1.830	1.0	1215	1.830	31449
2	2"BS 243 VC	2	A376	40	300	18400	300	2.375	.154	.597	1.0	1157	.597	10294
2	1½"BS 244 VC	1.5	A376	40	300	18400	300	1.90	.145	.351	1.0	983	.351	6113
3	2"BS 247-S	2	A106	40	250	15000	300	2.375	.154	.597	1.0	1157	.597	8264
4	4"BS 270A	4	A53	40	250	15000	150	4.50	.237	3.383	1.0	712	3.383	48336
4	4"BS 253-S	4	A106	40	250	15000	300	4.50	.237	3.383	1.0	1424	3.383	45928

8112 123

C7

CLASS 2 PIPE ANALYSIS

PRESSURE + DEAD WEIGHT PLUS OCCASIONAL LOADS

OCCASIONAL LOADS INCLUDE OBE & LOCE

EQUATION 9

$$S_{OL} = \frac{P_{max} D_o}{4 t_n} + .75 i \left(\frac{M_A + M_B}{Z}\right) \leq \begin{cases} 1.2 S_h & \text{OCCASIONAL} \\ 1.8 S_h & \text{EMERGENCY} \\ 2.4 S_h & \text{FAULTED} \end{cases}$$

P_{max} = PEAK PRESSURE (TAKEN AS DESIGN PRESSURE)
M_B = RESULTANT MOMENT LOADING ON CROSS SECTION DUE TO OCCASIONAL, EMERGENCY OR FAULTED CONDITIONS

SOLVING FOR $M_A + M_B$

$$\left[\begin{Bmatrix} 1.2 S_h \\ 1.8 S_h \\ 2.4 S_h \end{Bmatrix} - \frac{P_{max} D_o}{4 t_n}\right] \frac{Z}{.75 i} \geq (M_A + M_B)$$

EMERGENCY LOADS INCLUDE SSE
FAULTED LOADS INCLUDE SSE + LOCA

{ NOT ANALYZING FOR LOCE OR LOCA

MEETING REQUIREMENTS FOR SSE WILL SATISFY OBE (SEE APPENDIX A) }

→ IMPLICATIONS ARE THAT ANALYSIS FOR EMERGENCY CONDITIONS ARE ALL THAT IS NECESSARY FOR EQUATION 9

EQ 9 ~ STRAIGHT PIPE SECTIONS ~ ALLOWABLE MOMENT, MA+MB

PRESSURE PLUS DEAD WEIGHT PLUS SSE

MODEL #

Model #	Line Number	Description: Size	Description: Matl	Description: Sch	Design T	Sh	Design P	Do	tn	z	.75i	PDo/4tn	z/.75i	MA+MB (in lb)
1	2"BS-241-VC	2	A376	40	300	18400	300	2.375	.154	.597	1.0	1157	.597	19082
1	1"BS-256-VO	1	A376	40	300	18400	300	1.315	.133	.305	1.0	742	.305	9875
2	3"BS 242 VO	3	A376	40	300	18400	300	3.50	.216	1.830	1.0	1215	1.830	58386
2	2"BS 243 YC	2	A376	40	300	18400	300	2.375	.154	.597	1.0	1157	.597	19082
2	1½"BS 244 YC	1.5	A376	40	300	18400	300	1.90	.145	.351	1.0	983	.351	11280
3	2"BS 247-S	2	A106	40	250	15000	300	2.375	.154	.597	1.0	1157	.597	15428
4	4"BS 270A	4	A53	40	250	15000	150	4.50	.237	3.383	1.0	712	3.383	88932
4	4"BS 253-S	4	A106	40	250	15000	300	4.50	.237	3.383	1.0	1424	3.383	86524

CLASS 2 PIPE ANALYSIS

PRESSURE DEAD WEIGHT PLUS THERMAL LOADS

EQUATION 11

$$STE = \frac{PD_o}{4t_n} + .75i\left(\frac{M_A}{Z}\right) + i\left(\frac{M_C}{Z}\right) \leq S_h + S_A$$

M_C = RESULTANT MOMENT DUE TO THERMAL EXPANSION AND ANCHOR MOVEMENT.

S_A = ALLOWABLE STRESS RANGE FOR EXPANSION STRESSES (NC-3611.2)

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

f = STRESS RANGE REDUCTION FACTOR = .9 FOR LOFT (TABLE NC-3511.2(c)-1 LTR 10-11A

S_c = BASIC MATERIAL ALLOWABLE STRESS AT MINIMUM TEMPERATURE (70°F)

S_h = BASIC MATERIAL ALLOWABLE STRESS AT MAXIMUM TEMPERATURE (DESIGN)

LINE NUMBER	MATL	S_c (70°F)	DESIGN T	S_h	1.25 S_c	.25 S_h	S_A
2"BS 241 VC	A376	18800	300	18400	23500	4600	25290
1"BS 256YD	A376	18800	300	18400	23500	4600	25290
3"BS 242VC	A376	18800	300	18400	23500	4600	25290
2"BS 243VC	A376	18800	300	18400	23500	4600	25290
1½"BS 244 VC	A376	18800	300	18400	23500	4600	25290
2"BS 247-S	A106	15000	250	15000	18750	3750	20250
4"BS 220A	A53	15000	250	15000	18750	3750	20250
4"BS 253-S	A106	15000	250	15000	18750	3750	20250

CLASS 2 PIPE ANALYSIS

PRESSURE DEAD WEIGHT & THERMAL EXPANSION

FOR STRAIGHT PIPE SECTIONS, $i = .75i = 1.0$

$$\frac{PD_o}{4t_n} + \frac{1}{Z}(M_A + M_C) \leq S_h + S_A$$

$$(M_A + M_C) \leq Z\left(S_h + S_A - \frac{PD_o}{4t_n}\right)$$

Eq 11 ~ Straight Pipe Sections ~ Allowable Moment, Ma + Mc

Pressure Plus DeadWeight Plus Thermal Plus Anchor Movement

Model #	Line Number	Description: Size	Description: Matl	Description: Sch	Design Cond.: T	Design Cond.: P	Sh	Sa	$\frac{PDo}{4tn}$	Z	Ma + Mc (in lb)
1	2"BS 241 VC	2	A376	40	300	300	18400	25290	1157	.597	25392
1	1"BS 256 VD	1	A376	40	300	300	18400	25290	742	.305	13099
2	3"BS 242 VD	3	A376	40	300	300	18400	25290	1215	1.830	77729
2	2"BS 243 VC	2	A376	40	300	300	18400	25290	1157	.597	25392
2	1½"BS 244 VC	1.5	A376	40	300	300	18400	25290	983	.351	14990
3	2"BS 247-S	2	A106	40	250	300	15000	20250	1157	.597	20354
4	4"BS 270 A	4	A53	40	250	150	15000	20250	712	3.383	116842
4	4"BS 253-S	4	A106	40	250	300	15000	20250	1424	3.383	114433

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CLASS 2 PIPE

FITTINGS

THE FOLLOWING FITTINGS WERE ANALYZED AS PART OF THE SUBJECT PIPING:

MODEL #	LINE NUMBER	FITTING TYPE	DESIGN.	SIZE	MATL.	NOTES
1	2" BS 241 VC	FLANGE	FL1	4	A182	300# WN
		ELBOW	F18	6R	A403	4" PIPE
		ELBOW	F18	6R	A403	4" PIPE
		REDUCER	F31	4x2	A403	
		BEND		18R		
		BEND		10R		
		TEE	F28	2x2x3/4	A403	
		BEND		10R		
		FLANGE	FL3	2	A182	300# WN
		FLANGE	FL8			
1	1" BS 256 VD	BEND		5R		
		BEND		5R		
		BEND		5R		
		BEND		5R		
		TEE			A403	
2	3" BS 242 VC	FLANGE	FL1	4	A182	300# WN
		REDUCER	F30	4x3	A403	
		BEND		18R		
		BEND		18R		
		BEND		18R		
		FLANGE				FEP 138.139
		ELBOW	F19	4.5R	A403	
		TEE	F25	3x3x2	A403	
		TEE	F26	3x3x1½	A403	
2	2" BS 242 VC	FLANGE	FL3	2	A182	300# WN
		ELBOW 45°	F105	3R	A403	2" PIPE
		ELBOW 45°	F105	3R	A403	2" PIPE
		ELBOW	F20	3R	A403	2" PIPE
2	1½ BS 244 VC	BEND		10R		
		BEND		10R		45°
		BEND		10R		45°
3	2" BS 247-S	FLANGE	FL11	2	A105	300# WN
		BEND		10R		45°
		BEND		10R		45°
		ELBOW	F41	3R	A234	2in PIPE
		BEND		10R		

CLASS 2 PIPE

FITTINGS

MODEL #	LINE NUMBER	FITTING TYPE	DESIGN	SIZE	MATL	NOTES
4	4"BS 270A	BEND		18R		
		BEND		24R		
		BEND		18R		
		BEND		18R		
		FLANGE	FL10	4	A105	300# WN
4	4"BS 253-S	FLANGE	FL10	4	A105	300# WN
		BEND		24		
		ELBOW	F39	6R	A234	4" PIPE
		ELBOW	F39	6R	A234	4" PIPE
		FLANGE	FL1	4	A182	300# WN

CLASS 2 PIPE ANALYSIS

STRESS INTENSIFICATION FACTORS

WELDING ELBOW & PIPE BEND

FLEXIBILITY CHARACTERISTIC h

$$h = \frac{t_n R}{r^2}$$

R = RADIUS OF BEND
t_n = NOMINAL WALL THICKNESS
r = MEAN RADIUS

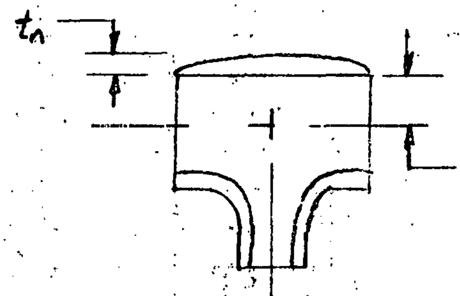
STRESS INTENSIFICATION FACTOR i

$$i = .9/h^{2/3}$$

NOTE: WHERE FLANGES ARE ATTACHED TO ONE OR BOTH ENDS OF THE ELBOW OR BEND THE VALUE OF i SHALL BE CORRECTED BY THE FACTOR C:

a) ONE END FLANGED $C = h^{1/6}$
b) BOTH ENDS FLANGED $C = h^{1/3}$

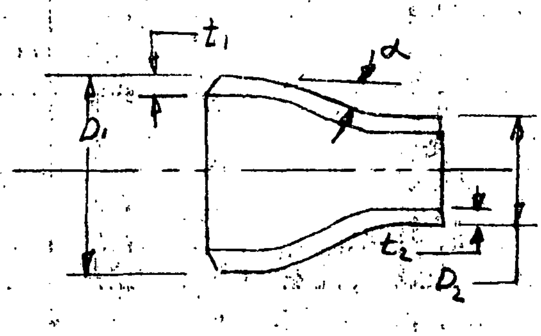
TEES



$h = 4.4 t_n / r$

$i = .9/h^{2/3}$

REDUCERS



$2.0 \geq i \geq 1.0$

$$i = 0.5 + 0.1\alpha \left(\frac{D_2}{t_2}\right)^{\frac{1}{2}}$$

STRESS INTENSIFICATION FACTORS ~ ELBOWS & BENDS

MODEL #	ELEMENT #	DESCRIPTION	DWG #	SCH	R	tn	r	h	i	C	ci	i*	.75i**
1	2	90° LR ELBOW w FLN (4 IN)	F-18	40	6	.237	2.132	.313	1.953	.824	1.609	1.609	1.207
	3	90° LR ELBOW (4 IN)	F18	40	6	.237	2.132	.313	1.953	—	—	1.953	1.465
	10	BEND 34° (2 IN)	—	40	18	.154	1.11	2.250	.524	—	—	1.00	1.00
	13	BEND 90° (2 IN)	—	40	10	.154	1.11	1.250	.776	—	—	1.00	1.00
	16	BEND 90° W FLNG (2 IN)	—	40	10	.154	1.11	1.250	.776	1.038	.805	1.00	1.00
	20	BEND 90° (1 IN)	—	40	5	.133	.591	1.904	.586	—	—	1.00	1.00
	21	BEND 90° (1 IN)	—	40	5	.133	.591	1.904	.586	—	—	1.00	1.00
	24	BEND 90° (1 IN)	—	40	5	.133	.591	1.904	.586	—	—	1.00	1.00
1	26	BEND 90° (1 IN)	—	40	5	.133	.591	1.904	.586	—	—	1.00	1.00
2	9	BEND 90° (3 IN)	—	40	18	.216	1.642	1.442	.705	—	—	1.00	1.00
	10	BEND 90° (3 IN)	—	40	18	.216	1.642	1.442	.705	—	—	1.00	1.00
	13	BEND 90° (3 IN)	—	40	18	.216	1.642	1.442	.705	—	—	1.00	1.00
	18	90° LR ELBOW (3 IN)	F9	40	4.5	.216	1.642	.861	1.776	—	—	1.776	1.332
	21	45° LR ELBOW w FLNG (2 IN)	F105	40	3	.154	1.11	.375	1.731	.849	1.470	1.470	1.102
	23	45° LR ELBOW (2 IN)	F105	40	3	.154	1.11	.375	1.731	—	—	1.731	1.298
	25	90° LR ELBOW (2 IN)	F20	40	3	.154	1.11	.375	1.731	—	—	1.731	1.298
	29	90° BEND (1½ IN)	—	40	10	.145	.878	1.881	.591	—	—	1.00	1.00
	31	45° BEND (1½ IN)	—	40	10	.145	.878	1.881	.591	—	—	1.00	1.00
2	33	45° BEND (1½ IN)	—	40	10	.145	.878	1.881	.591	—	—	1.00	1.00
3	3	45° BEND (2 IN)	—	40	10	.154	1.11	1.250	.776	—	—	1.00	1.00
	6	45° BEND (2 IN)	—	40	10	.154	1.11	1.250	.776	—	—	1.00	1.00
	10	90° LR ELBOW (2 IN)	F41	40	3	.154	1.11	.375	1.731	—	—	1.731	1.298
3	14	90° BEND (2 IN)	—	40	10	.154	1.11	1.250	.776	—	—	1.00	1.00
4	3	20° BEND (4 IN)	—	40	18	.237	2.132	.939	.939	—	—	1.00	1.00
	5	90° BEND (4 IN)	—	40	24	.237	2.132	1.251	.776	—	—	1.00	1.00
	7	90° BEND (4 IN)	—	40	18	.237	2.132	.939	.939	—	—	1.00	1.00
	8	90° BEND (4 IN)	—	40	18	.237	2.132	.939	.939	—	—	1.00	1.00
	16	20° BEND (4 IN)	—	40	24	.237	2.132	1.251	.776	—	—	1.00	1.00
	18	90° LR ELBOW (4 IN)	F39	40	6	.237	2.132	.313	1.953	—	—	1.953	1.465
4	24	90° LR ELBOW w FLNG (4 IN)	F39	40	6	.237	2.132	.313	1.953	.742	1.449	1.449	1.087

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CLASS 2 PIPE ANALYSIS

TEE

MODEL #	NODE #	DESCRIPTION		DWG #	SCH	r	t_n	h	i	.75i
1	15	2 x 2 x 3/4 A403 TEE	2 IN	F28	40	1.111	.154	.610	1.251	1.00
1	15	BRANCH	3/4 IN	F28	40	.469	.113	1.060	1.00	1.00
1	30	4 x 4 x 3/4 A403 TEE	4 IN	F36	40	2.132	.237	.489	1.450	1.088
1	30	BRANCH	3/4 IN	F36	40	.469	.113	1.060	1.00	1.00
2	21	3 x 3 x 2 A403 TEE	3 IN	F25	40	1.642	.216	.579	1.296	1.00
2	21	BRANCH	2 IN	F25	40	1.111	.154	.610	1.251	1.00
2	23	3 x 3 x 1½ A403 TEE	3 IN	F26	40	1.642	.216	.579	1.296	1.00
2	23	BRANCH	1½ IN	F26	40	.878	.145	.727	1.113	1.00

CLASS 2 PIPE ANALYSIS

REDUCERS

MODEL #	NODE #	DESCRIPTION	DWG #	SCH	α	D_2	t_2	i	$.75i$
1	4	4x2 REDUCER	F31	40	.349	2.375	.154	1.00	1.00
2	2	4x3 REDUCER	F30	40	.349	3.500	.216	1.00	1.00

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CLASS 2 PIPE ANALYSIS

FITTINGS

THE FOLLOWING FITTINGS HAVE STRESS INTENSIFICATION FACTORS GREATER THAN 1.0

MODEL #	ELE #	NODE #	DESCRIPTION	i	.75i
1	2		90° LR ELBOW w FLN (4IN)	1.609	1.207
1	3		90° LR ELBOW (4IN)	1.953	1.465
2	18		90° LR ELBOW (3IN)	1.776	1.332
2	21		45° LR ELBOW w FLNG (2IN)	1.470	1.102
2	23		45° LR ELBOW (2IN)	1.731	1.298
2	25		90° LR ELBOW (2IN)	1.731	1.298
3	10		90° LR ELBOW (2IN)	1.731	1.298
4	18		90° LR ELBOW (4IN)	1.953	1.465
4	24		90° LR ELBOW w FLN (4IN)	1.449	1.087
1		15	2x2x 3/4 TEE (2IN)	1.251	1.00
1		30	4x4x 3/4 TEE (4IN)	1.450	1.088
2		21	3x3x2 TEE (3IN)	1.296	1.00
2		21	(2IN BRANCH)	1.251	1.00
2		23	3x3x 1½ TEE (3IN)	1.296	1.00
2		23	(1½IN BRANCH)	1.113	1.00

CLASS 2 PIPE ANALYSIS

EQUATION 8 ~ PRESSURE PLUS DEAD WT ~ ALLOWABLE MOMENT

MODEL #	ELE #	NODE #	DESCRIP.	MATL	SCH	DESIGN T	S_h	DESIGN P	D_o	t_n	Z	.75i	$\frac{PD_o}{4t_n}$	$\frac{Z}{.75i}$	MA (IN lb)
1	2		ELBOW (4IN)	A403	40	300	18400	300	4.50	.237	3.384	1.207	1424	2.80	47533
1	3		ELBOW (4IN)	↑	↑	300	↑	300	4.50	.237	3.384	1.465	1424	2.31	39214
2	18		ELBOW (3IN)			300		300	3.50	.216	1.829	1.332	1215	1.37	23543
2	21		ELBOW (2IN)			300		300	2.375	.154	.597	1.102	1157	.54	9311
2	23		ELBOW (2IN)			300	↓	300	2.375	.154	.597	1.298	1157	.46	7931
2	25		ELBOW (2IN)			300	18400	300	2.375	.154	.597	1.298	1157	.46	7932
3	10		ELBOW (2IN)			250	15000	300	2.375	.154	.597	1.298	1157	.46	6368
4	18		ELBOW (4IN)			250	15000	300	4.50	.237	3.384	1.465	1424	2.31	31360
4	24		ELBOW (4IN)			250	15000	300	4.50	.237	3.394	1.097	1424	3.11	42221
1		15	TEE (2IN)			300	18400	300	2.375	.154	.597	1.00	—	—	—
1		30	TEE (4IN)			300	↑	300	4.50	.237	3.384	1.088	1424	3.11	52795
2		21	TEE (3IN)			300		300	3.50	.216	1.829	1.00	—	—	—
2		21	TEE (2IN)			300		300	2.375	.154	.597	1.00	—	—	—
2		23	TEE (3IN)	↓	↓	300	↓	300	3.50	.216	1.829	1.00	—	—	—
2		23	TEE (1½ IN)	A403	40	300	18400	300	1.90	.145	.3512	1.00	—	—	—

CLASS 2 PIPE ANALYSIS

EQUATION 9 ~ PRESSURE PLUS DEAD WEIGHT PLUS SSE

MODEL #	ELE #	NODE #	DESCRIPTION		Sh	1.8 Sh	$\frac{PD_o}{4t_n}$	$\frac{Z}{.75i}$	$M_A + M_B$ (in lb)
1	2		ELBOW	(4 IN)	18400	33120	1424	2.80	88749
1	3		ELBOW	(4 IN)			1424	2.31	73218
2	18		ELBOW	(3 IN)			1215	1.37	43710
2	21		ELBOW	(2 IN)			1157	.54	17260
2	23		ELBOW	(2 IN)			1157	.46	14702
2	25		ELBOW	(2 IN)	18400	33120	1157	.46	14702
3	10		ELBOW	(2 IN)	15000	27000	1157	.46	11889
4	18		ELBOW	(4 IN)	15000	27000	1424	2.31	59080
4	24		ELBOW	(4 IN)	15000	27000	1424	3.11	79541
1		15	TEE	(2 IN)	18400	33120	—	—	—
1		30	TEE	(4 IN)			1424	3.11	98575
2		21	TEE	(3 IN)			—	—	—
2		21	TEE	(2 IN)			—	—	—
2		23	TEE	(3 IN)			—	—	—
2		23	TEE	(1½ IN)	18400	33120	—	—	—

CLASS 2 PIPE ANALYSIS

$$\left\{\frac{M_A}{i} + M_C\right\} \le \frac{z}{i}\left\{S_h + S_A - \frac{PD_o}{4t_n}\right\}$$

EQUATION 11 $(i > 1.0 \quad .75i = 1.0)$

MODEL #	ELE #	NODE #	DESCRIPTION		S_h	S_A	INTENSIFICATION i	z	z/i	$\frac{PD_o}{4t_n}$	$(M_A/i + M_C)$ in-lb
1		15	2x2x3/4 TEE	2IN	18400	25178	1.251	.597	.48	1157	20362
2		21	3x3x2 TEE	3IN	18400	25178	1.296	1.829	1.41	1215	59732
2		21	2 IN BRACH	2IN	18400	25178	1.251	.597	.48	1157	20362
2		23	3x3x1½ TEE	3IN	18400	25178	1.296	1.829	1.41	1215	59732
2		23	1½ BRANCH		18400	25178	1.113	.3512	.32	983	13630

EQUATION 11 $(i > 1.0, \ .75i > 1.0)$ $\quad .75M_A + M_C \le \frac{z}{i}\left\{S_h + S_A - \frac{PD_o}{4t_n}\right\}$

MODEL #	ELE #	NODE #	DESCRIPTION		S_h	S_A	INTENSIFICATION i	z	z/i	$\frac{PD_o}{4t_n}$	$.75M_A + M_C$ in-lb
1	2		90° LR ELBOW w FLN	(4IN)	18400	25290	1.609	3.384	2.10	1424	88759
1	3		90° LR ELBOW	(4IN)		25290	1.953	3.384	1.73	1424	73120
2	18		90° LR ELBOW	(3IN)		25290	1.776	1.829	1.03	1215	43749
2	21		45° LR ELBOW w FLN	(2IN)		25290	1.470	.597	.42	1157	17864
2	23		45° LR ELBOW	(2IN)		25290	1.731	.597	.34	1157	14461
2	25		90° LR ELBOW	(2IN)	18400	25290	1.731	.597	.34	1157	14461
3	10		90° LR ELBOW	(2IN)	15000	20250	1.731	.597	.34	1157	11592
4	18		90° LR ELBOW	(4IN)	15000	20250	1.953	3.384	1.73	1424	58519
4	24		90° LR ELBOW w FLN		15000	20250	1.449	3.384	2.34	1424	79153
1		30	4x4x3/4 TEE	(4IN)	18400	25290	1.450	3.384	2.33	1424	98480

APPENDIX D

HANGER ANALYSIS

LINEAR TYPE SUPPORTS

CRITERIA

PER ARTICLE NF-3230 OF SECTION III OF THE ASME BOILER AND PRESSURE VESSEL CODE, 1974, THE FOLLOWING STRESS LIMITS APPLY TO THE ELASTIC ANALYSIS OF LINEAR TYPE SUPPORTS:

a) DESIGN, NORMAL AND UPSET CONDITIONS

THE STRESS LIMITS FOR DESIGN, NORMAL, AND UPSET CONDITIONS ARE GIVEN IN APPENDIX XVII OF THE CODE. THE FOLLOWING LOAD CASES FALL INTO THIS CATEGORY:

1) PRESSURE PLUS DEADWEIGHT
2) PRESSURE PLUS DEADWEIGHT PLUS OBE

THE ALLOWABLE STRESS FOR THE COMBINED MECHANICAL LOADS AND EFFECTS WHICH RESULT FROM CONSTRAINT OF FREE END DISPLACEMENTS SHALL BE LIMITED TO THREE (3) TIMES THE STRESS LIMITS OF XVII-2000. THE FOLLOWING LOAD CASE EXISTS IN THIS CATEGORY:

1) PRESSURE PLUS DEADWEIGHT PLUS THERMAL LOADS

b) EMERGENCY CONDITIONS

THE STRESS LIMITS FOR EMERGENCY CONDITIONS MAY BE INCREASED BY ONE-THIRD (1/3) OVER THE VALUES GIVEN IN XVII-2000. THE FOLLOWING LOAD CASE EXISTS IN THIS CATEGORY:

1) PRESSURE PLUS DEADWEIGHT PLUS SSE

NOTE:
OBE ~ OPERATING BASIS EARTHQUAKE
SSE - SAFE SHUTDOWN EARTHQUAKE

LINEAR TYPE SUPPORTS

CRITERIA

WELD MATERIAL

THE ALLOWABLE STRESS LIMITS FOR SUPPORT WELDS ANALYZED IN THE SUPPRESSION TANK SPRAY SYSTEM ARE AS DEFINED IN TABLE NF-3292.1-1 OF SECTION NF-3000 OF SECTION III OF THE CODE.

ANALYSIS

THE FOLLOWING HANGERS REMAINED UNCHANGED OR WERE ONLY SLIGHTLY CHANGED FROM THEIR ORIGINAL CONFIGURATION. THEY WERE ANALYZED SIMPLY BY COMPARING THE NEW LOADS FROM THE SAP IV RUN TO THE ANALYSIS PERFORMED IN LTR 112-100, "LOFT BLOWDOWN SUPPRESSION SYSTEM - SUPPRESSION TANK SPRAY SYSTEM STRUCTURAL ANALYSIS", 1976. ALL HANGERS WERE FOUND TO BE STRUCTURALLY ADEQUATE:

MODEL #	HANGER #	DRAWING REF.
1	H83	207360
2	H35	207344
2	H34 *	207342
2	H32	207341
2	H30	207341
3	H25	207338
4	H88	207459
4	H96	207458
4	H87	207458

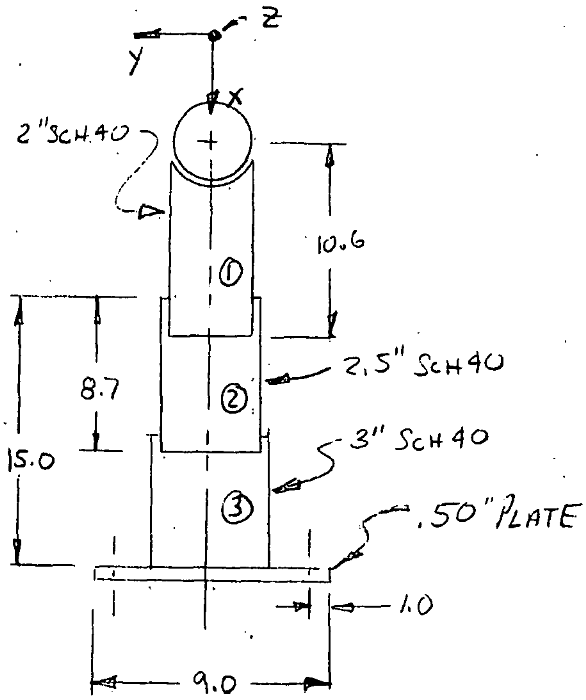
* H34 WAS CHANGED TO A SPRING HANGER AND SHOULD BE SET AT 68 lbs

LINEAR TYPE SUPPORTS

ANALYSIS

THE FOLLOWING ANALYSIS WAS CONDUCTED USING THE WORSE LOAD CONDITION WITH THE SMALLEST ALLOWABLE. THIS IS A CONSERVATIVE ANALYSIS AS IMPLIED BY THE ALLOWABLE CRITERIA.

MODEL 1, HANGER H26, DWG 208258



PIPE MATL A53 S_y = 35000 PSI
$E = 27.9 \times 10^6$ PSI

BASE METAL A36 S_y = 36000 PSI
$E = 29.0 \times 10^6$ PSI

BOLTS (4) ASTM A325 .5-13UNC

LOAD COORDINATES SHOWN
AXIAL (Z) FREEDOM ALLOWED
LOADS LISTED ON PAGE D4

ALL AXIAL LOADS ARE NOTED TO BE COMPRESSIVE

AXIAL STRESS

CALCULATE Kl/r FOR EACH SEGMENT

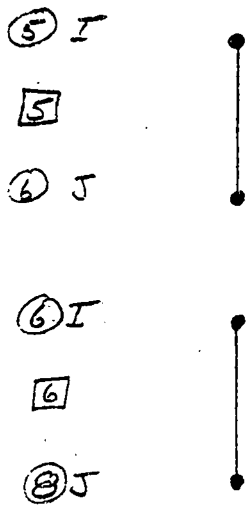
SECTION	K	l	r	Kl/r
①	2.1	10.6	.79	28
②	2.1	8.7	.94	19
③	2.1	6.3	1.16	11
TOTAL	2.1	26	.94	57

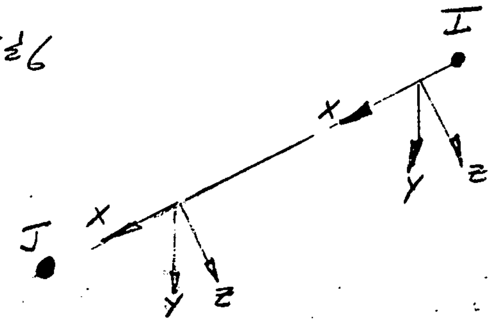
$$r = \sqrt{\frac{r_o^2 + r_i^2}{2}}$$

HANGER H26 208258-1

PIPE ELEMENTS 5 & 6

MODEL 1





LINEAR TYPE SUPPORTS

LOADS GIVEN IN lbs, IN-lb

CASE	ELEMENT	IX	IY	IZ	IMX	IMY	IMZ	JX	JY	JZ	JMX	JMY	JMZ
1	—												
2	5	-37	26	—	-31	-19	121	-40	26	—	-31	-19	-137
3		-2016	546	—	2273	1759	4806	-2019	546	-	2273	1759	-649
4		-107	51	-14	-91	-42	252	-114	51	-8	-91	-150	-256
5		-64	—	—	71	-39	-26	-71	-6	—	71	-39	1
1													
2		-40	26	—	-31	-19	-137	-44	26	—	-31	-19	-344
3	6	-2019	546	—	2273	1759	-648	-2023	546	—	2273	1759	-5013
4		-113	51	-8	-91	-150	-255	-123	51	—	-91	-182	-662
5		-71	-6	—	71	-37	1	-80	-14	-	71	-39	78

LINEAR TYPE SUPPORTS

ANALYSIS

CALCULATE C_c

$$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} = \sqrt{\frac{2\pi^2(27.9\times10^6)}{36000}} = 124$$

$Kl/r < C_c \quad \therefore$

$$F_{ALL} = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right] S_y}{\frac{5}{3} + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}}$$

$$F_{ALL} = \frac{\left[1 - \frac{28^2}{2(124)^2}\right] 36000}{\frac{5}{3} + \frac{3(28)}{8(124)} - \frac{28^3}{8(124)^3}} = 20015 \text{ PSI}$$

APPLIED STRESS

AREA (2" SCH 40) = 1.075 in^2

$$f_c = \frac{2016 \text{ lb}}{1.075 \text{ in}^2} = 1875 \text{ PSI}$$

$1875 < 20015$ OK

STRESS IN BENDING

ALLOWABLE BENDING STRESS

$F_b = .66 S_y = .66(36000) = 23760$ PSI

WORSE SECTION IS AT ① (2" SCH 40)

IMY = 1759 in lb

IMZ = 4806 in lb

$$M = \sqrt{1759^2 + 4806^2} = 5118 \text{ in lb}$$

$I_① = .6657 \text{ in}^4$

$C_① = 2.375/2 = 1.19$ in

$$f_b = \frac{5118(1.19)}{.6657} = 9149 \text{ PSI}$$

$9149 < 23760$ OK

LINEAR TYPE SUPPORTS

ANALYSIS

STRESS IN SHEAR

ALLOWABLE SHEAR STRESS $F_V = .40 S_Y$

$$F_V = .40(36000) = 14400 \text{ PSI}$$

MAX SHEAR (REF: BRUHN, ANALYSIS AND DESIGN OF FLIGHT VEHICLE STRUCTURES)

$$\tau_{MAX} = \frac{4V}{3A}\left(1 + \frac{D_o d_i}{D_o^2 + d_i^2}\right) \qquad D_o = 2.375 \text{ IN} \quad d_i = 2.067 \text{ IN}$$

$V = 546 \text{ lb}$

$$f_{v_{MAX}} = \frac{4}{3}\frac{(546)}{1.075}\left(1 + \frac{(2.375)(2.067)}{2.375^2 + 2.067^2}\right)$$

$f_{v_{max}} = 1013 \text{ PSI}$

$1013 < 14400$ OK

AXIAL COMPRESSION AND BENDING

THE REQUIREMENT FOR AXIAL COMPRESSION PLUS BENDING IS

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$$

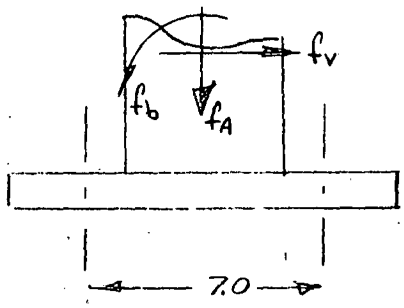
$F_{bx} = F_{by} = 23760 \text{ PSI}$

$$\frac{1875}{20015} + \frac{9149}{23760} = .48 \leq 1.0 \quad \text{OK}$$

LINEAR TYPE SUPPORTS

ANALYSIS

BOLT STRESSES



COMPUTE BOLT TENSION LOAD DUE TO AXIAL LOADING AND BENDING:

$$f_{bolt} = \frac{1759}{(7)(2)} + \frac{5013}{(7)(2)} - \frac{2019}{4}$$

f_{bolt} = -21 lb COMPRESSION

FOR BOLT TENSION CASE LOOK CONSERVATIVLY AT BENDING ONLY:

$$f_{T_{BOLT}} = \frac{1759+5013}{(2)(7)} = 484 \text{ lb}$$

BOLT SHEAR LOAD

$f_{V_{BOLT}} = 546/4 = 137$ lb

$F_V = .16(YS)_{bolt} = .16(50000) = 8000$ PSI

$F_T = 50000 - 1.6 F_V \leq 40000$ (CODE ALLOWABLE)

$F_T = 50000 - 1.6(8000) = 37200$ PSI

BOLT $A = .1695 \text{ IN}^2$

$f_T = 484/.1695 = 2855$ PSI

$2855 \leq 37200$ OK

$f_V = 137/.1695 = 808$ PSI

$808 \leq 8000$ OK

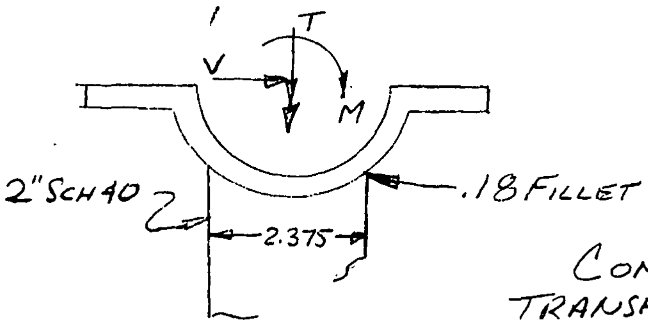
WELD STRESSES

REF: OMER W. BLODGETT, "DESIGN OF WELDMENTS", THE JAMES F LINCOLN ARC WELDING FOUNDATION, CLEVLAND, OHIO, 1965

LINEAR TYPE SUPPORTS

ANALYSIS

WELD AT CLAMP-PIPE JUNCTURE



$V = 546\ lb$
$T = 2273\ in\ lb$
$M = \sqrt{1759^2 + 4806^2} = 5118\ in\ lb$

COMPRESSIVE AXIAL LOAD IS ASSUMED TRANSFERRED BY BEARING

$$J_w = \frac{\pi d^3}{4} = \frac{\pi (2.375)^3}{4} = 10.5$$

$$f_T = \frac{(2273)(2.375/2)}{10.5} = 257\ lb/in$$

$$S_w = \frac{\pi d^2}{4} = \frac{\pi (2.375)^2}{4} = 4.43$$

$$f_m = \frac{5118}{4.43} = 1155\ lb/in$$

$$f_V = 546/(\pi(2.375)) = 73\ lb/in$$

$$f_w = \sqrt{(73+257)^2 + 1155^2} = 1201\ lb/in$$

$$\sigma_w = \frac{1201}{(.707)(.18)} = 9437\ PSI$$

ALLOWABLE CODE WELD STRESS = 18000 PSI

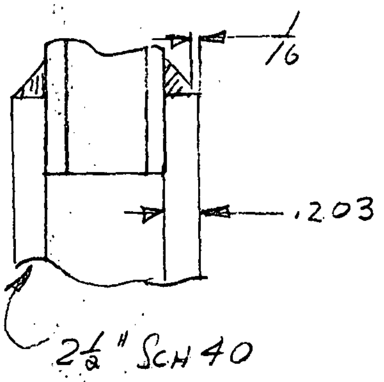
$9437 < 18000$ <u>OK</u>

WELD AT FIRST PIPE JOINT

WELD CARRIES TWISTING & COMPRESSIVE LOADS. BENDING IS ASSUMED CARRIED IN BEARING DUE TO LAP TYPE JOINT

LINEAR TYPE SUPPORTS

ANALYSIS



$T = 2273$ in lb
$F_C = 2016$ lb

$J_w = 10.5$

$f_T = \frac{(2273)(2.375/2)}{10.5} = 257$ lb/in

$f_c = \frac{2016}{\pi(2.375)} = 270$ lb/in

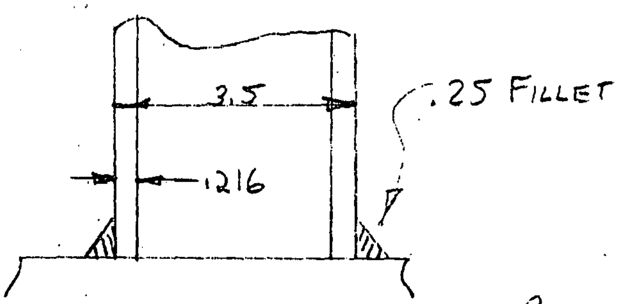
$f_w = \sqrt{270^2 + 257^2} = 373$ lb/in

$\sigma_w = \frac{373}{(.707)(.203-.17)} = 159$ PSI

$\sigma_{WALL} = 18000$ PSI

$18000 > 159$ OK

WELD AT BASE



$T = 2273$ in lb
$M = \sqrt{1759^2 + 5013^2} = 5313$ in lb
$V = 546$ lb

COMPRESSIVE AXIAL LOAD IS ASSUMED CARRIED IN BEARING

$J_w = \pi d^3/4 = 34$

$f_T = \frac{2273(3.5/2)}{34} = 117$ lb/in

$f_v = 546/\pi(3.5) = 50$ lb/in

LINEAR TYPE SUPPORTS

ANALYSIS

$S_w = \frac{\pi d^2}{4} = 9.6$

$f_m = 5313/9.6 = 553$ lb/in

$f_w = \sqrt{(117450)^2 + 553^2} = 578$ lb/in

$\sigma_w = \frac{578}{(.707)(.25)} = 3268$ lb/in²

$\sigma_{wALL} = 18000$ PSI

18000 > 3268 OK

BOLT PULL OUT

MAX BOLT TENSILE LOAD $= \frac{2023}{4} + \frac{5313}{7(2)} = 885$ lb

MAX BOLT SHEAR LOAD = 546/4 = 135 lb

FOR PHILLIPS .5 CONCRETE BOLT

ALLOWABLE TENSION = 9260 lb
ALLOWABLE SHEAR = 6356 lb

MODEL 1, HANGER H90, DWG 208261
MODEL 4, HANGER H24, DWG 208259

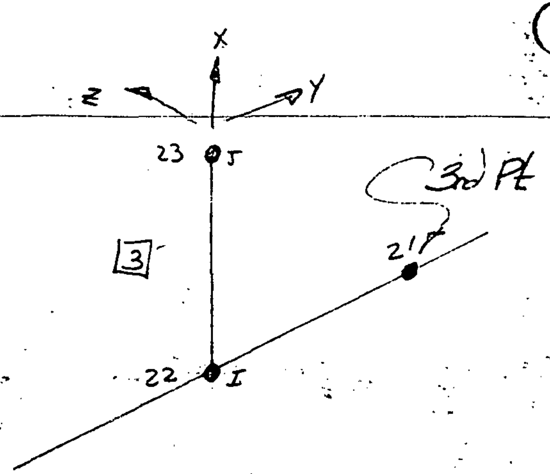
THESE TWO HANGERS ARE SIMILAR IN DESIGN, CARRY ONLY AXIAL LOAD, AND ARE ANALYZED FOR THE WORSE LOAD CASE (SEE PAGE D11, D12

$P_{AXIAL\ MAX} = 661$ lb TENSION

HANGER 24 DWG 208259-1

BM ELE #3

MODEL 4



LOAD CASE	ELE	IX	IY	IZ	IMX	IMY	IMZ	JX	JY	JZ	JMX	JMY	JMZ
2	12	-119	—	—	—	—	—	119	—	—	—	—	—
3		-661	—	—	—	-1	—	661	—	—	—	-2	1
4		-249	—	—	—	-2	—	249	—	—	—	-2	—
5		-279	—	—	—	—	—	279	—	—	—	—	—

NEGATIVE IX ⇒ AXIAL TENSION

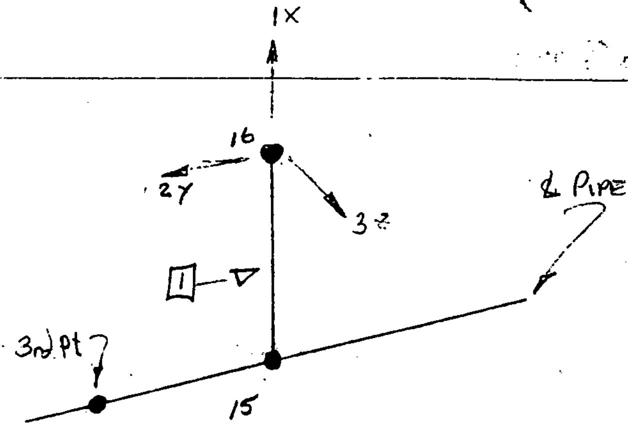
LTR 112 123

D11

HANGER H90 DWG 208251

BEAM ELEMENT #1

MODEL 1.



LOAD CASE	ELE	IX	IY	IZ	IMX	IMY	IMZ	JX	JY	JZ	JMX	JMY	JMZ
2	1	-25	—	—	—	—	—	25	—	—	—	—	—
3		-245	—	-26	—	—	—	-245	—	26	—	—	—
4		-41	—	2	—	-24	—	41	—	-2	—	—	—
5		-95	—	—	—	-7	-5	95	—	—	—	—	—

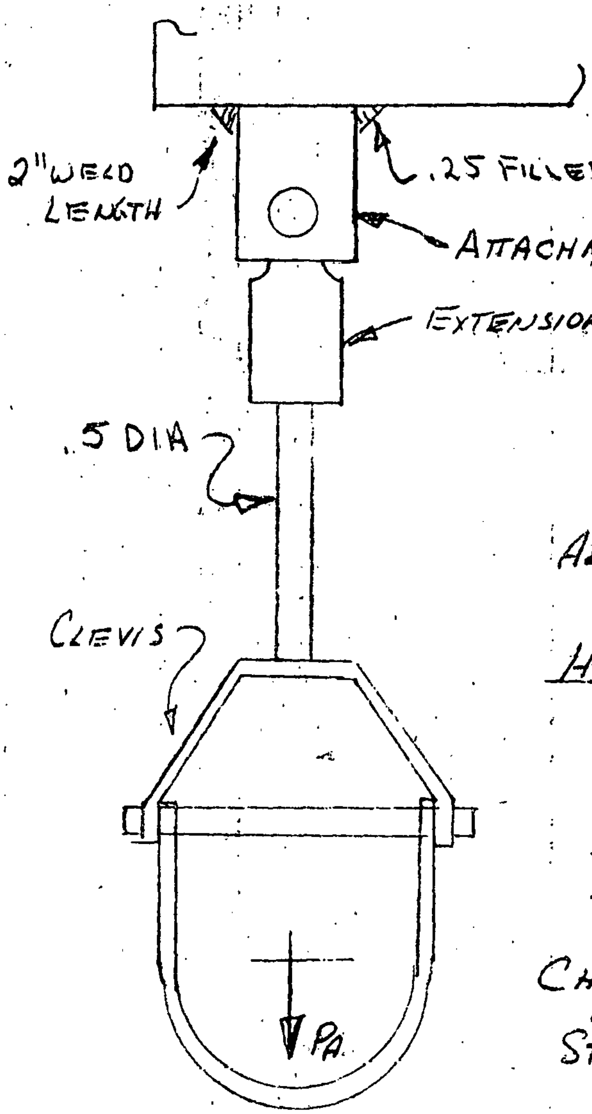
NEGATIVE IX => AXIAL TENSION

LTR 112 123

D 12

LINEAR TYPE SUPPORTS

ANALYSIS



	P_A
H90	245 lb
H24	661 lb

ALLOWABLE LOADS ITT GRINNEL HANGER BOOK

HANGER	CLEVIS	EXTENSION	ATTACHMENT
H90	1430	1130	1130
H24	610 *	1130	1130

* THESE VALUES HAVE A FACTOR OF SAFETY OF 5

CHECK ROD (ASSUME A108 MATL, $S_y = 36000$)

STRESS AREA ROD = .1695 in^2

$f_T = 661/.1695 = 3899$
$F_T = .60 S_y = .60(36000) = 21600$

OK

WELD ATTACHMENT TO BEAM

$f_{TW} = 661/4 = 165 \text{ lb/in}$

$\sigma_W = 165/((.707)(.25)) = 933$ PSI

$\sigma_{WALL} = 18000$ PSI OK

APPENDIX E

SAP IV COMPUTER OUTPUT