METAL Bellows CORPORATION 20977 KNAPP STREET CHATSWORTH, CALIFORNIA 91311	ENGINEER F. Shen	REFERENCE NUMBER CR 683 PW 77754	
	DATE 4-11-80	CUSTOMER TVA	PAGE OF 103

18.0 LOADING COMBINATION:

18.1. WEIGHT (1/2 HORIZONTAL HOSE)

SOCKET ADAPTOR	= .477 LB
FERRULE	= .057 LB
HOSE & BRAIDS (1.133 + .638).5	= .885 LB
FLUID IN HOSE (.727).5	= .364 LB
1/2 DEAD WEIGHT	= 1.783 LB

18.2. ACCIDENT FORCE:

18.2.1. DUE TO INERTIA:

$F = w \times g$

(a) $F_X = (\text{HORIZ. HOSE} + \text{FITTINGS} + \frac{1}{2}\text{VERT. HOSE}) \times g^*$

$= [(1.783 + 1.249) + .30 + \frac{1}{2}(2.37)] \times (8.6 \cos 30°)$

$= 4.517\ (7.44)$

$= 33.6$ LB

REF. PARA 18.1, 17.12.4.

(b) $F_Z = (\frac{1}{2}\text{ HORIZ. HOSE}) \times g^*$

$= (1.783) \times (8.6 \sin 30°)$

$= 7.66$ LB

(c) $F_Y = (1.783)(1.24) = 2.21$ LB

* NOTE: AT ELEVATION 754 FT. AZIMUTH 300 DEG. "g" PEAK VALUE (ACCIDENT RESPONSE CONDITION)

18.3. SEISMIC FORCES : (SSE)

18.3.1. DUE TO INERTIA

$F = w \times g$

(a) $F_x = (\text{HORIZ. HOSE} + \text{FITTINGS} + \frac{1}{2}\text{ VERT. HOSE}) \times g^*$

$= (4.517)(10.8 \cos 30°)$

$= 42.24$ LB (AT ELEVATION 757.5 HORIZ. ACCELERATION AT PEAK VALUE)

(b) $F_z = (\frac{1}{2}\text{ HORIZ HOSE}) \times g^*$

$= (1.783)(10.8 \sin 30°)$

$= 9.62$ LB.

(c) $F_y = (1.783)(.62) = 1.10$ LB (AT ELEVATION 763.5 VERTICAL ACCELERATION AT PEAK VALUE)

18.4. DUE TO MOVEMENT (ACCIDENT AND SEISMIC FORCE)

18.4.1. $F_x = K_o x$

$= 6.49\ (.74)$

$= 4.8$ LB REF. PARA 17 11.2, 15.1

18.4.2. $F_y = K_o y f^*$; f^* = LENGTH RATIOS 15.1.1.

$= (5.54)(.65)(.513)$

$= 1.84$ LB REF. PARA 16.11.2, 15.1

18.4.3 $F_z = K_o z$

$= (5.54)(.76) = 4.2$ REF. PARA 16.11.2 15.1.

18.5. VIBRATION FORCES

18.5.1. DUE TO INERTIA

$F = W \times g$

(a) F_x = (HORIZ. HOSE + FITTINGS + $\frac{1}{2}$ VERT. HOSE) × g

= 4.517 (.5g's)

= 2.258 LB

(b) $F_Y = F_Z$ = 2.011 (.5g's)

= 1.005 LB

18.6. TOTAL FORCE

18.6.1. IN x-DIRECTION

F_x = ACCIDENT AND SEISMIC FORCE DUE TO INERTIA & MOVEMENT) + VIBRATION

= (33.6 + 42.24 + 4.8) + 2.258

= 82.89 LB

SPECIFICATION ALLOWABLE

$P_x = .01\ \sigma_y A$

$= .01 (30{,}000) [.7854 (1.315^2 - 1.049^2)]$

= 149.16 LB

$P_x > F_x$

<u>DESIGN IS ADEQUATE</u>

METAL *Bellows* CORPORATION 20577 KNAPP STREET CHATSWORTH, CALIFORNIA 91311	ENGINEER J. Shen	REFERENCE NUMBER CR 683 P/N-77154	
	DATE 4-11-80	CUSTOMER TVA	PAGE OF 106

18.6.2. IN Y- DIRECTION:

F_Y = INSTALLATION MISALIGNMENT FORCE + ACCIDENT & SEISMIC FORCE DUE TO MOVEMENT + VIBRATION

= 2.84 + (2.21 + 1.1 + 1.84) + 1.005

= 8995 LBS REF. PARA 16.11.3, 18.4.2

SPECIFICATION ALLOWABLE

$P_Y = .01\ 6_y\ A$

= 148.16 LB

$P_Y > F_Y$

DESIGN IS ADEQUATE

18.6.3. IN Z- DIRECTION

F_Z = DEAD WEIGHT + (ACCIDENT AND SEISMIC FORCE DUE TO INERTIA & MOVEMENT) + VIBRATION

= 1.783 + (7.66 + 9.62 + 4.21) + 1.005

= 24.278 LB REF. PARA 18.0. 18.2.1.(b) 18.3.1(b), 18.4.3, 18.5.1(b)

SPECIFICATION ALLOWABLE

$P_Z = .01\ 6_y\ A.$

= 148.16 LB

$P_Z > F_Z$ DESIGN IS ADEQUATE

18.7. DYNAMIC MOMENT

MOMENT ARMS:

SOCKET ADAPTORS	.477 LB x .695 IN =	.33 IN-LB
FERRULE	.057 LB x 2.015 IN. =	.115 IN-LB
HOSE & BRAIDS	.885 LB x 6.296 IN. =	5.57 IN-LB
FLUID IN HOSE	.364 LB x 1.39 IN. =	.505 IN-LB
	TOTAL =	6.52 IN-LB

18.7.1. ACCIDENT MOMENT:

18.7.1.1. DUE TO INERTIA:

(a) $M_z = 6.52\ (8.6 \sin 30°)$

$= 28.03$ IN-LB

REF. PARA. 18.7.

(b) $M_y = 6.52\ (1.24) = 8.804$ IN-LB

18.7.2. SEISMIC MOMENT (SSE)

18.7.2.1. DUE TO INERTIA:

(a) $M_z = 6.52\ (10.8 \sin 30°)$

$= 35.208$ IN-LB

PARA. 18.7.

(b) $M_y = 6.52\ (.62) = 4.042$ IN-LB

18.7.3. MOMENT AT SOCKET ADAPTOR

HOSE FORCE x L (HOSE END TO SOCKET ADAPTOR)

18.7.3.1. $M_y = F_y\ (L)$

$= 1.84\ (1.39)$

$= 2.557$ IN-LB REF. PARA. 18.4.2.

18.7.3.2. $M_z = F_z (L)$

$= 4.21 (1.39)$

$= 5.85$ IN-LB

REF. PARA. 18.4.3.

18.7.4. TOTAL MOMENT

18.7.4.1. IN Y-DIRECTION

M_y = TOTAL DEFLECTION MOMENT (INCL. INSTALLATION & SEISMIC) + SEISMIC & ACCIDENT DUE TO MOVEMENT & INERTIA

$= [83.69 + (2.84)(1.39) + 1.0^{*}] + 8.804 + 9.042$

$= 109.76$ IN-LB

* ADDITIONAL DEFLECTION MOMENT DUE TO SEISMIC
REF. PARA 16.11.4, 16.11.3

SPECIFICATION ALLOWABLE 16.7.3.1.

$M_{by} = .0707\, \sigma_y Z$

$= .0707 (30,000)(.133)$

$= 282.09$ IN-LB

$M_{by} > M_y$
DESIGN IS ADEQUATE

WHERE

$Z = \frac{I}{C}$

$= .098 \frac{D^4 - d^4}{D}$

$= .098 \frac{1.315^4 - 1.049^4}{1.315}$

$= .133$

18.7.4.2. IN $\mathfrak{z}$-DIRECTION

M_z = DEAD WEIGHT + SEISMIC AND ACCIDENT DUE TO INERTIA & MOVEMENT

= 6.52 + [28.03 + 35.208 + (DEFLECTION MOMENT + MOMENT AT SOCKET ADAPTOR)]

= 6.52 + [28.03 + 35.208 + (123.93 + 5.85)]

= 199.538 IN-LB

REF. PARA. 18.7. 18.7.1.1. 18.7.2.1. 18.7.3.2.

DEFLECTION MOMENT IN $\mathfrak{z}$-DIRECTION

$F = (K_o)\,z$

$= (5.541)(.76)$

$= 4.21$ LB

$M = (F)(L)(F^{*})/2$

$= (4.21)(19.625)(3.0)/2$

$= 123.93$ IN-LB

f^{*} = LENGTH RATIOS

REF. 16.11.2.15.1.15.1.1.

SPECIFICATION ALLOWABLE

$M_{bz} = .0707\,\sigma_y\,z$

$= 282.09$ IN-LB

$M_{bz} > M_z$

DESIGN IS ADEQUATE

18. 8. TORSIONAL MOMENT

$M_x = F_y (L)$ — L = ELBOW RADIUS = 1.5 IN.

$= [f^* y\ K_0] (L)$ — f^* = LENGTH RATIO

$= [(.487)(.65)(6.49)] (1.5)$

$= 3.08$ (IN-LB)

REF. 15.1.1.15.1, 17.11.2

SPECIFICATION ALLOWABLE

$M_{tx} = .1 \frac{\sigma_y J}{R_o}$

$= .1 \frac{(30,000)\ .174}{1.315/2}$

$= 794$ IN-LB

$J = \frac{\pi}{32} (d_o^4 - d_i^4)$

$= \frac{\pi}{32} (1.315^4 - 1.049^4)$

$= .174$

$M_{tx} > M_x$

DESIGN IS ADEQUATE

19.0 MOTION AT CENTER DUE TO RESPONSE FROM ACCIDENT & SEISMIC CONDITION:

19.0.1. UNDER ACCIDENT CONDITION:

19.0.1.1. ASSUMPTIONS

A. SEISMIC INPUT of $\sqrt{(8.6 \sin 30°)^2 + 1.24^2}$

B. AMPLIFICATION FACTOR IS DERIVED FROM RESULTS of TEST DATA AND IS CONSIDERED CONSERVATIVE.

FREQUENCY* Hz	INPUT g	AMPLIFICATION	OUTPUT g	DISPLACEMENT INCHES	EXCURSION INCHES
30.5	4.475	4	17.9	.376	± .188

19.0.1.2.

EQUIVALENT AXIAL MOTION

$$e = \frac{3\, D_p\, \Delta}{(.5\, N)(1.5\, L)}$$

$$= \frac{3(1.145)(\pm.188)}{(76)(9.812)} = \pm .00086$$

$$S_5 = \frac{E_b\, t_p^2\, e}{2 W^3 C_f},$$

$$= \frac{(29 \times 10^6)(.019)^2}{2(.165)^3(1.50)}(\pm.00086) = \pm 668 \text{ PSI}$$

$$S_6 = \frac{5 E_b\, t_p\, e}{3 W^2 C_d}$$

$$= \frac{5(29 \times 10^6)(.019)}{3(.165)^2(1.56)}(\pm.00086) = \pm 18595 \text{ PSI}$$

* NOTE: IT IS WORST frequency. SEE 16.12.6 PAGE 83

19.0.2. UNDER SEISMIC CONDITION

19.0.2.1 ASSUMPTIONS

A. SEISMIC INPUT of $\sqrt{(10.8 \sin 30)^2 + (6)^2}$

FREQUENCY Hz	INPUT g	AMPLIFICATION	OUTPUT g	DISPLACEMENT IN.	EXCUR. IN.
30.5	5.435	4	21.74	.457	± .228

19.0.2.2.

EQUIVALENT AXIAL MOTION

$$e = \frac{3 D_p \Delta}{(.5N)(.5L)}$$

$$= \frac{3\,(1.145)(\pm .228)}{(76)\ (9.812)} = \pm .000\,104$$

$$S_5 = \frac{E_b t_p^2 e}{2 w^3 C_f}$$

$$= \frac{(29 \times 10^6)(.019)^2}{2(.165)^3(1.50)} (\pm .00104) = \pm 807 \text{ PSI}$$

$$S_6 = \frac{5 E_b t_p e}{3 w^2 C_f}$$

$$= \frac{5(29 \times 10^6)(.019)}{3(.165)^2(1.86)} (\pm .00104) = \pm 22487 \text{ PSI}$$

19.0.3. CYCLE LIFE (ACCIDENT + SSE)

$S_T = .7(S_3 + S_4) + (S_5 + S_6)_{ACCIDENT} + (S_5 + S_6)_{SSE}$

$= .7(4570 + 29424) + (1336 + 37190) + (1614 + 44974)$

$= 108909$ PSI

$$N_C = \left(\frac{1860000}{S_T - 54000}\right)^{3.4}$$

N_C = MORE THAN 659×10^5 CYCLES

SPECIFICATION ALLOWABLE = 500 CYCLES

DESIGN IS ADEQUATE

20.0 LOADING:

20.0.1. SUSTAINED LOAD. (NC-3652.1)

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

WHERE: M_A = MOMENT DUE TO DEFLECT HOSE + MOMENT DUE TO DEAD WEIGHT

NOTE: IN OPERATION, MOMENT TO DEFLECT WILL APPROACH TO ZERO, FOR CONSERVATIVE, FULL VALUE USED.

$$= \frac{1025\,(1.315)}{4\,(.133)} + \frac{.75\,(1.8)\left[\sqrt{(83.69+3.95)^2+(6.52)^2}\right]}{\pi\,(.591)^2\,(.133)}$$

= 2532 PSI + 813 PSI

= 3.345 KSI < 18.7 Ksi

REF. PARA 18.11.4. 18.7.

20.0.2 OCCASIONAL LOAD (NC-3652.2)

$$S_{OL} = \frac{P D_o^*}{4 t_n} + \frac{.75\, i\,(M_A + M_B)}{Z} \leq 1.2 S_R \quad \text{(NC-3652.2)}$$

$$= \frac{1025\,(1.315)}{4\,(.133)} + \frac{.75\,(1.8)\left[\sqrt{109.76^2+199.54^2}\right]}{\pi\,(.591)^2\,(.133)}$$

= 2532 PSI + 2106 PSI

= 4.638 Ksi < 18.7 Ksi

REF. PARA 18.7.4.1, 18.7.4.2

* CALCULATION WAS BASED ON ATTACHED SCH. 40 PIPE (1") IN THE FIELD.

21.0. PIPING:

21.0.1. ADAPTORS (P/N 77

21.0.1.1. BELLOWS END:

O.D. = 1.31 ±.03 IN.

I.D. = 1.02 $^{+.005}_{-.000}$

$t_{MIN.}$ = .1575 IN

$$t_{REQD} = \frac{PD}{2(S+Py)} + A \quad \text{(NC-3641.1)}$$

$$= \frac{1025(1.31)}{2(18700+1025(.4))}$$

= .035 IN.

$t_{MIN.} > t_{REQD}$ **ADEQUATE**

21.0.1.2. WELD END

O.D. = 1.31 ±.03 IN.

I.D. = 1.092 $^{+.005}_{-.000}$ IN

t_{MIN} = .109 IN.

$$t_{REQD} = \frac{PD}{2(S+Py)} + A$$

$$= \frac{1025(1.31)}{2(18700+1025(.4))}$$

= .035 IN.

$t_{MIN} > t_{REQD}$ **ADEQUATE**

21.0.2. ELBOW PER SA312, 376 TP 304 (2 Zp? SCH. 10)

O.D. = 1.315 IN.

I.D. = 1.097

t = .109 IN. NOM.

= .095 IN. MIN.

$$t_{REQD} = \frac{PD}{2(S + Py)} + A \qquad (NC-3641.1)$$

$$= \frac{1025\ (1.31)}{2(18700 + 1025(.4))}$$

$$= .035 \text{ IN.}$$

$t_{MIN.} > t_{REQD}$

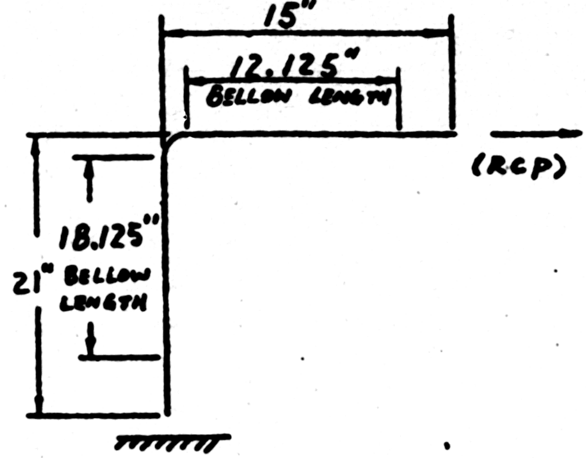
21.0.3. PIPING (CIRCUMFERENTIAL) WELD

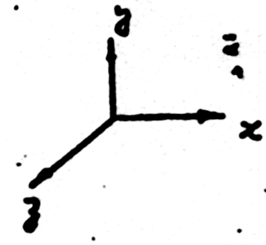
$$t = \frac{PR}{2S + .4P} \qquad (NC-3324.3)$$

$$= \frac{1025\ (.5485)}{2(18700) + .4(1025)}$$

$$= .0148 \text{ IN.}$$

22.0 MOTION CORRECTION FOR COMPUTER USE:





22.1. MOTIONS

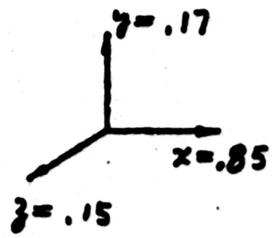
$\Delta = .059 \frac{L}{\sqrt{D}}$

$= .059 \frac{12.125}{\sqrt{.75}}$

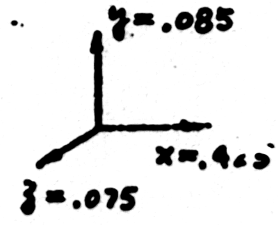
$= .826$

THERMAL

INSTALLATION



SSE



OBE

22.1.1. TOTAL LENGTH & LENGTH RATIOS:

TOTAL LENGTH: 12.125 + 18.125 = 30.25 IN

LENGTH RATIOS: $\frac{12.125}{30.25} = .401$

AND

LENGTH RATIOS: $\frac{18.125}{30.25} = .599$

22.1.2. MOTION FOR HORIZONTAL HOSE:

(a) THERMAL = (.826) .401 = .331 IN.

(b) SEISMIC OBE = $\sqrt{y^2 + [.401(z+\Delta)]^2}$

$= \sqrt{.085^2 + [.401(.075+.826)]^2}$

= .371 IN.

(c) SEISMIC SSE = $\sqrt{y^2 + [.401(z+\Delta)]^2}$

$= \sqrt{.17^2 + [.401(.15+.826)]^2}$

= .426 IN.

22.1.3. MOTION FOR VERTICAL HOSE:

(a) THERMAL = (.826) .599 = .495 IN.

(b) SEISMIC OBE = $\sqrt{x^2 + [.599(z+\Delta)]^2}$

$= \sqrt{.425^2 + [.599(.075+.826)]^2}$

= .686 IN.

(c) SEISMIC SSE = $\sqrt{x^2 + [.599(z+\Delta)]^2}$

$= \sqrt{.85^2 + [.599(.15+.826)]^2}$

= 1.03 IN.

22.1.4. MOTION FOR VIBRATION:

$$g = (.0511)\ f^2 D \qquad f = 15\ Hz$$

$$.5 = (.0511)\ (15^2)\ D$$

$$D = .043\ \text{IN.} \quad \text{(FOR WORST CONDITION)}$$

22.1.4.1. HORIZONTAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.401\,(.043 + .826)]^2}$$

$$= .35\ \text{IN.}$$

1.4.2. VERTICAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.599\,(.043 + .826)]^2}$$

$$= .52\ \text{IN.}$$

23.0 REFERENCES

23.0.1 TVA BOK A2-826892

HORIZ. HOSE 47W450-1001/1002 (PEN.NO.X-39B-I/-O)

23.0.2 METAL BELLOWS CORP DRAWING 77752

23.0.3 ASME BOILER AND PRESSURE VESSEL CODE, SECTION III

SUBSECTION NC CLASS 2 COMPONENTS

23.0.4 STANDARDS OF THE EXPANSION JOINT MANUFACTURERS

ASSOCIATION (EJMA) FOURTH EDITION

23.0.5 ASSESSMENT OF FLEXIBLE LINE FOR FLOW INDUCED

VIBRATION - GEORGE C. MARSHAL SPACE FLIGHT CENTER

REPORT NUMBER 20M02540.

23 | 1 DESIGN CONDITIONS

OPERATING PRESSURE	3 PSIG
DESIGN PRESSURE	150 PSIG
OPERATING TEMPERATURE	100 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	225 PSIG
BURST PRESSURE	600 PSIG
FLOW RATE, NITROGEN	0 LB/SEC
LINE SIZE	0.8 INCHES
MOTIONS	
THERMAL OFFSET, DT	0.331 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.350 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

23.2 HOSE DATA

23.2.1	BASIC TUBE,OD	0.750 INCHES
	OUTSIDE DIA. OD	1.040 INCHES
	INSIDE DIA, D	0.735 INCHES
	MEAN DIA, DP	0.887 INCHES
	THICKNESS, T	0.016 INCHES
	SPAN, W	0.152 INCHES
	PITCH, Q	0.125 INCHES
	LENGTH, L	12.125 INCHES
	NO OF CONVOLUTIONS, N	97

23.3 PERFORMANCE CONSTANTS

TP= T(D)EXP.5/(DP)EXP.5 (MATERIAL THINNING)

TP= 0.015 INCHES

Q/2W= 0.41

Q/2.2(DP(TP))EXP.5= 0.49

23.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.71

23.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.52

23.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.59

23.4 PERFORMANCE EQUATIONS

23.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

S1= (P)(D)(EB)/2((TC)(EC)+(N)(T)(EB))

S1= 353 PSI

CODE ALLOWABLE= 18550 PSI

23.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

S2= (P)(DP)/2N(TP)(.571+2W/Q)

S2= 1518 PSI

CODE ALLOWABLE= 18550 PSI

23.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

S3= (P)(W)/2N(TP)

S3= 785 PSI

23.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

S4= (P)(CP)(W/TP)EXP2/2N

S4= 5852 PSI

23.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

ET= 3DP(DT)/N(L) (THERMAL)

ET= 0.0007493 INCHES

EOBE=3DP(DOBE)/N(L) (SEISMIC-OBE)

EOBE= 0.0008399 INCHES

ESSE= 3DP(DSSE)/N(L) (SEISMIC-SSE)

ESSE= 0.0009644 INCHES

EV= 3DP(DV)/N((VIBRATION)

EV= 0.0007923 INCHES

23.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

S5= EB(TP)EXP2(ET)/2(W)EXP3(CF) (THERMAL)

S5= 440 PSI

S5= EB(TP)EXP2(EOBE)/2(W)EXP3(CF) (SEISMIC-OBE)

S5= 494 PSI

S5= EB(TP)EXP2(ESSE)/2(W)EXP3(CF) (SEISMIC-SSE)

S5= 567 PSI

S5= EB(TP)EXP2(EV)/2(W)EXP3(CF) (VIBRATION)

S5= 466 PSI

23.7 BELLOWS MERIDIONAL DEFLECTION STRESS

S6= 5EB(TP)(ET)/3(W)EXP2(CD) (THERMAL)

S6= 14790 PSI

S6= 5EB(TP)(EOBE)/3(W)EXP2(CD) (SEISMIC-OBE)

S6= 16578 PSI

S6= 5EB(TP)(ESSE)/3(W)EXP2(CD) (SEISMIC-SSE)

S6= 19035 PSI

S6= 5EB(TP)(EV)/3(W)EXP2(CD) (VIBRATION)

S6= 15639 PSI

23.8 TOTAL CYCLIC STRESS

ST = (S3+S4)+(S5+S6) (THERMAL)*

ST= 21869 PSI

ST = .7(S3+S4)+(S5+S6) (SEISMIC-OBE)**

ST= 21719 PSI

ST = .7(S3+S4)+(S5+S6) (SEISMIC-SSE)**

ST= 24249 PSI

ST = .7(S3+S4)+(S5+S6) (VIBRATION)

ST= 20752 PSI

* MODIFIED [illegible] ATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

23.9 CALCULATED LIFE

NC= ((C)(TF)/(ST-B))EXP3.4

NC= MORE THAN 1.0EXP 8 CYCLES (THERMAL)

REQUIRED LIFE= 10000 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (SEISMIC-OBE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (SEISMIC-SSE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (VIBRATION)

23.10 BRAID ANALYSIS

WIRE DIA, D= .0120 INCHES

NUMBER OF WIRES PER BUNDLE, N= 8

NUMBER OF BUNDLES, B= 36

ANGLE FROM HOSE AXIS, X=43 DEGREES

WEIGHT PER FOOT, BW= 0.168 LBS

23.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 92.79 LBS

23.10.2 BRAID AREA, TOTAL

A= .7854(D)EXP2(N)(B)

A= 0.033 SQ INCHES

23.10.3 BRAID STRESS

ST= F/ACOSX

ST= 3894 PSI

ALLOWABLE STRESS = 18550 PSI

23.11 SPRING RATES

23.11.1 AXIAL SPRING RATE

KA= 1.7(NP)(EB)(DP)(TP)EXP3/N(CF)(W)EXP3

KA= 266.48 LB/IN

23.11.2 OFFSET SPRING RATE

KO= 1.5(DP)EXP2(KA)(F1)/(L)EXP2

KO= 5.89 LB/IN

23.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 1.93 LB

MAXIMUM ALLOWABLE = N/A LBS

23.13.2.3 BELLOWS SPRING RATE

FROM PARA 23.11.1

KA= 266.48 LB/IN

23.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 51697.02 LB/IN

23.13.3 FREQUENCY RANGE (FLEX HOSE)

23.13.3.1 IN-PHASE LONGITUDINAL

FR1= (2KE/(MM+MF1))EXP.5/2(3.1416)

FR1= 20010.8 HZ

23.13.3.2 OUT-PHASE LONGITUDINAL

FR2= (2KE/(MM+MF2))EXP.5/2(3.1416)

FR2= 19860.7 HZ

23.13.3.3 FIRST BENDING MODE

FB1= (8KE/MM=MF2))EXP.5/2(3.1416)

FB1= 39721.3 HZ

23.13.4 VORTEX SHEDDING VELOCITY

23.13.4.1 PITCH (LAMDA)= 0.125 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.078 INCHES

LAMDA/SIGMA= 1.592

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .37921

LOWER STROUHAL NUMBER, SL= .16314

23.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4142. FT/SEC

VL= FR1(SIGMA)/SL

VL= 9629. FT/SEC

23.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 4111. FT/SEC

VL= FR2(SIGMA)/SL

VL= 9557.FT/SEC

23.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 8223. FT/SEC

VL= FB1(SIGMA)/SL

VL= 19113. FT/SEC

NO OVERLAP OCCURS BETWEEN THE BELLOWS HOSE FLOW AND THE VORTEX SHEDDING RANGE THEREFORE NO ADDITIONAL ANALYSIS IS REQUIRED ON HOSE ASSEMBLY FOR INDUCED VIBRATION

23.14 PRESSURE DROP

23.14.1 LOSS= (FRICTION FACTOR)(L)(DENSITY)(V)EXP2/(2G)

LOSS= .000E+00 PSI/FT

24.0 REFERENCES

24.0.1 TVA 80K-526892

VERT. HOSE 47W 450-1001/1002 (PEN.NO. X-39B-I/-C)

24.0.2 METAL BELLOWS CORP DRAWING 77752

24.0.3 ASME BOILER AND PRESSURE VESSEL CODE, SECTION III

SUBSECTION NC CLASS 2 COMPONENTS

24.0.4 STANDARDS OF THE EXPANSION JOINT MANUFACTURERS

ASSOCIATION (EJMA) FOURTH EDITION

24.0.5 ASSESSMENT OF FLEXIBLE LINE FOR FLOW INDUCED

VIBRATION - GEORGE C. MARSHAL SPACE FLIGHT CENTER

REPORT NUMBER 20M02540.

14.1 DESIGN CONDITIONS

OPERATING PRESSURE	3 PSIG
DESIGN PRESSURE	150 PSIG
OPERATING TEMPERATURE	100 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	225 PSIG
BURST PRESSURE	600 PSIG
FLOW RATE, NITROGEN	0 LB/SEC
LINE SIZE	0.8 INCHES
MOTIONS	
THERMAL OFFSET, DT	0.495 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.520 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

24.2 HOSE DATA

24.2.1	BASIC TUBE, OD	0.750 INCHES
	OUTSIDE DIA, OD	1.040 INCHES
	INSIDE DIA, D	0.735 INCHES
	MEAN DIA, DP	0.887 INCHES
	THICKNESS, T	0.016 INCHES
	SPAN, W	0.152 INCHES
	PITCH, Q	0.125 INCHES
	LENGTH, L	18.125 INCHES
	NO OF CONVOLUTIONS, N	145

24.3 PERFORMANCE CONSTANTS

TP= T(D)EXP.5/(DP)EXP.5 (MATERIAL THINNING)

TP= 0.015 INCHES

Q/2W= 0.41

Q/2.2(DP(TP))EXP.5= 0.49

24.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.71

24.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.52

24.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.59

24.4 PERFORMANCE EQUATIONS

24.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

S1= (P)(D)(EB)/2((TC)(EC)+(N)(T)(EB))

S1= 353 PSI

CODE ALLOWABLE= 18550 PSI

24.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

S2= (P)(DP)/2N(TP)(.571+2W/Q)

S2= 1518 PSI

CODE ALLOWABLE= 18550 PSI

24.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

S3= (P)(W)/2N(TP)

S3= 785 PSI

24.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

S4= (P)(CP)(W/TP)EXP2/2N

S4= 5852 PSI

24.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

ET= 3DP(DT)/N(L) (THERMAL)

ET= 0.0005015 INCHES

EOBE=3DP(DOBE)/N(L) (SEISMIC-OBE)

EOBE= 0.0006950 INCHES

ESSE= 3DP(DSSE)/N(L) (SEISMIC-SSE)

ESSE= 0.0010435 INCHES

EV= 3DP(DV)/N(L) (VIBRATION)

EV= 0.0005268 INCHES

24.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

S5= EB(TP)EXP2(ET)/2(W)EXP3(CF) (THERMAL)

S5= 295 PSI

S5= EB(TP)EXP2(EOBE)/2(W)EXP3(CF) (SEISMIC-OBE)

S5= 402 PSI

S5= EB(TP)EXP2(ESSE)/2(W)EXP3(CF) (SEISMIC-SSE)

S5= 613 PSI

S5= EB(TP)EXP2(EV)/2(W)EXP3(CF) (VIBRATION)

S5= 309 PSI

24.7 BELLOWS MERIDIONAL DEFLECTION STRESS

S6= 5EB(TP)(ET)/3(W)EXP2(CD) (THERMAL)

S6= 9898 PSI

S6= 5EB(TP)(EOBE)/3(W)EXP2(CD) (SEISMIC-OBE)

S6= 13718 PSI

S6= 5EB(TP)(ESSE)/3(W)EXP2(CD) (SEISMIC-SSE)

S6= 20597 PSI

S6= 5EB(TP)(EV)/3(W)EXP2(CD) (VIBRATION)

S6= 10398 PSI

24.8 TOTAL CYCLIC STRESS

ST = (S3+S4)+(S5+S6) (THERMAL)*

ST= 16831 PSI

ST = .7(S3+S4)+(S5+S6) (SEISMIC-OBE)**

ST= 18773 PSI

ST = .7(S3+S4)+(S5+S6) (SEISMIC-SSE)**

ST= 25857 PSI

ST = .7(S3+S4)+(S5+S6) (VIBRATION)

ST= 15355 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

24.9 CALCULATED LIFE

NC= ('C)(TF)/(ST-B))EXP3.4

NC= MORE THAN 1.0EXP 8 CYCLES (THERMAL)

REQUIRED LIFE= 10000 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (SEISMIC-OBE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (SEISMIC-SSE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (VIBRATION)

24.10 BRAID ANALYSIS

WIRE DIA, D= .0120 INCHES

NUMBER OF WIRES PER BUNDLE, N= 5

NUMBER OF BUNDLES, B= 36

ANGLE FROM HOSE AXIS, X=43 DEGREES

WEIGHT PER FOOT, BW= 0.162 LBS

24.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 92.79 LBS

24.10.2 BRAID AREA, TOTAL

A= .7854(D)EXP2(N)(B)

A= 0.033 SQ INCHES

24.10.3 BRAID STRESS

ST= F/ACOSX

ST= 3894 PSI

ALLOWABLE STRESS = 18550 PSI

24.11 SPRING RATES

24.11.1 AXIAL SPRING RATE

KA= 1.7(NP)(EB)(DP)(TP)EXP3/N(CF)(W)EXP3

KA= 178.27 LB/IN

24.11.2 OFFSET SPRING RATE

KO= 1.5(DP)EXP2(KA)(F1)/(L)EXP2

KO= 1.76 LB/IN

24.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 0.87 LB

MAXIMUM ALLOWABLE = N/A LBS

24.11.4 DEFLECTION MOMENTS

M= (F)(L)(F2)/2

M= 21.75 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

24.12 NATURAL FREQUENCIES

24.12.1 WEIGHT OF HOSE

W1= ((OD-D)N+.57(L))3.1416D(T)(.3)

W1= 0.607 LBS

24.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.000628)

W2= .704E-02 LBS

24.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.254 LBS

24.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 0.87 LBS

24.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

F= 9.81(KA/W)EXP.5(F3) (FIRST MODE)

F= 211.2 HZ

F= 19.6(KA/W)EXP.5(F3) (SECOND MODE)

F= 422.4 HZ

F= 29.2(KA/W)EXP.5(F3) (THIRD MODE)

F= 633.6 HZ

F= 38.6(KA/W)EXP.5(F3) (FOURTH MODE)

F= 844.8 HZ

24.12.6 LATERAL VIBRATION

F= 24.8(DP/L)(KA/W)EXP.5(KVL) (FIRST MODE)

F= 26.1 HZ

F= 68.2(DP/L)(KA/W)EXP.5(KVL) (SECOND MODE)

F= 71.9 HZ

F= 133(DP/L)(KA/W)EXP.5(KVL) (THIRD MODE)

F= 140.2 HZ

F= 221(DP/L)(KA/W)EXP.5(KVL) (FOURTH MODE)

F= 233.0 HZ

24.13 FLOW INDUCED VIBRATION

24.13.1 FLOW VELOCITY

24.13.1.1 SYSTEM FLOW

Q= FR/ 0 LB/CUFT/60 SEC/MIN

Q= 0.000 CUFT/SEC

24.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0029 SQFT

24.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

24.13.2 METAL MASS

24.13.2.1 MM= .3DP(T)3.1416(3.1416A+H-2A)(.00258)

MM= .0000065 LB-(SEC)EXP2/(IN)EXP4

24.13.2.2 FLUID MASS

MF1=.000628DP(H)(3.1416)(.00258)/2((2A-T(NP))

MF1= .161E-07 LB-(SEC)EXP2/(IN)EXP4

MF2=.000628DP(H)EXP3(3.1416)/3(...)

MF2= .115E-06 LB-(SEC)EXP2/(IN)EXP4

24.13.2.3 BELLOWS SPRING RATE

FROM PARA 24.11.1

KA= 175.27 LB/IN

24.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 51697.04 LB/IN

24.13.3 FREQUENCY RANGE (FLEX HOSE)

24.13.3.1 IN-PHASE LONGITUDINAL

FR1= (2KE/(MM+MF1))EXP.5/2(3.1416)

FR1= 20010.8 HZ

24.13.3.2 OUT-PHASE LONGITUDINAL

FR2= (2KE/(MM+MF2))EXP.5/2(3.1416)

FR2= 19860.7 HZ

24.13.3.3 FIRST BENDING MODE

FB1= (SKE/MM=MF2))EXP.5/2(3.1416)

FB1= 39721.5 HZ

24.13.4 VORTEX SHEDDING VELOCITY

24.13.4.1 PITCH (LAMDA)= 0.125 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.078 INCHES

LAMDA/SIGMA= 1.592

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .37921

LOWER STROUHAL NUMBER, SL= .16314

24.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4142. FT/SEC

VL= FR1(SIGMA)/SL

VL= 9629. FT/SEC

24.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 4111. FT/SEC

VL= FR2(SIGMA)/SL

VL= 9557.FT/SEC

24.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 8223. FT/SEC

VL= FB1(SIGMA)/SL

VL= 19113. FT/SEC

NO OVERLAP OCCURS BETWEEN THE BELLOWS HOSE FLOW AND THE VORTEX SHEDDING RANGE THEREFORE NO ADDITIONAL ANALYSIS IS REQUIRED ON HOSE ASSEMBLY FOR INDUCED VIBRATION

24.14 PRESSURE DROP

24.14.1 LOSS= (FRICTION FACTOR)(L)(DENSITY)(V)EXP2/2D(G)

LOSS= .000E+00 PSI/FT

25.0 LOADING COMBINATION:

25.1. WEIGHT (1/2 HORIZONTAL HOSE)

SOCKET ADAPTOR	= .24 LB
FERRULE	= .05 LB
HOSE & BRAIDS (.405 + .17).5	= .288 LB
FLUID IN HOSE (.00471) .5	= .002 LB

1/2 DEAD WEIGHT = .58 LB

25.2. ACCIDENT FORCE:

25.2.1. DUE TO INERTIA:

$F = w \times g$

(a) F_x = (HORIZ. HOSE + FITTINGS + $\frac{1}{2}$ VERT. HOSE) × g^*

$= \left[(.58 + .3) + .15 + \frac{1}{2}(.87) \right] \times (2.52 \cos 15°)$

$= (1.465)(2.43)$

$= 3.56$ LB

REF. PARA 25.1, 23 & 12.4.

(b) F_z = (1/2 HORIZ. HOSE) × g^*

$= (.58) \times (2.52 \sin 15°)$

$= .378$ LB

(c) $F_y = (.58) \cdot (.29) = .17$ LB

* NOTE: AT ELEVATION 716.5 AZIMUTH 285 DEG.
"g" PEAK VALUE (ACCIDENT RESPONSE CONDITION)

25.3. SEISMIC FORCES: (SSE)

25.3.1. DUE TO INERTIA

$F = W \times g$

(a) $F_x = (\text{HORIZ. HOSE} + \text{FITTINGS} + \frac{1}{2}\ \text{VERT. HOSE}) \times g^*$

$= (1.465)(2.4 \cos 15°)$

$= 3.396$ LB

(b) $F_z = (\frac{1}{2}\ \text{HORIZ. HOSE}) \times g^*$

$= (.58)(2.4 \sin 15°)$

$= .36$ LB.

(c) $F_y = (.58)(.6) = .35$ LB

* NOTE: AT ELEVATION 716.5 FT, AZIMUTH 285 DEG.
"g" AT PEAK VALUE (CONSERVATIVE VALUE)

25.4. DUE TO MOVEMENT
(ACCIDENT AND SEISMIC FORCE)

25.4.1. $F_x = K_o x$

$= 1.76 (.85)$

$= 1.49$ LB REF. PARA 24.11.2, 22.1

25.4.2. $F_y = K_o y$ f^* = LENGTH RATIOS 22.1.1.

$= 5.89 (.17)$

$= 1$ LB REF. PARA 23.11.2, 22.1

25.4.3 $F_z = K_o z f^*$ REF. PARA 23.1..2 22.1.

$= 5.89 (.15)(.401) = .354$ LB

25.5. VIBRATION FORCES

25.5.1. DUE TO INERTIA

$F = W \times g$

(a.) F_x = (HORIZ. HOSE + fittings + $\frac{1}{2}$ VERT. HOSE) × g

= 1.465 (.5 g's)

= .73 LB

(b) $F_y = F_z$ = .58 (.5 g's)

= .29 LB

25.6. TOTAL FORCE

25.6.1. IN x - DIRECTION

F_x = ACCIDENT AND SEISMIC FORCE DUE TO INERTIA & MOVEMENT) + VIBRATION

= (3.56 + 3.396 + 1.49) + .73

= 9.176 LB

SPECIFICATION ALLOWABLE

$P_x = .01 \, 6_y \, A$

$= .01 (30{,}000) [.7854 (1.05^2 - .824^2)]$

= 99.8 LB

$P_x > F_x$

<u>DESIGN IS ADEQUATE</u>

25.6.2. IN Z- DIRECTION:

F_z = INSTALLATION MISALIGNMENT FORCE + ACCIDENT & SEISMIC FORCE DUE TO MOVEMENT + VIBRATION

$= 1.95 + (.378 + .36 + .354) + .29$

$= 3.332$ LBS   REF. PARA 23.11.3, 25.4.2

SPECIFICATION ALLOWABLE

$P_z = .01\,\sigma_y A$

$= 99.8$ LB

$P_z > F_z$

DESIGN IS ADEQUATE

25.6.3. IN Y- DIRECTION

F_y = DEAD WEIGHT + (ACCIDENT AND SEISMIC FORCE DUE TO INERTIA & MOVEMENT) + VIBRATION

$= .58 + (.17 + .35 + 1) + .29$

$= 2.39$ LB   REF. PARA 25.0.25.2.1(b) 25.3.1(b), 25.4.3, 25.5.1(b)

SPECIFICATION ALLOWABLE

$P_y = .01\,\sigma_y A$

$= 99.8$ LB

$P_y > F_y$ DESIGN IS ADEQUATE

25.7. DYNAMIC MOMENT

MOMENT ARMS:

SOCKET ADAPTORS	.24 LB × .56 IN = .134 IN-LB
FERRULE	.05 LB × 1.78 IN. = .089 IN-LB
HOSE & BRAIDS	.288 LB × 4.18 IN. = 1.2 IN-LB
FLUID IN HOSE	.002 LB × 1.15 IN. = .002 IN-LB
	TOTAL = 1.425 IN-LB

25.7.1. ACCIDENT MOMENT:

25.7.1.1. DUE TO INERTIA:

$M_z = 1.425\ (2.52 \sin 15°)$

$= .929$ IN-LB

REF. PARA 25.7.

$M_y = 1.425\ (.29) = .413$ IN-LB

25.7.2. SEISMIC MOMENT (SSE)

25.7.2.1. DUE TO INERTIA:

$M_z = 1.425\ (2.4 \sin 15°)$

$= .885$ IN-LB

PARA 25.7.

$M_y = (1.425)\ (.6 g's) = .855$ LB

25.7.3. MOMENT AT SOCKET ADAPTOR

HOSE FORCE × L (HOSE END TO SOCKET ADAPTOR)

25.7.3.1. $M_y = F_y\ (L)$

$= 1\ (1.15)$

$= 1.15$ IN-LB REF. PARA. 25.4.2.

25.7.3.2. $M_z = F_z (L)$

$= .378 (1.15)$

$= .434$ IN-LB

REF. PARA. 25.4.3.

25.7.4. TOTAL MOMENT

25.7.4.1. IN z-DIRECTION

M_z = TOTAL DEFLECTION MOMENT (INCL. INSTALLATION & SEISMIC) + SEISMIC & ACCIDENT DUE TO MOVEMENT & INERTIA

$= [32.5 + (1.95)(1.15) + 5^*] + .929 + .885$

$= 41.55$ IN-LB

* ADDITIONAL DEFLECTION MOMENT DUE TO SEISMIC
REF. PARA 23.11.4, 23.11.3

SPECIFICATION ALLOWABLE

$M_{bz} = .0707\ \sigma_y Z$

$= .0707 (30,000)(.0704)$

$= 149.3$ IN-LB

$M_{bz} > M_z$

<u>DESIGN IS ADEQUATE</u>

WHERE

$Z = \frac{I}{C}$

$= .098 \frac{D^4 - d^4}{D}$

$= .098 \frac{1.05^4 - .824^4}{1.05}$

$= .0704$

25.7.4.2. IN Y-DIRECTION

M_y = DEAD WEIGHT + SEISMIC AND ACCIDENT DUE TO INERTIA & MOVEMENT

= 1.425 + [.413 + .855 + (DEFLECTION MOMENT + MOMENT AT SOCKET ADAPTOR)]

= 1.425 + [.413 + .855 + (14.67 + 1.15)]

= 18.51 IN-LB REF. PARA. 25.7. 25.7.1.1. 25.7.2.1. 25.7.3.2.

DEFLECTION MOMENT IN y-DIRECTION

F = (K.) y

= (5.89) (.15)

= .88 LB

f^K = LENGTH RATIOS

REF. 23.11.2 22.1. 22.1.1.

M = (F) (L) (F 2)/2

= (.88) (12.125) (2.75)/2

= 14.67 IN-LB

SPECIFICATION ALLOWABLE

M_{by} = .0707 σ_y Z

= 149.3 IN-LB

$M_{by} > M_y$ DESIGN IS ADEQUATE

25.8 TORSIONAL MOMENT

$M_x = F_y (L)$ L = ELBOW RADIUS

= 1.125 IN.

$= [f^* g K_0] (L)$ f^* = LENGTH RATIO

$= [(.599)(.15)(1.76)] (1.125)$

$= .178$ (IN-LB)

REF. 22 1.1.22.1, 24.11.2

SPECIFICATION ALLOWABLE:

$$M_{tx} = .1 \frac{\sigma_y J}{R_o}$$

$$= .1 \frac{(30,000)\ .074}{1.05/2}$$

= 422.8 IN-LB

$$J = \frac{\pi}{32}(d_o^4 - d_i^4)$$

$$= \frac{\pi}{32}(1.05^4 - .824^4)$$

$= .074$

$M_{tx} > M_x$

DESIGN IS ADEQUATE

26.0 MOTION AT CENTER DUE TO RESPONSE FROM ACCIDENT & SEISMIC CONDITION.

26.0.1. UNDER ACCIDENT CONDITION.

26.0.1.1. ASSUMPTIONS

A. SEISMIC INPUT OF $\sqrt{(2.52 \sin 15°)^2 + .29^2}$

B. AMPLIFICATION FACTOR IS DERIVED FROM RESULTS OF TEST DATA AND IS CONSIDERED CONSERVATIVE.

FREQUENCY* Hz	INPUT g	AMPLIFICATION	OUTPUT g	DISPLACEMENT INCHES	EXCURSION INCHES
58.4	.713	4	2.852	.016	±.008

26.0.1.2.

EQUIVALENT AXIAL MOTION

$$e = \frac{3 D_p \Delta}{(.5N)(1.5L)}$$

$$= \frac{3(.887)(\pm.008)}{(48.5)(6.06)} = \pm .000072$$

$$S_5 = \frac{E_b t_p^2 e}{2 w^3 C_f}$$

$$= \frac{(29 \times 10^6)(.015)^2}{2(.152)^3(1.52)} (\pm.000072) = \pm 44 \text{ PSI}$$

$$S_6 = \frac{5 E_b t_p e}{3 w^2 C_d}$$

$$= \frac{5(29 \times 10^6)(.015)}{3(.152)^2(1.59)} (\pm.000072) = \pm 1421 \text{ PSI}$$

* NOTE: IT IS WORST frequency. SEE 23.12.6 PAGE

26.0.3. CYCLE LIFE (ACCIDENT + SSE)

$S_T = .7(S_3 + S_4) + (S_5 + S_6)_{ACCIDENT} + (S_5 + S_6)_{SSE}$

$= .7(785 + 5852) + (88 + 2842) + (108 + 3512)$

$= 11,195$ PSI

$$N_C = \left(\frac{1,860,000}{S_T - 54000}\right)^{3.4}$$

SINCE $54,000 > S_T$

N_C = INFINITE CYCLES

SPECIFICATION ALLOWABLE = 500 CYCLES

DESIGN IS ADEQUATE

27.0 LOADING

27.0.1. SUSTAINED LOAD. (NC-3652.1)

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

WHERE: M_A = MOMENT DUE TO DEFLECT HOSE + MOMENT DUE TO DEAD WEIGHT

NOTE: IN OPERATION, MOMENT TO DEFLECT WILL APPROACH TO ZERO, FOR CONSERVATIVE, FULL VALUE USED.

$$= \frac{150(1.05)}{4(.113)} + \frac{.75(1.8)\left[\sqrt{(32.5+2.24)^2 + 1.425^2}\right.}{\pi(.468)^2(.113)}$$

= 348 PSI + 603 PSI

= .951 KSI < 18.55 Ksi

REF. PARA .11.4. .7.

27.0.2 OCCASIONAL LOAD (NC-3652.2)

$$S_{OL} = \frac{P D_o^*}{4 t_n} + \frac{.75\, i (M_A + M_B)}{Z} \leq 1.2 S_h \quad \text{(NC-3652.2)}$$

$$= \frac{150(1.05)}{4(.113)} + \frac{.75(1.8)\left[\sqrt{41.55^2 + 18.51^2}\right.}{\pi(.468)^2(.113)}$$

= 348.4 PSI + 789.7 PSI

= 1.138 Ksi < 18.55 Ksi

REF. PARA. 23.7.4.1, 23.7.4.2

* CALCULATION WAS BASED ON ATTACHED SCH. 40 PIPE (3/4") IN THE FIELD.

28.0 PIPING:

28.0.1 ADAPTORS (P/N 77209)

28.0.1.1 BELLOWS END:

O.D. = 1.05 ± .03 IN.

I.D. = .77 $^{+.005}_{-.000}$ IN.

$t_{MIN.}$ = .122 IN

$$t_{REQD} = \frac{PD}{2(S + Py)} + A \quad \text{(NC-3641.1)}$$

$$= \frac{150\,(1.05)}{2\,(18550 + 150\,(.4))}$$

= .004 IN.

$t_{MIN.} > t_{REQD}$ ADEQUATE

28.0.1.2 WELD END

O.D. = 1.05 ± .03 IN.

I.D. = .884 $^{+.005}_{-.000}$ IN

t_{MIN} = .083 IN.

$$t_{REQD} = \frac{PD}{2(S + Py)} + A$$

$$= \frac{150\,(1.05)}{2(18550 + 160(.4))}$$

= .004 IN.

$t_{MIN} > t_{REQD}$ ADEQUATE

28.0.2. ELBOW PER SA312, 376 TP 304 (3/4 IPS SCH. 10)

O.D. = 1.05

I.D. = .82

$t = .065$ IN. NOM.

$= .057$ IN. MIN.

$$t_{REQD} = \frac{PD}{2(S + Py)} + A \quad (NC\text{-}3641.1)$$

$$= \frac{150(1.05)}{2(18550 + 150(.4))}$$

$= .004$ IN.

$t_{MIN.} > t_{REQD}$

28.0.3. PIPING (CIRCUMFERENTIAL) WELD

$$t = \frac{PR}{2S + .4P} \quad (NC\text{-}3324.3)$$

$$= \frac{150(.41)}{2(18550) + .4(150)}$$

$= .0016$ IN.