METAL *Bellows* CORPORATION

CR 699

DESIGN REPORT

FOR

HOSE ASSEMBLY, FLEXIBLE METAL

PER ASME BOILER & PRESSURE VESSEL CODES

SECTION III, CLASS 2

FOR

TENNESSEE VALLEY AUTHORITY

CHATTANOGA, TENNESSEE

REFERENCE

MBC JOB NO. 14727

MBC P/N 77750

APPROVED
This approval does not relieve the Contractor from any part of his responsibility for the correctness of design, details, and dimensions
TENNESSEE VALLEY AUTHORITY
Date MAY 28 1980
(MECH. ENGR DR) BY G.A.CHANDLEY
Ans'd By Ltr. #

N3M-586

TVA MAY 15 1980
PROJECT: WATTS BAR
CONTRACT NO.: 80KA7-826892
USE: FLEX METAL
CHECKED: HOSE ASSY.

No. of Pages: 40

May 14, 1980

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PDR ADOCK 05000327
P PDR

Metal Bellows Corporation

VERIFICATION OF SPECIFICATION

Title: DESIGN REPORT FOR HOSE ASSEMPLY, FLEXIBLE METAL REPORT, CR 699, For MBC P/N's 77750

Revision: NC

Reference: TVA Specification 80K A2-826892

Prepared by: T. Chen Date: 5-13-80

Checked by: J. Huffman Date: 5-14-80

Quality Assurance: [illegible] Date: 14 May 1980

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This is to certify that the above document has been reviewed by me, the undersigned, and is correct, complete, and in compliance with the 1977 Edition, including the Winter of 1979 Addenda, of ASME Code, Section III, Paragraph NC-3000 and Code Case N-192.

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1.0 INTRODUCTION

This report, CR 699 was prepared by Metal Bellows Corporation, Chatsworth, California, for Tennessee Valley Authority, Chattanoga, Tennessee, in accordance with TVA Specification No. 80K AZ-826892.

This report provides the stress analysis for the hoses used for the Nuclear project at Watts Bar Nuclear Plants, Units 1 and 2.

The analysis is in accordance with the rules of ASME Boiler and Pressure Vessel Code Section III, Class 2 components.

The hose is analyzed to verify the hose meets all requirements. The bellows analysis uses the Standard EJMA Performance Equations and ignores the hoop support provided by the braid. The analysis of the braid is to show the stresses imposed by the pressure end load are within Code allowables. The braid inward force vector far exceeds the squirm force created by the hose, and bellows squirm calculations are ignored.

The hose consists of a basic "L" shaped sub-assembly with different length flex sections in each leg. To this basic sub-assembly, various configurations of pipe and elbow are attached to meet customer required end requirements.

A simplifying, conservative assumption is made that each hose flex section absorbs motion in offset only and motion out of the plane of the hose is shared by both hoses in proportion to the length of the particular hose. The offset mode and the shared mode are vectorally added and used for computation.

2.1.2. MOTION FOR HORIZONTAL HOSE:

(a) THERMAL = .399 (.572) = .228 IN.

(b) SEISMIC OBE $= \sqrt{y^2 + [.399(z+\Delta)]^2}$

$= \sqrt{.155^2 + [.399(.115 + .572)]^2}$

$= .315$

(c) SEISMIC SSE $= \sqrt{y^2 + [.399(z+\Delta)]^2}$

$= \sqrt{.31^2 + [.399(.23 + .572)]^2}$

$= .445$ IN.

2.1.3. MOTION FOR VERTICAL HOSE:

(a) THERMAL = .601 (.572) = .343 IN.

(b) SEISMIC OBE $= \sqrt{x^2 + [.601(z+\Delta)]^2}$

$= \sqrt{.455^2 + [.601(.115 + .572)]^2}$

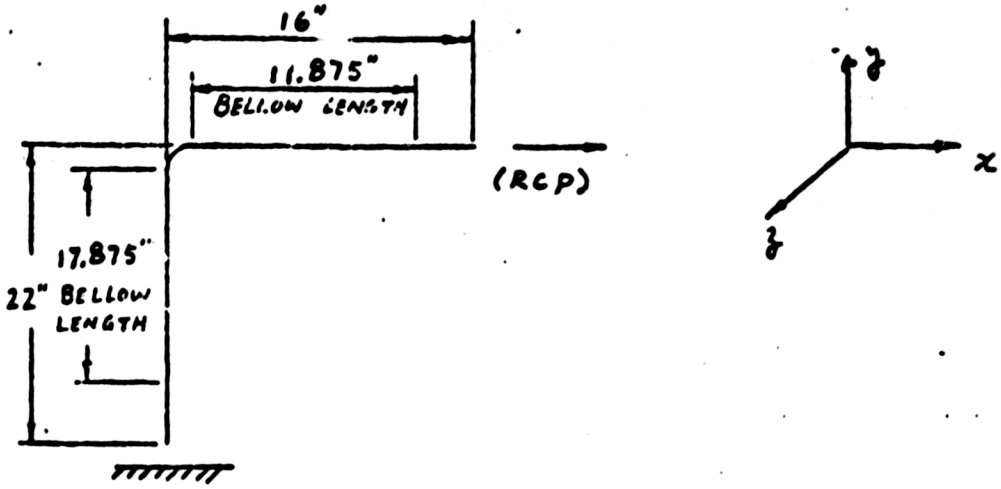
$= .614$ IN.

(c) SEISMIC SSE $= \sqrt{x^2 + [.601(z+\Delta)]^2}$

$= \sqrt{.91^2 + [.601(.23 + .572)]^2}$

$= 1.03$ IN.

2.0 MOTION CORRECTION FOR COMPUTER USE:



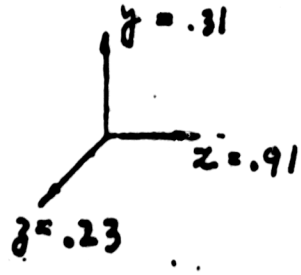
2.1. MOTIONS

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

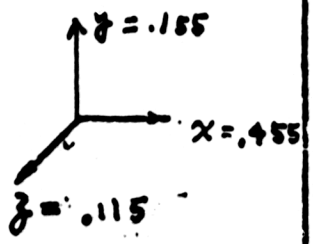
$$= .059 \frac{11.875}{\sqrt{1.5}}$$

$$= .572 \text{ IN.}$$

THERMAL INSTALLATION



SSE



OBE

2.1.1. TOTAL LENGTH & LENGTH RATIOS:

TOTAL LENGTH = 17.875 + 11.875 = 29.75 IN.

LENGTH RATIOS: $\frac{11.875}{29.75} = .399$

AND

LENGTH RATIOS: $\frac{17.875}{29.75} = .601$

2.1.4. MOTION FOR VIBRATION:

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

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

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

2.1.4.1. HORIZONTAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.399(.043 + .572)]^2}$$

$$= .249\ IN.$$

2.1.4.2. VERTICAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.601\ (.043 + .572)]^2}$$

$$= .372\ IN.$$

3.0 REFERENCES

3.0.1 TVA SPEC. 30K A2-826892
HORIZ. HOSE 47W 450-1007(PEN. NO.X-90-I)

3.0.2 METAL BELLOWS CORP DRAWING 77750

3.0.3 STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION (EJMA) FOURTH EDITION

3.0.4 ASSESSMENT OF FLEXIBLE LINE FOR FLOW INDUCED VIBRATION - GEORGE C. MARSHAL SPACE FLIGHT CENTER REPORT NUMBER 20M02540.

3.1 DESIGN CONDITIONS

OPERATING PRESSURE	120 PSIG
DESIGN PRESSURE	120 PSIG
OPERATING TEMPERATURE	100 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	180 PSIG
BURST PRESSURE	480 PSIG
FLOW RATE, NITROGEN	0 LB/SEC
LINE SIZE	1.5 INCHES
MOTIONS	
THERMAL OFFSET, DT	0.228 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.249 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

3.2 HOSE DATA

3.2.1	BASIC TUBE, OD	1.500 INCHES
	OUTSIDE DIA, OD	1.880 INCHES
	INSIDE DIA, D	1.480 INCHES
	MEAN DIA, DP	1.680 INCHES
	THICKNESS, T	0.020 INCHES
	SLOT, W	0.200 INCHES
	PITCH, Q	0.150 INCHES
	LENGTH, L	11.875 INCHES
	NO OF CONVOLUTIONS, N	79

3.3 PERFORMANCE CONSTANTS

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

TP= 0.019 INCHES

Q/2W= 0.38

Q/2.2(DP(TP))EXP.5= 0.38

3.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.73

3.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.48

3.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.55

3.4 PERFORMANCE EQUATIONS

3.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 522 PSI

ALLOWABLE STRESS = 18550 PSI

3.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 1661 PSI

ALLOWABLE STRESS = 18550 PSI

3.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 639 PSI

3.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 4977 PSI

3.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0012249 INCHES

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

EOBE= 0.0016923 INCHES

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

ESSE= 0.0023907 INCHES

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

EV= 0.0013377 INCHES

3.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 548 PSI

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

S5= 757 PSI

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

S5= 1070 PSI

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

S5= 599 PSI

3.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 18592 PSI

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

S6= 25687 PSI

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

S6= 36288 PSI

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

S6= 20304 PSI

3.8 TOTAL CYCLIC STRESS

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

ST= 24757 PSI

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

ST= 30376 PSI

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

ST= 41290 PSI

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

ST= 24835 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

3.9 CALCULATED LIFE

NC= ((C)(TF)/(ST-R))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)

3.10 BRAID ANALYSIS

WIRE DIA, D= .0180 INCHES

NUMBER OF WIRES PER BUNDLE, N= 13

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, BW= 0.677 LBS

3.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 266.01 LBS

3.10.2 BRAID AREA, TOTAL

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

A= 0.159 SQ INCHES

3.10.3 BRAID STRESS

ST= F/ACOSX

ST= 2020 PSI

ALLOWABLE STRESS = 18550 PSI

3.11 SPRING RATES

3.11.1 AXIAL SPRING RATE

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

KA= 607.92 LB/IN

3.11.2 OFFSET SPRING RATE

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

KO= 54.75 LB/IN

3.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 12.48 LB

MAXIMUM ALLOWABLE = N/A LBS

3.11.4 DEFLECTION MOMENTS

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

M= 222.37 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

3.12 NATURAL FREQUENCIES

3.12.1 WEIGHT OF HOSE

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

W1= 1.070 LBS

3.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.000444)

W2= .705E-02 LBS

3.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.670 LBS

3.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 1.75 LBS

3.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 366.0 HZ

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

F= 732.0 HZ

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

F= 1097.9 HZ

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

F= 1463.9 HZ

3.12.6 LATERAL VIBRATION

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

F= 130.9 HZ

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

F= 360.0 HZ

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

F= 702.0 HZ

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

F= 1166.4 HZ

3.13 FLOW INDUCED VIBRATION

3.13.1 FLOW VELOCITY

3.13.1.1 SYSTEM FLOW

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

Q= 0.000 CUFT/SEC

3.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0119 SQFT

3.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

3.13.2 METAL MASS

3.13.2.1 MM= .3DP(T)3.1416(3.1416A+H-2A)(.0(258)

MM= .0000199 LB-(SEC)EXP2/(IN)EXP4

3.13.2.2 FLUID MASS

MF1=.000444DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .335E-07 LB-(SEC)EXP2/(IN)EXP4

MF2=.000444DP(H)EXP3(3.1416)/3DEL

MF2= .294E-06 LB-(SEC)EXP2/(IN)EXP4

3.13.2.3 BELLOWS SPRING RATE

FROM PARA 3.11.1

KA= 607.92 LB/IN

3.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 96051.25 LB/IN

3.13.3 FREQUENCY RANGE (FLEX HOSE)

3.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 15613.3 HZ

3.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 15512.6 HZ

3.13.3.3 FIRST BENDING MODE

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

FB1= 31025.2 HZ

3.13.4 VORTEX SHEDDING VELOCITY

3.13.4.1 PITCH (LAMDA)= 0.150 INCHES

CONVOLUTION WIDTH (SIGMA) = 0.095 INCHES

LAMDA/SIGMA= 1.580

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .38279

LOWER STROUHAL NUMBER, SL= .16420

3.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 3881. FT/SEC

VL= FR1(SIGMA)/SL

VL= 9048. FT/SEC

3.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 3856. FT/SEC

VL= FR2(SIGMA)/SL

VL= 8990.FT/SEC

3.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 7713. FT/SEC

VL= FB1(SIGMA)/SL

VL= 17980. 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

3.14 PRESSURE DROP

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

LOSS= .000E+00 PSI/FT

4.0 REFERENCES

4.0.1 TVA SPEC.80K A2-826892
VERT. HOSE 47W 450-1007(PEN. NO.X-90-I)

4.0.2 METAL BELLOWS CORP DRAWING 77750

4.0.3 STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION (EJMA) FOURTH EDITION

4.0.4 ASSESSMENT OF FLEXIBLE LINE FOR FLOW INDUCED VIBRATION - GEORGE C. MARSHAL SPACE FLIGHT CENTER REPORT NUMBER 20M02540.

9.1 DESIGN CONDITIONS

OPERATING PRESSURE	120 PSIG
DESIGN PRESSURE	120 PSIG
OPERATING TEMPERATURE	100 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	180 PSIG
BURST PRESSURE	480 PSIG
FLOW RATE, NITROGEN	0 LB/SEC
LINE SIZE	1.5 INCHES
MOTIONS	
THERMAL OFFSET, DT	0.343 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.372 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

4.2 HOSE DATA

4.2.1 BASIC TUBE,OD 1.500 INCHES

OUTSIDE DIA, OD 1.880 INCHES

INSIDE DIA, D 1.480 INCHES

MEAN DIA, DP 1.680 INCHES

THICKNESS, T 0.020 INCHES

SPAN, W 0.200 INCHES

PITCH, Q 0.150 INCHES

LENGTH, L 17.875 INCHES

NO OF CONVOLUTIONS, N 119

4.3 PERFORMANCE CONSTANTS

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

TP= 0.019 INCHES

Q/2W= 0.38

Q/2.2(DP(TP))EXP.5= 0.39

4.3.1 FROM FIGURE 38, EJMA STANDARDS

ρ= 0.73

4.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.47

4.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.55

4.4 PERFORMANCE EQUATIONS

4.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 522 PSI

ALLOWABLE STRESS = 18550 PSI

4.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 1660 PSI

ALLOWABLE STRESS = 18550 PSI

4.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 639 PSI

4.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 4978 PSI

4.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0008127 INCHES

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

EOBE= 0.0014548 INCHES

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

ESSE= 0.0024405 INCHES

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

EV= 0.0008814 INCHES

4.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 364 PSI

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

S5= 651 PSI

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

S5= 1093 PSI

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

S5= 394 PSI

4.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 12338 PSI

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

S6= 22086 PSI

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

S6= 37050 PSI

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

S6= 13381 PSI

4.8 TOTAL CYCLIC STRESS

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

ST= 18319 PSI

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

ST= 26670 PSI

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

ST= 42076 PSI

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

ST= 17708 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

4.9 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)

4.10 BRAID ANALYSIS

WIRE DIA, D= .0180 INCHES

NUMBER OF WIRES PER BUNDLE, N= 13

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, DW= 0.677 LBS

4.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 266.01 LBS

4.10.2 BRAID AREA, TOTAL

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

A= 0.159 SQ INCHES

4.10.3 BRAID STRESS

ST= F/ACOSX

ST= 2020 PSI

ALLOWABLE STRESS = 18550 PSI

4.11 SPRING RATES

4.11.1 AXIAL SPRING RATE

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

KA= 403.68 LB/IN

4.11.2 OFFSET SPRING RATE

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

KO= 16.05 LB/IN

4.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 5.50 LB

MAXIMUM ALLOWABLE = N/A LBS

4.11.4 DEFLECTION MOMENTS

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

M= 147.57 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

4.12 NATURAL FREQUENCIES

4.12.1 WEIGHT OF HOSE

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

W1= 1.612 LBS

4.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.000444)

W2= .106E-01 LBS

4.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 1.008 LBS

4.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 2.63 LBS

4.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 243.0 HZ

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

F= 486.1 HZ

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

F= 729.1 HZ

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

F= 972.2 HZ

4.12.6 LATERAL VIBRATION

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

F= 57.7 HZ

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

F= 158.8 HZ

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

F= 309.7 HZ

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

F= 514.6 HZ

4.13 FLOW INDUCED VIBRATION

4.13.1 FLOW VELOCITY

4.13.1.1 SYSTEM FLOW

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

Q= 0.000 CUFT/SEC

4.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0119 SQFT

4.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

4.13.2 METAL MASS

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

MM= .0000199 LB-(SEC)EXP2/(IN)EXP4

4.13.2.2 FLUID MASS

MF1=.000444DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .335E-07 LB-(SEC)EXP2/(IN)EXP4

MF2=.000444DP(H)EXP3(3.1416)/3DEL

MF2= .294E-06 LB-(SEC)EXP2/(IN)EXP4

4.13.2.3 BELLOWS SPRING RATE

FROM PARA 4.11.1

KA= 403.68 LB/IN

4.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 96076.25 LB/IN

4.13.3 FREQUENCY RANGE (FLEX HOSE)

4.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 15616.3 HZ

4.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 15515.5 HZ

4.13.3.3 FIRST BENDING MODE

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

FB1= 31031.0 HZ

4.13.4 VORTEX SHEDDING VELOCITY

4.13.4.1 PITCH (LAMDA)= 0.150 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.095 INCHES

LAMDA/SIGMA= 1.579

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .38285

LOWER STROUHAL NUMBER, SL= .16422

4.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 3879. FT/SEC

VL= FR1(SIGMA)/SL

VL= 9044. FT/SEC

4.13.4.3 FOR FB2

VU= FR2(SIGMA)/SU

VU= 3854. FT/SEC

VL= FR2(SIGMA)/SL

VL= 8986.FT/SEC

4.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 7708. FT/SEC

VL= FB1(SIGMA)/SL

VL= 17971. FT/SEC

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

4.14 PRESSURE DROP

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

LOSS= .000E+00 PSI/FT

5.0 LOADING COMBINATION:

5.1. WEIGHT (1/2 HORIZONTAL HOSE)

SOCKET ADAPTOR	= .57 LB
FERRULE	= .13 LB
HOSE & BRAIDS (1.07 + .67).5	= .87 LB
FLUID IN HOSE (.007).5	= .003 LB
1/2 DEAD WEIGHT	= 1.573 LB

5.2. ACCIDENT FORCE:

5.2.1. DUE TO INERTIA:

$F = w \times g$

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

$= [(1.573 + .873) + .69 + \frac{1}{2}(2.63)] \times (6.4 \cos 15°)$

$= 4.451 \quad (6.18)$

$= 27.50$ LB

REF. PARA 5.1, 4 12.4.

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

$= (1.573) \times (6.4 \sin 15°)$

$= 2.605$ LB

(c) $F_y = (1.573) \times (1.67 \text{ g's}) = 1.054$ LB

* NOTE: AT ELEVATION 733.5 FT. AZIMUTH 285 DEG. "g" PEAK VALUE (ACCIDENT RESPONSE CONDITION)

5.3 SEISMIC FORCES (SSE)

$F = w \times g$

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

$= (4.451)(3.96 \cos 15°)$

$= 17.025$ LB

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

$= (1.573)(3.96 \sin 15°)$

$= 1.612$ LB

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

$= (1.573)(.64g) = 1$ LB

NOTE: AT ELEVATION 724.5 & 744.5 fx 285 DEG. 'g' AT PEAK VALUE (CONSERVATIVE VALUE)

5.4. DUE TO MOVEMENT

5.4.1. $F_x = k_o x$

$= (16.05)(.91)$

$= 14.6$ LB

REF. PARA 4.11.2.2.1

5.4.2 $F_z = K_o z f^*$

$= (54.75)(.23)(.399)$

$= 5.024$ LB

f^* = LENGTH RATIOS 2.1.1.

REF. PARA 3.11.2.2.1

5.4.3 $F_y = k_o y$

$= 54.75(.31) = 16.97$ LB

REF. PARA 3.11.2.2.1

5.5. VIBRATION FORCES

5.5.1. DUE TO INERTIA

$F = W \times g$

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

$= (4.451)(.5\ g's)$

$= 2.225$ LB

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

$= (1.573)(.5\ g's)$

$= .7865$ LB

5.6. TOTAL FORCE

5.6.1. IN x-DIRECTION

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

$= (27.5 + 17.025 + 14.6) + 2.225$

$= 61.35$ LB

SPECIFICATION ALLOWABLE

$P_x = .01\ \sigma_y A$

$= .01\ (30{,}000)\left[.7854\ (1.90^2 - 1.61^2)\right]$

$= 239.8$ LB

$P_x > F_x$

DESIGN IS ADEQUATE

5.6.2. IN Z- DIRECTION:

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

= 12.48 + (2.605 + 1.612 + 5.024) + .7865

= 22.5075 LB REF. PARA 3.11.3, 5.4.2

SPECIFICATION ALLOWABLE

$P_z = .01\ \sigma_y A$

= 239.8 LB

$P_z > F_z$

DESIGN IS ADEQUATE

5.6.3. IN Y- DIRECTION

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

= 1.573 + (1.054 + 1 + 16.97) + .7865

= 21.3835 LB REF. PARA 5.0, 5.2.1(c) 5.3.1(-), 5.4.3, 5.5.1(b)

SPECIFICATION ALLOWABLE

$P_y = .01\ \sigma_y A$

= 239.8 LB

$P_y > F_y$ DESIGN IS ADEQUATE

5.7. DYNAMIC MOMENT

MOMENT ARMS:

SOCKET ADAPTORS	.57 LB x .8 IN =	.456 IN-LB
FERRULE	.13 LB x 2.27 IN. =	.295 IN-LB
HOSE & BRAIDS	.87 LB x 4.57 IN. =	3.975 IN-LB
FLUID IN HOSE	.003 LB x 1.60 IN. =	.005 IN-LB
	TOTAL =	4.731 IN-LB

5.7.1. ACCIDENT MOMENT:

M = MOMENT ARMS x g

5.7.1.1. DUE TO INERTIA:

$M_z = 4.731\,[(6.4 \sin 15°)\,g's]$

$= 7.836$ IN-LB REF. PARA 5.7.

$M_y = 4.731\,(.67\ g's)$

$= 3.17$ IN-LB

5.7.2. SEISMIC MOMENT (SSE)

5.7.2.1. DUE TO INERTIA:

$M_y = 4.731\,(.64)$

$= 3.027$ IN-LB PARA 5.7.

$M_z = 4.731\,[3.96 \sin 15°] = 4.849$ IN-LB

5.7.3. MOMENT AT SOCKET ADAPTOR

HOSE FORCE x L (HOSE END TO SOCKET ADAPTOR)

5.7.3.1. $M_y = F_y\,(L)$

$= 16.97\,(1.60)$

$= 27.152$ IN-LB REF. PARA. 5.4.3.

5.7.4.2. IN Y-DIRECTION

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

= 4.731 + [3.17 + 3.027 + (DEFLECTION MOMENT + MOMENT AT SOCKET ADAPTOR)]

= 4.731 + [6.197 + (302.27 + 27.152)] –

= 340.35 IN-LB

REF. PARA. 5.7. 5.7.1.1. 5.7.2.1. 5.7.3.8

DEFLECTION MOMENT IN z-DIRECTION

$F = (K_a)\,y$

= (54.75) (.31)

= 16.97 LB

f^K = LENGTH RATIOS

REF. 3.11.2. 2.1. 2.1.1.

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

= (16.97)(11.875)(3.0)/2

= 302.27 IN-LB

SPECIFICATION ALLOWABLE

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

= 689.3 IN-LB

$M_{bz} > M_z$

DESIGN IS ADEQUATE

5.8. TORSIONAL MOMENT

$$M_x = F_z (L)$$

$$= [f^* z \; K_0] (L)$$

$$= [(.601)(.23)(16.05)] (2.25)$$

$$= 4.99 \text{ (IN-LB)}$$

L = ELBOW RADIUS
= 2.25 IN.
f^* = LENGTH RATIO

REF. 2.1.1. 2.1, 4.11.2

SPECIFICATION ALLOWABLE

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

$$= .1 \frac{(30,000)\ .620}{1.90/2}$$

$$= 1957.8 \text{ IN-LB}$$

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

$$= \frac{\pi}{32} (1.90^4 - 1.61^4)$$

$$= .620$$

$$M_{tx} > M_x$$

DESIGN IS ADEQUATE

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

6.0.1. UNDER ACCIDENT CONDITION:

6.0.1.1. ASSUMPTIONS

A. SEISMIC INPUT of $\sqrt{(6.4 \sin 15^\circ)^2 + (.67)^2}\ g = \sqrt{y^2+z^2}\ g$

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
130.9	1.786	4	7.144	.008	± .004

6.0.1.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(1.68)(\pm .004)}{(.5(79))(5.9375)} = \pm .000086$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.2)^3(1.48)}(\pm .000086) = \pm 38 \text{ PSI}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.2)^2(1.55)}(\pm .000086) = \pm 1273 \text{ PSI}$$

* NOTE: IT IS WORST frequency. SEE 3.12.6 PAGE 13

6.0.2. UNDER SEISMIC CONDITION

6.0.2.1 ASSUMPTIONS

A. SEISMIC INPUT of $\sqrt{(3.96 \sin 15°)^2 + .64^2}$

FREQUENCY Hz	INPUT g	Amplification	OUTPUT g	DISPLACEMENT IN.	EXCUR. IN.
130.9	1.208	4	4.832	.0055	±.00275

6.0.2.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(1.68)(\pm .00275)}{((.5)(79))(5.9375)} = \pm .0000591$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.20)^3(1.48)} (\pm .0000591) = \pm 26 \text{ PSI}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.20)^2(1.55)} (\pm .0000591) = \pm 875 \text{ PSI}$$

6.0.3. CYCLE LIFE (ACCIDENT + SSE)

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

$$= .7(639 + 4977) + (76 + 2546) + (52 + 1750)$$

$$= 8355 \text{ psi}$$

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

SINCE $54,000 > S_T$

N_c = INFINITE CYCLES

SPECIFICATION ALLOWABLE = 500 CYCLES

DESIGN IS ADEQUATE

7.0. LOADING:

7.0.1. 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.

$$= \frac{120(1.90)}{4(.145)} + \frac{.75(1.8)\left[\sqrt{(222.37+19.96)^2+4.731^2}\right]}{\pi(.878)^2(.145)}$$

$$= 393 \text{ PSI} + 932 \text{ PSI}$$

$$= 1.325 \text{ KSI} < 18.55 \text{ Ksi}$$

REF. PARA 3.11.4. 5.7.

7.0.2 OCCASIONAL LOAD. (NC-3652.2)

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

$$= \frac{120(1.90)}{4(.145)} + \frac{.75(1.8)\left[\sqrt{275.023^2+340.35^2}\right]}{\pi(.878)^2(.145)}$$

$$= 393 \text{ PSI} + 1682 \text{ PSI}$$

$$= 2.075 \text{ Ksi} < 22.26 \text{ Ksi}$$

REF. PARA 5.7.4.1, 5.7.4.2

* CALCULATION WAS BASED ON ATTACHED SCH. 40 PIPE ($1\frac{1}{2}$") IN THE FIELD.

8.0. PIPING:

8.0.1. ADAPTORS (P/N-77795)

8.0.1.1. BELLOWS END:

O.D. = 1.90 ± .03 IN.

I.D. = 1.60 $^{+.005}_{-.000}$

$t_{min.}$ = .1325 IN MIN.

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

$$= \frac{120(1.90)}{2(18550+160(.4))}$$

= .006 IN.

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

8.0.1.2. WELD END

O.D. = 2.5 ± .03 IN.

I.D. = 1.92 $^{+.005}_{-.000}$ IN

t_{MIN} = .2765 IN.

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

$$= \frac{120(2.5)}{2(18550+160(.4))}$$

= .008 IN.

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

8.0.2. ELBOW PER SA312, 376 TP304 (2 EPS SCH. 10)

O.D. = 1.90 IN

I.D. = 1.61 IN.

t = .145 IN. NOM.

= .126 IN. MIN.

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

$$= \frac{120\ (1.90)}{2\ (18550 + 160(.4))}$$

$$= .006 \text{ IN.}$$

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

8.0.3. PIPING (CIRCUMFERENTIAL) WELD

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

$$= \frac{120\ (.805)}{2(18550) + .4(120)}$$

$$= .0026 \text{ IN.}$$