METAL Bellows CORPORATION

CR 683

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. A14727

MBC PART NO: 77751, 77752, 77753 & 77754

N3M-586
TVA MAY 5 1980
PROJECT: WATTS BAR
CONTRACT NO.: 80MA2
826872
USE: FLEX METAL
CHECKED: HOSE ASSY

No. of Pages: 155

April 18, 1980

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
MAY 15 1980
BY A CHANDLEY

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VERIFICATION OF SPECIFICATION

Title: DESIGN REPORT FOR HOSE ASSEMBLY, FLEXIBLE METAL REPORT, CR 683

Revision: NC

Reference: TVA Specification 80K A2-826892

Prepared by: Frank Shen F. Shen **Date:** April 18, 1980

Checked by: John Hoffman **Date:** 4-18-80

Quality Assurance: [illegible] **Date:** 18 April 1980

****

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 683, 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.

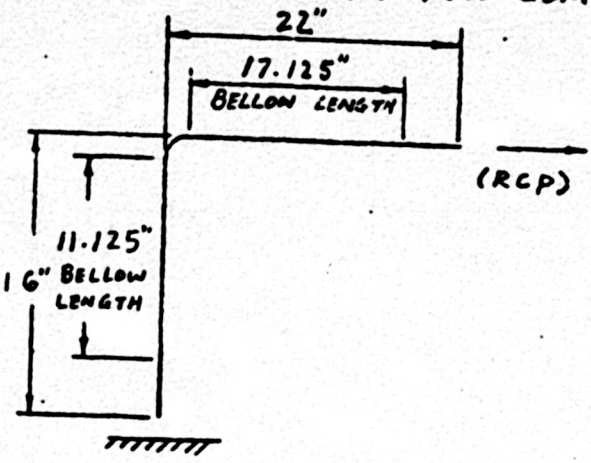
The analysis is in accordance with the rules of ASME Boiler and Pressure Vessel Code Section III, Class 2 components.

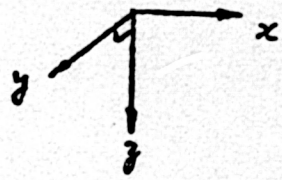
The hose is analyzed to verify the hose meets all requirements. The bellows analys.'s uses the Standard EJMA Performance Equations and ignores the hoop support provided by the braid. The analysis of the braid is to show the stresses imposed by the pressure end load are within Code allowables. The braid 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.

2.0 MOTION CORRECTION FOR COMPUTER USE:





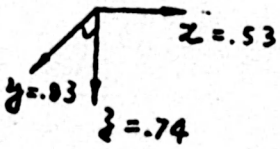
2.1. MOTIONS

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

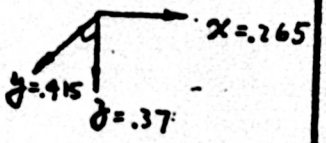
$$= .059 \frac{17.125}{\sqrt{2}}$$

$$= .714 \text{ IN.}$$

THERMAL INSTALLATION



SSE



OBE

2.1.1. TOTAL LENGTH & LENGTH RATIOS:

TOTAL LENGTH = 17.125 + 11.125 = 28.25 IN.

LENGTH RATIOS: $\frac{17.125}{28.25} = .606$

AND

LENGTH RATIOS: $\frac{11.125}{28.25} = .394$

2.1.2. MOTION FOR HORIZONTAL HOSE:

(a) THERMAL = .714 (.606) = .432 IN.

(b) SEISMIC OBE $= \sqrt{z^2 + [.606(y+\Delta)]^2}$

$= \sqrt{.37^2 + [.606(.415+.714)]^2}$

$= .778$ IN.

(c) SEISMIC SSE $= \sqrt{z^2 + [.606(y+\Delta)]^2}$

$= \sqrt{.74^2 + [.606(.83+.714)]^2}$

$= 1.19$ IN.

2.1.3. MOTION FOR VERTICAL HOSE:

(a) THERMAL = .714 (.394) = .282 IN.

(b) SEISMIC OBE $= \sqrt{x^2 + [.394(y+\Delta)]^2}$

$= \sqrt{.265^2 + [.394(.415+.714)]^2}$

$= .517$ IN.

(c) SEISMIC SSE $= \sqrt{x^2 + [.394(y+\Delta)]^2}$

$= \sqrt{.53^2 + [.394(.83+.714)]^2}$

$= .806$ IN.

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:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.606\,(.043 + .714)]^2}$$

$$= .46\ IN.$$

2.1.4.2. VERTICAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.394\,(.043 + .714)]^2}$$

$$= .30\ IN.$$

3.0 REFERENCES

3.0.1 TVA SOK A2-826892

HORIZONTAL HOSE 47W-450-1027 (PEN. NO. X-71-I)

3.0.2 METAL BELLOWS CORP DRAWING 77753

3.0.3 ASME BOILER AND PRESSURE VESSEL CODE, SECTION III SUBSECTION NC CLASS 2 COMPONENTS

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

3.0.5 ASSESSMENT OF FLEXIBLE LINE FOR FLOW INDUCED VIBRATION - GEORGE C. MARSHAL SPACE FLIGHT CENTER REPORT NUMBER 20N02540.

3.1 DESIGN CONDITIONS

OPERATING PRESSURE	150 PSIG
DESIGN PRESSURE	160 PSIG
OPERATING TEMPERATURE	150 F
DESIGN TEMPERATURE	200 F
ROOM TEMPERATURE PROOF PRESSURE	240 PSIG
BURST PRESSURE	640 PSIG
FLOW RATE	23 GPM
LINE SIZE	2.0 IPS
PRESSURE LOSS ALLOWABLE	2.0 PSI/FT
MOTIONS	
THERMAL OFFSET, DT	0.432 INCHES
CYCLE LIFE	10000 CYCLES
OBE SEISMIC OFFSET, DOBE	0.778 INCHES
CYCLE LIFE	500 CYCLES
SSE SEISMIC OFFSET, DSSE	1.190 INCHES
CYCLE LIFE	500 CYCLES
VIBRATION OFFSET DV	0.460 INCHES AT 15 HZ
LIFE	40 YEARS (SEE NOTE)
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

NOTE:

THE TERM "YEARS OF SERVICE" EXPRESSED OR IMPLIED IN THE DESIGN SPECIFICATION FOR THIS UNIT IS INTERPRETED BY METAL BELLOWS CORP TO BE A DESIGN OBJECTIVE ONLY. METAL BELLOWS ENGINEERING HAS TO THE BEST OF ITS ABILITY, BASED ON INFORMATION FURNISHED AND GENERAL APPLICATION KNOWLEDGE, TRIED TO DEFINE ALL OF THE SERVICE PARAMETERS THAT WOULD BE IMPOSED DURING "SERVICE LIFE" AND EVENTUALLY RESULT IN FATIGUE FAILURE, HOWEVER, IT MUST BE APPRECIATED THAT THERE ARE PRACTICAL LIMITATIONS IN DEFINING ALL CONDITIONS IMPOSED ON A UNIT DURING ITS "SERVICE LIFE" AND FOR THIS REASON THE UNIT WILL BE SUBJECT TO ALL TERMS AND CONDITIONS OF METAL BELLOWS CORPORATION S STANDARD WARRANTY

3.2 HOSE DATA

3.2.1 BASIC TUBE,OD 2.000 INCHES

OUTSIDE DIA, OD .430 INCHES

INSIDE DIA, D 1.980 INCHES

MEAN DIA, DP 2.205 INCHES

THICKNESS, T 0.020 INCHES

SPAN, W 0.225 INCHES

PITCH, Q 0.168 INCHES

LENGTH, L 17.125 INCHES

NO OF CONVOLUTIONS, N 102

3.3 PERFORMANCE CONSTANTS

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

TP= 0.019 INCHES

Q/2W= 0.37

Q/2.2(DP(TP))EXP.5= 0.37

3.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.73

3.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.47

3.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.54

3.4 PERFORMANCE EQUATIONS

3.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 791 PSI

CODE ALLOWABLE= 18400 PSI

3.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 2862 PSI

CODE ALLOWABLE= 18400 PSI

3.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 949 PSI

3.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 8257 PSI

3.5 EQUIVALENT AXIAL MOTION DUE TO GRAVITY

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

ET= 0.0016360 INCHES

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

EOBE= 0.0029463 INCHES

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

ESSE= 0.0045066 INCHES

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

EV= 0.0017420 INCHES

3.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 525 PSI

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

S5= 947 PSI

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

S5= 1448 PSI

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

S5= 560 PSI

3.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 19849 PSI

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

S6= 35747 PSI

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

S6= 54678 PSI

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

S6= 21136 PSI

3.8 TOTAL CYCLIC STRESS

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

ST= 29583 PSI

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

ST= 43140 PSI

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

ST= 62572 PSI

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

ST= 28141 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

3.9 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= 87850944 CYCLES (SEISMIC-SSE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (VIBRATION)

3.10 BRAID ANALYSIS

WIRE DIA, D= .0120 INCHES

NUMBER OF WIRES PER BUNDLE, N= 12

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=43 DEGREES

WEIGHT PER FOOT, BW= 0.333 LBS

3.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 610.98 LBS

3.10.2 BRAID AREA, TOTAL

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

A= 0.065 SQ INCHES

3.10.3 BRAID STRESS

ST= F/ACOSX

ST= 12822 PSI

CODE ALLOWABLE= 18400 PSI

3.11 SPRING RATES

3.11.1 AXIAL SPRING RATE

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

KA= 447.83 LB/IN

3.11.2 OFFSET SPRING RATE

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

KO= 27.84 LB/IN

3.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 12.03 LB

MAXIMUM ALLOWABLE = N/A LBS

3.11.4 DEFLECTION MOMENTS

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

M= 257.47 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= 2.077 LBS

3.12.2 WEIGHT OF FLUID

W2= .7851(DF)EXF2(L)(.036)

W2= 2.354 LBS

3.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.475 LBS

3.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 4.91 LBS

3.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 281.2 HZ

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

F= 562.3 HZ

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

F= 843.5 HZ

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

F= ***** HZ ——→ ACTUAL 1115 Hz

3.12.6 LATERAL VIBRATION

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

F= 91.5 HZ

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

F= 251.7 HZ

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

F= 490.8 HZ

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

F= 815.6 HZ

3.13 FLOW INDUCED VIBRATION

3.13.1 FLOW VELOCITY

3.13.1.1 SYSTEM FLOW

Q= FR/7.48GAL/CUFT/60SEC MIN

Q= 0.051 CUFT/SEC

3.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0214 SQFT

3.13.1.3 FLOW VELOCITY

V= Q/A

V= 2.40 FT/SEC

3.13.2 METAL MASS

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

MM= .0000294 LB-(SEC)EXP2/(IN)EXP4

3.13.2.2 FLUID MASS

MF1= .036DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .0000046 LB-(SEC)EXP2/(IN)EXP4

MF2= .036DP(H)EXP3(3.1416)/3DEL

MF2= .0000384 LB-(SEC)EXP2/(IN)EXP4

3.13.2.3 BELLOWS SPRING RATE

FROM PARA 3.11.1

KA= 447.83 LB/IN

3.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 91357.81 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= 11661.3 HZ

3.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 6265.3 HZ

3.13.3.3 FIRST BENDING MODE

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

FB1= 16530.7 HZ

3.13.4 VORTEX SHEDDING VELOCITY

3.13.4.1 PITCH (LAMDA)= 0.168 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.104 INCHES

LAMDA/SIGMA= 1.615

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .37279

LOWER STROUHAL NUMBER, SL= .16123

3.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 3252. FT/SEC

VL= FR1(SIGMA)/SL

VL= 7518. FT/SEC

3.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 2305. FT/SEC

VL= FR2(SIGMA)/SL

VL= 5329.FT/SEC

3.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 4609. FT/SEC

VL= FB1(SIGMA)/SL

VL= 10657. 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= 0.02 PSI/FT

PRESSURE LOSS ALLOWABLE= 2.0 PSI/FT

4.0 REFERENCES

4.0.1 TVA 80K A2-826892
VERTICAL HOSE 47W-450-1027(PEN.NO. X-71-I)

4.0.2 METAL BELLOWS CORP DRAWING 77753

4.0.3 ASME BOILER AND PRESSURE VESSEL CODE, SECTION III
SUBSECTION NC CLASS 2 COMPONENTS

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

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

4.1 DESIGN CONDITIONS

OPERATING PRESSURE	150 PSIG
DESIGN PRESSURE	160 PSIG
OPERATING TEMPERATURE	150 F
DESIGN TEMPERATURE	200 F
ROOM TEMPERATURE PROOF PRESSURE	240 PSIG
BURST PRESSURE	640 PSIG
FLOW RATE	23 GPM
LINE SIZE	2.0 IPS
PRESSURE LOSS ALLOWABLE	2.0 PSI/FT
MOTIONS	
THERMAL OFFSET, DT	0.282 INCHES
CYCLE LIFE	10000 CYCLES
OBE SEISMIC OFFSET, DOBE	0.517 INCHES
CYCLE LIFE	500 CYCLES
SSE SEISMIC OFFSET, DSSE	0.806 INCHES
CYCLE LIFE	500 CYCLES
VIBRATION OFFSET DV	0.460 INCHES AT 15 HZ
LIFE	40 YEARS (SEE NOTE)
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

NOTE:

THE TERM "YEARS OF SERVICE" EXPRESSED OR IMPLIED IN THE DESIGN SPECIFICATION FOR THIS UNIT IS INTERPRETED BY METAL BELLOWS CORP TO BE A DESIGN OBJECTIVE ONLY. METAL BELLOWS ENGINEERING HAS TO THE BEST OF ITS ABILITY, BASED ON INFORMATION FURNISHED AND GENERAL APPLICATION KNOWLEDGE, TRIED TO DEFINE ALL OF THE SERVICE PARAMETERS THAT WOULD BE IMPOSED DURING "SERVICE LIFE" AND EVENTUALLY RESULT IN FATIGUE FAILURE, HOWEVER, IT MUST BE APPRECIATED THAT THERE ARE PRACTICAL LIMITATIONS IN DEFINING ALL CONDITIONS IMPOSED ON A UNIT DURING ITS "SERVICE LIFE" AND FOR THIS REASON THE UNIT WILL BE SUBJECT TO ALL TERMS AND CONDITIONS OF METAL BELLOWS CORPORATION S STANDARD WARRANTY

4.2 HOSE DATA

4.2.1	BASIC TUBE,OD	2.000 INCHES
	OUTSIDE DIA, OD	2.430 INCHES
	INSIDE DIA, D	1.980 INCHES
	MEAN DIA, DP	2.205 INCHES
	THICKNESS, T	0.020 INCHES
	SPAN, W	0.225 INCHES
	PITCH, Q	0.169 INCHES
	LENGTH, L	11.125 INCHES
	NO OF CONVOLUTIONS, N	66

4.3 PERFORMANCE CONSTANTS

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

TP= 0.019 INCHES

Q/2W= 0.37

Q/2.2(DP(TP))EXP.5= 0.37

4.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.73

4.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.47

4.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.54

4.4 PERFORMANCE EQUATIONS

4.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 791 PSI

CODE ALLOWABLE= 18400 PSI

4.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 2872 PSI

CODE ALLOWABLE= 18400 PSI

4.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 949 PSI

4.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 8248 PSI

4.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0025406 INCHES

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

EOBE= 0.0046577 INCHES

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

ESSE= 0.0072614 INCHES

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

EV= 0.0041442 INCHES

4.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 815 PSI

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

S5= 1495 PSI

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

S5= 2331 PSI

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

S5= 1330 PSI

4.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 30790 PSI

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

S6= 56449 PSI

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

S6= 88004 PSI

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

S6= 50225 PSI

4.8 TOTAL CYCLIC STRESS

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

ST= 40803 PSI

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

ST= 64382 PSI

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

ST= 96773 PSI

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

ST= 57994 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= 45799776 CYCLES (SEISMIC-OBE)

REQUIRED LIFE= 500 CYCLES

NC= 371835 CYCLES (SEISMIC-SSE)

REQUIRED LIFE= 500 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (VIBRATION)

4.10 BRAID ANALYSIS

WIRE DIA, D= .0120 INCHES

NUMBER OF WIRES PER BUNDLE, N= 12

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=43 DEGREES

WEIGHT PER FOOT, BW= 0.333 LBS

4.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 610.98 LBS

4.10.2 BRAID AREA, TOTAL

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

A= 0.065 SQ INCHES

4.10.3. BRAID STRESS

ST= F/ACOSX

ST= 12822 PSI

CODE ALLOWABLE= 18400 PSI

4.11 SPRING RATES

4.11.1 AXIAL SPRING RATE

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

KA= 691.10 LB/IN

4.11.2 OFFSET SPRING RATE

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

KO= 61.09 LB/IN

4.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 17.23 LB

MAXIMUM ALLOWABLE = N/A LBS

4.11.4 DEFLECTION MOMENTS

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

M= 143.73 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= 1.343 LBS

4.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.036)

W2= 1.529 LBS

4.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.309 LBS

4.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 3.18 LBS

4.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 433.6 HZ

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

F= 867.3 HZ

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

F= ***** HZ ⟶ ACTUAL = 1292 Hz

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

F= ***** HZ ⟶ ACTUAL = 1708 Hz

4.12.6 LATERAL VIBRATION

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

F= 217.3 HZ

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

F= 597.5 HZ

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

F= ***** HZ → ACTUAL 1165 Hz

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

F= ***** HZ → ACTUAL 1936 Hz

4.13 FLOW INDUCED VIBRATION

4.13.1 FLOW VELOCITY

4.13.1.1 SYSTEM FLOW

Q= FR/7.48GAL/CUFT/60SEC MIN

Q= 0.051 CUFT/SEC

4.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0214 SQFT

4.13.1.3 FLOW VELOCITY

V= Q/A

V= 2.40 FT/SEC

4.13.2 METAL MASS

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

MM= .0000294 LB-(SEC)EXP2/(IN)EXP4

4.13.2.2 FLUID MASS

MF1= .036DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .0000047 LB-(SEC)EXP2/(IN)EXP4

MF2= .036DP(H)EXP3(3.1416)/3DEL

MF2= .0000382 LB-(SEC)EXP2/(IN)EXP4

4.13.2.3 BELLOWS SPRING RATE

FROM PARA 4.11.1

KA= 691.10 LB/IN

4.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 91225.19 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= 11645.2 HZ

4.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 8270.3 HZ

4.13.3.3 FIRST BENDING MODE

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

FB1= 16540.5 HZ

4.13.4 VORTEX SHEDDING VELOCITY

4.13.4.1 PITCH (LAMDA)= 0.169 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.104 INCHES

LAMDA/SIGMA= 1.616

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .37244

LOWER STROUHAL NUMBER, SL= .16113

4.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 3261. FT/SEC

VL= FR1(SIGMA)/SL

VL= 7537. FT/SEC

4.13.4.3 FOR FB2

VU= FB2(SIGMA)/SU

VU= 2316. FT/SEC

VL= FB2(SIGMA)/SL

VL= 5352.FT/SEC

4.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 4631. FT/SEC

VL= FB1(SIGMA)/SL

VL= 10705. 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

4.14 PRESSURE DROP

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

LOSS= 0.02 PSI/FT

PRESSURE LOSS ALLOWABLE= 2.0 PSI/FT

5.0 LOADING COMBINATION:

5.1. WEIGHT (½ HORIZONTAL HOSE)

SOCKET ADAPTOR	= 1.1 LB
FERRULE	= .2 LB
HOSE & BRAIDS (2.077+.475).5	= 1.28 LB
FLUID IN HOSE (2.354) .5	= 1.18 LB

½ DEAD WEIGHT = 3.76 LB

5.2. ACCIDENT FORCE:

5.2.1. DUE TO INERTIA:

$F = w \times g$

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

$= [(3.76 + 2.46) + 1.13 + \frac{1}{2}\ 3.18\ ] \times (10.3 \cos 30°)$

$= 8.94\ (8.92)$

$= 79.74$ LB

REF. PARA 5.1, 4.12.4.

(b) F_z = (½ HORIZ. HOSE) × g*

$= (3.76) \times (10.3 \sin 30°)$

$= 19.36$ LB

(c) $F_y = (3.76) \times (2.1\ g's) = 7.89$ LB

* NOTE: AT ELEVATION 792 FT. AZIMUTH 300 DEG. "g" PEAK VALUE (ACCIDENT RESPONSE CONDITION)

5.3 SEISMIC FORCES (SSE)

$F = w \times g$

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

$= (8.94)(19 \cos 30°)$

$= 147.1$ LB

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

$= (3.76)(19 \sin 30°)$

$= 35.72$ LB

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

$= (3.76)(1) = 3.76$ LB

NOTE: AT ELEVATION 792 ft & 801.5 ft 300 deg.
'g' AT PEAK VALUE (CONSERVATIVE VALUE)

5.4. DUE TO MOVEMENT

5.4.1. $F_x = k_o x$

$= (61.09)(.53)$

$= 32.37$ LB

REF. PARA 4.11.2.2.1

5.4.2 $F_y = K_o y f^*$

$= (27.84)(.83)(.606)$

$= 14$ LB

f^* = LENGTH RATIOS 2.1.1.

REF. PARA 3.11.2.2.1

5.4.3 $F_z = k_o z$

$= 27.84 (.74) = 20.6$ LB

REF. PARA 3.11.2 2.1

5.5. VIBRATION FORCES

5.5.1. DUE TO INERTIA

$F = W \times g$

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

$= 8.94\ (.5g's)$

$= 4.47$ LB

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

$= 3.76\ (.5\ g's)$

$= 1.88$ LB

5.6. TOTAL FORCE

5.6.1. IN X-DIRECTION

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

$= (79.74 + 147.1 + 32.37) + 4.47$

$= 263.68$ LB

SPECIFICATION ALLOWABLE

$P_x = .01\ \sigma_y A$

$= .01\ (30{,}000)\ [.7854\ (2.375^2 - 2.067^2)]$

$= 322.3$ LB

$P_x > F_x$

DESIGN IS ADEQUATE

5.6.2. IN Y- DIRECTION:

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

$= 12.03 + (7.89 + 3.76 + 14) + 1.88$

$= 39.56$ LBS

REF. PARA 3.11.3, 5.4.2

SPECIFICATION ALLOWABLE

$P_Y = .01\, \sigma_y A$

$= 322.3$ LB

$P_Y > F_Y$

DESIGN IS ADEQUATE

5.6.3. IN Z- DIRECTION

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

$= 3.76 + (19.36 + 35.72 + 20.6) + 1.88$

$= 81.32$ LB

REF. PARA 5.0. 5.2.1(b) 5.3.1(b), 5.4.3. 5.5.1(b)

SPECIFICATION ALLOWABLE

$P_Z = .01\, \sigma_y A$

$= 322.3$ LB

$P_Z > F_Z$

DESIGN IS ADEQUATE

5.7. DYNAMIC MOMENT

MOMENT ARMS:

SOCKET ADAPTORS	1.1 LB × .87 IN =	.96 IN-LB
FERRULE	.2 LB × 2.43 IN. =	.49 IN-LB
HOSE & BRAIDS	1.28 LB × 6.02 IN. =	7.7 IN-LB
FLUID IN HOSE	1.18 LB × 1.74 IN. =	2.05 IN-LB
	TOTAL =	11.2 IN-LB

5.7.1. ACCIDENT MOMENT:

M = MOMENT ARMS × g

5.7.1.1. DUE TO INERTIA:

$M_z = 11.2\,[(10.3 \sin 30°)\,g's]$

$= 57.68$ IN-LB REF. PARA 5.7.

$M_y = 11.2\,(2.1\,g's)$

$= 23.52$ IN-LB

5.7.2. SEISMIC MOMENT (SSE)

5.7.2.1. DUE TO INERTIA:

$M_y = 11.2\,(1)$

$= 11.2$ IN-LB

PARA. 5.7.

$M_z = 11.2\,[19 \sin 30°] = 106.4$ IN-LB

5.7.3. MOMENT AT SOCKET ADAPTOR

HOSE FORCE × L (HOSE END TO SOCKET ADAPTOR)

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

$= 14\,(1.74)$

$= 24.36$ IN-LB REF. PARA. 5.4.2.

5.7.3.2. $M_z = F_z (L)$

$= 20.6 (1.74)$

$= 35.84$ IN-LB

REF. PARA. 5.4.3.

5.7.4. TOTAL MOMENT

5.7.4.1. IN Y-DIRECTION

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

$= [257.47 + (12.03)(1.74) + 20^*] + 23.52 + 11.2$

$= 333.12$ IN-LB

* ADDITIONAL DEFLECTION MOMENT DUE TO SEISMIC

REF. PARA 3.11.4, 3.11.3

SPECIFICATION ALLOWABLE

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

$= .0707\ (30{,}000)(.559)$

$= 1185$ IN-LB

$M_{by} > M_y$

DESIGN IS ADEQUATE

WHERE:

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

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

$= .098\ \frac{2.375^4 - 2.067^4}{2.375}$

$= .559$

5.7.4.2. IN z-DIRECTION

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

= 11.2 + [57.68 + 106.4 + (DEFLECTION MOMENT + MOMENT AT SOCKET ADAPTOR)]

= 11.2 + [164.08 + (441 + 35.84)]

= 652.12 IN-LB

REF. PARA. 5.7. 5.7.1.1. 5.7.2.1. 5.7.3.2.

DEFLECTION MOMENT IN z-DIRECTION

$F = (K_o)z$

= (27.84) (.74)

= 20.6 LB

f^* = LENGTH RATIOS

REF. 3.11.2.2.1.2.1.1.

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

= (20.6)(17.125)(2.5)/2

= 441 IN-LB

SPECIFICATION ALLOWABLE

$M_{bz} = .0707 S_y z$

= 1185 IN-LB

$M_{bz} > M_z$

DESIGN IS ADEQUATE

5.8. TORSIONAL MOMENT

$M_x = F_y (L)$

$= [f^* y \; K_o] (L)$

$= [(.394)(.83)(61.09)] (3.0)$

$= 59.93$ (IN-LB)

L = ELBOW RADIUS
= 3.0 IN.
f^* = LENGTH RATIO

REF. 2.1.1. 2.1, 4.11.2

SPECIFICATION ALLOWABLE

$M_{tx} = .1 \dfrac{6yJ}{R_o}$

$= .1 \dfrac{(30{,}000)\,1.33}{2.375/2}$

$= 3360$ IN-LB

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

$= \dfrac{\pi}{32}(2.375^4 - 2.067^4)$

$= 1.33$

$M_{tx} > M_x$

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 $\sqrt{(10 \sin 30^\circ)^2 + (2.1)^2}\, g = \sqrt{y^2 + z^2}\, g$

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
91.5	5.423	4	21.692	.05	± .025

6.0.1.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(2.205)(\pm .025)}{(51)(8.56)} = \pm .00037$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.225)^3(1.47)}(\pm .00037) = \pm 115 \text{ PSI}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.225)^2(1.54)}(\pm .00037) = \pm 4356 \text{ PSI}$$

* 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 $\sqrt{(19 \sin 30°)^2 + 1^2}$

FREQUENCY Hz	INPUT g	AMPLIFICATION	OUTPUT g	DISPLACEMENT IN.	EXCUR. IN.
91.5	3.24	4	5	.030	±.015

6.0.2.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(2.205)(\pm .015)}{(51)(8.56)} = \pm .00022$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.225)^3(1.97)} (\pm .00022) \pm 68.55 \text{ PSI}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.225)^2(1.47)} (\pm .00022) \pm 2714 \text{ PSI}$$

6.0.3. CYCLE LIFE (ACCIDENT + SSE)

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

$= .7(949 + 8257) + (230 + 8712) + (137.1 + 5428)$

$= 20951$ 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

<u>DESIGN IS ADEQUATE</u>

7.0 LOADING:

7.0.1. SUSTAINED LOAD. (NC-3652.1)

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

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.

$$= \frac{160\,(2.375)}{4\,(.154)} + \frac{.75\,(1.8)\left[\sqrt{(257.47+20.93)^2 + 11.2^2}\right.}{\pi\,(1.11)^2\,(.154)}$$

$$= 616 \text{ PSI} + 631 \text{ PSI}$$

$$= 1.247 \text{ KSI} < 18.4 \text{ Ksi}$$

REF. PARA 3.11.4. 5.7.

7.0.2 OCCASIONAL LOAD. (NC-3652.2)

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

$$= \frac{160\,(2.375)}{4\,(.154)} + \frac{.75\,(1.8)\left[\sqrt{333.12^2 + 652.12^2}\right.}{\pi\,(1.11)^2\,(.154)}$$

$$= 616 \text{ PSI} + 1658 \text{ PSI}$$

$$= 2.274 \text{ Ksi} < 22.8 \text{ Ksi}$$

REF. PARA 5.7.4.1, 5.7.4.2

* CALCULATION WAS BASED ON ATTACHED SCH. 40 PIPE (2") IN THE FIELD.

8.0 PIPING:

8.0.1. ADAPTORS (P/N 77016)

8.0.1.1. BELLOWS END:

O.D. = 2.38 ± .03 IN.

I.D. = 2.02 $^{+.005}_{-.000}$

$t_{MIN.}$ = .1625 IN

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

$$= \frac{160\ (2.38)}{2\ (17800 + 160\ (.4))}$$

= .0106 IN.

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

8.0.1.2. WELD END

O.D. = 2.38 ± .03 IN.

I.D. = 2.162 $^{+.005}_{+.000}$ IN

t_{MIN} = .109 IN.

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

$$= \frac{160\ (2.38}{2(17800 + 160(.4))}$$

= .0106 IN.

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

8.0.2. ELBOW PER SA312,316 TP304 (2 IPS SCH.10)

O.D. = 2.38

I.D. = 2.157

t = .111 IN. NOM.

= .98 IN. MIN.

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

$$= \frac{160\,(2.38)}{2\,(17800 + 160(.4))}$$

$$= .0106 \text{ IN.}$$

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

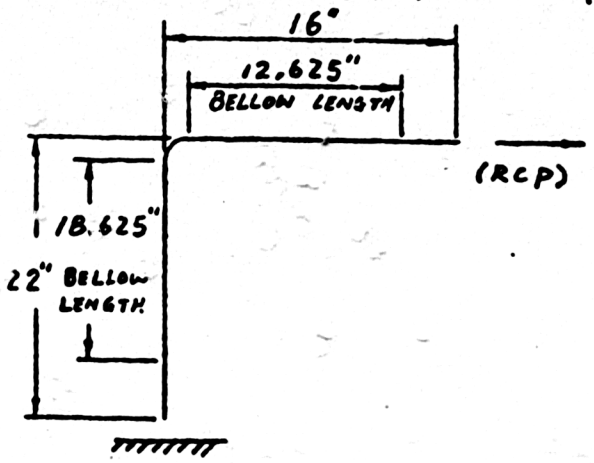
8.0.3. PIPING (CIRCUMFERENTIAL) WELD

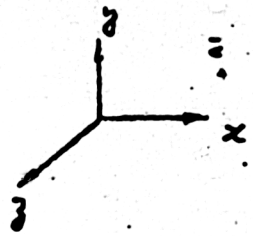
$$t = \frac{PR}{2S + .4P} \qquad (NC-3324.3)$$

$$= \frac{160\,(1.078)}{2(17800) + .4(160)}$$

$$= .0048 \text{ IN.}$$

9.0 MOTION CORRECTION FOR COMPUTER USE:





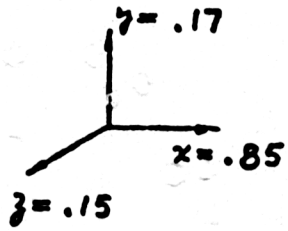
9.1. MOTIONS

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

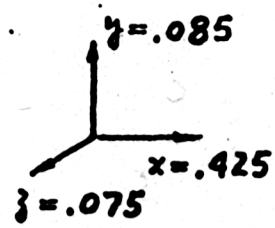
$$= .059 \frac{12.625}{\sqrt{1}}$$

$$= .745 \text{ IN.}$$

THERMAL INSTALLATION



SSE



OBE

9.1.1. TOTAL LENGTH & LENGTH RATIOS:

TOTAL LENGTH = 12.625 + 18.625 = 31.25 IN.

LENGTH RATIOS : $\frac{12.625}{31.25} = .404$

AND

LENGTH RATIOS : $\frac{18.625}{31.25} = .596$

9.1.2. MOTION FOR HORIZONTAL HOSE:

(a) THERMAL $= (.745).404 = .3$ IN.

(b) SEISMIC OBE $= \sqrt{y^2 + [.404\ (z+\Delta)]^2}$

$= \sqrt{.085^2 + [.404\ (.075+.745)]^2}$

$= .342$ IN.

(c) SEISMIC SSE $= \sqrt{y^2 + [(.404)\ (z+\Delta)]^2}$

$= \sqrt{.17^2 + [.404\ (.15+.745)]^2}$

$= .399$ IN.

9.1.3. MOTION FOR VERTICAL HOSE:

(a) THERMAL $= (.745)\ .596 = .445$ IN.

(b) SEISMIC OBE $= \sqrt{x^2 + [(.596)\ (z+\Delta)]^2}$

$= \sqrt{.425^2 + [.596\ (.075+.745)]^2}$

$= .647$ IN.

(c) SEISMIC SSE $= \sqrt{x^2 + [(.596)\ (z+\Delta)]^2}$

$= \sqrt{.85^2 + [.596\ (.15+.745)]^2}$

$= 1.0$ IN.

9.1.4. MOTION FOR VIBRATION:

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

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

$D = .043$ IN. (FOR WORST CONDITION)

9.1.4.1. HORIZONTAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [(.404)(.043 + .745)]^2}$$

$$= .32 \text{ IN.}$$

9.1.4.2. VERTICAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [(.596)(.043 + .745)]^2}$$

$$= .47 \text{ IN.}$$

10.0 REFERENCES

10.0.1 TVA 80K A2-826892
HORIZ. HOSF 47W 450-1003/1004(PEN.NO.X-39A-I/-O)

10.0.2 METAL BELLOWS CORP DRAWING 77751

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

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

10.1 DESIGN CONDITIONS

OPERATING PRESSURE	650 PSIG
DESIGN PRESSURE	900 PSIG
OPERATING TEMPERATURE	100 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	1350 PSIG
BURST PRESSURE	3600 PSIG
FLOW RATE,	0.0 LB/SEC
LINE SIZE	1.0 INCHES
MOTIONS	
THERMAL OFFSET, DT	0.300 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.320 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

10.2 HOSE DATA

10.2.1	BASIC TUBE,OD	1.000 INCHES
	OUTSIDE DIA, OD	1.310 INCHES
	INSIDE DIA, D	0.980 INCHES
	MEAN DIA, DP	1.145 INCHES
	THICKNESS, T	0.020 INCHES
	SPAN, W	0.165 INCHES
	PITCH, Q	0.129 INCHES
	LENGTH, L	12.625 INCHES
	NO OF CONVOLUTIONS, N	98

10.3 PERFORMANCE CONSTANTS

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

TP= 0.019 INCHES

Q/2W= 0.39

Q/2.2(DP(TP))EXP.5= 0.40

10.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.72

10.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.50

10.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.56

10.4 PERFORMANCE EQUATIONS

10.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 2672 PSI

ALLOWABLE STRESS = 18550 PSI

10.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 8889 PSI

ALLOWABLE STRESS = 18550 PSI

10.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 4012 PSI

10.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 25854 PSI

10.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0008329 INCHES

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

EOBE= 0.0009495 INCHES

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

ESSE= 0.0011077 INCHES

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

EV= 0.0008884 INCHES

10.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 636 PSI

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

S5= 725 PSI

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

S5= 846 PSI

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

S5= 678 PSI

10.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 18107 PSI

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

S6= 20642 PSI

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

S6= 24082 PSI

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

S6= 19314 PSI