METAL *Bellows* CORPORATION

AN
JHR
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CR 729

DESIGN REPORT

FOR

HOSE ASSEMBLY, FLEXIBLE METAL PER

ASME BOILER AND PRESSURE VESSEL CODE

SECTION III, SUBSECTION NC, CLASS 2

FOR

TENNESSEE VALLEY AUTHORITY

KNOXVILLE, TENNESSEE

REFERENCES

MBC PART NUMBER 78153

MBC JOB NUMBER A15278

N4M-526

DATE: OCT 21 1980

PROJECT BLN CONTRACT 80KA3828398

DRAWING # CR 729

SHEET ___ REV A UNIT 1&2

USE: FLEX HOSE ASSY FOR INSTR. & CONTROL SYS

No. of Pages: 27

September 22, 1980

Revision A, October 17, 1980

Metal Bellows Corporation

VERIFICATION OF SPECIFICATION

Title: DESIGN REPORT FOR HOSE ASSEMBLY, FLEXIBLE METAL REPORT, CR 729, MBC P/N 78153

Revision: A [signature] 10-17-80

Reference: TENNESSEE VALLEY AUTHORITY SPECIFICATION NUMBER BNP-DS-1940-4809-R0

Prepared by: [signature] Date: 9/23/80

Checked by: J. Huffman Date: 9-23-80

Quality Assurance: [signature] Date: 24 SEPT. 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-188-1 and N-192.
Paragrap

REGISTERED PROFESSIONAL ENGINEER
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Date: September 24 1980

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Date and Rev.	Pages Affected			Remarks	Revised By
	Revised	Added	Deleted		
10/17/80 A	Cover, i, ii	27, iii		Added loading requirement	J. Shem 10/17/80 R.G. Nyshon

1.0 INTRODUCTION

This report, CR 729, was prepared by Metal Bellows Corporation (MBC) Chatsworth, California for the Tennessee Valley Authority, Knoxville, Tennessee, in accordance with TVA Specification Number BNP-DS-1940-4809-R0.

This report provides the design analysis for a ½ inch hose assembly with 3/8 inch tube ends, for use in Bellefonte Nuclear Plant in various locations and applications. Actual operating conditions are less than design requirements.

The analysis is in accordance with the Rules of the ASME Boiler and Pressure Vessel Code Section III, Class 2. A simplifying, conservative assumption is to analyze the hose and braid separately. Association (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 loads is within Code allowables. The braid inward force vector far exceeds the squirm force created by the hose, and bellows squirm calculations are ignored.

A simplifying, conservative approach is to list the many possible motions and radius changes that will occur and perform the stress-life calculations for the single worst case. The seismic analysis is made assuming the hose is full of air and pressurized.

The mechanically induced vibration is analyzed at 10 Hz only. The other required frequencies will produce smaller displacements with resulting higher life and need not be considered.

The hose is identical to MBC P/N 73989 which has been seismic and cycle tested, reference CR 725.

2.0 REFERENCES

2.0.1 T.V.A.SPEC.NO.BNP-DS-1940-4809-R0

2.0.2 METAL BELLOWS CORP DRAWING 78153

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

2.0.4 STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION (EJMA) FIFTH EDITION

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

2.1 DESIGN CONDITIONS

OPERATING PRESSURE	150 PSIG
DESIGN PRESSURE	150 PSIG
OPERATING TEMPERATURE	150 F
DESIGN TEMPERATURE	150 F
ROOM TEMPERATURE PROOF PRESSURE	225 PSIG
BURST PRESSURE	600 PSIG
FLOW RATE	0 LB/SEC
LINE SIZE	0.5 IPS
PRESSURE LOSS ALLOWABLE	N/A
MOTIONS	
THERMAL OFFSET, DT	28.750 INCHES
CYCLE LIFE	5000 CYCLES
OBE SEISMIC OFFSET, DOBE	14.370 INCHES
CYCLE LIFE	100 CYCLES
SSE SEISMIC OFFSET, DSSE	28.750 INCHES
CYCLE LIFE	100 CYCLES
VIBRATION OFFSET DV	0.137 INCHES AT 10 HZ (.5g's)
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

2.2 HOSE DATA

2.2.1	BASIC TUBE,OD	0.500 INCHES
	OUTSIDE DIA, OD	0.700 INCHES
	INSIDE DIA, D	0.485 INCHES
	MEAN DIA, DP	0.592 INCHES
	THICKNESS, T	0.016 INCHES
	SPAN, W	0.108 INCHES
	PITCH, Q	0.100 INCHES
	LENGTH, L	36.000 INCHES
	NO OF CONVOLUTIONS, N	360

2.3 PERFORMANCE CONSTANTS

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

TP= 0.014 INCHES

Q/2W= 0.47

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

2.3.1 FROM FIGURE C18, EJMA STANDARDS

CP= 0.68

2.3.2 FROM FIGURE C19, EJMA STANDARDS

CF= 1.60

2.3.3 FROM FIGURE C20, EJMA STANDARDS

CD= 1.65

2.4 PERFORMANCE EQUATIONS

2.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 300 PSI

CODE ALLOWABLE= 27500 PSI

2.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 1128 PSI

CODE ALLOWABLE= 27500 PSI

2.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 556 PSI

2.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 2812 PSI

2.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0039431 INCHES

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

EOBE= 0.0019709 INCHES

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

ESSE= 0.0039431 INCHES

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

EV= 0.0000188 INCHES

2.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 6220 PSI

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

S5= 3109 PSI

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

S5= 6220 PSI

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

S5= 29 PSI

2.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 149592 PSI

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

S6= 74770 PSI

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

S6= 149592 PSI

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

S6= 712 PSI

2.8 TOTAL CYCLIC STRESS

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

ST= 159182 PSI

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

ST= 80237 PSI

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

ST= 158171 PSI

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

ST= 3100 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

2.9 CALCULATED LIFE $T_f = 1.1$ (INCONEL 625)

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

NC= 24125 CYCLES (THERMAL)

REQUIRED LIFE= 5000 CYCLES

NC= 2708762 CYCLES (SEISMIC-OBE)

REQUIRED LIFE= 100 CYCLES

NC= 24931 CYCLES (SEISMIC-SSE)

REQUIRED LIFE= 100 CYCLES

NC= MORE THAN 1.0EXP 8 CYCLES (VIBRATION)

2.10 BRAID ANALYSIS

WIRE DIA, D= .0200 INCHES

NUMBER OF WIRES PER BUNDLE, N= 7

NUMBER OF BUNDLES, B= 24

ANGLE FROM HOSE AXIS, X=33 DEGREES

WEIGHT PER FOOT, BW= 0.215 LBS

2.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 41.36 LBS

2.10.2 BRAID AREA, TOTAL

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

A= 0.053 SQ INCHES

2.10.3 BRAID STRESS

ST= F/ACOSX

ST= 934 PSI

CODE ALLOWABLE= 18550 PSI

2.11 SPRING RATES

2.11.1 AXIAL SPRING RATE

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

KA= 127.80 LB/IN

2.11.2 OFFSET SPRING RATE

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

KO= 0.30 LB/IN

2.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT) DT = 3 IN.

F= .90 LB

MAXIMUM ALLOWABLE = N/A LBS

2.11.4 DEFLECTION MOMENTS

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

M= 16.2 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

2.12 NATURAL FREQUENCIES

2.12.1 WEIGHT OF HOSE

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

W1= 0.716 LBS

2.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.000408)

W2= 0.004 LBS

2.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.645 LBS

2.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 1.36 LBS

2.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 118.7 HZ

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

F= 237.3 HZ

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

F= 356.0 HZ

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

F= 474.6 HZ

2.12.6 LATERAL VIBRATION

F= 24.8(DP/L)(KA/W)EXP.5(F4) (FIRST MODE)

F= 4.9 HZ

F= 68.2(DP/L)(KA/W)EXP.5(F4) (SECOND MODE)

F= 13.6 HZ

F= 133(DP/L)(KA/W)EXP.5(F4) (THIRD MODE)

F= 26.5 HZ

F= 221(DP/L)(KA/W)EXP.5(F4) (FOURTH MODE)

F= 44.0 HZ

2.13 FLOW INDUCED VIBRATION

2.13.1 FLOW VELOCITY

2.13.1.1 SYSTEM FLOW

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

Q= 0.000 CUFT/SEC

2.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0013 SQFT

2.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

2.13.2 METAL MASS

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

MM= .0000031 LB-(SEC)EXP2/(IN)EXP4

2.13.2.2 FLUID MASS

MF1=.000408DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .0000000 LB-(SEC)EXP2/(IN)EXP4

MF2=.000408DP(H)EXP3(3.1416)/3DEL

MF2= .0000000 LB-(SEC)EXP2/(IN)EXP4

2.13.2.3 BELLOWS SPRING RATE

FROM PARA 2.11.1

KA= 127.80 LB/IN

2.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 92015.50 LB/IN

2.13.3 FREQUENCY RANGE (FLEX HOSE)

2.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 38453.7 HZ

2.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 38330.1 HZ

2.13.3.3 FIRST BENDING MODE

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

FB1= 76660.1 HZ

2.13.4 VORTEX SHEDDING VELOCITY

2.13.4.1 PITCH (LAMDA)= 0.100 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.066 INCHES

LAMDA/SIGMA= 1.515

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .40094

LOWER STROUHAL NUMBER, SL= .16958

2.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 6330. FT/SEC

VL= FR1(SIGMA)/SL

VL= 14966. FT/SEC

HOSE ASSEMBLY P/N 78153

3.0 INSTALLATION CONFIGURATIONS & MOTIONS

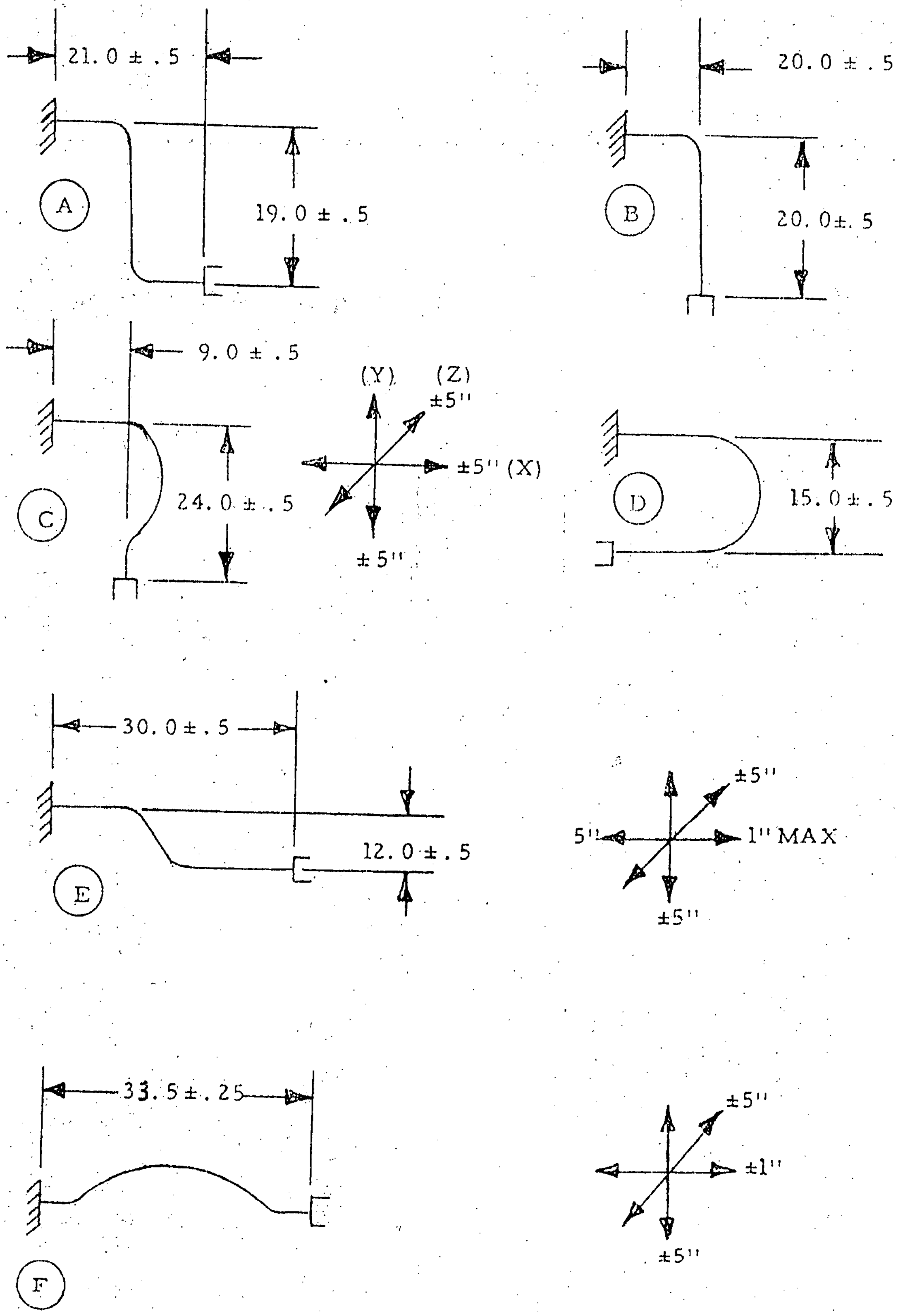


FIGURE 1

2.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 6310. FT/SEC

VL= FR2(SIGMA)/SL

VL= 14918.FT/SEC

2.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 12619. FT/SEC

VL= FB1(SIGMA)/SL

VL= 29835. 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

2.14. PRESSURE DROP

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

LOSS= 0.00 PSI/FT

PRESSURE LOSS ALLOWABLE= N/A

3.0.1. TYPICAL MOTIONS

Using configuration (D) (See Figure I) measured center line bend radii as hose was moved thru required motions:

NOTE: Configuration (D) indicated greatest changes.

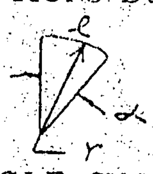
Condition I: Free end moves up 5 in. (+Y), center radius changes from 7.5 in. (installed) to 4.5 inches.

Condition II: Free end moves down 5 in. (-Y), center radius changes from 7.5 in. to 10.5 in. and straight ends to 11.0 in.

Condition III: Free end moves horizonally (±X) straight hose develops same 7.5 in. radius and radius becomes straight.

Condition IV: Free end moves out of paper (Z), radius does not change and 90° to radius, hose develops 2nd radius where hose goes into offset.

3.0.2 MOTIONS DURING ANGULATION (SMALL PORTION OF HOSE)



$$\alpha = \frac{\ell}{.01745\, r}$$

3.0.3 ANGLE CHANGE WHEN PORTION OF HOSE CHANGES RADIUS LENGTH

$$\Delta\alpha = \left(\frac{\ell}{.01745 r_1} - \frac{\ell}{.01745 r_2}\right) = \frac{\ell}{.01754}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

NOTE: When hose is straight, r_2 is considered infinity and fraction becomes ≈ zero.

NUMBER OF CONVOLUTIONS IN SMALL PORTION

$$N = \frac{\ell}{q}$$

3.0.4 MOTION PER CONVOLUTION DUE TO ANGULATION

$$e_\theta = \frac{d_p \; .017450}{2 \; N} \qquad \text{(EJMA EQ 3)}$$

$$= \frac{d_p \, (.01745) \, \frac{\ell}{.01745} \left(\frac{1}{r_1} - \frac{1}{r_2} \right)}{2 \; \frac{\ell}{q}}$$

$$= .5 \, d_p \, q \left(\frac{1}{r_1} - \frac{1}{r_2} \right) \text{ (in.)}$$

3.0.4.1. MOTION PER CONVOLUTION DUE TO ANGULATION FOR CONDITION I

$$e_\theta = .5 \, (.592) \, (.10) \left[\frac{1}{4.5} - \frac{1}{7.5} \right] = 2.63 \times 10^{-3}$$

3.0.4.2. MOTION PER CONVOLUTION DUE TO ANGULATION FOR CONDITION II

$$e_\theta = .5 \, (.592) \, (.1) \left[\frac{1}{7.5} - \frac{1}{10.5} \right] = 1.13 \times 10^{-3}$$

Or,

$$e_\theta = .5 \, (.592) \, (.1) \left[\frac{1}{11.0} - 0 \right] = 2.69 \times 10^{-3}$$

3.0.4.3. MOTION PER CONVOLUTION DUE TO ANGULATION FOR CONDITION III

$$e_\theta = .5 \, (.592) \, (.1) \left[\frac{1}{7.5} - 0 \right] = 3.94 \times 10^{-3}$$

3.0.4.4. MOTION PER CONVOLUTION DUE TO OFFSET FOR CONDITION IV.

$$e_y = \frac{3 D_P D_T}{(N_c)(LL)}$$

$$= \frac{3 (.592)(5)}{(360)(36)}$$

$$= 6.8 \times 10^{-4}$$

3.0.4.5. THE WORST CASE FOR EQUIVALENT THERMAL OFFSET MOTION SHALL BE UNDER CONDITION III.

$$D_T = \frac{e_\theta (N_c)(LL)}{3 D_P}$$

$$= \frac{(3.94 \times 10^{-3})(360)(36)}{3 (.592)}$$

$= 28.75$ IN. (USE IN COMPUTER PROGRAM)

3.1. FOR SEISMIC MOTION, THE WORST CASE SHALL BE FREE END MOVES HORIZONTALLY ± 1 IN. STRAIGHT HOSE DEVELOPS SAME 7.5 IN. RADIUS AND RADIUS BECOMES STRAIGHT.

$$e_\theta = .5 (.592)(.1)\left[\frac{1}{7.5} - 0\right] = 3.94 \times 10^{-3}$$

DSSE = 28.75 IN.

DOBE = 14.37 IN.

3. 2. MOVEMENT FOR VIBRATION OFFSET:

$$g = .0511\ f^2 D$$

$$0.5 = 0.0511\ (10)^2 D$$

$$D = .0978 \text{ IN.}$$

$$DV = \sqrt{.0978^2 + .0978^2}$$

$$= .137 \text{ IN.}$$

AT 10 HZ (WORST CONDITION)

4.0 LOADING COMBINATION:

THE WORST CASE FOR THE FORCE & MOMENT SHALL BE UNDER THE INSTALLATION CONFIGURATION (F)

4.1. SHEAR LOAD

END TUBE		=	.22 LB
ADAPTOR		=	.044 LB
SPRING		=	.12 LB
HOSE & BRAID	.5 (.716 + .645)	=	.68 LB
FLUID IN HOSE	.5 (.004)	=	.002 LB
	½ DEAD WEIGHT	=	1.066 LB

4.2. SEISMIC FORCES: (SSE)

4.2.1. DUE TO INERTIA:

$F_y = 1.066 \times 2g\text{'s} = 2.132$ LB

$F_z = 1.066 \times 3g\text{'s} = 3.198$ LB

$F = \sqrt{2.132^2 + 3.198^2}$ REF. PARA. 4.1

$= 3.844$ LB (SHEAR)

4.2.2. DUE TO MOVEMENT:

$F_y = F_z = .30\ (1.0)$

$= 0.3$ LB

$F = \sqrt{0.3^2 + 0.3^2} = .424$ IN.

4.3 SEISMIC FORCE: (OBE)

4.3.1. DUE TO INERTIA:

$F_y = 1.066 \times 1.5g = 1.599$ LB

$F_z = 1.066 \times 2.0g = 2.132$ LB

$F = \sqrt{1.599^2 + 2.132^2}$

$= 2.66$ LB (SHEAR)

4.3.2. DUE TO MOVEMENT:

$F_y = F_z = .30(.5)$

$= .15$ LB

$F = \sqrt{.15^2 + .15^2}$

$= .212$ LB

4.4. VIBRATION FORCES

4.4.1. DUE TO INERTIA:

$F_y = F_z = 1.066(.5g's)$

$= .533$ LB

$F = \sqrt{.533^2 + .533^2}$

$= .753$ LB

4.5. TOTAL SHEAR FORCE.

4.5.1. NORMAL CONDITION:

F = DEAD WEIGHT + THERMAL EXPANSION + VIBRATION

= 1.066 + .90 + .753

= 2.719 LB

REF. PARA. 4.1. 2.11.3
4.4.1.

4.5.2. UPSET CONDITION:

F = NORMAL + OBE

= 2.719 + (2.66 + .212)

= 5.591 LB

REF. PARA 4.5.1
4.3.1
4.3.2.

4.5.3. EMERGENCY CONDITION:

F = NORMAL + SSE

= 2.719 + (3.844 + .424)

= 6.987 LB

REF. PARA. 4.5.1
4.2.1
4.2.2

4.6. DYNAMIC MOMENT

MOMENT ARMS:

END TUBE	.22 LB × 1.19 IN.	= .26 IN-LB
ADAPTOR	.044 LB × 2.76 IN.	= .12 IN-LB
SPRING	.12 LB × 5.38 IN	= .65 IN-LB
HOSE & BRAID	.68 LB × 12.13 IN.	= 8.25 IN-LB
FLUID IN HOSE	.002 LB × 3.13 IN.	= .006 IN-LB
		9.286 IN-LB

4.6.1. SEISMIC MOMENT: (SSE)

$M_y = 9.286 \times 2g's = 18.572$ LB

$M_z = 9.286 \times 3g's = 27.858$ LB

REF. PARA. 4.6.

$M = \sqrt{M_y^2 + M_z^2}$

$= 33.481$ IN-LB

4.6.2. SEISMIC MOMENT: (OBE)

$M_y = 9.286 \times 1.5g's = 13.93$ LB

$M_z = 9.286 \times 2.0g's = 18.57$ LB

REF. PARA. 4.6

$M = \sqrt{13.93^2 + 18.57^2}$

$= 23.214$ IN-LB

4.6.3 MOMENT DUE TO VIBRATION:

$M_y = M_z = 9.286 \times .5g's$

$= 4.643$ IN-LB

$M = \sqrt{4.643^2 + 4.643^2}$

$= 6.566$ IN-LB

4.6.4 MOMENT AT TUBE:

HOSE FORCE × L (HOSE END TO TUBE)

4.6.4.1. .90 LB × 3.13 IN. = 2.817 IN-LB THERMAL

4.6.4.2. .424 LB × 3.13 IN. = 1.327 IN-LB SSE
REF. PARA 4.3.2

4.6.4.3. .212 LB × 3.13 IN. = .663 IN-LB OBE
REF. PARA. 4.3.2.

4.7. TOTAL MOMENT

4.7.1. NORMAL CONDITION

M = DEAD WEIGHT + THERMAL + VIBRATION

= 9.286 + (16.2 + 2.817) + 6.566

= 34.869 IN-LB

REF. PARA 4.6.4
2.11.4
4.6.3

4.7.2. UPSET CONDITION

M = NORMAL + OBE

= 34.869 + (23.214 + .663)

= 58.746 IN-LB

REF. PARA. 4.7.1
4.6.2
4.6.4.3

METAL Bellows CORPORATION 20977 KNAPP STREET CHATSWORTH, CALIFORNIA 91311	ENGINEER T. Fisher	REFERENCE NUMBER P/N 78153	
	DATE 9/19/80	CUSTOMER T. V. A	PAGE OF 23

4.7.3. EMERGENCY CONDITION

M = NORMAL + SSE

= 34.869 + (33.481 + 1.327)

= 69.677 IN-LB   REF. PARA 4.7.1.
4.6.1
4.6.4.3

5.0 MOTION AT CENTER DUE TO RESPONSE FROM SEISMIC INPUT

5.0.1. ASSUMPTIONS

(A) SEISMIC INPUT OF 3g

(B) AMPLIFICATION FACTOR IS DERIVED FROM RESULTS OF TEST DATA IS CONSIDERED CONSERVATIVE

FREQ	INPUT	AMPLIFICATION	OUTPUT	DISPL.	EXCUR.
HZ	g		g	IN.	IN.
4.9	3	2	6	4.89	±2.445

5.0.2. EQUIVALENT AXIAL MOTION AT CENTER:

$$e = \frac{3 D_p \Delta}{(.5N)(.5L)} = \frac{3(.592)(\pm 2.445)}{(.5)(360)(.5)(36)} = \pm .00134$$

5.0.3. MOTION STRESS AT CENTER:

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

$$= \frac{(29 \times 10^6)(.014)^2}{2 (.108)^3 (1.60)} (\pm .00134) = \pm 1{,}889 \text{ PSI}$$

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

$$= \frac{5 (29 \times 10^6)(.014)}{3 (.108)^2 (1.65)} (\pm .00134)$$

$$= \pm 47{,}113 \text{ PSI}$$

METAL Bellows CORPORATION 20977 KNAPP STREET CHATSWORTH, CALIFORNIA 91311	ENGINEER F. Shen	REFERENCE NUMBER P/N 78153	
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5.0.4. TOTAL STRESS

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

$$= .7(556 + 2812) + (3778 + 94226)$$

$$= 100,361 \text{ PSI}$$

5.0.5. CYCLE LIFE

$$N_c = \left(\frac{T_f 1.86 \times 10^6}{S_T - 54000}\right)^{3.4} \qquad T_f = 1.1$$

$$= 390,984 \text{ CYCLES}$$

ADEQUATE

6.0 PIPING:

6.0.1. ADAPTORS: (P/N 74991)

$O.D. = .71 \begin{smallmatrix} +.00 \\ -.01 \end{smallmatrix}$ IN.

$I.D. = .507 \begin{smallmatrix} +.003 \\ -.000 \end{smallmatrix}$ IN.

$t_{MIN} = .095$ IN.

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

$$= \frac{150\ (.71)}{2[27500 + 150\ (.4)]} + 0$$

$= .00193$ IN. $\qquad t_{MIN} > t_{REQD}$

DESIGN IS ADEQUATE

6.0.2. TUBE: (P/N 78157)

$O.D = .375 \begin{smallmatrix} +.00 \\ -.01 \end{smallmatrix}$ IN.

$I.D = .312 \begin{smallmatrix} +.002 \\ -.000 \end{smallmatrix}$ IN.

$t_{MIN} = .0255$ IN.

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

$$= \frac{150\ (.5)}{2[18300 + 150\ (.4)]} + 0$$

$= .002$ IN.

$t_{MIN} > t_{REQD}$

DESIGN IS ADEQUATE

7.0 LOADING: (AT VERY END of TUBE)

7.0.1 SUSTAINED LOAD: (UPSET CONDITION)

$$S_{SL} = \frac{P D_o^*}{4 t_n^*} + \frac{.75\ i\ M_A}{Z} \leq S_h \quad (NC-3652.1)$$

WHERE: M_A = MOMENT DUE TO UPSET CONDITION

$$= \frac{150\ (.375)}{4\ (.063)} + \frac{.75\ (1.8)\ (58.746)}{\pi\ (.156)^2 (.063)}$$

$$= 223 + 16465\ (psi)$$

$$= 16.688\ ksi < 18.3\ ksi$$

REF. PARA. 4.7.2.

7.0.2. OCCASIONAL LOAD

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

$$= \frac{150 (.375)}{4 (.063)} + \frac{.75\ (1.8)\ (69.677)}{\pi\ (.156)^2\ (.063)}$$

$$= 223 + 19529\ (psi)$$

$$= 19.752\ ksi < 21.96\ ksi$$

$M_A + M_B$ = MOMENT DUE TO EMERGENCY CONDITION

REF. PARA. 4.7.3.

* CALCULATION WAS BASED ON TUBE END (.375" O.D, .063" THK CRES 304 PER SA 479, 213)

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