10.8 TOTAL CYCLIC STRESS

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

ST= 48610 PSI

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

ST= 42274 PSI

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

ST= 45836 PSI

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

ST= 40900 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

10.9 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)

10.10 BRAID ANALYSIS

WIRE DIA, D= .0250 INCHES

NUMBER OF WIRES PER BUNDLE, N= 4

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, BW= 0.390 LBS

10.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 926.71 LBS

10.10.2 BRAID AREA, TOTAL

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

A= 0.094 SQ INCHES

10.10.3 BRAID STRESS

ST= F/ACOSX

ST= 11859 PSI

ALLOWABLE STRESS = 18550 PSI

10.11 SPRING RATES

10.11.1 AXIAL SPRING RATE

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

KA= 561.62 LB/IN

10.11.2 OFFSET SPRING RATE

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

KO= 20.79 LB/IN

10.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 6.24 LB

MAXIMUM ALLOWABLE = N/A LBS

10.11.4 DEFLECTION MOMENTS

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

M= 118.10 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

10.12 NATURAL FREQUENCIES

10.12.1 WEIGHT OF HOSE

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

W1= 0.730 LBS

10.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.003486)

W2= .453E-01 LBS

10.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.410 LBS

10.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 1.19 LBS

10.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 373.6 HZ

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

F= 747.2 HZ

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

F= 1120.8 HZ

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

F= 1494.5 HZ

10.12.6 LATERAL VIBRATION

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

F= 85.7 HZ

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

F= 235.6 HZ

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

F= 459.4 HZ

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

F= 763.3 HZ

10.13 FLOW INDUCED VIBRATION

10.13.1 FLOW VELOCITY

10.13.1.1 SYSTEM FLOW

Q= FR/ 0.0 LB/CUFT/60 SEC/MIN

Q= 0.000 CUFT/SEC

10.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0052 SQFT

10.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

10.13.2 METAL MASS

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

MM= .0000113 LB-(SEC)EXP2/(IN)EXP4

10.13.2.2 FLUID MASS

MF1=.003486DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .119E-06 LB-(SEC)EXP2/(IN)EXP4

MF2=.003486DP(H)EXP3(3.1416)/3DEL

MF2= .110E-05 LB-(SEC)EXP2/(IN)EXP4

10.13.2.3 BELLOWS SPRING RATE

FROM PARA 10.11.1

KA= 561.62 LB/IN

10.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 110077.06 LB/IN

10.13.3 FREQUENCY RANGE (FLEX HOSE)

10.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 22116.6 HZ

10.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 21226.5 HZ

10.13.3.3 FIRST BENDING MODE

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

FB1= 42453.0 HZ

10.13.4 VORTEX SHEDDING VELOCITY

10.13.4.1 PITCH (LAMDA)= 0.129 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.084 INCHES

LAMDA/SIGMA= 1.526

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .39784

LOWER STROUHAL NUMBER, SL= .16867

10.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4693. FT/SEC

VL= FR1(SIGMA)/SL

VL= 11069. FT/SEC

10.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 4504. FT/SEC

VL= FR2(SIGMA)/SL

VL= 10623.FT/SEC

10.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 9008. FT/SEC

VL= FB1(SIGMA)/SL

VL= 21247. 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

10.14 PRESSURE DROP

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

LOSS= .000E+00 PSI/FT

11.0 REFERENCES

11.0.1 TVA 80K A2-826892

VERT.HOSE 47W 450-1003/1004 (PEN.NO.X-39A-I/-O)

11.0.2 METAL BELLOWS CORP DRAWING 77751

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

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

11.1 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	0.445 INCHES
CYCLE LIFE	10000 CYCLES
VIBRATION OFFSET DV	0.470 INCHES AT 15 HZ
ALLOWABLE LOADS	
FORCE	N/A LBS
MOMENT	N/A IN-LBS

11.2 HOSE DATA

11.2.1

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	18.625	INCHES
NO OF CONVOLUTIONS, N	144	

11.3 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

11.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.72

11.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.50

11.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.56

11.4 PERFORMANCE EQUATIONS

11.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 2672 PSI

ALLOWABLE STRESS = 18550 PSI

11.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 8918 PSI

ALLOWABLE STRESS = 18550 PSI

11.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 4012 PSI

11.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 25822 PSI

11.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0005699 INCHES

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

EOBE= 0.0008287 INCHES

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

ESSE= 0.0012808 INCHES

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

EV= 0.0006020 INCHES

11.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 434 PSI

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

S5= 632 PSI

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

S5= 977 PSI

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

S5= 459 PSI

11.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 12376 PSI

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

S6= 17994 PSI

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

S6= 27811 PSI

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

S6= 13071 PSI

11.8 TOTAL CYCLIC STRESS

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

ST= 42646 PSI

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

ST= 39510 PSI

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

ST= 49673 PSI

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

ST= 34415 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

11.9 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)

11.10 BRAID ANALYSIS

WIRE DIA, D= .0250 INCHES

NUMBER OF WIRES PER BUNDLE, N= 4

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, BW= 0.390 LBS

11.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 926.71 LBS

11.10.2 BRAID AREA, TOTAL

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

A= 0.094 SQ INCHES

11.10.3 BRAID STRESS

ST= F/ACOSX

ST= 11859 PSI

ALLOWABLE STRESS = 18550 PSI

11.11 SPRING RATES

11.11.1 AXIAL SPRING RATE

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

KA= 381.64 LB/IN

11.11.2 OFFSET SPRING RATE

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

KO= 6.49 LB/IN

11.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 2.89 LB

MAXIMUN ALLOWABLE = N/A LBS

11.11.4 DEFLECTION MOMENTS

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

M= 80.69 IN-LB

MAX UM ALLOWABLE = N/A IN-LB

11.12 NATURAL FREQUENCIES

11.12.1 WEIGHT OF HOSE

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

W1= 1.074 LBS

11.12.2 WEIGHT OF FLUID

W2= .7851(DP)EXP2(L)(.003486)

W2= .669E-01 LBS

11.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.605 LBS

11.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 1.75 LBS

11.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 253.8 HZ

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

F= 507.6 HZ

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

F= 761.5 HZ

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

F= 1015.3 HZ

11.12.6 LATERAL VIBRATION

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

F= 39.4 HZ

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

F= 108.5 HZ

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

F= 211.6 HZ

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

F= 351.5 HZ

11.13 FLOW INDUCED VIBRATION

11.13.1 FLOW VELOCITY

11.13.1.1 SYSTEM FLOW

Q= FR/ 0.0 LB/CUFT/60 SEC/MIN

Q= 0.000 CUFT/SEC

11.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0052 SQFT

11.13.1.3 FLOW VELOCITY

V= Q/A

V= 0.00 FT/SEC

11.13.2 METAL MASS

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

MM= .0000113 LB-(SEC)EXP2/(IN)EXP4

11.13.2.2 FLUID MASS

MF1=.003486DP(H)(3.1416)(.00258)/2((2A-T(NF))

MF1= .120E-06 LB-(SEC)EXP2/(IN)EXP4

MF2=.003486DP(H)EXP3(3.1416)/3DEL

MF2= .109E-05 LB-(SEC)EXP2/(IN)EXP4

11.13.2.3 BELLOWS SPRING RATE

FROM PARA 11.11.1

KA= 381.64 LB/IN

11.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 109912.31 LB/IN

11.13.3 FREQUENCY RANGE (FLEX HOSE)

11.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 22091.4 HZ

11.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 21209.0 HZ

11.13.3.3 FIRST BENDING MODE

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

FB1= 42417.9 HZ

11.13.4 VORTEX SHEDDING VELOCITY

11.13.4.1 PITCH (LAMDA)= 0.129 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.085 INCHES

LAMDA/SIGMA= 1.528

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .39744

LOWER STROUHAL NUMBER, SL= .16855

11.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4706. FT/SEC

VL= FR1(SIGMA)/SL

VL= 11098. FT/SEC

11.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 4518. FT/SEC

VL= FR2(SIGMA)/SL

VL= 10654.FT/SEC

11.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 9037. FT/SEC

VL= FB1(SIGMA)/SL

VL= 21309. 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

11.14 PRESSURE DROP

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

LOSS= .000E+00 PSI/FT

12.0 LOADING COMBINATION:

12.1. WEIGHT (1/2 HORIZONTAL HOSE)

SOCKET ADAPTOR	= .477 LB
FERRULE	= .057 LB
HOSE & BRAIDS (.73 + .41).5	= .57 LB
FLUID IN HOSE (.0453) .5	= .022 LB

1/2 DEAD WEIGHT = 1.126 LB

12.2. ACCIDENT FORCE:

12.2.1. DUE TO INERTIA:

$F = \omega \times g$

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

$= [(1.126 + .592) + .30 + .875] \times (2.52 \cos 15°)$

$= (2.893)(2.434)$

$= 7.04$ LB

REF. PARA 12.1, 11.12.4.

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

$= (1.126) \times (2.52 \sin 15°)$

$= .734$ LB

(c) $F_y = (1.126) \times (.29\ g\text{'s}) = .326$ LB

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

12.3. SEISMIC FORCES : (SSE)

12.3.1. DUE TO INERTIA

$F = W \times g$

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

$= (2.893)(2.4 \cos 15^\circ \text{ g's})$

$= 6.7$ LB

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

$= (1.126)(2.4 \sin 15^\circ \text{ g's})$

$= .699$ LB.

(c) $F_y = (1.126)(.6 \text{ g's}) = .676$ LB

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

12.4. DUE TO MOVEMENT
(ACCIDENT AND SEISMIC FORCE)

12.4.1. $F_x = K_0 x$

$= 6.49 (.85)$

$= 5.51$ LB REF. PARA 11.11.2, 9.1

12.4.2. $F_y = K_0 y$

$= 20.79 (.17)$

$= 3.53$ LB REF. PARA 10.11.2, 9.1

12.4.3 $F_z = K_0 z f^*$ f^* = LENGTH RATIOS 9.1.1.

REF. PARA 10.11.2 9.1.

$= 20.79 (.15)(.404) = 1.26$ LB

12.5. VIBRATION FORCES

12.5.1. DUE TO INERTIA

$F = W \times g$

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

$= (2.893)(.5 g's)$

$= 1.446$ LB

(b) $F_y = F_z = 1.126\ (.5 g's)$

$= .563$ LB

12.6. TOTAL FORCE

12.6.1. IN x - DIRECTION

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

$= (7.04 + 6.7 + 5.51) + 1.446$

$= 20.696$ LB

SPECIFICATION ALLOWABLE

$P_x = .01\, \sigma_y A$

$= .01\,(30{,}000)\,[.7854\,(11.315^2 - 1.049^2)]$

$= 148.16$ LB

$P_x > F_x$

<u>DESIGN IS ADEQUATE</u>

12.6.2. IN Z- DIRECTION:

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

= 6.24 + (.734 + .699 + 1.26) + .563

= 9.496 LBS REF. PARA 10.11.3, 12.4.2

SPECIFICATION ALLOWABLE

$P_z = .01\,\sigma_y A$

= 148.16 LB

$P_z > F_z$ **DESIGN IS ADEQUATE**

12.6.3. IN Y - DIRECTION

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

= 1.126 + (.326 + .676 + 3.53) + .563

= 6.22 LB REF. PARA 12.0. 12.2.1(b) 12.3.1(b), 12.4.3, 12.5.1(b)

SPECIFICATION ALLOWABLE

$P_Y = .01\,\sigma_y A$

= 164.8 LB

$P_Y > F_Y$ **DESIGN IS ADEQUATE**

METAL Bellows CORPORATION
20977 KNAPP STREET
CHATSWORTH, CALIFORNIA 91311

ENGINEER	REFERENCE NUMBER		
F. Ahem	CR683 P/N-77751		
DATE	CUSTOMER	PAGE	OF
4-18-80	TVA	70	

12.7. DYNAMIC MOMENT

MOMENT ARMS:

SOCKET ADAPTORS	.477 LB x .695 IN = .332	IN-LB
FERRULE	.057 LB x 2.015 IN. = .115	IN-LB
HOSE & BRAIDS	.57 LB x 4.55 IN. = 2.593	IN-LB
FLUID IN HOSE	.023 LB x 1.39 IN. = .032	IN-LB
	TOTAL = 3.072	IN-LB

12.7.1. ACCIDENT MOMENT:

12.7.1.1. DUE TO INERTIA:

(a) $M_z = 3.072 (2.52 \sin 15°)$

$= 2.0$ IN-LB REF. PARA 12.7

(b) $M_y = 3.072(.29) = .89$ IN-LB

12.7.2. SEISMIC MOMENT (SSE)

12.7.2.1. DUE TO INERTIA:

(a) $M_z = 3.072 (2.4 \sin 15°)$

$= 1.908$ IN-LB

PARA. 12.7.

(b) $M_y = (3.072)(.6) = 1.84$ IN-LB

12.7.3. MOMENT AT SOCKET ADAPTOR

HOSE FORCE x L (HOSE END TO SOCKET ADAPTOR)

12.7.3.1. $M_y = F_y (L)$

$= 3.53 (1.39)$

$= 4.91$ IN-LB REF. PARA. 12.4.2.

12.7.3.2. $M_z = F_z (L)$

$= 1.26 (1.39)$

$= 1.751$ IN-LB

REF. PARA. 12.4.3.

12.7.4. TOTAL MOMENT

12.7.4.1. IN z - DIRECTION

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

$= [118.1 + (6.24)(1.39) + 10^*] + 2 + 1.908$

$= 140.68$ IN-LB

* ADDITIONAL DEFLECTION MOMENT DUE TO SEISMIC
REF. PARA 10.11.4, 10.11.3

SPECIFICATION ALLOWABLE 12.7.3.1.

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

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

$= 282.09$ IN-LB

$M_{bz} > M_z$

DESIGN IS ADEQUATE

WHERE:

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

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

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

$= .133$

12.7.4.2. IN Y-DIRECTION

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

= 3.072 + [.89 + 1.84 + (DEFLECTION MOMENT + MOMENT AT SOCKET ADAPTOR)]

= 3.072 + [(.89 + 1.84) + (22.91 + 4.9)]

= 33.62 IN-LB

REF. PARA. 12.7. 12.7.1.1. 12.7.2.1. 12.7.3.2.

DEFLECTION MOMENT IN Y-DIRECTION

$F = (K_o)\, \delta\, f^*$

$= (20.76)(.15)(.404)$

= 1.26 LB

f^* = LENGTH RATIOS

REF. 10.11.2. 9.1. 9.1.1.

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

$= (1.26)(12.125)(3)/2$

= 22.91 IN-LB

SPECIFICATION ALLOWABLE

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

= 282.09 IN-LB

$M_{by} > M_y$

DESIGN IS ADEQUATE

12.8. TORSIONAL MOMENT

$M_x = F_z (L)$

L = ELBOW RADIUS
= 1.5 IN.
f^* = LENGTH RATIO

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

$= [(.59)(.15)(6.49)](1.5)$

$= .86$ (LB-IN)

REF. 9.1.1. 9.1, 11.11.2

SPECIFICATION ALLOWABLE

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

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

= 794 IN-LB

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

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

$= .174$

$M_{tx} > M_x$

<u>DESIGN IS ADEQUATE</u>

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

13.0.1. UNDER ACCIDENT CONDITION:

13.0.1.1. ASSUMPTIONS

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

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
85.7	.713	4	2.852	.0075	±.00375

13.0.1.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(1.145)(\pm.00375)}{([illegible])(16.31)} = \pm.000041$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.16[illegible])^3(1.50)}(\pm.000041) = \pm 32 \text{ psi}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.165)^2(1.56)}(\pm.000041) = \pm 886 \text{ PSI}$$

* NOTE: IT IS WORST frequency. SEE 10.12.6 PAGE 52

13.0.2. UNDER SEISMIC CONDITION

13.0.2.1 ASSUMPTIONS

A. SEISMIC INPUT of $\sqrt{(2.4 \sin 15°)^2 + .6^2}$

FREQUENCY Hz	INPUT g	AMPLIFICATION	OUTPUT g	DISPLACEMENT IN.	EXCUR. IN.
85.7	.863		3.452	.0092	±.0046

13.0.2.2.

EQUIVALENT AXIAL MOTION

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

$$= \frac{3(1.145)(\pm.0046)}{(49)(6.31)} = \pm .0000492$$

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

$$= \frac{(29 \times 10^6)(.019)^2}{2(.165)^3(1.57)} (\pm .0000492) = \pm 38 \text{ PSI}$$

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

$$= \frac{5(29 \times 10^6)(.019)}{3(.165)^2(1.54)} (\pm .0000492) = \pm 1063 \text{ PSI}$$

13.0.3. CYCLE LIFE (ACCIDENT + SSE)

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

$$= .7(4012 + 25854) + (64 + 1772) + (76 + 2126)$$

$$= 24,944 \text{ PSI}$$

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

SINCE $54,000 > S_T$

N_C = INFINITE CYCLES

SPECIFICATION ALLOWABLE = 500 CYCLES

DESIGN IS ADEQUATE

14.0 LOADING:

14.0.1. 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 CONSERVATISM, FULL VALUE USED.

$$= \frac{900\,(1.315)}{4\,(.133)} + \frac{.75\,(1.8)\left[\sqrt{(118.1 + 8.67)^2 + (3.072)^2}\right]}{\pi\,(.591)^2\,(.133)}$$

$= 2224$ PSI $+ 1173$ PSI

$= 3.397$ KSI < 18.55 ksi

REF. PARA 12.11.4. 12.7.

14.0.2 OCCASIONAL LOAD. (NC-3652.2)

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

$$= \frac{900\,(1.315)}{4\,(.133)} + \frac{.75\,(1.8)\left[\sqrt{140.68^2 + 33.62^2}\right]}{\pi\,(.591)^2\,(.133)}$$

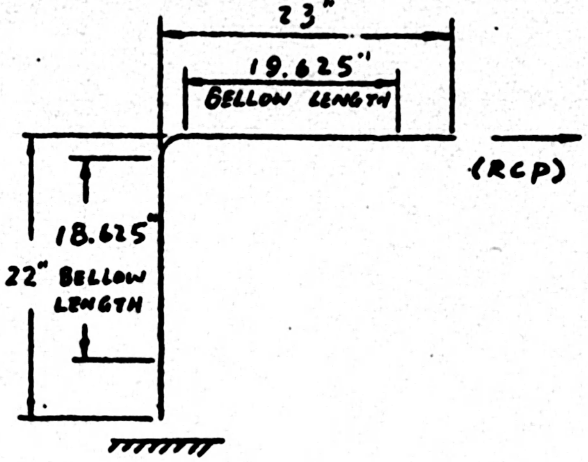
$= 2224$ PSI $+ 1338$ PSI

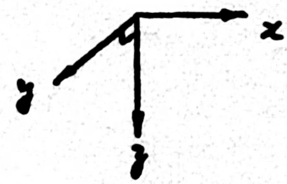
$= 3.562$ ksi < 18.55 ksi

REF. PARA 12.7.4.1, 12.7.4.2 UNDER DESIGN CONDITION

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

15.0 MOTION CORRECTION FOR COMPUTER USE:





15.1. MOTIONS

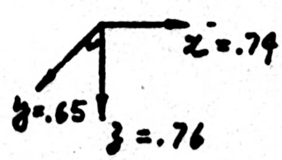
$$\Delta = .059 \frac{L}{\sqrt{D}}$$

$$= .059 \frac{19.625}{1}$$

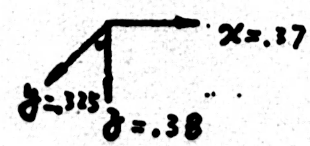
= 1 IN. (UPPER LIMIT)

THERMAL

INSTALLATION



SSE



OBE

15.1.1. TOTAL LENGTH & LENGTH RATIOS:

TOTAL LENGTH = 18.625 + 19.625 = 38.25 IN.

LENGTH RATIOS: $\frac{19.625}{38.25} = .513$

AND

LENGTH RATIOS: $\frac{18.625}{38.25} = .487$

15.1.2. MOTION FOR HORIZONTAL HOSE:

(a) THERMAL $= 1\ (.513) = .513$ IN.

(b) SEISMIC OBE $= \sqrt{z^2 + [.513(y+\Delta)]^2}$

$= \sqrt{.38^2 + [.513(.325+1)]^2}$

$= .778$ IN.

(c) SEISMIC SSE $= \sqrt{z^2 + [.513\ (y+\Delta)]^2}$

$= \sqrt{.76^2 + [.513\ (.65+1)]^2}$

$= 1.13$ IN.

15.1.3. MOTION FOR VERTICAL HOSE

(a) THERMAL $= 1\ (.487) = .487$ IN.

(b) SEISMIC OBE $= \sqrt{x^2 + [.487\ (y+\Delta)]^2}$

$= \sqrt{.37^2 + [.487(.325+1)]^2}$

$= .745$ IN.

(c) SEISMIC SSE $= \sqrt{x^2 + [.487\ (y+\Delta)]^2}$

$= \sqrt{.74^2 + [.487(.65+1)]^2}$

$= 1.09$ IN.

15.1.4. MOTION FOR VIBRATION:

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

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

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

15.1.4.1. HORIZONTAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.513(.043+1)]^2}$$

$$= .53 \text{ IN.}$$

15.1.4.2. VERTICAL HOSE:

$$\text{DISPLACEMENT} = \sqrt{.043^2 + [.487(.043+1)]^2}$$

$$= .51 \text{ IN.}$$

16.0 REFERENCES

16.0.1 TVA 80K A2-826892
HORIZ.HOSE 47W 450-1047(PEN.NO.X-40A-I)

16.0.2 METAL BELLOWS CORP DRAWING 77754

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

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

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

16.1 DESIGN CONDITIONS

OPERATING PRESSURE	1025 PSIG
DESIGN PRESSURE	1025 PSIG
OPERATING TEMPERATURE	70 F
DESIGN TEMPERATURE	70 F
ROOM TEMPERATURE PROOF PRESSURE	1537 PSIG
BURST PRESSURE	4100 PSIG
FLOW RATE	5 GPM
LINE SIZE	1.0 IPS
PF[illegible] .OSS ALLOWABLE	2.0 PSI/FT
MOTIONS	
THERMAL OFFSET, DT	0.513 INCHES
CYCLE LIFE	10000 CYCLES
OBE SEISMIC OFFSET, DOBE	0.778 INCHES
CYCLE LIFE	500 CYCLES
SSE SEISMIC OFFSET, DSSE	1.130 INCHES
CYCLE LIFE	500 CYCLES
VIBRATION OFFSET DV	0.530 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

16.2 HOSE DATA

16.2.1 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	19.625	INCHES
NO OF CONVOLUTIONS, N	152	

16.3 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

16.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.72

16.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.50

16.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.56

16.4 PERFORMANCE EQUATIONS

16.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 3043 PSI

CODE ALLOWABLE= 18700 PSI

16.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 10142 PSI

CODE ALLOWABLE= 18700 PSI

16.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 4570 PSI

16.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 29424 PSI

16.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0005907 INCHES

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

EOBE= 0.0008959 INCHES

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

ESSE= 0.0013012 INCHES

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

EV= 0.0006103 INCHES

16.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 450 PSI

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

S5= 683 PSI

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

S5= 993 PSI

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

S5= 465 PSI

16.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 12834 PSI

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

S6= 19464 PSI

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

S6= 28270 PSI

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

S6= 13259 PSI

16.8 TOTAL CYCLIC STRESS

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

ST= 47280 PSI

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

ST= 43944 PSI

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

ST= 53060 PSI

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

ST= 37522 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

16.9 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)

16.10 BRAID ANALYSIS

WIRE DIA, D= .0250 INCHES

NUMBER OF WIRES PER BUNDLE, N= 4

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, BW= 0.390 LBS

16.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 1055.42 LBS

16.10.2 BRAID AREA, TOTAL

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

A= 0.094 SQ INCHES

16.10.3 BRAID STRESS

ST= F/ACOSX

ST= 13506 PSI

CODE ALLOWABLE= 18700 PSI

16.11 SPRING RATES

16.11.1 AXIAL SPRING RATE

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

KA= 361.79 LB/IN

16.11.2 OFFSET SPRING RATE

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

KO= 5.54 LB/IN

16.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 2.84 LB

MAXIMUM ALLOWABLE = N/A LBS

16.11.4 DEFLECTION MOMENTS

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

M= 83.69 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

16.12 NATURAL FREQUENCIES

16.12.1 WEIGHT OF HOSE

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

W1= 1.133 LBS

16.12.2 WEIGHT OF FLUID

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

W2= 0.727 LBS

16.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.638 LBS

16.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 2.50 LBS

16.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 206.6 HZ

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

F= 413.2 HZ

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

F= 619.8 HZ

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

F= 826.4 HZ

16.12.6 LATERAL VIBRATION

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

F= 30.5 HZ

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

F= 83.8 HZ

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

F= 163.4 HZ

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

F= 271.5 HZ

16.13 FLOW INDUCED VIBRATION

16.13.1 FLOW VELOCITY

16.13.1.1 SYSTEM FLOW

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

Q= 0.011 CUFT/SEC

16.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0052 SQFT

16.13.1.3 FLOW VELOCITY

V= Q/A

V= 2.13 FT/SEC

16.13.2 METAL MASS

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

MM= .0000113 LB-(SEC)EXP2/(IN)EXP4

16.13.2.2 FLUID MASS

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

MF1= .0000012 LB-(SEC)EXP2/(IN)EXP4

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

MF2= .0000113 LB-(SEC)EXP2/(IN)EXP4

16.13.2.3 BELLOWS SPRING RATE

FROM PARA 16.11.1

KA= 361.79 LB/IN

16.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 109985.56 LB/IN

16.13.3 FREQUENCY RANGE (FLEX HOSE)

16.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 21096.6 HZ

16.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 15715.4 HZ

16.13.3.3 FIRST BENDING MODE

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

FB1= 31430.9 HZ

16.13.4 VORTEX SHEDDING VELOCITY

16.13.4.1 PITCH (LAMDA)= 0.129 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.085 INCHES

LAMDA/SIGMA= 1.527

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .39762

LOWER STROUHAL NUMBER, SL= .16860

16.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4486. FT/SEC

VL= FR1(SIGMA)/SL

VL= 10580. FT/SEC

16.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 3342. FT/SEC

VL= FR2(SIGMA)/SL

VL= 7882.FT/SEC

16.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 6684. FT/SEC

VL= FB1(SIGMA)/SL

VL= 15763. 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

16.14 PRESSURE DROP

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

LOSS= 0.03 PSI/FT

PRESSURE LOSS ALLOWABLE= 2.0 PSI/FT

17.0 REFERENCES

17.0.1 TVA 80K A2-826892

VERT. HOSE 47W 450-1047 (PEN.NO.X-40A-I)

17.0.2 METAL BELLOWS CORP DRAWING 77754

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

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

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

17.1 DESIGN CONDITIONS

OPERATING PRESSURE	1025 PSIG
DESIGN PRESSURE	1025 PSIG
OPERATING TEMPERATURE	70 F
DESIGN TEMPERATURE	70 F
ROOM TEMPERATURE PROOF PRESSURE	1537 PSIG
BURST PRESSURE	4100 PSIG
FLOW RATE	5 GPM
LINE SIZE	1.0 IPS
PRESSURE LOSS ALLOWABLE	2.0 PSI/FT
MOTIONS	
THERMAL OFFSET, DT	0.487 INCHES
CYCLE LIFE	10000 CYCLES
OBE SEISMIC OFFSET, DOBE	0.745 INCHES
CYCLE LIFE	500 CYCLES
SSE SEISMIC OFFSET, DSSE	1.090 INCHES
CYCLE LIFE	500 CYCLES
VIBRATION OFFSET DV	0.510 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

17.2 HOSE DATA

17.2.1 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	18.625 INCHES
NO OF CONVOLUTIONS, N	144

17.3 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

17.3.1 FROM FIGURE 38, EJMA STANDARDS

CP= 0.72

17.3.2 FROM FIGURE 39, EJMA STANDARDS

CF= 1.50

17.3.3 FROM FIGURE 40, EJMA STANDARDS

CD= 1.56

17.4 PERFORMANCE EQUATIONS

17.4.1 BELLOWS TANGENT CIRCUMFERENTIAL PRESSURE STRESS

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

S1= 3043 PSI

CODE ALLOWABLE= 18700 PSI

17.4.2 BELLOWS CIRCUMFERENTIAL MEMBRANE PRESSURE STRESS

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

S2= 10157 PSI

CODE ALLOWABLE= 18700 PSI

17.4.3 BELLOWS MERIDIONAL PRESSURE STRESS

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

S3= 4570 PSI

17.4.4 BELLOWS MERIDIONAL PRESSURE BENDING STRESS

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

S4= 29408 PSI

17.5 EQUIVALENT AXIAL MOTION DUE TO OFFSET

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

ET= 0.0006237 INCHES

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

EOBE= 0.0009542 INCHES

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

ESSE= 0.0013960 INCHES

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

EV= 0.0006532 INCHES

17.6 BELLOWS MERIDIONAL MEMBRANE DEFLECTION STRESS

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

S5= 475 PSI

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

S5= 727 PSI

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

S5= 1065 PSI

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

S5= 498 PSI

17.7 BELLOWS MERIDIONAL DEFLECTION STRESS

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

S6= 13544 PSI

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

S6= 20719 PSI

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

S6= 30314 PSI

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

S6= 14183 PSI

17.8 TOTAL CYCLIC STRESS

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

ST= 47999 PSI

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

ST= 45232 PSI

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

ST= 55164 PSI

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

ST= 38467 PSI

* MODIFIED EJMA FATIGUE ANALYSIS BASED ON CYCLING PRESSURE.

** EJMA FATIGUE ANALYSIS BASED ON CONSTANT PRESSURE.

17.9 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)

17.10 BRAID ANALYSIS

WIRE DIA, D= .0250 INCHES

NUMBER OF WIRES PER BUNDLE, N= 4

NUMBER OF BUNDLES, B= 48

ANGLE FROM HOSE AXIS, X=34 DEGREES

WEIGHT PER FOOT, BW= 0.390 LBS

17.10.1 END LOAD DUE TO PRESSURE

F= .7854(DP)EXP2(P)

F= 1055.42 LBS

17.10.2 BRAID AREA, TOTAL

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

A= 0.094 SQ INCHES

17.10.3 BRAID STRESS

ST= F/ACOSX

ST= 13506 PSI

CODE ALLOWABLE= 18700 PSI

17.11 SPRING RATES

17.11.1 AXIAL SPRING RATE

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

KA= 381.64 LB/IN

17.11.2 OFFSET SPRING RATE

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

KO= 6.49 LB/IN

17.11.3 THERMAL DEFLECTION FORCES

F= (KO)(DT)

F= 3.16 LB

MAXIMUM ALLOWABLE = N/A LBS

17.11.4 DEFLECTION MOMENTS

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

M= 88.31 IN-LB

MAXIMUM ALLOWABLE = N/A IN-LB

17.12 NATURAL FREQUENCIES

17.12.1 WEIGHT OF HOSE

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

W1= 1.074 LBS

17.12.2 WEIGHT OF FLUID

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

W2= 0.690 LBS

17.12.3 WEIGHT OF BRAID

W3= (BW)(L)/12

W3= 0.605 LBS

17.12.4 TOTAL WEIGHT

W= W1+W2+W3

W= 2.37 LBS

17.12.5 AXIAL VIBRATION (PARALLEL TO AXIS)

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

F= 217.9 HZ

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

F= 435.8 HZ

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

F= 653.6 HZ

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

F= 871.5 HZ

17.12.6 LATERAL VIBRATION

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

F= 33.9 HZ

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

F= 93.1 HZ

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

F= 181.6 HZ

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

F= 301.8 HZ

17.13 FLOW INDUCED VIBRATION

17.13.1 FLOW VELOCITY

17.13.1.1 SYSTEM FLOW

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

Q= 0.011 CUFT/SEC

17.13.1.2 FLOW AREA

A= .7854(D)EXP2

A= 0.0052 SQFT

17.13.1.3 FLOW VELOCITY

V= Q/A

V= 2.13 FT/SEC

17.13.2 METAL MASS

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

MM= .0000113 LB-(SEC)EXP2/(IN)EXP4

17.13.2.2 FLUID MASS

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

MF1= .0000012 LB-(SEC)EXP2/(IN)EXP4

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

MF2= .0000112 LB-(SEC)EXP2/(IN)EXP4

17.13.2.3 BELLOWS SPRING RATE

FROM PARA 17.11.1

KA= 381.64 LB/IN

17.13.2.4 ELEMENTAL SPRING RATE

KE= 2NC(KA)

KE= 109912.31 LB/IN

17.13.3 FREQUENCY RANGE (FLEX HOSE)

17.13.3.1 IN-PHASE LONGITUDINAL

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

FR1= 21083.8 HZ

17.13.3.2 OUT-PHASE LONGITUDINAL

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

FR2= 15719.0 HZ

17.13.3.3 FIRST BENDING MODE

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

FB1= 31438.0 HZ

17.13.4 VORTEX SHEDDING VELOCITY

17.13.4.1 PITCH (LAMDA)= 0.129 INCHES

CONVOLUTION WIDTH (SIGMA)= 0.085 INCHES

LAMDA/SIGMA= 1.528

FROM FIGURE 1

UPPER STROUHAL NUMBER, SU= .39744

LOWER STROUHAL NUMBER, SL= .16855

17.13.4.2 FOR FR1

VU= FR1(SIGMA)/SU

VU= 4492. FT/SEC

VL= FR1(SIGMA)/SL

VL= 10591. FT/SEC

17.13.4.3 FOR FR2

VU= FR2(SIGMA)/SU

VU= 3349. FT/SEC

VL= FR2(SIGMA)/SL

VL= 7896.FT/SEC

17.13.4.4 FOR FB1

VU= FB1(SIGMA)/SU

VU= 6698. FT/SEC

VL= FB1(SIGMA)/SL

VL= 15793. 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

17.14 PRESSURE DROP

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

LOSS= 0.03 PSI/FT

PRESSURE LOSS ALLOWABLE= 2.0 PSI/FT