TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

5/10/83

May 4, 1983

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Adensam:

In the Matter of the Application of	)	Docket No. 50-438
Tennessee Valley Authority	)	50-439

By letter dated April 28, 1983 TVA requested NRC approval for use of flexible metal hose at Bellefonte Nuclear Plant. Included with that letter was data demonstrating compliance with Regulatory Guide 1.84 and ASME Code applications addressed in Code Case N-192.

Because of an inadvertent error, the data transmitted was not complete. Enclosed are seven copies of the additional documentation demonstrating compliance with Code Case N-192 for use of flexible metal instrumentation hose assemblies at Bellefonte. Pursuant to section 50.55a(a)(2)(ii) of 10 CFR Part 50, the enclosed is provided for your review.

If you have any questions concerning this matter, please get in touch with Bill Watters at FTS 858-2691.

See Drawings Jacket

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Licensing

Sworn to and subscribed before me
this 4th day of May 1983

Bryant M. Lowery
Notary Public
My Commission Expires 4/8/86

Enclosures (7)
cc: U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30303
See Drawings Jacket

8305100358

No. 828398

TENNESSEE VALLEY AUTHORITY

DESIGN SPECIFICATION

BNP-DS-1940-4809-R0

BELLEFONTE NUCLEAR PLANT

FLEXIBLE METAL INSTRUMENTATION HOSES

FOR INSTRUMENTATION AND CONTROL SYSTEM

I certify that this design specification is correct and complete and is in compliance with Paragraph NCA-3252 of the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components. This design specification consists of the following:

		Revision No. or Date
1.	Item 1	R0
2.	Attachment C, Quality Assurance Requirements for ASME Section III Components (Excluding Pumps, Valves, and Automatic Backwash Filters), Component Supports, and Piping Subassemblies	8-20-80
3.	Attachment M, Marking and Certification Requirements for Pipe, Fittings, Flanges, and Bolting for Use in ASME Section III Nuclear Class 2 or 3 Systems	9-20-79
4.	Attachment Q, Pipe, Fittings, Tubing, and Miscellaneous Components Austenitic Stainless Steel Heat Treatment Welding Materials, Packaging, and Marking	3-25-80

Ivan L. Beltz
Registered Professional Engineer

IVAN LEE BELTZ
REGISTERED ENGINEER
NO. 9702
STATE OF TENNESSEE

Prepared	Date	Correlated	Date	Submitted	Date	Approved	Date
T.R. Witmer	9-3-80	H.W. Johnson	9-3-80	[illegible]	9-3-80	C.A. Chandley	9-3-80

TENNESSEE VALLEY AUTHORITY

ASME SECTION III

CLASS 2 FLEXIBLE HOSE ASSEMBLIES

DESIGN SPECIFICATION CRITERIA LOCATOR

INFORMATION REQUIRED BY NCA-3252 AND ITS LOCATION IN THIS SPECIFICATION

1.	Function of the component including any dimensions upon which the functional performance depends.	Schedule of prices
2.	The design requirements, i.e., the mechanical and operational loadings.	Schedule of prices
3.	The environmental conditions, including radiation.	Schedule of prices
4.	The code classification of the component.	Schedule of prices
5.	The definition of the component.	Schedule of prices
6.	Material requirements.	Schedule of prices
7.	Certification of the design specification.	Cover sheet
8.	Operability requirements.	Schedule of prices

Schedule of Prices

No. 828398
Page No. 1

ITEM No.	ARTICLES OR SERVICES (GIVE DESCRIPTION OR CATALOG NO.)	QUANTITY	UNIT	UNIT PRICE (Quote unit price and compute extension)	AMOUNT
	Flexible instrumentation hose - The flexible hose shall be a straight section of hose with end connections. Flexible hose shall be NPT stamped and meet the requirements of ASME B&PV Code Case N-192. The flexible hose is to have annular convolutions and be covered with braid. The pressure containing boundary consists of single-ply, welded or seamless tubing of inconel 625, ASME SB-443 (Material to meet the requirements of SB-444 as modified by ASME Code Case N-188. Pressure test may be performed at top assembly, reference ND-6114.), or SB-444. The braided wire covering the convoluted metal bellows shall be stainless and heat resisting steel wire in accordance with ASTM A 580-75 of material types listed in Tables I-7.0 and I-8.0 of ASME SA-479. All wire strands shall be welded to the welding collars and visually examined. The end connections shall be square cut 3/8" od tube with a wall thickness of 0.065", material of ASME SA-213, TP304. The end connections shall be of sufficient length to adapt to a standard compression fitting. Metal Bellows Corporation nuclear instrumentation hose assembly, or equal. The boundaries of the hose assemblies are the ends of the end connections. The complete flexible hose assembly requires NPT stamp.				

TVA 5051 (DP-9-73)

BIDDER _____

Schedule of Prices

No. 828398
Page No. 2

ITEM NO.	ARTICLES OR SERVICES (GIVE DESCRIPTION OR CATALOG NO.)	QUANTITY	UNIT	UNIT PRICE (Quote unit price and compute extension)	AMOUNT
	Design Requirements Function The hose assemblies will transport essential air from the systems essential air headers to the instrument air sources at various locations and elevations in the auxiliary building and the secondary containment of the reactor building. Internal Conditions Design pressure = 150 lb/in^2g Operating pressure = 100 lb/in^2g Design temperature = 150° F Operating temperature = 100° F Pneumatic test pressure = 187-1/2 lb/in^2g Pneumatic test temperature = Ambient Auxiliary Building Environment Conditions Nominal: Temperature = 50° F to 120° F Pressure = 14.3 to 16.0 Humidity = 30% to 80% Radiation = Up to 1×10^8 rads 40 years accumulated design Upset: Temperature = 50° F to 120° F Pressure = 14.3 to 16.0 Humidity = 10% to 98% Radiation = Up to 1×10^8 rads 40 years accumulated design Accident: Temperature = 400° F Pressure = 30 lb/in^2g Humidity = 100% Radiation = Up to 1×10^8 rads 40 years accumulated design				

TVA 5051 (DP-9-73)

BIDDER _____

ITEM NO.	ARTICLES OR SERVICES (GIVE DESCRIPTION OR CATALOG NO.)	QUANTITY	UNIT	UNIT PRICE	AMOUNT
				(Quote unit price and compute extension)	

Cyclic Life Requirements

General

The hose assemblies shall be designed for a total lifetime of 40 years while undergoing the conditions specified below. Each hose assembly shall be identical. Cyclic life design shall be based on analytical and test results. A certified design report shall be submitted for permanent retention by TVA. Satisfaction of the requirements of applicable ASME Code criteria shall be documented.

Model Description

The hose assemblies will be installed per Contractor's recommendations as delineated in an instruction manual to be submitted for permanent retention by TVA. Displacements are applied to one end connection along three orthogonal axes simultaneously. The assembly is filled with fluid and pressurized to the operating pressure. Flexible instrumentation hoses and material shall be manufactured in accordance with Section III of the ASME Boiler and Pressure Vessel Code, Division 1, latest edition and addenda in effect on contract date.

Installation

A nominal offset misalignment of $\pm 1/2''$ in the X, Y, and Z directions shall be assumed in the design calculations as a result of installation. Installation temperature is assumed to be 70° F.

Displacement Due to Thermal Expansion

The hose assemblies shall be capable of the following thermal expansion movements for 5000 cycles:

X axis =)
)
Y axis =) Vectorial sum = 5.0"
)
Z axis =)

Mechanically Induced Vibration

Sine wave input corresponding to 0.5 g acceleration in each direction at frequencies of 10, 15, 30, and 60 Hz. Evaluate for input at most critical frequency for 40 years of continuous service.

Schedule of Prices

No. - 828398
Page No. 4

ITEM NO.	ARTICLES OR SERVICES (GIVE DESCRIPTION OR CATALOG NO.)	QUANTITY	UNIT	UNIT PRICE (Quote unit price and compute extension)	AMOUNT
	Pressure Fluctuations Internal pressure from zero to operating pressure for 5000 cycles. Seismic Criteria Seismic test criteria shall be as delineated in Metal Bellows Corporation's qualification test procedure QTP73989, paragraph 4.6. Protection from Damage Contractor shall furnish data with respect to the susceptibility of the flexible instrumentation hose assemblies to damage by inadvertent mishandling (e.g., crushing and kinking) and also provide any special handling instruction/protection methods he feels are required to prevent such damage. Flexible instrumentation hoses and material shall be manufactured in accordance with Section III of the ASME Boiler and Pressure Vessel Code, Division 1, latest edition and addenda in effect on contract date. For additional requirements see attachments C, M, and Q and contract document requirements list. ASME Section III, Class 2				
1	3/8" od tube size — Mark No. 5GM0900-642	200	EA		
	Brand name & figure No. _____ Manufacturer _____ Point of manufacture _____ Drawing submittal after award, days _____				

TVA 5051 (DP-9-73)

BIDDER _____

Schedule of Prices

No. 828398
Page No. 5

ITEM NO.	ARTICLES OR SERVICES (GIVE DESCRIPTION OR CATALOG NO.)	QUANTITY	UNIT	UNIT PRICE (Quote unit price and compute extension)	AMOUNT
	Has the supplier's, manufacturer's or bidder's Quality System Certificate or Quality Assurance Program been approved on a previous TVA contract? Yes____ No ____ If not, please refer to attachment C and ensure that your bid complies with the submittal requirements therein. If yes, identify in the following space the previous TVA contract number on which approval was obtained: _____ Noncompliance with the above may result in your bid being ruled nonresponsive. Shipping Data. Bidder must state: Number of calendar days after award for delivery, days _____ Point of origin of shipment _____ Method of shipment from origin and name of first carrier _____ _____ Method of delivery at destination _____ Shipping weight _____				

TVA 5051 (DP-9-73)

BIDDER _____

METAL Bellows CORPORATION

#N
OKR
1-5-87

CR 730

DOCUMENTATION OF COMPLIANCE

FOR

MBC PART NO. 78153

TO THE REQUIREMENTS OF

ASME SECTION III NC-3649 AND CODE CASE N-192 & N-188-1

PREPARED FOR

TENNESSEE VALLEY AUTHORITY

KNOXVILLE, TENNESSEE

REFERENCES

MBC JOB NO. 15278

MBC DESIGN REPORT CR 729

N4M-526
DATE: OCT 21 1980
PROJECT BLN CONTRACT 80KA3828398
DRAWING # CR 730
SHEET ___ REV A UNIT 1 & 2
USE: FLEX HOSE ASSY. FOR
INSTR. & CONTROL SYS

No. of Pages: 5

September 22, 1980

Revision A, October 17, 1980

Metal Bellows Corporation

VERIFICATION OF SPECIFICATION

Title: DOCUMENTATION OF COMPLIANCE FOR METAL BELLOWS CORPORATION PART NO. 78153

Revision: A RHN 10-17-80

Reference: Tennessee Valley Authority SPECIFICATION NO. BNP-DS-1940-4809-R0 AND MBC DESIGN REPORT CR 729, REVISION A

Prepared by: T. Shen Date: 9/23/80

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

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

REGISTERED PROFESSIONAL ENGINEER
RONALD H. NYSTROM
No. 17261
MECHANICAL
STATE OF CALIFORNIA

Signature: Ronald H. Nystrom

Name: Ronald H. Nystrom

Number: 17261

Date: September 24, 1980

20960 Knapp Street • Chatsworth, California 91311 • U.S.A. • Telephone (213) 341-4900 • Telex 651-483

INDEX OF REVISIONS

Date and Rev.	Pages Affected			Remarks	Revised By
	Revised	Added	Deleted		
10/17/80 A	Cover, i			Changed to Revision A	RK Nystrom 10-17-80

SUB-ARTICLE NUMBER	SUB-PARA NO.	ASME SECTION III SUBSECTION ND 3649 REQUIREMENTS	COMPLIANCE BY OWNER	COMPLIANCE BY MBC	REMARKS /NOTES
3649.2	(A)	PIPING SYSTEM LAYOUT, ANCHORAGE, GUIDING AND MOTIONS	X		1
	(B)	RIGID ANCHORS	X		2
	(C)	INSTALLATION LOCATIONS AND INSPECTION ACCESSIBILITY	X		3
	(D)	SHIPPING BARS	NOT REQD		4
	(H)	FLOW DIRECTION MARKINGS	NOT REQD		5
	(F)	INTERNAL SLEEVES	NOT USED		6
3649.3		ALL PRESSURE BOUNDARY MATERIAL PER ND 2000		X	7
3649.4	(A)	ALLOWABLE CIRCUMFERENTIAL BELLOWS MEMBRANE STRESS		X	8
	(B)	ALLOWABLE MERIDIONAL MEMBRANE AND BENDING STRESS AT 1-1/2 DESIGN PRESSURE FOR NO PERMANENT DEFORMATION		X	9
	(C)	MINIMUM ALLOWED SQUIRM PRESSURE		X	10
	(D)	STRESS MULTIPLICATION FACTOR FOR DESIGN LIFE (KS)(S)(SF		X	11
	(E)	COMPLIANCE DEMONSTRATED BY (1),(2) OR (3)			
		(1) CALCULATED STRESSES VS STD LIFE VERIFIED BY TESTS		X	12
		(2) INDIVIDUAL TEST TO VERIFY SINGLE DESIGN	NOT APPLICABLE		
		(3) DESIGN ANALYSIS PER ND 3200	NOT APPLICABLE		
	(F)	PROCEDURES USED BY CERTIFICATE HOLDER TO VERIFY DESIGN		X	13
	(G)	TYPES OF SIGNIFICANT STRESSES FOR LIFE CALCULATIONS		X	14
	(H)	CERTIFICATE HOLDERS COMPLIANCE REPORT TO ND 3649		X	THIS REPORT
	(I)	CYLINDRICAL BELLOWS COLLARS		X	15
	(J)	EXPANSION JOINT SPRING RATES		X	16
CODE CASE NUMBER N-192 USE OF FLEXIBLE HOSE				X	17

REMARKS/NOTES

1 OWNER WILL COMPLY AND HAS STATED THE EXACT END MOTIONS REQUIRED OF THE HOSE.

2 THE BRAID PROVIDES THE AXIAL RESTRAINT CAUSED BY THE PRESSURE END LOAD, TO MINIMIZE THE NEED FOR RIGID ANCHORS

3 OWNER WILL COMPLY; THE PERVIOUS BRAID WILL ALLOW WATER TO LEAK, SEEP, OR FLOW THROUGH IF LEAK DEVELOPS IN HOSE.

4 EXTRA SHIPPING BARS ARE NOT REQUIRED TO MAINTAIN PROPER FACE-TO-FACE LENGTH BECAUSE THE HOSE BRAID PROVIDES REQUIRED RESTRAINT.

THE OWNER MUST COMPLY WITH ALIGNMENT INSTALLATION REQUIREMENTS.

5 FLOW DIRECTION NOT REQUIRED FOR A HOSE.

6 NOT REQUIRED. FLOW VELOCITIES ARE BELOW CRITICAL LEVELS NOTED IN STRESS REPORT CR 729

7 ALL PRESSURE BOUNDARY MATERIAL SHALL CONFORM TO ND2000. THE BRAID MATERIAL SHALL MEET THE REQUIREMENTS OF ASTM-A-580, AND MATERIAL PHYSICAL PROPERTIES SHALL MEET THE REQUIREMENTS OF SECTION III TABLE I-7-2, PLATE MATERIAL.

8 THE STRESS ANALYSIS IS PERFORMED ON THE BELLOWS ONLY AND IGNORES THE COMPRESSIVE HOOP SUPPORT PROVIDED BY THE BRAID.

CALCULATED HOOP STRESS PER CR 729 IS 1.13 KSI
CODE ALLOWABLE STRESS IS 27.50 KSI FOR 625 CRES AT 150 F

REQUIREMENT IS MET.

9 THE CALCULATED BENDING STRESS IS 2.81 KSI BENDING, PLUS 0.56 KSI MERIDIONAL, OR 3.37 KSI TOTAL BENDING STRESS AT OPERATING, TIMES 1.5 = 5.05 KSI PROOF PRESSURE STRESS. ALLOWABLE BENDING STRESS = 1.5 X 120 = 180 KSI FOR 2% CHANGE. DESIGN IS ADEQUATE FOR 7% CHANGE PERMITTED BY THE CODE.

10 THE BRAID PROVIDES THE EXTERNAL RESTRAINT TO THE HOSE BELLOWS AND REMAINS ON AT ALL TIMES.

NOTE: EXTERNAL RESTRAINT IS PERMITTED FOR SQUIRM TESTS PER LAST SENTENCE OF PARAGRAPH.

THE HOOP EXTERNAL RESTRAINT FORCE FAR EXCEEDS THE LOW OFFSET LOADS CAUSED BY THE HOSE SQUIRMING.

IN BURST TESTS TO FAILURE (4 TIMES MIN OPERATING PRESSURE), THE HOSE DOES NOT SQUIRM AT ANY TIME, EVEN THOUGH THE BELLOWS DEFORMS DRASTICALLY WITHIN THE BRAID. IN SEVERAL TESTS (AFTER FAILURE) THE BELLOWS HOSE APPEARED TO LOOK LIKE A TUBE INSIDE THE BRAID WITH INTERNAL STIFFENING RINGS. THE OUTSIDE RADIUS OF THE BELLOWS INCREASES TO LOOK LIKE A TUBE WHILE THE INSIDE BELLOWS RADIUS BECOMES VERY SMALL. THIS BURST TEST TO FOUR TIMES MINIMUM OPERATING EXCEEDS THE 2.25 TIMES SQUIRM REQUIREMENT BY THIS PARAGRAPH.

THE HOSE PITCH DOES NOT CHANGE BECAUSE OF THE FRICTION LOAD CAUSED BY THE HOOP SQUEEZE OF THE BRAID

(1) HOSES ARE NORMALLY HELD ONLY AT ONE END BY THE EQUIPMENT WHICH APPLIES THE TEST PRESSURE. THE OPPOSITE END IS ALLOWED TO MOVE AS REQUIRED TO FIT PRESSURE TEST TANK.

(2) PROOF TEST PRESSURE WAS INCREASED TO ACCOUNT FOR DESIGN TEMPERATURES.

11 (KS)(S)(SF

SF = 320 KSI FOR 5000 CYCLES

KS = (KCS)(KSS)

KSC = 2SC/(SC+SH) = 1.008
KSS = 1.470 - (.044)(NUMBER OF TESTS)
KSS = 1.470 - (.044)(25)

(ACTUALLY MBC HAS MORE THAN 25 TESTS PERFORMED TO

REAFFIRM S-N CURVE)

KSS = 0.37

KS = (1.008)(.37) = .37

KS = USE 1.25 (MIN CODE ALLOWABLE)

S = 159.10 KSI (SEE CR 729 PARA 2.8)

(1.25)(159.10) KSI < 320KSI
198.88 KSI < 320 KSI

REQUIREMENT IS MET.

12 MBC IS USING THE STANDARD PUBLISHED AND MODIFIED BY TEST EQUATIONS OF EJMA TO DEMONSTRATE COMPLIANCE WITH THIS LIFE REQUIREMENT. MBC STRESS REPORT, CR729 PROVIDES THE CALCULATIONS TO SHOW LIFE IS MET.

MBC HAS CONDUCTED MANY TESTS OF ITS OWN AND HAS FOUND RESULTS TO BE VERY SIMILAR TO EJMA RESULTS.

13 SEE DESIGN STRESS REPORT CR729 USED FOR DESIGN VERIFICATION. SEISMIC TEST REPORTS CR364, CR427, CR439 & CR725 ARE AVAILABLE FOR TEST VERIFICATION.

14 ALL TYPES OF STRESS CYCLES WERE CONSIDERED WITH PRESSURE STRESS AND MOTION STRESS OCCURRING SIMULTANEOUSLY TO PRODUCE THE SIGNIFICANT STRESS FOR LIFE CALCULATIONS.

CUMULATIVE STRESSES FOR SEISMIC AND THERMAL MOTION MEET ASME B & PV CODE REQUIREMENT PERND 3649.4(G) AS FOLLOWS

TYPE

T1 = 5000 THERMAL LIFE CYCLES
T2 = 100 SEISMIC LIFE CYCLES

CYCLES STRESS PER CR 729 PARA 2.8

STT = 159.10 KSI (THERMAL)
STS = 158.10 KSI (SEISMIC)

CALCULATED CYCLIC LIFE PER CR 729 PARA 2.9

N1 = 24125 CYCLES (THERMAL)
N2 = 24930 CYCLES (SEISMIC)

USAGE FACTORS

U1 = T1/N1 = .2072538
U2 = T2/N2 = .0040111

CUMULATIVE USAGE FACTORS SHALL NOT EXCEED 1.0

U1 + U2 + ETC < 1.0
.207254 + .004011< 1.0
.211265 < 1.0

REQUIREMENT IS MET.

15 CYLINDRICAL COLLARS ARE USED AND ARE ACCOUNTED FOR, SINCE THE COLLARS PROVIDE AN EXCELLENT LOCATION TO ATTACH THE LIGHT WALL BELLOWS MATERIAL TO HEAVIER RING WHERE THE BRAID AND TUBE STUB ARE ATTACHED. ATTACHMENT OF THE HOSE (OR BELLOWS) JOINTS MEETS THE REQUIREMENTS OF THE ASME B & PV CODE SECTION III PARA. ND4800.

16 THE SPRING RATE FOR A LONG HOSE IS USUALLY SO LOW THAT IT IS DIFFICULT TO MEASURE WITHOUT THE BRAID BECAUSE OF SQUIRM. CALCULATED SPRING RATES ARE PROVIDED IN CR729. FRICTION FORCES PROVIDE A LARGER PORTION OF THE LOADING THAN SPRING RATE LOADS AND ARE ALSO CONSIDERED, AND A FACTOR IS APPLIED TO SHOW THAT THE IMPOSED LOADS WILL BE LESS THAN THE ALLOWABLE REQUIRED BY THE CUSTOMER.

NO INDIVIDUAL SPRING RATE TESTS WILL BE PERFORMED ON PRODUCTION HOSE.

17 (A) REQUIRED NUMBER OF WIRES FOR HOSE - REF. CR729 PARA 2.10.

N = F/(SA)(COS A) = 5 WIRES

ACTUAL CONSTRUCTION = (24)(7) = 168 WIRES

REQUIREMENT IS MET.

(B) ALL OTHER REQUIREMENTS OF THIS CODE CASE HAVE BEEN MET AS NOTED IN OTHER PORTIONS OF THIS CHECK LIST.

METAL Bellows CORPORATION

N
JUR
1-5-81

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 10-17-80

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

Prepared by: T. Shen Date: 9/23/80

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

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

REGISTERED PROFESSIONAL ENGINEER
RONALD H. NYSTROM
No. 17261
MECHANICAL
STATE OF CALIFORNIA

Signature: Ronald H. Nystrom

Name: Ronald H. Nystrom

Number: 17261

Date: September 24 1980

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METAL Bellows CORP.

INDEX OF REVISIONS

Date and Rev.	Pages Affected			Remarks	Revised By
	Revised	Added	Deleted		
10/17/80 A	Cover, i, ii	27, iii		Added loading requirement	F. [illegible] 10/17/80 [illegible]

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-RO.

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-RO

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

CF= 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

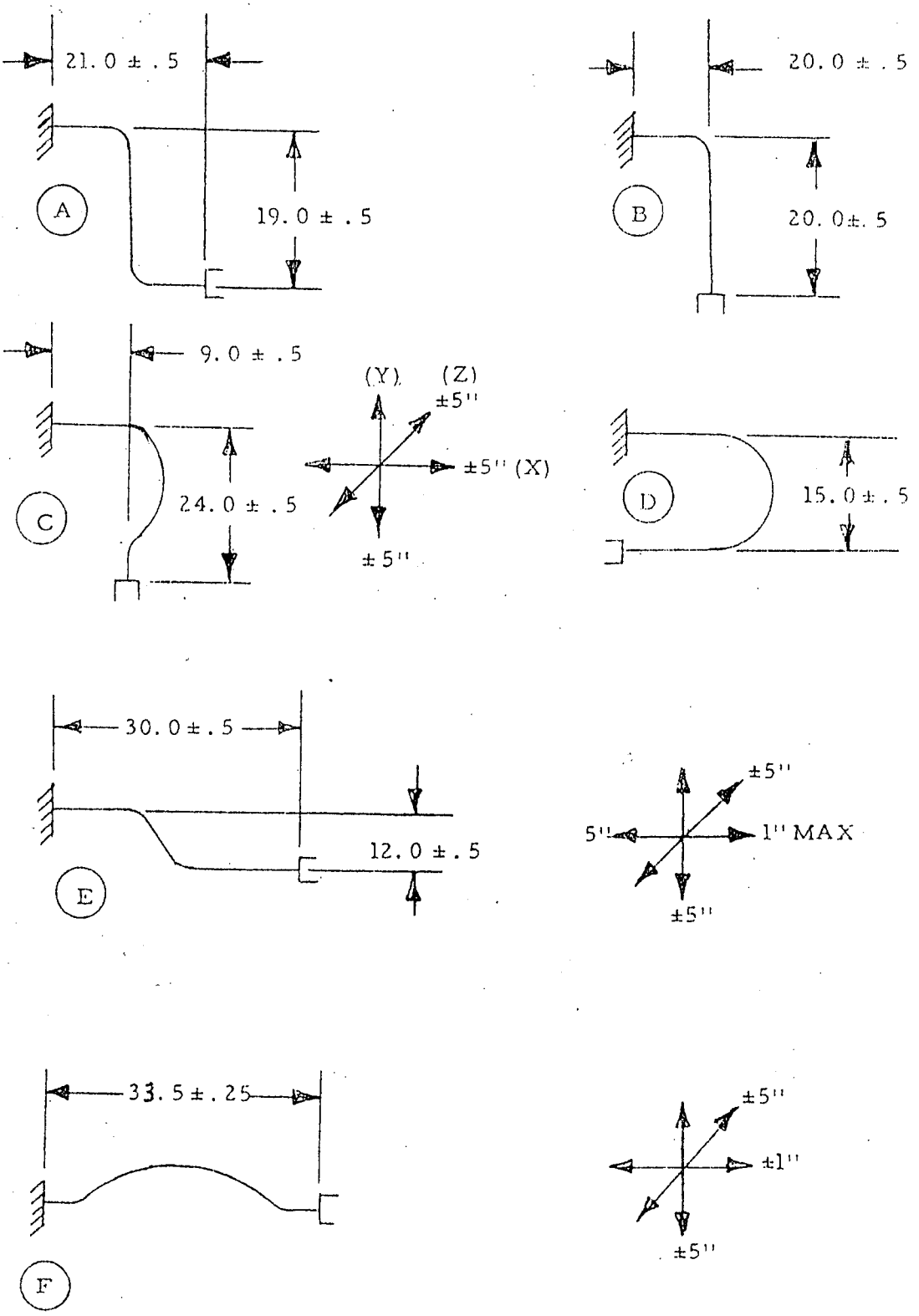

FIGURE 1

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

$$e_\theta = \frac{d_p \, .01745\theta}{2\,N} \qquad \text{(EJMA EQ 3)}$$

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

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

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.

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

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

$$= 28.75 \text{ IN. (USE IN COMPUTER PROGRAM)}$$

3.1. FOR SEISMIC MOTION, THE WORST CASE SHALL BE FREEEND 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:

$F_y = 1.066 \times 2\,g's = 2.132$ LB

$F_z = 1.066 \times 3\,g's = 3.198$ 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:

$$F_y = 1.066 \times 1.5\,g = 1.599 \text{ LB}$$

$$F_z = 1.066 \times 2.0\,g = 2.132 \text{ LB}$$

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

$$= 2.66 \text{ LB} \quad \text{(SHEAR)}$$

4.3.2. DUE TO MOVEMENT:

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

$$= .15 \text{ LB}$$

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

$$= .212 \text{ LB}$$

4.4. VIBRATION FORCES

4.4.1. DUE TO INERTIA:

$$F_y = F_z = 1.066\,(.5\,g\text{'s})$$

$$= .533 \text{ LB}$$

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

$$= .753 \text{ LB}$$

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

4.6.1. SEISMIC MOMENT: (SSE)

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

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

REF. PARA. 4.6.

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

$= 33.481\ IN\text{-}LB$

4.6.2. SEISMIC MOMENT: (OBE)

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

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

REF. PARA. 4.6

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

$= 23.214\ IN\text{-}LB$

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 4.2.2

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

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 3 g

(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:

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

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

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

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

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

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.

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

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

$= .002$ IN. $\qquad t_{MIN} > t_{REQD}$

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

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

$$= 223 + 16465 \text{ (psi)}$$

$$= 16.688 \text{ Ksi} < 18.3 \text{ Ksi}$$

REF. PARA. 4.7.2.

7.0.2. OCCASIONAL LOAD

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

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

$$= 223 + 19529 \text{ (psi)}$$

$$= 19.752 \text{ Ksi} < 21.96 \text{ Ksi}$$

$M_A + M_B$ = 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)