VOLUME II ATTACHMENTS

ATTACHMENT 2 Part II

LIGO-C960964-01-V

TITLE	DOCUMENT NO.	REVISION
I. 80 K Cryopumps		
Analysis of Pump Resevoir	V049-1-067	0
Pump Reservoir Supports	V049-1-070	0
Short Pump - Outer Shell Analysis	V049-1-081	0
Long Pump - Outer Shell Analysis	V049-1-082	0
External Shell Support Design	V049-1-083	1
80K Cryopump 1 1/2 ϕ GN_2 Regeneration Piping	V049-1-114	0
1 1/2 ϕ GN_2 Vent Piping	V049-1-123	0
II. Adapters and Spools		
Ion Pump	V049-1-045	1
Adapter A-1	V049-1-046	0
Adapter A-5	V049-1-051	0
Adapter A-7	V049-1-052	0
Spool B-1 (72 in)	V049-1-053	0
Spool B-2 (30 in)	V049-1-054	0
Spool B-3 (30 in)	V049-1-055	0
Spool B-4 (48 in)	V049-1-056	0
Spool B-5 (30 in)	V049-1-057	1

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REVISION HISTORY

Rev. 0 Original Issue

November 12, 1996

PREFACE

The 1-1/2" ∅ GN_2 regeneration piping for the 80k cryopumps has been analyzed for the design conditions specified in LIGO Project Memorandum Doc. No. V049-I-056 and the Specification for Piping Design and Material V049-2-037 rev. 3. Additional discussions were conducted to verify design conditions. The piping was analyzed using the ALGOR® *PipePlus* computer program for pipe stress analysis.

The 1-1/2" ∅ GN_2 vent piping is identical for both the 80k Long and 80k Short cryopumps. The vent piping is designed for two conditions;

- Normal Operating Condition
- Regeneration/ReGasification

During normal operating conditions the temperature of the 80k pump reservoir is consistently at -320^0 F and 40 psi. The vent pipe is at $-320.^0$F from the reservoir to where it leaves the building at which point it is heat traced. The vent pipe is at 40 psi from the pump reservoir to the bellows and at 25 psi from the bellows to the second support from the reservoir (the analytical model's termination point). At -320^0 F the reservoir *contracts* in the axial and radial directions. Additionally at this temperature, the pump reservoir is filled with GN_2 (liquid) which produces a downward displacement. The vent pipe's nozzle (anchor), which is located on the top of the reservoir, will be displaced relative to the pump reservoir. An unbalanced vacuum load acts at the bellows to vent pipe interface.

During the Regeneration/ReGasification process, nitrogen is pumped into the pump reservoir at 302^0F (150^0 C) and 25 psi. The vent pipe is at $302.^0$F and at 40 psi from the pump reservoir to the bellows and at 25 psi from the bellows to second support from the reservoir (the analytical model's termination point). At $302.^0$F the reservoir *expands* in the axial and radial directions. The pump reservoir is filled with GN_2 (gas) which reduces the weight of the reservoir resulting in lower displacements from the reservoir's weight. The vent pipe is analyzed at $302.^0$F and displaced relative to the pump reservoir. The unbalanced vacuum force is present at the bellows to vent pipe interface.

It is assumed that the bellows imposes negligible reactions on the piping.

PROCESS SYSTEMS INTERNATIONAL, INC.
WESTBOROUGH, MA

ENGINEERING CALCULATIONS	NO: V049-1-123
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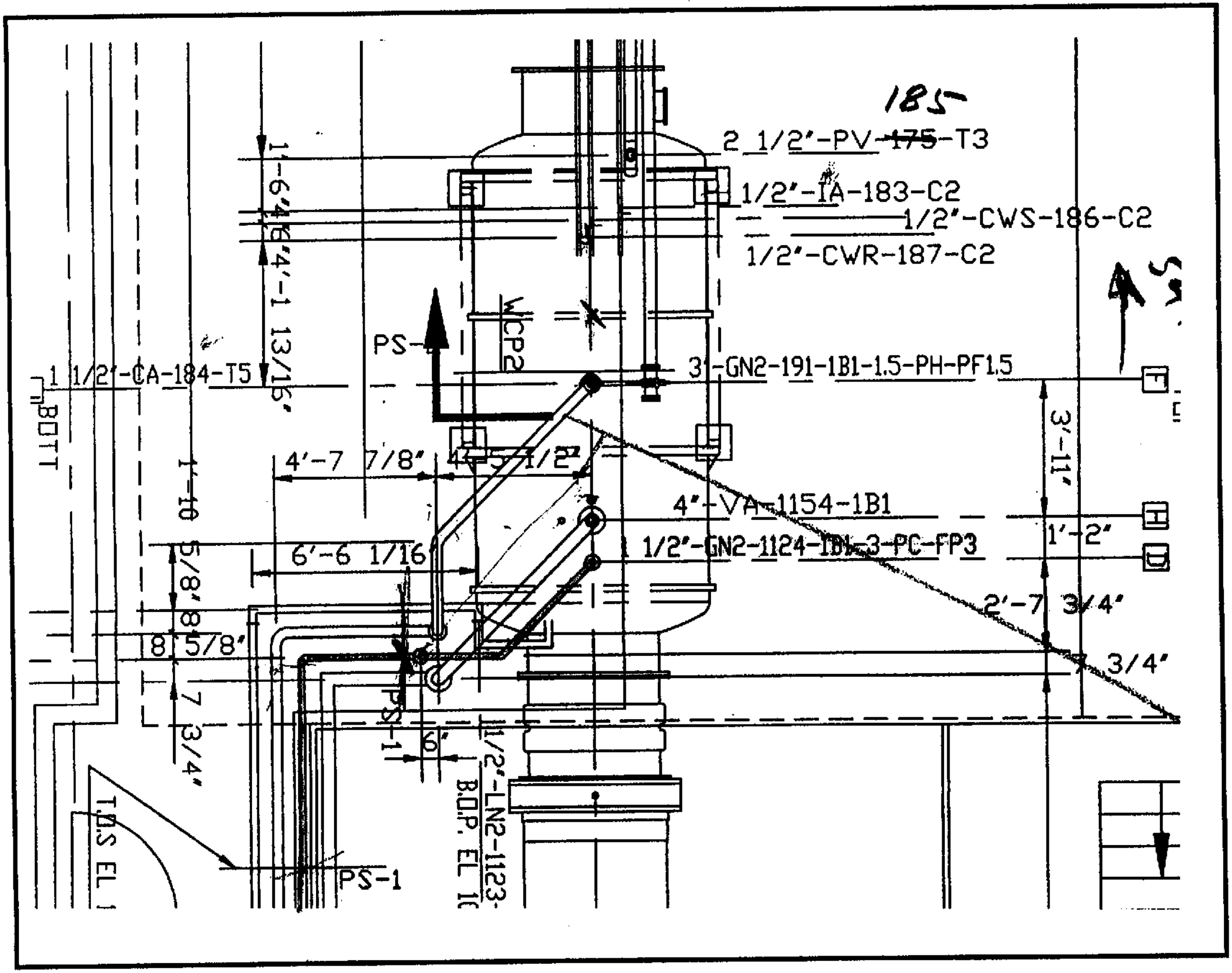
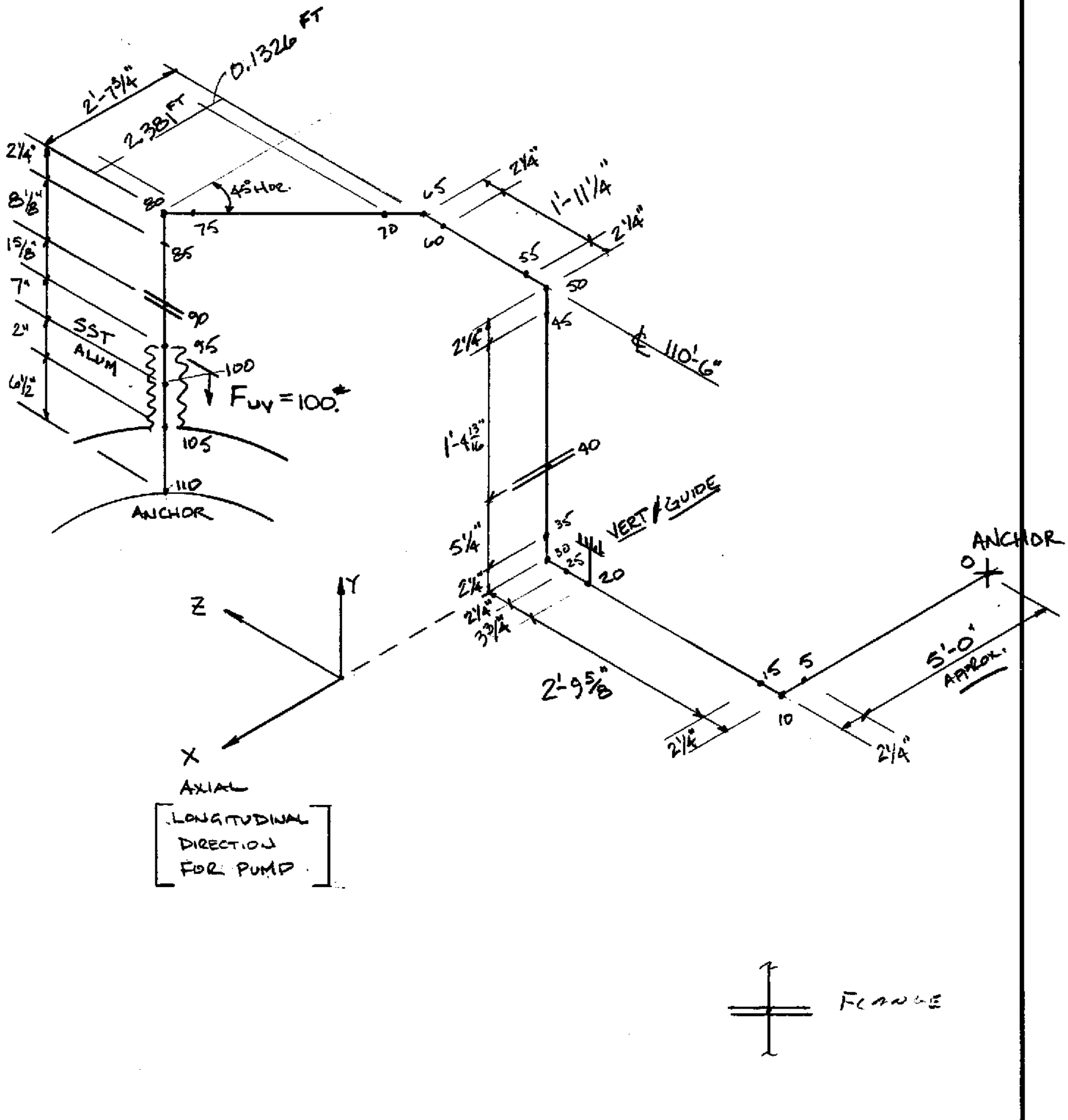
PROJECT: LIGO VACUUM EQUIPMENT

PROJECT NO: V59049

CALCULATION TITLE: 1-1/2" Ø GN, Vent Piping



1½" Φ GN2 VENT



					PSI	JOB NO V59049	PAGE 6
						CALC NO V049-1-123	OF 118
REV	BY	DATE	CHECKED	DATE			

Pipe Properties

Aluminum

1-1/2" ∅ GN_2

B241 AL 6061-T6, Seamless, SCH40S
OD = 1.90 in   ID = 1.610 in
Thks = 0.145 in
Contents (Nitrogen) S.G. = 0.9714
Density = 0.784 #/ft^3

Tensile Strength = 38000. psi (min.)
Yield Strength = 35000. psi
Modulus of Elasticity E = 10,500,000. psi @ −100.^{0}F
E = 9,200,000. psi @ 300.^{0}F

Allowable Stress Range
@ -320.^{0}F σ_{allow} = 6000. psi
@ 70.^{0}F σ_{allow} = 6000. psi
@ 302.^{0}F σ_{allow} = 5500. psi
@ 400.^{0}F σ_{allow} = 3500. psi

Austentic Stainless Steel

1-1/2" ∅ GN_2

SA-312 TP304L CMTR, Seamless, SCH 10S
OD = 1.90 in   ID = 1.682 in
Thks = 0.109 in
Contents (Nitrogen) S.G. = 0.9714
Density = 0.784 #/ft^3

Tensile Strength = 70000. psi (min.)
Yield Strength = 25000. psi
Modulus of Elasticity E = 29,100,000. psi @ −100.^{0}F
E = 27,000,000. psi @ 300.^{0}F

Allowable Stress Range
@ −320.^{0}F σ_{allow} = 15700. psi
@ 70.^{0}F σ_{allow} = 15700. psi
@ 302.^{0}F σ_{allow} = 15300. psi
@ 400.^{0}F σ_{allow} = 14700. psi

Design Operating Conditions

Normal Operation *Pump reservoir operates at -320.^{0}F.*
Vent piping temperature is at −320.^{0}F.
Pump reservoir is at it's heaviest (filled with GN_2 liquid.)
Reservoir is contracting radially and longitudinally (-320.^{0}F.)

Regeneration Process *Purging of pump reservoir with nitrogen gas at 302.^{0}F.*
Vent piping temperature is at 302.^{0}F.
Pump reservoir's weight is decreasing (liquid is being displaced by gas)
Reservoir is expanding radially and longitudinally (as it goes to 302.^{0}F.)

ReGasification *Pump reservoir is at 302.^{0}F*
Vent piping temperature is at 302.^{0}F
Pump reservoir is at it's lightest weight (liquid has changed to a gas).
Reservoir has expanded radially and longitudinally (302.^{0}F.).

Thermal Displacements at Nozzle (Node Pt. 110)

$$\delta_{\text{thermal}} = \alpha\ \Delta T\ L$$

where:

α = 0.0000099 in/in/^{0}F @ −325.^{0}F
α = 0.00001328 in/in/^{0}F @ 300.^{0}F
$\Delta T \Rightarrow {}^0F = (150.^0C. \times 9/5) + 32 = 302.^0F - 70.^0F = 232.^0F$
$\Rightarrow {}^0F = (-210.^0C. \times 9/5) + 32 = -320.^0F - 70.^0F = -390.^0F$
L = Length in inches

Longitudinal Direction

Normal Operation @ −320.^{0}F
$\delta_{\text{thermal}} = \alpha\ \Delta T\ L$
= (0.0000099 in/in/^{0}F) (−320.^{0}F − 70.^{0}F) (8.5 in)
= **−0.0328 in.** (contracting towards reservoirs axial restraints)

Regeneration/ReGasification Process @ 302.^{0}F
$\delta_{\text{thermal}} = \alpha\ \Delta T\ L$
= (0.00001328 in/in/^{0}F) (302.^{0}F − 70.^{0}F) (8.5 in)
= **0.026 in.** (expanding away from reservoirs axial restraints)

Radial Direction

Normal Operation @ −320.^{0}F
$\delta_{\text{thermal}} = \alpha\ \Delta T\ L$
= (0.0000099 in/in/^{0}F) (−320.^{0}F − 70.^{0}F) (29.75 in)
= **−0.1149 in.** (down - contracting toward reservoir's centerline)

Regeneration/ReGasification Process @ 302.^{0}F
$\delta_{\text{thermal}} = \alpha\ \Delta T\ L$
= (0.00001328 in/in/^{0}F) (302.^{0}F − 70.^{0}F) (29.75 in)
= **0.0911 in.** (up - expanding away from reservoir's centerline)

Unbalanced Vacuum Force At Bellows (Node Pt. 95)

$F_{UV} = P\,A$

where:

P = Vacuum Pressure

$P = 14.7\ \#/in^2$

A = Net Area

$A = \pi/4\,[\,(D_M\ in.)^2 - (D_I\ in.)^2\,]$

D_M in. = Inside Diameter of Bellows = 3.50 in.

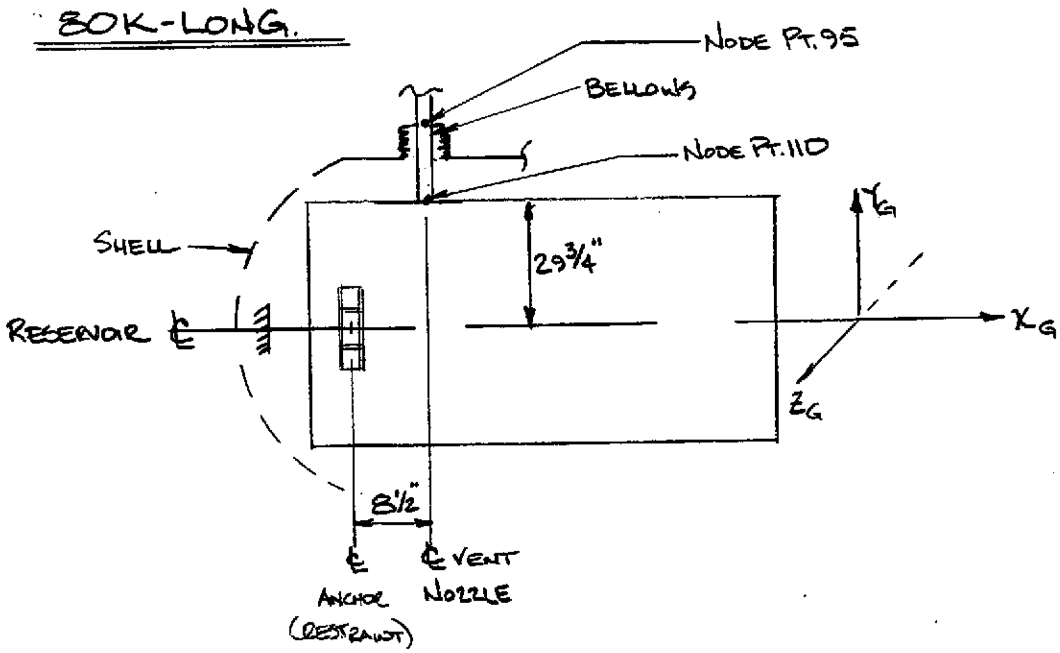
D_I in. = Outside Diameter of 1-1/2"Ø Pipe = 1.90 in.

$A = \pi/4\,[\,(3.50\ in.)^2 - (1.90\ in.)^2\,]$

$F_{UV} = (\,14.7\ \#/in^2\,)\ (\pi/4\,[\,(3.50\ in.)^2 - (1.90\ in.)^2\,])$

$F_{UV} = 99.75\ lbs. \approx 100.0\ lbs.$

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA	**ENGINEERING CALCULATIONS**	**NO: V049-1-** 123 **Rev. No. 0** **Page** 10 **of** 118
PROJECT: LIGO VACUUM EQUIPMENT	**PROJECT NO:**	**V59049**
CALCULATION TITLE: **1-1/2" Ø GN_2 Vent Piping**		



Load Combinations

Normal Operating Condition *(pump reservoir's weight is at it's greatest)*

- Deadweight + Pressure

  Pressure = 25.0 psia (piping beyond the bellows connection)
  Pressure = 25.0 psia + 14.7 psia ≈ 40.0 psia (piping from the reservoir to the bellows)

- Thermal

  $-320.^0$F. Vent piping from pump reservoir. (Vent line remains at $-320.^0$F up to the wall penetration, beyond which it is heat traced.)

- Thermal + Displacement

  $\Delta T = -320.^0$F.
  δ_{thrm} = −0.0328 in. (reservoir's longitudinal direction)
  δ_{thrm} = −0.1149 in. (reservoir's radial inward/contraction direction)
  Displacement (δ) upon loading of GN_2 = −0.078 in. *

- Deadweight + Pressure + Thermal + Displacement

- Deadweight + Pressure + Seismic

  $\delta_{seismic}$ = 0.05625 g (horizontal directions)

* Reference: Memorandum Doc. No. V049-I-104
Measured Weight of Short Cryopump Reservoir

Displacement (δ) is relevant to spring stiffness of the 80k long and short cryopumps

Load Combinations

Regeneration/ReGasification Process (*Purging of pump reservoir with nitrogen gas at 302.^{0}F.*)
(Pump reservoir's weight is decreasing)

- Deadweight + Pressure

  Pressure = 25.0 psia (piping beyond the bellows connection)
  Pressure = 25.0 psia + 14.7 psia ≈ 40.0 psia (piping from the reservoir to the bellows)

- Thermal

  302.^{0}F (Vent piping from the pump reservoir to the second support - model's boundary)

- Thermal + Displacement

  ΔT = 302.^{0}F.
  δ_{thrm} = 0.026 in. (reservoir's longitudinal direction)
  δ_{thrm} = 0.0911 in. (reservoir's radial inward/contraction direction)
  Pump reservoir's displacement (δ) due to purging of GN_2 liquid with gas ≈ 0.00 in.

- Deadweight + Pressure + Thermal + Displacement

- Deadweight + Pressure + Seismic

  $\delta_{seismic}$ = 0.05625 g (horizontal directions)

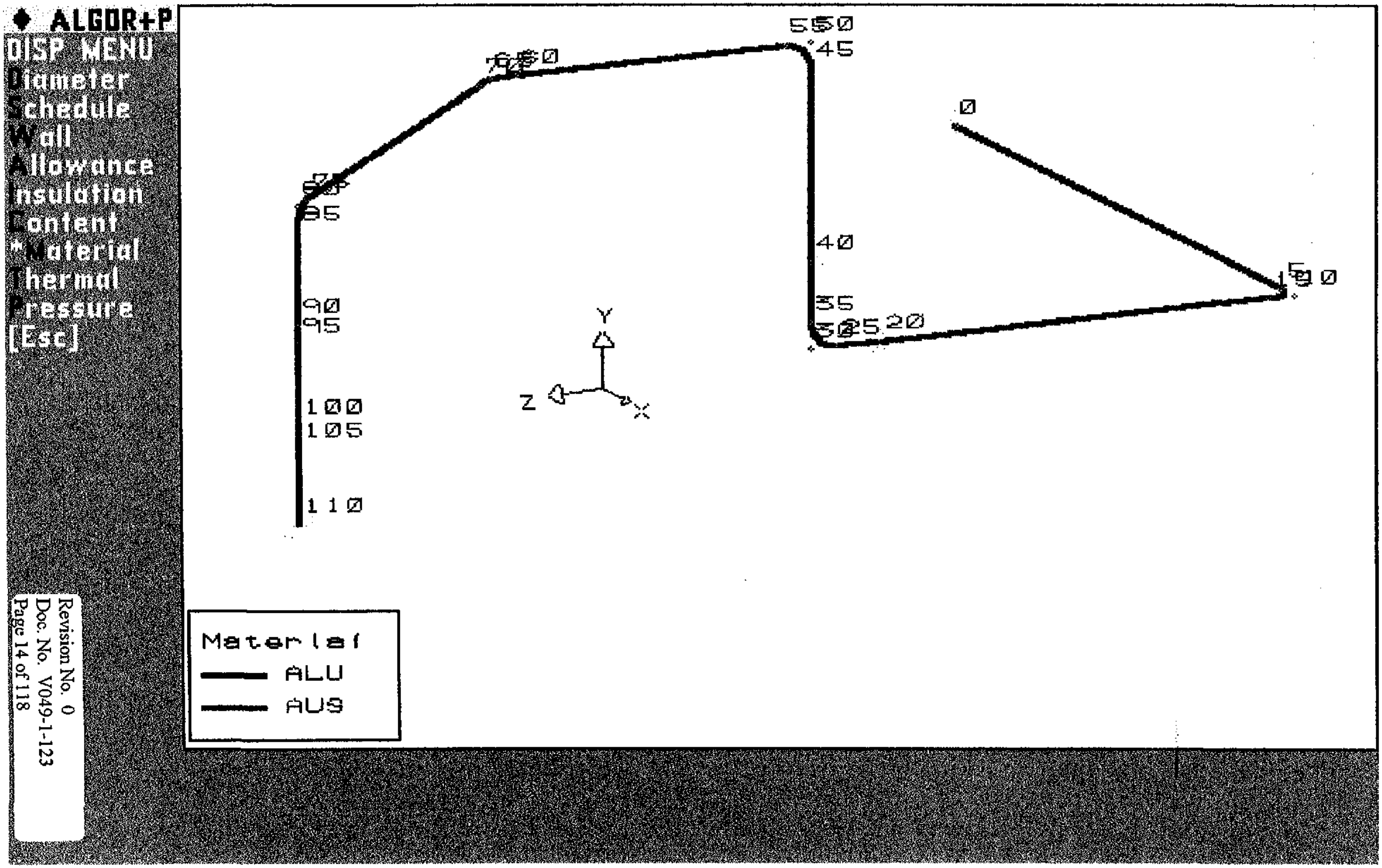
1-1/2" Ø GN_2 Vent Piping

Normal Operating Conditions

1-1/2" GN_2 VENT

Normal Operation

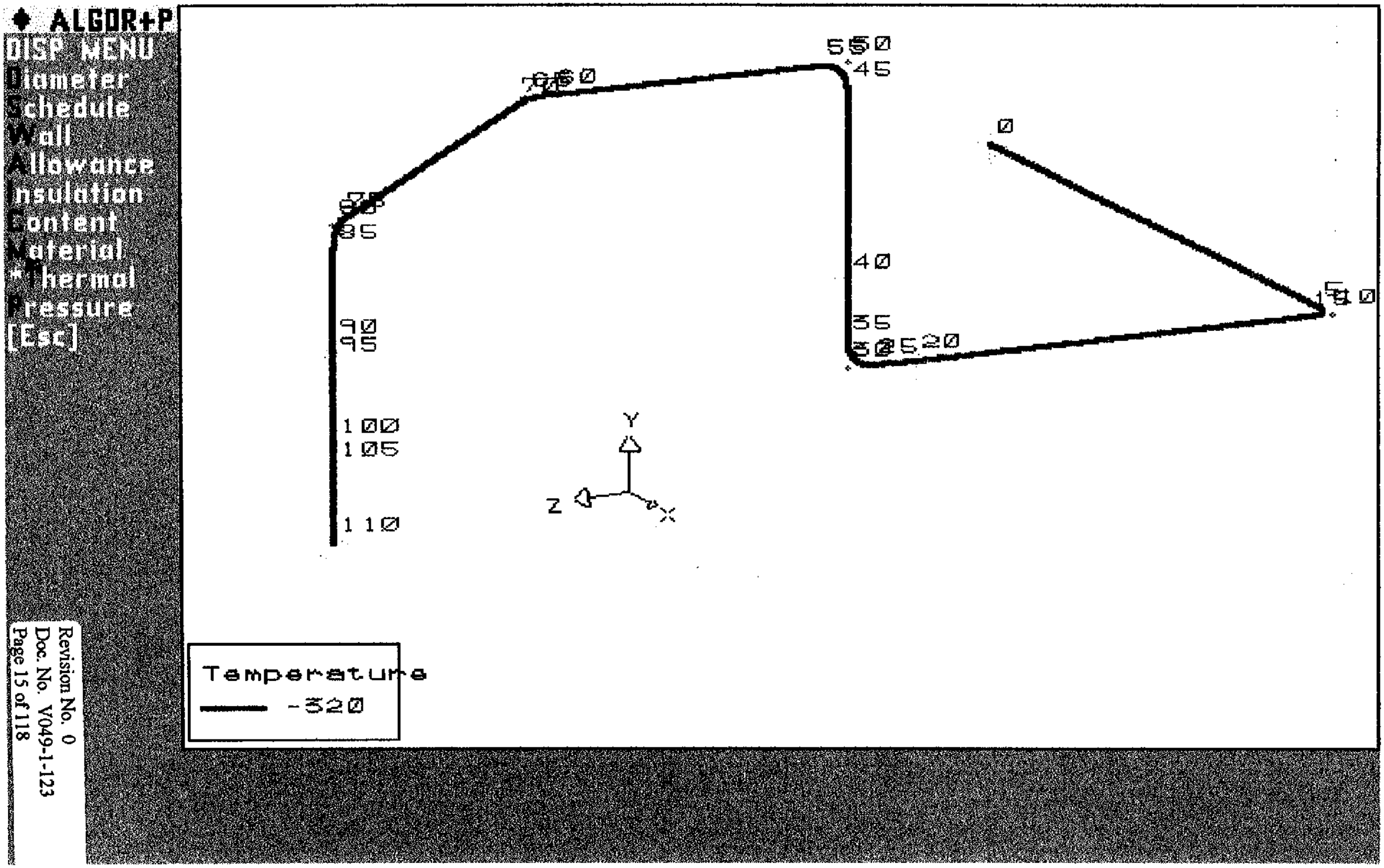
Material



1-1/2" GN2 VENT

Normal Operation

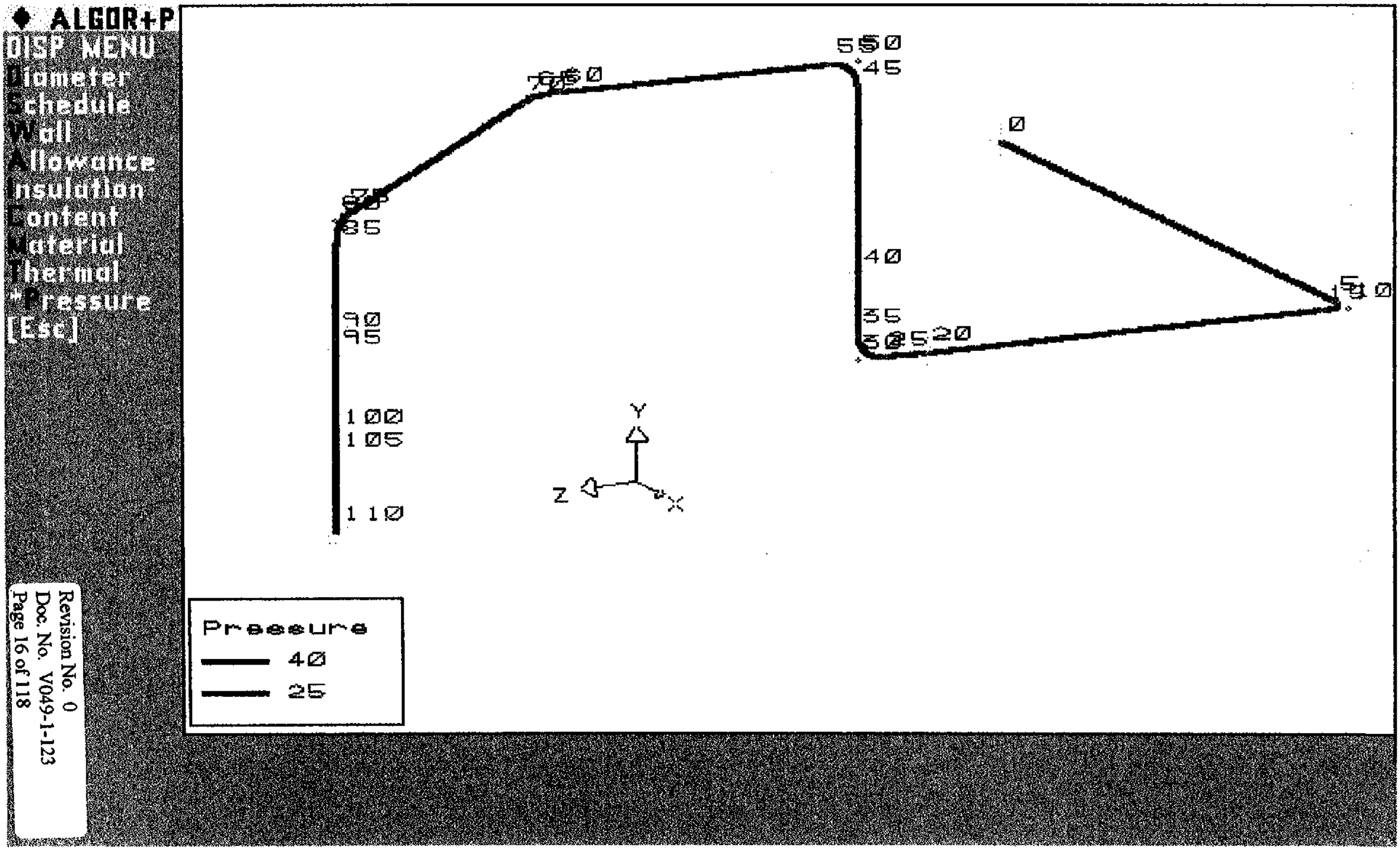
Thermal



1-1/2" GN_2 VENT

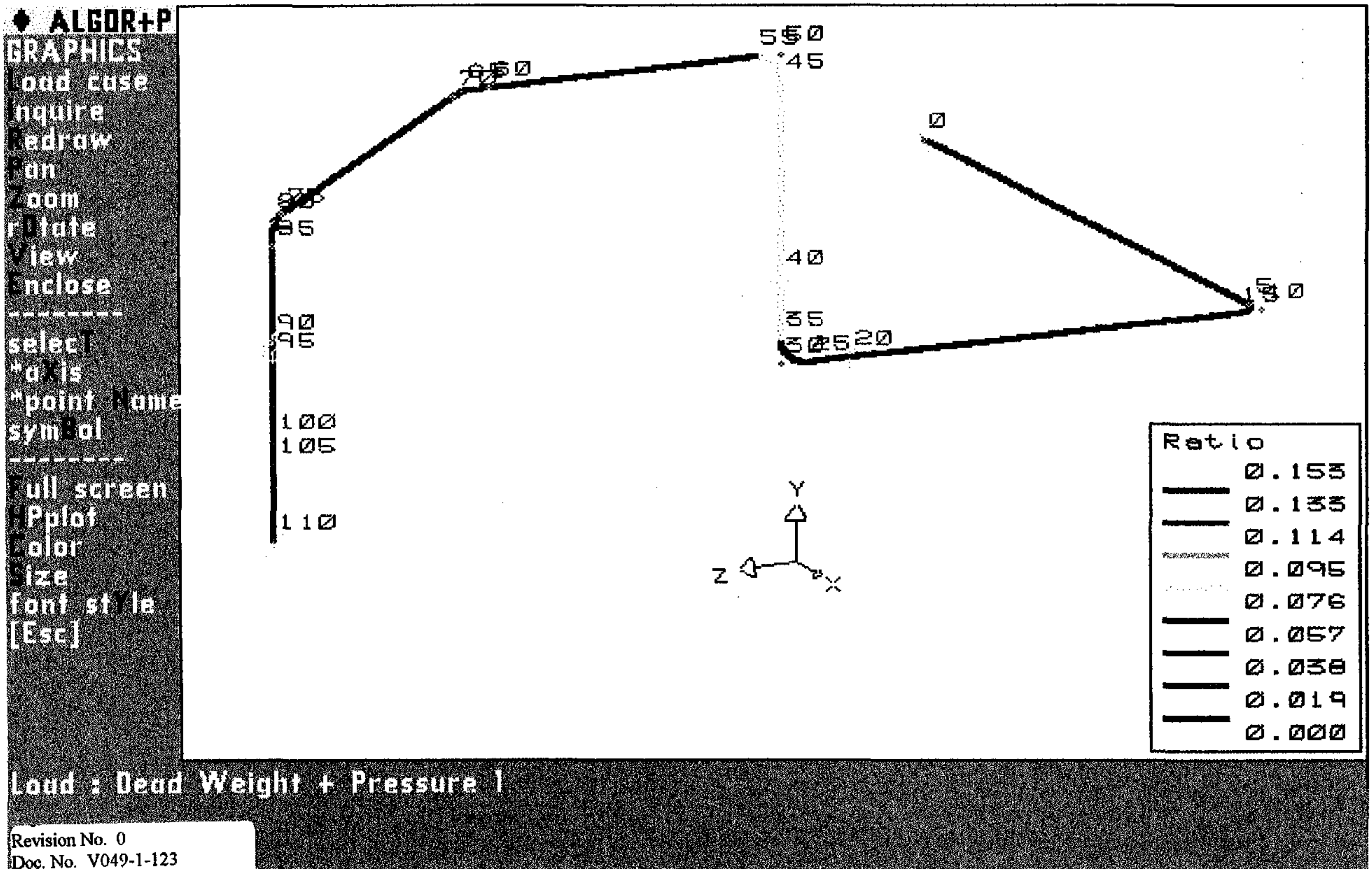
Normal Operation

Pressure



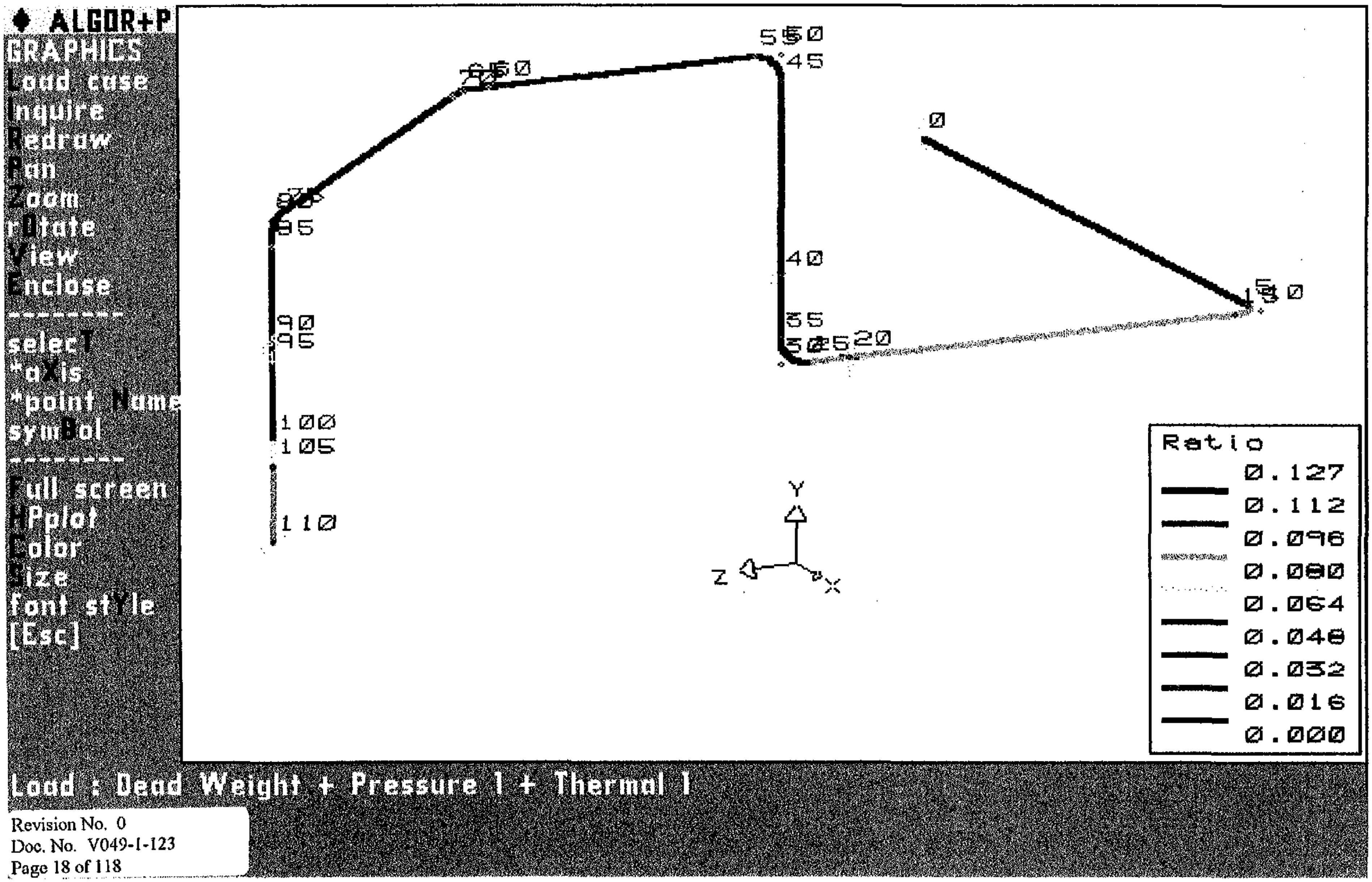
1-1/2" GN_2 VENT

Normal Operation



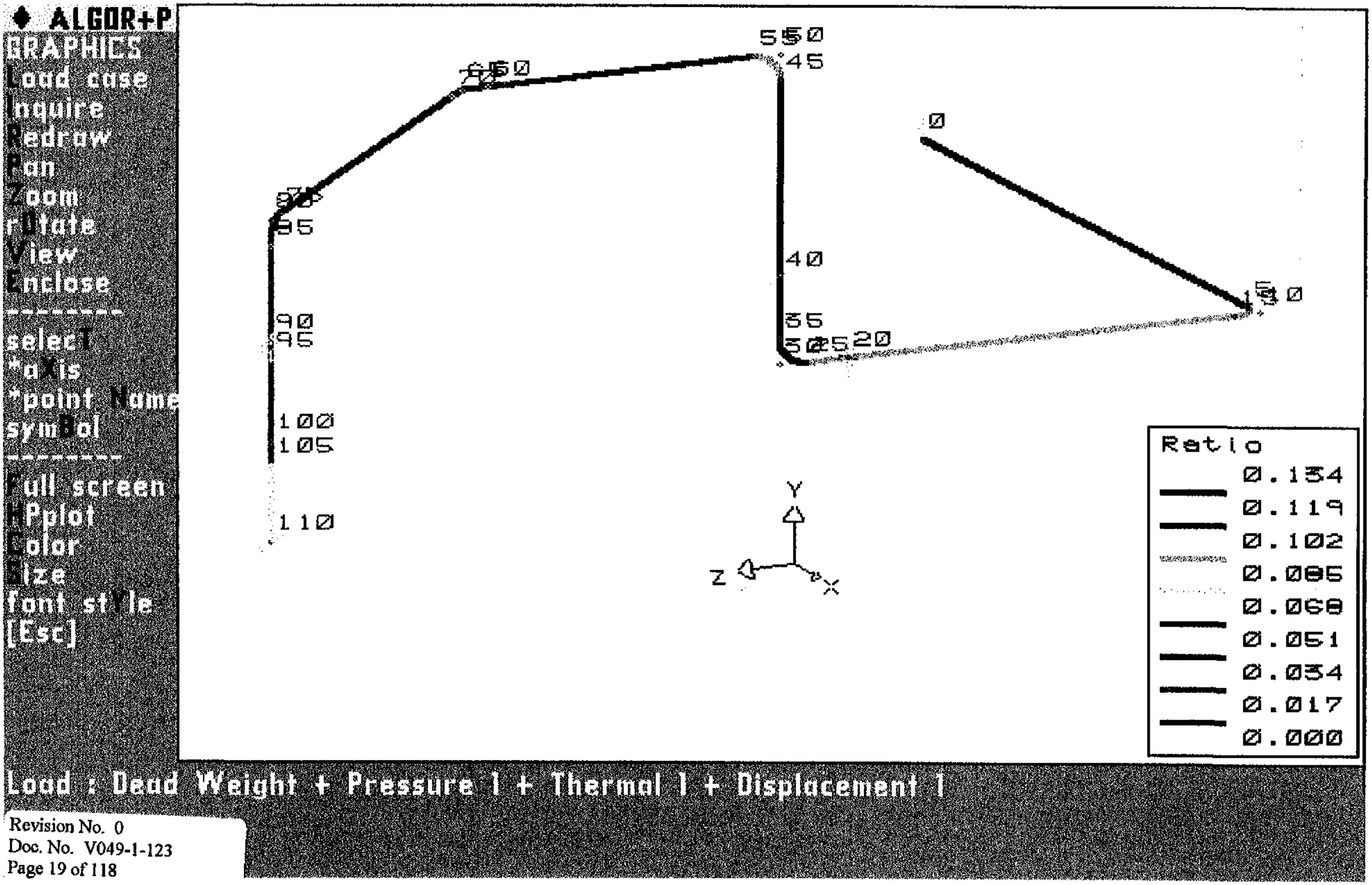
1-1/2" GN_2 VENT

Normal Operation



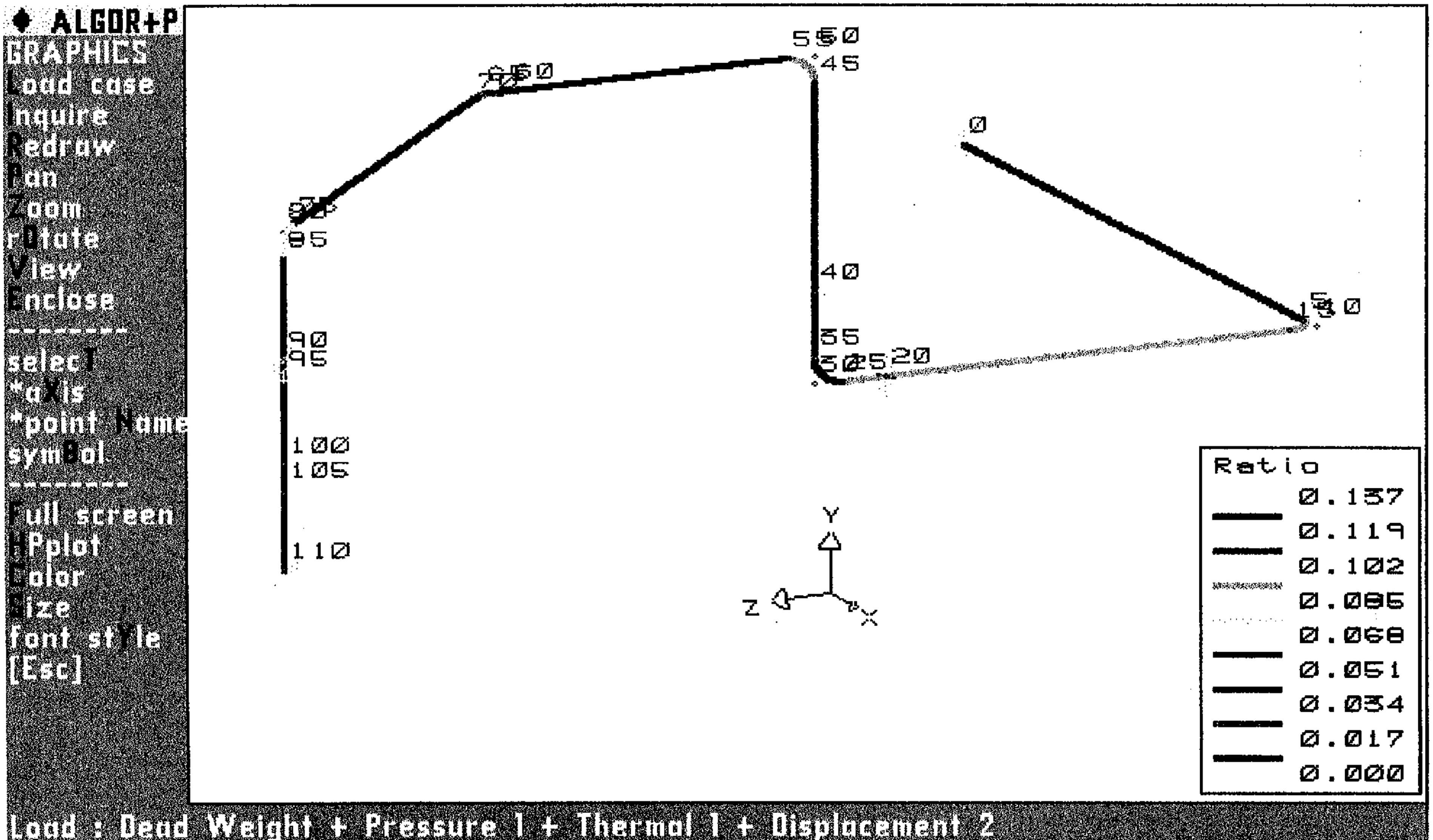
1-1/2" GN_2 VENT

Normal Operation



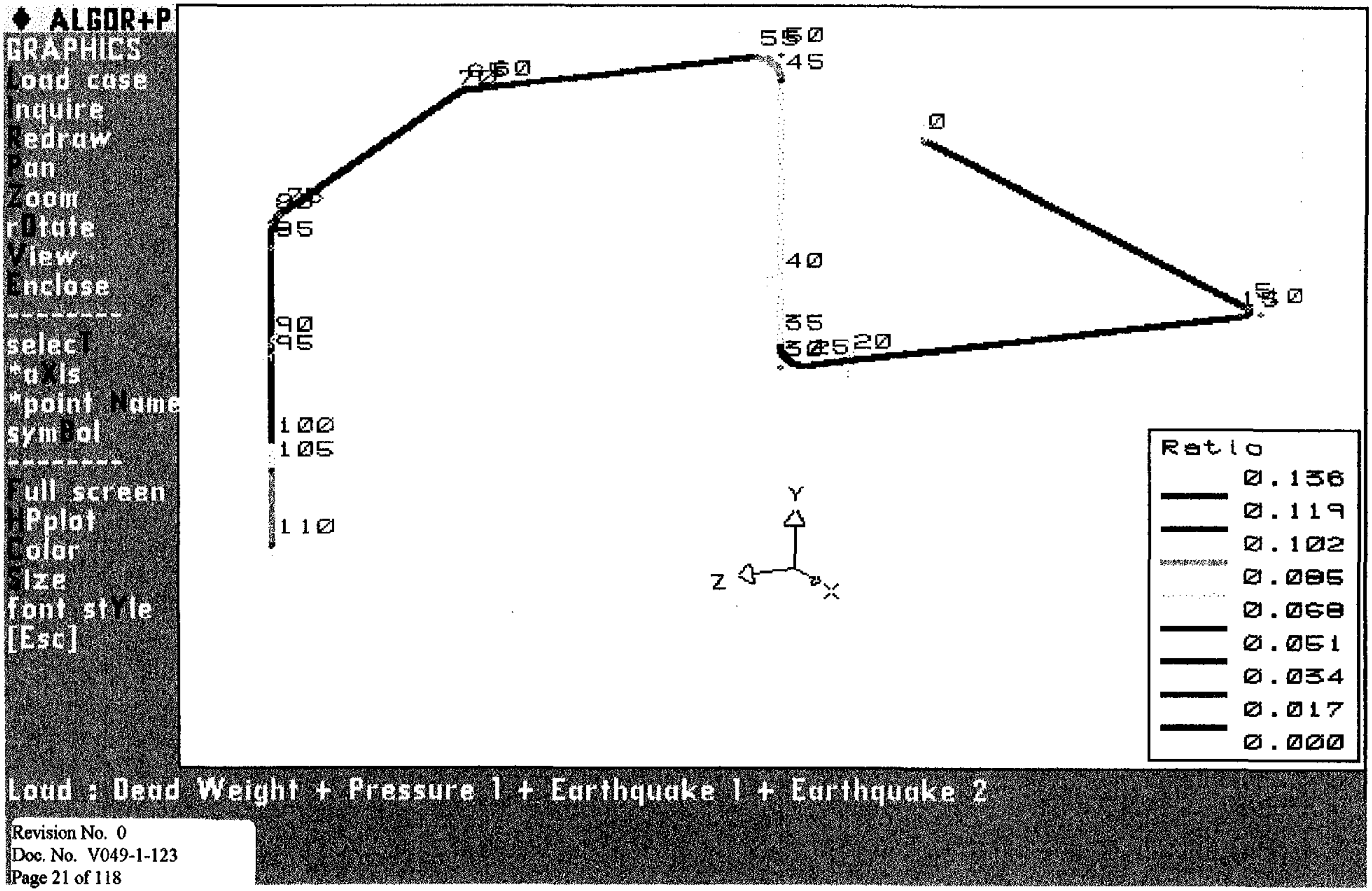
1-1/2" GN_2 VENT

Normal Operation



1-1/2" GN_2 VENT

Normal Operation



File Name	GN2VENTO
Project	LIGO
Department	744
Contract Number	
Description	80K CRYOPUMP 1-1/2" GN2 VENT NORMAL OPERATING CONDITION
Prepared by	W. BILYNSKY
Checked by	

ANSI code	ANSI B31.1	
Input unit	English	
Output unit	English	
Output columns	80	
Base temperature	70	
F factor	1.0	
E factor	1.2	
Number of dynamic modes..	12	
Cut-off frequency	33	Hz
Max no. of iterations ...	12	
Convergence tolerance ...	3	
Force tolerance	5	lb

Frm /To	Point name	DX (feet)	DY (feet)	DZ (feet)	Radius (inch)	X (feet)	Y (feet)	Z (feet)
F	0	0.	0.	0.		0.000	0.000	0.000
T	5	5.0				5.000	0.000	0.000
T	10	0.1875			Long	5.188	0.000	0.000
T	15			0.1875		5.188	0.000	0.188
T	20			2.8021		5.188	0.000	2.990
T	25			0.3125		5.188	0.000	3.302
T	30			0.1875	Long	5.188	0.000	3.490
T	35		0.1875			5.188	0.188	3.490
T	40		0.4375			5.188	0.625	3.490
T	45		1.4010			5.188	2.026	3.490
T	50		0.1875		Long	5.188	2.214	3.490
T	55			0.1875		5.188	2.214	3.677
T	60			1.9375		5.188	2.214	5.615
T	65			0.1875	Long	5.188	2.214	5.802
T	70	0.1326		0.1326		5.320	2.214	5.935
T	75	2.381		2.381		7.701	2.214	8.316
T	80	0.1326		0.1326	Long	7.834	2.214	8.448
T	85		-0.1875			7.834	2.026	8.448
T	90		-0.6771			7.834	1.349	8.448
T	95		-0.1354			7.834	1.214	8.448
T	100		-0.5833			7.834	0.630	8.448
T	105		-0.1667			7.834	0.464	8.448
T	110		-0.54167			7.834	-0.078	8.448

```
Point  Data      Description
-----  --------  ----------------------------------------------
0      Pipe      Pipe data identifier = 1
                 Nominal Diameter = 1"1/2
                 Pipe Schedule = 10S
                 Actual Pipe O. D. = 1.900    inch
                 Wall Thickness = .109     inch
                 Corrosion Allowance = 0.       inch
                 Insulation Thickness = 1.5      inch
                 Insulation Density = 7.0      lb/cu.ft
                 Content S. G. = .9714
                 Wind area O.D. = Insulation O.D.
       Material  Data Identifier = 1
                 Austenitic stainless (301-309, 316, 321, 237)
                 Density = 0.2899   lb/cu.inch
                 Tempera.   Modulus    Expansion
                 (deg.F)   (psi     )  (inch/inch)
                 -325.     30400000   -0.00321
                 -150.     29900000   -0.00189
                 -50.      29400000   -0.00103
                 70.       28300000   0.00000
                 200.      27700000   0.00122
                 300.      27100000   0.00218
                 400.      26600000   0.00317
                 500.      26100000   0.00417
                 600.      25400000   0.00520
                 700.      24800000   0.00625
                 800.      24100000   0.00733
                 900.      23400000   0.00843
                 1000.     22700000   0.00957
                 1100.     22000000   0.01070
                 1200.     21300000   0.01183
                 1300.     20700000   0.01297
                 1400.     19300000   0.01410
                 Temperature  Allowable stresses
                   (deg.F)             (psi)
                    -320.              15700.
                    70.                15700.
                    302.               15300.
                    400.               14700.
       Load      Load data identifier = 1
                 Case  Temperature  Pressure   Expansion
                  No.    (deg.F)     (psig   ) (inch/inch)
                   1      -320.        25.0      -0.003172
       Guide
       Support   Limit Stop
                 Spring constant = Rigid    lb/inch
                 Gap in positive direction = 0.0625    inch
                 Gap in negative direction = 0.0       inch
                 Friction coefficient = 0.30
                 Y directional limit stop

5
```

```
Point  Data      Description
-----  --------  ------------------------------------------------
10
15
20     Guide
       Support   Limit Stop
                 Spring constant = Rigid    lb/inch
                 Gap in positive direction = 0.0625   inch
                 Gap in negative direction = 0.0      inch
                 Friction coefficient = 0.30
                 Y directional limit stop
25
30
35
40     Flange    Weld neck flange (SIF=1.0)
                 Class  = 150
                 Weight = 12.      lb
                 Gasket diameter = N/A inch
45
50
55
60
65
70
75
80
85
90     Flange    Weld neck flange (SIF=1.0)
                 Class  = 150
                 Weight = 12.      lb
                 Gasket diameter = N/A inch
95     Load      Load data identifier = 2
                 Case  Temperature  Pressure   Expansion
                  No.    (deg.F)     (psig   ) (inch/inch)
                   1      -320.        40.0      -0.003172
       Weight    Concentrated weight = -100.    lb
100    Pipe      Pipe data identifier = 2
                 Nominal Diameter = 1"1/2
                 Pipe Schedule = 40S
                 Actual Pipe O. D. = 1.900    inch
                 Wall Thickness = .145     inch
                 Corrosion Allowance = 0.       inch
                 Insulation Thickness = 1.5      inch
                 Insulation Density = 7.0      lb/cu.ft
                 Content S. G. = .9714
                 Wind area O.D. = Insulation O.D.
       Material  Data Identifier = 2
                 Aluminum, aluminum alloys
                 Density = 0.0978   lb/cu.inch
                 Tempera.   Modulus   Expansion
                 (deg.F)    (psi    )  (inch/inch)
                 -325.      11300000   -0.00390
```

```
Point  Data      Description
-----  --------  -------------------------------------------------
                 -150.      11100000    -0.00240
                 -50.       10900000    -0.00139
                 70.        10600000    0.00000
                 200.       10400000    0.00167
                 300.       10200000    0.00306
                 400.       9500000     0.00449
                 500.       8500000     0.00598
                 Temperature  Allowable stresses
                   (deg.F)           (psi)
                    400              3500.
                    302.             5500.
                    70.              6000.
                    -320.            6000.
105
110    Anchor    Rigid in all directions
                 Initial displacement (inch,degree) :
                 Case 1, translational X = -0.0328  inch
                 Case 1, translational Y = -0.1149  inch
                 Case 2, translational X = -0.0328  inch
                 Case 2, translational Y = -0.2219  inch
```

Case number	Combination
1	D.W. + Pres1
2	D.W. + Pres1 + Ther1
3	D.W. + Pres1 + Ther1 + Disp1
4	D.W. + Pres1 + Ther1 + Disp2
5	D.W. + Pres1 + Quake1 + Quake2

Earthquake Load Factors

Case number	X factor	Y factor	Z factor
1	0.05625		
2			0.05625

*** Support Summary ***

Forces/lb or Moments/inch-lb

Point Name	Global Direction	Sustain	Expansion Max	Expansion Min	Occasional Max	Occasional Min	Total Max	Total Min
0	Fy	-5	2	0	0	-0	-3	-5
	Fz	-0	6	0	1	-1	6	-1
0	Fx	0	0	0	0	0	0	0
	Fy	-5	2	0	0	-0	-3	-5
20	Fx	1	11	0	4	-4	15	-3
	Fy	-29	0	-3	0	-0	-28	-32
20	Fy	-29	0	-3	0	-0	-28	-32
	Fz	4	4	0	0	0	8	4
110	Fx	-1	0	-11	4	-4	3	-16
	Fy	72	3	-2	1	-1	75	69
	Fz	-4	0	-10	1	-1	-3	-15
	Mx	-91	53	-216	22	-22	-15	-329
	My	-53	91	0	24	-24	62	-77
	Mz	15	208	0	41	-41	264	-27

*** Flange Loading Report ***

Point Name	Flange Class	Operating Pressure (psig)	Temp. (deg.F)	Force (lb)	Moment (inch-lb)	Gasket Diameter (inch)	Equivalent Pressure (psig)
40	150	25	-320	18	313	N/A	N/A
90	150	25	-320	26	85	N/A	N/A

Load : Dead Weight + Pressure 1

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	0.004	-0.000	-0.000	-0.212	-0.002	-0.140
5	0.004	-0.117	0.002	-0.212	-0.004	-0.079
10.Near	0.004	-0.117	0.002	-0.212	-0.004	-0.079
10.Far	0.004	-0.112	0.003	-0.212	-0.005	-0.075
15	0.004	-0.112	0.003	-0.212	-0.005	-0.075
20	0.000	-0.000	0.003	-0.144	-0.008	-0.063
25	-0.001	0.009	0.003	-0.130	-0.008	-0.062
30.Near	-0.001	0.009	0.003	-0.130	-0.008	-0.062
30.Far	0.001	0.013	-0.001	-0.076	-0.011	-0.058
35	0.001	0.013	-0.001	-0.076	-0.011	-0.058
40	0.007	0.013	-0.007	-0.063	-0.012	-0.057
45	0.022	0.013	-0.020	-0.026	-0.014	-0.050
50.Near	0.022	0.013	-0.020	-0.026	-0.014	-0.050
50.Far	0.024	0.013	-0.021	0.007	-0.018	-0.044
55	0.024	0.013	-0.021	0.007	-0.018	-0.044
60	0.016	0.007	-0.021	0.018	-0.023	-0.030
65.Near	0.015	0.006	-0.021	0.017	-0.023	-0.030
65.Far	0.014	0.006	-0.021	0.012	-0.026	-0.027
70	0.014	0.005	-0.020	0.012	-0.027	-0.026
75	-0.000	-0.000	-0.006	-0.014	-0.024	-0.002
80.Near	-0.000	-0.000	-0.006	-0.014	-0.024	-0.002
80.Far	-0.001	0.000	-0.005	-0.015	-0.020	0.002
85	-0.001	0.000	-0.005	-0.015	-0.020	0.002
90	-0.000	0.000	-0.003	-0.014	-0.015	0.002
95	-0.000	0.000	-0.002	-0.014	-0.014	0.002
100	-0.000	0.000	-0.001	-0.011	-0.010	0.002
105	-0.000	0.000	-0.001	-0.009	-0.008	0.001
110	-0.000	0.000	-0.000	-0.000	-0.000	0.000

Load : Dead Weight + Pressure 1

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-5	-0	0	0	0
0	0	-5	-0	0	0	0
20	1	-29	0	0	0	0
20	0	-29	4	0	0	0
110	-1	72	-4	-91	-53	15

Load : Dead Weight + Pressure 1

*** Forces and Moments in Element Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	11	0	-0	0	0
5	0	9	-0	0	-9	54
5	-0	0	9	0	-54	-9
10.Near	-0	0	9	0	-54	-9
10.Far	-0	-0	-10	33	-21	10
10.Far	0	-10	0	-33	10	21
15	0	-10	0	-33	10	21
20	-0	21	-0	33	-10	-534
20	-4	36	1	-33	10	534
25	4	-35	-1	33	-13	-400
25	-4	35	1	-33	13	400
30.Near	-4	35	1	-33	13	400
30.Far	-34	-4	-1	-15	-35	-313
30.Far	34	-4	-1	15	-35	-313
35	34	-4	-1	15	-35	-313
40	-32	4	1	-15	40	293
40	20	-4	-1	15	-40	-293
45	-15	4	1	-15	54	231
45	15	-4	-1	15	-54	-231
50.Near	15	-4	-1	15	-54	-231
50.Far	4	14	1	56	17	190
50.Far	-4	14	1	-56	17	190
55	-4	14	1	-56	17	190
60	4	-6	-1	56	-37	46
60	-4	6	1	-56	37	-46
65.Near	4	-6	-1	56	-38	54
65.Near	-4	-1	6	-56	54	38
65.Far	3	-2	-5	-2	-87	-37
65.Far	-3	5	-2	2	37	-87
70	3	-5	2	-2	-34	93
70	-3	5	-2	2	34	-93
75	3	8	2	-2	48	34
75	-3	8	2	2	48	34
80.Near	-3	8	2	2	48	34
80.Far	-9	-3	-2	-53	-2	-7
80.Far	9	-4	1	53	-7	-4
85	9	-4	1	53	-7	-4
90	-12	4	-1	-53	-0	-27
90	24	-4	1	53	0	27
95	-24	4	-1	-53	-1	-33
95	-76	-4	1	53	1	33
100	74	4	-1	-53	-7	-59
100	-74	-4	1	53	7	59
105	73	4	-1	-53	-9	-66
105	-73	-4	1	53	9	66
110	72	4	-1	-53	-15	-91

Load : Dead Weight + Pressure 1

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	11	0	-0	0	0
5	0	9	-0	0	-9	54
5	-0	-9	0	0	9	-54
10.Near	-0	-9	0	0	9	-54
10.Far	0	10	-0	21	-10	33
10.Far	-0	-10	0	-21	10	-33
15	-0	-10	0	-21	10	-33
20	0	21	-0	534	-10	33
20	-1	36	-4	-534	10	-33
25	1	-35	4	400	-13	33
25	-1	35	-4	-400	13	-33
30.Near	-1	35	-4	-400	13	-33
30.Far	1	-34	4	313	-15	35
30.Far	-1	34	-4	-313	15	-35
35	-1	34	-4	-313	15	-35
40	1	-32	4	293	-15	40
40	-1	20	-4	-293	15	-40
45	1	-15	4	231	-15	54
45	-1	15	-4	-231	15	-54
50.Near	-1	15	-4	-231	15	-54
50.Far	1	-14	4	190	-17	56
50.Far	-1	14	-4	-190	17	-56
55	-1	14	-4	-190	17	-56
60	1	-6	4	-46	-37	56
60	-1	6	-4	46	37	-56
65.Near	1	-6	4	-54	-38	56
65.Near	-1	6	-4	54	38	-56
65.Far	1	-5	4	-63	-37	60
65.Far	-1	5	-4	63	37	-60
70	1	-5	4	-68	-34	64
70	-1	5	-4	68	34	-64
75	1	8	4	-25	48	22
75	-1	-8	-4	25	-48	-22
80.Near	-1	-8	-4	25	-48	-22
80.Far	1	9	4	-4	53	7
80.Far	-1	-9	-4	4	-53	-7
85	-1	-9	-4	4	-53	-7
90	1	12	4	27	53	-0
90	-1	-24	-4	-27	-53	0
95	1	24	4	33	53	-1
95	-1	76	-4	-33	-53	1
100	1	-74	4	59	53	-7
100	-1	74	-4	-59	-53	7
105	1	-73	4	66	53	-9
105	-1	73	-4	-66	-53	9
110	1	-72	4	91	53	-15

Load : Dead Weight + Pressure 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	15700
5	1.00	1.00	0.26	208	300	300	319	15700
5	1.98	1.98	0.26	208	506	506	421	15700
10.Near	1.98	1.98	0.26	208	506	506	421	15700
10.Far	1.98	1.98	0.26	208	268	308	341	15700
10.Far	1.00	1.00	0.26	208	180	259	265	15700
15	1.00	1.00	0.26	208	180	259	265	15700
20	1.00	1.00	0.26	208	2146	2148	2169	15700
20	1.00	1.00	0.26	208	2153	2155	2169	15700
25	1.00	1.00	0.26	208	1636	1639	1654	15700
25	1.98	1.98	0.26	208	3149	3150	2406	15700
30.Near	1.98	1.98	0.26	208	3149	3150	2406	15700
30.Far	1.98	1.98	0.26	208	2439	2440	1914	15700
30.Far	1.00	1.00	0.26	208	1248	1248	1323	15700
35	1.00	1.00	0.26	208	1248	1248	1323	15700
40	1.00	1.00	0.26	208	1178	1178	1250	15700
40	1.00	1.00	0.26	208	1197	1198	1250	15700
45	1.00	1.00	0.26	208	978	979	1023	15700
45	1.98	1.98	0.26	208	1874	1874	1467	15700
50.Near	1.98	1.98	0.26	208	1874	1874	1467	15700
50.Far	1.98	1.98	0.26	208	1553	1562	1247	15700
50.Far	1.00	1.00	0.26	208	831	849	874	15700
55	1.00	1.00	0.26	208	831	849	874	15700
60	1.00	1.00	0.26	208	322	387	420	15700
60	1.00	1.00	0.26	208	322	387	420	15700
65.Near	1.00	1.00	0.26	208	350	408	441	15700
65.Near	1.98	1.98	0.26	208	598	626	603	15700
65.Far	1.98	1.98	0.26	208	814	814	647	15700
65.Far	1.00	1.00	0.26	208	458	458	471	15700
70	1.00	1.00	0.26	208	479	479	492	15700
70	1.00	1.00	0.26	208	479	479	492	15700
75	1.00	1.00	0.26	208	322	322	335	15700
75	1.98	1.98	0.26	208	544	544	446	15700
80.Near	1.98	1.98	0.26	208	544	544	446	15700
80.Far	1.98	1.98	0.26	208	135	280	414	15700
80.Far	1.00	1.00	0.26	208	106	271	314	15700
85	1.00	1.00	0.26	208	106	271	314	15700
90	1.00	1.00	0.26	208	174	294	337	15700
90	1.00	1.00	0.26	208	155	286	337	15700
95	1.00	1.00	0.26	208	177	295	348	15700
95	1.00	1.00	0.26	333	395	470	413	15700
100	1.00	1.00	0.26	333	493	542	480	15700
100	1.00	1.00	0.33	246	376	415	375	6000
105	1.00	1.00	0.33	246	399	434	393	6000
105	1.00	1.00	0.33	246	399	434	393	6000

Load : Dead Weight + Pressure 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	473	499	456	6000

*** System Maxima ***

Maximum X displacement = 0.024 inch at point 50.Far
Maximum Y displacement = -0.117 inch at point 5
Maximum Z displacement = -0.021 inch at point 50.Far

Maximum X rotation = -0.212 degree at point 10.Far
Maximum Y rotation = -0.027 degree at point 70
Maximum Z rotation = -0.140 degree at point 0

Maximum X force = -1 lb at point 20
Maximum Y force = 76 lb at point 95
Maximum Z force = -4 lb at point 20

Maximum X moment = 534 inch-lb at point 15
Maximum Y moment = 53 inch-lb at point 80.Near
Maximum Z moment = 64 inch-lb at point 70

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3149 psi at point 25
Maximum principal stress = 3150 psi at point 25
Maximum code stress = 2406 psi at point 25
Maximum stress ratio (code/allowable) = 0.15 at point 25

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	0.286	-0.000	0.000	-0.181	-0.317	-0.105
5	0.096	-0.092	0.304	-0.181	-0.236	-0.077
10.Near	0.096	-0.092	0.304	-0.181	-0.236	-0.077
10.Far	0.081	-0.088	0.305	-0.176	-0.184	-0.086
15	0.081	-0.088	0.305	-0.176	-0.184	-0.086
20	0.000	-0.000	0.199	-0.097	-0.091	-0.122
25	-0.006	0.006	0.187	-0.080	-0.082	-0.126
30.Near	-0.006	0.006	0.187	-0.080	-0.082	-0.126
30.Far	-0.003	0.001	0.178	-0.013	-0.052	-0.145
35	-0.003	0.001	0.178	-0.013	-0.052	-0.145
40	0.010	-0.016	0.178	0.002	-0.038	-0.146
45	0.052	-0.069	0.183	0.030	0.009	-0.134
50.Near	0.052	-0.069	0.183	0.030	0.009	-0.134
50.Far	0.058	-0.078	0.177	0.040	0.025	-0.124
55	0.058	-0.078	0.177	0.040	0.025	-0.124
60	0.073	-0.093	0.104	0.026	0.042	-0.070
65.Near	0.074	-0.093	0.099	0.024	0.042	-0.067
65.Far	0.073	-0.094	0.094	0.009	0.036	-0.058
70	0.071	-0.095	0.090	0.008	0.035	-0.055
75	-0.007	-0.095	-0.013	-0.039	0.017	0.015
80.Near	-0.007	-0.095	-0.013	-0.039	0.017	0.015
80.Far	-0.011	-0.086	-0.016	-0.049	0.014	0.028
85	-0.011	-0.086	-0.016	-0.049	0.014	0.028
90	-0.006	-0.060	-0.010	-0.047	0.011	0.030
95	-0.006	-0.055	-0.008	-0.046	0.010	0.030
100	-0.002	-0.033	-0.003	-0.037	0.007	0.025
105	-0.001	-0.025	-0.002	-0.030	0.006	0.021
110	-0.000	0.000	-0.000	-0.000	0.000	0.000

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-4	5	0	0	0
0	0	-4	0	0	0	0
20	12	-29	0	0	0	0
20	0	-29	8	0	0	0
110	-12	70	-13	-307	39	223

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments in Element Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	8	-5	0	-0	0
5	0	11	5	-0	328	-76
5	-0	-5	11	0	76	328
10.Near	-0	-5	11	0	76	328
10.Far	5	-0	-12	-101	-26	-340
10.Far	-5	-12	0	101	-340	26
15	-5	-12	0	101	-340	26
20	5	23	-0	-101	330	-611
20	-13	34	12	101	-330	611
25	13	-33	-12	-101	285	-485
25	-13	33	12	101	-285	485
30.Near	-13	33	12	101	-285	485
30.Far	-32	-13	-12	258	74	-381
30.Far	32	-13	-12	-258	74	-381
35	32	-13	-12	-258	74	-381
40	-30	13	12	258	-11	313
40	18	-13	-12	-258	11	-313
45	-13	13	12	258	190	93
45	13	-13	-12	-258	-190	-93
50.Near	13	-13	-12	-258	-190	-93
50.Far	13	12	12	216	-231	36
50.Far	-13	12	12	-216	-231	36
55	-13	12	12	-216	-231	36
60	13	-4	-12	216	-47	153
60	-13	4	12	-216	47	-153
65.Near	13	-4	-12	216	-62	159
65.Near	-13	-12	4	-216	159	62
65.Far	18	-1	-3	38	-271	-73
65.Far	-18	3	-1	-38	73	-271
70	18	-3	1	38	-72	275
70	-18	3	-1	-38	72	-275
75	18	10	1	38	-40	135
75	-18	10	1	-38	-40	135
80.Near	-18	10	1	-38	-40	135
80.Far	-11	-18	-1	39	-40	-72
80.Far	11	-13	12	-39	-79	-23
85	11	-13	12	-39	-79	-23
90	-14	13	-12	39	-18	-83
90	26	-13	12	-39	18	83
95	-26	13	-12	39	-37	-105
95	-74	-13	12	-39	37	105
100	72	13	-12	39	-121	-196
100	-72	-13	12	-39	121	196
105	71	13	-12	39	-145	-222
105	-71	-13	12	-39	145	222
110	70	13	-12	39	-223	-307

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments in Global Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	8	-5	0	-0	0
5	0	11	5	-0	328	-76
5	-0	-11	-5	0	-328	76
10.Near	-0	-11	-5	0	-328	76
10.Far	0	12	5	26	340	-101
10.Far	-0	-12	-5	-26	-340	101
15	-0	-12	-5	-26	-340	101
20	0	23	5	611	330	-101
20	-12	34	-13	-611	-330	101
25	12	-33	13	485	285	-101
25	-12	33	-13	-485	-285	101
30.Near	-12	33	-13	-485	-285	101
30.Far	12	-32	13	381	258	-74
30.Far	-12	32	-13	-381	-258	74
35	-12	32	-13	-381	-258	74
40	12	-30	13	313	258	-11
40	-12	18	-13	-313	-258	11
45	12	-13	13	93	258	190
45	-12	13	-13	-93	-258	-190
50.Near	-12	13	-13	-93	-258	-190
50.Far	12	-12	13	36	231	216
50.Far	-12	12	-13	-36	-231	-216
55	-12	12	-13	-36	-231	-216
60	12	-4	13	-153	-47	216
60	-12	4	-13	153	47	-216
65.Near	12	-4	13	-159	-62	216
65.Near	-12	4	-13	159	62	-216
65.Far	12	-3	13	-165	-73	219
65.Far	-12	3	-13	165	73	-219
70	12	-3	13	-168	-72	222
70	-12	3	-13	168	72	-222
75	12	10	13	-69	-40	123
75	-12	-10	-13	69	40	-123
80.Near	-12	-10	-13	69	40	-123
80.Far	12	11	13	-23	-39	79
80.Far	-12	-11	-13	23	39	-79
85	-12	-11	-13	23	39	-79
90	12	14	13	83	-39	-18
90	-12	-26	-13	-83	39	18
95	12	26	13	105	-39	-37
95	-12	74	-13	-105	39	37
100	12	-72	13	196	-39	-121
100	-12	72	-13	-196	39	121
105	12	-71	13	222	-39	-145
105	-12	71	-13	-222	39	145
110	12	-70	13	307	-39	-223

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	39250
5	1.00	1.00	0.26	208	1386	1386	1708	39250
5	1.98	1.98	0.26	208	2659	2659	3176	39250
10.Near	1.98	1.98	0.26	208	2659	2659	3176	39250
10.Far	1.98	1.98	0.26	208	2698	2714	3195	39250
10.Far	1.00	1.00	0.26	208	1410	1441	1704	39250
15	1.00	1.00	0.26	208	1410	1441	1704	39250
20	1.00	1.00	0.26	208	2774	2788	3606	39250
20	1.00	1.00	0.26	208	2786	2801	3606	39250
25	1.00	1.00	0.26	208	2276	2294	2953	39250
25	1.98	1.98	0.26	208	4403	4412	4983	39250
30.Near	1.98	1.98	0.26	208	4403	4412	4983	39250
30.Far	1.98	1.98	0.26	208	3004	3089	4218	39250
30.Far	1.00	1.00	0.26	208	1534	1699	2485	39250
35	1.00	1.00	0.26	208	1534	1699	2485	39250
40	1.00	1.00	0.26	208	1246	1446	2322	39250
40	1.00	1.00	0.26	208	1266	1462	2322	39250
45	1.00	1.00	0.26	208	883	1146	2309	39250
45	1.98	1.98	0.26	208	1682	1834	4019	39250
50.Near	1.98	1.98	0.26	208	1682	1834	4019	39250
50.Far	1.98	1.98	0.26	208	1899	1996	3789	39250
50.Far	1.00	1.00	0.26	208	1013	1190	2157	39250
55	1.00	1.00	0.26	208	1013	1190	2157	39250
60	1.00	1.00	0.26	208	728	959	1165	39250
60	1.00	1.00	0.26	208	728	959	1165	39250
65.Near	1.00	1.00	0.26	208	768	990	1185	39250
65.Near	1.98	1.98	0.26	208	1413	1543	2079	39250
65.Far	1.98	1.98	0.26	208	2262	2265	2116	39250
65.Far	1.00	1.00	0.26	208	1200	1206	1212	39250
70	1.00	1.00	0.26	208	1215	1220	1224	39250
70	1.00	1.00	0.26	208	1215	1220	1224	39250
75	1.00	1.00	0.26	208	663	674	877	39250
75	1.98	1.98	0.26	208	1197	1202	1520	39250
80.Near	1.98	1.98	0.26	208	1197	1202	1520	39250
80.Far	1.98	1.98	0.26	208	702	713	1317	39250
80.Far	1.00	1.00	0.26	208	390	417	769	39250
85	1.00	1.00	0.26	208	390	417	769	39250
90	1.00	1.00	0.26	208	397	422	757	39250
90	1.00	1.00	0.26	208	377	405	757	39250
95	1.00	1.00	0.26	208	475	495	817	39250
95	1.00	1.00	0.26	333	693	708	882	39250
100	1.00	1.00	0.26	333	1148	1155	1250	39250
100	1.00	1.00	0.33	246	897	903	988	15000
105	1.00	1.00	0.33	246	1004	1008	1085	15000
105	1.00	1.00	0.33	246	1004	1008	1085	15000

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	1352	1355	1417	15000

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Maxima ***

Maximum X displacement = 0.286 inch at point 0
Maximum Y displacement = -0.095 inch at point 70
Maximum Z displacement = 0.305 inch at point 10.Far

Maximum X rotation = -0.181 degree at point 0
Maximum Y rotation = -0.317 degree at point 0
Maximum Z rotation = -0.146 degree at point 40

Maximum X force = -12 lb at point 20
Maximum Y force = 74 lb at point 95
Maximum Z force = -13 lb at point 20

Maximum X moment = 611 inch-lb at point 15
Maximum Y moment = 340 inch-lb at point 10.Near
Maximum Z moment = -223 inch-lb at point 110

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 4403 psi at point 25
Maximum principal stress = 4412 psi at point 25
Maximum code stress = 4983 psi at point 25
Maximum stress ratio (code/allowable) = 0.13 at point 25

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	0.332	-0.000	0.000	-0.081	-0.336	-0.041
5	0.105	-0.029	0.323	-0.081	-0.253	-0.025
10.Near	0.105	-0.029	0.323	-0.081	-0.253	-0.025
10.Far	0.088	-0.027	0.324	-0.074	-0.199	-0.039
15	0.088	-0.027	0.324	-0.074	-0.199	-0.039
20	0.000	-0.000	0.197	0.010	-0.103	-0.095
25	-0.006	-0.001	0.183	0.028	-0.094	-0.101
30.Near	-0.006	-0.001	0.183	0.028	-0.094	-0.101
30.Far	-0.005	-0.012	0.177	0.097	-0.061	-0.125
35	-0.005	-0.012	0.177	0.097	-0.061	-0.125
40	0.007	-0.032	0.187	0.113	-0.046	-0.130
45	0.045	-0.095	0.225	0.142	0.002	-0.124
50.Near	0.045	-0.095	0.225	0.142	0.002	-0.124
50.Far	0.050	-0.110	0.222	0.152	0.020	-0.119
55	0.050	-0.110	0.222	0.152	0.020	-0.119
60	0.064	-0.169	0.134	0.132	0.039	-0.077
65.Near	0.065	-0.172	0.130	0.129	0.038	-0.075
65.Far	0.063	-0.176	0.123	0.111	0.033	-0.065
70	0.060	-0.179	0.119	0.108	0.032	-0.063
75	-0.036	-0.226	0.000	0.020	0.015	-0.002
80.Near	-0.036	-0.226	0.000	0.020	0.015	-0.002
80.Far	-0.042	-0.218	-0.006	-0.010	0.011	0.020
85	-0.042	-0.218	-0.006	-0.010	0.011	0.020
90	-0.038	-0.187	-0.004	-0.017	0.008	0.024
95	-0.038	-0.181	-0.004	-0.018	0.008	0.024
100	-0.035	-0.155	-0.002	-0.017	0.006	0.022
105	-0.034	-0.145	-0.001	-0.015	0.004	0.018
110	-0.033	-0.115	-0.000	-0.000	0.000	0.000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-4	6	0	0	0
0	0	-4	0	0	0	0
20	12	-30	0	0	0	0
20	0	-30	8	0	0	0
110	-12	72	-14	-174	29	197

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments in Element Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	7	-6	0	-0	0
5	0	12	6	-0	339	-128
5	-0	-6	12	-0	128	339
10.Near	-0	-6	12	-0	128	339
10.Far	6	-0	-13	-156	-28	-351
10.Far	-6	-13	0	156	-351	28
15	-6	-13	0	156	-351	28
20	6	24	-0	-156	340	-643
20	-14	37	12	156	-340	643
25	14	-36	-12	-156	294	-507
25	-14	36	12	156	-294	507
30.Near	-14	36	12	156	-294	507
30.Far	-35	-14	-12	266	128	-396
30.Far	35	-14	-12	-266	128	-396
35	35	-14	-12	-266	128	-396
40	-33	14	12	266	-64	325
40	21	-14	-12	-266	64	-325
45	-16	14	12	266	141	96
45	16	-14	-12	-266	-141	-96
50.Near	16	-14	-12	-266	-141	-96
50.Far	14	14	12	169	-239	32
50.Far	-14	14	12	-169	-239	32
55	-14	14	12	-169	-239	32
60	14	-7	-12	169	-45	216
60	-14	7	12	-169	45	-216
65.Near	14	-7	-12	169	-61	225
65.Near	-14	-12	7	-169	225	61
65.Far	18	-1	-6	-44	-288	-72
65.Far	-18	6	-1	44	72	-288
70	18	-6	1	-44	-71	296
70	-18	6	-1	44	71	-296
75	18	7	1	-44	-31	257
75	-18	7	1	44	-31	257
80.Near	-18	7	1	44	-31	257
80.Far	-9	-18	-1	29	41	-199
80.Far	9	-14	12	-29	-111	-170
85	9	-14	12	-29	-111	-170
90	-11	14	-12	29	12	59
90	23	-14	12	-29	-12	-59
95	-24	14	-12	29	-8	37
95	-76	-14	12	-29	8	-37
100	74	14	-12	29	-93	-58
100	-74	-14	12	-29	93	58
105	74	14	-12	29	-118	-85
105	-74	-14	12	-29	118	85
110	72	14	-12	29	-197	-174

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	7	-6	0	-0	0
5	0	12	6	-0	339	-128
5	-0	-12	-6	-0	-339	128
10.Near	-0	-12	-6	-0	-339	128
10.Far	0	13	6	28	351	-156
10.Far	-0	-13	-6	-28	-351	156
15	-0	-13	-6	-28	-351	156
20	0	24	6	643	340	-156
20	-12	37	-14	-643	-340	156
25	12	-36	14	507	294	-156
25	-12	36	-14	-507	-294	156
30.Near	-12	36	-14	-507	-294	156
30.Far	12	-35	14	396	266	-128
30.Far	-12	35	-14	-396	-266	128
35	-12	35	-14	-396	-266	128
40	12	-33	14	325	266	-64
40	-12	21	-14	-325	-266	64
45	12	-16	14	96	266	141
45	-12	16	-14	-96	-266	-141
50.Near	-12	16	-14	-96	-266	-141
50.Far	12	-14	14	32	239	169
50.Far	-12	14	-14	-32	-239	-169
55	-12	14	-14	-32	-239	-169
60	12	-7	14	-216	-45	169
60	-12	7	-14	216	45	-169
65.Near	12	-7	14	-225	-61	169
65.Near	-12	7	-14	225	61	-169
65.Far	12	-6	14	-234	-72	173
65.Far	-12	6	-14	234	72	-173
70	12	-6	14	-240	-71	178
70	-12	6	-14	240	71	-178
75	12	7	14	-213	-31	151
75	-12	-7	-14	213	31	-151
80.Near	-12	-7	-14	213	31	-151
80.Far	12	9	14	-170	-29	111
80.Far	-12	-9	-14	170	29	-111
85	-12	-9	-14	170	29	-111
90	12	11	14	-59	-29	12
90	-12	-23	-14	59	29	-12
95	12	24	14	-37	-29	-8
95	-12	76	-14	37	29	8
100	12	-74	14	58	-29	-93
100	-12	74	-14	-58	29	93
105	12	-74	14	85	-29	-118
105	-12	74	-14	-85	29	118
110	12	-72	14	174	-29	-197

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	39250
5	1.00	1.00	0.26	208	1485	1485	1830	39250
5	1.98	1.98	0.26	208	2855	2855	3416	39250
10.Near	1.98	1.98	0.26	208	2855	2855	3416	39250
10.Far	1.98	1.98	0.26	208	2785	2819	3444	39250
10.Far	1.00	1.00	0.26	208	1454	1522	1830	39250
15	1.00	1.00	0.26	208	1454	1522	1830	39250
20	1.00	1.00	0.26	208	2898	2931	3753	39250
20	1.00	1.00	0.26	208	2911	2944	3753	39250
25	1.00	1.00	0.26	208	2366	2407	3099	39250
25	1.98	1.98	0.26	208	4581	4601	5272	39250
30.Near	1.98	1.98	0.26	208	4581	4601	5272	39250
30.Far	1.98	1.98	0.26	208	3213	3298	4474	39250
30.Far	1.00	1.00	0.26	208	1638	1802	2614	39250
35	1.00	1.00	0.26	208	1638	1802	2614	39250
40	1.00	1.00	0.26	208	1312	1513	2409	39250
40	1.00	1.00	0.26	208	1331	1530	2409	39250
45	1.00	1.00	0.26	208	724	1040	2268	39250
45	1.98	1.98	0.26	208	1371	1565	3937	39250
50.Near	1.98	1.98	0.26	208	1371	1565	3937	39250
50.Far	1.98	1.98	0.26	208	1952	2010	3696	39250
50.Far	1.00	1.00	0.26	208	1040	1152	2109	39250
55	1.00	1.00	0.26	208	1040	1152	2109	39250
60	1.00	1.00	0.26	208	961	1082	1207	39250
60	1.00	1.00	0.26	208	961	1082	1207	39250
65.Near	1.00	1.00	0.26	208	1009	1124	1234	39250
65.Near	1.98	1.98	0.26	208	1889	1950	2176	39250
65.Far	1.98	1.98	0.26	208	2386	2389	2240	39250
65.Far	1.00	1.00	0.26	208	1263	1270	1274	39250
70	1.00	1.00	0.26	208	1290	1297	1298	39250
70	1.00	1.00	0.26	208	1290	1297	1298	39250
75	1.00	1.00	0.26	208	1118	1126	1262	39250
75	1.98	1.98	0.26	208	2098	2102	2284	39250
80.Near	1.98	1.98	0.26	208	2098	2102	2284	39250
80.Far	1.98	1.98	0.26	208	1625	1627	2035	39250
80.Far	1.00	1.00	0.26	208	858	862	1132	39250
85	1.00	1.00	0.26	208	858	862	1132	39250
90	1.00	1.00	0.26	208	305	330	794	39250
90	1.00	1.00	0.26	208	285	314	794	39250
95	1.00	1.00	0.26	208	198	258	762	39250
95	1.00	1.00	0.26	333	415	443	827	39250
100	1.00	1.00	0.26	333	689	697	936	39250
100	1.00	1.00	0.33	246	532	538	737	15000
105	1.00	1.00	0.33	246	640	645	813	15000
105	1.00	1.00	0.33	246	640	645	813	15000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	998	1000	1119	15000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Maxima ***

Maximum X displacement = 0.332 inch at point 0
Maximum Y displacement = -0.226 inch at point 75
Maximum Z displacement = 0.324 inch at point 10.Far

Maximum X rotation = 0.152 degree at point 50.Far
Maximum Y rotation = -0.336 degree at point 0
Maximum Z rotation = -0.130 degree at point 40

Maximum X force = -12 lb at point 20
Maximum Y force = 76 lb at point 95
Maximum Z force = -14 lb at point 20

Maximum X moment = 643 inch-lb at point 15
Maximum Y moment = 351 inch-lb at point 10.Near
Maximum Z moment = -197 inch-lb at point 110

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 4581 psi at point 25
Maximum principal stress = 4601 psi at point 25
Maximum code stress = 5272 psi at point 25
Maximum stress ratio (code/allowable) = 0.13 at point 25

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** System Deflections ***

Point Name	Displacements/inch X	Displacements/inch Y	Displacements/inch Z	Rotations/degree X	Rotations/degree Y	Rotations/degree Z
0	0.320	-0.000	0.000	0.007	-0.307	0.015
5	0.094	0.026	0.295	0.007	-0.229	0.021
10.Near	0.094	0.026	0.295	0.007	-0.229	0.021
10.Far	0.078	0.026	0.294	0.015	-0.177	0.002
15	0.078	0.026	0.294	0.015	-0.177	0.002
20	0.000	-0.000	0.167	0.103	-0.087	-0.069
25	-0.005	-0.007	0.153	0.122	-0.078	-0.077
30.Near	-0.005	-0.007	0.153	0.122	-0.078	-0.077
30.Far	-0.004	-0.022	0.151	0.193	-0.046	-0.105
35	-0.004	-0.022	0.151	0.193	-0.046	-0.105
40	0.006	-0.042	0.170	0.209	-0.032	-0.111
45	0.039	-0.105	0.237	0.240	0.013	-0.112
50.Near	0.039	-0.105	0.237	0.240	0.013	-0.112
50.Far	0.045	-0.123	0.238	0.252	0.032	-0.111
55	0.045	-0.123	0.238	0.252	0.032	-0.111
60	0.063	-0.223	0.150	0.228	0.048	-0.082
65.Near	0.064	-0.228	0.145	0.225	0.047	-0.080
65.Far	0.062	-0.235	0.139	0.204	0.041	-0.072
70	0.060	-0.239	0.134	0.200	0.040	-0.070
75	-0.034	-0.331	0.012	0.076	0.021	-0.018
80.Near	-0.034	-0.331	0.012	0.076	0.021	-0.018
80.Far	-0.039	-0.325	0.004	0.029	0.013	0.011
85	-0.039	-0.325	0.004	0.029	0.013	0.011
90	-0.037	-0.294	0.001	0.013	0.010	0.017
95	-0.036	-0.288	0.001	0.010	0.009	0.018
100	-0.034	-0.262	-0.000	0.003	0.007	0.017
105	-0.034	-0.252	-0.000	0.001	0.005	0.014
110	-0.033	-0.222	-0.000	-0.000	0.000	0.000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-3	5	0	0	0
0	0	-3	0	0	0	0
20	12	-32	0	0	0	0
20	0	-32	8	0	0	0
110	-12	75	-13	-37	35	162

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** Forces and Moments in Element Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	7	-5	-0	-0	0
5	0	12	5	0	320	-170
5	-0	-5	12	0	170	320
10.Near	-0	-5	12	0	170	320
10.Far	5	-0	-14	-199	-30	-332
10.Far	-5	-14	0	199	-332	30
15	-5	-14	0	199	-332	30
20	5	24	-0	-199	321	-668
20	-13	39	12	199	-321	668
25	13	-38	-12	-199	276	-523
25	-13	38	12	199	-276	523
30.Near	-13	38	12	199	-276	523
30.Far	-37	-13	-12	249	173	-407
30.Far	37	-13	-12	-249	173	-407
35	37	-13	-12	-249	173	-407
40	-35	13	12	249	-110	337
40	23	-13	-12	-249	110	-337
45	-18	13	12	249	91	110
45	18	-13	-12	-249	-91	-110
50.Near	18	-13	-12	-249	-91	-110
50.Far	13	17	12	118	-222	41
50.Far	-13	17	12	-118	-222	41
55	-13	17	12	-118	-222	41
60	13	-9	-12	118	-55	264
60	-13	9	12	-118	55	-264
65.Near	13	-9	-12	118	-71	276
65.Near	-13	-12	9	-118	276	71
65.Far	18	-1	-8	-118	-293	-81
65.Far	-18	8	-1	118	81	-293
70	18	-8	1	-118	-80	303
70	-18	8	-1	118	80	-303
75	18	5	1	-118	-37	365
75	-18	5	1	118	-37	365
80.Near	-18	5	1	118	-37	365
80.Far	-6	-18	-1	35	115	-312
80.Far	6	-13	12	-35	-139	-302
85	6	-13	12	-35	-139	-302
90	-9	13	-12	35	42	193
90	21	-13	12	-35	-42	-193
95	-21	13	-12	35	23	171
95	-79	-13	12	-35	-23	-171
100	77	13	-12	35	-61	77
100	-77	-13	12	-35	61	-77
105	76	13	-12	35	-85	50
105	-76	-13	12	-35	85	-50
110	75	13	-12	35	-162	-37

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	7	-5	-0	-0	0
5	0	12	5	0	320	-170
5	-0	-12	-5	0	-320	170
10.Near	-0	-12	-5	0	-320	170
10.Far	0	14	5	30	332	-199
10.Far	-0	-14	-5	-30	-332	199
15	-0	-14	-5	-30	-332	199
20	0	24	5	668	321	-199
20	-12	39	-13	-668	-321	199
25	12	-38	13	523	276	-199
25	-12	38	-13	-523	-276	199
30.Near	-12	38	-13	-523	-276	199
30.Far	12	-37	13	407	249	-173
30.Far	-12	37	-13	-407	-249	173
35	-12	37	-13	-407	-249	173
40	12	-35	13	337	249	-110
40	-12	23	-13	-337	-249	110
45	12	-18	13	110	249	91
45	-12	18	-13	-110	-249	-91
50.Near	-12	18	-13	-110	-249	-91
50.Far	12	-17	13	41	222	118
50.Far	-12	17	-13	-41	-222	-118
55	-12	17	-13	-41	-222	-118
60	12	-9	13	-264	-55	118
60	-12	9	-13	264	55	-118
65.Near	12	-9	13	-276	-71	118
65.Near	-12	9	-13	276	71	-118
65.Far	12	-8	13	-290	-81	124
65.Far	-12	8	-13	290	81	-124
70	12	-8	13	-298	-80	131
70	-12	8	-13	298	80	-131
75	12	5	13	-341	-37	175
75	-12	-5	-13	341	37	-175
80.Near	-12	-5	-13	341	37	-175
80.Far	12	6	13	-302	-35	139
80.Far	-12	-6	-13	302	35	-139
85	-12	-6	-13	302	35	-139
90	12	9	13	-193	-35	42
90	-12	-21	-13	193	35	-42
95	12	21	13	-171	-35	23
95	-12	79	-13	171	35	-23
100	12	-77	13	-77	-35	-61
100	-12	77	-13	77	35	61
105	12	-76	13	-50	-35	-85
105	-12	76	-13	50	35	85
110	12	-75	13	37	-35	-162

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	39250
5	1.00	1.00	0.26	208	1488	1488	1852	39250
5	1.98	1.98	0.26	208	2860	2860	3462	39250
10.Near	1.98	1.98	0.26	208	2860	2860	3462	39250
10.Far	1.98	1.98	0.26	208	2640	2699	3492	39250
10.Far	1.00	1.00	0.26	208	1381	1495	1854	39250
15	1.00	1.00	0.26	208	1381	1495	1854	39250
20	1.00	1.00	0.26	208	2952	3005	3808	39250
20	1.00	1.00	0.26	208	2965	3018	3808	39250
25	1.00	1.00	0.26	208	2387	2453	3158	39250
25	1.98	1.98	0.26	208	4623	4656	5388	39250
30.Near	1.98	1.98	0.26	208	4623	4656	5388	39250
30.Far	1.98	1.98	0.26	208	3405	3476	4576	39250
30.Far	1.00	1.00	0.26	208	1732	1871	2665	39250
35	1.00	1.00	0.26	208	1732	1871	2665	39250
40	1.00	1.00	0.26	208	1396	1565	2429	39250
40	1.00	1.00	0.26	208	1415	1583	2429	39250
45	1.00	1.00	0.26	208	612	930	2148	39250
45	1.98	1.98	0.26	208	1154	1354	3699	39250
50.Near	1.98	1.98	0.26	208	1154	1354	3699	39250
50.Far	1.98	1.98	0.26	208	1838	1869	3448	39250
50.Far	1.00	1.00	0.26	208	983	1044	1984	39250
55	1.00	1.00	0.26	208	983	1044	1984	39250
60	1.00	1.00	0.26	208	1151	1203	1298	39250
60	1.00	1.00	0.26	208	1151	1203	1298	39250
65.Near	1.00	1.00	0.26	208	1211	1260	1339	39250
65.Near	1.98	1.98	0.26	208	2290	2314	2384	39250
65.Far	1.98	1.98	0.26	208	2437	2460	2481	39250
65.Far	1.00	1.00	0.26	208	1289	1334	1396	39250
70	1.00	1.00	0.26	208	1327	1372	1431	39250
70	1.00	1.00	0.26	208	1327	1372	1431	39250
75	1.00	1.00	0.26	208	1531	1569	1725	39250
75	1.98	1.98	0.26	208	2918	2937	3200	39250
80.Near	1.98	1.98	0.26	208	2918	2937	3200	39250
80.Far	1.98	1.98	0.26	208	2622	2623	2996	39250
80.Far	1.00	1.00	0.26	208	1362	1366	1616	39250
85	1.00	1.00	0.26	208	1362	1366	1616	39250
90	1.00	1.00	0.26	208	837	844	1261	39250
90	1.00	1.00	0.26	208	818	825	1261	39250
95	1.00	1.00	0.26	208	721	730	1207	39250
95	1.00	1.00	0.26	333	938	946	1273	39250
100	1.00	1.00	0.26	333	648	661	1135	39250
100	1.00	1.00	0.33	246	499	509	896	15000
105	1.00	1.00	0.33	246	499	510	896	15000
105	1.00	1.00	0.33	246	499	510	896	15000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	706	712	1007	15000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 2

*** System Maxima ***

Maximum X displacement = 0.320 inch at point 0
Maximum Y displacement = -0.331 inch at point 75
Maximum Z displacement = 0.295 inch at point 5

Maximum X rotation = 0.252 degree at point 50.Far
Maximum Y rotation = -0.307 degree at point 0
Maximum Z rotation = -0.112 degree at point 45

Maximum X force = -12 lb at point 20
Maximum Y force = 79 lb at point 95
Maximum Z force = -13 lb at point 20

Maximum X moment = 668 inch-lb at point 15
Maximum Y moment = 332 inch-lb at point 10.Near
Maximum Z moment = -199 inch-lb at point 10.Near

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 4623 psi at point 25
Maximum principal stress = 4656 psi at point 25
Maximum code stress = 5388 psi at point 25
Maximum stress ratio (code/allowable) = 0.14 at point 25

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	0.014	-0.000	-0.000	-0.230	-0.017	-0.151
5	0.014	-0.128	0.017	-0.230	-0.017	-0.090
10.Near	0.014	-0.128	0.017	-0.230	-0.017	-0.090
10.Far	0.014	-0.123	0.018	-0.231	-0.021	-0.086
15	0.014	-0.123	0.018	-0.231	-0.021	-0.086
20	0.000	-0.000	0.018	-0.163	-0.024	-0.077
25	-0.002	0.010	0.018	-0.149	-0.023	-0.076
30.Near	-0.002	0.010	0.018	-0.149	-0.023	-0.076
30.Far	0.003	0.015	-0.015	-0.096	-0.025	-0.074
35	0.003	0.015	-0.015	-0.096	-0.025	-0.074
40	0.008	0.015	-0.020	-0.083	-0.024	-0.072
45	0.028	0.015	-0.028	-0.044	-0.024	-0.065
50.Near	0.028	0.015	-0.028	-0.044	-0.024	-0.065
50.Far	0.030	0.016	-0.028	0.018	-0.026	-0.058
55	0.030	0.016	-0.028	0.018	-0.026	-0.058
60	0.020	0.012	-0.028	0.023	-0.029	-0.041
65.Near	0.019	0.012	-0.028	0.022	-0.030	-0.041
65.Far	0.018	0.011	-0.028	0.015	-0.034	-0.038
70	0.018	0.010	-0.028	0.014	-0.035	-0.037
75	-0.002	-0.001	-0.009	-0.021	-0.035	-0.008
80.Near	-0.002	-0.001	-0.009	-0.021	-0.035	-0.008
80.Far	-0.003	0.000	-0.007	-0.022	-0.028	0.008
85	-0.003	0.000	-0.007	-0.022	-0.028	0.008
90	-0.002	0.000	-0.004	-0.020	-0.022	0.007
95	-0.001	0.000	-0.003	-0.019	-0.020	0.007
100	-0.001	0.000	-0.001	-0.015	-0.015	0.006
105	-0.000	0.000	-0.001	-0.012	-0.011	0.005
110	-0.000	0.000	-0.000	-0.000	-0.000	0.000

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments acting on Restraints ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	-5	-1	0	0	0
0	0	-5	-0	0	0	0
20	4	-29	0	0	0	0
20	0	-29	4	0	0	0
110	-5	72	-5	-113	-77	56

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments in Element Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	11	1	-0	0	0
5	1	9	-1	0	-39	72
5	-1	1	9	0	-72	-39
10.Near	-1	1	9	0	-72	-39
10.Far	-1	-1	-10	52	-22	38
10.Far	1	-10	1	-52	38	22
15	1	-10	1	-52	38	22
20	-1	21	-2	52	-31	-545
20	-5	37	3	-52	31	545
25	5	-36	-3	52	-31	-412
25	-5	36	3	-52	31	412
30.Near	-5	36	3	-52	31	412
30.Far	-35	-5	-3	-31	-50	-324
30.Far	35	-5	-3	31	-50	-324
35	35	-5	-3	31	-50	-324
40	-33	5	3	-31	47	302
40	21	-6	-2	31	-47	-302
45	-16	6	2	-31	70	268
45	16	-6	-2	31	-70	-268
50.Near	16	-6	-2	31	-70	-268
50.Far	6	14	2	75	35	232
50.Far	-6	14	2	-75	35	232
55	-6	14	2	-75	35	232
60	7	-7	-2	75	-78	75
60	-7	7	2	-75	78	-75
65.Near	7	-7	-2	75	-81	82
65.Near	-7	-2	7	-75	82	81
65.Far	6	-3	-6	-20	-115	-80
65.Far	-6	6	-3	20	80	-115
70	6	-6	3	-20	-76	121
70	-6	6	-3	20	76	-121
75	7	8	4	-20	68	46
75	-7	8	4	20	68	46
80.Near	-7	8	4	20	68	46
80.Far	-10	-7	-4	-77	-20	-20
80.Far	10	-7	2	77	-28	-8
85	10	-7	2	77	-28	-8
90	-12	8	-2	-77	-32	-55
90	24	-8	3	77	32	55
95	-25	8	-3	-77	-36	-68
95	-76	-5	5	77	36	68
100	74	5	-5	-77	-30	-87
100	-74	-5	5	77	30	87
105	74	5	-5	-77	-34	-93
105	-74	-5	5	77	34	93
110	72	5	-5	-77	-56	-113

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments in Global Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	-0	11	1	-0	0	0
5	1	9	-1	0	-39	72
5	-1	-9	1	0	39	-72
10.Near	-1	-9	1	0	39	-72
10.Far	1	10	-1	22	-38	52
10.Far	-1	-10	1	-22	38	-52
15	-1	-10	1	-22	38	-52
20	2	21	-1	545	-31	52
20	-3	37	-5	-545	31	-52
25	3	-36	5	412	-31	52
25	-3	36	-5	-412	31	-52
30.Near	-3	36	-5	-412	31	-52
30.Far	3	-35	5	324	-31	50
30.Far	-3	35	-5	-324	31	-50
35	-3	35	-5	-324	31	-50
40	3	-33	5	302	-31	47
40	-2	21	-6	-302	31	-47
45	2	-16	6	268	-31	70
45	-2	16	-6	-268	31	-70
50.Near	-2	16	-6	-268	31	-70
50.Far	2	-14	6	232	-35	75
50.Far	-2	14	-6	-232	35	-75
55	-2	14	-6	-232	35	-75
60	2	-7	7	-75	-78	75
60	-2	7	-7	75	78	-75
65.Near	2	-7	7	-82	-81	75
65.Near	-2	7	-7	82	81	-75
65.Far	2	-6	7	-91	-80	78
65.Far	-2	6	-7	91	80	-78
70	2	-6	7	-95	-76	83
70	-2	6	-7	95	76	-83
75	2	8	7	-38	68	41
75	-2	-8	-7	38	-68	-41
80.Near	-2	-8	-7	38	-68	-41
80.Far	2	10	7	-8	77	28
80.Far	-2	-10	-7	8	-77	-28
85	-2	-10	-7	8	-77	-28
90	2	12	8	55	77	-32
90	-3	-24	-8	-55	-77	32
95	3	25	8	68	77	-36
95	-5	76	-5	-68	-77	36
100	5	-74	5	87	77	-30
100	-5	74	-5	-87	-77	30
105	5	-74	5	93	77	-34
105	-5	74	-5	-93	-77	34
110	5	-72	5	113	77	-56

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	18840
5	1.00	1.00	0.26	208	436	436	453	18840
5	1.98	1.98	0.26	208	774	774	620	18840
10.Near	1.98	1.98	0.26	208	774	774	620	18840
10.Far	1.98	1.98	0.26	208	485	531	535	18840
10.Far	1.00	1.00	0.26	208	290	378	395	18840
15	1.00	1.00	0.26	208	290	378	395	18840
20	1.00	1.00	0.26	208	2241	2254	2286	18840
20	1.00	1.00	0.26	208	2247	2261	2286	18840
25	1.00	1.00	0.26	208	1720	1736	1763	18840
25	1.98	1.98	0.26	208	3314	3323	2569	18840
30.Near	1.98	1.98	0.26	208	3314	3323	2569	18840
30.Far	1.98	1.98	0.26	208	2580	2587	2056	18840
30.Far	1.00	1.00	0.26	208	1319	1332	1418	18840
35	1.00	1.00	0.26	208	1319	1332	1418	18840
40	1.00	1.00	0.26	208	1221	1239	1327	18840
40	1.00	1.00	0.26	208	1241	1259	1327	18840
45	1.00	1.00	0.26	208	1136	1144	1193	18840
45	1.98	1.98	0.26	208	2187	2191	1720	18840
50.Near	1.98	1.98	0.26	208	2187	2191	1720	18840
50.Far	1.98	1.98	0.26	208	1903	1916	1528	18840
50.Far	1.00	1.00	0.26	208	1010	1035	1064	18840
55	1.00	1.00	0.26	208	1010	1035	1064	18840
60	1.00	1.00	0.26	208	523	594	630	18840
60	1.00	1.00	0.26	208	523	594	630	18840
65.Near	1.00	1.00	0.26	208	554	618	653	18840
65.Near	1.98	1.98	0.26	208	999	1030	919	18840
65.Far	1.98	1.98	0.26	208	1211	1214	960	18840
65.Far	1.00	1.00	0.26	208	661	666	681	18840
70	1.00	1.00	0.26	208	675	680	696	18840
70	1.00	1.00	0.26	208	675	680	696	18840
75	1.00	1.00	0.26	208	418	429	450	18840
75	1.98	1.98	0.26	208	729	735	615	18840
80.Near	1.98	1.98	0.26	208	729	735	615	18840
80.Far	1.98	1.98	0.26	208	299	453	597	18840
80.Far	1.00	1.00	0.26	208	189	369	437	18840
85	1.00	1.00	0.26	208	189	369	437	18840
90	1.00	1.00	0.26	208	337	469	523	18840
90	1.00	1.00	0.26	208	318	461	523	18840
95	1.00	1.00	0.26	208	369	498	560	18840
95	1.00	1.00	0.26	333	587	672	625	18840
100	1.00	1.00	0.26	333	635	698	648	18840
100	1.00	1.00	0.33	246	489	538	508	7200
105	1.00	1.00	0.33	246	511	557	526	7200
105	1.00	1.00	0.33	246	511	557	526	7200

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	618	652	617	7200

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Maxima ***

Maximum X displacement = 0.030 inch at point 50.Far
Maximum Y displacement = -0.128 inch at point 5
Maximum Z displacement = -0.028 inch at point 50.Far

Maximum X rotation = -0.231 degree at point 10.Far
Maximum Y rotation = -0.035 degree at point 75
Maximum Z rotation = -0.151 degree at point 0

Maximum X force = -5 lb at point 95
Maximum Y force = 76 lb at point 95
Maximum Z force = 8 lb at point 95

Maximum X moment = 545 inch-lb at point 15
Maximum Y moment = -81 inch-lb at point 65.Near
Maximum Z moment = 83 inch-lb at point 70

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3314 psi at point 25
Maximum principal stress = 3323 psi at point 25
Maximum code stress = 2569 psi at point 25
Maximum stress ratio (code/allowable) = 0.14 at point 25

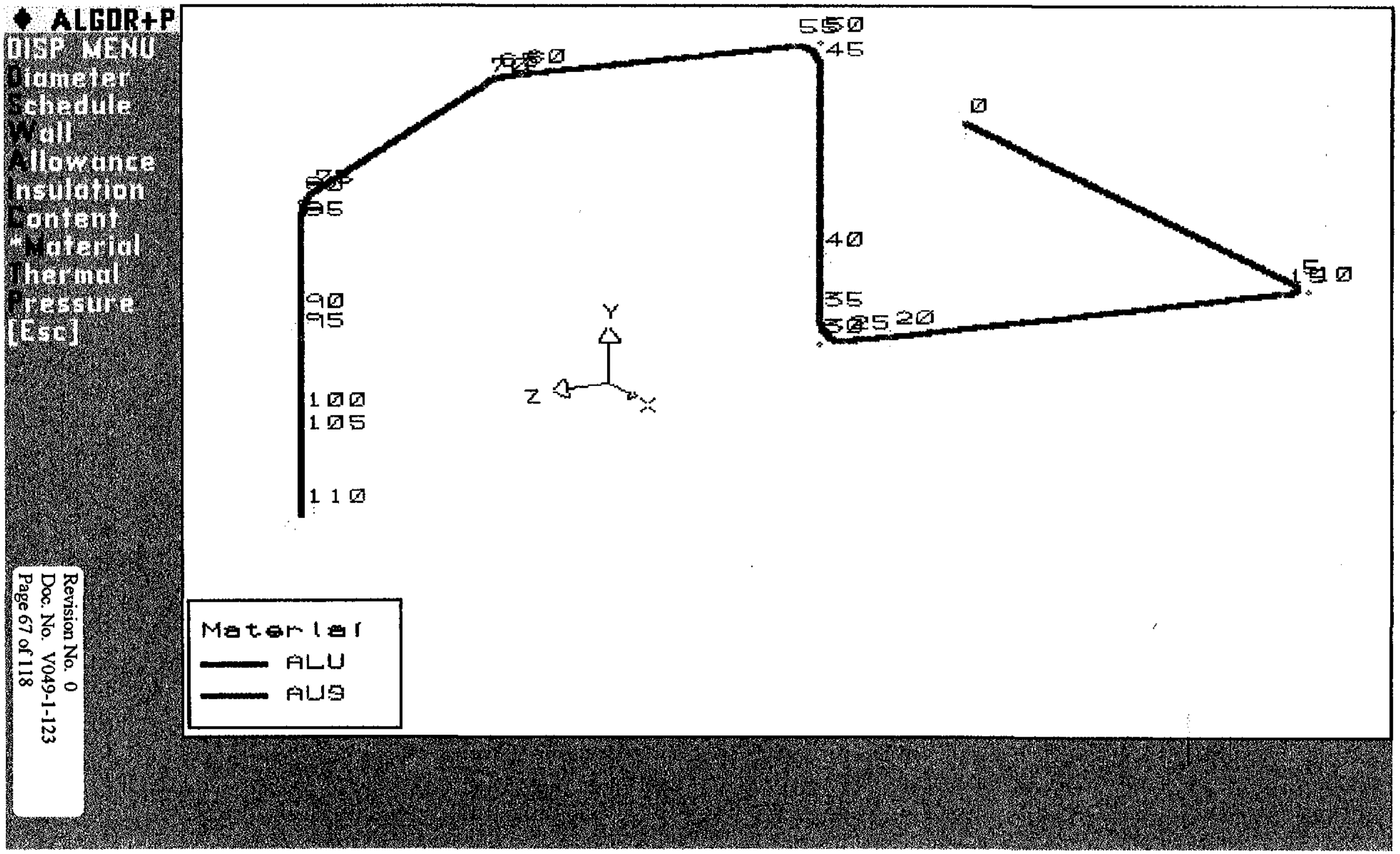
1-1/2″ ∅ GN_2 Vent Piping

Regeneration/ReGasification

1-1/2" GN_2 VENT

Regeneration/ReGasification

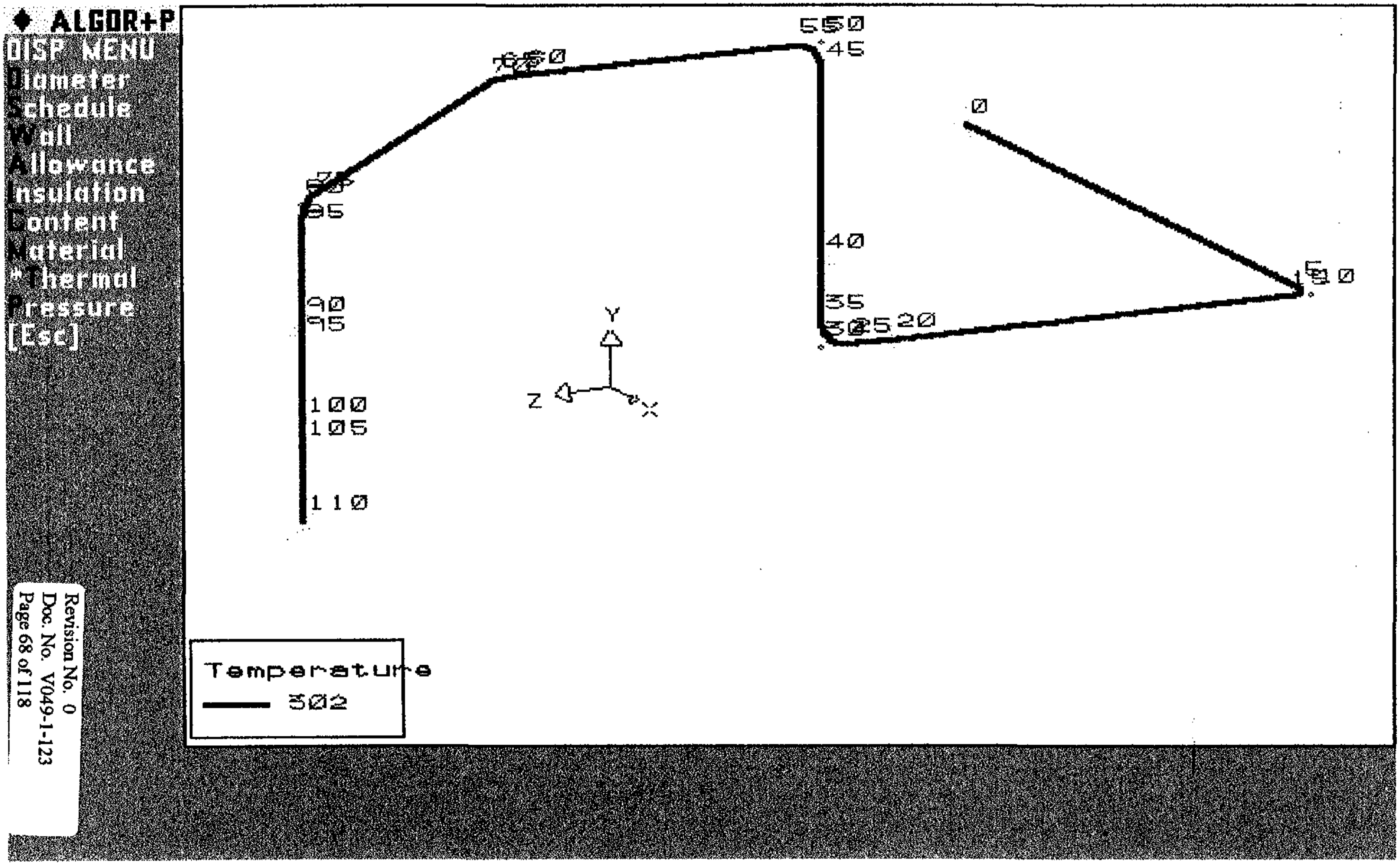
Material



1-1/2" GN_2 VENT

Regeneration/ReGasification

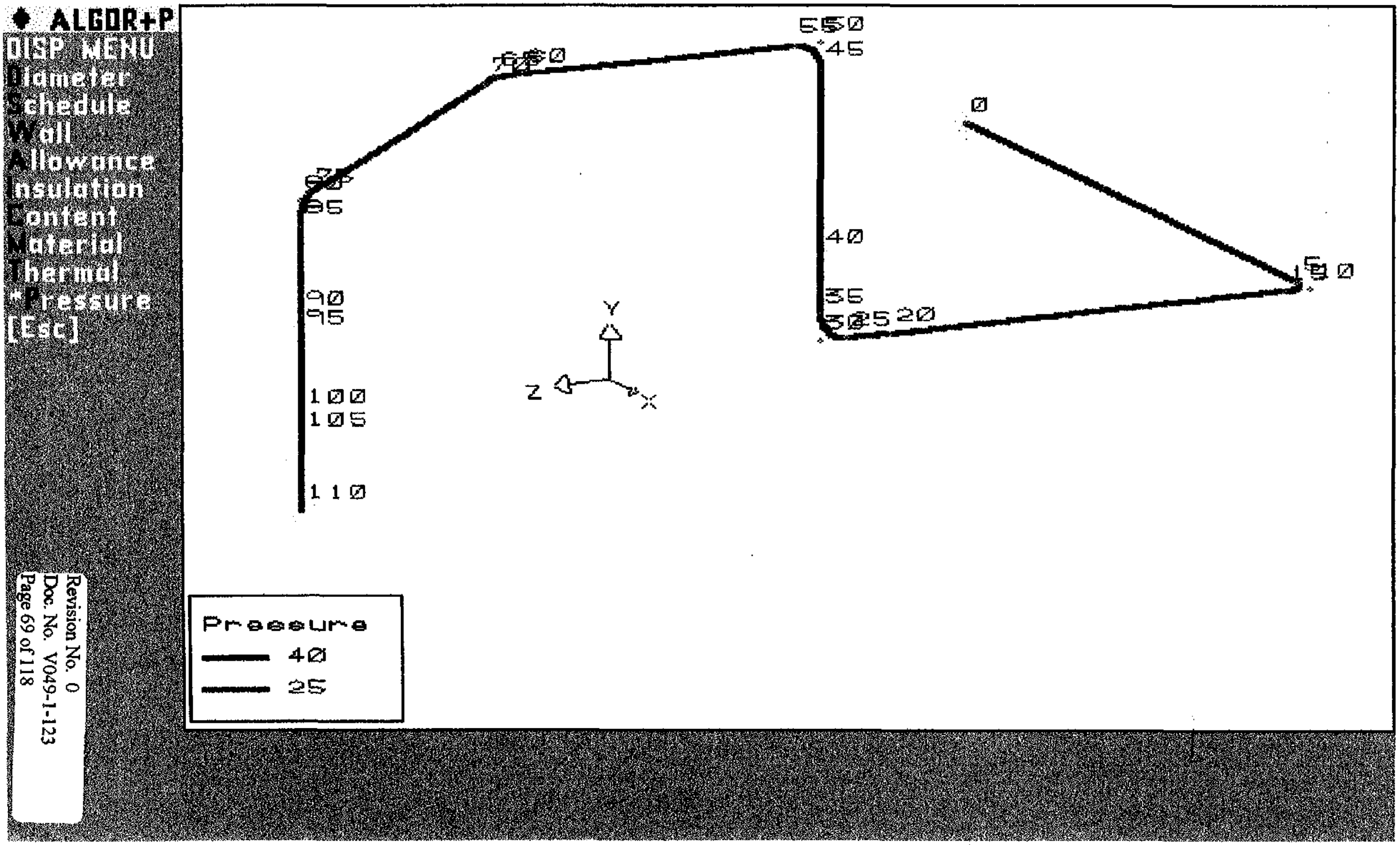
Thermal



1-1/2" GN_2 VENT

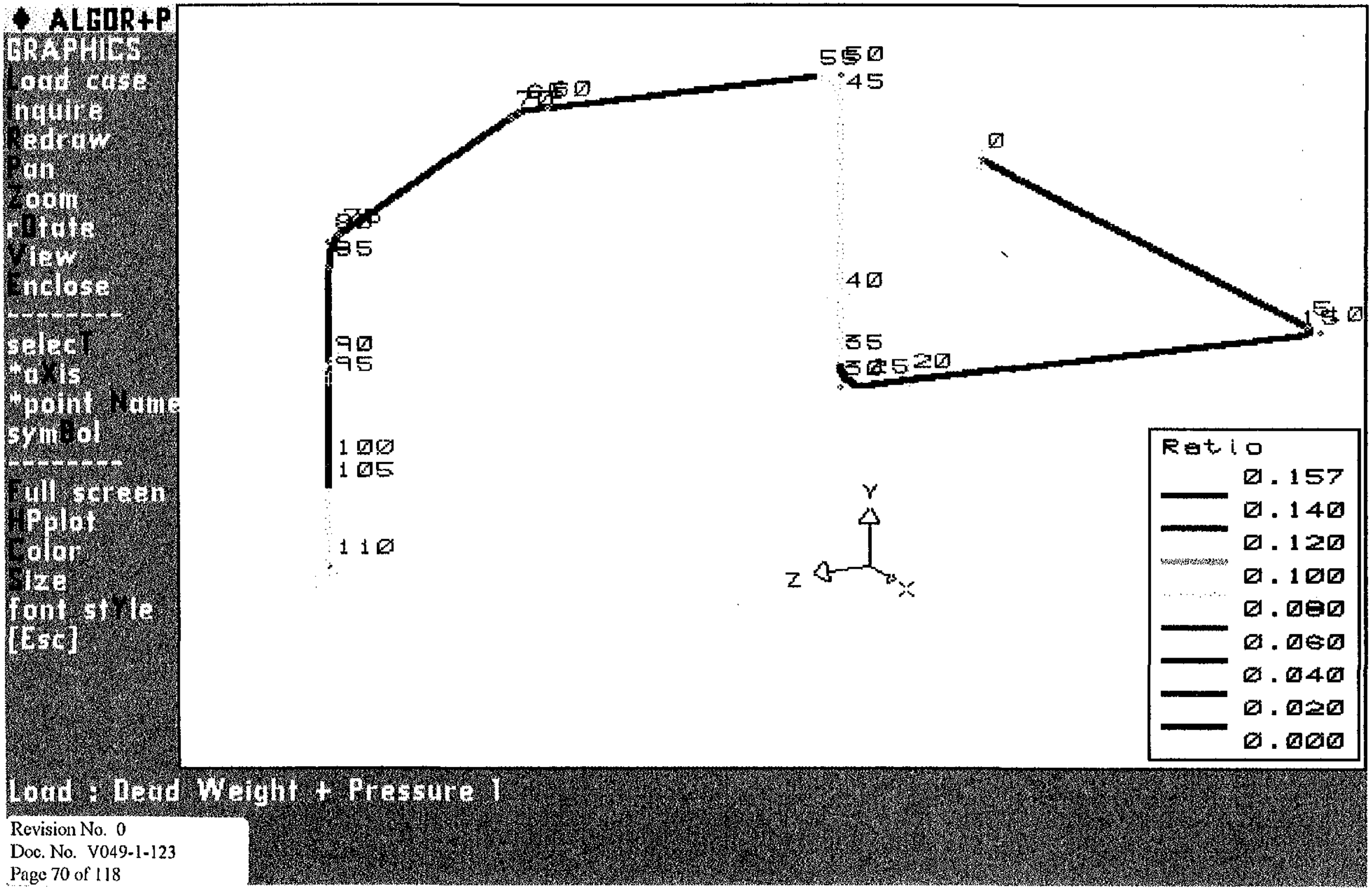
Regeneration/ReGasification

Pressure



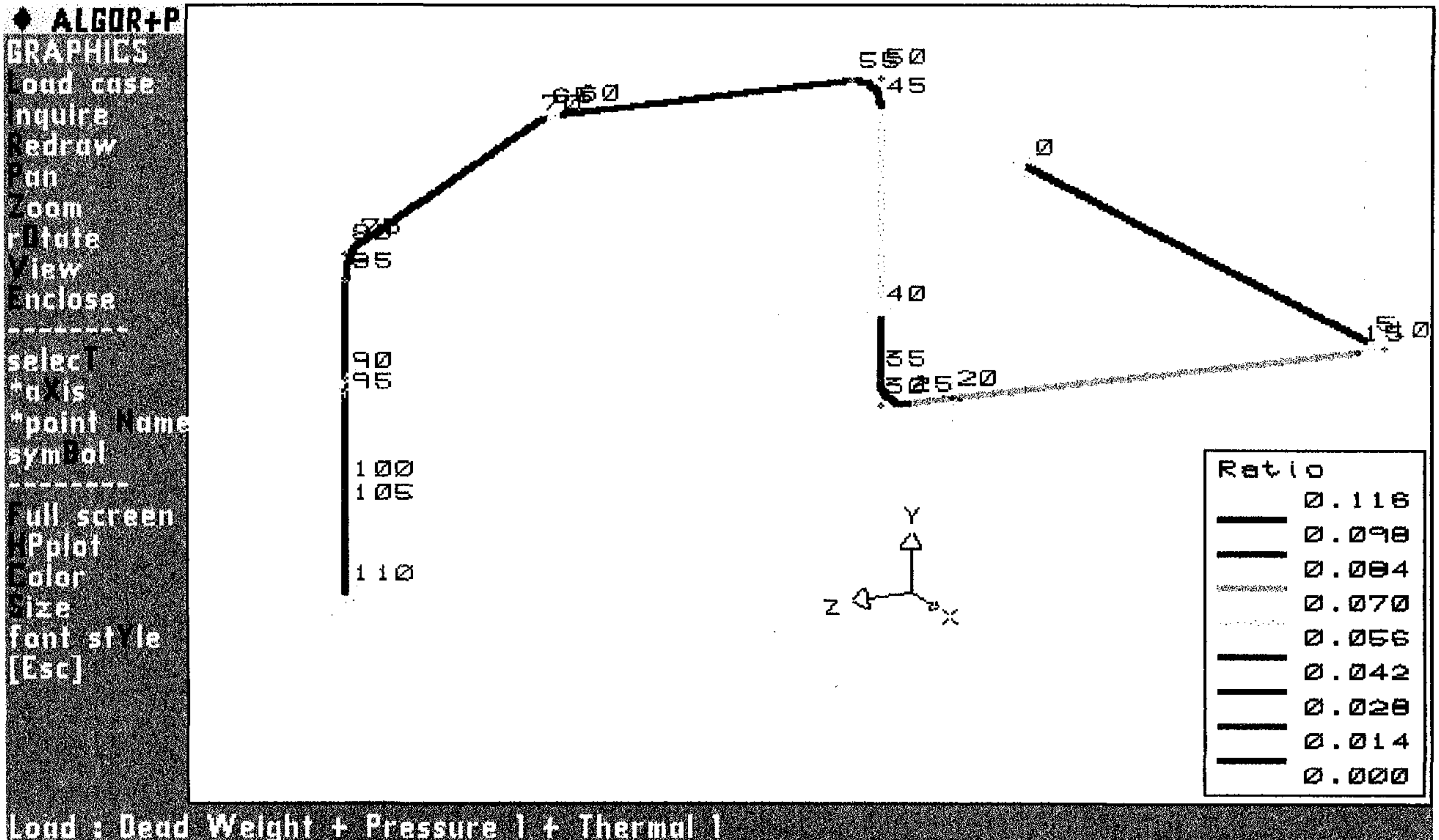
1-1/2" GN_2 VENT

Regeneration/ReGasification



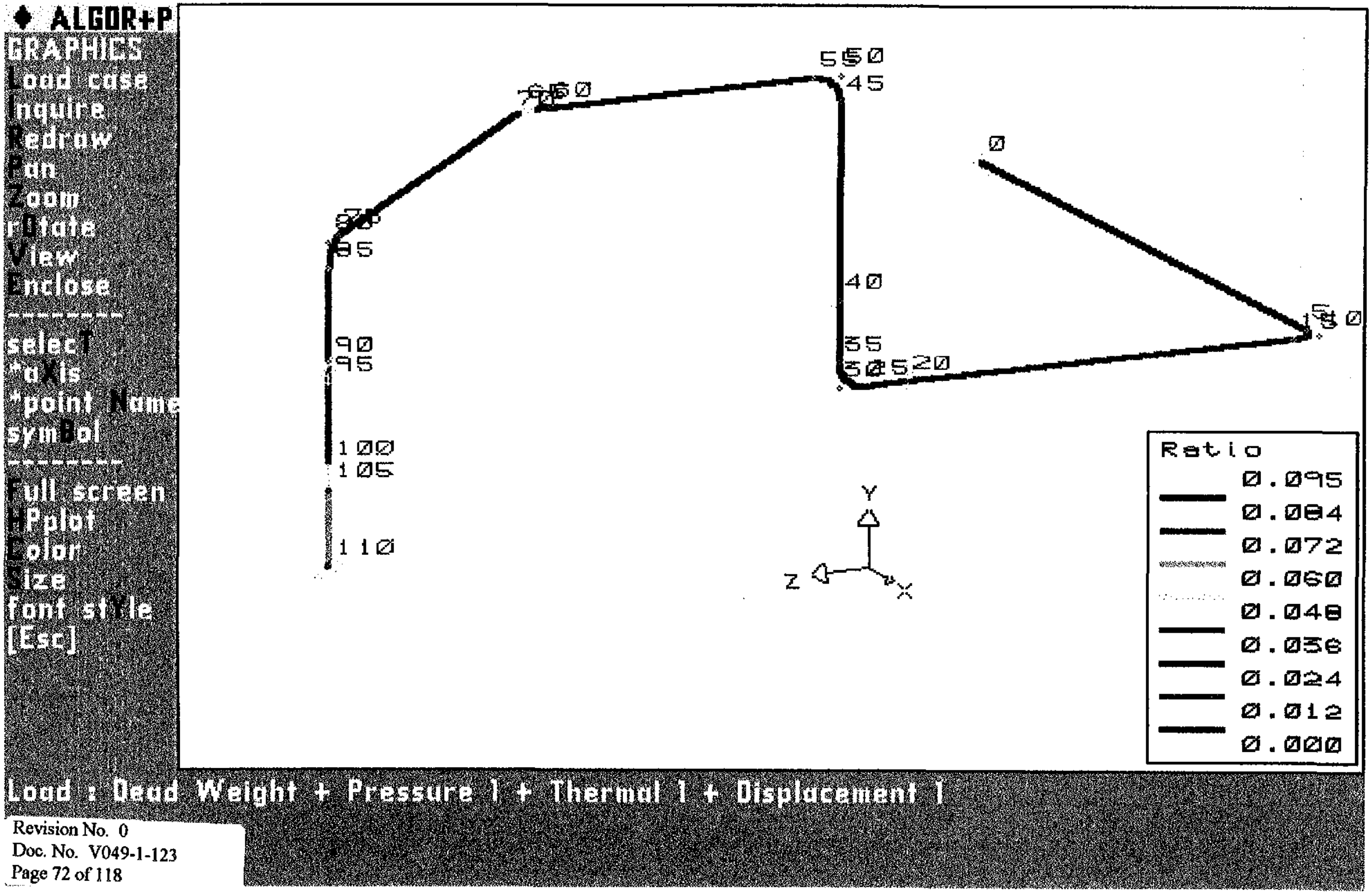
1-1/2" GN_2 VENT

Regeneration/ReGasification



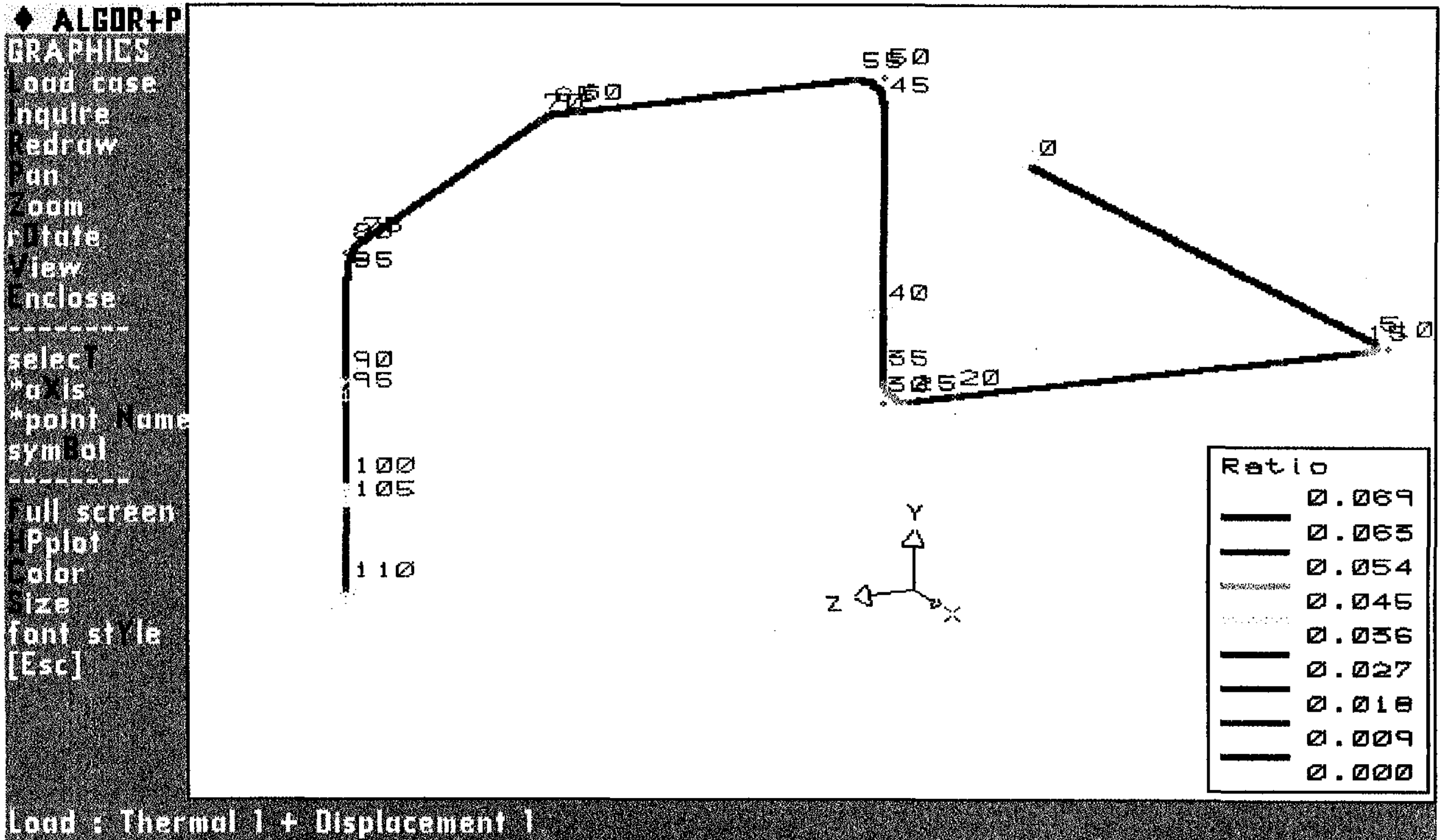
1-1/2" GN_2 VENT

Regeneration/ReGasification



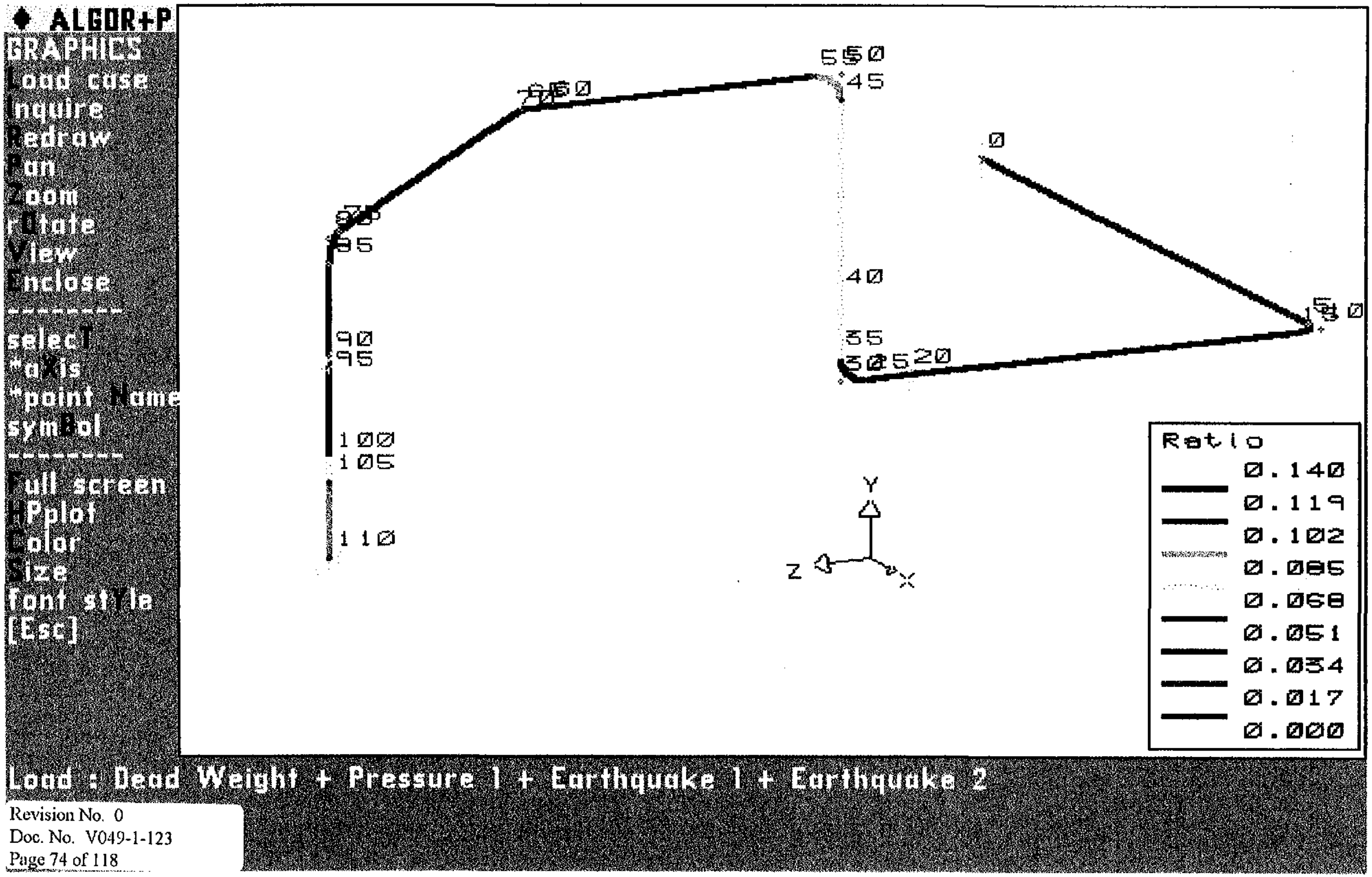
1-1/2" GN_2 VENT

Regeneration/ReGasification



1-1/2" GN_2 VENT

Regeneration/ReGasification



```
File Name ............... GN2VENTR
Project ................. LIGO
Department .............. 744
Contract Number .........
Description ............. 80K CRYOPUMP 1-1/2" GN2 VENT
                          Regeneration/ReGasification Process
Prepared by ............. W. BILYNSKY
Checked by ..............

ANSI code ............... ANSI B31.1
Input unit .............. English
Output unit ............. English
Output columns .......... 80
Base temperature ........ 70
F factor ................ 1.0
E factor ................ 1.2

Number of dynamic modes.. 12
Cut-off frequency ....... 33        Hz
Max no. of iterations ... 12
Convergence tolerance ... 3
Force tolerance ......... 5         lb
```

Frm /To	Point name	DX (feet)	DY (feet)	DZ (feet)	Radius (inch)	X (feet)	Y (feet)	Z (feet)
F	0	0.	0.	0.		0.000	0.000	0.000
T	5	5.0				5.000	0.000	0.000
T	10	0.1875			Long	5.188	0.000	0.000
T	15			0.1875		5.188	0.000	0.188
T	20			2.8021		5.188	0.000	2.990
T	25			0.3125		5.188	0.000	3.302
T	30			0.1875	Long	5.188	0.000	3.490
T	35		0.1875			5.188	0.188	3.490
T	40		0.4375			5.188	0.625	3.490
T	45		1.4010			5.188	2.026	3.490
T	50		0.1875		Long	5.188	2.214	3.490
T	55			0.1875		5.188	2.214	3.677
T	60			1.9375		5.188	2.214	5.615
T	65			0.1875	Long	5.188	2.214	5.802
T	70	0.1326		0.1326		5.320	2.214	5.935
T	75	2.381		2.381		7.701	2.214	8.316
T	80	0.1326		0.1326	Long	7.834	2.214	8.448
T	85		-0.1875			7.834	2.026	8.448
T	90		-0.6771			7.834	1.349	8.448
T	95		-0.1354			7.834	1.214	8.448
T	100		-0.5833			7.834	0.630	8.448
T	105		-0.1667			7.834	0.464	8.448
T	110		-0.54167			7.834	-0.078	8.448

```
Point  Data      Description
-----  --------  ----------------------------------------------
0      Pipe      Pipe data identifier = 1
                 Nominal Diameter = 1"1/2
                 Pipe Schedule = 10S
                 Actual Pipe O. D. = 1.900    inch
                 Wall Thickness = .109     inch
                 Corrosion Allowance = 0.       inch
                 Insulation Thickness = 1.5      inch
                 Insulation Density = 7.0      lb/cu.ft
                 Content S. G. = .9714
                 Wind area O.D. = Insulation O.D.
       Material  Data Identifier = 1
                 Austenitic stainless (301-309, 316, 321, 237)
                 Density = 0.2899   lb/cu.inch
                 Tempera.   Modulus   Expansion
                 (deg.F)   (psi    )  (inch/inch)
                 -325.     30400000   -0.00321
                 -150.     29900000   -0.00189
                 -50.      29400000   -0.00103
                 70.       28300000   0.00000
                 200.      27700000   0.00122
                 300.      27100000   0.00218
                 400.      26600000   0.00317
                 500.      26100000   0.00417
                 600.      25400000   0.00520
                 700.      24800000   0.00625
                 800.      24100000   0.00733
                 900.      23400000   0.00843
                 1000.     22700000   0.00957
                 1100.     22000000   0.01070
                 1200.     21300000   0.01183
                 1300.     20700000   0.01297
                 1400.     19300000   0.01410
                 Temperature  Allowable stresses
                   (deg.F)          (psi)
                    -320.           15700.
                    70.             15700.
                    302.            15300.
                    400.            14700.
       Load      Load data identifier = 1
                 Case  Temperature  Pressure   Expansion
                  No.    (deg.F)     (psig   ) (inch/inch)
                   1      302.        25.0      0.002200
       Guide
       Support   Limit Stop
                 Spring constant = Rigid    lb/inch
                 Gap in positive direction = 0.0625   inch
                 Gap in negative direction = 0.0      inch
                 Friction coefficient = 0.30
                 Y directional limit stop

5
```

```
Point Data      Description
----- --------- ------------------------------------------------
10
15
20    Guide
      Support   Limit Stop
                Spring constant = Rigid    lb/inch
                Gap in positive direction = 0.0625   inch
                Gap in negative direction = 0.0      inch
                Friction coefficient = 0.30
                Y directional limit stop
25
30
35
40    Flange    Weld neck flange (SIF=1.0)
                Class  = 150
                Weight = 12.      lb
                Gasket diameter = N/A inch
45
50
55
60
65
70
75
80
85
90    Flange    Weld neck flange (SIF=1.0)
                Class  = 150
                Weight = 12.      lb
                Gasket diameter = N/A inch
95    Load      Load data identifier = 2
                Case  Temperature  Pressure   Expansion
                 No.   (deg.F)     (psig   ) (inch/inch)
                  1      302.         40.0     0.002200
      Weight    Concentrated weight = -100.    lb
100   Pipe      Pipe data identifier = 2
                Nominal Diameter = 1"1/2
                Pipe Schedule = 40S
                Actual Pipe O. D. = 1.900    inch
                Wall Thickness = .145     inch
                Corrosion Allowance = 0.       inch
                Insulation Thickness = 1.5      inch
                Insulation Density = 7.0      lb/cu.ft
                Content S. G. = .9714
                Wind area O.D. = Insulation O.D.
      Material  Data Identifier = 2
                Aluminum, aluminum alloys
                Density = 0.0978   lb/cu.inch
                Tempera.   Modulus   Expansion
                (deg.F)    (psi    )  (inch/inch)
                -325.      11300000  -0.00390
```

Point	Data	Description
		-150. 11100000 -0.00240
		-50. 10900000 -0.00139
		70. 10600000 0.00000
		200. 10400000 0.00167
		300. 10200000 0.00306
		400. 9500000 0.00449
		500. 8500000 0.00598
		Temperature Allowable stresses
		(deg.F) (psi)
		400 3500.
		302. 5500.
		70. 6000.
		-320. 6000.
105		
110	Anchor	Rigid in all directions
		Initial displacement (inch,degree) :
		Case 1, translational X = 0.026 inch
		Case 1, translational Y = 0.0911 inch

Case number	Combination
1	D.W. + Pres1
2	D.W. + Pres1 + Ther1
3	D.W. + Pres1 + Ther1 + Disp1
4	Ther1 + Disp1
5	D.W. + Pres1 + Quake1 + Quake2

Earthquake Load Factors

Case number	X factor	Y factor	Z factor
1	0.05625		
2			0.05625

*** Support Summary ***

Forces/lb or Moments/inch-lb

Point Name	Global Direction	Sustain	Expansion Max	Expansion Min	Occasional Max	Occasional Min	Total Max	Total Min
0	Fy	-5	0	-1	0	-0	-5	-6
	Fz	-0	0	-3	1	-1	1	-4
0	Fx	0	0	-0	0	0	0	-0
	Fy	-5	0	-1	0	-0	-5	-6
20	Fx	1	0	-10	4	-4	4	-13
	Fy	-29	1	-1	0	-0	-28	-29
20	Fy	-29	1	-1	0	-0	-28	-29
	Fz	4	0	-10	0	0	4	-6
110	Fx	-1	10	0	4	-4	13	-5
	Fy	72	3	0	1	-1	76	71
	Fz	-4	14	0	1	-1	11	-5
	Mx	-91	307	0	22	-22	239	-113
	My	-53	14	-19	24	-24	-15	-95
	Mz	15	0	-247	41	-41	56	-273

*** Flange Loading Report ***

Point Name	Flange Class	Operating Pressure (psig)	Temp. (deg.F)	Force (lb)	Moment (inch-lb)	Gasket Diameter (inch)	Equivalent Pressure (psig)
40	150	25	302	24	316	N/A	N/A
90	150	25	302	20	85	N/A	N/A

Load : Dead Weight + Pressure 1

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	0.004	-0.000	-0.000	-0.212	-0.002	-0.140
5	0.004	-0.117	0.002	-0.212	-0.004	-0.079
10.Near	0.004	-0.117	0.002	-0.212	-0.004	-0.079
10.Far	0.004	-0.112	0.003	-0.212	-0.005	-0.075
15	0.004	-0.112	0.003	-0.212	-0.005	-0.075
20	0.000	-0.000	0.003	-0.144	-0.008	-0.063
25	-0.001	0.009	0.003	-0.130	-0.008	-0.062
30.Near	-0.001	0.009	0.003	-0.130	-0.008	-0.062
30.Far	0.001	0.013	-0.001	-0.076	-0.011	-0.058
35	0.001	0.013	-0.001	-0.076	-0.011	-0.058
40	0.007	0.013	-0.007	-0.063	-0.012	-0.057
45	0.022	0.013	-0.020	-0.026	-0.014	-0.050
50.Near	0.022	0.013	-0.020	-0.026	-0.014	-0.050
50.Far	0.024	0.013	-0.021	0.007	-0.018	-0.044
55	0.024	0.013	-0.021	0.007	-0.018	-0.044
60	0.016	0.007	-0.021	0.018	-0.023	-0.030
65.Near	0.015	0.006	-0.021	0.017	-0.023	-0.030
65.Far	0.014	0.006	-0.021	0.012	-0.026	-0.027
70	0.014	0.005	-0.020	0.012	-0.027	-0.026
75	-0.000	-0.000	-0.006	-0.014	-0.024	-0.002
80.Near	-0.000	-0.000	-0.006	-0.014	-0.024	-0.002
80.Far	-0.001	0.000	-0.005	-0.015	-0.020	0.002
85	-0.001	0.000	-0.005	-0.015	-0.020	0.002
90	-0.000	0.000	-0.003	-0.014	-0.015	0.002
95	-0.000	0.000	-0.002	-0.014	-0.014	0.002
100	-0.000	0.000	-0.001	-0.011	-0.010	0.002
105	-0.000	0.000	-0.001	-0.009	-0.008	0.001
110	-0.000	0.000	-0.000	-0.000	-0.000	0.000

Load : Dead Weight + Pressure 1

*** Forces and Moments acting on Restraints ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	-5	-0	0	0	0
0	0	-5	-0	0	0	0
20	1	-29	0	0	0	0
20	0	-29	4	0	0	0
110	-1	72	-4	-91	-53	15

Load : Dead Weight + Pressure 1

*** Forces and Moments in Element Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	11	0	-0	0	0
5	0	9	-0	0	-9	54
5	-0	0	9	0	-54	-9
10.Near	-0	0	9	0	-54	-9
10.Far	-0	-0	-10	33	-21	10
10.Far	0	-10	0	-33	10	21
15	0	-10	0	-33	10	21
20	-0	21	-0	33	-10	-534
20	-4	36	1	-33	10	534
25	4	-35	-1	33	-13	-400
25	-4	35	1	-33	13	400
30.Near	-4	35	1	-33	13	400
30.Far	-34	-4	-1	-15	-35	-313
30.Far	34	-4	-1	15	-35	-313
35	34	-4	-1	15	-35	-313
40	-32	4	1	-15	40	293
40	20	-4	-1	15	-40	-293
45	-15	4	1	-15	54	231
45	15	-4	-1	15	-54	-231
50.Near	15	-4	-1	15	-54	-231
50.Far	4	14	1	56	17	190
50.Far	-4	14	1	-56	17	190
55	-4	14	1	-56	17	190
60	4	-6	-1	56	-37	46
60	-4	6	1	-56	37	-46
65.Near	4	-6	-1	56	-38	54
65.Near	-4	-1	6	-56	54	38
65.Far	3	-2	-5	-2	-87	-37
65.Far	-3	5	-2	2	37	-87
70	3	-5	2	-2	-34	93
70	-3	5	-2	2	34	-93
75	3	8	2	-2	48	34
75	-3	8	2	2	48	34
80.Near	-3	8	2	2	48	34
80.Far	-9	-3	-2	-53	-2	-7
80.Far	9	-4	1	53	-7	-4
85	9	-4	1	53	-7	-4
90	-12	4	-1	-53	-0	-27
90	24	-4	1	53	0	27
95	-24	4	-1	-53	-1	-33
95	-76	-4	1	53	1	33
100	74	4	-1	-53	-7	-59
100	-74	-4	1	53	7	59
105	73	4	-1	-53	-9	-66
105	-73	-4	1	53	9	66
110	72	4	-1	-53	-15	-91

Load : Dead Weight + Pressure 1

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	11	0	-0	0	0
5	0	9	-0	0	-9	54
5	-0	-9	0	0	9	-54
10.Near	-0	-9	0	0	9	-54
10.Far	0	10	-0	21	-10	33
10.Far	-0	-10	0	-21	10	-33
15	-0	-10	0	-21	10	-33
20	0	21	-0	534	-10	33
20	-1	36	-4	-534	10	-33
25	1	-35	4	400	-13	33
25	-1	35	-4	-400	13	-33
30.Near	-1	35	-4	-400	13	-33
30.Far	1	-34	4	313	-15	35
30.Far	-1	34	-4	-313	15	-35
35	-1	34	-4	-313	15	-35
40	1	-32	4	293	-15	40
40	-1	20	-4	-293	15	-40
45	1	-15	4	231	-15	54
45	-1	15	-4	-231	15	-54
50.Near	-1	15	-4	-231	15	-54
50.Far	1	-14	4	190	-17	56
50.Far	-1	14	-4	-190	17	-56
55	-1	14	-4	-190	17	-56
60	1	-6	4	-46	-37	56
60	-1	6	-4	46	37	-56
65.Near	1	-6	4	-54	-38	56
65.Near	-1	6	-4	54	38	-56
65.Far	1	-5	4	-63	-37	60
65.Far	-1	5	-4	63	37	-60
70	1	-5	4	-68	-34	64
70	-1	5	-4	68	34	-64
75	1	8	4	-25	48	22
75	-1	-8	-4	25	-48	-22
80.Near	-1	-8	-4	25	-48	-22
80.Far	1	9	4	-4	53	7
80.Far	-1	-9	-4	4	-53	-7
85	-1	-9	-4	4	-53	-7
90	1	12	4	27	53	-0
90	-1	-24	-4	-27	-53	0
95	1	24	4	33	53	-1
95	-1	76	-4	-33	-53	1
100	1	-74	4	59	53	-7
100	-1	74	-4	-59	-53	7
105	1	-73	4	66	53	-9
105	-1	73	-4	-66	-53	9
110	1	-72	4	91	53	-15

Load : Dead Weight + Pressure 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	91	208	109	15300
5	1.00	1.00	0.26	208	300	300	319	15300
5	1.98	1.98	0.26	208	506	506	421	15300
10.Near	1.98	1.98	0.26	208	506	506	421	15300
10.Far	1.98	1.98	0.26	208	268	308	341	15300
10.Far	1.00	1.00	0.26	208	180	259	265	15300
15	1.00	1.00	0.26	208	180	259	265	15300
20	1.00	1.00	0.26	208	2146	2148	2169	15300
20	1.00	1.00	0.26	208	2153	2155	2169	15300
25	1.00	1.00	0.26	208	1636	1639	1654	15300
25	1.98	1.98	0.26	208	3149	3150	2406	15300
30.Near	1.98	1.98	0.26	208	3149	3150	2406	15300
30.Far	1.98	1.98	0.26	208	2439	2440	1914	15300
30.Far	1.00	1.00	0.26	208	1248	1248	1323	15300
35	1.00	1.00	0.26	208	1248	1248	1323	15300
40	1.00	1.00	0.26	208	1178	1178	1250	15300
40	1.00	1.00	0.26	208	1197	1198	1250	15300
45	1.00	1.00	0.26	208	978	979	1023	15300
45	1.98	1.98	0.26	208	1874	1874	1467	15300
50.Near	1.98	1.98	0.26	208	1874	1874	1467	15300
50.Far	1.98	1.98	0.26	208	1553	1562	1247	15300
50.Far	1.00	1.00	0.26	208	831	849	874	15300
55	1.00	1.00	0.26	208	831	849	874	15300
60	1.00	1.00	0.26	208	322	387	420	15300
60	1.00	1.00	0.26	208	322	387	420	15300
65.Near	1.00	1.00	0.26	208	350	408	441	15300
65.Near	1.98	1.98	0.26	208	598	626	603	15300
65.Far	1.98	1.98	0.26	208	814	814	647	15300
65.Far	1.00	1.00	0.26	208	458	458	471	15300
70	1.00	1.00	0.26	208	479	479	492	15300
70	1.00	1.00	0.26	208	479	479	492	15300
75	1.00	1.00	0.26	208	322	322	335	15300
75	1.98	1.98	0.26	208	544	544	446	15300
80.Near	1.98	1.98	0.26	208	544	544	446	15300
80.Far	1.98	1.98	0.26	208	135	280	414	15300
80.Far	1.00	1.00	0.26	208	106	271	314	15300
85	1.00	1.00	0.26	208	106	271	314	15300
90	1.00	1.00	0.26	208	174	294	337	15300
90	1.00	1.00	0.26	208	155	286	337	15300
95	1.00	1.00	0.26	208	177	295	348	15300
95	1.00	1.00	0.26	333	395	470	413	15300
100	1.00	1.00	0.26	333	493	542	480	15300
100	1.00	1.00	0.33	246	376	415	375	5500
105	1.00	1.00	0.33	246	399	434	393	5500
105	1.00	1.00	0.33	246	399	434	393	5500

Load : Dead Weight + Pressure 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	473	499	456	5500

Load : Dead Weight + Pressure 1

*** System Maxima ***

Maximum X displacement = 0.024 inch at point 50.Far
Maximum Y displacement = -0.117 inch at point 5
Maximum Z displacement = -0.021 inch at point 50.Far

Maximum X rotation = -0.212 degree at point 10.Far
Maximum Y rotation = -0.027 degree at point 70
Maximum Z rotation = -0.140 degree at point 0

Maximum X force = -1 lb at point 20
Maximum Y force = 76 lb at point 95
Maximum Z force = -4 lb at point 20

Maximum X moment = 534 inch-lb at point 15
Maximum Y moment = 53 inch-lb at point 80.Near
Maximum Z moment = 64 inch-lb at point 70

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3149 psi at point 25
Maximum principal stress = 3150 psi at point 25
Maximum code stress = 2406 psi at point 25
Maximum stress ratio (code/allowable) = 0.16 at point 25

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Deflections ***

Point Name	Displacements/inch X	Y	Z	Rotations/degree X	Y	Z
0	-0.168	-0.000	-0.000	-0.304	0.166	-0.209
5	-0.036	-0.179	-0.155	-0.304	0.112	-0.117
10.Near	-0.036	-0.179	-0.155	-0.304	0.112	-0.117
10.Far	-0.027	-0.171	-0.154	-0.309	0.077	-0.101
15	-0.027	-0.171	-0.154	-0.309	0.077	-0.101
20	-0.000	-0.000	-0.080	-0.252	0.016	-0.042
25	0.001	0.016	-0.072	-0.240	0.009	-0.035
30.Near	0.001	0.016	-0.072	-0.240	0.009	-0.035
30.Far	0.002	0.030	-0.075	-0.199	-0.013	-0.014
35	0.002	0.030	-0.075	-0.199	-0.013	-0.014
40	0.003	0.041	-0.093	-0.187	-0.023	-0.009
45	0.004	0.078	-0.141	-0.134	-0.052	-0.007
50.Near	0.004	0.078	-0.141	-0.134	-0.052	-0.007
50.Far	0.002	0.087	-0.140	-0.060	-0.064	-0.008
55	0.002	0.087	-0.140	-0.060	-0.064	-0.008
60	-0.027	0.098	-0.089	-0.006	-0.071	-0.029
65.Near	-0.028	0.098	-0.086	-0.005	-0.070	-0.030
65.Far	-0.029	0.098	-0.082	0.005	-0.063	-0.034
70	-0.028	0.097	-0.079	0.006	-0.062	-0.035
75	0.012	0.070	0.008	0.024	-0.034	-0.037
80.Near	0.012	0.070	0.008	0.024	-0.034	-0.037
80.Far	0.013	0.063	0.011	0.032	-0.026	-0.039
85	0.013	0.063	0.011	0.032	-0.026	-0.039
90	0.007	0.045	0.007	0.032	-0.020	-0.036
95	0.006	0.042	0.006	0.031	-0.019	-0.035
100	0.002	0.026	0.002	0.026	-0.014	-0.029
105	0.001	0.020	0.001	0.021	-0.011	-0.023
110	0.000	0.000	0.000	0.000	-0.000	-0.000

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments acting on Restraints ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	-6	-4	0	0	0
0	-0	-6	-0	0	0	0
20	-9	-29	0	0	0	0
20	-0	-29	-6	0	0	0
110	9	75	10	217	-71	-232

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments in Element Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	13	4	0	0	-0
5	-0	7	-4	-0	-218	180
5	0	4	7	0	-180	-218
10.Near	0	4	7	0	-180	-218
10.Far	-4	0	-8	164	-17	226
10.Far	4	-8	-0	-164	226	17
15	4	-8	-0	-164	226	17
20	-4	19	0	164	-221	-459
20	10	40	-9	-164	221	459
25	-10	-39	9	164	-186	-312
25	10	39	-9	-164	186	312
30.Near	10	39	-9	-164	186	312
30.Far	-37	10	9	-165	-143	-249
30.Far	37	10	9	165	-143	-249
35	37	10	9	165	-143	-249
40	-36	-10	-9	-165	94	301
40	24	10	9	165	-94	-301
45	-18	-10	-9	-165	-63	471
45	18	10	9	165	63	-471
50.Near	18	10	9	165	63	-471
50.Far	-10	17	-9	-84	144	454
50.Far	10	17	-9	84	144	454
55	10	17	-9	84	144	454
60	-10	-10	9	-84	74	-140
60	10	10	-9	84	-74	140
65.Near	-10	-9	9	-84	86	-128
65.Near	10	9	9	84	-128	-86
65.Far	-14	1	-9	25	135	94
65.Far	14	9	1	-25	-94	135
70	-14	-8	-1	25	93	-124
70	14	8	1	-25	-93	124
75	-14	5	-1	25	73	-49
75	14	5	-1	-25	73	-49
80.Near	14	5	-1	-25	73	-49
80.Far	-6	14	1	-71	-24	29
80.Far	6	10	-9	71	4	37
85	6	10	-9	71	4	37
90	-8	-10	9	-71	72	44
90	20	10	-9	71	-72	-44
95	-21	-10	9	-71	87	61
95	-79	10	-9	71	-87	-61
100	77	-10	9	-71	153	131
100	-77	10	-9	71	-153	-131
105	76	-10	9	-71	171	151
105	-76	10	-9	71	-171	-151
110	75	-10	9	-71	232	217

Load : Dead Weight + Pressure 1 + Thermal 1

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	13	4	0	0	-0
5	-0	7	-4	-0	-218	180
5	0	-7	4	0	218	-180
10.Near	0	-7	4	0	218	-180
10.Far	-0	8	-4	17	-226	164
10.Far	0	-8	4	-17	226	-164
15	0	-8	4	-17	226	-164
20	-0	19	-4	459	-221	164
20	9	40	10	-459	221	-164
25	-9	-39	-10	312	-186	164
25	9	39	10	-312	186	-164
30.Near	9	39	10	-312	186	-164
30.Far	-9	-37	-10	249	-165	143
30.Far	9	37	10	-249	165	-143
35	9	37	10	-249	165	-143
40	-9	-36	-10	301	-165	94
40	9	24	10	-301	165	-94
45	-9	-18	-10	471	-165	-63
45	9	18	10	-471	165	63
50.Near	9	18	10	-471	165	63
50.Far	-9	-17	-10	454	-144	-84
50.Far	9	17	10	-454	144	84
55	9	17	10	-454	144	84
60	-9	-10	-10	140	74	-84
60	9	10	10	-140	-74	84
65.Near	-9	-9	-10	128	86	-84
65.Near	9	9	10	-128	-86	84
65.Far	-9	-9	-10	113	94	-78
65.Far	9	9	10	-113	-94	78
70	-9	-8	-10	105	93	-70
70	9	8	10	-105	-93	70
75	-9	5	-10	52	73	-17
75	9	-5	10	-52	-73	17
80.Near	9	-5	10	-52	-73	17
80.Far	-9	6	-10	37	71	-4
80.Far	9	-6	10	-37	-71	4
85	9	-6	10	-37	-71	4
90	-9	8	-10	-44	71	72
90	9	-20	10	44	-71	-72
95	-9	21	-10	-61	71	87
95	9	79	10	61	-71	-87
100	-9	-77	-10	-131	71	153
100	9	77	10	131	-71	-153
105	-9	-76	-10	-151	71	171
105	9	76	10	151	-71	-171
110	-9	-75	-10	-217	71	232

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	90	208	109	38750
5	1.00	1.00	0.26	208	1180	1180	1259	38750
5	1.98	1.98	0.26	208	2250	2250	2286	38750
10.Near	1.98	1.98	0.26	208	2250	2250	2286	38750
10.Far	1.98	1.98	0.26	208	1815	1875	2274	38750
10.Far	1.00	1.00	0.26	208	958	1073	1240	38750
15	1.00	1.00	0.26	208	958	1073	1240	38750
20	1.00	1.00	0.26	208	2043	2096	3168	38750
20	1.00	1.00	0.26	208	2033	2086	3168	38750
25	1.00	1.00	0.26	208	1470	1545	2554	38750
25	1.98	1.98	0.26	208	2842	2880	4192	38750
30.Near	1.98	1.98	0.26	208	2842	2880	4192	38750
30.Far	1.98	1.98	0.26	208	2219	2267	3407	38750
30.Far	1.00	1.00	0.26	208	1134	1232	2076	38750
35	1.00	1.00	0.26	208	1134	1232	2076	38750
40	1.00	1.00	0.26	208	1248	1336	1864	38750
40	1.00	1.00	0.26	208	1267	1355	1864	38750
45	1.00	1.00	0.26	208	1888	1946	2200	38750
45	1.98	1.98	0.26	208	3684	3712	3802	38750
50.Near	1.98	1.98	0.26	208	3684	3712	3802	38750
50.Far	1.98	1.98	0.26	208	3705	3712	3720	38750
50.Far	1.00	1.00	0.26	208	1905	1920	2122	38750
55	1.00	1.00	0.26	208	1905	1920	2122	38750
60	1.00	1.00	0.26	208	683	733	1410	38750
60	1.00	1.00	0.26	208	683	733	1410	38750
65.Near	1.00	1.00	0.26	208	666	717	1442	38750
65.Near	1.98	1.98	0.26	208	1247	1272	2588	38750
65.Far	1.98	1.98	0.26	208	1324	1326	2622	38750
65.Far	1.00	1.00	0.26	208	702	706	1467	38750
70	1.00	1.00	0.26	208	665	670	1467	38750
70	1.00	1.00	0.26	208	665	670	1467	38750
75	1.00	1.00	0.26	208	404	415	681	38750
75	1.98	1.98	0.26	208	734	739	1132	38750
80.Near	1.98	1.98	0.26	208	734	739	1132	38750
80.Far	1.98	1.98	0.26	208	367	446	767	38750
80.Far	1.00	1.00	0.26	208	226	354	492	38750
85	1.00	1.00	0.26	208	226	354	492	38750
90	1.00	1.00	0.26	208	403	474	733	38750
90	1.00	1.00	0.26	208	384	459	733	38750
95	1.00	1.00	0.26	208	466	526	850	38750
95	1.00	1.00	0.26	333	684	731	915	38750
100	1.00	1.00	0.26	333	1045	1071	1440	38750
100	1.00	1.00	0.33	246	815	836	1139	14375
105	1.00	1.00	0.33	246	898	916	1262	14375
105	1.00	1.00	0.33	246	898	916	1262	14375

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	1169	1182	1666	14375

Load : Dead Weight + Pressure 1 + Thermal 1

*** System Maxima ***

Maximum X displacement = -0.168 inch at point 0
Maximum Y displacement = -0.179 inch at point 5
Maximum Z displacement = -0.155 inch at point 5

Maximum X rotation = -0.309 degree at point 10.Far
Maximum Y rotation = 0.166 degree at point 0
Maximum Z rotation = -0.209 degree at point 0

Maximum X force = 9 lb at point 20
Maximum Y force = 79 lb at point 95
Maximum Z force = 10 lb at point 20

Maximum X moment = 471 inch-lb at point 45
Maximum Y moment = -226 inch-lb at point 10.Near
Maximum Z moment = 232 inch-lb at point 110

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3705 psi at point 50.Near
Maximum principal stress = 3712 psi at point 45
Maximum code stress = 4192 psi at point 25
Maximum stress ratio (code/allowable) = 0.12 at point 110

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Deflections ***

Point Name	Displacements/inch X	Displacements/inch Y	Displacements/inch Z	Rotations/degree X	Rotations/degree Y	Rotations/degree Z
0	-0.112	-0.000	-0.000	-0.362	0.082	-0.241
5	-0.016	-0.213	-0.076	-0.362	0.053	-0.152
10.Near	-0.016	-0.213	-0.076	-0.362	0.053	-0.152
10.Far	-0.011	-0.204	-0.074	-0.367	0.035	-0.136
15	-0.011	-0.204	-0.074	-0.367	0.035	-0.136
20	-0.000	-0.000	-0.020	-0.309	0.002	-0.080
25	0.000	0.020	-0.014	-0.297	-0.001	-0.074
30.Near	0.000	0.020	-0.014	-0.297	-0.001	-0.074
30.Far	0.002	0.034	-0.021	-0.253	-0.016	-0.056
35	0.002	0.034	-0.021	-0.253	-0.016	-0.056
40	0.007	0.043	-0.044	-0.241	-0.021	-0.050
45	0.020	0.070	-0.108	-0.193	-0.036	-0.041
50.Near	0.020	0.070	-0.108	-0.193	-0.036	-0.041
50.Far	0.020	0.079	-0.111	-0.131	-0.044	-0.036
55	0.020	0.079	-0.111	-0.131	-0.044	-0.036
60	0.001	0.121	-0.074	-0.084	-0.046	-0.033
65.Near	0.000	0.123	-0.072	-0.083	-0.045	-0.033
65.Far	-0.000	0.125	-0.069	-0.075	-0.040	-0.035
70	0.001	0.125	-0.066	-0.073	-0.039	-0.034
75	0.032	0.141	-0.006	-0.034	-0.022	-0.015
80.Near	0.032	0.141	-0.006	-0.034	-0.022	-0.015
80.Far	0.033	0.137	-0.002	-0.014	-0.014	-0.020
85	0.033	0.137	-0.002	-0.014	-0.014	-0.020
90	0.030	0.124	-0.001	-0.006	-0.011	-0.019
95	0.029	0.122	-0.000	-0.005	-0.010	-0.019
100	0.027	0.111	0.000	-0.002	-0.008	-0.015
105	0.027	0.106	0.000	-0.001	-0.006	-0.012
110	0.026	0.091	0.000	0.000	-0.000	-0.000

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments acting on Restraints ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	-6	-2	0	0	0
0	-0	-6	-0	0	0	0
20	-5	-28	0	0	0	0
20	-0	-28	-4	0	0	0
110	5	72	6	15	-39	-126

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments in Element Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	12	2	-0	0	0
5	-0	7	-2	0	-116	172
5	0	2	7	-0	-172	-116
10.Near	0	2	7	-0	-172	-116
10.Far	-2	0	-8	156	-17	120
10.Far	2	-8	-0	-156	120	17
15	2	-8	-0	-156	120	17
20	-2	19	0	156	-117	-463
20	6	37	-5	-156	117	463
25	-6	-36	5	156	-96	-328
25	6	36	-5	-156	96	328
30.Near	6	36	-5	-156	96	328
30.Far	-34	6	5	-84	-144	-262
30.Far	34	6	5	84	-144	-262
35	34	6	5	84	-144	-262
40	-33	-6	-5	-84	115	295
40	21	6	5	84	-115	-295
45	-15	-6	-5	-84	24	400
45	15	6	5	84	-24	-400
50.Near	15	6	5	84	-24	-400
50.Far	-6	14	-5	12	72	381
50.Far	6	14	-5	-12	72	381
55	6	14	-5	-12	72	381
60	-6	-7	5	12	54	-137
60	6	7	-5	-12	-54	137
65.Near	-6	-6	5	12	61	-128
65.Near	6	5	6	-12	-128	-61
65.Far	-8	1	-6	95	72	65
65.Far	8	6	1	-95	-65	72
70	-8	-5	-1	95	64	-65
70	8	5	1	-95	-64	65
75	-8	8	-1	95	40	-108
75	8	8	-1	-95	40	-108
80.Near	8	8	-1	-95	40	-108
80.Far	-9	8	1	-39	-94	108
80.Far	9	6	-5	39	10	142
85	9	6	-5	39	10	142
90	-11	-6	5	-39	34	-92
90	23	6	-5	39	-34	92
95	-24	-6	5	-39	43	-82
95	-76	6	-5	39	-43	82
100	74	-6	5	-39	81	-38
100	-74	6	-5	39	-81	38
105	74	-6	5	-39	91	-25
105	-74	6	-5	39	-91	25
110	72	-6	5	-39	126	15

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** Forces and Moments in Global Coordinate System ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	12	2	-0	0	0
5	-0	7	-2	0	-116	172
5	0	-7	2	-0	116	-172
10.Near	0	-7	2	-0	116	-172
10.Far	-0	8	-2	17	-120	156
10.Far	0	-8	2	-17	120	-156
15	0	-8	2	-17	120	-156
20	-0	19	-2	463	-117	156
20	5	37	6	-463	117	-156
25	-5	-36	-6	328	-96	156
25	5	36	6	-328	96	-156
30.Near	5	36	6	-328	96	-156
30.Far	-5	-34	-6	262	-84	144
30.Far	5	34	6	-262	84	-144
35	5	34	6	-262	84	-144
40	-5	-33	-6	295	-84	115
40	5	21	6	-295	84	-115
45	-5	-15	-6	400	-84	24
45	5	15	6	-400	84	-24
50.Near	5	15	6	-400	84	-24
50.Far	-5	-14	-6	381	-72	12
50.Far	5	14	6	-381	72	-12
55	5	14	6	-381	72	-12
60	-5	-7	-6	137	54	12
60	5	7	6	-137	-54	-12
65.Near	-5	-6	-6	128	61	12
65.Near	5	6	6	-128	-61	-12
65.Far	-5	-6	-6	118	65	16
65.Far	5	6	6	-118	-65	-16
70	-5	-5	-6	113	64	21
70	5	5	6	-113	-64	-21
75	-5	8	-6	144	40	-9
75	5	-8	6	-144	-40	9
80.Near	5	-8	6	-144	-40	9
80.Far	-5	9	-6	142	39	-10
80.Far	5	-9	6	-142	-39	10
85	5	-9	6	-142	-39	10
90	-5	11	-6	92	39	34
90	5	-23	6	-92	-39	-34
95	-5	24	-6	82	39	43
95	5	76	6	-82	-39	-43
100	-5	-74	-6	38	39	81
100	5	74	6	-38	-39	-81
105	-5	-74	-6	25	39	91
105	5	74	6	-25	-39	-91
110	-5	-72	-6	-15	39	126

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	208	90	208	109	38750
5	1.00	1.00	0.26	208	889	889	933	38750
5	1.98	1.98	0.26	208	1675	1675	1638	38750
10.Near	1.98	1.98	0.26	208	1675	1675	1638	38750
10.Far	1.98	1.98	0.26	208	1015	1114	1603	38750
10.Far	1.00	1.00	0.26	208	555	728	902	38750
15	1.00	1.00	0.26	208	555	728	902	38750
20	1.00	1.00	0.26	208	1926	1977	2852	38750
20	1.00	1.00	0.26	208	1919	1970	2852	38750
25	1.00	1.00	0.26	208	1394	1466	2289	38750
25	1.98	1.98	0.26	208	2686	2722	3666	38750
30.Near	1.98	1.98	0.26	208	2686	2722	3666	38750
30.Far	1.98	1.98	0.26	208	2318	2330	2971	38750
30.Far	1.00	1.00	0.26	208	1186	1212	1856	38750
35	1.00	1.00	0.26	208	1186	1212	1856	38750
40	1.00	1.00	0.26	208	1257	1282	1646	38750
40	1.00	1.00	0.26	208	1277	1301	1646	38750
45	1.00	1.00	0.26	208	1609	1628	1737	38750
45	1.98	1.98	0.26	208	3127	3136	2885	38750
50.Near	1.98	1.98	0.26	208	3127	3136	2885	38750
50.Far	1.98	1.98	0.26	208	3043	3043	2803	38750
50.Far	1.00	1.00	0.26	208	1574	1575	1659	38750
55	1.00	1.00	0.26	208	1574	1575	1659	38750
60	1.00	1.00	0.26	208	645	646	1221	38750
60	1.00	1.00	0.26	208	645	646	1221	38750
65.Near	1.00	1.00	0.26	208	625	627	1254	38750
65.Near	1.98	1.98	0.26	208	1161	1161	2214	38750
65.Far	1.98	1.98	0.26	208	819	869	2267	38750
65.Far	1.00	1.00	0.26	208	451	549	1288	38750
70	1.00	1.00	0.26	208	428	532	1301	38750
70	1.00	1.00	0.26	208	428	532	1301	38750
75	1.00	1.00	0.26	208	522	606	999	38750
75	1.98	1.98	0.26	208	960	1002	1761	38750
80.Near	1.98	1.98	0.26	208	960	1002	1761	38750
80.Far	1.98	1.98	0.26	208	1166	1172	1542	38750
80.Far	1.00	1.00	0.26	208	626	639	883	38750
85	1.00	1.00	0.26	208	626	639	883	38750
90	1.00	1.00	0.26	208	448	470	624	38750
90	1.00	1.00	0.26	208	429	452	624	38750
95	1.00	1.00	0.26	208	406	431	607	38750
95	1.00	1.00	0.26	333	623	641	672	38750
100	1.00	1.00	0.26	333	608	627	832	38750
100	1.00	1.00	0.33	246	467	482	655	14375
105	1.00	1.00	0.33	246	484	498	728	14375
105	1.00	1.00	0.33	246	484	498	728	14375

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	583	593	999	14375

Load : Dead Weight + Pressure 1 + Thermal 1 + Displacement 1

*** System Maxima ***

Maximum X displacement = -0.112 inch at point 0
Maximum Y displacement = -0.213 inch at point 5
Maximum Z displacement = -0.111 inch at point 50.Far

Maximum X rotation = -0.367 degree at point 10.Far
Maximum Y rotation = 0.082 degree at point 0
Maximum Z rotation = -0.241 degree at point 0

Maximum X force = 5 lb at point 20
Maximum Y force = 76 lb at point 95
Maximum Z force = 6 lb at point 20

Maximum X moment = 463 inch-lb at point 15
Maximum Y moment = -120 inch-lb at point 10.Near
Maximum Z moment = 172 inch-lb at point 5

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3127 psi at point 45
Maximum principal stress = 3136 psi at point 45
Maximum code stress = 3666 psi at point 25
Maximum stress ratio (code/allowable) = 0.09 at point 25

Load : Thermal 1 + Displacement 1

*** System Deflections ***

Point Name	Displacements/inch X	Displacements/inch Y	Displacements/inch Z	Rotations/degree X	Rotations/degree Y	Rotations/degree Z
0	-0.116	-0.000	-0.000	-0.150	0.083	-0.101
5	-0.020	-0.096	-0.078	-0.150	0.057	-0.072
10.Near	-0.020	-0.096	-0.078	-0.150	0.057	-0.072
10.Far	-0.015	-0.093	-0.077	-0.154	0.040	-0.061
15	-0.015	-0.093	-0.077	-0.154	0.040	-0.061
20	-0.000	0.000	-0.023	-0.165	0.010	-0.017
25	0.001	0.011	-0.017	-0.167	0.007	-0.012
30.Near	0.001	0.011	-0.017	-0.167	0.007	-0.012
30.Far	0.001	0.021	-0.020	-0.177	-0.005	0.002
35	0.001	0.021	-0.020	-0.177	-0.005	0.002
40	0.000	0.030	-0.036	-0.178	-0.009	0.006
45	-0.002	0.056	-0.087	-0.166	-0.021	0.010
50.Near	-0.002	0.056	-0.087	-0.166	-0.021	0.010
50.Far	-0.004	0.066	-0.090	-0.138	-0.026	0.008
55	-0.004	0.066	-0.090	-0.138	-0.026	0.008
60	-0.014	0.114	-0.053	-0.102	-0.022	-0.002
65.Near	-0.015	0.117	-0.051	-0.100	-0.021	-0.003
65.Far	-0.014	0.119	-0.048	-0.087	-0.013	-0.008
70	-0.013	0.121	-0.046	-0.085	-0.012	-0.008
75	0.032	0.141	0.000	-0.020	0.003	-0.013
80.Near	0.032	0.141	0.000	-0.020	0.003	-0.013
80.Far	0.033	0.137	0.003	0.001	0.005	-0.022
85	0.033	0.137	0.003	0.001	0.005	-0.022
90	0.030	0.124	0.002	0.008	0.004	-0.021
95	0.030	0.122	0.002	0.009	0.004	-0.021
100	0.027	0.110	0.001	0.009	0.003	-0.017
105	0.027	0.106	0.001	0.008	0.002	-0.014
110	0.026	0.091	0.000	0.000	0.000	-0.000

Load : Thermal 1 + Displacement 1

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-1	-2	0	0	0
0	-0	-1	-0	0	0	0
20	-6	1	0	0	0	0
20	-0	1	-8	0	0	0
110	6	0	10	106	14	-141

Load : Thermal 1 + Displacement 1

*** Forces and Moments in Element Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	0	2	2	0	0	0
5	-0	-2	-2	-0	-107	118
5	0	2	-2	-0	-118	-107
10.Near	0	2	-2	-0	-118	-107
10.Far	-2	0	2	123	4	111
10.Far	2	2	-0	-123	111	-4
15	2	2	-0	-123	111	-4
20	-2	-2	0	123	-107	71
20	10	0	-6	-123	107	-71
25	-10	-0	6	123	-83	72
25	10	0	-6	-123	83	-72
30.Near	10	0	-6	-123	83	-72
30.Far	-0	10	6	-69	-109	51
30.Far	0	10	6	69	-109	51
35	0	10	6	69	-109	51
40	-0	-10	-6	-69	76	2
40	0	10	6	69	-76	-2
45	-0	-10	-6	-69	-29	170
45	0	10	6	69	29	-170
50.Near	0	10	6	69	29	-170
50.Far	-10	0	-6	-44	55	191
50.Far	10	0	-6	44	55	191
55	10	0	-6	44	55	191
60	-10	-0	6	-44	90	-182
60	10	0	-6	44	-90	182
65.Near	-10	-0	6	-44	99	-182
65.Near	10	6	0	44	-182	-99
65.Far	-11	3	-0	97	159	102
65.Far	11	0	3	-97	-102	159
70	-11	-0	-3	97	99	-158
70	11	0	3	-97	-99	158
75	-11	-0	-3	97	-8	-142
75	11	-0	-3	-97	-8	-142
80.Near	11	-0	-3	-97	-8	-142
80.Far	0	11	3	14	-91	115
80.Far	-0	10	-6	-14	17	146
85	-0	10	-6	-14	17	146
90	0	-10	6	14	34	-65
90	-0	10	-6	-14	-34	65
95	0	-10	6	14	44	-49
95	-0	10	-6	-14	-44	49
100	0	-10	6	14	88	21
100	-0	10	-6	-14	-88	-21
105	0	-10	6	14	101	41
105	-0	10	-6	-14	-101	-41
110	0	-10	6	14	141	106

Load : Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
0	1.00	1.00	0.26	0	0	0	0	23450
5	1.00	1.00	0.26	0	614	614	614	23450
5	1.98	1.98	0.26	0	1218	1218	1218	23450
10.Near	1.98	1.98	0.26	0	1218	1218	1218	23450
10.Far	1.98	1.98	0.26	0	849	911	1263	23450
10.Far	1.00	1.00	0.26	0	430	534	637	23450
15	1.00	1.00	0.26	0	430	534	637	23450
20	1.00	1.00	0.26	0	496	591	683	23450
20	1.00	1.00	0.26	0	510	602	683	23450
25	1.00	1.00	0.26	0	441	544	635	23450
25	1.98	1.98	0.26	0	859	919	1260	23450
30.Near	1.98	1.98	0.26	0	859	919	1260	23450
30.Far	1.98	1.98	0.26	0	916	935	1057	23450
30.Far	1.00	1.00	0.26	0	462	498	533	23450
35	1.00	1.00	0.26	0	462	498	533	23450
40	1.00	1.00	0.26	0	292	344	395	23450
40	1.00	1.00	0.26	0	292	344	395	23450
45	1.00	1.00	0.26	0	664	689	715	23450
45	1.98	1.98	0.26	0	1315	1329	1417	23450
50.Near	1.98	1.98	0.26	0	1315	1329	1417	23450
50.Far	1.98	1.98	0.26	0	1536	1540	1555	23450
50.Far	1.00	1.00	0.26	0	783	792	785	23450
55	1.00	1.00	0.26	0	783	792	785	23450
60	1.00	1.00	0.26	0	799	807	800	23450
60	1.00	1.00	0.26	0	799	807	800	23450
65.Near	1.00	1.00	0.26	0	812	820	813	23450
65.Near	1.98	1.98	0.26	0	1593	1597	1611	23450
65.Far	1.98	1.98	0.26	0	1458	1481	1619	23450
65.Far	1.00	1.00	0.26	0	744	789	817	23450
70	1.00	1.00	0.26	0	736	781	809	23450
70	1.00	1.00	0.26	0	736	781	809	23450
75	1.00	1.00	0.26	0	566	623	663	23450
75	1.98	1.98	0.26	0	1105	1135	1315	23450
80.Near	1.98	1.98	0.26	0	1105	1135	1315	23450
80.Far	1.98	1.98	0.26	0	1123	1124	1128	23450
80.Far	1.00	1.00	0.26	0	567	568	569	23450
85	1.00	1.00	0.26	0	567	568	569	23450
90	1.00	1.00	0.26	0	283	285	287	23450
90	1.00	1.00	0.26	0	283	285	287	23450
95	1.00	1.00	0.26	0	254	257	259	23450
95	1.00	1.00	0.26	0	254	257	259	23450
100	1.00	1.00	0.26	0	349	351	352	23450
100	1.00	1.00	0.33	0	278	280	281	8875
105	1.00	1.00	0.33	0	333	335	336	8875
105	1.00	1.00	0.33	0	333	335	336	8875

Load : Thermal 1 + Displacement 1

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	0	542	543	543	8875

Load : Thermal 1 + Displacement 1

*** System Maxima ***

Maximum X displacement = -0.116 inch at point 0
Maximum Y displacement = 0.141 inch at point 75
Maximum Z displacement = -0.090 inch at point 50.Far

Maximum X rotation = -0.178 degree at point 40
Maximum Y rotation = 0.083 degree at point 0
Maximum Z rotation = -0.101 degree at point 0

Maximum X force = 6 lb at point 20
Maximum Y force = -2 lb at point 15
Maximum Z force = 10 lb at point 20

Maximum X moment = 191 inch-lb at point 50.Near
Maximum Y moment = -111 inch-lb at point 10.Near
Maximum Z moment = 141 inch-lb at point 110

Maximum hoop stress = 0 psi at point
Maximum longitudinal stress = 1593 psi at point 65.Near
Maximum principal stress = 1597 psi at point 65.Near
Maximum code stress = 1619 psi at point 65.Far
Maximum stress ratio (code/allowable) = 0.07 at point 65.Far

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Deflections ***

Point	Displacements/inch			Rotations/degree		
Name	X	Y	Z	X	Y	Z
0	0.014	-0.000	-0.000	-0.230	-0.017	-0.151
5	0.014	-0.128	0.017	-0.230	-0.017	-0.090
10.Near	0.014	-0.128	0.017	-0.230	-0.017	-0.090
10.Far	0.014	-0.123	0.018	-0.231	-0.021	-0.086
15	0.014	-0.123	0.018	-0.231	-0.021	-0.086
20	0.000	-0.000	0.018	-0.163	-0.024	-0.077
25	-0.002	0.010	0.018	-0.149	-0.023	-0.076
30.Near	-0.002	0.010	0.018	-0.149	-0.023	-0.076
30.Far	0.003	0.015	-0.015	-0.096	-0.025	-0.074
35	0.003	0.015	-0.015	-0.096	-0.025	-0.074
40	0.008	0.015	-0.020	-0.083	-0.024	-0.072
45	0.028	0.015	-0.028	-0.044	-0.024	-0.065
50.Near	0.028	0.015	-0.028	-0.044	-0.024	-0.065
50.Far	0.030	0.016	-0.028	0.018	-0.026	-0.058
55	0.030	0.016	-0.028	0.018	-0.026	-0.058
60	0.020	0.012	-0.028	0.023	-0.029	-0.041
65.Near	0.019	0.012	-0.028	0.022	-0.030	-0.041
65.Far	0.018	0.011	-0.028	0.015	-0.034	-0.038
70	0.018	0.010	-0.028	0.014	-0.035	-0.037
75	-0.002	-0.001	-0.009	-0.021	-0.035	-0.008
80.Near	-0.002	-0.001	-0.009	-0.021	-0.035	-0.008
80.Far	-0.003	0.000	-0.007	-0.022	-0.028	0.008
85	-0.003	0.000	-0.007	-0.022	-0.028	0.008
90	-0.002	0.000	-0.004	-0.020	-0.022	0.007
95	-0.001	0.000	-0.003	-0.019	-0.020	0.007
100	-0.001	0.000	-0.001	-0.015	-0.015	0.006
105	-0.000	0.000	-0.001	-0.012	-0.011	0.005
110	-0.000	0.000	-0.000	-0.000	-0.000	0.000

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments acting on Restraints ***

Point	Forces/lb			Moments/inch-lb		
Name	X	Y	Z	X	Y	Z
0	0	-5	-1	0	0	0
0	0	-5	-0	0	0	0
20	4	-29	0	0	0	0
20	0	-29	4	0	0	0
110	-5	72	-5	-113	-77	56

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments in Element Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	11	1	-0	0	0
5	1	9	-1	0	-39	72
5	-1	1	9	0	-72	-39
10.Near	-1	1	9	0	-72	-39
10.Far	-1	-1	-10	52	-22	38
10.Far	1	-10	1	-52	38	22
15	1	-10	1	-52	38	22
20	-1	21	-2	52	-31	-545
20	-5	37	3	-52	31	545
25	5	-36	-3	52	-31	-412
25	-5	36	3	-52	31	412
30.Near	-5	36	3	-52	31	412
30.Far	-35	-5	-3	-31	-50	-324
30.Far	35	-5	-3	31	-50	-324
35	35	-5	-3	31	-50	-324
40	-33	5	3	-31	47	302
40	21	-6	-2	31	-47	-302
45	-16	6	2	-31	70	268
45	16	-6	-2	31	-70	-268
50.Near	16	-6	-2	31	-70	-268
50.Far	6	14	2	75	35	232
50.Far	-6	14	2	-75	35	232
55	-6	14	2	-75	35	232
60	7	-7	-2	75	-78	75
60	-7	7	2	-75	78	-75
65.Near	7	-7	-2	75	-81	82
65.Near	-7	-2	7	-75	82	81
65.Far	6	-3	-6	-20	-115	-80
65.Far	-6	6	-3	20	80	-115
70	6	-6	3	-20	-76	121
70	-6	6	-3	20	76	-121
75	7	8	4	-20	68	46
75	-7	8	4	20	68	46
80.Near	-7	8	4	20	68	46
80.Far	-10	-7	-4	-77	-20	-20
80.Far	10	-7	2	77	-28	-8
85	10	-7	2	77	-28	-8
90	-12	8	-2	-77	-32	-55
90	24	-8	3	77	32	55
95	-25	8	-3	-77	-36	-68
95	-76	-5	5	77	36	68
100	74	5	-5	-77	-30	-87
100	-74	-5	5	77	30	87
105	74	5	-5	-77	-34	-93
105	-74	-5	5	77	34	93
110	72	5	-5	-77	-56	-113

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** Forces and Moments in Global Coordinate System ***

Point Name	Forces/lb X	Forces/lb Y	Forces/lb Z	Moments/inch-lb X	Moments/inch-lb Y	Moments/inch-lb Z
0	-0	11	1	-0	0	0
5	1	9	-1	0	-39	72
5	-1	-9	1	0	39	-72
10.Near	-1	-9	1	0	39	-72
10.Far	1	10	-1	22	-38	52
10.Far	-1	-10	1	-22	38	-52
15	-1	-10	1	-22	38	-52
20	2	21	-1	545	-31	52
20	-3	37	-5	-545	31	-52
25	3	-36	5	412	-31	52
25	-3	36	-5	-412	31	-52
30.Near	-3	36	-5	-412	31	-52
30.Far	3	-35	5	324	-31	50
30.Far	-3	35	-5	-324	31	-50
35	-3	35	-5	-324	31	-50
40	3	-33	5	302	-31	47
40	-2	21	-6	-302	31	-47
45	2	-16	6	268	-31	70
45	-2	16	-6	-268	31	-70
50.Near	-2	16	-6	-268	31	-70
50.Far	2	-14	6	232	-35	75
50.Far	-2	14	-6	-232	35	-75
55	-2	14	-6	-232	35	-75
60	2	-7	7	-75	-78	75
60	-2	7	-7	75	78	-75
65.Near	2	-7	7	-82	-81	75
65.Near	-2	7	-7	82	81	-75
65.Far	2	-6	7	-91	-80	78
65.Far	-2	6	-7	91	80	-78
70	2	-6	7	-95	-76	83
70	-2	6	-7	95	76	-83
75	2	8	7	-38	68	41
75	-2	-8	-7	38	-68	-41
80.Near	-2	-8	-7	38	-68	-41
80.Far	2	10	7	-8	77	28
80.Far	-2	-10	-7	8	-77	-28
85	-2	-10	-7	8	-77	-28
90	2	12	8	55	77	-32
90	-3	-24	-8	-55	-77	32
95	3	25	8	68	77	-36
95	-5	76	-5	-68	-77	36
100	5	-74	5	87	77	-30
100	-5	74	-5	-87	-77	30
105	5	-74	5	93	77	-34
105	-5	74	-5	-93	-77	34
110	5	-72	5	113	77	-56

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Stresses (ANSI B31.1) ***

Point Name	In-Plane SIF	Out Plane SIF	Section Modulus	Stresses/psi Hoop	Longitu.	Principal	Code	Allow.
110	1.00	1.00	0.33	246	618	652	617	6600

Load : Dead Weight + Pressure 1 + Earthquake 1 + Earthquake 2

*** System Maxima ***

Maximum X displacement = 0.030 inch at point 50.Far
Maximum Y displacement = -0.128 inch at point 5
Maximum Z displacement = -0.028 inch at point 50.Far

Maximum X rotation = -0.231 degree at point 10.Far
Maximum Y rotation = -0.035 degree at point 75
Maximum Z rotation = -0.151 degree at point 0

Maximum X force = -5 lb at point 95
Maximum Y force = 76 lb at point 95
Maximum Z force = 8 lb at point 95

Maximum X moment = 545 inch-lb at point 15
Maximum Y moment = -81 inch-lb at point 65.Near
Maximum Z moment = 83 inch-lb at point 70

Maximum hoop stress = 333 psi at point 95
Maximum longitudinal stress = 3314 psi at point 25
Maximum principal stress = 3323 psi at point 25
Maximum code stress = 2569 psi at point 25
Maximum stress ratio (code/allowable) = 0.14 at point 25

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-045 PAGE 1 OF 9
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0141	4/25/96	WDB	RDC	**ION Pump Support**	
1	0293	10/4/96	RDC	WDB		
					BY: R. D. Ciatto	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Establish loads that ion pumps apply to tubular spool pieces B-2, B-3, B-5, B-4, and A-7. Also, confirm structural adequacy of ion pump nozzle to shell junction.

METHOD: Hand calculations and finite element method using IMAGES program.

ASSUMPTIONS:

INPUTS: LIGO project drawings of spools and adapters.
Calc. No. V049-1-066, Structural Design Criteria
Seismic acceleration = .05625 G.
Vacuum pressure = 14.7 psi.

REFERENCES: ASME Boiler & Pressure Vessel Code, Sect. VIII, Div. 1 & 2, Pressure Vessels
IMAGES-3D, R. L. Cloud & Assoc.
Calculations V049-1-052, -056, & -057

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: Design loads for the ion pumps are about 10% greater than actual loads.
Adequacy of the 14 in nozzle to shell junction is confirmed by a finite element analysis.

NOTES: IMAGES computer files are: IONPMP72.*

TABLE OF CONTENTS

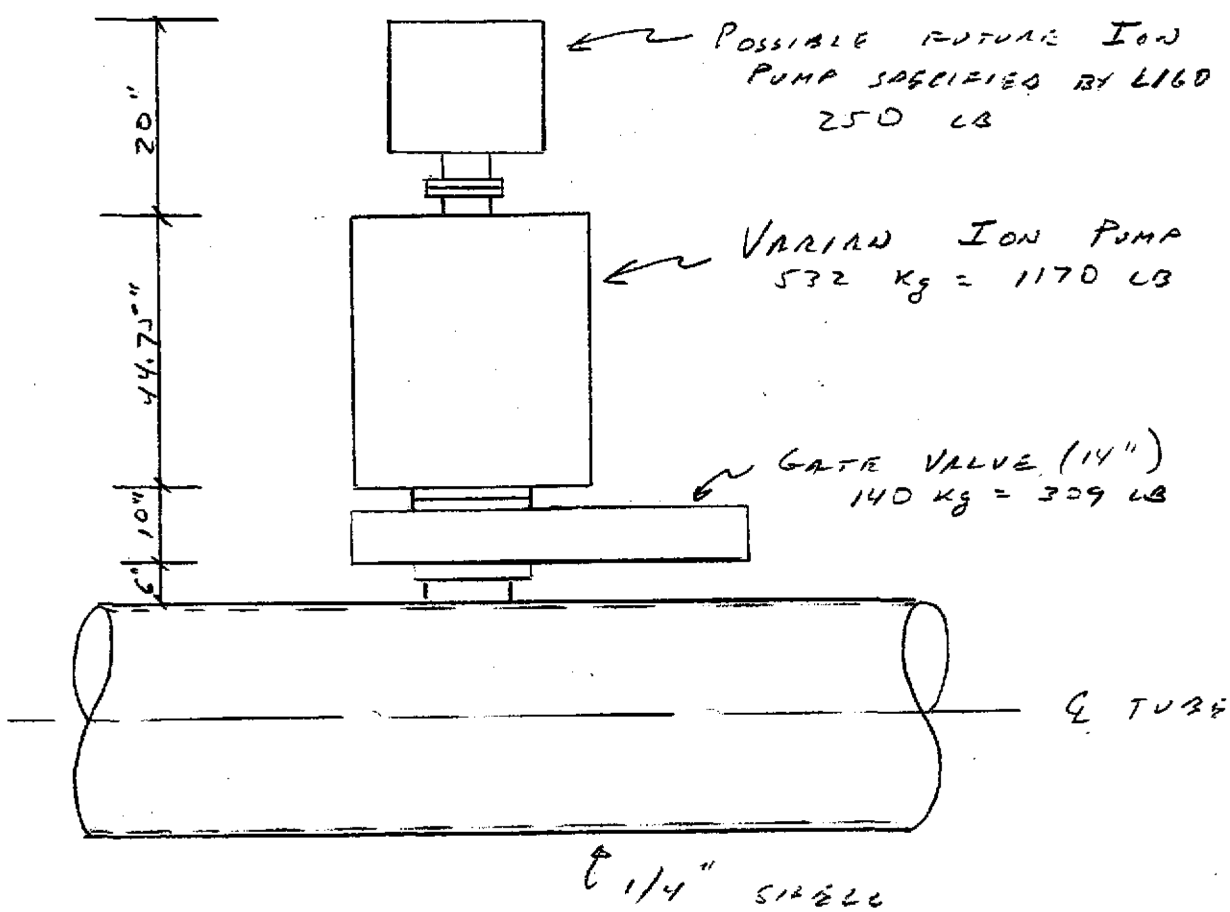
REVISION HISTORY

Rev. 0 Original Issue - April 25, 1996

Rev. 1 Issue Date - Oct. 4, 1996

- Revised weights to account for purchased ion pump
- Summarized nozzle to shell stresses at ion pump from WRC 107 analyses
- Included confirmatory analysis of nozzle to shell stresses for ion pump nozzle to 72 in shell

Ion Pump Arrangement



LOADS		C.G. (IN) FROM SHELL	MOMENT IN-LB
ION PUMP WEGHT 532 kg =	1170 LB	$16 + \frac{44.75}{2} = 38.4$ IN	44,900
14" GATE VALVE 140 kg =	309 LB	$6 + 10/2 = 11$ IN	3,400
FUTURE 2ND PUMP	250 LB	$60.75 + \frac{20}{2} = 70.75$	17,700
TOTAL WEIGHT & MOMENT	1729 LB		66,000 IN-LB
SEISMIC SHEAR FORCE & MOMENT MULTIPLY BY .05625	97 LB (HORIZ)		3712 IN-LB
END CAP LOAD FROM EXTERNAL PRESSURE $14.7\pi(\frac{14}{2})^2$ =	2263 LB		
TOTAL VERTICAL FORCE 1729 + 2263 =	3992 LB		
FORCES USED FOR DESIGN ARE GREATER (REF CALCS 052, 056, 057) VERTICAL LOAD	4354		
HORIZ. SEISMIC SHEAR & MOMENT	126.5 LB		4542 IN-LB

FOR CONSERVATISM THE SEISMIC FORCES WERE INCLUDED WITH WEIGHT AND PRESSURE FORCES IN THE ANALYSES OF THE SPOOLS BY WRC 107. IN ALL CASES FOLLOWING PARAMETERS WERE USED

SHELL THICKNESS t = .25 IN

NOZZLE I.D. = 13.5 IN

NOZZLE THICKNESS t_n = .25 IN

STRESS SUMMARY

STRESSES FROM THE 3 CALCS ARE

CALC. NO V049-1-	SPOOL	SHELL I.D.	MAX PRIMARY STRESS	MAX COMBINED STRESS	
052	A-7	72.25 IN	10.6 KSI	34 KSI	*
056	B-4	48.25	11.5 KSI	36.1	
057	B-2,3,5	30.5	8.5	35.6	

* AT REPAD OD

FE ANALYSIS

TO CONFIRM THE ADEQUACY OF THE NOZZLE-SHELL JUNCTION, AN IMAGES FE MODEL OF A-7 WAS PERFORMED. FOR THIS ANALYSIS, A RADIAL FORCE WAS INPUT. ITS VALUE IS Fz = 4263 LB > 3992 LB (DESIGN FORCE) ALSO A CASE WAS RUN FOR COMBINED PRESSURE AND NOZZLE RADIAL LOAD. THE MAXIMUM SURFACE STRESS INTENSITY IS ONLY 23.9 KSI. ∴ THE INTEGRITY OF THE NOZZLE-SHELL JUNCTION IS CONFIRMED.

ID = 14 in

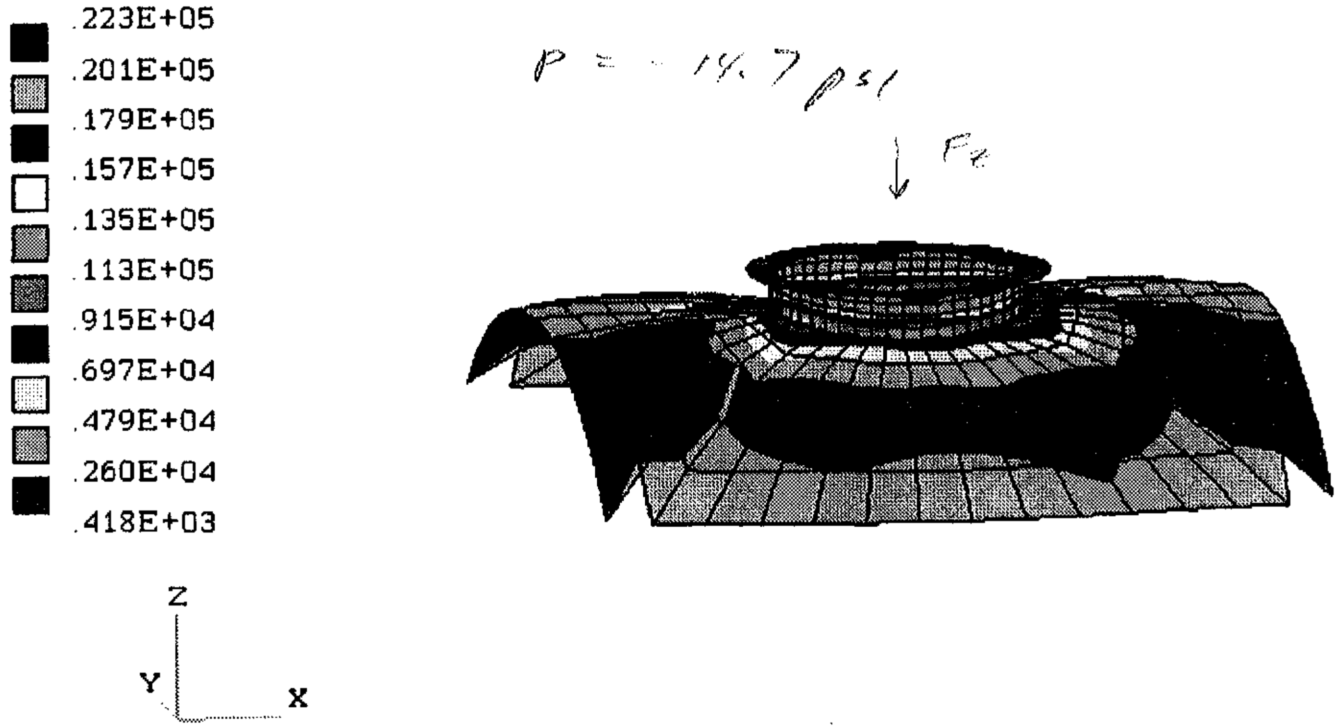
t_{noz} = 1/16

t_{sh} = 1/4

F_z = 4263

P = -14.7 psi

IMAGES-3D
Version 3.0



Load Case	Stress Contour Plot		8/19/96
2	Surf: Top	Stress Intensity	17:22:50

t_{NOZ} = 1/4 in

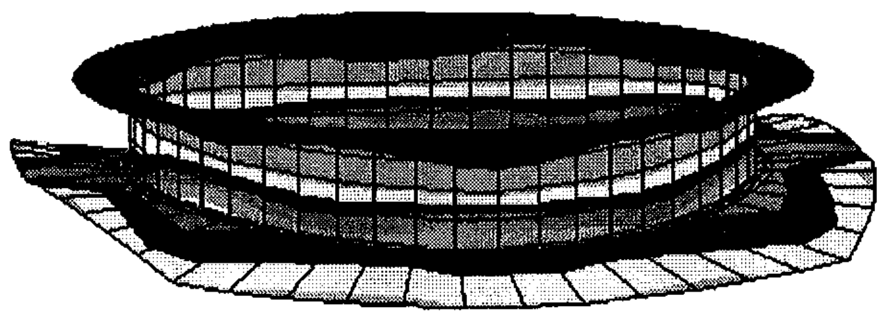
t_{SH} = 1/4 in

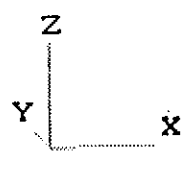
F_t = 4263

P = -14.7 psi

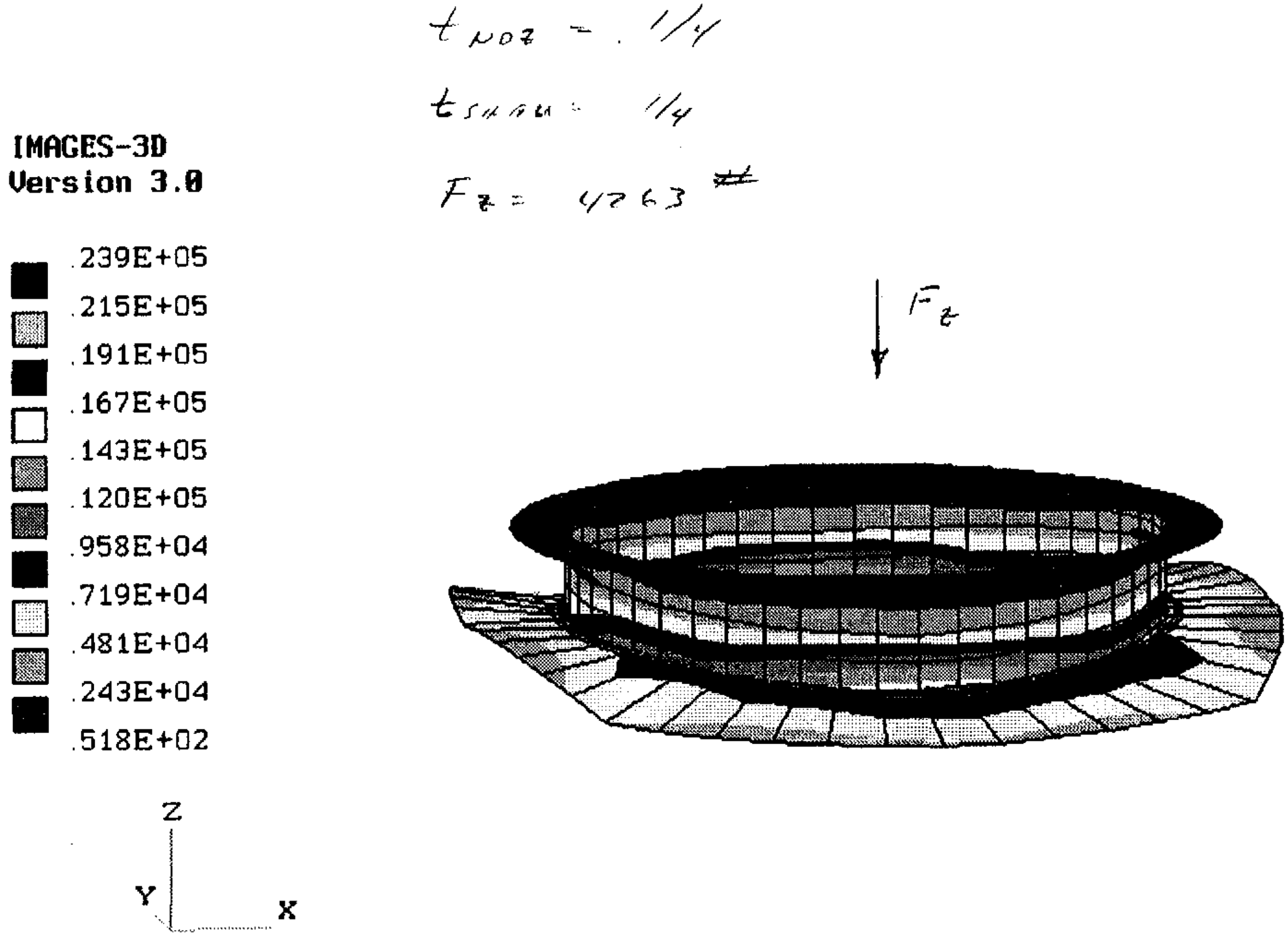
IMAGES-3D
Version 3.0

.223E+05
.201E+05
.180E+05
.158E+05
.137E+05
.115E+05
.937E+04
.722E+04
.507E+04
.292E+04
.771E+03





Load Case	Stress Contour Plot	8/19/96
2	Surf: Top Stress Intensity	17:18:27



Load Case 1

Stress Contour Plot

Surf: Top

Stress Intensity

8/19/96
17:13:14

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-046
REV.	DEO #	DATE	BY:	CHECK		PAGE 1 OF 7
0	0131	2-16-96	G ARENA	RDC	TITLE: DESIGN OF "ADAPTER-A1"	
					By: G ARENA	DEPT.: 744

PROJECT: LIGO VACUUM EQUIPMENT

PROJECT NO: V59049

PURPOSE: SEE BODY OF CALC

METHOD:

ASSUMPTIONS:

INPUTS:

REFERENCES:

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS:

NOTES: BELLOWS ENGINEERING DATA TO BE VERIFIED.

COMPUTER FILES ARE A1FLG.* & A1JKGLUG.*

1.0 OBJECTIVE

The objective of this calculation is to perform the structural design and analysis of Adapter "A-1" (72" x 44 ") assembly shown in Drawing V049-4-A1 using the optional "Sight-Port" reducing flange concept.

2.0 METHOD OF ANALYSIS / COMPUTER PROGRAMS & VERSION

The following computer programs are used in the execution of this calculation:

1. IMAGES-3D Finite Element Analysis Program, Version 2.0

2. COMPRESS Computer Aided Pressure Vessel Design, Version 4.2

The reducing flange sub-assembly is analyzed as an Axisymmetric finite element model to determine the minimum thickness (not less than 1") to maintain a vacuum seal at the "O"-Rings under a full vacuum load and the end load effects (pressure and spring force) of the bellows.

The Jacking bolt assembly is analyzed as a plate and shell finite element partial model to size the lug and to determine the shell displacements at the bellows weld to ensure the weld is not damaged by local bending during equipment servicing. No pressure loads are applied in this analysis because this component is operated during installation or equipment servicing only.

The Jacking lug / shell interface is qualified by the nozzle shell analysis (WRC-107) sub-routine in COMPRESS. *

Welds are sized by traditional manual calculations found in standard engineering texts.

3.0 GENERAL ASSUMPTIONS

1. All bellows engineering data and geometry are assumed and must be verified once vendor information becomes available.

4.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section VIII, Division I, 1995 Edition

2. Roark & Young, Formulas for Stress and Strain, Fifth Edition

3. Blodgett, Design of Welded Structures

4. Welding Research Council, Bulletins 107 & 297, Local Stresses in Spherical and Cylindrical Shells due to External Loadings.

5. LIGO Vacuum Equipment Structural Design Criteria – V049-1-066

6. AISC Steel Construction Manual

* SEE V049-1-084 FOR FINAL JACKING LUG

5.0 CONCLUSIONS

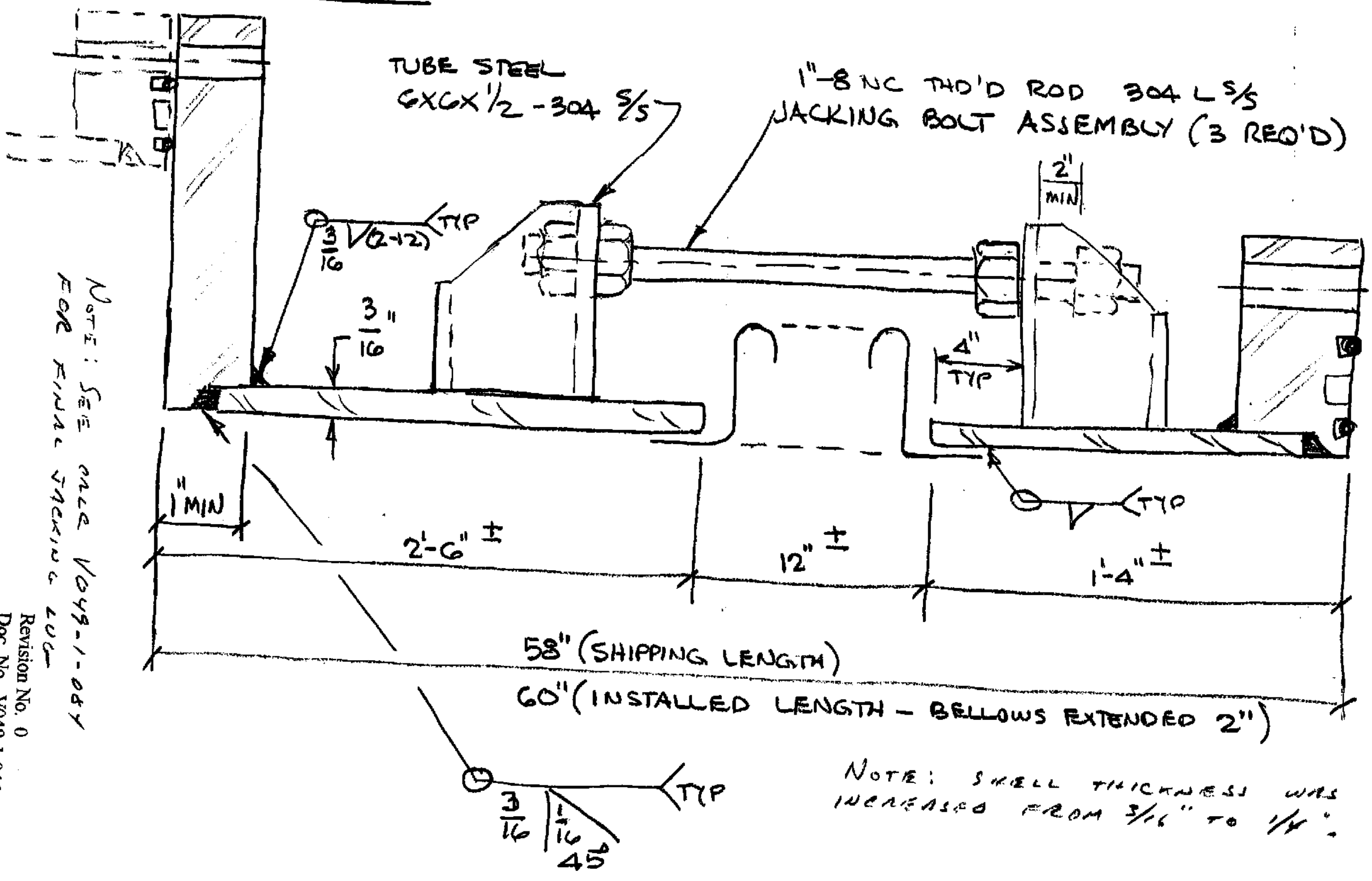
The separation of the flange faces from bending under operating loads is 2.8 E-04 " at the outer "O"-Ring. The "O"-Ring pre-compression is from 0.058" to 0.080" , hence the vacuum seal is maintained.

The maximum stress intensity in the flange is 845 psi at node 132.

The maximum stress intensity in the shell is 2568 psi under operating loads and is 39134 psi < 48900 psi allowable during installation adjacent to the Jacking Lug.

The maximum local radial displacement at the bellows/shell weld is 0.0144" near the Jacking Lug during installation and has no significant effect on the bellows attachment weld.

1. ASSEMBLY DETAIL



2. AXI-SYMMETRICAL FEA MODEL DEVELOPMENT FOR FLANGE/SHELL INTERACTION

1. DETERMINE SHELL LENGTH REQUIREMENTS TO DISSIPATE END MOMENT EFFECTS

$72\frac{1}{4}$" O.D × $\frac{1}{4}$ THK SHELL

SHELL LENGTH PARAMETER $\lambda = \left[\frac{3(1-\nu^2)}{R^2 t^2}\right]^{1/4}$ ROARK 5TH PG 458

$$\lambda = \left[\frac{3(1-.3^2)}{\overline{36}^2 \times \overline{.25}^2}\right]^{1/4} = .428$$

FOR LONG SHELL $\lambda L > 6$ $L = \frac{6}{\lambda} \approx \underline{\underline{14''}}$

$44\frac{5}{8}$ ID × $\frac{3}{16}$ THK SHELL

$$\lambda = \left[\frac{3(1-.3^2)}{\overline{22.40625}^2 \times \overline{.1875}^2}\right]^{1/4} = .627$$

$$L = \frac{6}{\lambda} = 9.5'' \Rightarrow \underline{\underline{10''}}$$

2. RING LOADS DUE TO BELLOWS SPRING GRADIENT AND EXTERNAL PRESSURE ON BELLOWS

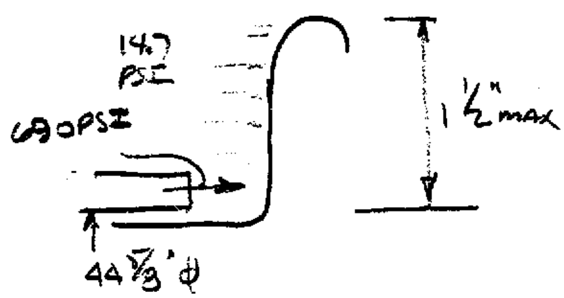
BELLOWS TO BE COLD PULLED 2" AT INSTALLATION

∴ SPRING LOAD AND VACUUM ARE ADDITIVE

VACUUM LOAD

$$14.7 \times \frac{\pi}{4}\left(\overline{47.625}^2 - \overline{44.625}^2\right)$$

$\approx 3200^{\#}$ TOTAL



SPRING LOAD @ $k = 7500^{\#}/\text{IN}$

$F = 2 \times 7500 = 15000^{\#}$

EQUIV PRESSURE ON SHELL END

$$\text{TOTAL LOAD} = 18200^{\#} \Rightarrow P_{PSI} = \frac{18200 \times 4}{(45^2 - 44\frac{5}{8}^2)\,\pi} = 690 \text{ PSI}$$

KOCH PROCESSOR SYSTEMS S/N:801743A 03/04/96
PAGE 15 RUN ID= 05:05:10

=============== I M A G E S - 3 D ==============

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GEOMETRY PLOT Version 2.0

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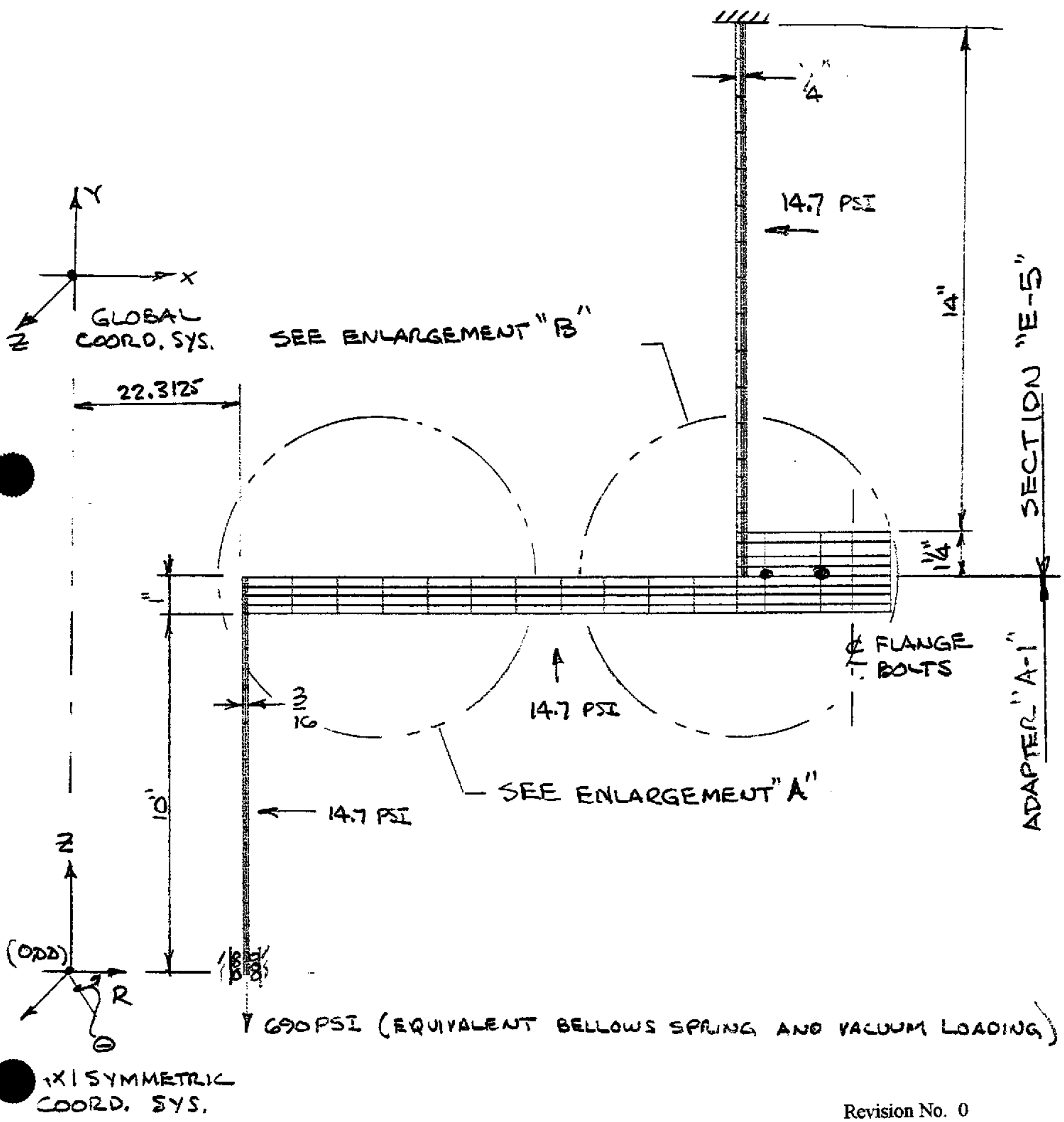
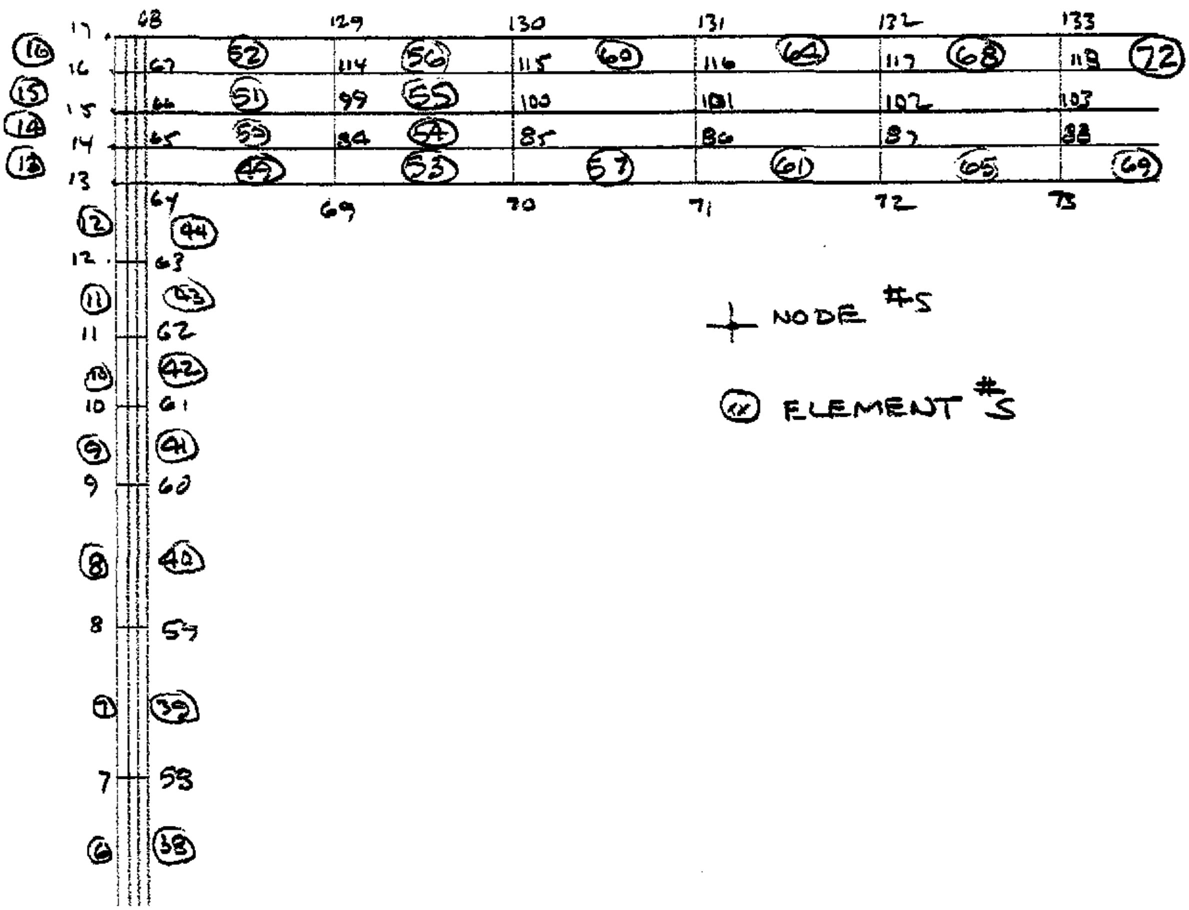


GEOMETRY PLOT Version 2.0

A1 REDUCING FLANGE W/SHELL



ENLARGEMENT "A"

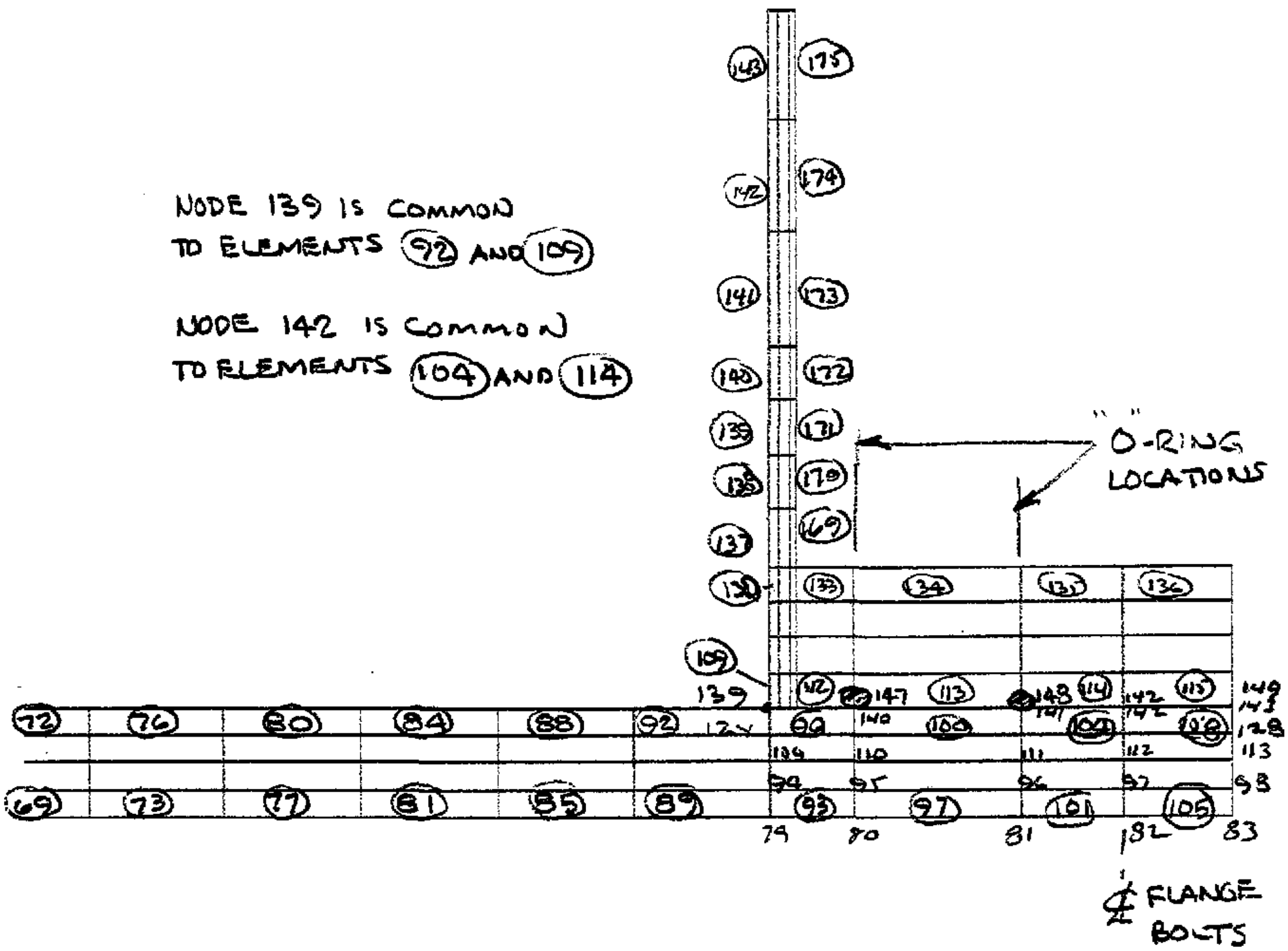
9

GEOMETRY PLOT Version 2.0

A1 REDUCING FLANGE W/SHELL

NODE 139 IS COMMON TO ELEMENTS (92) AND (109)

NODE 142 IS COMMON TO ELEMENTS (104) AND (114)



ENLARGEMENT "B"

+ NODE #S

(XX) ELEMENT #S

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Interactive Microcomputer Analysis & Graphics of Engineering Systems

IMAGES-3D Version 2.0 07/01/90

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=                 Berkeley,CA                  =
=                    94710                     =
=                                              =
=                415-843-0977                  =
================================================
```

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A1 REDUCING FLANGE W/SHELL

MATERIAL PROPERTIES

Material No	Modulus of Elasticity	Weight Density	Coeff of Thermal Exp.	Poisson's Ratio	Shear Web Modulus
1	2.66000E+07	2.87000E-01	9.90000E-06	3.00E-01	0.00000E+00

NODE COORDINATES

Node	X-Coord.	Y-Coord.	Z-Coord.
1	2.23125E+01	0.00000E+00	0.00000E+00
2	2.23125E+01	1.00000E+00	0.00000E+00
3	2.23125E+01	2.00000E+00	0.00000E+00
4	2.23125E+01	3.00000E+00	0.00000E+00
5	2.23125E+01	4.00000E+00	0.00000E+00
6	2.23125E+01	5.00000E+00	0.00000E+00
7	2.23125E+01	6.00000E+00	0.00000E+00
8	2.23125E+01	7.00000E+00	0.00000E+00
9	2.23125E+01	8.00000E+00	0.00000E+00
10	2.23125E+01	8.50000E+00	0.00000E+00
11	2.23125E+01	9.00000E+00	0.00000E+00
12	2.23125E+01	9.50000E+00	0.00000E+00
13	2.23125E+01	1.00000E+01	0.00000E+00
14	2.23125E+01	1.02500E+01	0.00000E+00
15	2.23125E+01	1.05000E+01	0.00000E+00
16	2.23125E+01	1.07500E+01	0.00000E+00
17	2.23125E+01	1.10000E+01	0.00000E+00
18	2.23750E+01	0.00000E+00	0.00000E+00
19	2.23750E+01	1.00000E+00	0.00000E+00
20	2.23750E+01	2.00000E+00	0.00000E+00
21	2.23750E+01	3.00000E+00	0.00000E+00
22	2.23750E+01	4.00000E+00	0.00000E+00
23	2.23750E+01	5.00000E+00	0.00000E+00
24	2.23750E+01	6.00000E+00	0.00000E+00
25	2.23750E+01	7.00000E+00	0.00000E+00
26	2.23750E+01	8.00000E+00	0.00000E+00
27	2.23750E+01	8.50000E+00	0.00000E+00
28	2.23750E+01	9.00000E+00	0.00000E+00
29	2.23750E+01	9.50000E+00	0.00000E+00
30	2.23750E+01	1.00000E+01	0.00000E+00

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
31	2.23750E+01	1.02500E+01	0.00000E+00
32	2.23750E+01	1.05000E+01	0.00000E+00
33	2.23750E+01	1.07500E+01	0.00000E+00
34	2.23750E+01	1.10000E+01	0.00000E+00
35	2.24375E+01	0.00000E+00	0.00000E+00
36	2.24375E+01	1.00000E+00	0.00000E+00
37	2.24375E+01	2.00000E+00	0.00000E+00
38	2.24375E+01	3.00000E+00	0.00000E+00
39	2.24375E+01	4.00000E+00	0.00000E+00
40	2.24375E+01	5.00000E+00	0.00000E+00
41	2.24375E+01	6.00000E+00	0.00000E+00
42	2.24375E+01	7.00000E+00	0.00000E+00
43	2.24375E+01	8.00000E+00	0.00000E+00
44	2.24375E+01	8.50000E+00	0.00000E+00
45	2.24375E+01	9.00000E+00	0.00000E+00
46	2.24375E+01	9.50000E+00	0.00000E+00
47	2.24375E+01	1.00000E+01	0.00000E+00
48	2.24375E+01	1.02500E+01	0.00000E+00
49	2.24375E+01	1.05000E+01	0.00000E+00
50	2.24375E+01	1.07500E+01	0.00000E+00
51	2.24375E+01	1.10000E+01	0.00000E+00
52	2.25000E+01	0.00000E+00	0.00000E+00
53	2.25000E+01	1.00000E+00	0.00000E+00
54	2.25000E+01	2.00000E+00	0.00000E+00
55	2.25000E+01	3.00000E+00	0.00000E+00
56	2.25000E+01	4.00000E+00	0.00000E+00
57	2.25000E+01	5.00000E+00	0.00000E+00
58	2.25000E+01	6.00000E+00	0.00000E+00
59	2.25000E+01	7.00000E+00	0.00000E+00
60	2.25000E+01	8.00000E+00	0.00000E+00
61	2.25000E+01	8.50000E+00	0.00000E+00
62	2.25000E+01	9.00000E+00	0.00000E+00
63	2.25000E+01	9.50000E+00	0.00000E+00
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66	2.25000E+01	1.05000E+01	0.00000E+00
67	2.25000E+01	1.07500E+01	0.00000E+00
68	2.25000E+01	1.10000E+01	0.00000E+00
69	2.37500E+01	1.00000E+01	0.00000E+00
70	2.49625E+01	1.00000E+01	0.00000E+00
71	2.61750E+01	1.00000E+01	0.00000E+00
72	2.73875E+01	1.00000E+01	0.00000E+00

=============== I M A G E S 3 D ===============

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A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
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74	2.98125E+01	1.00000E+01	0.00000E+00
75	3.10250E+01	1.00000E+01	0.00000E+00
76	3.22375E+01	1.00000E+01	0.00000E+00
77	3.34500E+01	1.00000E+01	0.00000E+00
78	3.46625E+01	1.00000E+01	0.00000E+00
79	3.58750E+01	1.00000E+01	0.00000E+00
80	3.66250E+01	1.00000E+01	0.00000E+00
81	3.81250E+01	1.00000E+01	0.00000E+00
82	3.90000E+01	1.00000E+01	0.00000E+00
83	4.00000E+01	1.00000E+01	0.00000E+00
84	2.37500E+01	1.02500E+01	0.00000E+00
85	2.49625E+01	1.02500E+01	0.00000E+00
86	2.61750E+01	1.02500E+01	0.00000E+00
87	2.73875E+01	1.02500E+01	0.00000E+00
88	2.86000E+01	1.02500E+01	0.00000E+00
89	2.98125E+01	1.02500E+01	0.00000E+00
90	3.10250E+01	1.02500E+01	0.00000E+00
91	3.22375E+01	1.02500E+01	0.00000E+00
92	3.34500E+01	1.02500E+01	0.00000E+00
93	3.46625E+01	1.02500E+01	0.00000E+00
94	3.58750E+01	1.02500E+01	0.00000E+00
95	3.66250E+01	1.02500E+01	0.00000E+00
96	3.81250E+01	1.02500E+01	0.00000E+00
97	3.90000E+01	1.02500E+01	0.00000E+00
98	4.00000E+01	1.02500E+01	0.00000E+00
99	2.37500E+01	1.05000E+01	0.00000E+00
100	2.49625E+01	1.05000E+01	0.00000E+00
101	2.61750E+01	1.05000E+01	0.00000E+00
102	2.73875E+01	1.05000E+01	0.00000E+00
103	2.86000E+01	1.05000E+01	0.00000E+00
104	2.98125E+01	1.05000E+01	0.00000E+00
105	3.10250E+01	1.05000E+01	0.00000E+00
106	3.22375E+01	1.05000E+01	0.00000E+00
107	3.34500E+01	1.05000E+01	0.00000E+00
108	3.46625E+01	1.05000E+01	0.00000E+00
109	3.58750E+01	1.05000E+01	0.00000E+00
110	3.66250E+01	1.05000E+01	0.00000E+00
111	3.81250E+01	1.05000E+01	0.00000E+00
112	3.90000E+01	1.05000E+01	0.00000E+00
113	4.00000E+01	1.05000E+01	0.00000E+00
114	2.37500E+01	1.07500E+01	0.00000E+00

CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
115	2.49625E+01	1.07500E+01	0.00000E+00
116	2.61750E+01	1.07500E+01	0.00000E+00
117	2.73875E+01	1.07500E+01	0.00000E+00
118	2.86000E+01	1.07500E+01	0.00000E+00
119	2.98125E+01	1.07500E+01	0.00000E+00
120	3.10250E+01	1.07500E+01	0.00000E+00
121	3.22375E+01	1.07500E+01	0.00000E+00
122	3.34500E+01	1.07500E+01	0.00000E+00
123	3.46625E+01	1.07500E+01	0.00000E+00
124	3.58750E+01	1.07500E+01	0.00000E+00
125	3.66250E+01	1.07500E+01	0.00000E+00
126	3.81250E+01	1.07500E+01	0.00000E+00
127	3.90000E+01	1.07500E+01	0.00000E+00
128	4.00000E+01	1.07500E+01	0.00000E+00
129	2.37500E+01	1.10000E+01	0.00000E+00
130	2.49625E+01	1.10000E+01	0.00000E+00
131	2.61750E+01	1.10000E+01	0.00000E+00
132	2.73875E+01	1.10000E+01	0.00000E+00
133	2.86000E+01	1.10000E+01	0.00000E+00
134	2.98125E+01	1.10000E+01	0.00000E+00
135	3.10250E+01	1.10000E+01	0.00000E+00
136	3.22375E+01	1.10000E+01	0.00000E+00
137	3.34500E+01	1.10000E+01	0.00000E+00
138	3.46625E+01	1.10000E+01	0.00000E+00
139	3.58750E+01	1.10000E+01	0.00000E+00
140	3.66250E+01	1.10000E+01	0.00000E+00
141	3.81250E+01	1.10000E+01	0.00000E+00
142	3.90000E+01	1.10000E+01	0.00000E+00
143	4.00000E+01	1.10000E+01	0.00000E+00
144	3.59583E+01	1.10000E+01	0.00000E+00
145	3.60417E+01	1.10000E+01	0.00000E+00
146	3.61250E+01	1.10000E+01	0.00000E+00
147	3.66250E+01	1.10000E+01	0.00000E+00
148	3.81250E+01	1.10000E+01	0.00000E+00
149	4.00000E+01	1.10000E+01	0.00000E+00
150	3.58750E+01	1.13125E+01	0.00000E+00
151	3.59583E+01	1.13125E+01	0.00000E+00
152	3.60417E+01	1.13125E+01	0.00000E+00
153	3.61250E+01	1.13125E+01	0.00000E+00
154	3.66250E+01	1.13125E+01	0.00000E+00
155	3.81250E+01	1.13125E+01	0.00000E+00
156	3.90000E+01	1.13125E+01	0.00000E+00

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A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
157	4.00000E+01	1.13125E+01	0.00000E+00
158	3.58750E+01	1.16250E+01	0.00000E+00
159	3.59583E+01	1.16250E+01	0.00000E+00
160	3.60417E+01	1.16250E+01	0.00000E+00
161	3.61250E+01	1.16250E+01	0.00000E+00
162	3.66250E+01	1.16250E+01	0.00000E+00
163	3.81250E+01	1.16250E+01	0.00000E+00
164	3.90000E+01	1.16250E+01	0.00000E+00
165	4.00000E+01	1.16250E+01	0.00000E+00
166	3.58750E+01	1.19375E+01	0.00000E+00
167	3.59583E+01	1.19375E+01	0.00000E+00
168	3.60417E+01	1.19375E+01	0.00000E+00
169	3.61250E+01	1.19375E+01	0.00000E+00
170	3.66250E+01	1.19375E+01	0.00000E+00
171	3.81250E+01	1.19375E+01	0.00000E+00
172	3.90000E+01	1.19375E+01	0.00000E+00
173	4.00000E+01	1.19375E+01	0.00000E+00
174	3.58750E+01	1.22500E+01	0.00000E+00
175	3.59583E+01	1.22500E+01	0.00000E+00
176	3.60417E+01	1.22500E+01	0.00000E+00
177	3.61250E+01	1.22500E+01	0.00000E+00
178	3.66250E+01	1.22500E+01	0.00000E+00
179	3.81250E+01	1.22500E+01	0.00000E+00
180	3.90000E+01	1.22500E+01	0.00000E+00
181	4.00000E+01	1.22500E+01	0.00000E+00
182	3.58750E+01	1.27500E+01	0.00000E+00
183	3.58750E+01	1.32500E+01	0.00000E+00
184	3.58750E+01	1.37500E+01	0.00000E+00
185	3.58750E+01	1.42500E+01	0.00000E+00
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188	3.58750E+01	1.72500E+01	0.00000E+00
189	3.58750E+01	1.82500E+01	0.00000E+00
190	3.58750E+01	1.92500E+01	0.00000E+00
191	3.58750E+01	2.02500E+01	0.00000E+00
192	3.58750E+01	2.12500E+01	0.00000E+00
193	3.58750E+01	2.22500E+01	0.00000E+00
194	3.58750E+01	2.32500E+01	0.00000E+00
195	3.58750E+01	2.42500E+01	0.00000E+00
196	3.58750E+01	2.52500E+01	0.00000E+00
197	3.58750E+01	2.62500E+01	0.00000E+00
198	3.59583E+01	1.27500E+01	0.00000E+00

CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
199	3.59583E+01	1.32500E+01	0.00000E+00
200	3.59583E+01	1.37500E+01	0.00000E+00
201	3.59583E+01	1.42500E+01	0.00000E+00
202	3.59583E+01	1.52500E+01	0.00000E+00
203	3.59583E+01	1.62500E+01	0.00000E+00
204	3.59583E+01	1.72500E+01	0.00000E+00
205	3.59583E+01	1.82500E+01	0.00000E+00
206	3.59583E+01	1.92500E+01	0.00000E+00
207	3.59583E+01	2.02500E+01	0.00000E+00
208	3.59583E+01	2.12500E+01	0.00000E+00
209	3.59583E+01	2.22500E+01	0.00000E+00
210	3.59583E+01	2.32500E+01	0.00000E+00
211	3.59583E+01	2.42500E+01	0.00000E+00
212	3.59583E+01	2.52500E+01	0.00000E+00
213	3.59583E+01	2.62500E+01	0.00000E+00
214	3.60417E+01	1.27500E+01	0.00000E+00
215	3.60417E+01	1.32500E+01	0.00000E+00
216	3.60417E+01	1.37500E+01	0.00000E+00
217	3.60417E+01	1.42500E+01	0.00000E+00
218	3.60417E+01	1.52500E+01	0.00000E+00
219	3.60417E+01	1.62500E+01	0.00000E+00
220	3.60417E+01	1.72500E+01	0.00000E+00
221	3.60417E+01	1.82500E+01	0.00000E+00
222	3.60417E+01	1.92500E+01	0.00000E+00
223	3.60417E+01	2.02500E+01	0.00000E+00
224	3.60417E+01	2.12500E+01	0.00000E+00
225	3.60417E+01	2.22500E+01	0.00000E+00
226	3.60417E+01	2.32500E+01	0.00000E+00
227	3.60417E+01	2.42500E+01	0.00000E+00
228	3.60417E+01	2.52500E+01	0.00000E+00
229	3.60417E+01	2.62500E+01	0.00000E+00
230	3.61250E+01	1.27500E+01	0.00000E+00
231	3.61250E+01	1.32500E+01	0.00000E+00
232	3.61250E+01	1.37500E+01	0.00000E+00
233	3.61250E+01	1.42500E+01	0.00000E+00
234	3.61250E+01	1.52500E+01	0.00000E+00
235	3.61250E+01	1.62500E+01	0.00000E+00
236	3.61250E+01	1.72500E+01	0.00000E+00
237	3.61250E+01	1.82500E+01	0.00000E+00
238	3.61250E+01	1.92500E+01	0.00000E+00
239	3.61250E+01	2.02500E+01	0.00000E+00
240	3.61250E+01	2.12500E+01	0.00000E+00

=============== I M A G E S 3 D ===============

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
241	3.61250E+01	2.22500E+01	0.00000E+00
242	3.61250E+01	2.32500E+01	0.00000E+00
243	3.61250E+01	2.42500E+01	0.00000E+00
244	3.61250E+01	2.52500E+01	0.00000E+00
245	3.61250E+01	2.62500E+01	0.00000E+00

"O"-RING LOCATIONS

*** WARNING - *** Nodes 140 & 147 are <=0.0001 apart in all 3 dirs. ***
*** WARNING - *** Nodes 141 & 148 are <=0.0001 apart in all 3 dirs. ***
*** WARNING - *** Nodes 143 & 149 are <=0.0001 apart in all 3 dirs. ***

O.D. FLANGES

AXI-SOLID ELEMENT CONNECTIVITY

Axi-Solid No.	NODES I	J	K	L	Mat No.	Volume per rad.
1	1	18	19	2	1	1.396E+00
2	2	19	20	3	1	1.396E+00
3	3	20	21	4	1	1.396E+00
4	4	21	22	5	1	1.396E+00
5	5	22	23	6	1	1.396E+00
6	6	23	24	7	1	1.396E+00
7	7	24	25	8	1	1.396E+00
8	8	25	26	9	1	1.396E+00
9	9	26	27	10	1	6.982E-01
10	10	27	28	11	1	6.982E-01
11	11	28	29	12	1	6.982E-01
12	12	29	30	13	1	6.982E-01
13	13	30	31	14	1	3.491E-01
14	14	31	32	15	1	3.491E-01
15	15	32	33	16	1	3.491E-01
16	16	33	34	17	1	3.491E-01
17	18	35	36	19	1	1.400E+00
18	19	36	37	20	1	1.400E+00
19	20	37	38	21	1	1.400E+00
20	21	38	39	22	1	1.400E+00
21	22	39	40	23	1	1.400E+00
22	23	40	41	24	1	1.400E+00
23	24	41	42	25	1	1.400E+00
24	25	42	43	26	1	1.400E+00
25	26	43	44	27	1	7.002E-01
26	27	44	45	28	1	7.002E-01

CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Axi-Solid No.	NODES I	J	K	L	Mat No.	Volume per rad.
27	28	45	46	29	1	7.002E-01
28	29	46	47	30	1	7.002E-01
29	30	47	48	31	1	3.501E-01
30	31	48	49	32	1	3.501E-01
31	32	49	50	33	1	3.501E-01
32	33	50	51	34	1	3.501E-01
33	35	52	53	36	1	1.404E+00
34	36	53	54	37	1	1.404E+00
35	37	54	55	38	1	1.404E+00
36	38	55	56	39	1	1.404E+00
37	39	56	57	40	1	1.404E+00
38	40	57	58	41	1	1.404E+00
39	41	58	59	42	1	1.404E+00
40	42	59	60	43	1	1.404E+00
41	43	60	61	44	1	7.021E-01
42	44	61	62	45	1	7.021E-01
43	45	62	63	46	1	7.021E-01
44	46	63	64	47	1	7.021E-01
45	47	64	65	48	1	3.511E-01
46	48	65	66	49	1	3.511E-01
47	49	66	67	50	1	3.511E-01
48	50	67	68	51	1	3.511E-01
49	64	69	84	65	1	7.227E+00
50	65	84	99	66	1	7.227E+00
51	66	99	114	67	1	7.227E+00
52	67	114	129	68	1	7.227E+00
53	69	70	85	84	1	7.383E+00
54	84	85	100	99	1	7.383E+00
55	99	100	115	114	1	7.383E+00
56	114	115	130	129	1	7.383E+00
57	70	71	86	85	1	7.751E+00
58	85	86	101	100	1	7.751E+00
59	100	101	116	115	1	7.751E+00
60	115	116	131	130	1	7.751E+00
61	71	72	87	86	1	8.118E+00
62	86	87	102	101	1	8.118E+00
63	101	102	117	116	1	8.118E+00
64	116	117	132	131	1	8.118E+00
65	72	73	88	87	1	8.486E+00
66	87	88	103	102	1	8.486E+00
67	102	103	118	117	1	8.486E+00

=============== I M A G E S 3 D ==============

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Axi-Solid No.	NODES I	J	K	L	Mat No.	Volume per rad.
68	117	118	133	132	1	8.486E+00
69	73	74	89	88	1	8.853E+00
70	88	89	104	103	1	8.853E+00
71	103	104	119	118	1	8.853E+00
72	118	119	134	133	1	8.853E+00
73	74	75	90	89	1	9.221E+00
74	89	90	105	104	1	9.221E+00
75	104	105	120	119	1	9.221E+00
76	119	120	135	134	1	9.221E+00
77	75	76	91	90	1	9.588E+00
78	90	91	106	105	1	9.588E+00
79	105	106	121	120	1	9.588E+00
80	120	121	136	135	1	9.588E+00
81	76	77	92	91	1	9.956E+00
82	91	92	107	106	1	9.956E+00
83	106	107	122	121	1	9.956E+00
84	121	122	137	136	1	9.956E+00
85	77	78	93	92	1	1.032E+01
86	92	93	108	107	1	1.032E+01
87	107	108	123	122	1	1.032E+01
88	122	123	138	137	1	1.032E+01
89	78	79	94	93	1	1.069E+01
90	93	94	109	108	1	1.069E+01
91	108	109	124	123	1	1.069E+01
92	123	124	139	138	1	1.069E+01
93	79	80	95	94	1	6.797E+00
94	94	95	110	109	1	6.797E+00
95	109	110	125	124	1	6.797E+00
96	124	125	140	139	1	6.797E+00
97	80	81	96	95	1	1.402E+01
98	95	96	111	110	1	1.402E+01
99	110	111	126	125	1	1.402E+01
100	125	126	141	140	1	1.402E+01
101	81	82	97	96	1	8.436E+00
102	96	97	112	111	1	8.436E+00
103	111	112	127	126	1	8.436E+00
104	126	127	142	141	1	8.436E+00
105	82	83	98	97	1	9.875E+00
106	97	98	113	112	1	9.875E+00
107	112	113	128	127	1	9.875E+00
108	127	128	143	142	1	9.875E+00

=============== I M A G E S 3 D ===============

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Axi-Solid No.	NODES I	J	K	L	Mat No.	Volume per rad.
109	139	144	151	150	1	9.353E-01
110	144	145	152	151	1	9.376E-01
111	145	146	153	152	1	9.396E-01
112	146	147	154	153	1	5.684E+00
113	147	148	155	154	1	1.752E+01
114	148	142	156	155	1	1.054E+01
115	142	149	157	156	1	1.234E+01
116	150	151	159	158	1	9.353E-01
117	151	152	160	159	1	9.376E-01
118	152	153	161	160	1	9.396E-01
119	153	154	162	161	1	5.684E+00
120	154	155	163	162	1	1.752E+01
121	155	156	164	163	1	1.054E+01
122	156	157	165	164	1	1.234E+01
123	158	159	167	166	1	9.353E-01
124	159	160	168	167	1	9.376E-01
125	160	161	169	168	1	9.396E-01
126	161	162	170	169	1	5.684E+00
127	162	163	171	170	1	1.752E+01
128	163	164	172	171	1	1.054E+01
129	164	165	173	172	1	1.234E+01
130	166	167	175	174	1	9.353E-01
131	167	168	176	175	1	9.376E-01
132	168	169	177	176	1	9.396E-01
133	169	170	178	177	1	5.684E+00
134	170	171	179	178	1	1.752E+01
135	171	172	180	179	1	1.054E+01
136	172	173	181	180	1	1.234E+01
137	174	175	198	182	1	1.496E+00
138	182	198	199	183	1	1.496E+00
139	183	199	200	184	1	1.496E+00
140	184	200	201	185	1	1.496E+00
141	185	201	202	186	1	2.993E+00
142	186	202	203	187	1	2.993E+00
143	187	203	204	188	1	2.993E+00
144	188	204	205	189	1	2.993E+00
145	189	205	206	190	1	2.993E+00
146	190	206	207	191	1	2.993E+00
147	191	207	208	192	1	2.993E+00
148	192	208	209	193	1	2.993E+00
149	193	209	210	194	1	2.993E+00

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Axi-Solid No.	NODES I	J	K	L	Mat No.	Volume per rad.
150	194	210	211	195	1	2.993E+00
151	195	211	212	196	1	2.993E+00
152	196	212	213	197	1	2.993E+00
153	175	176	214	198	1	1.500E+00
154	198	214	215	199	1	1.500E+00
155	199	215	216	200	1	1.500E+00
156	200	216	217	201	1	1.500E+00
157	201	217	218	202	1	3.000E+00
158	202	218	219	203	1	3.000E+00
159	203	219	220	204	1	3.000E+00
160	204	220	221	205	1	3.000E+00
161	205	221	222	206	1	3.000E+00
162	206	222	223	207	1	3.000E+00
163	207	223	224	208	1	3.000E+00
164	208	224	225	209	1	3.000E+00
165	209	225	226	210	1	3.000E+00
166	210	226	227	211	1	3.000E+00
167	211	227	228	212	1	3.000E+00
168	212	228	229	213	1	3.000E+00
169	176	177	230	214	1	1.503E+00
170	214	230	231	215	1	1.504E+00
171	215	231	232	216	1	1.504E+00
172	216	232	233	217	1	1.504E+00
173	217	233	234	218	1	3.007E+00
174	218	234	235	219	1	3.007E+00
175	219	235	236	220	1	3.007E+00
176	220	236	237	221	1	3.007E+00
177	221	237	238	222	1	3.007E+00
178	222	238	239	223	1	3.007E+00
179	223	239	240	224	1	3.007E+00
180	224	240	241	225	1	3.007E+00
181	225	241	242	226	1	3.007E+00
182	226	242	243	227	1	3.007E+00
183	227	243	244	228	1	3.007E+00
184	228	244	245	229	1	3.007E+00

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CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

RESTRAINTS

Node No	Global/Local	Restraint Directions
1	GLOBAL	- Y Z RX RY RZ
245	GLOBAL	X Y Z RX RY RZ

KOCH PROCESSOR SYSTEMS S/N:801743A 03/04/96
PAGE 13 Run ID= 05:02:50

=============== I M A G E S 3 D ===============

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RENUMBER NODES Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node Renumbering Cross Reference List

Was	Is	Was	Is	Was	Is	Was	Is	Was	Is
1	1	2	5	3	9	4	13	5	17
6	21	7	25	8	29	9	33	10	37
11	39	12	41	13	43	14	44	15	45
16	46	17	47	18	2	19	6	20	10
21	14	22	18	23	22	24	26	25	30
26	34	27	38	28	48	29	50	30	52
31	53	32	54	33	55	34	56	35	3
36	7	37	11	38	15	39	19	40	23
41	27	42	31	43	35	44	40	45	49
46	57	47	59	48	60	49	61	50	62
51	63	52	4	53	8	54	12	55	16
56	20	57	24	58	28	59	32	60	36
61	42	62	51	63	58	64	64	65	65
66	66	67	67	68	68	69	69	70	74
71	79	72	84	73	89	74	94	75	99
76	101	77	103	78	105	79	107	80	108
81	109	82	110	83	111	84	70	85	75
86	80	87	85	88	90	89	95	90	100
91	112	92	114	93	116	94	118	95	119
96	120	97	121	98	122	99	71	100	76
101	81	102	86	103	91	104	96	105	102
106	113	107	123	108	125	109	127	110	128
111	129	112	130	113	131	114	72	115	77
116	82	117	87	118	92	119	97	120	104
121	115	122	124	123	132	124	134	125	135
126	137	127	139	128	141	129	73	130	78
131	83	132	88	133	93	134	98	135	106
136	117	137	126	138	133	139	142	140	136
141	138	142	148	143	140	144	143	145	144
146	145	147	146	148	147	149	149	150	154
151	155	152	156	153	157	154	158	155	159
156	160	157	150	158	164	159	165	160	166
161	167	162	168	163	169	164	161	165	151
166	172	167	173	168	174	169	175	170	176
171	170	172	162	173	152	174	178	175	179
176	180	177	181	178	177	179	171	180	163
181	153	182	182	183	186	184	190	185	194
186	198	187	202	188	206	189	210	190	214
191	218	192	222	193	226	194	230	195	234
196	238	197	242	198	183	199	187	200	191

RENUMBER NODES Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

Node Renumbering Cross Reference List

Was	Is	Was	Is	Was	Is	Was	Is	Was	Is
201	195	202	199	203	203	204	207	205	211
206	215	207	219	208	223	209	227	210	231
211	235	212	239	213	243	214	184	215	188
216	192	217	196	218	200	219	204	220	208
221	212	222	216	223	220	224	224	225	228
226	232	227	236	228	240	229	244	230	185
231	189	232	193	233	197	234	201	235	205
236	209	237	213	238	217	239	221	240	225
241	229	242	233	243	237	244	241	245	245

PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1

EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
1	.5488E+03	-.5987E+01	-.2005E+04	/	.2326E+04	.2554E+04
2	.5392E+03	-.3302E+00	-.1958E+04	/	.2276E+04	.2497E+04
3	.5729E+03	-.3765E+01	-.1899E+04	/	.2240E+04	.2472E+04
4	.6182E+03	-.6999E+01	-.1831E+04	/	.2204E+04	.2449E+04
5	.6700E+03	-.1019E+02	-.1729E+04	/	.2142E+04	.2399E+04
6	.7160E+03	-.1283E+02	-.1570E+04	/	.2023E+04	.2286E+04
7	.7390E+03	-.1241E+02	-.1334E+04	/	.1818E+04	.2073E+04
8	.7190E+03	-.1779E+02	-.1006E+04	/	.1499E+04	.1725E+04
9	.6660E+03	-.4789E+02	-.6523E+03	/	.1143E+04	.1318E+04
10	.5227E+03	-.3411E+02	-.3887E+03	/	.7957E+03	.9113E+03
11	.2384E+03	-.1265E+03	-.2558E+03	/	.4439E+03	.4942E+03
12	.7974E+02	-.1380E+03	-.4644E+03	/	.4744E+03	.5441E+03
13	.3832E+03	-.3284E+03	-.1250E+04	/	.1418E+04	.1633E+04
14	.2810E+02	-.3897E+03	-.9334E+03	/	.8350E+03	.9615E+03
15	-.3326E+02	-.1050E+03	-.2870E+03	/	.2266E+03	.2537E+03
16	.1360E+02	-.2341E+02	-.3642E+03	/	.3608E+03	.3778E+03
17	.1122E+02	-.4802E+01	-.4012E+03	/	.4047E+03	.4124E+03
18	.5618E+03	-.7518E+01	-.2000E+04	/	.2330E+04	.2562E+04
19	.5483E+03	-.5819E+01	-.1953E+04	/	.2275E+04	.2501E+04
20	.5621E+03	-.5359E+01	-.1895E+04	/	.2228E+04	.2457E+04
21	.5821E+03	-.4952E+01	-.1828E+04	/	.2176E+04	.2410E+04
22	.6036E+03	-.2832E+01	-.1729E+04	/	.2096E+04	.2332E+04
23	.6231E+03	-.1492E+01	-.1571E+04	/	.1958E+04	.2194E+04
24	.6308E+03	.2826E+01	-.1337E+04	/	.1741E+04	.1968E+04
25	.6274E+03	-.6988E+01	-.1007E+04	/	.1427E+04	.1635E+04
26	.5964E+03	-.4102E+02	-.6557E+03	/	.1084E+04	.1252E+04
27	.5520E+03	-.3374E+02	-.3883E+03	/	.8224E+03	.9402E+03
28	.4107E+03	-.5882E+02	-.2527E+03	/	.5908E+03	.6634E+03
29	.2223E+03	-.8335E+02	-.1127E+03	/	.3213E+03	.3350E+03
30	.5751E+03	-.2981E+03	-.7582E+03	/	.1173E+04	.1333E+04
31	-.1395E+03	-.3676E+03	-.4949E+03	/	.3119E+03	.3554E+03
32	-.1219E+02	-.1202E+03	-.3111E+03	/	.2622E+03	.2989E+03
33	.3618E+01	-.7326E+01	-.3515E+03	/	.3498E+03	.3551E+03
34	.1112E+02	.1679E+01	-.4075E+03	/	.4139E+03	.4186E+03
35	.5760E+03	-.6463E+01	-.1987E+04	/	.2327E+04	.2563E+04
36	.5599E+03	-.1082E+02	-.1943E+04	/	.2272E+04	.2503E+04
37	.5497E+03	-.1075E+02	-.1893E+04	/	.2216E+04	.2443E+04
38	.5341E+03	-.1037E+02	-.1837E+04	/	.2151E+04	.2371E+04
39	.5143E+03	-.7516E+01	-.1751E+04	/	.2055E+04	.2265E+04
40	.4981E+03	-.7292E+01	-.1604E+04	/	.1900E+04	.2102E+04
41	.4825E+03	.1480E+01	-.1381E+04	/	.1675E+04	.1863E+04

KOCH PROCESSOR SYSTEMS S/N:801743A 03/04/96
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=============== I M A G E S 3 D ===============

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PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1

EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
42	.5052E+03	-.1558E+02	-.1040E+04	/	.1361E+04	.1545E+04
43	.4971E+03	-.4281E+02	-.6899E+03	/	.1029E+04	.1187E+04
44	.6106E+03	-.4295E+02	-.3692E+03	/	.8642E+03	.9799E+03
45	.7335E+03	.2971E+01	-.1672E+03	/	.8288E+03	.9006E+03
46	.1082E+04	.2219E+03	-.1553E+03	/	.1098E+04	.1237E+04
47	.1384E+04	.9631E+00	-.4373E+03	/	.1646E+04	.1821E+04
48	.1222E+03	-.2070E+03	-.3987E+03	/	.4563E+03	.5209E+03
49	.8505E+01	-.9811E+02	-.3473E+03	/	.3162E+03	.3558E+03
50	.2010E+02	-.1223E+02	-.3337E+03	/	.3388E+03	.3538E+03
51	.1456E+02	.7353E+01	-.4150E+03	/	.4260E+03	.4296E+03
52	.5846E+03	-.1003E+02	-.1981E+04	/	.2326E+04	.2566E+04 SHELL
53	.5661E+03	-.1481E+02	-.1938E+04	/	.2270E+04	.2504E+04
54	.5402E+03	-.1323E+02	-.1889E+04	/	.2205E+04	.2429E+04
55	.4980E+03	-.8314E+01	-.1834E+04	/	.2124E+04	.2332E+04
56	.4484E+03	-.6090E+00	-.1750E+04	/	.2012E+04	.2199E+04
57	.4060E+03	.3239E+01	-.1604E+04	/	.1842E+04	.2010E+04
58	.3735E+03	.1747E+02	-.1385E+04	/	.1610E+04	.1758E+04
59	.4167E+03	-.7930E+01	-.1040E+04	/	.1297E+04	.1456E+04
60	.4241E+03	-.3266E+02	-.6963E+03	/	.9758E+03	.1120E+04
61	.6633E+03	-.6409E+02	-.3624E+03	/	.9138E+03	.1026E+04
62	.9815E+03	-.1189E+02	-.1734E+03	/	.1083E+04	.1155E+04
63	.1752E+04	.2770E+03	-.3073E+03	/	.1838E+04	.2059E+04
64	.6942E+03	-.1454E+03	-.1822E+03	/	.8585E+03	.8763E+03
65	.3050E+03	-.1100E+03	-.2025E+03	/	.4682E+03	.5075E+03
66	.8992E+02	-.3087E+02	-.2815E+03	/	.3281E+03	.3714E+03
67	.4981E+02	.9913E+01	-.3398E+03	/	.3713E+03	.3897E+03
68	.8619E+02	.1325E+02	-.3973E+03	/	.4514E+03	.4834E+03
69	-.2775E+02	-.8506E+02	-.1387E+03	/	.9611E+02	.1110E+03
70	.5105E+02	-.2785E+03	-.5097E+03	/	.4881E+03	.5608E+03
71	.1543E+02	-.2813E+03	-.6502E+03	/	.5776E+03	.6657E+03
72	.4457E+02	-.3454E+03	-.7778E+03	/	.7125E+03	.8223E+03
73	.3859E+02	-.3640E+03	-.7945E+03	/	.7216E+03	.8331E+03
74	.4036E+02	-.3787E+03	-.7493E+03	/	.6843E+03	.7896E+03
75	.3170E+02	-.3695E+03	-.6290E+03	/	.5765E+03	.6607E+03
76	.2064E+02	-.3436E+03	-.4478E+03	/	.4260E+03	.4684E+03
77	.7487E+01	-.2022E+03	-.2964E+03	/	.2694E+03	.3039E+03
78	.1006E+03	-.2085E+02	-.2316E+03	/	.2911E+03	.3322E+03
79	.3395E+03	-.7016E+02	-.1522E+03	/	.4563E+03	.4918E+03
80	.2288E+03	-.2982E+02	-.1628E+03	/	.3449E+03	.3916E+03
81	.8735E+02	-.1230E+02	-.1839E+03	/	.2376E+03	.2712E+03
82	.1601E+02	-.1347E+02	-.1852E+03	/	.1882E+03	.2012E+03

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=============== I M A G E S 3 D ===============

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PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1
EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
83	-.4816E+01	-.1074E+02	-.1873E+03	/	.1796E+03	.1825E+03
84	-.3636E+02	-.5468E+02	-.1592E+03	/	.1148E+03	.1229E+03
85	.3295E+01	-.2748E+03	-.2947E+03	/	.2885E+03	.2980E+03
86	-.1515E+02	-.3036E+03	-.3761E+03	/	.3307E+03	.3609E+03
87	-.8087E+01	-.3394E+03	-.4499E+03	/	.3982E+03	.4418E+03
88	-.1103E+02	-.3488E+03	-.4681E+03	/	.4107E+03	.4571E+03
89	-.1008E+02	-.3490E+03	-.4457E+03	/	.3962E+03	.4356E+03
90	-.1000E+02	-.3336E+03	-.3817E+03	/	.3502E+03	.3717E+03
91	-.1155E+02	-.2788E+03	-.3034E+03	/	.2803E+03	.2918E+03
92	-.8399E+01	-.1408E+03	-.2577E+03	/	.2161E+03	.2493E+03
93	.3017E+02	-.1262E+02	-.2058E+03	/	.2178E+03	.2360E+03
94	.1962E+03	-.7503E+02	-.1324E+03	/	.3041E+03	.3287E+03
95	.1435E+03	-.2727E+02	-.1468E+03	/	.2527E+03	.2903E+03
96	.5631E+02	-.1224E+02	-.1613E+03	/	.1928E+03	.2177E+03
97	.6564E+01	-.1482E+02	-.1662E+03	/	.1631E+03	.1728E+03
98	-.8181E+01	-.1252E+02	-.1682E+03	/	.1579E+03	.1600E+03
99	.5274E+02	-.3594E+02	-.2385E+03	/	.2586E+03	.2913E+03
100	.1653E+02	-.1756E+02	-.2405E+03	/	.2418E+03	.2570E+03
101	.1182E+02	-.2352E+02	-.2323E+03	/	.2285E+03	.2441E+03
102	-.1225E+01	-.1998E+02	-.2186E+03	/	.2086E+03	.2174E+03
103	-.4612E+01	-.2539E+02	-.2125E+03	/	.1983E+03	.2079E+03
104	-.7982E+01	-.2943E+02	-.2034E+03	/	.1857E+03	.1954E+03
105	-.6138E+01	-.3794E+02	-.1980E+03	/	.1781E+03	.1918E+03
106	-.5421E+01	-.4489E+02	-.1916E+03	/	.1699E+03	.1861E+03
107	-.4010E+01	-.5029E+02	-.1821E+03	/	.1600E+03	.1781E+03
108	.1069E+02	-.7395E+02	-.2011E+03	/	.1846E+03	.2118E+03
109	.5345E+02	-.1580E+03	-.1620E+03	/	.2134E+03	.2154E+03
110	.7805E+02	-.7519E+02	-.1617E+03	/	.2103E+03	.2397E+03
111	.2004E+02	-.1661E+02	-.1397E+03	/	.1449E+03	.1597E+03
112	.6474E+01	-.2028E+02	-.1433E+03	/	.1383E+03	.1497E+03
113	-.7198E+01	-.1289E+02	-.1443E+03	/	.1343E+03	.1371E+03
114	.1252E+03	.3497E+01	-.2848E+03	/	.3648E+03	.4101E+03
115	.2781E+03	-.1046E+02	-.2064E+03	/	.4222E+03	.4846E+03
116	.3710E+03	-.2755E+01	-.1506E+03	/	.4657E+03	.5216E+03
117	.4208E+03	-.5263E+01	-.1029E+03	/	.4824E+03	.5237E+03
118	.4238E+03	-.4723E+01	-.7351E+02	/	.4667E+03	.4973E+03
119	.3851E+03	-.3983E+01	-.5997E+02	/	.4198E+03	.4450E+03
120	.3093E+03	-.5850E+01	-.5948E+02	/	.3451E+03	.3688E+03
121	.1906E+03	-.8008E+00	-.8440E+02	/	.2442E+03	.2750E+03
122	.5441E+02	-.1420E+02	-.9940E+02	/	.1335E+03	.1538E+03
123	.2543E+02	-.1664E+03	-.2034E+03	/	.2127E+03	.2288E+03

=============== I M A G E S 3 D ===============

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PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1
EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
124	-.5574E+02	-.1904E+03	-.2898E+03	/	.2035E+03	.2341E+03
125	.3514E+02	-.1350E+03	-.1758E+03	/	.1938E+03	.2110E+03
126	-.3315E+01	-.3326E+02	-.1157E+03	/	.1008E+03	.1124E+03
127	.6820E+01	-.2725E+02	-.1218E+03	/	.1154E+03	.1286E+03
128	-.2369E+01	-.2100E+02	-.1217E+03	/	.1112E+03	.1194E+03
129	.2205E+03	-.3365E+01	-.3349E+03	/	.4840E+03	.5554E+03
130	.4837E+03	-.3438E+02	-.2390E+03	/	.6452E+03	.7227E+03
131	.6580E+03	-.4433E+02	-.1638E+03	/	.7691E+03	.8218E+03
132	.7433E+03	-.5296E+02	-.1014E+03	/	.8215E+03	.8447E+03 FLG
133	.7528E+03	-.5578E+02	-.5689E+02	/	.8091E+03	.8097E+03
134	.6865E+03	-.3220E+02	-.5233E+02	/	.7290E+03	.7388E+03
135	.5600E+03	-.2117E+02	-.5068E+02	/	.5964E+03	.6106E+03
136	.3532E+03	-.2746E+02	-.4786E+02	/	.3912E+03	.4010E+03
137	.1273E+03	-.3977E+02	-.5587E+02	/	.1757E+03	.1832E+03
138	.5443E+02	-.1812E+03	-.2579E+03	/	.2819E+03	.3123E+03
139	-.8984E+02	-.1732E+03	-.4768E+03	/	.3528E+03	.3870E+03
140	.3989E+02	-.1639E+03	-.2071E+03	/	.2285E+03	.2470E+03
141	-.9943E+01	-.5570E+02	-.9210E+02	/	.7131E+02	.8216E+02
142	.3270E+01	-.5398E+02	-.9963E+02	/	.8930E+02	.1029E+03
143	.1223E-01	-.3584E+02	-.1005E+03	/	.8826E+02	.1005E+03
144	.2473E+03	-.3747E+03	-.1243E+04	/	.1297E+04	.1491E+04
145	.7869E+02	-.2415E+03	-.5007E+03	/	.5027E+03	.5794E+03
146	-.9718E+02	-.1105E+03	-.1431E+03	/	.4088E+02	.4587E+02
147	.2036E+02	-.1340E+03	-.1482E+03	/	.1619E+03	.1686E+03
148	.9496E+01	-.1130E+03	-.1326E+03	/	.1334E+03	.1421E+03
149	.7745E+01	-.1860E+02	-.9045E+02	/	.8803E+02	.9820E+02
150	.1008E+03	-.3517E+03	-.9981E+03	/	.9566E+03	.1099E+04
151	-.7953E+02	-.3281E+03	-.6444E+03	/	.4904E+03	.5649E+03
152	-.1481E+03	-.1942E+03	-.4017E+03	/	.2340E+03	.2537E+03
153	-.1091E+03	-.1549E+03	-.1764E+03	/	.5955E+02	.6731E+02
154	.3845E+02	-.1120E+03	-.1562E+03	/	.1767E+03	.1946E+03
155	-.5960E+01	-.7648E+02	-.8945E+02	/	.7782E+02	.8349E+02
156	-.1238E+02	-.4456E+02	-.7236E+02	/	.5200E+02	.5999E+02
157	.6232E+01	-.3110E+02	-.6462E+02	/	.6139E+02	.7085E+02
158	-.8155E+02	-.1584E+03	-.6484E+03	/	.5326E+03	.5669E+03
159	-.5169E+02	-.2032E+03	-.6492E+03	/	.5380E+03	.5975E+03
160	-.5613E+02	-.2613E+03	-.5377E+03	/	.4186E+03	.4816E+03
161	-.1086E+03	-.1328E+03	-.2217E+03	/	.1032E+03	.1132E+03
162	.9440E+02	-.6873E+02	-.1406E+03	/	.2085E+03	.2350E+03
163	-.5522E+01	-.1170E+02	-.2726E+02	/	.1941E+02	.2174E+02
164	-.6583E+01	-.2592E+02	-.3915E+02	/	.2837E+02	.3257E+02

PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1
EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
165	-.7621E+00	-.2257E+02	-.3088E+02	/	.2694E+02	.3012E+02
166	.6191E+02	-.3575E+03	-.1631E+04	/	.1527E+04	.1692E+04
167	-.1055E+03	-.3145E+03	-.1062E+04	/	.8705E+03	.9560E+03
168	-.7570E+02	-.7859E+02	-.5120E+03	/	.4349E+03	.4363E+03
169	.2707E+03	.9519E+02	-.1183E+03	/	.3374E+03	.3890E+03
170	.1258E+03	.5515E+02	-.4000E+02	/	.1441E+03	.1658E+03
171	.4731E+02	.1491E+02	-.1374E+02	/	.5290E+02	.6105E+02
172	.5709E+01	.5592E+01	-.1801E+02	/	.2366E+02	.2372E+02
173	.2141E+00	-.5848E+00	-.1438E+02	/	.1422E+02	.1460E+02
174	.3003E+03	-.4434E+03	-.2247E+04	/	.2269E+04	.2547E+04
175	.2942E+03	-.4084E+03	-.1402E+04	/	.1476E+04	.1696E+04
176	.7898E+03	-.3423E+02	-.5104E+03	/	.1139E+04	.1300E+04
177	.1119E+04	.4465E+02	-.1204E+03	/	.1166E+04	.1240E+04
178	.2905E+03	.1008E+03	-.7716E+02	/	.3185E+03	.3677E+03
179	.6027E+02	.1924E+02	-.1271E+01	/	.5427E+02	.6154E+02
180	.4076E+02	.2240E+02	-.3049E+02	/	.6408E+02	.7125E+02
181	.1852E+02	-.8129E+01	-.9133E+01	/	.2717E+02	.2766E+02
182	.1059E+03	-.3535E+03	-.1729E+04	/	.1653E+04	.1834E+04
183	.8469E+02	-.4402E+03	-.1199E+04	/	.1117E+04	.1283E+04
184	.2722E+02	-.5560E+03	-.7140E+03	/	.6762E+03	.7412E+03
185	-.1619E+01	-.4039E+03	-.7747E+03	/	.6697E+03	.7731E+03
186	.2750E+01	-.2253E+03	-.1125E+04	/	.1032E+04	.1127E+04
187	-.7565E+01	-.1134E+03	-.1494E+04	/	.1436E+04	.1486E+04
188	-.1661E+02	-.5391E+02	-.1790E+04	/	.1755E+04	.1774E+04
189	-.8245E+01	-.3542E+02	-.2008E+04	/	.1986E+04	.2000E+04
190	.9806E+01	-.3486E+02	-.2133E+04	/	.2121E+04	.2143E+04
191	.3248E+02	-.3640E+02	-.2161E+04	/	.2160E+04	.2193E+04
192	.6056E+02	-.3949E+02	-.2084E+04	/	.2096E+04	.2144E+04
193	.8439E+02	-.3854E+02	-.1899E+04	/	.1925E+04	.1983E+04
194	.9539E+02	-.4370E+02	-.1594E+04	/	.1625E+04	.1690E+04
195	.6304E+02	-.3624E+02	-.1193E+04	/	.1209E+04	.1256E+04
196	.6394E+02	-.1572E+03	-.6546E+03	/	.6374E+03	.7185E+03
197	.1297E+03	-.2299E+03	-.4257E+03	/	.4879E+03	.5554E+03
198	-.3723E+02	-.2864E+03	-.9235E+03	/	.7917E+03	.8863E+03
199	.1419E+02	-.4299E+03	-.7357E+03	/	.6531E+03	.7499E+03
200	-.5503E+01	-.5262E+03	-.5457E+03	/	.5307E+03	.5401E+03
201	-.3983E+01	-.4247E+03	-.7752E+03	/	.6688E+03	.7712E+03
202	.7978E+01	-.3268E+03	-.1128E+04	/	.1011E+04	.1136E+04
203	.6729E+01	-.2774E+03	-.1500E+04	/	.1386E+04	.1506E+04
204	.1310E+01	-.2491E+03	-.1796E+04	/	.1687E+04	.1798E+04
205	.2303E+01	-.2375E+03	-.2015E+04	/	.1908E+04	.2017E+04

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=============== I M A G E S 3 D ===============

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PRINT NODAL STRESS Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

L O A D C A S E 1
EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
206	.2106E+01	-.2288E+03	-.2140E+04	/	.2036E+04	.2142E+04
207	.3509E+01	-.2203E+03	-.2168E+04	/	.2069E+04	.2172E+04
208	.2872E+01	-.2082E+03	-.2091E+04	/	.1997E+04	.2094E+04
209	.5866E+01	-.1992E+03	-.1909E+04	/	.1821E+04	.1915E+04
210	-.2549E+01	-.1889E+03	-.1603E+04	/	.1516E+04	.1601E+04
211	.1852E+02	-.2192E+03	-.1207E+04	/	.1126E+04	.1225E+04
212	.7101E+01	-.2676E+03	-.6606E+03	/	.5813E+03	.6677E+03
213	.1517E+03	-.2372E+03	-.5505E+03	/	.6093E+03	.7022E+03
214	.2685E+03	.1068E+03	-.1474E+03	/	.3631E+03	.4159E+03
215	.6640E+02	-.1544E+03	-.2729E+03	/	.2983E+03	.3393E+03
216	-.7262E+01	-.2718E+03	-.4596E+03	/	.3936E+03	.4523E+03
217	-.7480E+01	-.4576E+03	-.7891E+03	/	.6795E+03	.7816E+03
218	-.2360E+01	-.4724E+03	-.1171E+04	/	.1018E+04	.1168E+04
219	.2047E+01	-.5145E+03	-.1570E+04	/	.1388E+04	.1573E+04
220	-.4343E+01	-.5297E+03	-.1877E+04	/	.1673E+04	.1872E+04
221	-.2370E+01	-.5419E+03	-.2102E+04	/	.1888E+04	.2099E+04
222	-.3416E+01	-.5487E+03	-.2230E+04	/	.2011E+04	.2227E+04
223	-.1748E+01	-.5585E+03	-.2265E+04	/	.2042E+04	.2263E+04
224	-.3227E+01	-.5677E+03	-.2194E+04	/	.1970E+04	.2191E+04
225	.1919E+01	-.5815E+03	-.2020E+04	/	.1803E+04	.2022E+04
226	-.8597E+01	-.5764E+03	-.1715E+04	/	.1505E+04	.1707E+04
227	.1851E+02	-.5859E+03	-.1319E+04	/	.1160E+04	.1338E+04
228	-.3369E+02	-.5051E+03	-.7363E+03	/	.6202E+03	.7027E+03
229	.2106E+03	-.2953E+03	-.7998E+03	/	.8750E+03	.1010E+04
230	.1117E+04	.1739E+03	-.3173E+03	/	.1263E+04	.1435E+04
231	.3491E+03	-.5078E+02	-.2715E+03	/	.5449E+03	.6207E+03
232	.3710E+02	-.1593E+03	-.4431E+03	/	.4182E+03	.4802E+03
233	-.1912E-02	-.4882E+03	-.7926E+03	/	.6925E+03	.7926E+03
234	.9843E+01	-.5811E+03	-.1173E+04	/	.1024E+04	.1183E+04
235	.2801E+02	-.6903E+03	-.1577E+04	/	.1393E+04	.1605E+04
236	.2481E+02	-.7363E+03	-.1882E+04	/	.1663E+04	.1907E+04
237	.3010E+02	-.7661E+03	-.2108E+04	/	.1872E+04	.2138E+04
238	.3027E+02	-.7842E+03	-.2236E+04	/	.1989E+04	.2267E+04
239	.3425E+02	-.8075E+03	-.2272E+04	/	.2021E+04	.2306E+04
240	.3514E+02	-.8326E+03	-.2202E+04	/	.1953E+04	.2237E+04
241	.4332E+02	-.8621E+03	-.2030E+04	/	.1800E+04	.2073E+04
242	.3373E+02	-.8625E+03	-.1725E+04	/	.1523E+04	.1759E+04
243	.5881E+02	-.8516E+03	-.1332E+04	/	.1223E+04	.1391E+04
244	-.8161E+01	-.7070E+03	-.7406E+03	/	.7162E+03	.7325E+03
245	.2581E+03	-.2952E+03	-.9858E+03	/	.1079E+04	.1244E+04

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COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Load Combination Method
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Node	Dx	Dy	Dz	Rx	Ry	Rz
1	-1.829E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	-1.779E-03	4.205E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	-1.735E-03	8.452E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	-1.685E-03	1.280E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	-1.609E-03	1.726E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	-1.484E-03	2.180E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	-1.289E-03	2.630E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
8	-1.013E-03	3.051E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
9	-6.655E-04	3.405E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	-4.702E-04	3.559E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
11	-2.816E-04	3.630E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
12	-1.438E-04	3.589E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
13	-1.200E-04	3.420E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
14	-1.723E-04	3.267E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
15	-2.339E-04	3.252E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
16	-2.949E-04	3.260E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
17	-3.563E-04	3.270E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
18	-1.828E-03	-3.710E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
19	-1.778E-03	3.927E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
20	-1.735E-03	8.176E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
21	-1.685E-03	1.242E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
22	-1.608E-03	1.665E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
23	-1.483E-03	2.082E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
24	-1.288E-03	2.483E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
25	-1.013E-03	2.854E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
26	-6.655E-04	3.173E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
27	-4.703E-04	3.313E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
28	-2.815E-04	3.415E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
29	-1.436E-04	3.481E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
30	-1.186E-04	3.473E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
31	-1.716E-04	3.416E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
32	-2.338E-04	3.405E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
33	-2.946E-04	3.412E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
34	-3.561E-04	3.423E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
35	-1.827E-03	-7.224E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
36	-1.777E-03	3.643E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
37	-1.734E-03	7.902E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
38	-1.684E-03	1.205E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
39	-1.608E-03	1.605E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
40	-1.482E-03	1.984E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
41	-1.288E-03	2.336E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
42	-1.012E-03	2.657E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
43	-6.654E-04	2.941E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
44	-4.705E-04	3.068E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
45	-2.817E-04	3.202E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
46	-1.445E-04	3.370E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
47	-1.177E-04	3.541E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
48	-1.719E-04	3.549E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
49	-2.334E-04	3.557E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
50	-2.944E-04	3.565E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
51	-3.558E-04	3.577E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
52	-1.826E-03	-1.057E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
53	-1.776E-03	3.355E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
54	-1.733E-03	7.629E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
55	-1.683E-03	1.168E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
56	-1.607E-03	1.544E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
57	-1.482E-03	1.886E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
58	-1.287E-03	2.190E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
59	-1.012E-03	2.460E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
60	-6.651E-04	2.709E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
61	-4.709E-04	2.821E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
62	-2.819E-04	2.991E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
63	-1.465E-04	3.251E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
64	-1.172E-04	3.629E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
65	-1.730E-04	3.680E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
66	-2.331E-04	3.705E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
67	-2.943E-04	3.719E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
68	-3.555E-04	3.731E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
69	-1.137E-04	6.756E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
70	-1.279E-04	9.402E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
71	-1.535E-04	1.149E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
72	-1.859E-04	1.277E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
73	-2.213E-04	1.315E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
74	-2.557E-04	1.262E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
75	-2.860E-04	1.125E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
76	-3.088E-04	9.190E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
77	-3.215E-04	6.666E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
78	-3.205E-04	3.966E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
79	-3.048E-04	1.474E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
80	-2.904E-04	1.977E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
81	-2.798E-04	-2.059E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
82	-2.767E-04	-3.317E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
83	-2.746E-04	-4.741E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
84	-1.737E-04	6.743E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
85	-1.770E-04	9.430E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
86	-1.885E-04	1.152E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
87	-2.031E-04	1.280E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
88	-2.196E-04	1.318E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
89	-2.358E-04	1.265E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
90	-2.502E-04	1.128E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
91	-2.611E-04	9.210E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
92	-2.669E-04	6.679E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
93	-2.665E-04	3.969E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
94	-2.578E-04	1.463E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
95	-2.506E-04	1.944E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
96	-2.432E-04	-2.056E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
97	-2.409E-04	-3.314E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
98	-2.391E-04	-4.736E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
99	-2.309E-04	6.747E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
100	-2.261E-04	9.440E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
101	-2.228E-04	1.153E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
102	-2.201E-04	1.282E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
103	-2.178E-04	1.320E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
104	-2.161E-04	1.266E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
105	-2.148E-04	1.129E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
106	-2.139E-04	9.221E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
107	-2.131E-04	6.687E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
108	-2.134E-04	3.975E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
109	-2.117E-04	1.456E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
110	-2.096E-04	1.970E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
111	-2.067E-04	-2.053E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
112	-2.049E-04	-3.310E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
113	-2.036E-04	-4.733E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
114	-2.880E-04	6.753E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
115	-2.751E-04	9.440E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
116	-2.572E-04	1.153E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
117	-2.370E-04	1.281E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
118	-2.161E-04	1.320E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
119	-1.964E-04	1.266E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
120	-1.794E-04	1.129E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
121	-1.667E-04	9.222E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
122	-1.593E-04	6.690E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
123	-1.600E-04	3.987E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
124	-1.661E-04	1.449E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
125	-1.689E-04	2.057E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
126	-1.701E-04	-2.051E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
127	-1.689E-04	-3.308E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
128	-1.681E-04	-4.729E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
129	-3.462E-04	6.757E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
130	-3.246E-04	9.433E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
131	-2.921E-04	1.152E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
132	-2.542E-04	1.280E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
133	-2.145E-04	1.318E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
134	-1.765E-04	1.265E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
135	-1.436E-04	1.127E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
136	-1.189E-04	9.215E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
137	-1.052E-04	6.684E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
138	-1.051E-04	4.008E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
139	-1.211E-04	1.441E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
140	-1.294E-04	2.214E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
141	-1.334E-04	-2.050E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
142	-1.327E-04	-3.305E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
143	-1.328E-04	-4.725E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
144	-1.216E-04	1.229E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
145	-1.217E-04	1.070E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
146	-1.214E-04	9.317E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
147	-1.224E-04	2.065E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
148	-1.293E-04	-1.972E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
149	-1.322E-04	-4.841E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
150	-7.629E-05	1.288E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
151	-7.470E-05	1.183E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
152	-7.461E-05	1.054E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
153	-7.510E-05	9.262E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
154	-7.754E-05	2.193E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
155	-8.320E-05	-1.963E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
156	-8.421E-05	-3.301E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
157	-8.454E-05	-4.837E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
158	-3.298E-05	1.236E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
159	-3.275E-05	1.120E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
160	-3.191E-05	1.010E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
161	-3.132E-05	9.025E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
162	-3.389E-05	2.378E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
163	-3.685E-05	-1.964E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
164	-3.646E-05	-3.300E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
165	-3.686E-05	-4.834E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
166	9.686E-06	1.133E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
167	1.140E-05	1.041E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
168	1.139E-05	9.681E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
169	1.019E-05	8.946E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
170	6.969E-06	2.529E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
171	1.055E-05	-1.972E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
172	1.091E-05	-3.299E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
173	1.088E-05	-4.834E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
174	3.075E-05	8.502E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
175	3.366E-05	8.951E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
176	3.575E-05	9.282E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
177	3.718E-05	9.418E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
178	5.067E-05	2.316E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
179	5.755E-05	-1.969E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
180	5.854E-05	-3.305E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
181	5.866E-05	-4.834E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
182	-6.113E-05	4.423E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
183	-2.669E-04	1.629E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
184	-5.360E-04	3.961E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
185	-8.314E-04	-5.909E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
186	-1.409E-03	-5.283E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
187	-1.923E-03	5.935E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
188	-2.338E-03	2.401E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
189	-2.637E-03	4.661E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
190	-2.811E-03	7.202E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
191	-2.853E-03	9.915E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
192	-2.756E-03	1.271E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
193	-2.511E-03	1.548E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
194	-2.108E-03	1.809E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
195	-1.546E-03	2.025E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
196	-8.314E-04	2.168E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
197	-2.992E-06	2.161E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
198	-5.941E-05	6.969E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
199	-2.655E-04	5.694E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
200	-5.350E-04	4.811E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
201	-8.302E-04	4.340E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
202	-1.408E-03	4.079E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
203	-1.922E-03	4.495E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
204	-2.336E-03	5.390E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
205	-2.635E-03	6.637E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
206	-2.808E-03	8.109E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
207	-2.851E-03	9.698E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
208	-2.754E-03	1.130E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
209	-2.509E-03	1.280E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
210	-2.107E-03	1.407E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
211	-1.544E-03	1.490E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
212	-8.309E-04	1.517E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
213	-2.283E-06	1.450E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
214	-5.941E-05	9.510E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
215	-2.647E-04	9.727E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
216	-5.342E-04	9.557E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
217	-8.291E-04	9.263E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
218	-1.407E-03	8.681E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
219	-1.920E-03	8.392E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
220	-2.334E-03	8.376E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
221	-2.633E-03	8.612E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
222	-2.806E-03	9.015E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
223	-2.848E-03	9.480E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
224	-2.751E-03	9.890E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
225	-2.507E-03	1.011E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
226	-2.105E-03	1.005E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
227	-1.543E-03	9.565E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
228	-8.301E-04	8.677E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
229	-1.286E-06	7.308E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
230	-6.146E-05	1.217E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
231	-2.643E-04	1.375E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
232	-5.339E-04	1.433E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
233	-8.279E-04	1.418E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
234	-1.405E-03	1.328E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
235	-1.918E-03	1.229E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
236	-2.332E-03	1.136E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
237	-2.630E-03	1.059E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
238	-2.803E-03	9.920E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
239	-2.845E-03	9.263E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
240	-2.749E-03	8.480E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
241	-2.504E-03	7.430E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
242	-2.103E-03	6.031E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00

=============== I M A G E S 3 D ===============

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COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
243	-1.541E-03	4.222E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
244	-8.290E-04	2.214E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
245	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

3. JACKING BOLT ASSEMBLY

BELLOWS TO BE EXTENDED 2" TOTAL TO ALLOW INSERTION OF "O" RINGS INTO FLANGE GROOVES

TOTAL EXTENSION LOAD =

$7354\ \#/\text{inch} \times 2\ \text{inches} = 14708\ \#$

LOAD PER ROD (3 RODS)

$24512\ \# / 3 = 4902\ \#$

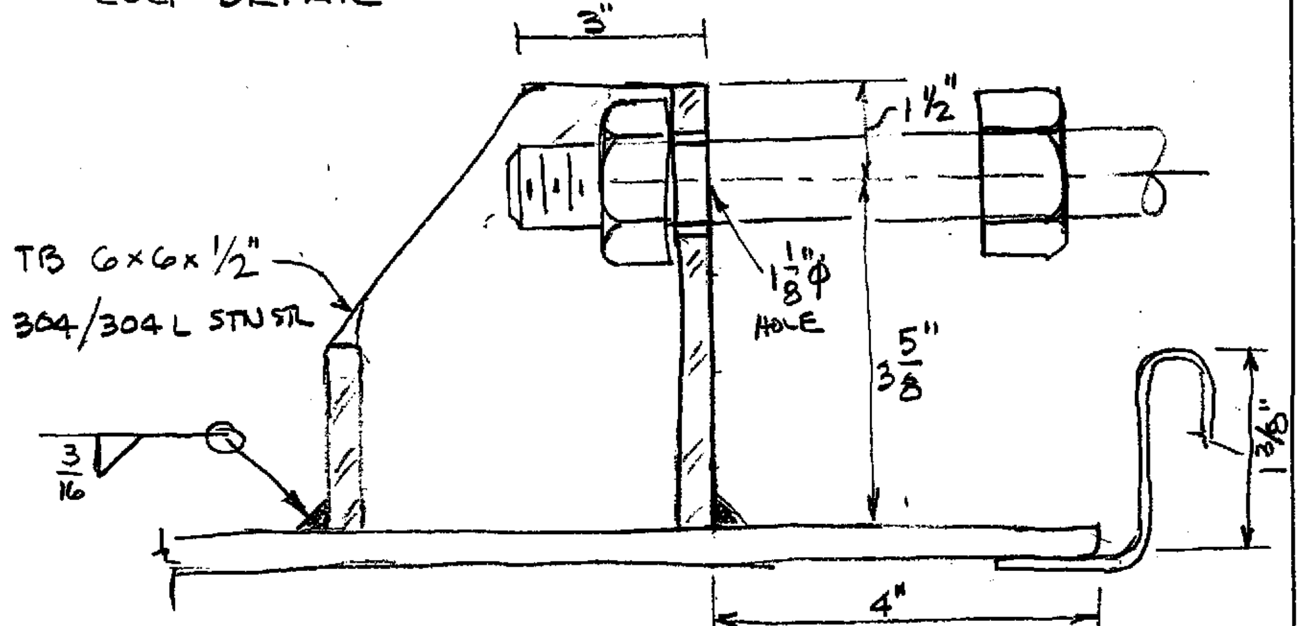
ROD/NUT MATERIAL 304L STN-STL

$S = .6\,F_y = .6\,(25000) = 15000\ \text{PSI}$

REQUIRED TENSILE STRESS AREA $= \dfrac{4902}{15000} = .33\ \text{in}^2$

USE 1"-8 THD'D ROD TSA $= .606\ \text{in}^2 > .33\ \text{in}^2$ REQ'D

LUG DETAIL

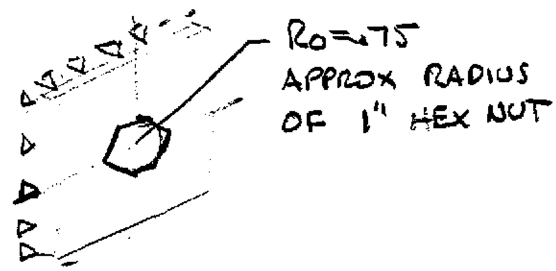


VARIABLE SHEET

St	Input	Name	Output	Unit	Comment
					Table 26 - Roark & Young (6 ed) Formulas for Flat Plates with Straight Boundaries and Constant Thickness Case 1b - Rectangular plate; all edges simply supported. Load on small concentric circle (p.458)
		case	'Case_1b		Reference Number
		caution	'_		Caution Message
	2.83E7	E		psi	Young's Modulus
	.3	nu			Table's Poisson's ratio
	5	a		in	Length
	5	b		in	Width
	.5	t		in	Plate thickness
	.75	r0		in	Radius of loaded central region
	5000	W		lbf	Total Load
		r`0	.75	in	Equivalent radius of contact
		maxsig	22098.967	psi	Maximum bending stress
		maxy	-.004477	in	Maximum deflection

CHECK EFFECTS OF JACKING ON LUG WALL

CONSIDER TUBE STEEL WALL TO BE A RECTANGULAR PLATE SIMPLY SUPPORTED AND LOADED IN CENTER



PER AISC

F_y FOR 304 SS = 30 KSI $F_b = .75 F_y = 22.5$ KSI

$\sigma_{MAX} = 22$ KSI

PLATE ACCEPTABLE

LUG WRC bulletin 107 design

ASME Code Addenda used - A90
Internal design pressure P = 0 psi
Design temperature is = 70 deg F
Corrosion allowance C = 0 in.
Shell inner diameter, new Di = 44.625 in.
Shell thickness, new t = .1875 in.
Mat'l is exempt from impact testing per UHA-51(a)
Allowable tensile stress S = 16300 psi for SA 240 304L LOW A88
Lug length, circ direction a = 6 in.
Lug length, long direction b = 6 in.
Lug interface radius = .25 in.

Applied Loads

Radial load Pr = 0 lbf
Circumferential moment Mc = 0 lb-in
Longitudinal moment ML = 17770 lb-in
Circumferential shear Vc = 0 lbf
Longitudinal shear VL = 4902 lbf

Stresses at the lug interface per WRC bulletin 107

Geometric factor gamma = 119.5
Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

From Fig.	Value read	beta	Circumferential (hoop) stress psi Au	Al	Bu	Bl	Cu	Cl	Du	Dl
pressure stress*			0	0	0	0	0	0	0	0
4C*	15.672	.134	0	0	0	0				
3C*	9.56	.134					0	0	0	0
2C-1	.034	.134	0	0	0	0				
1C	.068	.134					0	0	0	0
3A*	4.65	.134					0	0	0	0
1A	.071	.134					0	0	0	0
3B*	11.288	.134	-15902	-15902	15902	15902				
1B-1	.023	.134	-23232	23232	23232	-23232				
Total hoop stress			-39134	7330	39134	-7330	0	0	0	0
Primary membrane circ. stress*			-15902	-15902	15902	15902	0	0	0	0

Maximum primary membrane circ. stress =-15902 psi
Allowable primary membrane circ. stress = +-1.5*S = +- 24450 psi

The maximum primary membrane circ. stress is within allowable limits

From Fig.	Value read	beta	Longitudinal (axial) stress psi Au	Al	Bu	Bl	Cu	Cl	Du	Dl
pressure stress*			0	0	0	0	0	0	0	0
4C*	15.672	.134					0	0	0	0
3C*	9.56	.134	0	0	0	0				
1C-1	.064	.134	0	0	0	0				
2C	.04	.134					0	0	0	0
4A*	9.538	.134					0	0	0	0
2A	.034	.134					0	0	0	0
4B*	4.506	.134	-6348	-6348	6348	6348				
2B	.029	.134	-29293	29293	29293	-29293				
Total Axial stress			-35641	22945	35641	-22945	0	0	0	0
Primary membrane long. stress*			-6348	-6348	6348	6348	0	0	0	0

Maximum primary membrane long. stress =-6348 psi
Allowable primary membrane long. stress = +-1.5*S = +- 24450 psi

The maximum primary membrane long. stress is within allowable limits

Loading	Shear stress psi Au	Al	Bu	Bl	Cu	Cl	Du	Dl
torsion moment Mt	0	0	0	0	0	0	0	0
Circ. load Vc	0	0	0	0				
Long. load Vc					-2179	-2179	2179	2179
Total Shear stress	0	0	0	0	-2179	-2179	2179	2179

	Combined stress intensity, psi							
At point -->	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Combined stress	-39134	22945	39134	-22945	4358	4358	4358	4358

Maximum combined stress =-39134 psi
Allowable combined stress = +-3*S = +- 48900 psi

The maximum combined stress is within allowable limits.

KOCH PROCESSOR SYSTEMS S/N:801743A 02/14/96
PAGE 1 RUN ID= 13:19:02

=============== I M A G E S - 3 D ==============

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GEOMETRY PLOT Version 2.0

ADAPTER A-1 JACKING LUG DEFLECTIONS

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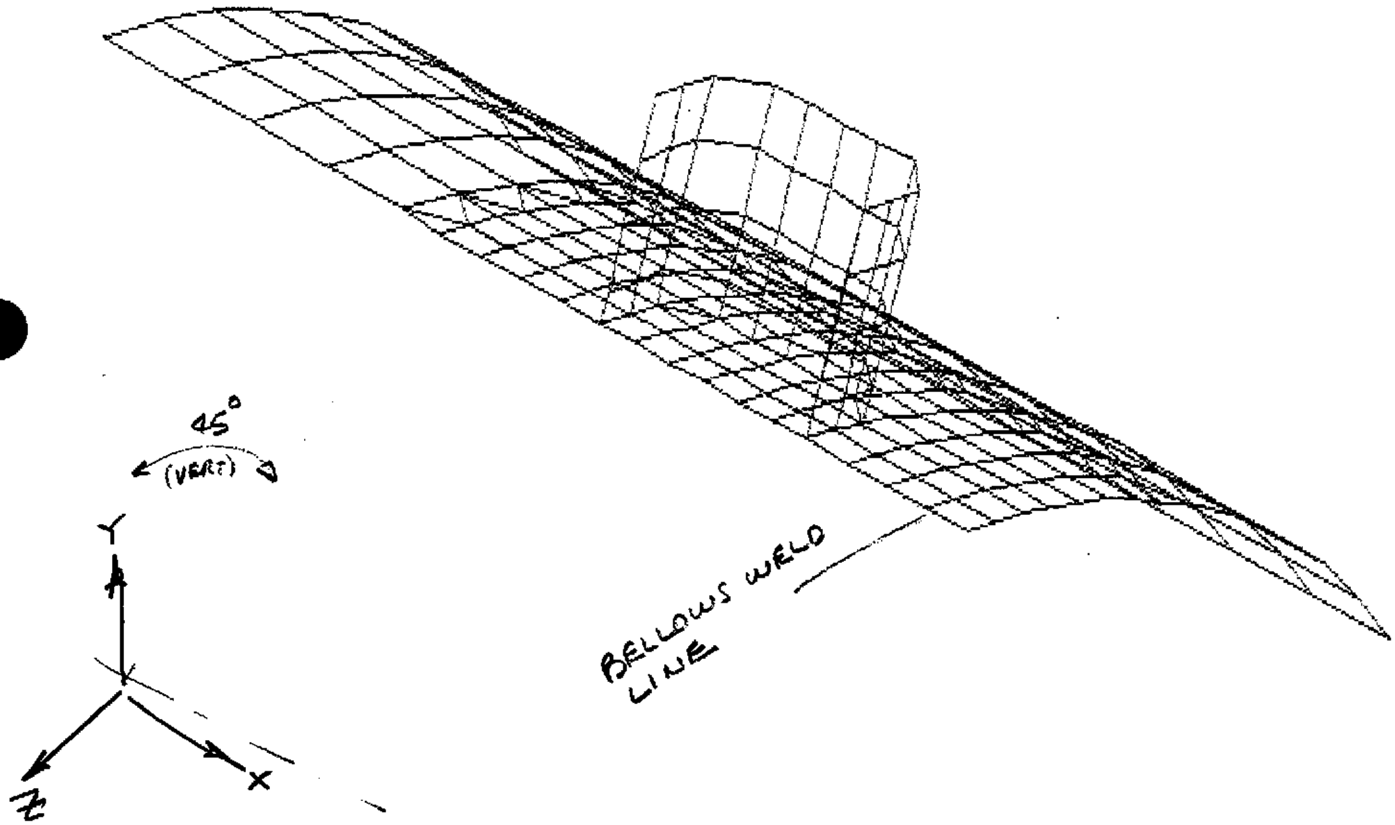
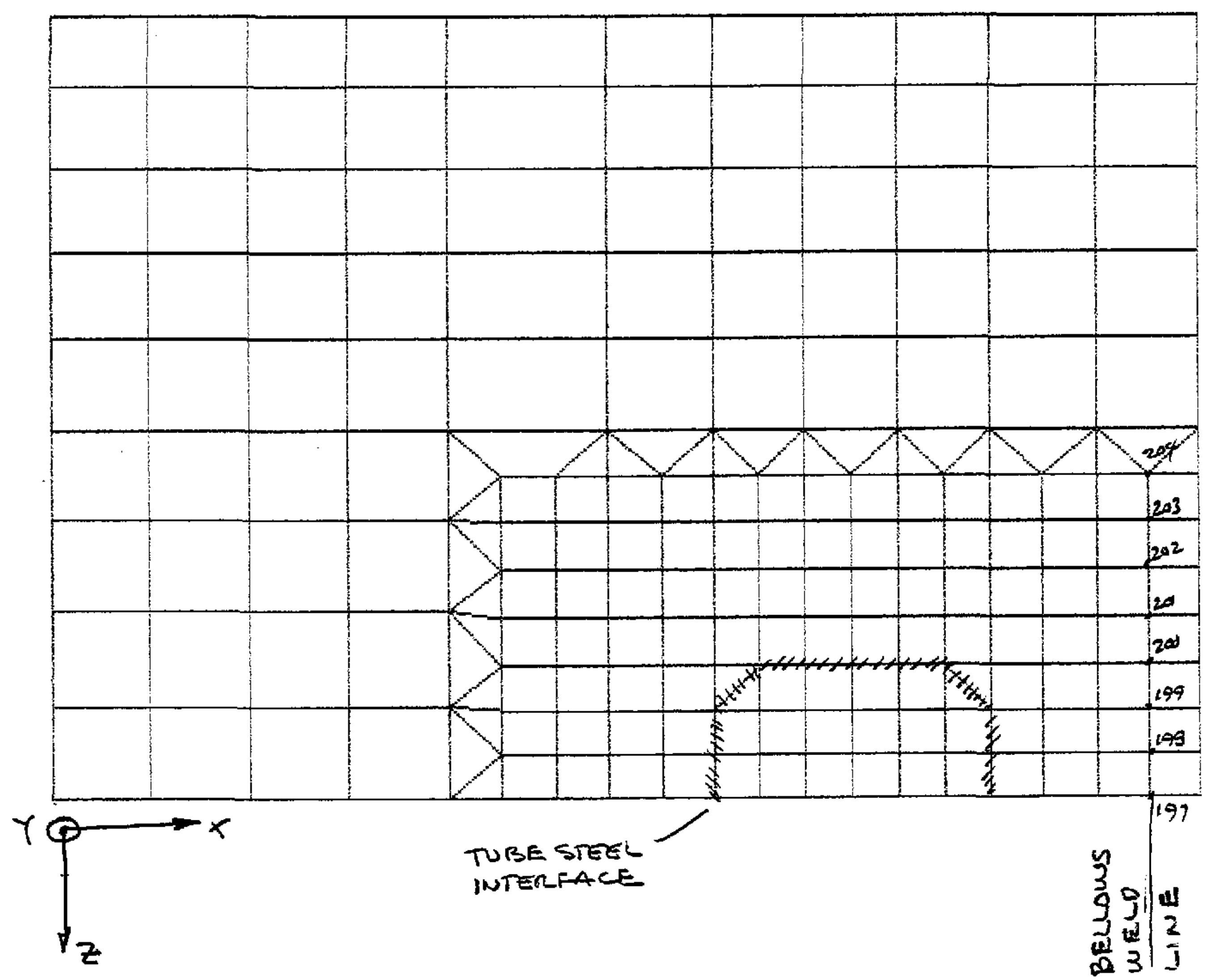


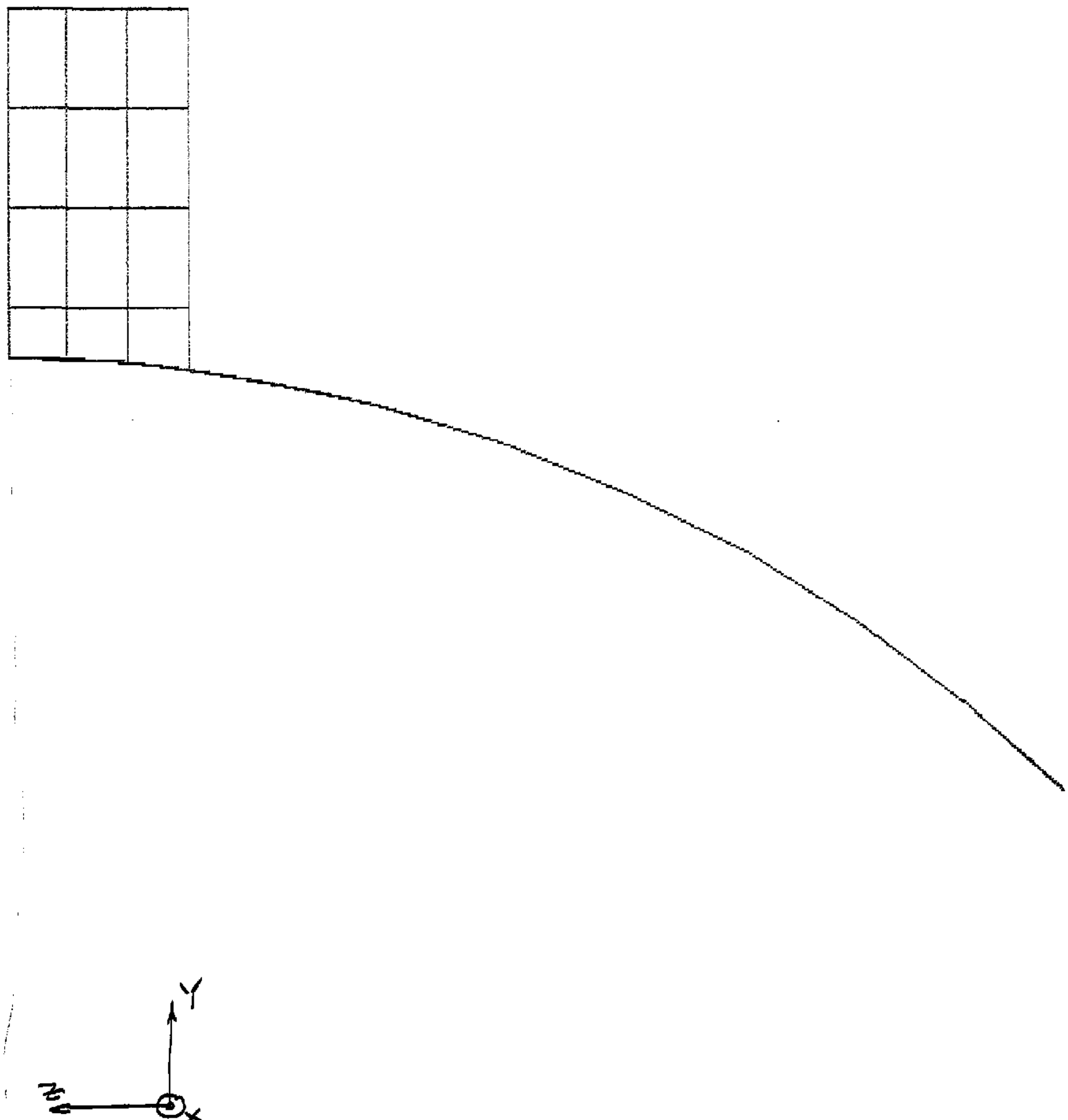
GEOMETRY PLOT Version 2.0

ADAPTER A-1 JACKING LUG DEFLECTIONS



GEOMETRY PLOT Version 2.0

ADAPTER A-1 JACKING LUG DEFLECTIONS



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CHECK GEOMETRY Version 2.0 07/01/90

ADAPTER A-1 JACKING LUG DEFLECTIONS

MATERIAL PROPERTIES

Material No	Modulus of Elasticity	Weight Density	Coeff of Thermal Exp.	Poisson's Ratio	Shear Web Modulus
1	2.66000E+07	2.87000E-01	9.90000E-06	3.00E-01	0.00000E+00
2	2.83000E+07	2.87000E-01	9.90000E-06	3.00E-01	0.00000E+00

NODE COORDINATES

Node	X-Coord.	Y-Coord.	Z-Coord.
1	0.00000E+00	2.24375E+01	0.00000E+00
2	0.00000E+00	2.23563E+01	-1.90679E+00
3	0.00000E+00	2.21134E+01	-3.79978E+00
4	0.00000E+00	2.17105E+01	-5.66528E+00
5	0.00000E+00	2.11505E+01	-7.48979E+00
6	0.00000E+00	2.04010E+01	-9.34030E+00
7	0.00000E+00	1.94899E+01	-1.11168E+01
8	0.00000E+00	1.84245E+01	-1.28054E+01
9	0.00000E+00	1.72133E+01	-1.43925E+01
10	0.00000E+00	1.58657E+01	-1.58657E+01
11	2.00000E+00	2.24375E+01	0.00000E+00
12	2.00000E+00	2.23563E+01	-1.90679E+00
13	2.00000E+00	2.21134E+01	-3.79978E+00
14	2.00000E+00	2.17105E+01	-5.66528E+00
15	2.00000E+00	2.11505E+01	-7.48979E+00
16	2.00000E+00	2.04010E+01	-9.34030E+00
17	2.00000E+00	1.94899E+01	-1.11168E+01
18	2.00000E+00	1.84245E+01	-1.28054E+01
19	2.00000E+00	1.72133E+01	-1.43925E+01
20	2.00000E+00	1.58657E+01	-1.58657E+01
21	4.00000E+00	2.24375E+01	0.00000E+00
22	4.00000E+00	2.23563E+01	-1.90679E+00
23	4.00000E+00	2.21134E+01	-3.79978E+00
24	4.00000E+00	2.17105E+01	-5.66528E+00
25	4.00000E+00	2.11505E+01	-7.48979E+00
26	4.00000E+00	2.04010E+01	-9.34030E+00
27	4.00000E+00	1.94899E+01	-1.11168E+01
28	4.00000E+00	1.84245E+01	-1.28054E+01
29	4.00000E+00	1.72133E+01	-1.43925E+01

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
30	4.00000E+00	1.58657E+01	-1.58657E+01
31	6.00000E+00	2.24375E+01	0.00000E+00
32	6.00000E+00	2.23563E+01	-1.90679E+00
33	6.00000E+00	2.21134E+01	-3.79978E+00
34	6.00000E+00	2.17105E+01	-5.66528E+00
35	6.00000E+00	2.11505E+01	-7.48979E+00
36	6.00000E+00	2.04010E+01	-9.34030E+00
37	6.00000E+00	1.94899E+01	-1.11168E+01
38	6.00000E+00	1.84245E+01	-1.28054E+01
39	6.00000E+00	1.72133E+01	-1.43925E+01
40	6.00000E+00	1.58657E+01	-1.58657E+01
41	8.00000E+00	2.24375E+01	0.00000E+00
42	8.00000E+00	2.23563E+01	-1.90679E+00
43	8.00000E+00	2.21134E+01	-3.79978E+00
44	8.00000E+00	2.17105E+01	-5.66528E+00
45	8.00000E+00	2.11505E+01	-7.48979E+00
46	8.00000E+00	2.04010E+01	-9.34030E+00
47	8.00000E+00	1.94899E+01	-1.11168E+01
48	8.00000E+00	1.84245E+01	-1.28054E+01
49	8.00000E+00	1.72133E+01	-1.43925E+01
50	8.00000E+00	1.58657E+01	-1.58657E+01
51	1.11875E+01	2.11505E+01	-7.48979E+00
52	1.11875E+01	2.04010E+01	-9.34030E+00
53	1.11875E+01	1.94899E+01	-1.11168E+01
54	1.11875E+01	1.84245E+01	-1.28054E+01
55	1.11875E+01	1.72133E+01	-1.43925E+01
56	1.11875E+01	1.58657E+01	-1.58657E+01
57	1.33125E+01	2.11505E+01	-7.48979E+00
58	1.33125E+01	2.04010E+01	-9.34030E+00
59	1.33125E+01	1.94899E+01	-1.11168E+01
60	1.33125E+01	1.84245E+01	-1.28054E+01
61	1.33125E+01	1.72133E+01	-1.43925E+01
62	1.33125E+01	1.58657E+01	-1.58657E+01
63	1.51458E+01	2.11505E+01	-7.48979E+00
64	1.51458E+01	2.04010E+01	-9.34030E+00
65	1.51458E+01	1.94899E+01	-1.11168E+01
66	1.51458E+01	1.84245E+01	-1.28054E+01
67	1.51458E+01	1.72133E+01	-1.43925E+01
68	1.51458E+01	1.58657E+01	-1.58657E+01
69	1.69792E+01	2.11505E+01	-7.48979E+00
70	1.69792E+01	2.04010E+01	-9.34030E+00
71	1.69792E+01	1.94899E+01	-1.11168E+01

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
72	1.69792E+01	1.84245E+01	-1.28054E+01
73	1.69792E+01	1.72133E+01	-1.43925E+01
74	1.69792E+01	1.58657E+01	-1.58657E+01
75	1.88125E+01	2.11505E+01	-7.48979E+00
76	1.88125E+01	2.04010E+01	-9.34030E+00
77	1.88125E+01	1.94899E+01	-1.11168E+01
78	1.88125E+01	1.84245E+01	-1.28054E+01
79	1.88125E+01	1.72133E+01	-1.43925E+01
80	1.88125E+01	1.58657E+01	-1.58657E+01
81	2.09375E+01	2.11505E+01	-7.48979E+00
82	2.09375E+01	2.04010E+01	-9.34030E+00
83	2.09375E+01	1.94899E+01	-1.11168E+01
84	2.09375E+01	1.84245E+01	-1.28054E+01
85	2.09375E+01	1.72133E+01	-1.43925E+01
86	2.09375E+01	1.58657E+01	-1.58657E+01
87	2.30625E+01	2.11505E+01	-7.48979E+00
88	2.30625E+01	2.04010E+01	-9.34030E+00
89	2.30625E+01	1.94899E+01	-1.11168E+01
90	2.30625E+01	1.84245E+01	-1.28054E+01
91	2.30625E+01	1.72133E+01	-1.43925E+01
92	2.30625E+01	1.58657E+01	-1.58657E+01
93	9.06250E+00	2.24375E+01	0.00000E+00
94	9.06250E+00	2.24189E+01	-9.13500E-01
95	9.06250E+00	2.23631E+01	-1.82548E+00
96	9.06250E+00	2.22703E+01	-2.73444E+00
97	9.06250E+00	2.21298E+01	-3.70326E+00
98	9.06250E+00	2.19472E+01	-4.66502E+00
99	9.06250E+00	2.17228E+01	-5.61790E+00
100	9.06250E+00	2.14571E+01	-6.56009E+00
101	1.01250E+01	2.24375E+01	0.00000E+00
102	1.01250E+01	2.24189E+01	-9.13500E-01
103	1.01250E+01	2.23631E+01	-1.82548E+00
104	1.01250E+01	2.22703E+01	-2.73444E+00
105	1.01250E+01	2.21298E+01	-3.70326E+00
106	1.01250E+01	2.19472E+01	-4.66502E+00
107	1.01250E+01	2.17228E+01	-5.61790E+00
108	1.01250E+01	2.14571E+01	-6.56009E+00
109	1.11875E+01	2.24375E+01	0.00000E+00
110	1.11875E+01	2.24189E+01	-9.13500E-01
111	1.11875E+01	2.23631E+01	-1.82548E+00
112	1.11875E+01	2.22703E+01	-2.73444E+00
113	1.11875E+01	2.21298E+01	-3.70326E+00

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
114	1.11875E+01	2.19472E+01	-4.66502E+00
115	1.11875E+01	2.17228E+01	-5.61790E+00
116	1.11875E+01	2.14571E+01	-6.56009E+00
117	1.22500E+01	2.24375E+01	0.00000E+00
118	1.22500E+01	2.24189E+01	-9.13500E-01
119	1.22500E+01	2.23631E+01	-1.82548E+00
120	1.22500E+01	2.22703E+01	-2.73444E+00
121	1.22500E+01	2.21298E+01	-3.70326E+00
122	1.22500E+01	2.19472E+01	-4.66502E+00
123	1.22500E+01	2.17228E+01	-5.61790E+00
124	1.22500E+01	2.14571E+01	-6.56009E+00
125	1.33125E+01	2.24375E+01	0.00000E+00
126	1.33125E+01	2.24189E+01	-9.13500E-01
127	1.33125E+01	2.23631E+01	-1.82548E+00
128	1.33125E+01	2.22703E+01	-2.73444E+00
129	1.33125E+01	2.21298E+01	-3.70326E+00
130	1.33125E+01	2.19472E+01	-4.66502E+00
131	1.33125E+01	2.17228E+01	-5.61790E+00
132	1.33125E+01	2.14571E+01	-6.56009E+00
133	1.42292E+01	2.24375E+01	0.00000E+00
134	1.42292E+01	2.24189E+01	-9.13500E-01
135	1.42292E+01	2.23631E+01	-1.82548E+00
136	1.42292E+01	2.22703E+01	-2.73444E+00
137	1.42292E+01	2.21298E+01	-3.70326E+00
138	1.42292E+01	2.19472E+01	-4.66502E+00
139	1.42292E+01	2.17228E+01	-5.61790E+00
140	1.42292E+01	2.14571E+01	-6.56009E+00
141	1.51458E+01	2.24375E+01	0.00000E+00
142	1.51458E+01	2.24189E+01	-9.13500E-01
143	1.51458E+01	2.23631E+01	-1.82548E+00
144	1.51458E+01	2.22703E+01	-2.73444E+00
145	1.51458E+01	2.21298E+01	-3.70326E+00
146	1.51458E+01	2.19472E+01	-4.66502E+00
147	1.51458E+01	2.17228E+01	-5.61790E+00
148	1.51458E+01	2.14571E+01	-6.56009E+00
149	1.60625E+01	2.24375E+01	0.00000E+00
150	1.60625E+01	2.24189E+01	-9.13500E-01
151	1.60625E+01	2.23631E+01	-1.82548E+00
152	1.60625E+01	2.22703E+01	-2.73444E+00
153	1.60625E+01	2.21298E+01	-3.70326E+00
154	1.60625E+01	2.19472E+01	-4.66502E+00
155	1.60625E+01	2.17228E+01	-5.61790E+00

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
156	1.60625E+01	2.14571E+01	-6.56009E+00
157	1.69792E+01	2.24375E+01	0.00000E+00
158	1.69792E+01	2.24189E+01	-9.13500E-01
159	1.69792E+01	2.23631E+01	-1.82548E+00
160	1.69792E+01	2.22703E+01	-2.73444E+00
161	1.69792E+01	2.21298E+01	-3.70326E+00
162	1.69792E+01	2.19472E+01	-4.66502E+00
163	1.69792E+01	2.17228E+01	-5.61790E+00
164	1.69792E+01	2.14571E+01	-6.56009E+00
165	1.78958E+01	2.24375E+01	0.00000E+00
166	1.78958E+01	2.24189E+01	-9.13500E-01
167	1.78958E+01	2.23631E+01	-1.82548E+00
168	1.78958E+01	2.22703E+01	-2.73444E+00
169	1.78958E+01	2.21298E+01	-3.70326E+00
170	1.78958E+01	2.19472E+01	-4.66502E+00
171	1.78958E+01	2.17228E+01	-5.61790E+00
172	1.78958E+01	2.14571E+01	-6.56009E+00
173	1.88125E+01	2.24375E+01	0.00000E+00
174	1.88125E+01	2.24189E+01	-9.13500E-01
175	1.88125E+01	2.23631E+01	-1.82548E+00
176	1.88125E+01	2.22703E+01	-2.73444E+00
177	1.88125E+01	2.21298E+01	-3.70326E+00
178	1.88125E+01	2.19472E+01	-4.66502E+00
179	1.88125E+01	2.17228E+01	-5.61790E+00
180	1.88125E+01	2.14571E+01	-6.56009E+00
181	1.98750E+01	2.24375E+01	0.00000E+00
182	1.98750E+01	2.24189E+01	-9.13500E-01
183	1.98750E+01	2.23631E+01	-1.82548E+00
184	1.98750E+01	2.22703E+01	-2.73444E+00
185	1.98750E+01	2.21298E+01	-3.70326E+00
186	1.98750E+01	2.19472E+01	-4.66502E+00
187	1.98750E+01	2.17228E+01	-5.61790E+00
188	1.98750E+01	2.14571E+01	-6.56009E+00
189	2.09375E+01	2.24375E+01	0.00000E+00
190	2.09375E+01	2.24189E+01	-9.13500E-01
191	2.09375E+01	2.23631E+01	-1.82548E+00
192	2.09375E+01	2.22703E+01	-2.73444E+00
193	2.09375E+01	2.21298E+01	-3.70326E+00
194	2.09375E+01	2.19472E+01	-4.66502E+00
195	2.09375E+01	2.17228E+01	-5.61790E+00
196	2.09375E+01	2.14571E+01	-6.56009E+00
197	2.20000E+01	2.24375E+01	0.00000E+00

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
198	2.20000E+01	2.24189E+01	-9.13500E-01
199	2.20000E+01	2.23631E+01	-1.82548E+00
200	2.20000E+01	2.22703E+01	-2.73444E+00
201	2.20000E+01	2.21298E+01	-3.70326E+00
202	2.20000E+01	2.19472E+01	-4.66502E+00
203	2.20000E+01	2.17228E+01	-5.61790E+00
204	2.20000E+01	2.14571E+01	-6.56009E+00
205	2.30625E+01	2.24375E+01	0.00000E+00
206	2.30625E+01	2.24189E+01	-9.13500E-01
207	2.30625E+01	2.23631E+01	-1.82548E+00
208	2.30625E+01	2.22703E+01	-2.73444E+00
209	2.30625E+01	2.21298E+01	-3.70326E+00
210	2.30625E+01	2.19472E+01	-4.66502E+00
211	2.30625E+01	2.17228E+01	-5.61790E+00
212	2.30625E+01	2.14571E+01	-6.56009E+00
213	1.33125E+01	2.31875E+01	0.00000E+00
214	1.33125E+01	2.46875E+01	0.00000E+00
215	1.33125E+01	2.61875E+01	0.00000E+00
216	1.33125E+01	2.76875E+01	0.00000E+00
217	1.33125E+01	2.31875E+01	-9.13500E-01
218	1.33125E+01	2.46875E+01	-9.13500E-01
219	1.33125E+01	2.61875E+01	-9.13500E-01
220	1.33125E+01	2.76875E+01	-9.13500E-01
221	1.33125E+01	2.31875E+01	-1.82550E+00
222	1.33125E+01	2.46875E+01	-1.82550E+00
223	1.33125E+01	2.61875E+01	-1.82550E+00
224	1.33125E+01	2.76875E+01	-1.82550E+00
225	1.42292E+01	2.31875E+01	-2.73444E+00
226	1.42292E+01	2.46875E+01	-2.73444E+00
227	1.42292E+01	2.61875E+01	-2.73444E+00
228	1.42292E+01	2.76875E+01	-2.73444E+00
229	1.51459E+01	2.31875E+01	-2.73444E+00
230	1.51459E+01	2.46875E+01	-2.73444E+00
231	1.51459E+01	2.61875E+01	-2.73444E+00
232	1.51459E+01	2.76875E+01	-2.73444E+00
233	1.60626E+01	2.31875E+01	-2.73444E+00
234	1.60626E+01	2.46875E+01	-2.73444E+00
235	1.60626E+01	2.61875E+01	-2.73444E+00
236	1.60626E+01	2.76875E+01	-2.73444E+00
237	1.69793E+01	2.31875E+01	-2.73444E+00
238	1.69793E+01	2.46875E+01	-2.73444E+00
239	1.69793E+01	2.61875E+01	-2.73444E+00

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Node	X-Coord.	Y-Coord.	Z-Coord.
240	1.69793E+01	2.76875E+01	-2.73444E+00
241	1.78960E+01	2.31875E+01	-2.73444E+00
242	1.78960E+01	2.46875E+01	-2.73444E+00
243	1.78960E+01	2.61875E+01	-2.73444E+00
244	1.78960E+01	2.76875E+01	-2.73444E+00
245	1.88127E+01	2.31875E+01	-1.82544E+00
246	1.88127E+01	2.46875E+01	-1.82544E+00
247	1.88127E+01	2.61875E+01	-1.82544E+00
248	1.88127E+01	2.76875E+01	-1.82544E+00
249	1.88127E+01	2.31875E+01	-9.12720E-01
250	1.88127E+01	2.46875E+01	-9.12720E-01
251	1.88127E+01	2.61875E+01	-9.12720E-01
252	1.88127E+01	2.76875E+01	-9.12720E-01
253	1.88127E+01	2.31875E+01	0.00000E+00
254	1.88127E+01	2.46875E+01	0.00000E+00
255	1.88127E+01	2.61875E+01	0.00000E+00
256	1.88127E+01	2.76875E+01	0.00000E+00

PLATE ELEMENT CONNECTIVITY

	Plate No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	1	1	2	12	11	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	2	2	3	13	12	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	3	3	4	14	13	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	4	4	5	15	14	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	5	5	6	16	15	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	6	6	7	17	16	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	7	7	8	18	17	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	8	8	9	19	18	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	9	9	10	20	19	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	10	11	12	22	21	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	11	12	13	23	22	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	12	13	14	24	23	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	13	14	15	25	24	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	14	15	16	26	25	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	15	16	17	27	26	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	16	17	18	28	27	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	17	18	19	29	28	1	1.875E-01	3.993E+00		9.983E-01	M+B

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Plate	No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	18	19	20	30	29	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	19	21	22	32	31	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	20	22	23	33	32	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	21	23	24	34	33	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	22	24	25	35	34	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	23	25	26	36	35	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	24	26	27	37	36	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	25	27	28	38	37	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	26	28	29	39	38	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	27	29	30	40	39	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	28	31	32	42	41	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	29	32	33	43	42	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	30	33	34	44	43	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	31	34	35	45	44	1	1.875E-01	3.817E+00		9.543E-01	M+B
QUAD	32	35	36	46	45	1	1.875E-01	3.993E+00		9.983E-01	M+B
[illegible]D	33	36	37	47	46	1	1.875E-01	3.993E+00		9.983E-01	M+B
[illegible]AD	34	37	38	48	47	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	35	38	39	49	48	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	36	39	40	50	49	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	37	45	46	52	51	1	1.875E-01	6.364E+00		6.264E-01	M+B
QUAD	38	46	47	53	52	1	1.875E-01	6.364E+00		6.264E-01	M+B
QUAD	39	47	48	54	53	1	1.875E-01	6.364E+00		6.264E-01	M+B
QUAD	40	48	49	55	54	1	1.875E-01	6.364E+00		6.264E-01	M+B
QUAD	41	49	50	56	55	1	1.875E-01	6.364E+00		6.264E-01	M+B
QUAD	42	51	52	58	57	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	43	52	53	59	58	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	44	53	54	60	59	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	45	54	55	61	60	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	46	55	56	62	61	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	47	57	58	64	63	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	48	58	59	65	64	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	49	59	60	66	65	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	50	60	61	67	66	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	51	61	62	68	67	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	52	63	64	70	69	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	53	64	65	71	70	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	54	65	66	72	71	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	55	66	67	73	72	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	56	67	68	74	73	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	57	69	70	76	75	1	1.875E-01	3.660E+00		1.089E+00	M+B
[illegible]D	58	70	71	77	76	1	1.875E-01	3.660E+00		1.089E+00	M+B

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Plate	No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	59	71	72	78	77	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	60	72	73	79	78	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	61	73	74	80	79	1	1.875E-01	3.660E+00		1.089E+00	M+B
QUAD	62	75	76	82	81	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	63	76	77	83	82	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	64	77	78	84	83	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	65	78	79	85	84	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	66	79	80	86	85	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	67	81	82	88	87	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	68	82	83	89	88	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	69	83	84	90	89	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	70	84	85	91	90	1	1.875E-01	4.243E+00		9.395E-01	M+B
QUAD	71	85	86	92	91	1	1.875E-01	4.243E+00		9.396E-01	M+B
QUAD	72	93	94	102	101	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	73	94	95	103	102	1	1.875E-01	9.708E-01		8.599E-01	M+B
[illegible]D	74	95	96	104	103	1	1.875E-01	9.708E-01		8.599E-01	M+B
[illegible]D	75	96	97	105	104	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	76	97	98	106	105	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	77	98	99	107	106	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	78	99	100	108	107	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	79	101	102	110	109	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	80	102	103	111	110	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	81	103	104	112	111	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	82	104	105	113	112	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	83	105	106	114	113	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	84	106	107	115	114	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	85	107	108	116	115	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	86	109	110	118	117	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	87	110	111	119	118	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	88	111	112	120	119	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	89	112	113	121	120	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	90	113	114	122	121	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	91	114	115	123	122	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	92	115	116	124	123	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	93	117	118	126	125	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	94	118	119	127	126	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	95	119	120	128	127	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	96	120	121	129	128	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	97	121	122	130	129	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	98	122	123	131	130	1	1.875E-01	1.040E+00		9.214E-01	M+B
[illegible]AD	99	123	124	132	131	1	1.875E-01	1.040E+00		9.214E-01	M+B

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ADAPTER A-1 JACKING LUG DEFLECTIONS

	Plate No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	100	125	126	134	133	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	101	126	127	135	134	1	1.875E-01	8.376E-01		9.967E-01	M+B
TRI	102	127	136	135		1	1.875E-01	4.188E-01		2.000E+00	M+B
QUAD	103	128	129	137	136	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	104	129	130	138	137	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	105	130	131	139	138	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	106	131	132	140	139	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	107	133	134	142	141	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	108	134	135	143	142	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	109	135	136	144	143	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	110	136	137	145	144	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	111	137	138	146	145	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	112	138	139	147	146	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	113	139	140	148	147	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	114	141	142	150	149	1	1.875E-01	8.376E-01		9.967E-01	M+B
[illegible]	115	142	143	151	150	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	116	143	144	152	151	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	117	144	145	153	152	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	118	145	146	154	153	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	119	146	147	155	154	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	120	147	148	156	155	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	121	149	150	158	157	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	122	150	151	159	158	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	123	151	152	160	159	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	124	152	153	161	160	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	125	153	154	162	161	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	126	154	155	163	162	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	127	155	156	164	163	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	128	157	158	166	165	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	129	158	159	167	166	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	130	159	160	168	167	1	1.875E-01	8.375E-01		9.968E-01	M+B
QUAD	131	160	161	169	168	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	132	161	162	170	169	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	133	162	163	171	170	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	134	163	164	172	171	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	135	165	166	174	173	1	1.875E-01	8.376E-01		9.967E-01	M+B
QUAD	136	166	167	175	174	1	1.875E-01	8.376E-01		9.967E-01	M+B
TRI	137	167	168	175		1	1.875E-01	4.188E-01		8.921E-01	M+B
QUAD	138	168	169	177	176	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	139	169	170	178	177	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	140	170	171	179	178	1	1.875E-01	8.974E-01		1.068E+00	M+B

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ADAPTER A-1 JACKING LUG DEFLECTIONS

Plate	No.	I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	141	171	172	180	179	1	1.875E-01	8.974E-01		1.068E+00	M+B
QUAD	142	173	174	182	181	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	143	174	175	183	182	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	144	175	176	184	183	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	145	176	177	185	184	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	146	177	178	186	185	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	147	178	179	187	186	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	148	179	180	188	187	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	149	181	182	190	189	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	150	182	183	191	190	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	151	183	184	192	191	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	152	184	185	193	192	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	153	185	186	194	193	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	154	186	187	195	194	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	155	187	188	196	195	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	156	189	190	198	197	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	157	190	191	199	198	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	158	191	192	200	199	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	159	192	193	201	200	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	160	193	194	202	201	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	161	194	195	203	202	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	162	195	196	204	203	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	163	197	198	206	205	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	164	198	199	207	206	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	165	199	200	208	207	1	1.875E-01	9.708E-01		8.599E-01	M+B
QUAD	166	200	201	209	208	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	167	201	202	210	209	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	168	202	203	211	210	1	1.875E-01	1.040E+00		9.214E-01	M+B
QUAD	169	203	204	212	211	1	1.875E-01	1.040E+00		9.214E-01	M+B
TRI	170	41	94	93		1	1.875E-01	4.854E-01		2.000E+00	M+B
TRI	171	41	42	94		1	1.875E-01	1.014E+00		1.795E+00	M+B
TRI	172	42	95	94		1	1.875E-01	4.854E-01		9.755E-01	M+B
TRI	173	42	96	95		1	1.875E-01	4.854E-01		1.854E+00	M+B
TRI	174	42	43	96		1	1.875E-01	1.014E+00		1.784E+00	M+B
TRI	175	43	97	96		1	1.875E-01	5.201E-01		9.222E-01	M+B
TRI	176	43	98	97		1	1.875E-01	5.201E-01		1.825E+00	M+B
TRI	177	43	44	98		1	1.875E-01	1.014E+00		1.792E+00	M+B
TRI	178	44	99	98		1	1.875E-01	5.201E-01		9.368E-01	M+B
TRI	179	44	100	99		1	1.875E-01	5.201E-01		1.910E+00	M+B
TRI	180	44	45	100		1	1.875E-01	1.014E+00		1.795E+00	M+B
QUAD	181	100	45	51	108	1	1.875E-01	2.080E+00		4.607E-01	M+B

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ADAPTER A-1 JACKING LUG DEFLECTIONS

	Plate No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
TRI	182	108	51	116		1	1.875E-01	5.201E-01		2.000E+00	M+B
TRI	183	116	51	124		1	1.875E-01	5.201E-01		8.368E-01	M+B
TRI	184	51	57	124		1	1.875E-01	1.040E+00		2.171E+00	M+B
TRI	185	124	57	132		1	1.875E-01	5.201E-01		2.000E+00	M+B
TRI	186	132	57	140		1	1.875E-01	4.487E-01		9.420E-01	M+B
TRI	187	57	63	140		1	1.875E-01	8.974E-01		1.873E+00	M+B
TRI	188	140	63	148		1	1.875E-01	4.487E-01		2.000E+00	M+B
TRI	189	148	63	156		1	1.875E-01	4.487E-01		9.420E-01	M+B
TRI	190	63	69	156		1	1.875E-01	8.974E-01		1.873E+00	M+B
TRI	191	156	69	164		1	1.875E-01	4.487E-01		2.000E+00	M+B
TRI	192	164	69	172		1	1.875E-01	4.487E-01		9.421E-01	M+B
TRI	193	69	75	172		1	1.875E-01	8.974E-01		1.873E+00	M+B
TRI	194	172	75	180		1	1.875E-01	4.487E-01		2.000E+00	M+B
TRI	195	180	75	188		1	1.875E-01	5.201E-01		8.368E-01	M+B
TRI	196	75	81	188		1	1.875E-01	1.040E+00		2.171E+00	M+B
TRI	197	188	81	196		1	1.875E-01	5.201E-01		2.000E+00	M+B
TRI	198	196	81	204		1	1.875E-01	5.201E-01		8.368E-01	M+B
TRI	199	204	81	87		1	1.875E-01	1.040E+00		8.665E-01	M+B
TRI	200	204	87	212		1	1.875E-01	5.201E-01		2.000E+00	M+B
TRI	201	127	128	136		1	1.875E-01	4.188E-01		8.921E-01	M+B
TRI	202	168	176	175		1	1.875E-01	4.188E-01		8.968E-01	M+B
QUAD	203	125	126	217	213	2	5.000E-01	6.936E-01		1.203E+00	M+B
QUAD	204	213	217	218	214	2	5.000E-01	1.370E+00		6.090E-01	M+B
QUAD	205	214	218	219	215	2	5.000E-01	1.370E+00		6.090E-01	M+B
QUAD	206	215	219	220	216	2	5.000E-01	1.370E+00		6.090E-01	M+B
QUAD	207	126	127	221	217	2	5.000E-01	7.264E-01		1.146E+00	M+B
QUAD	208	217	221	222	218	2	5.000E-01	1.368E+00		6.080E-01	M+B
QUAD	209	218	222	223	219	2	5.000E-01	1.368E+00		6.080E-01	M+B
QUAD	210	219	223	224	220	2	5.000E-01	1.368E+00		6.080E-01	M+B
QUAD	211	127	136	225	221	2	5.000E-01	1.124E+00		1.483E+00	M+B
QUAD	212	221	225	226	222	2	5.000E-01	1.936E+00		8.606E-01	M+B
QUAD	213	222	226	227	223	2	5.000E-01	1.936E+00		8.606E-01	M+B
QUAD	214	223	227	228	224	2	5.000E-01	1.936E+00		8.606E-01	M+B
QUAD	215	136	144	229	225	2	5.000E-01	8.408E-01		9.994E-01	M+B
QUAD	216	225	229	230	226	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	217	226	230	231	227	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	218	227	231	232	228	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	219	144	152	233	229	2	5.000E-01	8.408E-01		9.994E-01	M+B
QUAD	220	229	233	234	230	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	221	230	234	235	231	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	222	231	235	236	232	2	5.000E-01	1.375E+00		6.111E-01	M+B

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CHECK GEOMETRY Version 2.0 07/01/90

ADAPTER A-1 JACKING LUG DEFLECTIONS

	Plate No.	Nodes I	J	K	L	Mat No.	Thickness	Area	Shear Web Thickness	Aspect Ratio	Plate Type
QUAD	223	152	160	237	233	2	5.000E-01	8.408E-01		9.994E-01	M+B
QUAD	224	233	237	238	234	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	225	234	238	239	235	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	226	235	239	240	236	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	227	160	168	241	237	2	5.000E-01	8.408E-01		9.994E-01	M+B
QUAD	228	237	241	242	238	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	229	238	242	243	239	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	230	239	243	244	240	2	5.000E-01	1.375E+00		6.111E-01	M+B
QUAD	231	168	175	245	241	2	5.000E-01	1.124E+00		1.483E+00	M+B
QUAD	232	241	245	246	242	2	5.000E-01	1.936E+00		8.607E-01	M+B
QUAD	233	242	246	247	243	2	5.000E-01	1.936E+00		8.607E-01	M+B
QUAD	234	243	247	248	244	2	5.000E-01	1.936E+00		8.607E-01	M+B
QUAD	235	175	174	249	245	2	5.000E-01	7.267E-01		1.146E+00	M+B
QUAD	236	245	249	250	246	2	5.000E-01	1.369E+00		6.085E-01	M+B
QUAD	237	246	250	251	247	2	5.000E-01	1.369E+00		6.085E-01	M+B
QUAD	238	247	251	252	248	2	5.000E-01	1.369E+00		6.085E-01	M+B
QUAD	239	174	173	253	249	2	5.000E-01	6.933E-01		1.203E+00	M+B
QUAD	240	249	253	254	250	2	5.000E-01	1.369E+00		6.085E-01	M+B
QUAD	241	250	254	255	251	2	5.000E-01	1.369E+00		6.085E-01	M+B
QUAD	242	251	255	256	252	2	5.000E-01	1.369E+00		6.085E-01	M+B

RESTRAINTS

Node No	Global/Local	Restraint Directions
1	GLOBAL	X Y Z RX RY RZ
2	GLOBAL	X Y Z RX RY RZ
3	GLOBAL	X Y Z RX RY RZ
4	GLOBAL	X Y Z RX RY RZ
5	GLOBAL	X Y Z RX RY RZ
6	GLOBAL	X Y Z RX RY RZ
7	GLOBAL	X Y Z RX RY RZ
8	GLOBAL	X Y Z RX RY RZ
9	GLOBAL	X Y Z RX RY RZ
10	GLOBAL	X Y Z RX RY RZ
11	LOCAL	- - - RX - RZ
20	GLOBAL	X Y Z RX RY RZ
21	GLOBAL	- - - RX - RZ
30	LOCAL	X Y Z RX RY RZ

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CHECK GEOMETRY Version 2.0 07/01/90

ADAPTER A-1 JACKING LUG DEFLECTIONS

Node No	Global/Local	Restraint Directions
31	LOCAL	- - - RX - RZ
40	LOCAL	X Y Z RX RY RZ
41	LOCAL	- - - RX - RZ
50	GLOBAL	X Y Z RX RY RZ
56	GLOBAL	X Y Z RX RY RZ
62	GLOBAL	X Y Z RX RY RZ
68	GLOBAL	X Y Z RX RY RZ
74	GLOBAL	X Y Z RX RY RZ
80	GLOBAL	X Y Z RX RY RZ
86	GLOBAL	X Y Z RX RY RZ
92	GLOBAL	X Y Z RX RY RZ
93	GLOBAL	- - - RX - RZ
101	GLOBAL	- - - RX - RZ
109	GLOBAL	- - - RX - RZ
117	GLOBAL	- - - RX - RZ
125	GLOBAL	- - - RX - RZ
133	GLOBAL	- - - RX - RZ
141	GLOBAL	- - - RX - RZ
149	GLOBAL	- - - RX - RZ
157	GLOBAL	- - - RX - RZ
165	GLOBAL	- - - RX - RZ
173	GLOBAL	- - - RX - RZ
181	GLOBAL	- - - RX - RZ
189	GLOBAL	- - - RX - RZ
197	GLOBAL	- - - RX - RZ
205	GLOBAL	- - - RX - RZ
213	GLOBAL	- - Z - RY RZ
214	GLOBAL	- - Z - RY RZ
215	GLOBAL	- - Z - RY RZ
216	GLOBAL	- - Z - RY RZ
253	GLOBAL	- - Z - RY RZ
254	GLOBAL	- - Z - RY RZ
255	GLOBAL	- - Z - RY RZ
256	GLOBAL	- - Z - RY RZ

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RENUMBER NODES Version 2.0 07/01/90

ADAPTER A-1 JACKING LUG DEFLECTIONS

Node Renumbering Cross Reference List

Was	Is	Was	Is	Was	Is	Was	Is	Was	Is
1	1	2	2	3	3	4	4	5	5
6	6	7	7	8	8	9	9	10	10
11	11	12	12	13	13	14	14	15	15
16	16	17	17	18	18	19	19	20	20
21	21	22	22	23	23	24	24	25	25
26	26	27	27	28	28	29	29	30	30
31	31	32	32	33	33	34	34	35	35
36	36	37	37	38	38	39	39	40	40
41	41	42	42	43	43	44	44	45	45
46	46	47	47	48	48	49	49	50	50
51	51	52	52	53	53	54	54	55	55
56	56	57	57	58	58	59	59	60	60
61	61	62	62	63	63	64	64	65	65
66	66	67	67	68	68	69	69	70	70
71	71	72	72	73	73	74	74	75	75
76	76	77	77	78	78	79	79	80	80
81	81	82	82	83	83	84	84	85	85
86	86	87	87	88	88	89	89	90	90
91	91	92	92	93	93	94	94	95	95
96	96	97	97	98	98	99	99	100	100
101	101	102	102	103	103	104	104	105	105
106	106	107	107	108	108	109	109	110	110
111	111	112	112	113	113	114	114	115	115
116	116	117	117	118	118	119	119	120	120
121	121	122	122	123	123	124	124	125	125
126	126	127	127	128	128	129	129	130	130
131	131	132	132	133	133	134	134	135	135
136	136	137	137	138	138	139	139	140	140
141	141	142	142	143	143	144	144	145	145
146	146	147	147	148	148	149	149	150	150
151	151	152	152	153	153	154	154	155	155
156	156	157	157	158	158	159	159	160	160
161	161	162	162	163	163	164	164	165	165
166	166	167	167	168	168	169	169	170	170
171	171	172	172	173	173	174	174	175	175
176	176	177	177	178	178	179	179	180	180
181	181	182	182	183	183	184	184	185	185
186	186	187	187	188	188	189	189	190	190
191	191	192	192	193	193	194	194	195	195
196	196	197	197	198	198	199	199	200	200

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RENUMBER NODES Version 2.0 07/01/90

ADAPTER A-1 JACKING LUG DEFLECTIONS

Node Renumbering Cross Reference List

Was	Is	Was	Is	Was	Is	Was	Is	Was	Is
201	201	202	202	203	203	204	204	205	205
206	206	207	207	208	208	209	209	210	210
211	211	212	212	213	213	214	214	215	215
216	216	217	217	218	218	219	219	220	220
221	221	222	222	223	223	224	224	225	225
226	226	227	227	228	228	229	229	230	230
231	231	232	232	233	233	234	234	235	235
236	236	237	237	238	238	239	239	240	240
241	241	242	242	243	243	244	244	245	245
246	246	247	247	248	248	249	249	250	250
251	251	252	252	253	253	254	254	255	255
256	256								

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COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Load Combination Method
f[1,1]

Node	Dx	Dy	Dz	Rx	Ry	Rz
1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
8	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
9	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
11	1.716E-04	5.344E-05	-3.736E-05	0.000E+00	-6.515E-05	0.000E+00
12	1.553E-04	-5.979E-05	2.133E-05	4.429E-05	-5.593E-05	0.000E+00
13	1.348E-04	-1.501E-04	6.894E-05	1.594E-04	-4.468E-05	0.000E+00
14	1.090E-04	-2.149E-04	1.072E-04	2.295E-04	-3.046E-05	0.000E+00
15	7.816E-05	-2.301E-04	1.261E-04	2.552E-04	9.415E-06	0.000E+00
16	4.241E-05	-1.698E-04	1.063E-04	1.952E-04	5.410E-05	0.000E+00
17	1.156E-05	-6.694E-05	4.982E-05	8.132E-05	6.364E-05	0.000E+00
18	-5.628E-06	6.465E-06	-3.673E-06	-7.688E-06	2.711E-05	0.000E+00
19	-7.501E-06	1.183E-05	-1.282E-05	-1.722E-05	-1.716E-05	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
21	3.630E-04	1.075E-04	-3.345E-05	0.000E+00	-8.543E-05	0.000E+00
22	3.327E-04	-7.440E-05	3.023E-05	-4.238E-05	-1.073E-04	0.000E+00
23	2.816E-04	-3.026E-04	1.119E-04	2.584E-06	-1.404E-04	0.000E+00
24	2.233E-04	-5.237E-04	2.016E-04	9.255E-05	-1.047E-04	0.000E+00
25	1.541E-04	-5.890E-04	2.512E-04	1.251E-04	2.434E-05	0.000E+00
26	7.773E-05	-4.132E-04	1.960E-04	6.351E-05	1.594E-04	0.000E+00
27	1.610E-05	-1.133E-04	4.664E-05	-4.270E-05	1.752E-04	0.000E+00
28	-1.506E-05	7.907E-05	-7.569E-05	-9.270E-05	5.244E-05	0.000E+00
29	-1.546E-05	5.722E-05	-5.858E-05	-4.733E-05	-8.026E-05	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
31	5.843E-04	1.611E-04	-6.426E-05	0.000E+00	-1.174E-05	0.000E+00
32	5.176E-04	4.778E-05	2.118E-06	-9.599E-05	-1.118E-04	0.000E+00
33	4.361E-04	-2.945E-04	9.733E-05	-8.013E-06	-2.566E-04	0.000E+00
34	3.385E-04	-6.998E-04	2.258E-04	8.334E-05	-1.871E-04	0.000E+00
35	2.235E-04	-8.072E-04	2.828E-04	9.182E-05	6.288E-05	0.000E+00
36	1.034E-04	-4.731E-04	1.582E-04	-2.473E-05	2.937E-04	0.000E+00
37	1.374E-05	3.433E-05	-1.003E-04	-1.577E-04	2.757E-04	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
38	-2.623E-05	2.889E-04	-2.600E-04	-1.843E-04	2.436E-05	0.000E+00
39	-2.264E-05	1.475E-04	-1.465E-04	-7.872E-05	-2.050E-04	0.000E+00
40	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
41	8.259E-04	2.143E-04	-1.438E-04	0.000E+00	1.759E-04	0.000E+00
42	7.156E-04	2.230E-04	-7.652E-05	-9.467E-05	-1.701E-04	0.000E+00
43	5.996E-04	-3.665E-04	6.083E-05	7.827E-05	-4.571E-04	0.000E+00
44	4.520E-04	-1.037E-03	2.497E-04	2.502E-04	-2.622E-04	0.000E+00
45	2.801E-04	-1.078E-03	2.862E-04	1.343E-04	2.328E-04	0.000E+00
46	1.147E-04	-4.189E-04	2.214E-05	-8.103E-05	4.979E-04	0.000E+00
47	2.791E-06	3.579E-04	-3.779E-04	-2.609E-04	3.747E-04	0.000E+00
48	-3.849E-05	6.225E-04	-5.419E-04	-2.498E-04	-6.379E-05	0.000E+00
49	-2.857E-05	2.749E-04	-2.670E-04	-9.721E-05	-3.785E-04	0.000E+00
50	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
51	3.302E-04	-1.258E-03	5.792E-05	-2.339E-04	6.188E-04	0.000E+00
52	9.724E-05	1.639E-04	-5.264E-04	-3.950E-04	8.825E-04	0.000E+00
53	-2.514E-05	1.285E-03	-1.102E-03	-4.693E-04	3.767E-04	0.000E+00
54	-5.574E-05	1.317E-03	-1.114E-03	-3.131E-04	-3.430E-04	0.000E+00
55	-3.445E-05	5.032E-04	-4.783E-04	-9.874E-05	-6.884E-04	0.000E+00
56	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
57	3.198E-04	-6.743E-04	-4.897E-04	-4.301E-04	1.121E-03	0.000E+00
58	7.082E-05	1.198E-03	-1.263E-03	-7.768E-04	9.738E-04	0.000E+00
59	-4.453E-05	2.221E-03	-1.784E-03	-6.153E-04	1.743E-04	0.000E+00
60	-6.359E-05	1.843E-03	-1.535E-03	-3.196E-04	-6.272E-04	0.000E+00
61	-3.606E-05	6.483E-04	-6.089E-04	-8.630E-05	-8.831E-04	0.000E+00
62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
63	3.043E-04	5.233E-04	-1.325E-03	-7.472E-04	1.557E-03	0.000E+00
64	5.114E-05	2.614E-03	-2.175E-03	-1.039E-03	8.183E-04	0.000E+00
65	-5.651E-05	3.207E-03	-2.474E-03	-6.923E-04	-1.540E-04	0.000E+00
66	-6.801E-05	2.302E-03	-1.895E-03	-3.173E-04	-9.198E-04	0.000E+00
67	-3.666E-05	7.570E-04	-7.047E-04	-7.279E-05	-1.029E-03	0.000E+00
68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
69	3.102E-04	2.102E-03	-2.355E-03	-7.864E-04	1.934E-03	0.000E+00
70	4.619E-05	4.280E-03	-3.217E-03	-1.082E-03	5.417E-04	0.000E+00
71	-6.326E-05	4.264E-03	-3.202E-03	-7.064E-04	-5.617E-04	0.000E+00
72	-7.116E-05	2.750E-03	-2.242E-03	-3.014E-04	-1.230E-03	0.000E+00
73	-3.688E-05	8.547E-04	-7.895E-04	-6.994E-05	-1.158E-03	0.000E+00
74	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
75	3.393E-04	3.580E-03	-3.322E-03	-5.382E-04	2.194E-03	0.000E+00
76	5.535E-05	5.839E-03	-4.203E-03	-9.095E-04	3.310E-04	0.000E+00
77	-6.524E-05	5.301E-03	-3.917E-03	-6.637E-04	-9.381E-04	0.000E+00
78	-7.303E-05	3.187E-03	-2.581E-03	-3.025E-04	-1.562E-03	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
79	-3.624E-05	9.366E-04	-8.593E-04	-4.824E-05	-1.270E-03	0.000E+00
80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
81	3.729E-04	4.875E-03	-4.217E-03	-5.205E-04	2.388E-03	0.000E+00
82	7.072E-05	7.335E-03	-5.180E-03	-7.533E-04	2.804E-04	0.000E+00
83	-6.349E-05	6.424E-03	-4.693E-03	-6.187E-04	-1.312E-03	0.000E+00
84	-7.440E-05	3.719E-03	-2.982E-03	-3.251E-04	-1.891E-03	0.000E+00
85	-3.460E-05	1.070E-03	-9.682E-04	-1.164E-04	-1.439E-03	0.000E+00
86	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
87	3.835E-04	6.319E-03	-5.134E-03	-1.072E-03	2.635E-03	0.000E+00
88	8.012E-05	9.022E-03	-6.220E-03	-1.100E-03	2.424E-04	0.000E+00
89	-6.150E-05	7.724E-03	-5.545E-03	-8.438E-04	-1.701E-03	0.000E+00
90	-7.572E-05	4.271E-03	-3.369E-03	-3.110E-04	-2.376E-03	0.000E+00
91	-3.956E-05	1.151E-03	-1.006E-03	3.693E-05	-1.533E-03	0.000E+00
92	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
93	9.547E-04	2.793E-04	-2.123E-04	0.000E+00	2.413E-04	0.000E+00
94	8.912E-04	4.101E-04	-1.799E-04	-1.579E-04	4.804E-05	0.000E+00
95	8.332E-04	3.594E-04	-1.441E-04	-1.468E-04	-1.844E-04	0.000E+00
96	7.685E-04	9.481E-05	-8.154E-05	-1.006E-04	-4.055E-04	0.000E+00
97	6.993E-04	-3.800E-04	1.924E-05	5.849E-05	-5.813E-04	0.000E+00
98	6.125E-04	-8.949E-04	1.464E-04	8.191E-05	-5.052E-04	0.000E+00
99	5.155E-04	-1.273E-03	2.511E-04	2.279E-04	-2.933E-04	0.000E+00
100	4.119E-04	-1.406E-03	3.017E-04	2.128E-04	5.674E-05	0.000E+00
101	1.086E-03	3.625E-04	-2.978E-04	0.000E+00	3.783E-04	0.000E+00
102	1.015E-03	6.397E-04	-2.703E-04	-3.045E-04	2.249E-04	0.000E+00
103	9.534E-04	6.606E-04	-2.342E-04	-4.132E-04	-1.868E-04	0.000E+00
104	8.858E-04	3.164E-04	-1.616E-04	-3.220E-04	-5.745E-04	0.000E+00
105	7.977E-04	-3.336E-04	-3.314E-05	-1.293E-04	-7.762E-04	0.000E+00
106	6.910E-04	-1.030E-03	1.208E-04	8.246E-05	-6.756E-04	0.000E+00
107	5.696E-04	-1.497E-03	2.432E-04	1.867E-04	-3.086E-04	0.000E+00
108	4.433E-04	-1.590E-03	2.692E-04	7.321E-05	1.295E-04	0.000E+00
109	1.199E-03	3.987E-04	-3.909E-04	0.000E+00	8.392E-04	0.000E+00
110	1.143E-03	1.041E-03	-3.706E-04	-4.717E-04	5.466E-04	0.000E+00
111	1.088E-03	1.218E-03	-3.459E-04	-6.367E-04	-1.501E-04	0.000E+00
112	1.011E-03	7.640E-04	-2.707E-04	-5.397E-04	-8.652E-04	0.000E+00
113	9.006E-04	-2.015E-04	-1.119E-04	-1.339E-04	-1.117E-03	0.000E+00
114	7.650E-04	-1.134E-03	7.159E-05	8.536E-05	-8.160E-04	0.000E+00
115	6.166E-04	-1.670E-03	1.955E-04	1.042E-04	-3.032E-04	0.000E+00
116	4.661E-04	-1.690E-03	1.982E-04	7.747E-05	2.556E-04	0.000E+00
117	1.283E-03	4.046E-04	-4.261E-04	0.000E+00	1.724E-03	0.000E+00
118	1.278E-03	1.624E-03	-4.425E-04	-6.163E-04	9.493E-04	0.000E+00
119	1.232E-03	1.877E-03	-4.487E-04	-5.981E-04	-4.764E-04	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
120	1.142E-03	1.059E-03	-3.635E-04	-3.744E-06	-1.275E-03	0.000E+00
121	9.986E-04	-2.079E-04	-1.908E-04	1.181E-04	-1.315E-03	0.000E+00
122	8.290E-04	-1.276E-03	-6.465E-06	1.458E-04	-8.900E-04	0.000E+00
123	6.512E-04	-1.803E-03	9.628E-05	9.243E-05	-1.964E-04	0.000E+00
124	4.801E-04	-1.686E-03	4.223E-05	6.669E-05	4.705E-04	0.000E+00
125	1.417E-03	2.629E-04	-3.885E-04	0.000E+00	-5.513E-04	0.000E+00
126	1.394E-03	6.689E-04	-3.493E-04	5.580E-04	-2.108E-05	-2.580E-03
127	1.386E-03	8.669E-04	-3.811E-04	1.420E-04	-3.064E-04	-2.576E-03
128	1.270E-03	4.424E-04	-3.667E-04	1.153E-03	-1.026E-03	0.000E+00
129	1.084E-03	-6.601E-04	-2.430E-04	7.185E-04	-1.221E-03	0.000E+00
130	8.769E-04	-1.623E-03	-1.021E-04	4.582E-04	-7.304E-04	0.000E+00
131	6.732E-04	-1.921E-03	-6.573E-05	4.183E-05	1.178E-04	0.000E+00
132	4.833E-04	-1.519E-03	-2.022E-04	-1.762E-04	7.850E-04	0.000E+00
133	1.423E-03	-2.064E-03	-2.565E-04	0.000E+00	7.283E-04	0.000E+00
134	1.492E-03	-1.706E-03	-2.542E-04	3.801E-03	9.692E-05	0.000E+00
135	1.463E-03	-1.617E-03	-2.288E-04	2.560E-03	-1.818E-04	0.000E+00
136	1.386E-03	-1.404E-03	-2.429E-04	4.291E-04	-2.115E-04	-2.899E-03
137	1.138E-03	-1.712E-03	-2.398E-04	1.572E-03	-9.371E-04	0.000E+00
138	9.081E-04	-2.217E-03	-1.836E-04	7.561E-04	-9.822E-05	0.000E+00
139	6.845E-04	-2.012E-03	-2.634E-04	5.817E-05	5.543E-04	0.000E+00
140	4.824E-04	-1.239E-03	-5.059E-04	-5.221E-06	1.207E-03	0.000E+00
141	1.479E-03	-4.462E-03	-1.026E-04	0.000E+00	3.051E-05	0.000E+00
142	1.567E-03	-4.376E-03	-7.831E-05	3.398E-03	1.531E-04	0.000E+00
143	1.539E-03	-4.257E-03	-6.505E-05	2.825E-03	9.531E-05	0.000E+00
144	1.445E-03	-3.972E-03	-8.081E-05	5.516E-04	-1.895E-04	-2.775E-03
145	1.188E-03	-3.517E-03	-1.603E-04	2.269E-03	3.698E-04	0.000E+00
146	9.318E-04	-3.040E-03	-2.686E-04	9.918E-04	6.540E-04	0.000E+00
147	6.930E-04	-2.133E-03	-4.995E-04	6.499E-05	1.254E-03	0.000E+00
148	4.831E-04	-8.426E-04	-8.734E-04	-3.658E-04	1.543E-03	0.000E+00
149	1.571E-03	-6.845E-03	5.200E-05	0.000E+00	-4.360E-05	0.000E+00
150	1.643E-03	-6.886E-03	8.146E-05	3.413E-03	-4.642E-05	0.000E+00
151	1.598E-03	-6.853E-03	1.016E-04	2.518E-03	1.289E-04	0.000E+00
152	1.479E-03	-6.514E-03	8.030E-05	6.138E-04	-1.653E-04	-2.852E-03
153	1.218E-03	-5.590E-03	-5.950E-05	2.196E-03	1.292E-03	0.000E+00
154	9.511E-04	-4.081E-03	-3.447E-04	1.192E-03	1.846E-03	0.000E+00
155	7.041E-04	-2.227E-03	-7.742E-04	-4.864E-06	2.031E-03	0.000E+00
156	4.865E-04	-3.597E-04	-1.293E-03	1.390E-04	2.059E-03	0.000E+00
157	1.688E-03	-9.228E-03	1.783E-04	0.000E+00	-1.193E-04	0.000E+00
158	1.725E-03	-9.342E-03	2.091E-04	3.286E-03	-1.154E-04	0.000E+00
159	1.645E-03	-9.336E-03	2.307E-04	2.574E-03	1.237E-04	0.000E+00
160	1.486E-03	-9.051E-03	2.120E-04	5.185E-04	-7.755E-05	-2.748E-03

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
161	1.228E-03	-7.691E-03	2.006E-05	2.322E-03	2.322E-03	0.000E+00
162	9.686E-04	-5.058E-03	-4.476E-04	8.377E-04	3.087E-03	0.000E+00
163	7.189E-04	-2.255E-03	-1.075E-03	-8.257E-05	2.780E-03	0.000E+00
164	4.986E-04	1.720E-04	-1.735E-03	-3.835E-04	2.406E-03	0.000E+00
165	1.834E-03	-1.161E-02	2.550E-04	0.000E+00	-3.866E-04	0.000E+00
166	1.809E-03	-1.180E-02	3.015E-04	3.417E-03	-8.342E-05	0.000E+00
167	1.673E-03	-1.183E-02	2.953E-04	2.515E-03	4.607E-05	0.000E+00
168	1.470E-03	-1.161E-02	2.727E-04	3.747E-04	2.950E-05	-2.938E-03
169	1.241E-03	-9.409E-03	3.006E-05	1.278E-03	3.961E-03	0.000E+00
170	9.857E-04	-5.672E-03	-6.172E-04	4.406E-04	3.788E-03	0.000E+00
171	7.392E-04	-2.195E-03	-1.385E-03	-2.256E-04	3.455E-03	0.000E+00
172	5.146E-04	7.148E-04	-2.165E-03	4.710E-04	2.759E-03	0.000E+00
173	2.044E-03	-1.398E-02	3.102E-04	0.000E+00	-5.594E-04	0.000E+00
174	1.858E-03	-1.434E-02	2.900E-04	-5.177E-04	1.990E-04	-3.455E-03
175	1.676E-03	-1.448E-02	3.123E-04	1.478E-05	-2.717E-05	-2.961E-03
176	1.488E-03	-1.328E-02	2.716E-04	1.100E-03	2.443E-03	0.000E+00
177	1.251E-03	-1.005E-02	-1.166E-04	1.027E-04	4.051E-03	0.000E+00
178	1.005E-03	-5.927E-03	-8.323E-04	-2.290E-05	4.439E-03	0.000E+00
179	7.603E-04	-1.988E-03	-1.705E-03	-3.608E-04	3.798E-03	0.000E+00
180	5.346E-04	1.219E-03	-2.570E-03	-2.692E-04	3.020E-03	0.000E+00
181	2.046E-03	-1.428E-02	1.442E-04	0.000E+00	-1.952E-03	0.000E+00
182	1.873E-03	-1.560E-02	1.998E-04	-8.293E-04	-9.123E-04	0.000E+00
183	1.686E-03	-1.544E-02	2.325E-04	-1.078E-03	1.347E-03	0.000E+00
184	1.489E-03	-1.339E-02	6.230E-05	-5.647E-04	3.092E-03	0.000E+00
185	1.260E-03	-9.866E-03	-4.018E-04	-5.185E-04	4.138E-03	0.000E+00
186	1.021E-03	-5.727E-03	-1.141E-03	-4.543E-04	4.440E-03	0.000E+00
187	7.817E-04	-1.669E-03	-2.055E-03	-3.942E-04	4.034E-03	0.000E+00
188	5.559E-04	1.748E-03	-2.981E-03	8.914E-04	3.124E-03	0.000E+00
189	2.094E-03	-1.437E-02	-7.618E-05	0.000E+00	-7.247E-04	0.000E+00
190	1.880E-03	-1.479E-02	-6.417E-05	-6.479E-04	-1.734E-04	0.000E+00
191	1.681E-03	-1.433E-02	-9.241E-05	-1.034E-03	1.177E-03	0.000E+00
192	1.480E-03	-1.254E-02	-2.694E-04	-1.059E-03	2.778E-03	0.000E+00
193	1.259E-03	-9.270E-03	-7.319E-04	-6.898E-04	3.952E-03	0.000E+00
194	1.028E-03	-5.287E-03	-1.471E-03	-4.848E-04	4.307E-03	0.000E+00
195	7.956E-04	-1.289E-03	-2.391E-03	-4.548E-04	4.067E-03	0.000E+00
196	5.707E-04	2.213E-03	-3.358E-03	-4.763E-05	3.378E-03	0.000E+00
197	2.115E-03	-1.441E-02	-3.558E-04	0.000E+00	-1.481E-05	0.000E+00
198	1.883E-03	-1.426E-02	-3.604E-04	-3.479E-04	3.590E-04	0.000E+00
199	1.673E-03	-1.348E-02	-4.173E-04	-6.044E-04	1.365E-03	0.000E+00
200	1.471E-03	-1.168E-02	-6.145E-04	-6.187E-04	2.590E-03	0.000E+00
201	1.253E-03	-8.645E-03	-1.067E-03	-5.697E-04	3.683E-03	0.000E+00

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
202	1.029E-03	-4.838E-03	-1.796E-03	-4.728E-04	4.227E-03	0.000E+00
203	8.003E-04	-8.651E-04	-2.731E-03	-4.822E-04	4.101E-03	0.000E+00
204	5.795E-04	2.710E-03	-3.733E-03	-1.242E-03	3.314E-03	0.000E+00
205	2.117E-03	-1.443E-02	-6.318E-04	0.000E+00	2.800E-04	0.000E+00
206	1.885E-03	-1.403E-02	-6.407E-04	-1.097E-04	5.998E-04	0.000E+00
207	1.667E-03	-1.309E-02	-7.047E-04	-1.776E-04	1.455E-03	0.000E+00
208	1.463E-03	-1.126E-02	-9.088E-04	-2.396E-04	2.578E-03	0.000E+00
209	1.246E-03	-8.240E-03	-1.373E-03	-2.790E-04	3.654E-03	0.000E+00
210	1.024E-03	-4.431E-03	-2.122E-03	-4.048E-04	4.262E-03	0.000E+00
211	7.988E-04	-3.663E-04	-3.099E-03	-6.017E-04	4.261E-03	0.000E+00
212	5.800E-04	3.370E-03	-4.163E-03	1.966E-04	3.735E-03	0.000E+00
213	2.759E-03	4.249E-04	0.000E+00	2.611E-03	0.000E+00	0.000E+00
214	6.879E-03	6.379E-04	0.000E+00	2.783E-03	0.000E+00	0.000E+00
215	1.085E-02	7.133E-04	0.000E+00	2.519E-03	0.000E+00	0.000E+00
216	1.448E-02	7.532E-04	0.000E+00	2.313E-03	0.000E+00	0.000E+00
217	3.163E-03	6.524E-04	-1.099E-04	2.420E-03	-4.616E-04	0.000E+00
218	7.081E-03	6.691E-04	3.654E-05	2.762E-03	-4.975E-04	0.000E+00
219	1.105E-02	7.390E-04	3.598E-05	2.548E-03	-4.176E-04	0.000E+00
220	1.470E-02	7.678E-04	5.243E-05	2.341E-03	-5.035E-04	0.000E+00
221	3.648E-03	8.476E-04	-1.783E-04	3.852E-04	-4.728E-04	-2.675E-03
222	7.671E-03	8.087E-04	3.508E-05	6.972E-05	-7.129E-04	-2.665E-03
223	1.162E-02	7.934E-04	6.656E-05	7.216E-05	-8.551E-04	-2.604E-03
224	1.544E-02	7.995E-04	8.761E-05	1.304E-04	-1.096E-03	-2.435E-03
225	4.043E-03	-1.416E-03	1.683E-04	4.491E-04	-3.313E-04	-2.796E-03
226	8.313E-03	-1.455E-03	6.566E-04	2.753E-04	-6.586E-04	-2.722E-03
227	1.250E-02	-1.484E-03	9.734E-04	2.286E-04	-1.048E-03	-2.707E-03
228	1.664E-02	-1.491E-03	1.313E-03	3.121E-04	-1.421E-03	-2.581E-03
229	4.055E-03	-3.982E-03	4.432E-04	5.478E-04	-2.714E-04	0.000E+00
230	8.318E-03	-3.983E-03	1.196E-03	4.258E-04	-4.998E-04	0.000E+00
231	1.252E-02	-3.992E-03	1.819E-03	3.840E-04	-7.832E-04	0.000E+00
232	1.666E-02	-4.007E-03	2.505E-03	5.137E-04	-1.086E-03	0.000E+00
233	4.067E-03	-6.516E-03	6.510E-04	6.098E-04	-1.663E-04	0.000E+00
234	8.324E-03	-6.514E-03	1.532E-03	5.489E-04	-2.111E-04	0.000E+00
235	1.254E-02	-6.518E-03	2.340E-03	5.219E-04	-3.314E-04	0.000E+00
236	1.669E-02	-6.530E-03	3.265E-03	7.203E-04	-4.901E-04	0.000E+00
237	4.074E-03	-9.049E-03	7.055E-04	5.115E-04	5.623E-05	0.000E+00
238	8.337E-03	-9.045E-03	1.531E-03	5.371E-04	2.424E-04	0.000E+00
239	1.256E-02	-9.047E-03	2.353E-03	5.081E-04	3.354E-04	0.000E+00
240	1.672E-02	-9.061E-03	3.320E-03	7.596E-04	4.469E-04	0.000E+00
241	4.073E-03	-1.161E-02	5.129E-04	3.061E-04	3.471E-04	-3.040E-03
242	8.351E-03	-1.158E-02	1.030E-03	4.521E-04	8.710E-04	-3.060E-03

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

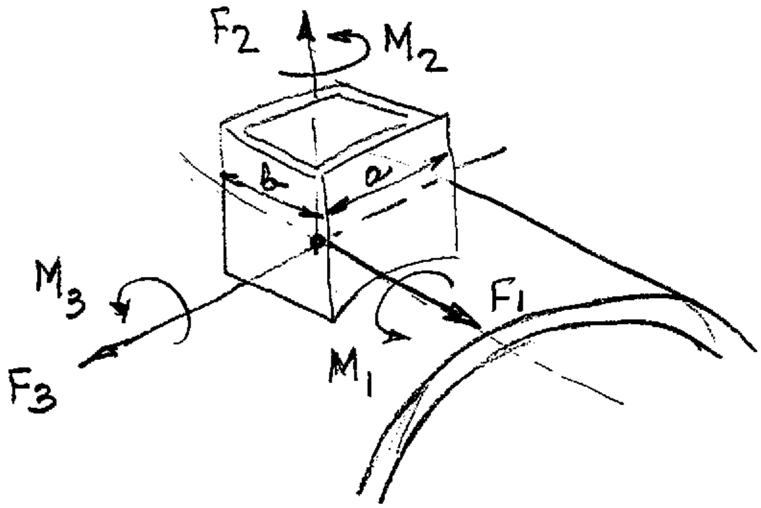
Node	Dx	Dy	Dz	Rx	Ry	Rz
243	1.260E-02	-1.157E-02	1.639E-03	3.876E-04	1.307E-03	-2.958E-03
244	1.676E-02	-1.159E-02	2.295E-03	6.197E-04	1.823E-03	-2.911E-03
245	4.350E-03	-1.448E-02	1.717E-04	-6.024E-05	2.393E-04	-3.375E-03
246	9.421E-03	-1.447E-02	-3.409E-05	3.441E-04	1.374E-03	-3.646E-03
247	1.441E-02	-1.446E-02	-8.735E-05	1.197E-04	2.507E-03	-3.292E-03
248	1.915E-02	-1.447E-02	-5.076E-05	2.853E-04	3.127E-03	-3.125E-03
249	4.334E-03	-1.432E-02	9.766E-05	-3.469E-03	-1.352E-04	0.000E+00
250	1.053E-02	-1.434E-02	-3.212E-05	-4.554E-03	9.277E-04	0.000E+00
251	1.682E-02	-1.441E-02	-4.180E-05	-3.624E-03	2.468E-03	0.000E+00
252	2.175E-02	-1.445E-02	-3.952E-05	-3.027E-03	2.161E-03	0.000E+00
253	4.028E-03	-1.413E-02	0.000E+00	-3.890E-03	0.000E+00	0.000E+00
254	1.099E-02	-1.431E-02	0.000E+00	-5.250E-03	0.000E+00	0.000E+00
255	1.828E-02	-1.439E-02	0.000E+00	-3.895E-03	0.000E+00	0.000E+00
256	2.271E-02	-1.443E-02	0.000E+00	-2.476E-03	0.000E+00	0.000E+00

4. WELD SIZE

filename: FULLRECT.WR1

1. ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part JACKING LUG and part SHELL



LOAD INPUT (LBS., INCH-LBS.)

F1	F2	F3	M1	M2	M3
4902.00	0.00	0.00	0.00	0.00	17770.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90°>ß<120°)
6.000	6.000	14700	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
24.000	48.000	48.000	288.000	3.000	3.000

EFFECTIVE THROAT CORRECTION FACTOR

Mf
1.00

MAXIMUM WELD LOAD (f) - #/INCH

f
423

REQUIRED FILLET WELD SIZE (INCHES)

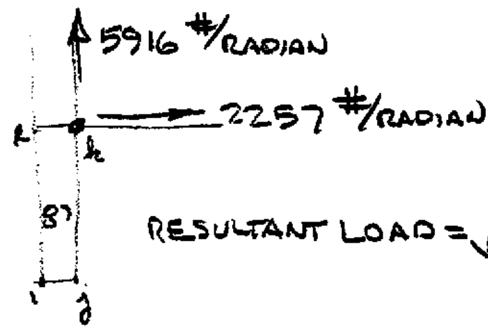
w
0.041

USE $\frac{3}{16}$" MIN FILLET (AISC MINIMUM)

2. STITCH WELD AROUND REDUCING FLANGE

FROM AXISYMMETRIC IMAGES MODEL:

CORNER LOADS AT ELEMENT 87, NODE K



RESULTANT LOAD $= \sqrt{5916^2 + 2257^2} = 6332$ #/RAD

TOTAL LOAD AROUND CIRCUMFERENCE $= 6332 \times 2\pi = 39785$ #

FOR 3/16" FILLET WELD TOTAL LENGTH REQUIRED

$$L = \frac{39785^{\#}}{(.1875)(.7071) \times 14700 \text{ PSI}} = 20.5''$$

AT 30° INCREMENTS (12 SPACES AROUND CIRCUMFERENCE)

ARC LENGTH $= 22.5'' R \times \frac{30 \times \pi}{180}$ RADIANS $= \underline{11.8''} \Rightarrow 12''$

WELD LENGTH REQUIRED $= \frac{20.5}{12} = 1.708 \Rightarrow 2''$

USE 3/16" FILLET WELD x 2" LONG ON 12" CTRS

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-051 PAGE 1 OF 7
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0141	4-25-96	WDB	AGR	**ADAPTER A-5**	
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE:

Evaluate flanges/plates for external pressure loading due to non-standard spool to flange/plate fitup. Verify acceptance of 1" plate.

METHOD:

Hand calculations utilizing Roark and Young's Formulas for Stress and Strain

ASSUMPTIONS: (See Attached)

INPUTS:

1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.

REFERENCES:

1. Doc. No. V049-1-066 - LIGO Vacuum Equipment Structural Design Criteria
2. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
3. *Roark and Young's Formulas for Stress and Strain* fifth edition
4. Doc. No. V049-1-066 - Adapter A-1.

CALCULATIONS:

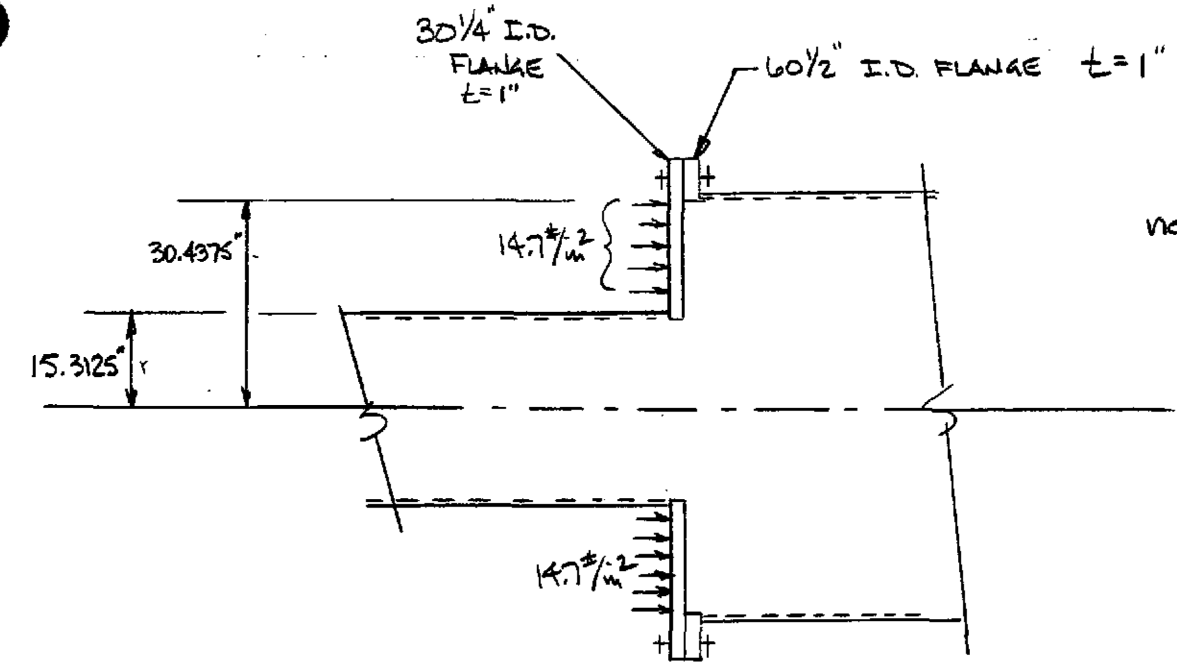
(See Attached)

CONCLUSIONS:

1" thick adapter plates for transition spool pieces 60" x 30" are acceptable.

NOTES: Spool piece A-5 has been voided. This calc is the basis for reducer in mode cleaner tube and other reducers.

DETERMINE IF EXTERNAL PRESSURE OF 14.7 PSIA ON EXPOSED PORTION OF 30 1/4" FLANGE PRODUCES BENDING STRESSES WITHIN ALLOWABLE LIMITS.

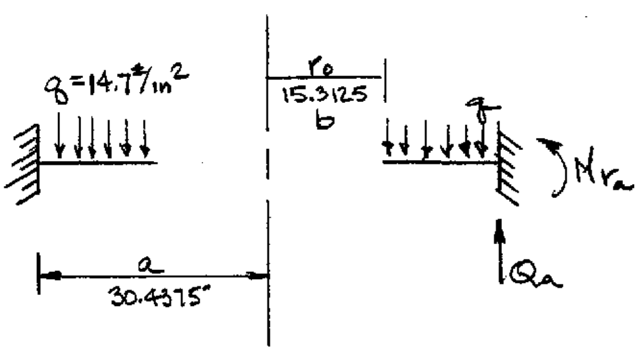


nom t = .1875 in. (TYP) U.N.O.

REF. ROARK'S FORMULAS FOR STRESS & STRAIN
CHAPTER 10 ART. 10.2 - FLAT PLATES.
TABLE 24

CONSIDER CASE 2. - ANNULAR PLATE WITH A UNIFORMLY DISTRIBUTED PRESSURE q OVER THE PORTION FROM r_o to a.

CONSERVATIVELY
USE CASE 2e. - OUTER EDGE FIXED, INNER EDGE FREE.



$$M_{ra} = -q a^2 \left(L_{17} - \frac{C_7}{C_4} L_{14} \right)$$

$$Q_a = \frac{-q}{2a} \left(a^2 - r_o^2 \right)$$

$$L_{17} = \frac{1}{4}\left\{1 - \frac{1-\nu}{4}\left[1-\left(\frac{r_o}{a}\right)^4\right] - \left(\frac{r_o}{a}\right)^2\left[1+(1+\nu)\ln\frac{a}{r_o}\right]\right\}$$

$$= \frac{1}{4}\left\{1 - \frac{1-.3}{4}\left[1-\left(\frac{15.3125}{30.4375}\right)^4\right] - \left(\frac{15.3125}{30.4375}\right)^2\left[1+(1+.3)\ln\frac{30.4375}{15.3125}\right]\right\}$$

$$= \frac{1}{4}\left\{0.825\left[0.936\right] - (.2531)\left[1+(1.3)(.687)\right]\right\}$$

$$= 1/4\left\{0.7722 - (.2531)(1.8931)\right\}$$

$$= 1/4\left\{.293\right\}$$

$$L_{17} = 0.0733$$

$$L_{14} = \frac{1}{16}\left[1-\left(\frac{r_o}{a}\right)^4 - 4\left(\frac{r_o}{a}\right)^2\ln\frac{a}{r_o}\right]$$

$$= \frac{1}{16}\left[1-\left(\frac{15.3125}{30.4375}\right)^4 - 4\left(\frac{15.3125}{30.4375}\right)^2\ln\frac{30.4375}{15.3125}\right]$$

$$= 1/16\left[1 - 0.064 - 4(.2531)(0.687)\right]$$

$$= 1/16\left[.2405\right]$$

$$L_{14} = 0.015$$

$$C_4 = \frac{1}{2}\left[(1+\nu)\frac{b}{a} + (1-\nu)\frac{a}{b}\right] = .5\left[(1+.3)\left(\frac{15.3125}{30.4375}\right) + (1-.3)\left(\frac{30.4375}{15.3125}\right)\right]$$

$$C_4 = 1.023$$

$$C_7 = \frac{1}{2}(1-\nu^2)\left(\frac{a}{b}-\frac{b}{a}\right) \Rightarrow \frac{1}{2}(1-.3^2)\left(\frac{30.4375}{15.3125}-\frac{15.3125}{30.4375}\right)$$

$$C_7 = .6755$$

$$M_{ra} = -q\, a^2 \left(L_{17} - \frac{C_7}{C_4} L_{14} \right)$$

$$= \left(-14.7 \frac{\text{lbs/in}^2}{\text{in}}\right)\left(30.4375 \text{ in}\right)^2 \left[\left(0.0733 - \left(\frac{.6755}{1.023}\right)\left(0.015\right)\right)\right]$$

$$M_{ra} = 863.4 \text{ lbs-in/in}$$

$$Q_a = \frac{-q}{2a}\left(a^2 - r_o^2\right)$$

$$= \frac{-14.7 \text{ lbs/in}^2\text{/in}}{2\ (30.4375 \text{ in})}\left((30.4375 \text{ in})^2 - (15.3125 \text{ in})^2 \right)$$

$$Q_a = 167.\ \text{lbs}$$

$$\text{Max } \sigma = 6 M_{ra}/t^2 \Rightarrow \frac{6\ (863.4 \text{ in-lbs/in})}{(1.00 \text{ in})^2} = 5180.4 \text{ lbs/in}^2$$

FOR TYPE 304L

$S = 14.7$ KSI @ 400°F for membrane stress

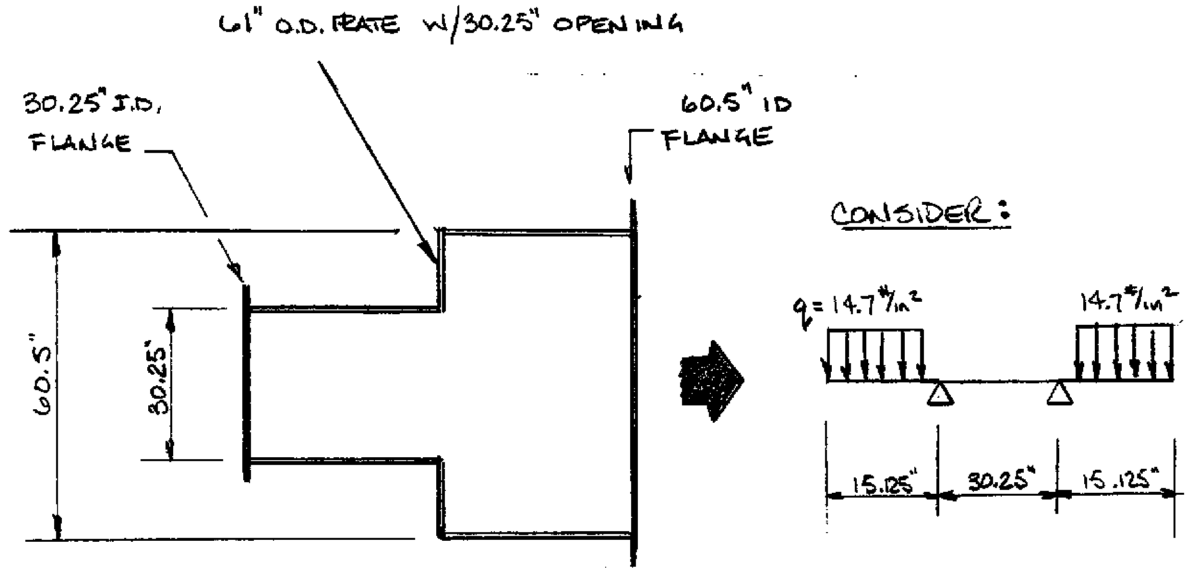
$S = 1.5S = 22$ KSI @ 400°F for membrane + bending stress

$\therefore$ Max $\sigma < S$

$5180.4 \text{ lbs/in}^2 < 22000. \text{ lbs/in}^2$

1" THK PLATE <u>O.K.</u>

60" x 30" REDUCER - EVALUATE 61" O.D. PLATE'S EXPOSED AREA



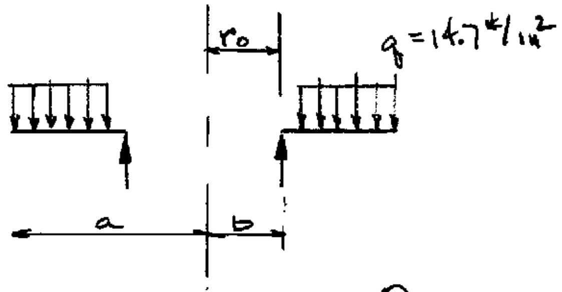
REF. ROARK'S - FORMULAS FOR STRESS & STRAIN

Chapter 10 - TABLE 24 - CASE 2K

CONSIDERING OUTER EDGE FREE, INNER EDGE SIMPLY SUPPORTED.

No BENDING STRESSES

SHEAR FORCE



$r_o = 15.125" = b$

$a = 30.25"$

$$Q_b = \frac{q}{2b}\left(a^2 - r_o^2\right)$$

Revision No. 0
Doc. No. V049-1-051
Page 5 of 7

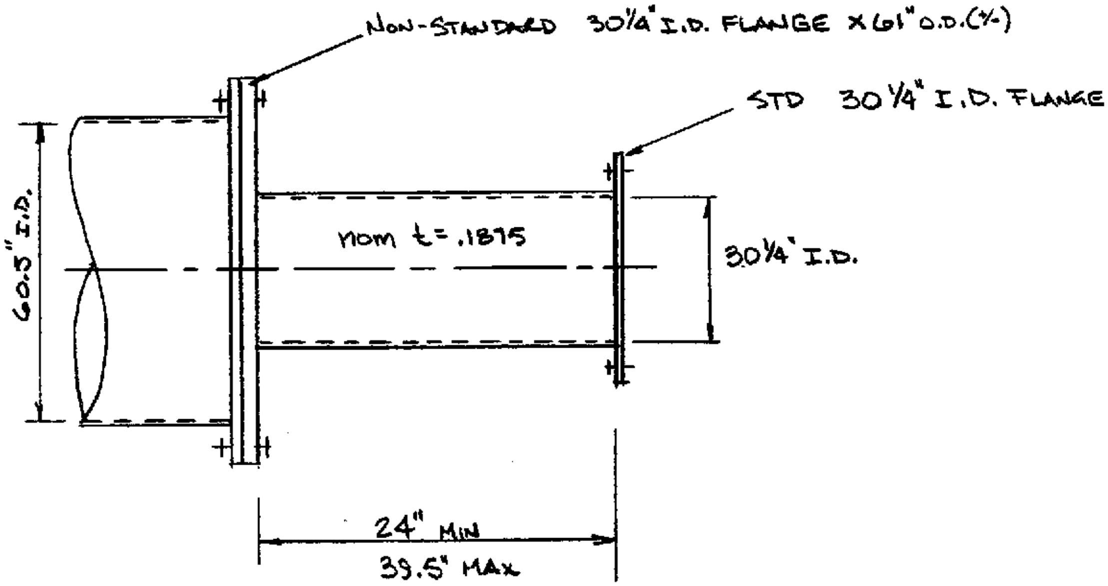
$$= \frac{14.7\#/in^2/in}{2(15.125\,in)}\left[(30.25\,in)^2 - (15.125\,in)^2\right]$$

$$= 333.5 \text{ lbs}$$

Shear force will be resisted by the circumferential weld which will provide a min strength of $W = .125"(.707)(18000\,psi) \times \frac{\pi D}{4}$

$= 1591 \#/in \times \frac{\pi D}{4} = 37794\#$

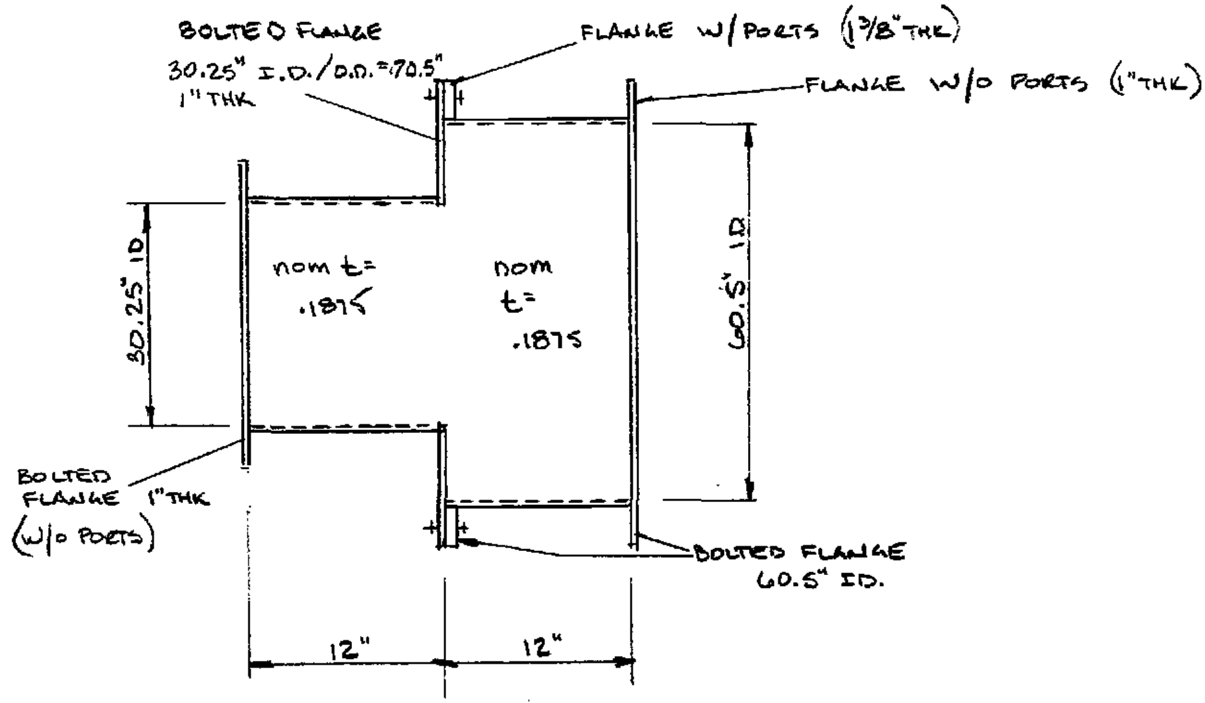
ADAPTER A-5



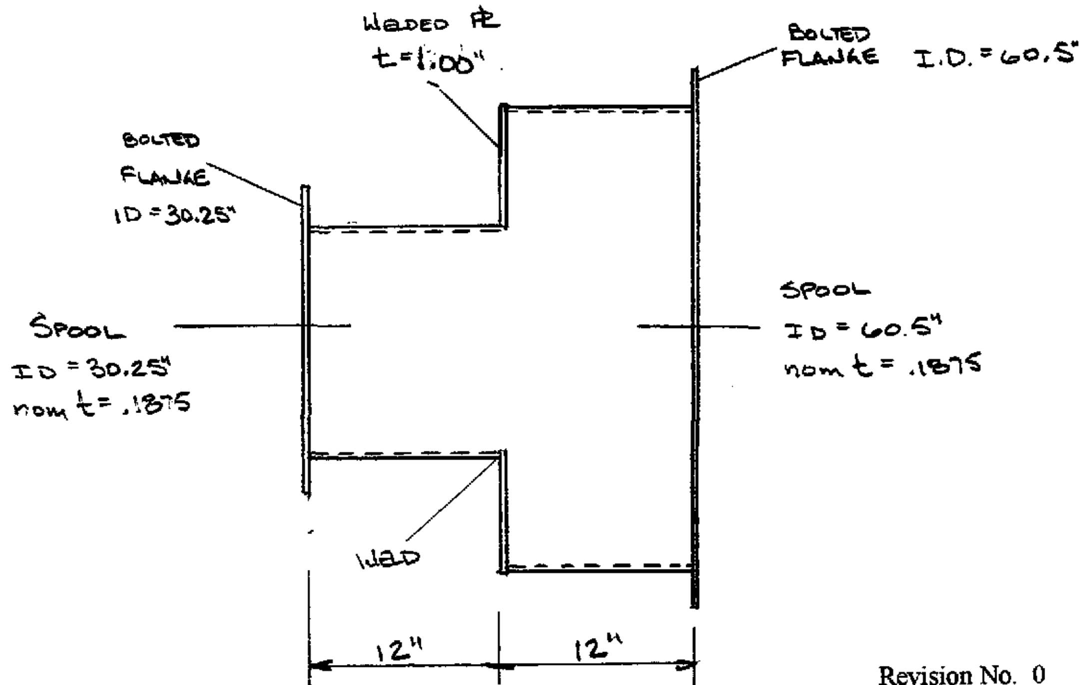
NON-STANDARD 30¼" I.D. FLANGE X 61" O.D.(+/-)
STD 30¼" I.D. FLANGE
60.5" I.D.
nom t=.1875
30¼" I.D.
24" MIN
39.5" MAX

ADAPTER A-5 30" x 60" SPOOL

OPTION - FLANGED SPOOL PIECES



OPTION



PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-052 PAGE 1 OF 43
REV.	DEO #	DATE	BY:	CHECK	TITLE: ADAPTER A-7 (ION PUMP 72IN X 60IN)	
0	0131	4/19/96	WDB	RDC		
1	0293	8/9/96	WDB	RDC		
					BY: W. BILYNSKY	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool/adapter shell thickness. Additionally when applicable, evaluate nozzle opening(s), calculate size and spacing of stiffener rings and support rings.

METHOD: Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.31.

ASSUMPTIONS:

See Calculation

INPUTS:

1. Design Temperature = 400° F.
2. Vacuum pressure = 14.7 psi
3. 16"CF Nozzle Loads
   P_R = 4354.0 lbf; $M_C = M_L$ = 378.5 in-lbf; $V_C = V_L$ = 126.5 lbf
   REF. DOC. NO V049-1-045
4. 12"CF Nozzle Loads
   P_R = 1042.0 lbf

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.53, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-066 LIGO Vacuum Equipment Structural Design Criteria

CALCULATIONS:
1. V049-1-062 Design Of Flexible Support For Adapter A-7

CONCLUSIONS:.

The requirements of the ASME Code are met for adapter A-7 outer shell

NOTES: Flanges were included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, & 019.

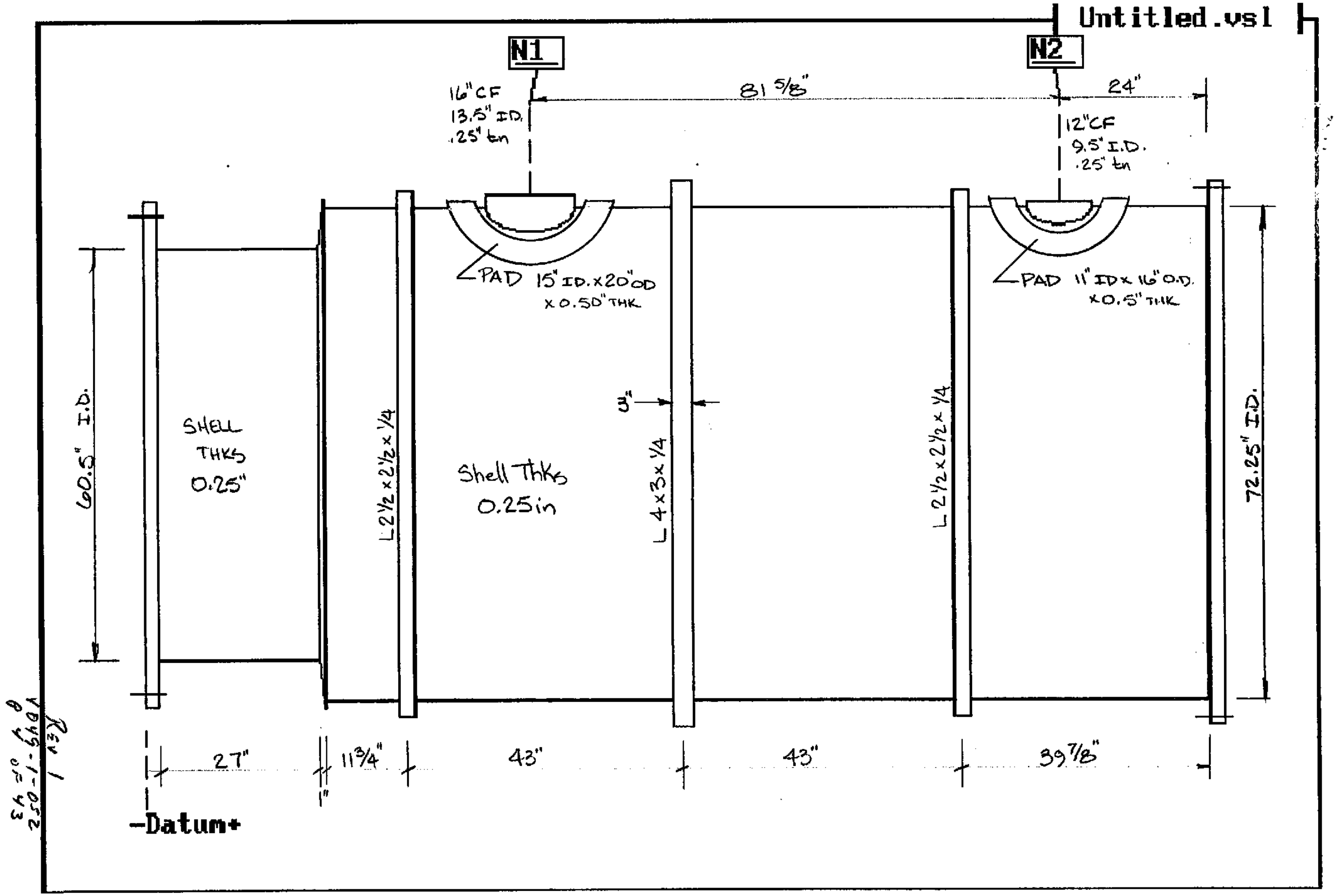
TABLE OF CONTENTS

REVISION HISTORY

Rev. 0 Original Issue
April 19, 1996

Rev. 1 Issue Date
August 9, 1996

- Reduced the thickness of the 72" ∅ and 60" ∅ shells to 0.250 in.
- Added reinforcing pads at the 16"CF and 12"CF nozzles
- Changed the stiffener rings to 2-1/2"x2-1/2"x1/4"
- Revised the nozzle loads to incorporate the vacuum force + valve weight
- Recalculated the local and primary membrane stresses at the nozzles


Untitled.vsl
N1
N2
16" CF
13.5" I.D.
.25" tn
81 5/8"
24"
12" CF
9.5" I.D.
.25" tn
PAD 15" ID. x 20" OD
x 0.50" THK
PAD 11" ID x 16" O.D.
x 0.5" THK
60.5" I.D.
SHELL
THKS
0.25"
L 2½ x 2½ x ¼
Shell ThKs
0.25in
3"
L 4 x 3 x ¼
L 2½ x 2½ x ¼
72.25" I.D.
27"
1"
11¾"
43"
43"
39⅞"
-Datum+

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
60.5" I.D. Cylinder	0.0	400.0	102.7	116.7	27.6	1.136		Not applicable	0.000
Reducing Flange	0.0	400.0	507.3	576.3	290.5	1.136		Not applicable	0.000
70.25" I.D. Cylinde	0.0	400.0	86.1	97.8	22.1	1.136		Not applicable	0.000
Stiffner Rings					14.7				
Support Ring					14.7				
N1 N1 16"CF (14"od)	0.0	400.0	101.3	115.0	14.7	1.136		Not applicable	0.000
N2 N2 12"CF (10"od)	0.0	400.0	101.3	115.0	14.7	1.136		Not applicable	0.000
Flange	0.0	400.0	7.1	7.1		1.000		Not applicable	0.000
flange	0.0	400.0	0.2	0.2		1.000		Not applicable	0.000

Vessel MAWP hot & corroded is 0.26 psi @ 400 degrees F.

Vessel MAP new & cold is 0.26 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 22 psi

Vessel hydrotest pressure is 22 psi.

Weight Summary

Component	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
	Weight (lbs) Contributed by Vessel Elements											
60.5" i.d. cyli	374	374	0	0	0	0	0	0	0	0	2802	0
Reducing flange	1400	1400	0	0	0	0	0	0	0	0	17	0
70.25" i.d. cyl	2256	2256	0	0	0	0	0	0	275	0	20224	54
Flange	1991	1991	0	0	0	0	0	0	0	0	0	0
flange	1243	1243	0	0	0	0	0	0	0	0	0	0
	7264	7264	0	0	0	0	0	0	275	0	23043	54

Vessel operating weight, corroded:	7,593 lbs
Vessel empty weight, corroded:	7,593 lbs
Vessel empty weight, new:	7,593 lbs
Vessel test weight, new:	30,636 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	7,593 lbs
Center of gravity to seam:	99.3 in

Nozzle Schedule

Nozzle mark	Service	Size	Materials Nozzle	Impact?	Norm?	Pad	Impact?	Norm?	Flange
N1	16"cf (14"od)	13.50 IDx0.25	SA 240 304L HIGH	n	n	SA 240 304L HIG	n	n	.
N2	12"cf (10"od)	9.50 IDx0.25	SA 240 304L HIGH	n	n	SA 240 304L HIG	n	n	

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
60.5" i.d. cylinder	60.50	27.00	0.2500	0.1679	0.85	external			
Reducing flange	61.00	1.50	5.8750	1.3215	0.85	external			
70.25" i.d. cylinde	72.25	136.62	0.2500	0.1991	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

60.5" I.D. Cylinder

= 4*5052.4/(3*61/0.25)
= 27.6087 psi

Reducing Flange

ASME Section VIII Division 1, 1995 Edition, A95 Addenda

Component:	Transition			
Material specification:	SA 240 304L HIGH			
External design pressure:	Pe= 14.7	psi @ 400	deg F	
Corrosion allowance: Inner C = 0		Outer= 0	in	

PWHT is not performed

Radiography:	Category A joints -	Full UW-11(a) type 1
	Category B joints -	Full UW-11(a) type 1

Estimated weight:	new = 1399.7	corr = 1399.7	lb
capacity:	new = 2	corr = 2	US ga

Axial Lc= 1.5	big end OD = 72.75	small end OD = 61	in
Cone tc = 5.875			in (min)

MAP: (New & at 0 deg F) Appendix 1-4(e)

P = 2*S*E*t*cos(alpha)/(Do - 0.8*t*cos(alpha)) - Ps
= 2*16700*0.85*5.875*cos(75.6773)/(72.75 - 0.8*5.875*cos(75.6773)) - 0
= 576.3782 psi

MAWP: (Corroded & at 400 deg F) Appendix 1-4(e)

P = 2*S*E*t*cos(alpha)/(Do - 0.8*t*cos(alpha)) - Ps
= 2*14700*0.85*5.875*cos(75.6773)/(72.75 - 0.8*5.875*cos(75.6773)) - 0
= 507.3509 psi

Design thickness for external pressure Pa = 14.7 psi:

NOTE: As alpha > 60 use UG-34 see UG-33(f)(2)

t = d*Sqr(C*Pa/(S*E)) + Corrosion
= 72.75*Sqr(0.33*14.7/(14700*1)) + 0
= 1.321569 in

Allowable external pressure

Pa = (S*E/C)*(t/d)^2
= (14700*1/0.33)*(5.875/72.75)^2
= 290.5047 psi

70.25" I.D. Cylinder

SME Section VIII Division 1, 1995 Edition, A95 Addenda

Component: Cylinder
Material specification: SA 240 304L HIGH

External design pressure: Pe= 14.7 psi @ 400 deg F

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight: new = 2256.1 corr = 2256.1 lb
capacity: new = 2424.842 corr = 2424.842 US ga

ID = 72.25 length Lc= 136.625 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(36.125 + 0.6*0.25) - 0
= 97.82909 psi

IAWP: (Corroded & at 400 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 14700*0.85*0.25/(36.125 + 0.6*0.25) - 0
= 86.11303 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 46.64583/72.75 =0.6412 Do/t = 72.75/0.19757 = 368.2239
From table G: A = 0.000307
From table HA-3: B = 4060.8

Pa= 4*B/(3*Do/t)
= 4*4060.8/(3*72.75/0.19757)
= 14.7041 psi

Design thickness for external pressure Pa = 14.7041 psi:

= t + Corrosion
= 0.19757 + 0
= 0.19757 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 46.64583/72.75 =0.6412 Do/t = 72.75/0.25 = 291
From table G: A = 0.000427
From table HA-3: B = 4838.6

Pa= 4*B/(3*Do/t)

N1 16"CF (14"od)

Opening N1 Reinforcement Calculations Per UG-37

Located on:	70.25" I.D. Cylinder
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Pad material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	39.375 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3 in

```
      tn ->|  |<-                             corrosion allow = 0 in
dp->|          _          _     |<-           noz thick new tn= .25 in
    |        |  |<- d ->|  |tw1 |             nozzle id. new d= 13.5 in
->| |<tw2    |  |       |> |<-  |             pad diameter dp = 20 in
__| |  ___/  |  |       |\___                 pad thickness te= .505 in
te|/|        |  |       |       |\            fillet weld tw1 = .25 in
_________ |_|_v         |  __________         fillet weld tw2 = .3125 in
________/|_|_tw3        |_|\________          groove weld tw3 = .25 in
              ^
<----- L ----->|                              To datum L= 60 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 101.3094*6.75/(14700*1 - 0.6*101.3094)
= 0.0467 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 101.3094*36.125/(14700*1 - 0.6*101.3094)
= 0.25 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, Sp = 14700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

N1 16"CF (14"od)

fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.25*1 + 2*0.25*0.25*1*(1 - 1)
= 3.375 in^2

Area available

A1 = larger of the following = 0 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

A2 = smaller of the following = 0.254 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0467)*1*0.25
= .254 in^2

= 2*(tn - trn)*(2.5*tn + te)*fr2
= 2*(0.25 - 0.0467)*(2.5*0.25 + 0.505)*1
= .459 in^2

A41 = Leg^2*fr3
= 0.12^2*1 = .014 in^2 (Part of weld is outside of limits)

A42 = Leg^2*fr4
= 0.3125^2*1 = .098 in^2

A5 = (Dp - d - 2*tn)*te*fr4
= (20 - 13.5 - 2*0.25)*0.505*1
= 3.03 in^2

Area = A1 + A2 + A41 + A42 + A5
= 0 + 0.254 + 0.014 + 0.098 + 3.03
= 3.396 in^2

As Area > A the reinforcement is adequate for MAWP = 101.3094 at 400 Deg F

Check the welds - From UW-16(c)(2)

Inner Fillet: tmin = lesser of 0.75 or tn or te, tmin = 0.25 in
tw(min) = 0.7*tmin = 0.175 in
tw(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in

Outer Fillet: tmin = lesser of 0.75 or te or t, tmin = 0.25 in
tw(min) = 0.5*tmin = 0.125 in
tw(actual) = 0.7*Leg = 0.7*0.3125 = 0.21875 in

N1 16"CF (14"od)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0467 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.25 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.25 in
The lesser of tr4 or tr5:	tr6 = 0.25 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.25 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*14700 = 10878 psi
Nozzle wall in shear = 0.7*14700 = 10290 psi
Inner fillet weld in shear = 0.49*14700 = 7203 psi
Outer fillet weld in shear = 0.49*14700 = 7203 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*7203 = 39580.49 lbf

(2) Outer fillet weld in shear
(Pi/2)*Pad O.D.*Leg*So = 1.57*20*0.3125*7203 = 70679.44 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*10290 = 55533.84 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.25*10878 = 59774.61 lbf

Loading on welds per UG-41(b)(1)

W = (A - A1 + 2*tn*fr1*(E1*t - F*tr))*Sv
= (3.375 - 0 + 2*0.25*1*(1*0.25 - 1*0.25))*14700
= 49612.5 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.254 + 3.03 + 0.014 + 0.098)*14700
= 49921.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.254 + 0 + 0.014 + 0 + 2*0.25*0.25*1)*14700
= 5777.1 lbf

W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2*tn*t*fr1)*Sv
= (0.254 + 0 + 3.03 + 0.014 + 0.098 + 0 + 2*0.25*0.25*1)*14700
= 51758.7 lbf

Load for path 1-1 lesser of W or W1-1 = 49612.5 lbf

Path 1-1 Thru (2) & (3) = 70679.44 + 55533.84 = 126213.3 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 5777.1 lbf
Path 2-2 Thru (1), (4) = 39580.49 + 59774.61 = 99355.1 lbf
Path 2-2 is stronger than W2-2 so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W3-3 = 49612.5 lbf
Path 3-3 Thru (2), (4) = 70679.44 + 59774.61 = 130454 lbf
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Pad strength = A5*Sp = 44541 lbf
Outer fillet weld strength is adequate.

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 115.0931*6.75/(16700*1 - 0.6*115.0931)
= 0.0467 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 115.0931*36.125/(16700*1 - 0.6*115.0931)
= 0.25 in

Area required

Allowable stresses: Sn = *16700*, Sv = *16700*, Sp = 16700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1
fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.25*1 + 2*0.25*0.25*1*(1 - 1)
= 3.375 in^2

Area available

A1 = larger of the following = 0 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

N1 16"CF (14"od)

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi
Outer fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(2) Outer fillet weld in shear
(Pi/2)*Pad O.D.*Leg*So = 1.57*20*0.3125*8183 = 80295.69 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.25*12358 = 67907.21 lbf

Loading on welds per UG-41(b)(1)

W = (A - A1 + 2*tn*fr1*(E1*t - F*tr))*Sv
= (3.375 - 0 + 2*0.25*1*(1*0.25 - 1*0.25))*16700
= 56362.5 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.254 + 3.03 + 0.014 + 0.098)*16700
= 56713.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.254 + 0 + 0.014 + 0 + 2*0.25*0.25*1)*16700
= 6563.1 lbf

W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2*tn*t*fr1)*Sv
= (0.254 + 0 + 3.03 + 0.014 + 0.098 + 0 + 2*0.25*0.25*1)*16700
= 58800.7 lbf

Load for path 1-1 lesser of W or W1-1 = 56362.5 lbf
Path 1-1 Thru (2) & (3) = 80295.69 + 63089.47 = 143385.2 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 6563.1 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 67907.21 = 112872.8 lbf
Path 2-2 is stronger than W2-2 so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W3-3 = 56362.5 lbf
Path 3-3 Thru (2), (4) = 80295.69 + 67907.21 = 148202.9 lbf
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Pad strength = A5*Sp = 50601 lbf
Outer fillet weld strength is adequate.

Reinforcement Calculations for External Pressure

N1 16"CF (14"od)

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 3/14 = .2143   Do/t = 14/0.02965 = 472.1754
From table G: A = 0.000668
From table HA-3:   B = 5234.9

Pa= 4*B/(3*Do/t)
= 4*5234.9/(3*14/0.02965)
= 14.7824 psi

Nozzle required thickness trn = .02965 in

Required thickness tr from UG-37(d)(1) = .1976 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, Sp = 14700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1
fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.1976*1 + 2*0.25*0.1976*1*(1 - 1))
= 1.3338 in^2

Area available

A1 = larger of the following = .707 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1976) - 2*0.25*(1*0.25-1*0.1976)*(1-1)
= .707 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1976) - 2*0.25*(1*0.25-1*0.1976)*(1-1)
= .052 in^2

A2 = smaller of the following = 0.275 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02965)*1*0.25
= .275 in^2

= 2*(tn - trn)*(2.5*tn + te)*fr2
= 2*(0.25 - 0.02965)*(2.5*0.25 + 0.505)*1
= .498 in^2

N1 16"CF (14"od)

A41 = Leg^2*fr3
= 0.12^2*1 = .014 in^2 (Part of weld is outside of limits)

A42 = Leg^2*fr4
= 0.3125^2*1 = .098 in^2

A5 = (Dp - d - 2*tn)*te*fr4
= (20 - 13.5 - 2*0.25)*0.505*1
= 3.03 in^2

Area = A1 + A2 + A41 + A42 + A5
= 0.707 + 0.275 + 0.014 + 0.098 + 3.03
= 4.124 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02965 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N1 16"CF (14"od)

Applied Loads

Radial load	Pr = 4354 lbf
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 36.25 in
Rm/t = 48.01324

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = [redacted] 4719.14 PSI

Local long. pressure stress = P*Rm/2t = [redacted] 1065.75 PSI

Maximum combined stress = [redacted] 10686. PSI
Allowable combined stress = +-3*S = +-44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = [redacted] 7053. PSI.
Allowable primary membrane stress = +-1.5*S = +-22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_L = \frac{(14.7\text{ psi})(36.25)}{2(.25\text{ in})} = 1065.75\text{ psi}$$

$$\sigma_C = \frac{(14.7\text{ psi})(36.25)}{.25\text{ in}} = 2131.5\text{ psi} \longrightarrow \sigma_C = 2131.5\text{ psi}(2.214) = 4719.14\text{ psi}$$

MAX COMBINED STRESS = 4901 PSI + 4719 PSI + 1066 PSI
= 10686 PSI

MAX PRIMARY MEMBRANE STRESS = 1268 PSI + 4719 PSI + 1066 PSI = 7053. PSI

N1 16"CF (14"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	4.9992	0.169					-795	-795	-795	-795
4C*	7.0901	0.169	-1128	-1128	-1128	-1128				
1C	0.0751	0.169					-3442	3442	-3442	3442
2C-1	0.0414	0.169	-1897	1897	-1897	1897				
3A*	1.9491	0.169					-53	-53	53	53
1A	0.0783	0.169					-611	611	611	-611
3B*	5.1720	0.169	-140	-140	140	140				
1B-1	0.0285	0.169	-222	222	222	-222				
pressure stress*			-4719.	-4719.	-4719	-4719	-4719	-4719	-4719	-4719
Total circ stress			-8106	-3868	-7382	-4032.	-9620	-1514.	-8292.	-2630
Primary membrane circ stress*			-5987.	-5987	-5707.	-5707.	-5567.	-5567.	-5461	-5461.
3C*	4.9992	0.169	-795	-795	-795	-795				
4C*	7.0901	0.169					-1128	-1128	-1128	-1128
1C-1	0.0754	0.169	-3456	3456	-3456	3456				
2C	0.0437	0.169					-2003	2003	-2003	2003
4A*	3.5798	0.169					-97	-97	97	97
2A	0.0398	0.169					-311	311	311	-311
4B*	1.9470	0.169	-53	-53	53	53				
2B-1	0.0421	0.169	-329	329	329	-329				
pressure stress*			-1066.	-1066.	-1066.	-1066.	-1066.	-1066.	-1066.	-1066.
Total long stress			-5699	1871.	-4935.	1319.	-4605.	23.	-3789.	-405.
Primary membrane long stress*			-1914	-1914.	-1808.	-1808.	-2291.	-2291.	-2097	-2097
torsion moment Mt										
Circ shear from Vc			8	8	-8	-8				
Long shear from VL							-8	-8	8	8
Total Shear stress			8	8	-8	-8	-8	-8	8	8
Combined stress			-8106	-5987	-7382.	-5707.	-9620.	-5567.	-8292.	-5461.
MEMBRANE STRESS			-1066	-1066.	-1066	-1066	-1066	-1066.	-1066.	-1066.
MAX COMBINED STRESS			-9172.	-7053.	-8448.	-6773.	-10686	-6633.	-9358.	-6527
MAX PRIMARY STRESS			-5987.	-5987.	-5707	-5707.	-5567	-5567	-5461	-5461
PRIMARY MEMBRANE STRESS			-1066.	-1066.	-1066	-1066	-1066	-1066.	-1066.	-1066.
MAX TOTAL PRIMARY MEMBRANE			-7053	-7053.	-6773.	-6773.	-6633	-6633.	-6527	-6527.

N1 16"CF (14"od)

Stresses at the pad edge per WRC bulletin 107 (psi)

Mean radius Rm = 36.25 in
Rm/t = 145

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/10.3125)^2 + 3*(6.75/10.3125)^4)
= 1.459

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 3110. PSI

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 1066 PSI.

Maximum combined stress = ~~29779 psi~~ 33955. PSI
Allowable combined stress = +-3*S = +- 44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~6463 psi~~ 10639 PSI
Allowable primary membrane stress = +-1.5*S = +- 22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_L = \frac{(14.7\,\text{psi})(36.25)}{2(.25\,\text{in})} = 1066.\ \text{psi}$$

$$\sigma_C = \frac{(14.7\,\text{psi})(36.25)}{.25\,\text{in}} = 2131.5\ \text{psi} \longrightarrow \sigma_C = 1.459(2131.5\ \text{psi}) = 3110.\ \text{psi}$$

MAX COMBINED STRESS = 29779 PSI + 1066. PSI + 3110. PSI
= 33955 PSI.

MAX PRIMARY MEMBRANE STRESS = 6463 PSI + 3110. PSI + 1066 PSI.
= 10639 PSI.

N1 16"CF (14"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	4.0569	0.241					-1949	-1949	-1949	-1949
4C*	11.983	0.241	-5757	-5757	-5757	-5757				
1C	0.0600	0.241					-25079	25079	-25079	25079
2C-1	0.0097	0.241	-4054	4054	-4054	4054				
3A*	3.4900	0.241					-200	-200	200	200
1A	0.0512	0.241					-2551	2551	2551	-2551
3B*	7.2184	0.241	-413	-413	413	413				
1B-1	0.0086	0.241	-429	429	429	-429				
pressure stress*			-3110.	-3110	-3110.	-3110	-3110	-3110	-3110	-3110
Total circ stress			-13763.	-4797.	-12079.	-4829.	-32889.	22371	-27387.	17669.
Primary membrane circ stress*			-9280.	-9280.	-8454.	-8454.	-5259.	-5259.	-4859	-4852
3C*	4.0569	0.241	-1949	-1949	-1949	-1949				
4C*	11.983	0.241					-5757	-5757	-5757	-5757
1C-1	0.0275	0.241	-11495	11495	-11495	11495				
2C	0.0323	0.241					-13501	13501	-13501	13501
4A*	12.318	0.241					-706	-706	706	706
2A	0.0211	0.241					-1051	1051	1051	-1051
4B*	3.4751	0.241	-199	-199	199	199				
2B-1	0.0132	0.241	-658	658	658	-658				
pressure stress*			-1066	-1066	-1066	-1066.	-1066.	-1066	-1066	-1066.
Total long stress			-15367.	8939.	-13653.	8021.	-22081	7023.	-18567	6333.
Primary membrane long stress*			-3214.	-3214.	-2816.	-2816	-7529	-7529.	-6117.	-6117.
torsion moment Mt										
Circ shear from Vc			16	16	-16	-16				
Long shear from VL							-16	-16	16	16
Total Shear stress			16	16	-16	-16	-16	-16	16	16
Combined stress			-15367.	13736.	-13653.	12850.	-32889.	22371.	-27387.	17669.
MEMBRANE STRESS			-3110.		-3110.		-1066.	-1066.	-1066.	-1066.
MAX COMBINED STRESS			-18477.	13736.	-16763	12850.	-35955.	21305.	-28453.	16603.
MAX PRIMARY STRESS			-9280	-9280.	-8454	-8454.	-7529.	-7529.	-6117.	-6117.
PRIMARY MEMBRANE STRESS			-1066.	-1066	-1066.	-1066	-3110.	-3110	-3110	-3110.
MAX TOTAL PRIMARY MEMBRANE			-10346	-10346	-9520.	-9520.	-10639	-10639	-9227	-9227.

N2 12"CF (10"od)

Opening N2 Reinforcement Calculations Per UG-37

Located on:	70.25" I.D. Cylinder
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Pad material specification:	SA 240 304L HIGH
Nozzle orientation:	90 degrees
End of nozzle to shell center:	38 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	1.625 in

```
     tn ->| |<-                              corrosion allow = 0 in
dp->|        _        _  |<-    noz thick new tn= .25 in
    |       | |<- d ->| |tw1 |              nozzle id. new d= 9.5 in
->| |<tw2 | |         > | |<-|              pad diameter dp = 16 in
__|  ___/ | |         | \___                pad thickness te= .5 in
te|/|     | |         |     |\              fillet weld tw1 = .25 in
________|_|_v         |________             fillet weld tw2 = .3125 in
_______/|_|_tw3       |_|\_______           groove weld tw3 = .25 in
           ^
<---- L ---->|                              To datum L= 141.625 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 101.3094*4.75/(14700*1 - 0.6*101.3094)
= 0.0329 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 101.3094*36.125/(14700*1 - 0.6*101.3094)
= 0.25 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, Sp = 14700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

N2 12"CF (10"od)

fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.5*0.25*1 + 2*0.25*0.25*1*(1 - 1)
= 2.375 in^2

Area available

A1 = larger of the following = 0 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

A2 = smaller of the following = 0.271 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0329)*1*0.25
= .271 in^2

= 2*(tn - trn)*(2.5*tn + te)*fr2
= 2*(0.25 - 0.0329)*(2.5*0.25 + 0.5)*1
= .488 in^2

A41 = Leg^2*fr3
= 0.125^2*1 = .016 in^2 (Part of weld is outside of limits)

A42 = Leg^2*fr4
= 0.3125^2*1 = .098 in^2

A5 = (Dp - d - 2*tn)*te*fr4
= (16 - 9.5 - 2*0.25)*0.5*1
= 3 in^2

Area = A1 + A2 + A41 + A42 + A5
= 0 + 0.271 + 0.016 + 0.098 + 3
= 3.385 in^2

As Area > A the reinforcement is adequate for MAWP = 101.3094 at 400 Deg F

Check the welds - From UW-16(c)(2)

Inner Fillet: tmin = lesser of 0.75 or tn or te, tmin = 0.25 in
tw(min) = 0.7*tmin = 0.175 in
tw(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in

Outer Fillet: tmin = lesser of 0.75 or te or t, tmin = 0.25 in
tw(min) = 0.5*tmin = 0.125 in
tw(actual) = 0.7*Leg = 0.7*0.3125 = 0.21875 in

N2 12"CF (10"od)

Path 1-1 Thru (2) & (3) = 56543.55 + 39378.55 = 95922.09 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 6056.4 lbf
Path 2-2 Thru (1), (4) = 28271.78 + 42696.15 = 70967.93 lbf
Path 2-2 is stronger than W2-2 so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W3-3 = 34912.5 lbf
Path 3-3 Thru (2), (4) = 56543.55 + 42696.15 = 99239.7 lbf
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Pad strength = A5*Sp = 44100 lbf
Outer fillet weld strength is adequate.

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 115.0931*4.75/(16700*1 - 0.6*115.0931)
= 0.0329 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 115.0931*36.125/(16700*1 - 0.6*115.0931)
= 0.25 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, Sp = 16700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1
fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.5*0.25*1 + 2*0.25*0.25*1*(1 - 1)
= 2.375 in^2

Area available

A1 = larger of the following = 0 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.25) - 2*0.25*(1*0.25-1*0.25)*(1-1)
= 0 in^2

N2 12"CF (10"od)

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi
Outer fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*10*0.25*8183 = 32118.28 lbf

(2) Outer fillet weld in shear
(Pi/2)*Pad O.D.*Leg*So = 1.57*16*0.3125*8183 = 64236.55 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*9.75*0.25*11690 = 44736.17 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10*0.25*12358 = 48505.15 lbf

Loading on welds per UG-41(b)(1)

W = (A - A1 + 2*tn*fr1*(E1*t - F*tr))*Sv
= (2.375 - 0 + 2*0.25*1*(1*0.25 - 1*0.25))*16700
= 39662.5 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.271 + 3 + 0.016 + 0.098)*16700
= 56529.5 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.271 + 0 + 0.016 + 0 + 2*0.25*0.25*1)*16700
= 6880.4 lbf

W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2*tn*t*fr1)*Sv
= (0.271 + 0 + 3 + 0.016 + 0.098 + 0 + 2*0.25*0.25*1)*16700
= 58617 lbf

Load for path 1-1 lesser of W or W1-1 = 39662.5 lbf
Path 1-1 Thru (2) & (3) = 64236.55 + 44736.17 = 108972.7 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 6880.4 lbf
Path 2-2 Thru (1), (4) = 32118.28 + 48505.15 = 80623.43 lbf
Path 2-2 is stronger than W2-2 so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W3-3 = 39662.5 lbf
Path 3-3 Thru (2), (4) = 64236.55 + 48505.15 = 112741.7 lbf
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Pad strength = A5*Sp = 50100 lbf
Outer fillet weld strength is adequate.

Reinforcement Calculations for External Pressure

N2 12"CF (10"od)

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.5 in
Normal to the vessel wall outside 2.5*(t-C) = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 1.625/10 = .1625 Do/t = 10/0.02026 = 493.5834
From table G: A = 0.000838
From table HA-3: B = 5447.9

Pa= 4*B/(3*Do/t)
= 4*5447.9/(3*10/0.02026)
= 14.7166 psi

Nozzle required thickness trn = .02026 in

Required thickness tr from UG-37(d)(1) = .1976 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, Sp = 14700 psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1
fr3 = lesser of fr2 or Sp/Sv so fr3 = 1
fr4 = lesser of 1 or Sp/Sv so fr4 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(9.5*0.1976*1 + 2*0.25*0.1976*1*(1 - 1))
= .9386 in^2

Area available

A1 = larger of the following = .498 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.1976) - 2*0.25*(1*0.25-1*0.1976)*(1-1)
= .498 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1976) - 2*0.25*(1*0.25-1*0.1976)*(1-1)
= .052 in^2

A2 = smaller of the following = 0.287 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02026)*1*0.25
= .287 in^2

= 2*(tn - trn)*(2.5*tn + te)*fr2
= 2*(0.25 - 0.02026)*(2.5*0.25 + 0.5)*1
= .517 in^2

N2 12"CF (10"od)

A41 = Leg^2*fr3
= 0.125^2*1 = .016 in^2 (Part of weld is outside of limits)

A42 = Leg^2*fr4
= 0.3125^2*1 = .098 in^2

A5 = (Dp - d - 2*tn)*te*fr4
= (16 - 9.5 - 2*0.25)*0.5*1
= 3 in^2

Area = A1 + A2 + A41 + A42 + A5
= 0.498 + 0.287 + 0.016 + 0.098 + 3
= 3.899 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02026 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.319375 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N2 12"CF (10"od)

Applied Loads

Radial load	Pr = 1042 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf
Longitudinal moment	ML = 0 lbf-ft
Longitudinal shear	VL = 0 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 36.25 in
Rm/t = 48.33333

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(4.75/5.25)^2 + 3*(4.75/5.25)^4)
= 2.117

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 4512. psi.

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 1066. psi.

Maximum combined stress = ~~1400 psi~~ -6978. psi.
Allowable combined stress = +-3*S = +- 44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~305 psi~~ -5883. psi
Allowable primary membrane stress = +-1.5*S = +- 22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_L = \frac{(14.7\text{ psi})(36.25\text{ in})}{2(.25\text{ in})} = 1066.\text{ psi}$$

$$\sigma_c = \frac{(14.7\text{ psi})(36.25\text{ in})}{.25\text{ in}} = 2131.5\text{ psi} \longrightarrow \sigma_c = 2.117(2131.5\text{ psi}) = 4512.\text{ psi}$$

MAX COMBINED STRESS = 1400 psi + 4512. psi + 1066 psi
= 6978. psi

MAX PRIMARY STRESS = -305 psi + -1066. psi + -4512. psi
= -5883. psi

N2 12"CF (10"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	6.5789	0.121					-252	-252	-252	-252
4C*	7.9700	0.121	-305	-305	-305	-305				
1C	0.1010	0.121					-1123	1123	-1123	1123
2C-1	0.0667	0.121	-741	741	-741	741				
3A*	1.7513	0.121								
1A	0.0898	0.121								
3B*	5.4467	0.121								
1B-1	0.0387	0.121								
pressure stress*			-4512.	-4512	-4512.	-4512	-4512.	-4512.	-4512.	-4512.
Total circ stress			-5558	-4076.	-5558	-4076.	-5887.	-3641	-5887.	-3641.
Primary membrane circ stress*			-4817	-4817	-4817	-4817	-4764	-4764	-4764	-4764.
3C*	6.5789	0.121	-252	-252	-252	-252				
4C*	7.9700	0.121					-305	-305	-305	-305
1C-1	0.1033	0.121	-1148	1148	-1148	1148				
2C	0.0671	0.121					-746	746	-746	746
4A*	2.7335	0.121								
2A	0.0478	0.121								
4B*	1.6948	0.121								
2B-1	0.0591	0.121								
pressure stress*			-1066.	-1066.	-1066.	-1066.	-1066.	-1066.	-1066.	-1066.
Total long stress			-2466	-170	-2466	-170	-2117.	-625.	-2117.	-625.
Primary membrane long stress*			-1318	-1318.	-1318.	-1318.	-1371	-1371	-1371	-1371
torsion moment Mt										
Circ shear from Vc										
Long shear from VL										
Total Shear stress										
Combined stress			-2466	-4076.	-2466.	-4076.	-5887.	-3641	-5887.	-3641.
Membrane Stress			-4512.	-1066	-4512.	-1066	-1066	-1066	-1066	-1066
Max Combined Stress			-6978.	-5142.	-6978.	-5142.	-6953.	-4707	-6953.	-4707.
Max Primary Stress			-4817	-4817	-4817	-4817	-4764	-4764	-4764	-4764.
Primary Membrane Stress			-1066	-1066	-1066	-1066	-1066	-1066	-1066	-1066
Max Total Primary Stress			-5883.	-5883	-5883	-5883	-5830	-5830	-5830	-5830

N2 12"CF (10"od)

Stresses at the pad edge per WRC bulletin 107 (psi)

Mean radius Rm = 36.25 in
Rm/t = 145

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(4.75/8.3125)^2 + 3*(4.75/8.3125)^4)
= 1.325

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 2824. PSI

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 1066. PSI

Maximum combined stress = -~~6678 psi~~ 10568 PSI
Allowable combined stress = +-3*S = +- 44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = -~~1650 psi~~ 5549 PSI.
Allowable primary membrane stress = +-1.5*S = +- 22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_C = \frac{(14.7\,\text{psi})(36.25\,\text{in})}{.25\,\text{in}} = 2131.5\,\text{psi} \longrightarrow \sigma_C = 2131.5\,\text{psi}\,(1.325) = 2824.\,\text{psi}$$

$$\sigma_L = \frac{(14.7\,\text{psi})(36.25\,\text{in})}{2\,(.25\,\text{in})} = 1066\,\text{psi}$$

MAX COMBINED STRESS = 6678 PSI + 2824 PSI + 1066 PSI

= 10568 PSI

MAX PRIMARY MEMBRANE STRESS = 1659 PSI + 2824 PSI + 1066 PSI

= -5549 PSI

N2 12"CF (10"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	5.8800	0.193					-676	-676	-676	-676
4C*	14.427	0.193	-1659	-1659	-1659	-1659				
1C	0.0600	0.193					-6002	6002	-6002	6002
2C-1	0.0157	0.193	-1571	1571	-1571	1571				
3A*	4.3624	0.193								
1A	0.0563	0.193								
3B*	9.3422	0.193								
1B-1	0.0118	0.193								
pressure stress*			-2824	-2824	-2824	-2824	-2824	-2824	-2824	-2824
Total circ stress			-6054	-2912.	-6054	-2912.	-9502	2502	-9502	2502.
Primary membrane circ stress*			-4483	-4483	-4483	-4483	-3500	-3500	-3500	-3500
3C*	5.8800	0.193	-676	-676	-676	-676				
4C*	14.427	0.193					-1659	-1659	-1659	-1659
1C-1	0.0387	0.193	-3871	3871	-3871	3871				
2C	0.0343	0.193					-3431	3431	-3431	3431
4A*	12.560	0.193								
2A	0.0240	0.193								
4B*	4.1625	0.193								
2B-1	0.0162	0.193								
pressure stress*			-1066	-1066.	-1066.	-1066.	-1066.	-1066	-1066.	-1066.
Total long stress			-5613	2129.	-5613	2129.	-6156	706	-6156.	706.
Primary membrane long stress*			-1742	-1742	-1742	-1742.	-2725	-2725	-2725	-2725
torsion moment Mt										
Circ shear from Vc										
Long shear from VL										
Total Shear stress										
Combined stress			-6054	-2912	-6054	-2912.	-9502.	2502	-9502.	2502
Membrane Stress			-1066	-1066	-1066	-1066	-1066	-1066	-1066	-1066
Max Combined Stress			-7120	-3978.	-7120.	-3978	-10568	1436	-10568	1436.
Max Primary Mem. Stress			-4483.	-4483	-4483	-4483	-3500	-3500	-3500	-3500
Primary Mem. Stress			-1066	-1066	-1066	-1066	-1066	-1066	-1066	-1066
Max Total Primary Mem Stress			-5549	-5549	-5549	-5549.	-4566	-4566	-4566	-4566

Support Ring

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.69*2.885/(1.172787 + 1.69)
= 1.703113 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 4.691149*0.25^3/12 + 1.172787*1.703113^2
= 3.407887 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.703113 - 2.885)^2
= 5.130688 in^4

Total available I = I1 + I2 = 8.538576 in^4

The 4x3x1/4 Un Equal Ang vacuum stiffener is satisfactory.

Stiffner Rings

= 1.908 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.19*1.908/(1.172787 + 1.19)
= .9609499 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 4.691149*0.25^3/12 + 1.172787*0.9609499^2
= 1.089089 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.703 + 1.19*(0.9609499 - 1.908)^2
= 1.770316 in^4

Total available I = I1 + I2 = 2.859405 in^4

The 2.5x2.5x1/4 Equal A vacuum stiffener is satisfactory.

Calculations for ring 40 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.19757 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	72.75 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	41.375 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*72.75/(0.19757 + 1.19/41.375))
= 3543.781

From table HA-3 (ring) A = 2.682585E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (72.75^2*41.375*(0.19757 + 1.19/41.375)*2.682585E-04)/10.9
= 1.219764 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.691149

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(72.75*0.25)
= 4.691149 in

W = Ls = 41.375 in

Stiffner Rings

Shell area A1 = W*ts = 1.172787 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.783 + 0.25/2
 = 1.908 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 1.19*1.908/(1.172787 + 1.19)
 = .9609499 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 4.691149*0.25^3/12 + 1.172787*0.9609499^2
 = 1.089089 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.703 + 1.19*(0.9609499 - 1.908)^2
 = 1.770316 in^4

Total available I = I1 + I2 = 2.859405 in^4

The 2.5x2.5x1/4 Equal A vacuum stiffener is satisfactory.

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1- 053 PAGE 1 OF 10
REV.	DEO #	DATE	BY:	CHECK	TITLE: **SPOOL B-1 (72 in)**	
0	0131	4/19/96	WDB	RDL		
					BY: W. B[illegible]	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool/adapter shell thickness. Additionally when applicable, evaluate nozzle opening(s), calculate size and spacing of stiffener rings and support rings.

METHOD: Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.31.

ASSUMPTIONS:

INPUTS:
1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.31, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-046, LIGO Vacuum Equip Struct. Design Criteria

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The requirements of the ASME Code are met for spool B-1 outer shell.

NOTES: Flanges were included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, & 019.

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Doc. No. V049-1-053
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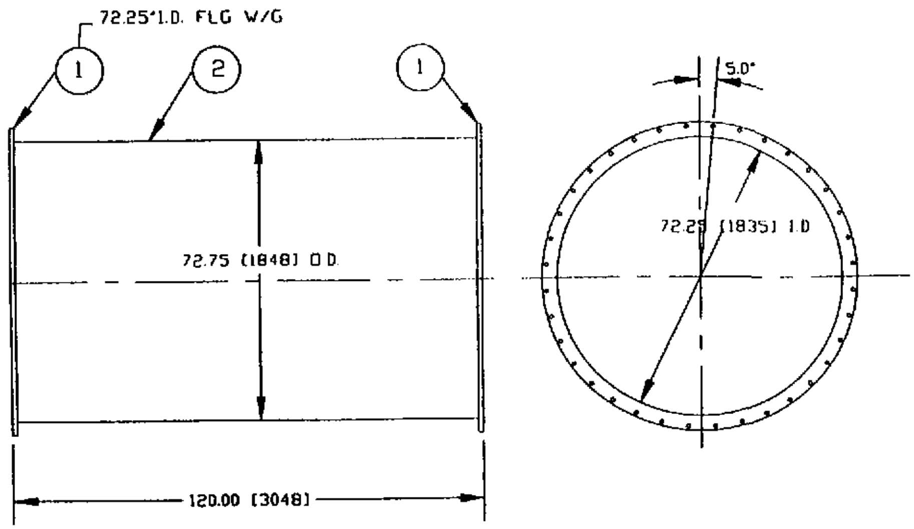

12 REQ'D

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH ±0°-30' BEND ±2°
TWO PLACE DECIMAL ± .010
THREE PLACE DECIMAL ± .005
FINISHED SURFACE RMS
BREAK CORNERS: IN OUT
REMOVE ALL BURRS

DO NOT SCALE THIS DWG.
USED ON:
NEXT ASS'Y:

REV	DESCRIPTION					CHK'D	DRWN	DATE	DCO#
X	X					X	X	X	X

ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

SPOOL B-1
72"
LIGO VACUUM EQUIPMENT

CAD FILE	SIZE	DWG NO	REV.
B1	B	V049-4-B1	0
SCALE 3/8"=1'-0"		SHEET 1 OF 1	

Jan 17, 1996 - 14:34:15

4 3 2 1

B A

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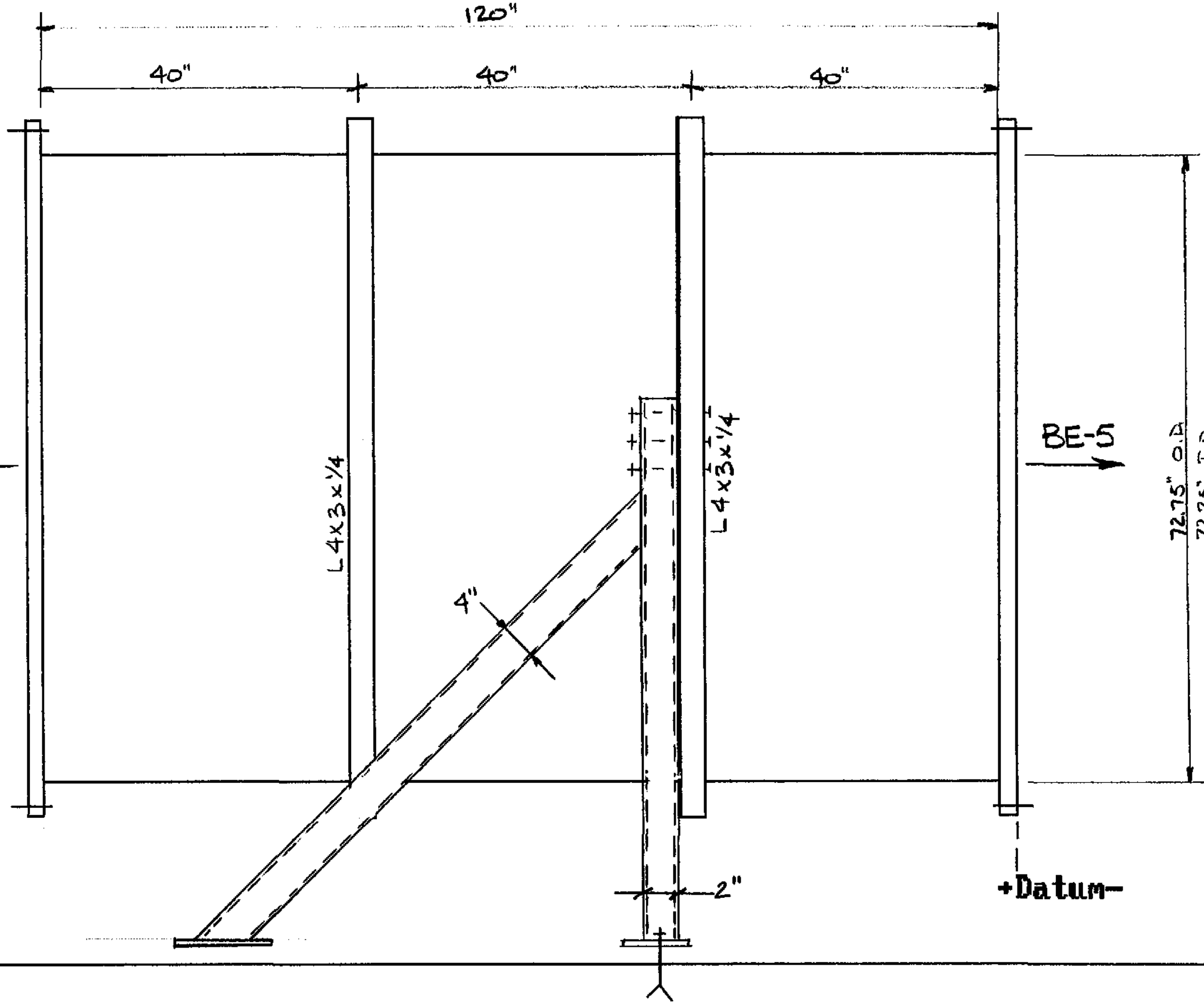


Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
Spool B-1 72" dia	0.0	0.0	97.8	97.8	22.8	1.000		Not applicable	0.000
72.25" id Flange	0.0	0.0	17.5	17.5		1.000		Not applicable	0.000
72.25" id Flange	0.0	0.0	17.5	17.5		1.000		Not applicable	0.000
Support Rings					14.7				

Vessel MAWP hot & corroded is 17.53 psi @ 0 degrees F.

Vessel MAP new & cold is 17.53 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on MAWP

= 1.5*(MAWP + Operating Liquid Head)*1 = 26.3 psi

Vessel hydrotest pressure is 26.3 psi.

Note: vessel MAP rating not valid unless hydrotest pressure based on MAP.

Weight Summary

Component	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Spool b-1 72" d	1982	1982	0	0	0	0	0	0	229	0	17763	0
72.25" id flang	840	840	0	0	0	0	0	0	0	0	0	0
72.25" id flang	840	840	0	0	0	0	0	0	0	0	0	0
	3662	3662	0	0	0	0	0	0	229	0	17763	0

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded:	3,891 lbs
Vessel empty weight, corroded:	3,891 lbs
Vessel empty weight, new:	3,891 lbs
Vessel test weight, new:	21,654 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	3,891 lbs
Center of gravity to seam:	60 in

NOTE: FLANGE WEIGHT IS BASED ON A 3" THK FLANGE
ACTUAL FLANGE THICKNESS WILL BE LESS.

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
Spool b-1 72" dia	72.25	120.00	0.2500	0.1869	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

Spool B-1 72" dia

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: Cylinder
Material specification: SA 240 304L HIGH

External design pressure: Pe= 14.7 psi @ 400 deg F

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight:	new = 1981.6	corr = 1981.6	lb
capacity:	new = 2129.779	corr = 2129.779	US ga

ID = 72.25 length Lc= 120 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(36.125 + 0.6*0.25) - 0
= 97.82909 psi

MAWP: (Corroded & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(36.125 + 0.6*0.25) - 0
= 97.82909 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 40/72.75 =0.5498 Do/t = 72.75/0.18693 = 389.1831
From table G: A = 0.000325
From table HA-3: B = 4301.3

Pa= 4*B/(3*Do/t)
= 4*4301.3/(3*72.75/0.18693)
= 14.7362 psi

Design thickness for external pressure Pa = 14.7362 psi:

= t + Corrosion
= 0.18693 + 0
= 0.18693 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 40/72.75 =0.5498 Do/t = 72.75/0.25 = 291
From table G: A = 0.000503
From table HA-3: B = 4980

Spool B-1 72" dia

Pa= 4*B/(3*Do/t)
 = 4*4980/(3*72.75/0.25)
 = 22.8179 psi

Support Rings

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Rings
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		40 in
Ring spacing:		40 in
Ring description:		4x3x1/4 Un Equal Ang
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.69 in^2
Ring moment of inertia:	Ir =	2.77 in^4

Calculations for ring 40 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.18693 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	72.75 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	40 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*72.75/(0.18693 + 1.69/40))
= 3499.733

From table HA-3 (ring) A = 2.649556E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (72.75^2*40*(0.18693 + 1.69/40)*2.649556E-04)/10.9
= 1.179368 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.691149

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(72.75*0.25)
= 4.691149 in

W = Ls = 40 in

Shell area A1 = W*ts = 1.172787 in^2

Distance to the ring neutral axis

Support Rings

Y2 = Ring NA + ts/2
 = 2.76 + 0.25/2
 = 2.885 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 1.69*2.885/(1.172787 + 1.69)
 = 1.703113 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 4.691149*0.25^3/12 + 1.172787*1.703113^2
 = 3.407887 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 2.77 + 1.69*(1.703113 - 2.885)^2
 = 5.130688 in^4

Total available I = I1 + I2 = 8.538576 in^4

The 4x3x1/4 Un Equal Ang vacuum stiffener is satisfactory.

Calcs for ring 80 in from datum identical to ring 40 in from datum.

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-054 PAGE 1 OF 34
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0131	4/19/96	WDB	RDL	SPOOL B-2 (30 in)	
					BY: W. Bilynski	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool/adapter shell thickness. Additionally when applicable, evaluate nozzle opening(s), calculate size and spacing of stiffener rings and support rings.

METHOD: Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.31.

ASSUMPTIONS: None

INPUTS:
1. Vacuum Pressure = 14.7 psi
2. Design Temperature = 400 F.
3. Ion Pump Nozzle Loads

Pr = 2250.0 lbs
Mc = Ml = 4542.0 in-lbs
Vc = Vl = 126.5 lbs

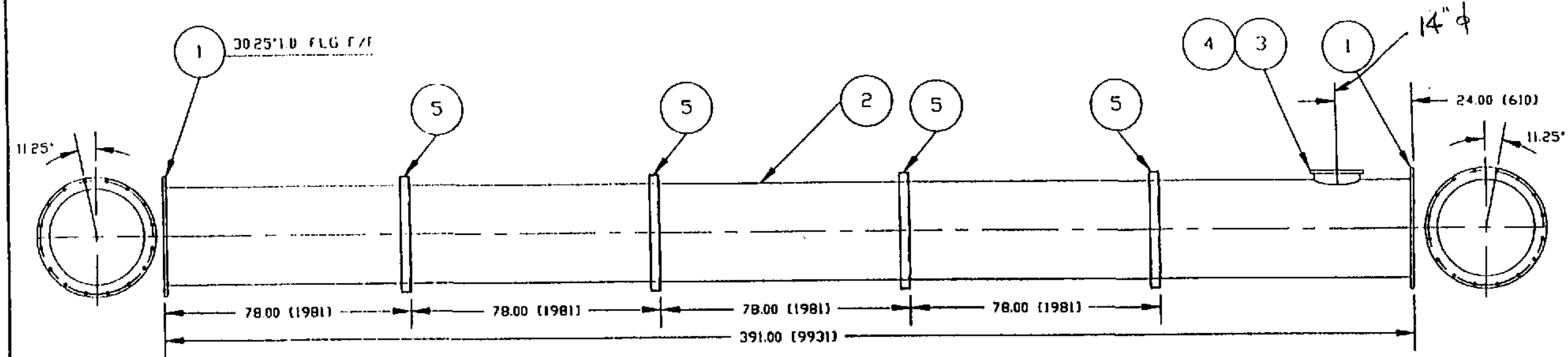
REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.31, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-066, LIGO Vac. Equip. Struct. Design Criteria

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The requirements of the ASME Code are met for spool B-2 outer shell.

NOTES: Flanges were included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, 019.& 051

See B3 + B5



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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH ±0°-30' BEND ±2°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005
FINISHED SURFACE
BREAK CORNERS
REMOVE ALL BURRS

DO NOT SCALE THIS DWG.
USED ON
NEXT ASS'Y:

REV	DESCRIPTION	CHKD	DRWN	DATE	DEDR
X	X		X	X	X

ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

SPOOL B-2
30"
LIGO VACUUM EQUIPMENT

CAD FILE	SIZE	DWG. NO.	REV.
B2	B	V049-4-B2	0

SCALE 3/8"=1'-0" SHEET 1 OF 1

Dec 19, 1995 - 08:36:09

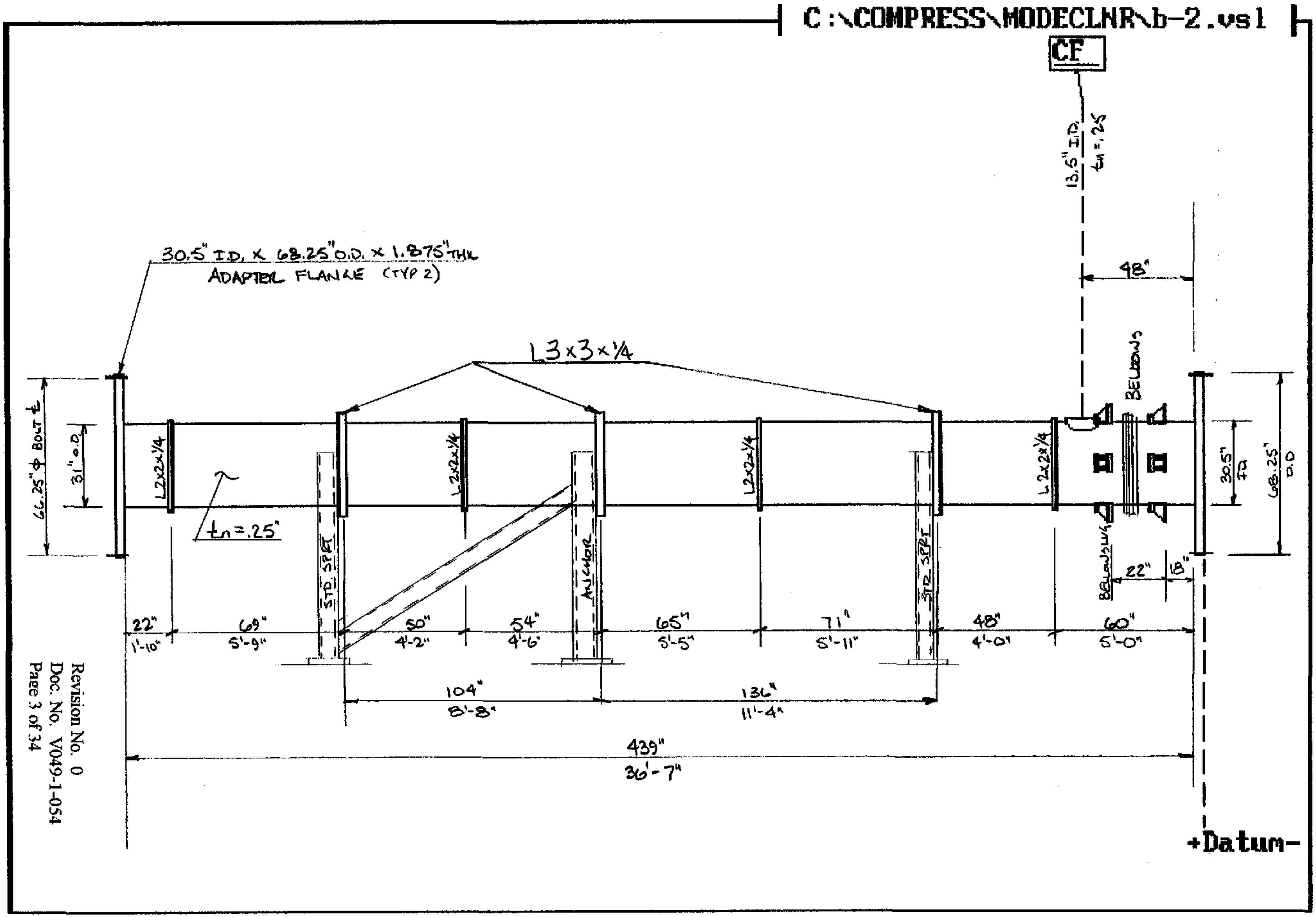

C:\COMPRESS\MODECLNR\b-2.vsl
CF
13.5" I.D.
tn=.25
30.5" I.D. x 68.25" O.D. x 1.875" THK
ADAPTER FLANGE (TYP 2)
L3x3x1/4
48"
BELLOWS
66.25" ⌀ BOLT ℄
31" O.D.
L2x2x1/4
tn=.25"
STD. SPRT
ANCHOR
STD SPRT
30.5" I.D.
68.25" O.D.
BELLOWS LG
22"
18"
22"
1'-10"
69"
5'-9"
50"
4'-2"
54"
4'-6"
65"
5'-5"
71"
5'-11"
48"
4'-0"
60"
5'-0"
104"
8'-8"
136"
11'-4"
439"
36'-7"
+Datum-

TABLE OF CONTENTS

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
Spool B-2	0.0	0.0	230.4	230.4	51.5	1.000		Not applicable	0.000
CF CF w/14" od tube	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
Stiffener Rings					14.7				
30-1/2"id Flange	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
30-1/2" id Flange	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
Support Rings					14.7				
Support Ring					14.7				

Vessel MAWP hot & corroded is 0 psi @ 0 degrees F.

Vessel MAP new & cold is 0 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 22 psi

Vessel hydrotest pressure is 22 psi.

Weight Summary

Component	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Spool b-2	3075	3075	0	0	0	0	0	0	239	0	11580	8
30-1/2"id flang	1539	1539	0	0	0	0	0	0	0	0	0	0
30-1/2" id flan	1539	1539	0	0	0	0	0	0	0	0	0	0
	6153	6153	0	0	0	0	0	0	239	0	11580	8

Vessel operating weight, corroded: 6,400 lbs
Vessel empty weight, corroded: 6,400 lbs
Vessel empty weight, new: 6,400 lbs
Vessel test weight, new: 17,980 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 6,400 lbs
Center of gravity to seam: 219.9 in

Nozzle Summary

Nozzle mark	OD (in)	tn (in)	Req tn (in)	A1?	A2?	Nom t (in)	Req t (in)	User t (in)	Corr (in)	Aa/Ar (%)
CF	14.00	0.2500	0.0625	y	y	0.2500	0.1445	0.2500	0.0000	180.7

tn - nozzle thickness
Req tn - nozzle thickness required per UG-45/16
Nom t - vessel wall thickness
Req t - required vessel wall thickness due to pressure + corr per UG-37
User t - local vessel wall thickness (near opening)
Aa - area available per UG-37, governing condition
Ar - area required per UG-37, governing condition
Corr - corrosion allowance on nozzle id.

Nozzle Schedule

Nozzle mark	Service	Size	Materials Nozzle	Impact?	Norm?	Pad	Impact?	Norm?	Flange
CF	w/14" od tube	13.50 IDx0.25	SA 240 304L HIGH	n	n				

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
Spool b-2	30.50	439.00	0.2500	0.1444	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

Spool B-2

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder
Material specification:	SA 240 304L HIGH

External design pressure: Pe= 14.7 psi @ 400 deg F

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight:	new = 3074.7	corr = 3074.7	lb
capacity:	new = 1388.487	corr = 1388.487	US ga

ID = 30.5 length Lc= 439 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 230.4383 psi

MAWP: (Corroded & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 230.4383 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 71/31 =2.2903 Do/t = 31/0.14446 = 214.5923
From table G: A = 0.000181
From table HA-3: B = 2382.1

Pa= 4*B/(3*Do/t)
= 4*2382.1/(3*31/0.14446)
= 14.8008 psi

Design thickness for external pressure Pa = 14.8008 psi:

= t + Corrosion
= 0.14446 + 0
= 0.14446 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 71/31 =2.2903 Do/t = 31/0.25 = 124
From table G: A = 0.000404
From table HA-3: B = 4791.6

Pa = 4*B/(3*Do/t)
= 4*4791.6/(3*31/0.25)
= 51.5226 psi

CF w/14" od tube

Opening CF Reinforcement Calculations Per UG-37

Located on:	Spool B-2
User input vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	18.125 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	2.625 in

```
     tn ->| |<-
                                     corrosion allow = 0 in
           |¯||<- d ->|¯|            noz thick new tn= .25 in
twl->|  |<        |   |              nozzle id. new d= 13.5 in
     |/ |   v     |   |\             fillet weld twl = .25 in
_____.-| |_       |   |-.______      groove weld tw2 = .175 in
_____\|_|_tw2     |_|/______
          ^
<--- L --->|                         To datum L= 48 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*6.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*15.25/(16700*1 - 0.6*0)
= 0 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 =1
fr2 = lesser of 1 or Sn/Sv so fr2 =1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 3.375 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= 3.375 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= .25 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.25
= .313 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0)*1*0.25
= .313 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 3.375 + 0.313 + 0.063
= 3.751 in^2

As Area > A the reinforcement is adequate for MAWP = 0 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.175 in
t1 + t2 = 0.35 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.175*12358 = 47535.05 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
 = (0 - (13.5 - 2*0.25)*(1*0.25 - 1*0))*16700
 =-54275 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
 = (0.313 + 0 + 0.063 + 0)*16700
 = 6279.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
 = (0.313 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
 = 8366.7 lbf

Load for path 1-1 lesser of W or W1-1 =-54275 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 =-54275 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 47535.05 = 92500.64 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

CF w/14" od tube

Nozzle required thickness

L/Do = 2.625/14 = .1875 Do/t = 14/0.02904 = 482.0937
From table G: A = 0.000746
From table HA-3: B = 5337.6

Pa= 4*B/(3*Do/t)
= 4*5337.6/(3*14/0.02904)
= 14.7623 psi

Nozzle required thickness trn = .02904 in

Required thickness tr from UG-37(d)(1) = .1445 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 =1
fr2 = lesser of 1 or Sn/Sv so fr2 =1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.1445*1 + 2*0.25*0.1445*1*(1 - 1))
= .9754 in^2

Area available

A1 = larger of the following = 1.424 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1445) - 2*0.25*(1*0.25-1*0.1445)*(1-1)
= 1.424 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1445) - 2*0.25*(1*0.25-1*0.1445)*(1-1)
= .105 in^2

A2 = smaller of the following = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02904)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02904)*1*0.25
= .276 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.424 + 0.276 + 0.063
= 1.763 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02904 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

CF w/14" od tube

Applied Loads

Radial load	Pr = 2250 lbf
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress =-19254 psi
Allowable combined stress = +-3*S = +- 50100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-3663 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

CF w/14" od tube

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	1.5557	0.398					-911	-911	-911	-911
4C*	4.3911	0.398	-2570	-2570	-2570	-2570				
1C	0.0648	0.398					-13997	13997	-13997	13997
2C-1	0.0065	0.398	-1404	1404	-1404	1404				
3A*	1.3830	0.398					-267	-267	267	267
1A	0.0573	0.398					-4079	4079	4079	-4079
3B*	2.5018	0.398	-483	-483	483	483				
1B-1	0.0079	0.398	-562	562	562	-562				
pressure stress*										
Total circ stress			-5019	-1087	-2929	-1245	-19254	16898	-10562	9274
Primary membrane circ stress*			-3053	-3053	-2087	-2087	-1178	-1178	-644	-644
3C*	1.5557	0.398	-911	-911	-911	-911				
4C*	4.3911	0.398					-2570	-2570	-2570	-2570
1C-1	0.0160	0.398	-3456	3456	-3456	3456				
2C	0.0300	0.398					-6480	6480	-6480	6480
4A*	5.6652	0.398					-1093	-1093	1093	1093
2A	0.0227	0.398					-1616	1616	1616	-1616
4B*	1.4487	0.398	-279	-279	279	279				
2B-1	0.0158	0.398	-1125	1125	1125	-1125				
pressure stress*										
Total long stress			-5771	3391	-2963	1699	-11759	4433	-6341	3387
Primary membrane long stress*			-1190	-1190	-632	-632	-3663	-3663	-1477	-1477
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-5772	4478	-2975	2944	-19254	16898	-10562	9274

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Stiffener Rings
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		4
Distance first ring to datum line:		60 in
Ring spacing:		119 in
Ring description:		2x2x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	0.938 in^2
Ring moment of inertia:	Ir =	0.348 in^4

Calculations for ring 60 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	54 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14446 + 0.938/54))
= 2111.934

From table HA-3 (ring) A = 1.606581E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*54*(0.14446 + 0.938/54)*1.606581E-04)/10.9
= .1237808 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 54 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 179 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	68 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14446 + 0.938/68))
 = 2159.659

From table HA-3 (ring) A = 1.642538E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*68*(0.14446 + 0.938/68)*1.642538E-04)/10.9
 = .155839 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)

Stiffener Rings

= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 68 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2
= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 298 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	52 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14446 + 0.938/52))
= 2103.251

From table HA-3 (ring) A = 1.600038E-04

Required moment of inertia of the combined ring-shell section

Stiffener Rings

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*52*(0.14446 + 0.938/52)*1.600038E-04)/10.9
 = .119201 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
 = 1.1*Sqr(31*0.25)
 = 3.06227 in

W = Ls = 52 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 417 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	45.5 in

Stiffener Rings

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14446 + 0.938/45.5))
= 2070.418

From table HA-3 (ring) A = 1.575296E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*45.5*(0.14446 + 0.938/45.5)*1.575296E-04)/10.9
= .1043164 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 45.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2
= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Rings

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Rings
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		108 in
Ring spacing:		136 in
Ring description:		3x3x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.44 in^2
Ring moment of inertia:	Ir =	1.24 in^4

Calculations for ring 108 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14446 + 1.44/59.5))
= 2026.394

From table HA-3 (ring) A = 1.542115E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*59.5*(0.14446 + 1.44/59.5)*1.542115E-04)/10.9
= .1364417 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 2.158 + 0.25/2
 = 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 1.44*2.283/(0.7655676 + 1.44)
 = 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*1.490555^2
 = 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 1.24 + 1.44*(1.490555 - 2.283)^2
 = 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 244 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14446 + 1.44/59.5))
 = 2026.394

From table HA-3 (ring) A = 1.542115E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*59.5*(0.14446 + 1.44/59.5)*1.542115E-04)/10.9
 = .1364417 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)

= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 2.158 + 0.25/2
= 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.44*2.283/(0.7655676 + 1.44)
= 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*1.490555^2
= 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 1.24 + 1.44*(1.490555 - 2.283)^2
= 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Ring

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Ring
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		1
Distance first ring to datum line:		348 in
Ring description:		3x3x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.44 in^2
Ring moment of inertia:	Ir =	1.24 in^4

Calculations for ring 348 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14446 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14446 + 1.44/59.5))
 = 2026.394

From table HA-3 (ring) A = 1.542115E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*59.5*(0.14446 + 1.44/59.5)*1.542115E-04)/10.9
 = .1364417 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
 = 1.1*Sqr(31*0.25)
 = 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2

= 2.158 + 0.25/2
= 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.44*2.283/(0.7655676 + 1.44)
= 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*1.490555^2
= 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 1.24 + 1.44*(1.490555 - 2.283)^2
= 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Bellows Lugs

Lug material specification		= SA 240 304L High
Lug allowable stress		= 24000 psi
Top plate width	wp	= 2 in
Base plate width	wb	= 6 in
Top plate thickness	t	= 0.375 in
Base plate thickness	tb	= 0.375 in
Lug length circ. direction	L	= 6 in
Gusset height	h	= 6 in
Gusset thickness	tg	= 0.375 in
Number of lugs		= 4
Angular position, first lug		= 90 degrees
Fillet weld size	tw	= 0.25 in
Force bearing width	Fb	= 3 in
Distance to load	d	= 4.5 in

Refer to Calculation V049-1-084 for final design of Bellows Lugs.

Lug top plate required thickness, Bednar pg 153

ta = 0.75*(VL*d*L)/(Sa*wp^2*h)
= 0.75*(1604*4.5*6)/(24000*2^2*6)
= 0.25 in

Lug gusset required thickness

Sc = 18000/(1 + (1/18000)*(h/(0.289*tg))^2)
= 18000/(1 + (1/18000)*(6/(0.289*0.375))^2)
= 15380.89 psi

tg = VL*(3*d - wb)/(Sc*wb^2*SIN(Alpha)^2)
= 1604*(3*4.5 - 6)/(15380.89*6^2*SIN(56.31)^2)
= 0.0314 in

Lug base plate required thickness

From Escoe table 4-8

fc = VL/(Fb*L) = 89.11111 psi

Mx = Cx*fc*Gs^2
= 0.1085*89.11111*5.25^2 = 266.4896

My = Cy*fc*wb^2
= -.124*89.11111*6^2 =-397.792

tb = Sqr(6*Mmax / Sa)
= Sqr(6*397.792 / 24000)
= 0.3154 in

Check lug attachment stresses

Radial load	Pr =	0 lbf
Circumferential moment	Mc =	0 lbf-ft
Circumferential shear	Vc =	0 lbf

Bellows Lugs

Longitudinal moment ML =0 lbf-ft
Longitudinal shear VL = 1604 lbf
Internal pressure P = 0 psi

Stresses at the lug edge per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

C1 = 3, C2 = 3.375 in

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Local circ. pressure stress = P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress = 950 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 0 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Bellows Lugs

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.9083	0.222								
4C*	7.5544	0.213								
1C	0.0648	0.203								
2C-1	0.0257	0.203								
3A*	2.3818	0.203								
1A	0.0649	0.223								
3B*	5.3623	0.211								
1B-1	0.0191	0.208								
pressure stress*										
Total circ stress										
Primary membrane circ stress*										
3C*	4.1149	0.213								
4C*	7.3854	0.222								
1C-1	0.0500	0.215								
2C	0.0334	0.215								
4A*	5.3293	0.203								
2A	0.0274	0.237								
4B*	2.3936	0.211								
2B-1	0.0268	0.226								
pressure stress*										
Total long stress										
Primary membrane long stress*										
torsion moment Mt										
Circ shear from Vc										
Long shear from VL							-475	-475	475	475
Total Shear stress							-475	-475	475	475
Combined stress							950	950	950	950

Bellows Lugs

Lug material specification	= SA 240 304L High
Lug allowable stress	= 24000 psi
Top plate width	wp = 2 in
Base plate width	wb = 6 in
Top plate thickness	t = 0.375 in
Base plate thickness	tb = 0.375 in
Lug length circ. direction	L = 6 in
Gusset height	h = 6 in
Gusset thickness	tg = 0.375 in
Number of lugs	= 4
Angular position, first lug	= 90 degrees
Fillet weld size	tw = 0.25 in
Force bearing width	Fb = 3 in
Distance to load	d = 4.5 in

REFER TO CALCULATION V049-1-084 FOR FINAL DESIGN OF BELLOWS LUGS

Lug top plate required thickness, Bednar pg 153

ta = 0.75*(VL*d*L)/(Sa*wp^2*h)
= 0.75*(1604*4.5*6)/(24000*2^2*6)
= 0.25 in

Lug gusset required thickness

Sc = 18000/(1 + (1/18000)*(h/(0.289*tg))^2)
= 18000/(1 + (1/18000)*(6/(0.289*0.375))^2)
= 15380.89 psi

tg = VL*(3*d - wb)/(Sc*wb^2*SIN(Alpha)^2)
= 1604*(3*4.5 - 6)/(15380.89*6^2*SIN(56.31)^2)
= 0.0314 in

Lug base plate required thickness

From Escoe table 4-8

fc = VL/(Fb*L) = 89.11111 psi

Mx = Cx*fc*Gs^2
= 0.1085*89.11111*5.25^2 = 266.4896

My = Cy*fc*wb^2
= -.124*89.11111*6^2 =-397.792

tb = Sqr(6*Mmax / Sa)
= Sqr(6*397.792 / 24000)
= 0.3154 in

Check lug attachment stresses

Radial load	Pr = 0 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf

Bellows Lugs

Longitudinal moment ML = 0 lbf-ft
Longitudinal shear VL = 1604 lbf
Internal pressure P = 0 psi

Stresses at the lug edge per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

C1 = 3, C2 = 3.375 in

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Local circ. pressure stress = P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress = 950 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 0 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Bellows Lugs

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.9083	0.222								
4C*	7.5544	0.213								
1C	0.0648	0.203								
2C-1	0.0257	0.203								
3A*	2.3818	0.203								
1A	0.0649	0.223								
3B*	5.3623	0.211								
1B-1	0.0191	0.208								
pressure stress*										
Total circ stress										
Primary membrane circ stress*										
3C*	4.1149	0.213								
4C*	7.3854	0.222								
1C-1	0.0500	0.215								
2C	0.0334	0.215								
4A*	5.3293	0.203								
2A	0.0274	0.237								
4B*	2.3936	0.211								
2B-1	0.0268	0.226								
pressure stress*										
Total long stress										
Primary membrane long stress*										
torsion moment Mt										
Circ shear from Vc										
Long shear from VL							-475	-475	475	475
Total Shear stress							-475	-475	475	475
Combined stress							950	950	950	950

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-055 PAGE 1 OF 41
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0131	4/19/96	WDB	RDC	**SPOOL B-3 (30 in)**	
					BY: W. Bilyeu	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool/adapter shell thickness. Additionally when applicable, evaluate nozzle opening(s), calculate size and spacing of stiffener rings and support rings.

METHOD: Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.31.

ASSUMPTIONS: None

INPUTS:
1. Vacuum Pressure = 14.7 psi
2. Design Temperature = 400 F.
3. Ion Pump Nozzle Loads

   Pr = 2250.0 lbs

   Mc = Ml = 4542.0 in-lbs

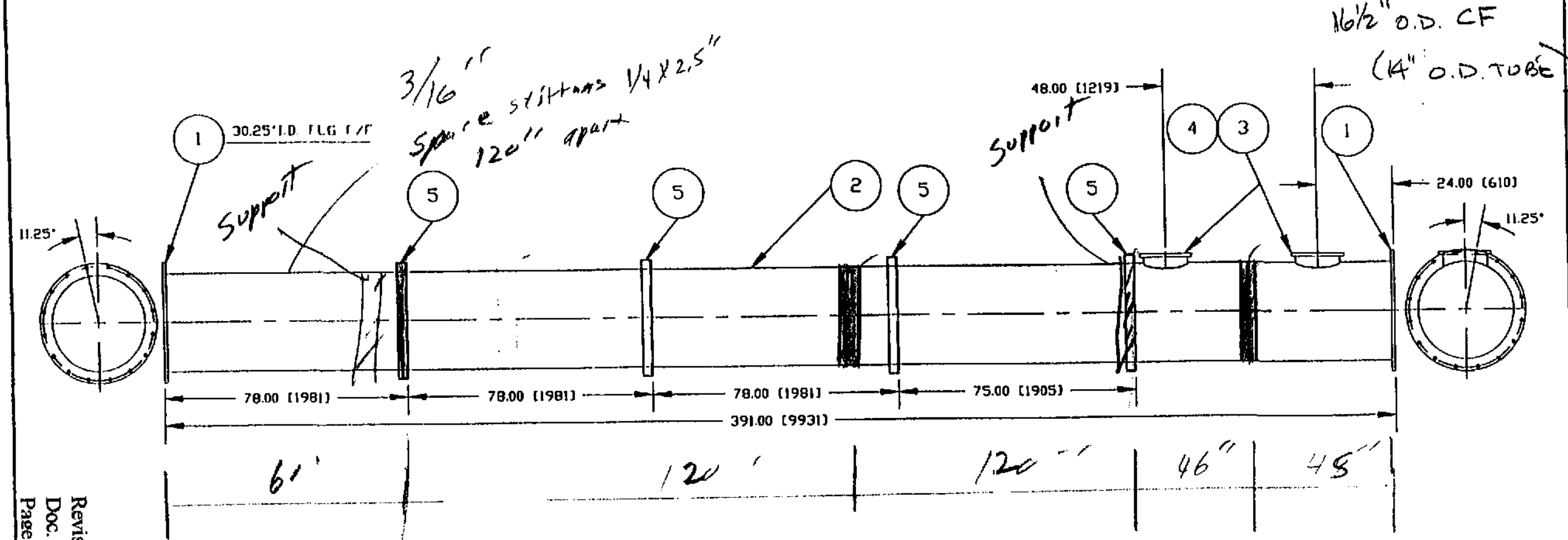
   Vc = Vl = 126.5 lbs

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.31, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-066, LIGO Vacuum Equip Struct. Design Criteria

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The requirements of the ASME Code are met for spool B-3 outer shell.

NOTES: Flanges were included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, 019.& 051



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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR MACH ±0°-30' BEND ±2°
TWO PLACE DECIMAL ± .010
THREE PLACE DECIMAL ± .005
FINISHED SURFACE ...
BREAK CORNERS ... OUT-
REMOVE ALL BURRS

DO NOT SCALE THIS DWG
USED ON
NEXT ASS'Y:

REV	DESCRIPTION	CHKD	DRWN	DATE	DED#
X	X		X	X	X

ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

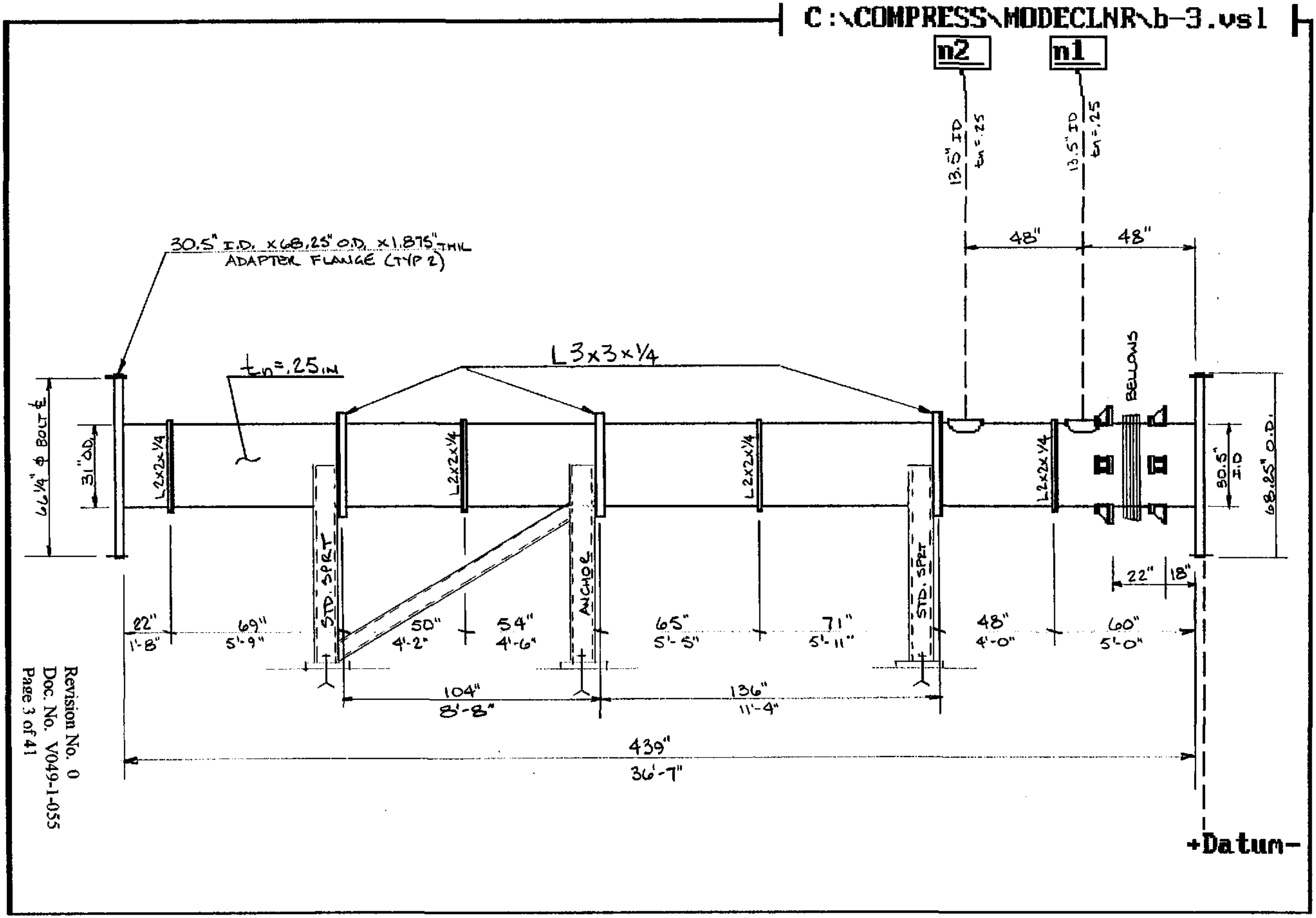
SPOOL B-3
30"
LIGO VACUUM EQUIPMENT

CAD FILE	SIZE	DWG NO.	REV.
B3	B	V049-4-B3	0

SCALE 3/8"=1'-0" SHEET 1 OF 1

4 3 2 1

Dec 19, 1995 - 10:33:27



C:\COMPRESS\MODECLNR\b-3.vsl
n2
n1
13.5" ID
t_n=.25
13.5" ID
t_n=.25
48"
48"
30.5" I.D. x 68.25" O.D. x 1.875" THK
ADAPTER FLANGE (TYP 2)
t_n=.25 IN
L3x3x1/4
BELLOWS
66 1/4" Φ BOLT ℄
31" O.D.
L2x2x1/4
L2x2x1/4
L2x2x1/4
L2x2x1/4
30.5" I.D
68.25" O.D.
STD. SPRT
ANCHOR
STD. SPRT
22"
18"
22"
1'-8"
69"
5'-9"
50"
4'-2"
54"
4'-6"
65"
5'-5"
71"
5'-11"
48"
4'-0"
60"
5'-0"
104"
8'-8"
136"
11'-4"
439"
36'-7"
+Datum-

TABLE OF CONTENTS

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
Spool B-3	0.0	0.0	230.4	230.4	51.5	1.000		Not applicable	0.000
30.50"id FLNG	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
30.50"id FLNG	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
n1 16-1/2"od CF	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n2 16-1/2"od CF	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
Stiffner Rings					14.7				
Support Rings					14.7				
Support Ring					14.7				

Vessel MAWP hot & corroded is 0 psi @ 0 degrees F.

Vessel MAP new & cold is 0 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 22 psi

Vessel hydrotest pressure is 22 psi.

Weight Summary

Component	Weight (lbs) Contributed by Vessel Elements										
	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Spool b-3	3075	3075	0	0	0	0	0	0	239	0	11580	17
30.50"id flng	1539	1539	0	0	0	0	0	0	0	0	0	0
30.50"id flng	1539	1539	0	0	0	0	0	0	0	0	0	0
	6153	6153	0	0	0	0	0	0	239	0	11580	17

Vessel operating weight, corroded: 6,409 lbs
Vessel empty weight, corroded: 6,409 lbs
Vessel empty weight, new: 6,409 lbs
Vessel test weight, new: 17,989 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 6,410 lbs
Center of gravity to seam: 219.5 in

Nozzle Summary

Nozzle mark	OD (in)	tn (in)	Req tn (in)	A1?	A2?	Nom t (in)	Req t (in)	User t (in)	Corr (in)	Aa/Ar (%)
n1	14.00	0.2500	0.0625	y	y	0.2500	0.1450	0.2500	0.0000	179.5
n2	14.00	0.2500	0.0625	y	y	0.2500	0.1450	0.2500	0.0000	179.5

tn - nozzle thickness
Req tn - nozzle thickness required per UG-45/16
Nom t - vessel wall thickness
Req t - required vessel wall thickness due to pressure + corr per UG-37
User t - local vessel wall thickness (near opening)
Aa - area available per UG-37, governing condition
Ar - area required per UG-37, governing condition
Corr - corrosion allowance on nozzle id.

Nozzle Schedule

Nozzle mark	Service	Size	Materials Nozzle	Impact?	Norm?	Pad	Impact?	Norm?	Flange
n1	16-1/2"od cf	13.50 IDx0.25	SA 240 304L HIGH	n	n				
n2	16-1/2"od cf	13.50 IDx0.25	SA 240 304L HIGH	n	n				

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
Spool b-3	30.50	439.00	0.2500	0.1449	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

Spool B-3

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: Cylinder
Material specification: SA 240 304L HIGH

External design pressure: Pe= 14.7 psi @ 400 deg F

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight: new = 3074.7 corr = 3074.7 lb
capacity: new = 1388.487 corr = 1388.487 US ga

ID = 30.5 length Lc= 439 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 230.4383 psi

MAWP: (Corroded & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 230.4383 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 71/31 =2.2903 Do/t = 31/0.14496 = 213.8521
From table G: A = 0.000182
From table HA-3: B = 2395.3

Pa= 4*B/(3*Do/t)
= 4*2395.3/(3*31/0.14496)
= 14.9343 psi

Design thickness for external pressure Pa = 14.9343 psi:

= t + Corrosion
= 0.14496 + 0
= 0.14496 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 71/31 =2.2903 Do/t = 31/0.25 = 124
From table G: A = 0.000404
From table HA-3: B = 4791.6

Spool B-3

Pa= 4*B/(3*Do/t)
= 4*4791.6/(3*31/0.25)
= 51.5226 psi

16-1/2"od CF

Opening n1 Reinforcement Calculations Per UG-37

Located on:	Spool B-3
User input vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	18.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	2.75 in

```
  tn ->| |<-
        _         _
       | |<- d ->| |          corrosion allow = 0 in
twl->| |<         | |         noz thick new tn= .25 in
     |/| v        | |\        nozzle id. new d= 13.5 in
_____.-| -        | |-._____  fillet weld twl = .25 in
_____\|_|_tw2     |_|/_____   groove weld tw2 = .1875 in
         ^
<---- L ---->|                To datum L= 48 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*6.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr = P*R/(S*E - 0.6*P)
= 0*15.25/(16700*1 - 0.6*0)
= 0 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 3.375 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= 3.375 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= .25 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.25
= .313 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0)*1*0.25
= .313 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 3.375 + 0.313 + 0.063
= 3.751 in^2

As Area > A the reinforcement is adequate for MAWP = 0 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*12358 = 50930.41 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
 = (0 - (13.5 - 2*0.25)*(1*0.25 - 1*0))*16700
 =-54275 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
 = (0.313 + 0 + 0.063 + 0)*16700
 = 6279.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
 = (0.313 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
 = 8366.7 lbf

Load for path 1-1 lesser of W or W1-1 =-54275 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 =-54275 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 50930.41 = 95896 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 2.75/14 = .1964 Do/t = 14/0.02915 = 480.2744
From table G: A = 0.000712
From table HA-3: B = 5294

Pa= 4*B/(3*Do/t)
= 4*5294/(3*14/0.02915)
= 14.6972 psi

Nozzle required thickness trn = .02915 in

Required thickness tr from UG-37(d)(1) = .145 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 =1
fr2 = lesser of 1 or Sn/Sv so fr2 =1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.145*1 + 2*0.25*0.145*1*(1 - 1))
= .9787 in^2

Area available

A1 = larger of the following = 1.418 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.145) - 2*0.25*(1*0.25-1*0.145)*(1-1)
= 1.418 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.145) - 2*0.25*(1*0.25-1*0.145)*(1-1)
= .105 in^2

A2 = smaller of the following = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02915)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02915)*1*0.25
= .276 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.418 + 0.276 + 0.063
= 1.757 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02915 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

16-1/2"od CF

Applied Loads

Radial load	Pr = 2250 lbf
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress =-19254 psi
Allowable combined stress = +-3*S = +- 50100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-3663 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

16-1/2"od CF

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	1.5557	0.398					-911	-911	-911	-911
4C*	4.3911	0.398	-2570	-2570	-2570	-2570				
1C	0.0648	0.398					-13997	13997	-13997	13997
2C-1	0.0065	0.398	-1404	1404	-1404	1404				
3A*	1.3830	0.398					-267	-267	267	267
1A	0.0573	0.398					-4079	4079	4079	-4079
3B*	2.5018	0.398	-483	-483	483	483				
1B-1	0.0079	0.398	-562	562	562	-562				
pressure stress*										
Total circ stress			-5019	-1087	-2929	-1245	-19254	16898	-10562	9274
Primary membrane circ stress*			-3053	-3053	-2087	-2087	-1178	-1178	-644	-644
3C*	1.5557	0.398	-911	-911	-911	-911				
4C*	4.3911	0.398					-2570	-2570	-2570	-2570
1C-1	0.0160	0.398	-3456	3456	-3456	3456				
2C	0.0300	0.398					-6480	6480	-6480	6480
4A*	5.6652	0.398					-1093	-1093	1093	1093
2A	0.0227	0.398					-1616	1616	1616	-1616
4B*	1.4487	0.398	-279	-279	279	279				
2B-1	0.0158	0.398	-1125	1125	1125	-1125				
pressure stress*										
Total long stress			-5771	3391	-2963	1699	-11759	4433	-6341	3387
Primary membrane long stress*			-1190	-1190	-632	-632	-3663	-3663	-1477	-1477
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-5772	4478	-2975	2944	-19254	16898	-10562	9274

16-1/2"od CF

Opening n2 Reinforcement Calculations Per UG-37

Located on:	Spool B-3
User input vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	18.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	2.75 in

```
  tn ->| |<-
        _   _           _
       | |<- d ->|       | |
twl->| |<                 
     |/| | v     |       | |\
_____.-| |-      |       | |-._____
_____\|_|_tw2    |_|/______
          ^
<--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .25 in
nozzle id. new d= 13.5 in
fillet weld twl = .25 in
groove weld tw2 = .1875 in

To datum L= 96 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*6.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*15.25/(16700*1 - 0.6*0)
= 0 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 =1
fr2 = lesser of 1 or Sn/Sv so fr2 =1

16-1/2"od CF

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 3.375 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= 3.375 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= .25 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.25
= .313 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0)*1*0.25
= .313 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 3.375 + 0.313 + 0.063
= 3.751 in^2

As Area > A the reinforcement is adequate for MAWP = 0 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

16-1/2"od CF

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*12358 = 50930.41 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (13.5 - 2*0.25)*(1*0.25 - 1*0))*16700
=-54275 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.313 + 0 + 0.063 + 0)*16700
= 6279.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.313 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 8366.7 lbf

Load for path 1-1 lesser of W or W1-1 =-54275 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 =-54275 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 50930.41 = 95896 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

16-1/2"od CF

Nozzle required thickness

L/Do = 2.75/14 = .1964 Do/t = 14/0.02915 = 480.2744
From table G: A = 0.000712
From table HA-3: B = 5294

Pa= 4*B/(3*Do/t)
= 4*5294/(3*14/0.02915)
= 14.6972 psi

Nozzle required thickness trn = .02915 in

Required thickness tr from UG-37(d)(1) = .145 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 =1
fr2 = lesser of 1 or Sn/Sv so fr2 =1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.145*1 + 2*0.25*0.145*1*(1 - 1))
= .9787 in^2

Area available

A1 = larger of the following = 1.418 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.145) - 2*0.25*(1*0.25-1*0.145)*(1-1)
= 1.418 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.145) - 2*0.25*(1*0.25-1*0.145)*(1-1)
= .105 in^2

A2 = smaller of the following = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02915)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02915)*1*0.25
= .276 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.418 + 0.276 + 0.063
= 1.757 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02915 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

16-1/2"od CF

Applied Loads

Radial load	Pr = 2250 lbf
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress =-19254 psi
Allowable combined stress = +-3*S = +- 50100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-3663 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

16-1/2"od CF

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	1.5557	0.398					-911	-911	-911	-911
4C*	4.3911	0.398	-2570	-2570	-2570	-2570				
1C	0.0648	0.398					-13997	13997	-13997	13997
2C-1	0.0065	0.398	-1404	1404	-1404	1404				
3A*	1.3830	0.398					-267	-267	267	267
1A	0.0573	0.398					-4079	4079	4079	-4079
3B*	2.5018	0.398	-483	-483	483	483				
1B-1	0.0079	0.398	-562	562	562	-562				
pressure stress*										
Total circ stress			-5019	-1087	-2929	-1245	-19254	16898	-10562	9274
Primary membrane circ stress*			-3053	-3053	-2087	-2087	-1178	-1178	-644	-644
3C*	1.5557	0.398	-911	-911	-911	-911				
4C*	4.3911	0.398					-2570	-2570	-2570	-2570
1C-1	0.0160	0.398	-3456	3456	-3456	3456				
2C	0.0300	0.398					-6480	6480	-6480	6480
4A*	5.6652	0.398					-1093	-1093	1093	1093
2A	0.0227	0.398					-1616	1616	1616	-1616
4B*	1.4487	0.398	-279	-279	279	279				
2B-1	0.0158	0.398	-1125	1125	1125	-1125				
pressure stress*										
Total long stress			-5771	3391	-2963	1699	-11759	4433	-6341	3387
Primary membrane long stress*			-1190	-1190	-632	-632	-3663	-3663	-1477	-1477
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-5772	4478	-2975	2944	-19254	16898	-10562	9274

Stiffner Rings

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Stiffner Rings
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		4
Distance first ring to datum line:		60 in
Ring spacing:		119 in
Ring description:		2x2x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	0.938 in^2
Ring moment of inertia:	Ir =	0.348 in^4

Calculations for ring 60 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	56.27083 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14496 + 0.938/56.27083))
 = 2114.56

From table HA-3 (ring) A = 1.60856E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*56.27083*(0.14496 + 0.938/56.27083)*1.60856E-04)/10.9
 = .1289846 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
 = 1.1*Sqr(31*0.25)
 = 3.06227 in

W = Ls = 56.27083 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Stiffner Rings

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 179 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	68 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14496 + 0.938/68))
 = 2152.857

From table HA-3 (ring) A = 1.637414E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*68*(0.14496 + 0.938/68)*1.637414E-04)/10.9
 = .1558437 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)

= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 68 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2
= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 298 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	52 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14496 + 0.938/52))
= 2096.799

From table HA-3 (ring) A = 1.595176E-04

Required moment of inertia of the combined ring-shell section

Stiffner Rings

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*52*(0.14496 + 0.938/52)*1.595176E-04)/10.9
 = .1192045 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
 = 1.1*Sqr(31*0.25)
 = 3.06227 in

W = Ls = 52 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 417 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	45.5 in

Stiffner Rings

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14496 + 0.938/45.5))
= 2064.166

From table HA-3 (ring) A = 1.570584E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*45.5*(0.14496 + 0.938/45.5)*1.570584E-04)/10.9
= .1043195 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 45.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2
= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Rings

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Rings
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		108 in
Ring spacing:		136 in
Ring description:		3x3x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.44 in^2
Ring moment of inertia:	Ir =	1.24 in^4

Calculations for ring 108 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14496 + 1.44/59.5))
= 2020.404

From table HA-3 (ring) A = 1.5376E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*59.5*(0.14496 + 1.44/59.5)*1.5376E-04)/10.9
= .1364455 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Support Rings

Y2 = Ring NA + ts/2
 = 2.158 + 0.25/2
 = 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 1.44*2.283/(0.7655676 + 1.44)
 = 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*1.490555^2
 = 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 1.24 + 1.44*(1.490555 - 2.283)^2
 = 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 244 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*31/(0.14496 + 1.44/59.5))
 = 2020.404

From table HA-3 (ring) A = 1.5376E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (31^2*59.5*(0.14496 + 1.44/59.5)*1.5376E-04)/10.9
 = .1364455 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)

Support Rings

= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 2.158 + 0.25/2
= 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.44*2.283/(0.7655676 + 1.44)
= 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*1.490555^2
= 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 1.24 + 1.44*(1.490555 - 2.283)^2
= 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Ring

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Ring
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		1
Distance first ring to datum line:		348 in
Ring description:		3x3x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.44 in^2
Ring moment of inertia:	Ir =	1.24 in^4

Calculations for ring 348 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14496 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	59.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14496 + 1.44/59.5))
= 2020.404

From table HA-3 (ring) A = 1.5376E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*59.5*(0.14496 + 1.44/59.5)*1.5376E-04)/10.9
= .1364455 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 59.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2

= 2.158 + 0.25/2
= 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.44*2.283/(0.7655676 + 1.44)
= 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*1.490555^2
= 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 1.24 + 1.44*(1.490555 - 2.283)^2
= 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Bellows Lugs

REFER TO CALCULATION V049-1-084 FOR FINAL DESIGN OF BELLOWS LUGS

Lug material specification		= SA 204 340L High
Lug allowable stress		= 24000 psi
Top plate width	wp	= 2 in
Base plate width	wb	= 6 in
Top plate thickness	t	= 0.375 in
Base plate thickness	tb	= 0.375 in
Lug length circ. direction	L	= 6 in
Gusset height	h	= 6 in
Gusset thickness	tg	= 0.375 in
Number of lugs		= 4
Angular position, first lug		= 90 degrees
Fillet weld size	tw	= 0.25 in
Force bearing width	Fb	= 3 in
Distance to load	d	= 4.5 in

Lug top plate required thickness, Bednar pg 153

ta = 0.75*(VL*d*L)/(Sa*wp^2*h)
= 0.75*(1604*4.5*6)/(24000*2^2*6)
= 0.25 in

Lug gusset required thickness

Sc = 18000/(1 + (1/18000)*(h/(0.289*tg))^2)
= 18000/(1 + (1/18000)*(6/(0.289*0.375))^2)
= 15380.89 psi

tg = VL*(3*d - wb)/(Sc*wb^2*SIN(Alpha)^2)
= 1604*(3*4.5 - 6)/(15380.89*6^2*SIN(56.31)^2)
= 0.0314 in

Lug base plate required thickness

From Escoe table 4-8

fc = VL/(Fb*L) = 89.11111 psi

Mx = Cx*fc*Gs^2
= 0.1085*89.11111*5.25^2 = 266.4896

My = Cy*fc*wb^2
= -.124*89.11111*6^2 =-397.792

tb = Sqr(6*Mmax / Sa)
= Sqr(6*397.792 / 24000)
= 0.3154 in

Check lug attachment stresses

Radial load	Pr = 0 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf

Bellows Lugs

Longitudinal moment ML = 0 lbf-ft
Longitudinal shear VL = 1604 lbf
Internal pressure P = 0 psi

Stresses at the lug edge per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

C1 = 3, C2 = 3.375 in

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Local circ. pressure stress = P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress = 950 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 0 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Bellows Lugs

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.9083	0.222								
4C*	7.5544	0.213								
1C	0.0648	0.203								
2C-1	0.0257	0.203								
3A*	2.3818	0.203								
1A	0.0649	0.223								
3B*	5.3623	0.211								
1B-1	0.0191	0.208								
pressure stress*										
Total circ stress										
Primary membrane circ stress*										
3C*	4.1149	0.213								
4C*	7.3854	0.222								
1C-1	0.0500	0.215								
2C	0.0334	0.215								
4A*	5.3293	0.203								
2A	0.0274	0.237								
4B*	2.3936	0.211								
2B-1	0.0268	0.226								
pressure stress*										
Total long stress										
Primary membrane long stress*										
torsion moment Mt										
Circ shear from Vc										
Long shear from VL							-475	-475	475	475
Total Shear stress							-475	-475	475	475
Combined stress							950	950	950	950

Bellows lugs

Lug material specification	= SA 204 340L High
Lug allowable stress	= 24000 psi
Top plate width	wp = 2 in
Base plate width	wb = 6 in
Top plate thickness	t = 0.375 in
Base plate thickness	tb = 0.375 in
Lug length circ. direction	L = 6 in
Gusset height	h = 6 in
Gusset thickness	tg = 0.375 in
Number of lugs	= 4
Angular position, first lug	= 90 degrees
Fillet weld size	tw = 0.25 in
Force bearing width	Fb = 3 in
Distance to load	d = 4.5 in

REFER TO CALCULATION V049-1-084 FOR FINAL DESIGN OF LUGS

Lug top plate required thickness, Bednar pg 153

ta = 0.75*(VL*d*L)/(Sa*wp^2*h)
= 0.75*(1604*4.5*6)/(24000*2^2*6)
= 0.25 in

Lug gusset required thickness

Sc = 18000/(1 + (1/18000)*(h/(0.289*tg))^2)
= 18000/(1 + (1/18000)*(6/(0.289*0.375))^2)
= 15380.89 psi

tg = VL*(3*d - wb)/(Sc*wb^2*SIN(Alpha)^2)
= 1604*(3*4.5 - 6)/(15380.89*6^2*SIN(56.31)^2)
= 0.0314 in

Lug base plate required thickness

From Escoe table 4-8

fc = VL/(Fb*L) = 89.11111 psi

Mx = Cx*fc*Gs^2
= 0.1085*89.11111*5.25^2 = 266.4896

My = Cy*fc*wb^2
= -.124*89.11111*6^2 =-397.792

tb = Sqr(6*Mmax / Sa)
= Sqr(6*397.792 / 24000)
= 0.3154 in

Check lug attachment stresses

Radial load	Pr = 0 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf

Bellows lugs

Longitudinal moment	ML = 0 lbf-ft
Longitudinal shear	VL = 1604 lbf
Internal pressure	P = 0 psi

Stresses at the lug edge per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

C1 = 3, C2 = 3.375 in

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Local circ. pressure stress = P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress = 950 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 0 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Bellows lugs

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.9083	0.222								
4C*	7.5544	0.213								
1C	0.0648	0.203								
2C-1	0.0257	0.203								
3A*	2.3818	0.203								
1A	0.0649	0.223								
3B*	5.3623	0.211								
1B-1	0.0191	0.208								
pressure stress*										
Total circ stress										
Primary membrane circ stress*										
3C*	4.1149	0.213								
4C*	7.3854	0.222								
1C-1	0.0500	0.215								
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2A	0.0274	0.237								
4B*	2.3936	0.211								
2B-1	0.0268	0.226								
pressure stress*										
Total long stress										
Primary membrane long stress*										
torsion moment Mt										
Circ shear from Vc										
Long shear from VL							-475	-475	475	475
Total Shear stress							-475	-475	475	475
Combined stress							950	950	950	950

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-056 PAGE 1 OF 20
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0136	4/23/96	WDB	RPC	**SPOOL B-4 (48 in)**	
1	0293	8/15/96	WDB	RDC		
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool shell thickness. Additionally, evaluate the nozzle opening, additionally, check the adequacy of the bolted flange connection at the gate valve

METHOD:

Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.53.

ASSUMPTIONS: None

INPUTS:

1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400° F.
3. Ion Pump 16"CF Nozzle Loads

   P_R = 4354.0 lbf; $M_C = M_L$ = 378.5 in-lbf; $V_C = V_L$ = 126.5 lbf

   REF: Doc No V049-1-045

REFERENCES:

1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels
2. COMPRESS 5.53, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. Doc. No. V049-1-066 LIGO Equipment Structural Design Criteria

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS:

The requirements of the ASME Code are met for spool B-4's outer shell. The bolted flange connection at the gate valve is acceptable.

NOTES: Flanges were included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, & 019.

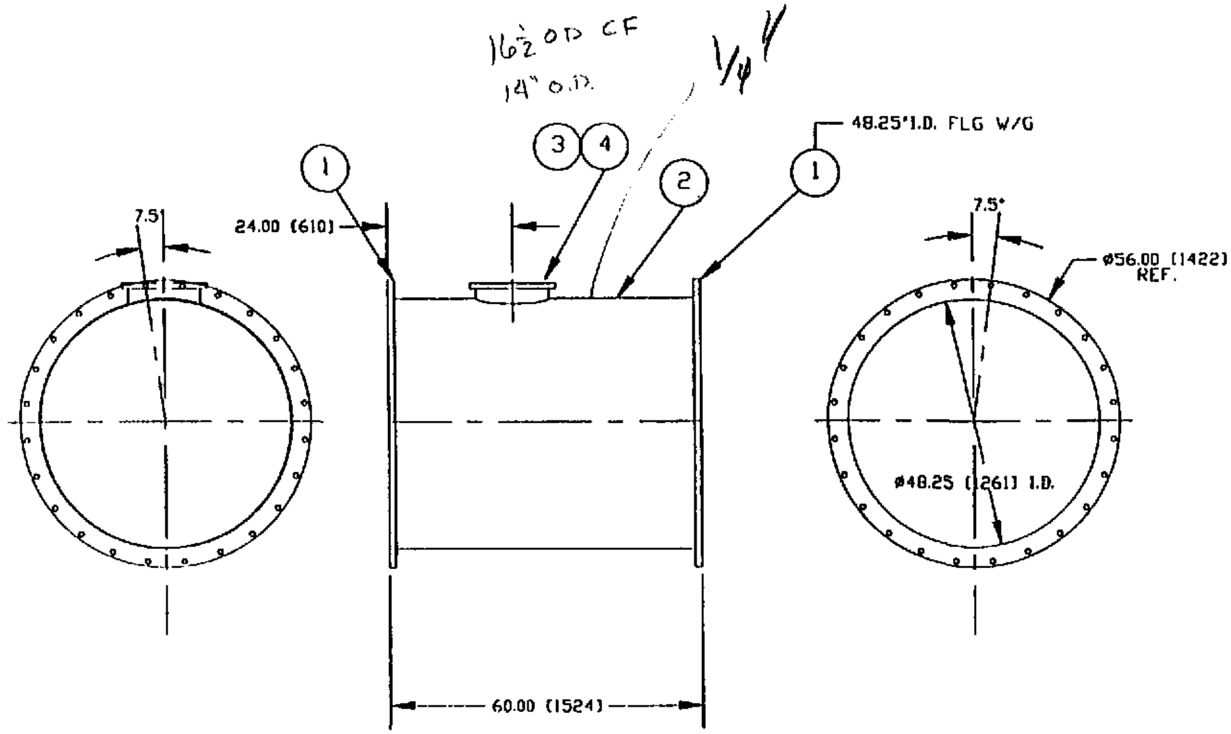
TABLE OF CONTENTS

REVISION HISTORY

Rev. 0 Original Issue
April 23, 1996

Rev. 1 Issue Date
August 15, 1996

- Revised the loading on the 16"CF nozzle, incorporating;
  valve weight + vacuum force
- Recalculated the local and primary membrane stresses at the nozzle
- Revised the calculation which checked the bolting at the gate valve's flange connection.



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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH 10°-30° BEND 1/2°
TWO PLACE DECIMAL ± .010
THREE PLACE DECIMAL ± .005
FINISHED SURFACE RMS
BREAK CORNERS: IN OUT:
REMOVE ALL BURRS

DO NOT SCALE THIS DWG
USED ON:
NEXT ASS'Y:

REV	DESCRIPTION					CHKD	DRWN	DATE	DEDI
X	X					X	X	X	X

ISSUE DESCRIPTION

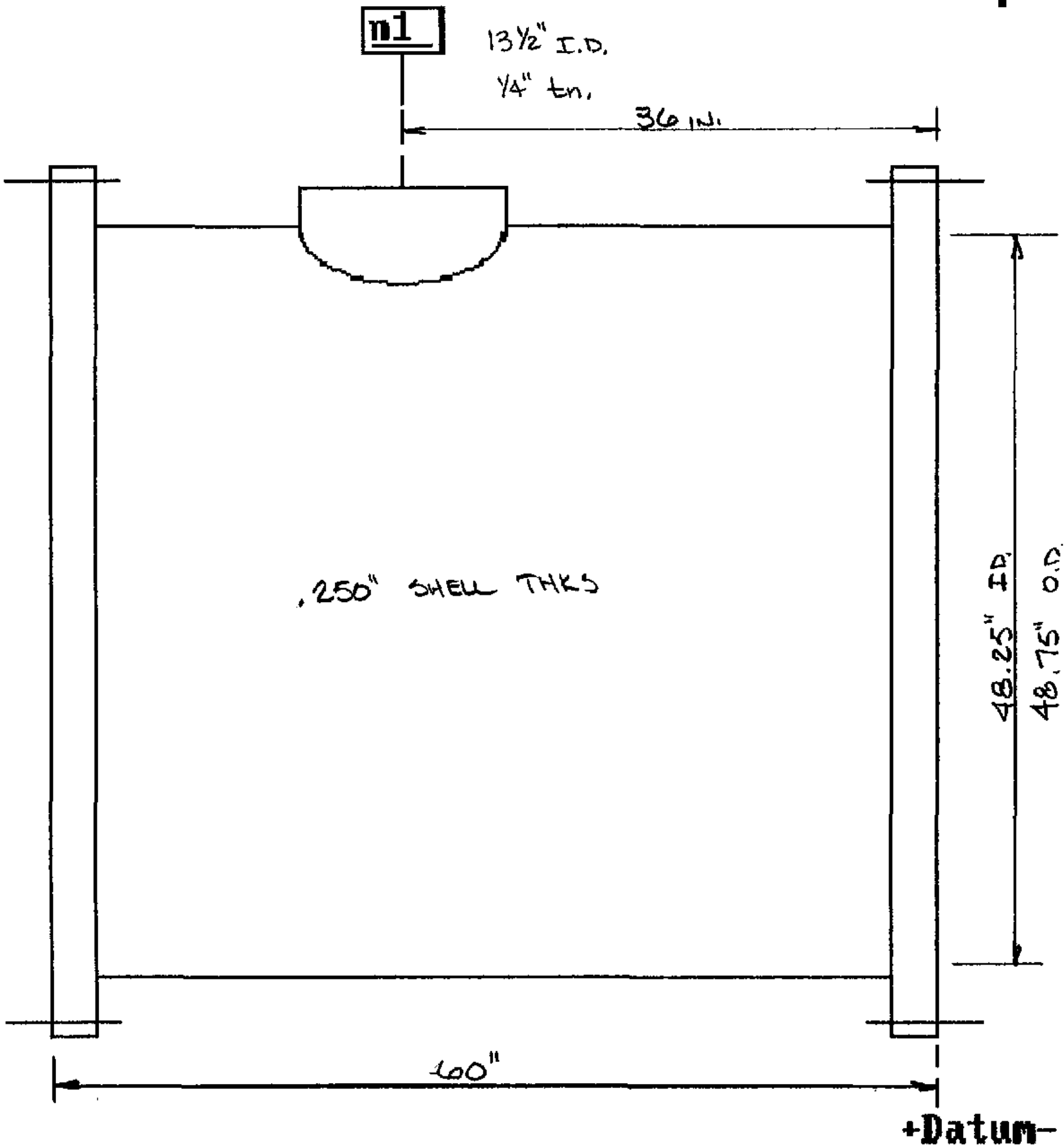
PROCESS SYSTEMS INTERNATIONAL INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

SPOOL B-4
48"
LIGO VACUUM EQUIPMENT

CAD FILE	SIZE	DWG NO	REV.
B4	B	V049-4-B4	0
SCALE 1/2"=1'-0"		SHEET 1 OF 1	

4 3 2 1

C :\COMPRESS\ADAPTER\B-4.vsl



Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
Spool B-4	0.0	0.0	146.1	146.1	32.6	1.000		Not applicable	0.000
N1 N1 16"CF (14"od)	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
48.25" id Flange	0.0	0.0	5.2	5.2		1.000		Not applicable	0.000
48.25" id Flange	0.0	0.0	5.2	5.2		1.000		Not applicable	0.000

Vessel MAWP hot & corroded is 0 psi @ 0 degrees F.

Vessel MAP new & cold is 0 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 22 psi

Vessel hydrotest pressure is 22 psi.

Weight Summary

Component	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Spool b-4	663	663	0	0	0	0	0	0	0	0	3961	9
48.25" id flang	448	448	0	0	0	0	0	0	0	0	0	0
48.25" id flang	448	448	0	0	0	0	0	0	0	0	0	0
	1559	1559	0	0	0	0	0	0	0	0	3961	9

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded: 1,568 lbs
Vessel empty weight, corroded: 1,568 lbs
Vessel empty weight, new: 1,568 lbs
Vessel test weight, new: 5,529 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 1,568 lbs
Center of gravity to seam: 30 in

Nozzle Summary

Nozzle mark	OD (in)	tn (in)	Req tn (in)	A1?	A2?	Nom t (in)	Req t (in)	User t (in)	Corr (in)	Aa/Ar (%)
N1	14.00	0.2500	0.0625	y	y	0.2500	0.1757		0.0000	113.2

tn - nozzle thickness
Req tn - nozzle thickness required per UG-45/16
Nom t - vessel wall thickness
Req t - required vessel wall thickness due to pressure + corr per UG-37
User t - local vessel wall thickness (near opening)
Aa - area available per UG-37, governing condition
Ar - area required per UG-37, governing condition
Corr - corrosion allowance on nozzle id.

Nozzle Schedule

Nozzle mark	Service	Size	Materials Nozzle	Impact?	Norm?	Pad	Impact?	Norm?	Flange
N1	16"cf (14"od)	13.50 IDx0.25	SA 240 304L HIGH	n	n				

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
Spool b-4	48.25	60.00	0.2500	0.1756	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

Spool B-4

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: Cylinder
Material specification: SA 240 304L HIGH

External design pressure: Pe = 14.7 psi @ 400 deg F

Corrosion allowance: Inner C = 0 Outer = 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight: new = 662.8 corr = 662.8 lb
capacity: new = 474.923 corr = 474.923 US ga

ID = 48.25 length Lc = 60 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(24.125 + 0.6*0.25) - 0
= 146.1895 psi

MAWP: (Corroded & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(24.125 + 0.6*0.25) - 0
= 146.1895 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 60/48.75 = 1.2308 Do/t = 48.75/0.17569 = 277.4774
From table G: A = 0.000234
From table HA-3: B = 3087.2

Pa = 4*B/(3*Do/t)
= 4*3087.2/(3*48.75/0.17569)
= 14.8346 psi

Design thickness for external pressure Pa = 14.8346 psi:

= t + Corrosion
= 0.17569 + 0
= 0.17569 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 60/48.75 = 1.2308 Do/t = 48.75/0.25 = 195
From table G: A = 0.000398
From table HA-3: B = 4779

Spool B-4

Pa= 4*B/(3*Do/t)
= 4*4779/(3*48.75/0.25)
= 32.6769 psi

N1 16"CF (14"od)

Opening N1 Reinforcement Calculations Per UG-37

Located on:	Spool B-4
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	27.375 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3 in

```
   tn ->|  |<-
           _                _
          | |<- d ->|  |
  tw1->|  |<|          | |
       |/ | |  v       | |\
  ____.-  | | __       | |-.____
  ____\|_|_tw2         |_|/____
              ^
  <--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .25 in
nozzle id. new d= 13.5 in
fillet weld tw1 = .25 in
groove weld tw2 = .1875 in

To datum L= 36 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*6.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*24.125/(16700*1 - 0.6*0)
= 0 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)

= 13.5*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 3.375 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= 3.375 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0) - 2*0.25*(1*0.25-1*0)*(1-1)
= .25 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.25
= .313 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0)*1*0.25
= .313 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 3.375 + 0.313 + 0.063
= 3.751 in^2

As Area > A the reinforcement is adequate for MAWP = 0 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

N1 16"CF (14"od)

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*12358 = 50930.41 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (13.5 - 2*0.25)*(1*0.25 - 1*0))*16700
=-54275 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.313 + 0 + 0.063 + 0)*16700
= 6279.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.313 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 8366.7 lbf

Load for path 1-1 lesser of W or W1-1 =-54275 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 =-54275 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 50930.41 = 95896 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 3/14 = .2143 Do/t = 14/0.02957 = 473.4528

N1 16"CF (14"od)

From table G: A = 0.000665
From table HA-3: B = 5230.8

Pa= 4*B/(3*Do/t)
= 4*5230.8/(3*14/0.02957)
= 14.7309 psi

Nozzle required thickness trn = .02957 in

Required thickness tr from UG-37(d)(1) = .1757 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.1757*1 + 2*0.25*0.1757*1*(1 - 1))
= 1.186 in^2

Area available

A1 = larger of the following = 1.003 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1757) - 2*0.25*(1*0.25-1*0.1757)*(1-1)
= 1.003 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1757) - 2*0.25*(1*0.25-1*0.1757)*(1-1)
= .074 in^2

A2 = smaller of the following = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02957)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02957)*1*0.25
= .276 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.003 + 0.276 + 0.063
= 1.342 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

N1 16"CF (14"od)

Wall thickness per UG-45(a):	tr1 = 0.02957 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0241 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N1 16"CF (14"od)

Applied Loads

Radial load	Pr = 4354 lbf	→ Pump Weight + Vacuum Force
Circumferential moment	Mc = 387.5 lbf-ft	
Circumferential shear	Vc = 126.5 lbf	
Longitudinal moment	ML = 387.5 lbf-ft	
Longitudinal shear	VL = 126.5 lbf	
Torsion moment	Mt = 0 lbf-ft	
Internal pressure	P = 0 psi	

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 24.25 in
Rm/t = 97

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 3157 PSI

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 713 PSI

Maximum combined stress = ~~32271 psi~~ -36141 PSI
Allowable combined stress = +-3*S = +- 50100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~7679 psi~~ - 11549 PSI
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_C = \frac{(14.7\ \text{PSI})(24.25\ \text{IN})}{.25} = 1425.9\ \text{PSI} \longrightarrow \sigma_C = 2.214\,(1425.9\ \text{PSI}) = 3157\ \text{PSI}$$

$$\sigma_L = \frac{(14.7\ \text{PSI})(24.25\ \text{IN})}{2\,(.25\ \text{IN})} = 713.\ \text{PSI}$$

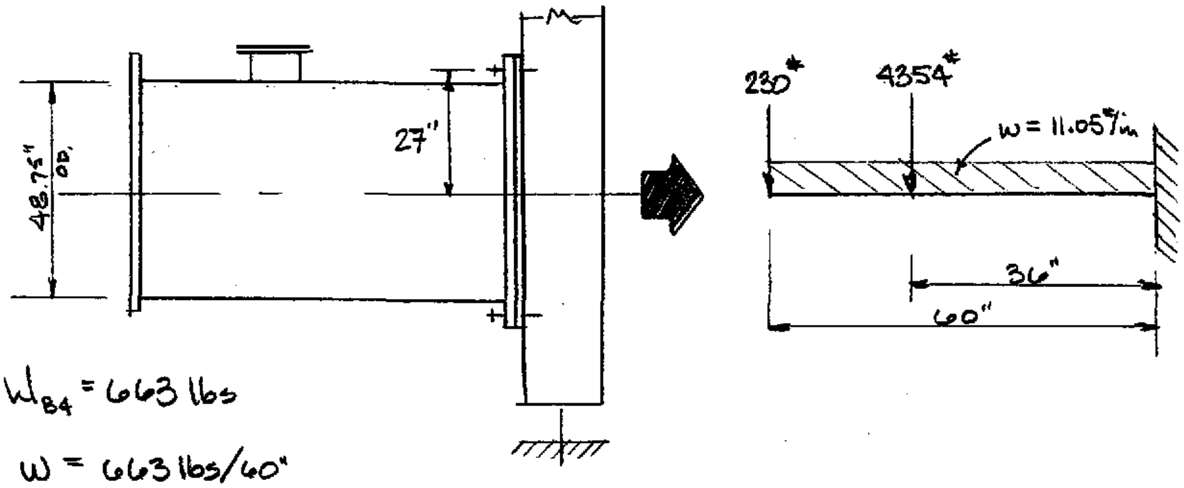
MAX COMBINED STRESS = -32271 PSI + $^{-}3157$ PSI + $^{-}713.$ PSI = $^{-}36141$ PSI

MAX PRIMARY MEMBRANE STRESS = $^{-}7679$ PSI + $^{-}3157$ PSI + $^{-}713$ PSI = $^{-}11549$ PSI

N1 16"CF (14"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.5688	0.253					-2563	-2563	-2563	-2563
4C*	9.1371	0.253	-6562	-6562	-6562	-6562				
1C	0.0610	0.253					-25497	25497	-25497	25497
2C-1	0.0111	0.253	-4640	4640	-4640	4640				
3A*	2.7210	0.253					-341	-341	341	341
1A	0.0531	0.253					-3870	3870	3870	-3870
3B*	5.8265	0.253	-730	-730	730	730				
1B-1	0.0100	0.253	-729	729	729	-729				
pressure stress*			-3157	-3157	-3157.	-3157.	-3157	-3157.	-3157.	-3157
Total circ stress			-15818	-5080.	-12900.	-5078.	-35428.	23306.	-27006.	16248.
Primary membrane circ stress*			-10449.	-10449.	-8989.	-8989.	-6061.	-6061.	-5379.	-5379.
3C*	3.5688	0.253	-2563	-2563	-2563	-2563				
4C*	9.1371	0.253					-6562	-6562	-6562	-6562
1C-1	0.0293	0.253	-12247	12247	-12247	12247				
2C	0.0319	0.253					-13334	13334	-13334	13334
4A*	8.9209	0.253					-1117	-1117	1117	1117
2A	0.0222	0.253					-1618	1618	1618	-1618
4B*	3.0067	0.253	-377	-377	377	377				
2B-1	0.0154	0.253	-1122	1122	1122	-1122				
pressure stress*			-713	-713	-713	-713	-713	-713	-713	-713
Total long stress			-17022.	9716.	-14024.	8226.	-23344.	6560.	-17874.	5558
Primary membrane long stress*			-3653.	-3653.	-2899.	-2899.	-8392.	-8392.	-6158.	-6158.
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-17022.	20165.	-14024	17215.	-35428.	23306	-27006.	16248.
MEMBRANE STRESS			-3157.		-3157.		-713	-713	-713	-713
MAX COMBINED STRESS			-20179	20165	-17181.	17215.	36141	24019	27719.	16961.
MAX PRIMARY MEMBRANE			-10449	-10449.	-8989.	-8989.	-8392	-8392.	-6158.	-6158.
PRIMARY MEMBRANE			-713	-713	-713	-713	-3157	-3157.	-3157.	-3157.
MAX TOTAL PRIM. MEMBRANE			11162	11162	9702	9702.	-11549	-11549	9315	9315.

CHECK BOLTS @ Gate Valve's Flange Connection



W_{B4} = 663 lbs

W = 663 lbs/60"
= 11.05#/in

$$M = \frac{(11.05\text{\#/in}^2)(60\text{ in})^2}{2} + (4354\text{ lbs})(36\text{ in}) + (230\text{ lbs})(60\text{ in})$$

M = 190434 in-lbs ⇒ SAY 191000 in-lbs.

BOLTS 7/8" φ SA 193 B7

T_{ALL} = 12000 lbs V_{ALL} = 6000 lbs

ASSUME ALL SHEAR & TENSION @ 1 BOLT

$$\text{TENSION} = \frac{191000\text{ in-lbs}}{27\text{ in}} = 7074.\text{ lbs}$$

$$\text{SHEAR} = \frac{663\text{ lbs} + 4354\text{ lbs} + 230\text{ lbs}}{1\text{ BOLT}} = 5247.\text{ lbs.}$$

THERE ARE 24 BOLTS FOR THE Valve to B-4 connection

BY comparison WITH ABOVE TENSION & SHEAR FORCES @ 1 BOLT

No SUPPORT IS REQUIRED @ B-4. Gate Valve can adequately support the cantilevered B-4 SPOOL.

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-057
						PAGE 1 OF 63
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0131	4/19/96	WDB	RDC	**SPOOL B-5 (30 in)**	
1	0253	9/20/96	WDB	RDC	**Mode Cleaner Tube**	
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Determine spool/adapter shell thickness. Additionally when applicable, evaluate nozzle opening(s), calculate size and spacing of stiffener rings and support rings.

METHOD: Thickness requirements per the ASME code, Section VIII, Division I, are derived using the COMPRESS computer program, version 5.53.

ASSUMPTIONS: None

INPUTS:

1. Design Temperature = 400° F.
2. Ion Pump 16 in. ∅ Nozzle Loads
   P_R = 4354.0 lbf; M_C = M_L = 378.5ft-lbf; V_C = V_L = 126.5 lbf Ref: V049-1-045
3. Vacuum Pressure = 14.7 psi
4. DWG V049-4-B5A

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.53, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. Doc. No. V049-1-066 LIGO Vacuum Equipment Structural Design Criteria

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The requirements of the ASME Code are met for spool B-5 outer shell.

NOTES: Flanges are included in the COMPRESS model simulating radial stiffeners at the cylinders open end(s). For flange design and analysis see calculation numbers V049-1-016, 017, 018, 019.& 051
12″ CF Nozzle is a hillside nozzle offset 4″ above B-5's CL. Unbalanced vacuum load at 8″ nozzle (382. lbs) is omitted

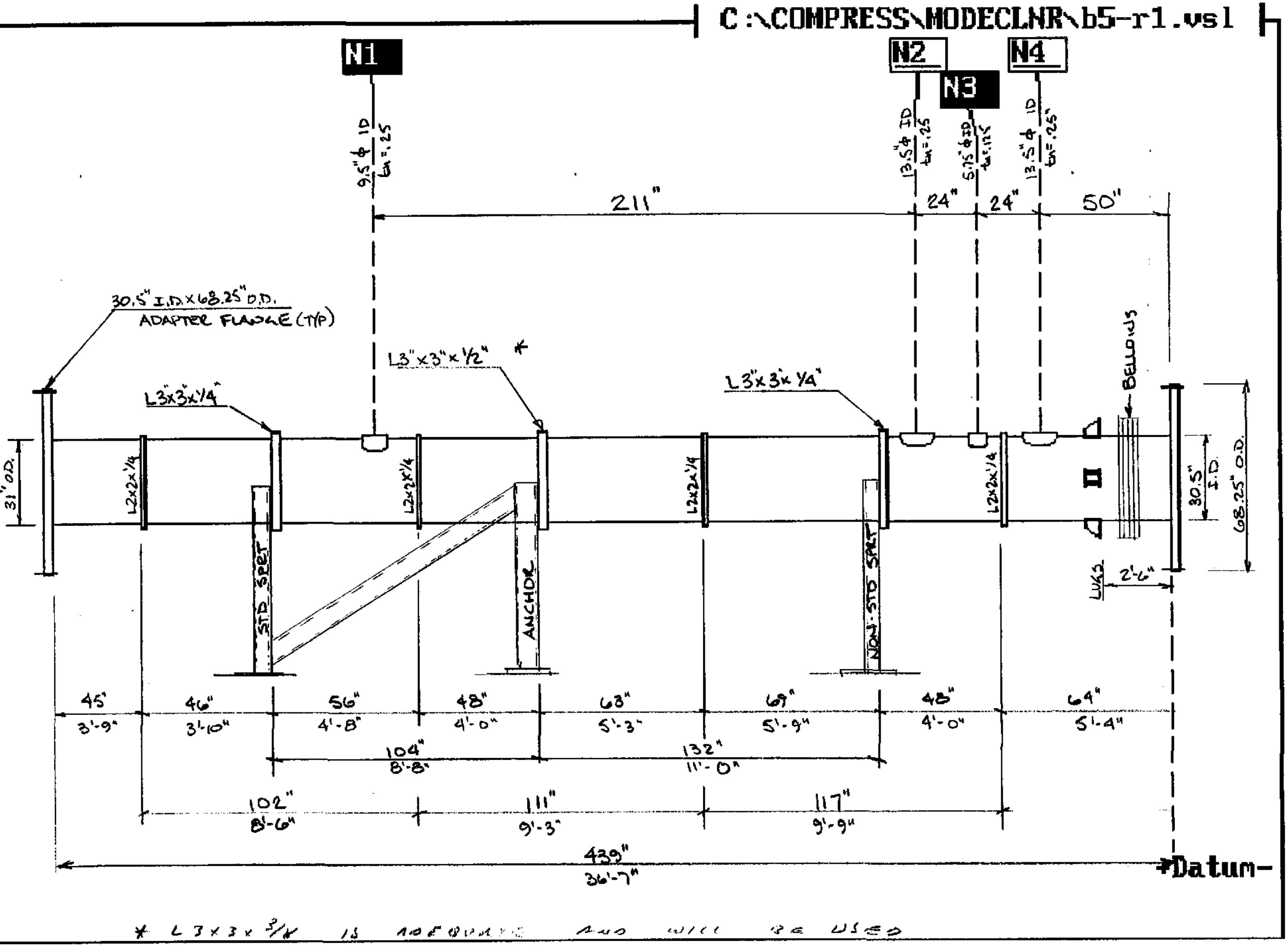
TABLE OF CONTENTS

REVISION HISTORY

Rev. 0 Original Issue
April 19, 1996

Rev. 1 Issue Date
September 20, 1996

- Revised 8″CF & 12″CF nozzles to hillside nozzles
- Added unbalanced vacuum load at 12″CF nozzle
- Recalculated local and primary membrane stresses at the nozzles
- Revised the loading at the 16″ CF nozzles, incorporating;
  valve weight + vacuum force
- Reversed locations of the 8″CF & 12″CF nozzles.
- Revised location of 12″CF nozzle and nearby 2″ x 2″ x 1/4″ stiffner ring.
- Revised stiffner ring at anchor support to 3″ x 3″ x 1/2″.



C:\COMPRESS\MODECLNR\b5-r1.vsl
N1
N2
N3
N4
9.5" ϕ ID
tn=.25
13.5" ϕ ID
tn=.25
5.75" ϕ ID
tn=.125
13.5" ϕ ID
tn=.25
211"
24"
24"
50"
30.5" I.D.x68.25" O.D.
ADAPTER FLANGE (TYP)
L3"x3"x1/2" *
L3x3x1/4"
L3"x3"x1/4"
BELLOWS
31" O.D.
L2x2x1/4
L2x2x1/4
L2x2x1/4
L2x2x1/4
30.5" I.D.
68.25" O.D.
STD SPRT
ANCHOR
NON-STD SPRT
LUGS
2'-6"
45" 3'-9"
46" 3'-10"
56" 4'-8"
48" 4'-0"
63" 5'-3"
69" 5'-9"
48" 4'-0"
64" 5'-4"
104" 8'-8"
132" 11'-0"
102" 8'-6"
111" 9'-3"
117" 9'-9"
439" 36'-7"
Datum
* L3x3x3/4

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	P design (psi)	T design (deg F)	MAWP (psi)	MAP (psi)	Pe external (psi)	UG-99 Ratio	UCS-66 MDMT (deg F)	UCS-66 Exemption or Stress Reduction	Corrosion Allowance (in)
Spool B-5	0.0	400.0	202.8	230.4	51.7	1.136		Not applicable	0.000
N4 N4 16" CF (14"od	0.0	400.0	130.5	148.2	14.7	1.136		Not applicable	0.000
N2 N2 16"CF (14"od)	0.0	400.0	130.5	148.2	14.7	1.136		Not applicable	0.000
N3 N3 8" CF (6"od)	0.0	400.0	119.9	136.2	14.7	1.136		Not applicable	0.000
N1 N1 12"CF (10"od)	0.0	400.0	135.9	154.4	14.7	1.136		Not applicable	0.000
Stiffner Rings (A)					14.7				
Support Rings (A)					14.7				
Support Ring (B)					14.7				
WHAM-5 END CONN.	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
WHAM-6 END CONN.	0.0	0.0	9.0	9.0		1.000		Not applicable	0.000
Stiffener Rings (B)					14.7				

Vessel MAWP hot & corroded is 9.03 psi @ 0 degrees F.

Vessel MAP new & cold is 9.03 psi @ 0 degrees F.

Vessel allowable external pressure is 14.7 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 22 psi

Vessel hydrotest pressure is 22 psi.

Weight Summary

Component	Metal New	Metal Corr	Trays & sup	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Spool b-5	3075	3075	0	0	0	0	0	0	278	0	11580	26
Wham-5 end conn	1539	1539	0	0	0	0	0	0	0	0	0	0
Wham-6 end conn	1539	1539	0	0	0	0	0	0	0	0	0	0
	6153	6153	0	0	0	0	0	0	278	0	11580	26

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded: 6,457 lbs
Vessel empty weight, corroded: 6,457 lbs
Vessel empty weight, new: 6,457 lbs
Vessel test weight, new: 18,037 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 6,456 lbs
Center of gravity to seam: 219.7 in

Nozzle Summary

Nozzle mark	OD (in)	tn (in)	Req tn (in)	A1?	A2?	Nom t (in)	Req t (in)	User t (in)	Corr (in)	Aa/Ar (%)
N4	14.00	0.2500	0.1361	y	y	0.2500	0.1428	0.2500	0.0000	100.0
N2	14.00	0.2500	0.1361	y	y	0.2500	0.1428	0.2500	0.0000	100.0
N3	6.00	0.1250	0.1250	y	y	0.2500	0.1428		0.0000	117.6
N1	10.00	0.2500	0.1418	y	y	0.2500	0.1428		0.0000	100.1

tn - nozzle thickness
Req tn - nozzle thickness required per UG-45/16
Nom t - vessel wall thickness
Req t - required vessel wall thickness due to pressure + corr per UG-37
User t - local vessel wall thickness (near opening)
Aa - area available per UG-37, governing condition
Ar - area required per UG-37, governing condition
Corr - corrosion allowance on nozzle id.

Nozzle Schedule

Nozzle mark	Service	Size	Materials Nozzle	Impact?	Norm?	Pad	Impact?	Norm?	Flange
N4	16" cf (14"od)	13.50 IDx0.25	SA 240 304L HIGH	n	n				
N2	16"cf (14"od)	13.50 IDx0.25	SA 240 304L HIGH	n	n				
N3	8" cf (6"od)	5.75 IDx0.12	SA 240 304L HIGH	n	n				
N1	12"cf (10"od)	9.50 IDx0.25	SA 240 304L HIGH	n	n				

Thickness Summary

Component Identifier	ID (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Load	Governing Status	Stress	Deflect (in)
Spool b-5	30.50	439.00	0.2500	0.1428	0.85	external			

Nom t - vessel wall thickness
Req t - required vessel wall thickness due to governing loading
E - longitudinal seam joint efficiency

Load:
internal - circ stress due to internal pressure governs
external - external pressure governs
wind - combined long stress due to STATUS + wind governs
seismic - combined long stress due to STATUS + seismic governs

Spool B-5

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder			
Material specification:	SA 240 304L HIGH			
External design pressure:	Pe= 14.7	psi @	400	deg F
Corrosion allowance: Inner C = 0		Outer= 0		in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Category B joints - Spot UW-11(b) type 1

Estimated weight:	new = 3074.7	corr = 3074.7	lb
capacity:	new = 1388.487	corr = 1388.487	US ga

ID = 30.5 length Lc= 439 t = 0.25 in (new)

MAP: (New & at 0 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 230.4383 psi

MAWP: (Corroded & at 400 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 14700*0.85*0.25/(15.25 + 0.6*0.25) - 0
= 202.8409 psi

External Pressure: (Corroded & at 400 deg F) UG-28

L/Do = 69/31 =2.2258 Do/t = 31/0.14281 = 217.0716
From table G: A = 0.000183
From table HA-3: B = 2408.6

Pa= 4*B/(3*Do/t)
= 4*2408.6/(3*31/0.14281)
= 14.7945 psi

Design thickness for external pressure Pa = 14.7945 psi:

= t + Corrosion
= 0.14281 + 0
= 0.14281 in

Maximum Allowable External Pressure: (Corroded @ 400 deg F)

L/Do = 69/31 =2.2258 Do/t = 31/0.25 = 124
From table G: A = 0.000416
From table HA-3: B = 4816.4

Pa= 4*B/(3*Do/t)

= 4*4816.4/(3*31/0.25)
= 51.7892 psi

N1 12"CF (10"od)

Opening N1 Reinforcement Calculations Per UG-37

Located on:	Spool B-5
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	75.5 degrees
End of nozzle to shell center:	18.125 in
Nozzle offset from center Lo:	4 in
Projection outside vessel Lpr:	3.15 in

```
  tn ->| |<-
         _        _
        | |<- d ->| |                corrosion allow = 0 in
tw1->|  |<|       | |                noz thick new tn= .25 in
     |/ | |  v    | |\               nozzle id. new d= 9.5 in
______.-| | --    | |-._____         fillet weld tw1 = .25 in
______\|_|_tw2    |_|/_____          groove weld tw2 = .1875 in
            ^
<--- L --->|                         To datum L= 309 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.883 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 4.75)/15.3209)
= 55.17227

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 4.75)/15.3209)
= 92.80641

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3209*Sin((92.80641 - 55.17227)/2)
= 9.883 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 135.9225*4.75/(14700*1 - 0.6*135.9225)
= 0.0442 in

Required thickness tr from UG-37(a)

N1 12"CF (10"od)

tr= P*R/(S*E - 0.6*P)
= 135.9225*15.25/(14700*1 - 0.6*135.9225)
= 0.1418 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.883*0.1418*0.5 + 2*0.25*0.1418*0.5*(1 - 1)
= .7007 in^2

Area available

A1 = larger of the following = 1.77 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.883*(1*0.25-0.5*0.1418) - 2*0.25*(1*0.25-0.5*0.1418)*(1-1)
= 1.77 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-0.5*0.1418) - 2*0.25*(1*0.25-0.5*0.1418)*(1-1)
= .179 in^2

A2 = smaller of the following = 0.257 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0442)*1*0.25
= .257 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0442)*1*0.25
= .257 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.77 + 0.257 + 0.063
= 2.09 in^2

As Area > A the reinforcement is adequate for MAWP = 135.9225 at 400 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.5*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
= 1.3471 in^2

Area available

N1 12"CF (10"od)

A1 = larger of the following = 1.028 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= 1.028 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= .108 in^2

Area = A1 + A2 + A41
= 1.028 + 0.257 + 0.063
= 1.348 in^2

As Area > A the reinforcement is adequate for MAWP = 135.9225 at 400 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0442 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1418 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.319375 in
The greater of tr2 or tr3:	tr5 = 0.1418 in
The lesser of tr4 or tr5:	tr6 = 0.1418 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1418 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*14700 = 10878 psi
Nozzle wall in shear = 0.7*14700 = 10290 psi
Inner fillet weld in shear = 0.49*14700 = 7203 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*10*0.25*7203 = 28271.78 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*9.75*0.25*10290 = 39378.55 lbf

N1 12"CF (10"od)

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10*0.1875*10878 = 32022.11 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.3471 - (9.5 - 2*0.25)*(1*0.25 - 1*0.1418))*14700
= 5487.51 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.257 + 0 + 0.063 + 0)*14700
= 4704 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.257 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*14700
= 6541.5 lbf

Load for path 1-1 lesser of W or W1-1 = 4704 lbf
Path 1-1 Thru (1) & (3) = 28271.78 + 39378.55 = 67650.33 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 5487.51 lbf
Path 2-2 Thru (1), (4) = 28271.78 + 32022.11 = 60293.89 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.883 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 4.75)/15.3209)
= 55.17227

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 4.75)/15.3209)
= 92.80641

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3209*Sin((92.80641 - 55.17227)/2)
= 9.883 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 154.4704*4.75/(16700*1 - 0.6*154.4704)
= 0.0442 in

Required thickness tr from UG-37(a)

N1 12"CF (10"od)

tr = P*R/(S*E - 0.6*P)
= 154.4704*15.25/(16700*1 - 0.6*154.4704)
= 0.1418 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.883*0.1418*0.5 + 2*0.25*0.1418*0.5*(1 - 1)
= .7007 in^2

Area available

A1 = larger of the following = 1.77 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.883*(1*0.25-0.5*0.1418) - 2*0.25*(1*0.25-0.5*0.1418)*(1-1)
= 1.77 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-0.5*0.1418) - 2*0.25*(1*0.25-0.5*0.1418)*(1-1)
= .179 in^2

A2 = smaller of the following = 0.257 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0442)*1*0.25
= .257 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0442)*1*0.25
= .257 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.77 + 0.257 + 0.063
= 2.09 in^2

As Area > A the reinforcement is adequate for MAP = 154.4704 at 0 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.5*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
= 1.3471 in^2

Area available

N1 12"CF (10"od)

A1 = larger of the following = 1.028 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= 1.028 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= .108 in^2

Area = A1 + A2 + A41
= 1.028 + 0.257 + 0.063
= 1.348 in^2

As Area > A the reinforcement is adequate for MAP = 154.4704 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0442 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1418 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.319375 in
The greater of tr2 or tr3:	tr5 = 0.1418 in
The lesser of tr4 or tr5:	tr6 = 0.1418 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1418 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*10*0.25*8183 = 32118.28 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*9.75*0.25*11690 = 44736.17 lbf

N1 12"CF (10"od)

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10*0.1875*12358 = 36378.86 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.3471 - (9.5 - 2*0.25)*(1*0.25 - 1*0.1418))*16700
= 6234.11 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.257 + 0 + 0.063 + 0)*16700
= 5344 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.257 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7431.5 lbf

Load for path 1-1 lesser of W or W1-1 = 5344 lbf
Path 1-1 Thru (1) & (3) = 32118.28 + 44736.17 = 76854.45 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 6234.11 lbf
Path 2-2 Thru (1), (4) = 32118.28 + 36378.86 = 68497.14 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 9.883 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 4.75)/15.3214)
= 55.17357

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 4.75)/15.3214)
= 92.80632

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3214*Sin((92.80632 - 55.17357)/2)
= 9.883 in

Nozzle required thickness

L/Do = 3.15/10 = .315   Do/t = 10/0.02239 = 446.628
From table G: A = 0.000481
From table HA-3:   B = 4941

Pa= 4*B/(3*Do/t)
= 4*4941/(3*10/0.02239)

N1 12"CF (10"od)

= 14.7505 psi

Nozzle required thickness trn = .02239 in

Required thickness tr from UG-37(d)(1) = .1428 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(9.883*0.1428*0.5 + 2*0.25*0.1428*0.5*(1 - 1))
= .3528 in^2

Area available

A1 = larger of the following = 1.765 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.883*(1*0.25-0.5*0.1428) - 2*0.25*(1*0.25-0.5*0.1428)*(1-1)
= 1.765 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-0.5*0.1428) - 2*0.25*(1*0.25-0.5*0.1428)*(1-1)
= .179 in^2

A2 = smaller of the following = 0.285 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02239)*1*0.25
= .285 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02239)*1*0.25
= .285 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.765 + 0.285 + 0.063
= 2.113 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(9.5*0.1428*1 + 2*0.25*0.1428*1*(1 - 1))
= .6783 in^2

N1 12"CF (10"od)

Area available

A1 = larger of the following = 1.018 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= 1.018 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= .107 in^2

Area = A1 + A2 + A41
= 1.018 + 0.285 + 0.063
= 1.366 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02239 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.319375 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N1 12"CF (10"od)

Applied Loads

Radial load	Pr = 1042 lbf	= VACUUM FORCE (END CAP LOAD)
Circumferential moment	Mc = 0 lbf-ft	
Circumferential shear	Vc = 0 lbf	
Longitudinal moment	ML = 0 lbf-ft	
Longitudinal shear	VL = 0 lbf	$P_R = \pi r^2 (14.7)$
Torsion moment	Mt = 0 lbf-ft	
Internal pressure	P = 0 psi	

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(4.75/5.25)^2 + 3*(4.75/5.25)^4)
= 2.117

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 1914. PSI

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 452. PSI

Maximum combined stress = ~~7215 psi~~ 9581. PSI
Allowable combined stress = +-3*S = +- 44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~1677 psi~~ 4043. PSI
Allowable primary membrane stress = +-1.5*S = +- 22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_L = \frac{(14.7\,\text{psi})(15.375\,\text{in})}{2(.25\,\text{in})} = 452.\ \text{psi}$$

$$\sigma_C = \frac{(14.7\,\text{psi})(15.375\,\text{in})}{.25\,\text{in}} = 904\,\text{psi} \longrightarrow \sigma_C = (904\,\text{psi})(2.117) = 1914\,\text{psi}$$

MAX COMBINED STRESS = 7215 PSI + 452 PSI + 1914 PSI
= 9581. PSI

MAX PRIMARY STRESS = 1677 PSI + 452. PSI + 1914 PSI = 4043 PSI

N1 12"CF (10"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	2.7030	0.285					-733	-733	-733	-733
4C*	6.1853	0.285	-1677	-1677	-1677	-1677				
1C	0.0648	0.285					-6482	6482	-6482	6482
2C-1	0.0135	0.285	-1350	1350	-1350	1350				
3A*	1.8945	0.285								
1A	0.0591	0.285								
3B*	3.9817	0.285								
1B-1	0.0125	0.285								
pressure stress*			-1914.	-1914.	-1914.	-1914.	-1914.	-1914.	-1914	-1914
Total circ stress			-4941.	-2241.	-4941	-2241.	-9129.	+3835	-9129	3835.
Primary membrane circ stress*			-3591	-3591	-3591	-3591.	-2647.	-2647.	-2647.	-2647.
3C*	2.7030	0.285	-733	-733	-733	-733				
4C*	6.1853	0.285					-1677	-1677	-1677	-1677
1C-1	0.0320	0.285	-3201	3201	-3201	3201				
2C	0.0306	0.285					-3061	3061	-3061	3061
4A*	5.8096	0.285								
2A	0.0245	0.285								
4B*	2.0592	0.285								
2B-1	0.0218	0.285								
pressure stress*			-452.	-452.	-452.	-452.	-452.	-452.	-452.	-452.
Total long stress			-4386.	2016.	-4386.	2016	-5190.	932.	-5190.	932.
Primary membrane long stress*			-1185.	-1185.	-1185.	-1185.	-2129	-2129	-2129.	-2129.
torsion moment Mt										
Circ shear from Vc										
Long shear from VL										
Total Shear stress										
Combined stress			-4941	-3591	-4941.	-3591	-9129.	3835	-9129	3835
MEMBRANE STRESS			-452.	-452.	-452.	-452.	-452.	-452.	-452.	-452.
MAX COMBINED STRESS			-5393	-4043	-5393.	-4043.	-9581	3383	-9581.	3383
MAX PRIMARY MEMBRANE			-3591	-3591	-3591	-3591.	-2647	-2647	-2647.	-2647
PRIMARY MEMBRANE STRESS			-452.	-452.	-452.	-452.	-452.	-452.	-452.	-452
MAX TOTAL PRIMARY MEMBRANE			-4043.	-4043.	-4043.	-4043.	-3099	-3099	-3099	-3099

N2 16"CF (14"od)

Opening N2 Reinforcement Calculations Per UG-37

Located on: Spool B-5
User input vessel thickness: .25 in
Liquid static head included: 0 psi
Flange description: Not installed

Nozzle material specification: SA 240 304L HIGH

Nozzle orientation: 0 degrees
End of nozzle to shell center: 18.125 in
Nozzle offset from center Lo: 0 in
Projection outside vessel Lpr: 2.625 in

```
    tn ->|  |<-
            _              _
           | |<- d ->|  | |           corrosion allow = 0 in
 tw1->|    | |<          | |           noz thick new tn= .25 in
      |/   | |   v       | |\          nozzle id. new d= 13.5 in
_____.-    | |  --       | |-._____    fillet weld tw1 = .25 in
_____\|_|_tw2           |_|/_____      groove weld tw2 = .1875 in
               ^
<---- L ---->|                          To datum L= 98 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 130.5334*6.75/(14700*1 - 0.6*130.5334)
= 0.0603 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 130.5334*15.25/(14700*1 - 0.6*130.5334)
= 0.1361 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.1361*1 + 2*0.25*0.1361*1*(1 - 1)

N2 16"CF (14"od)

= 1.8373 in^2

Area available

A1 = larger of the following = 1.538 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= 1.538 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= .114 in^2

A2 = smaller of the following = 0.237 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.538 + 0.237 + 0.063
= 1.838 in^2

As Area > A the reinforcement is adequate for MAWP = 130.5334 at 400 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0603 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.1361 in
The lesser of tr4 or tr5:	tr6 = 0.1361 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1361 in

Available nozzle wall thickness new, tn = 0.25 in

N2 16"CF (14"od)

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*14700 = 10878 psi
Nozzle wall in shear = 0.7*14700 = 10290 psi
Inner fillet weld in shear = 0.49*14700 = 7203 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*7203 = 39580.49 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*10290 = 55533.84 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*10878 = 44830.96 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.8373 - (13.5 - 2*0.25)*(1*0.25 - 1*0.1361))*14700
= 5242.018 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.237 + 0 + 0.063 + 0)*14700
= 4410 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.237 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*14700
= 6247.5 lbf

Load for path 1-1 lesser of W or W1-1 = 4410 lbf
Path 1-1 Thru (1) & (3) = 39580.49 + 55533.84 = 95114.33 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 5242.018 lbf
Path 2-2 Thru (1), (4) = 39580.49 + 44830.96 = 84411.45 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 148.2763*6.75/(16700*1 - 0.6*148.2763)
= 0.0603 in

N2 16"CF (14"od)

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 148.2763*15.25/(16700*1 - 0.6*148.2763)
= 0.1361 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.1361*1 + 2*0.25*0.1361*1*(1 - 1)
= 1.8373 in^2

Area available

A1 = larger of the following = 1.538 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= 1.538 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= .114 in^2

A2 = smaller of the following = 0.237 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.538 + 0.237 + 0.063
= 1.838 in^2

As Area > A the reinforcement is adequate for MAP = 148.2763 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

N2 16"CF (14"od)

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0603 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.1361 in
The lesser of tr4 or tr5:	tr6 = 0.1361 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1361 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*12358 = 50930.41 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.8373 - (13.5 - 2*0.25)*(1*0.25 - 1*0.1361))*16700
= 5955.218 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.237 + 0 + 0.063 + 0)*16700
= 5010 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.237 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7097.5 lbf

Load for path 1-1 lesser of W or W1-1 = 5010 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 5955.218 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 50930.41 = 95896 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

N2 16"CF (14"od)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 2.625/14 = .1875 Do/t = 14/0.02907 = 481.5962
From table G: A = 0.000747
From table HA-3: B = 5338.9

Pa= 4*B/(3*Do/t)
= 4*5338.9/(3*14/0.02907)
= 14.7811 psi

Nozzle required thickness trn = .02907 in

Required thickness tr from UG-37(d)(1) = .1428 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.1428*1 + 2*0.25*0.1428*1*(1 - 1))
= .9639 in^2

Area available

A1 = larger of the following = 1.447 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= 1.447 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= .107 in^2

A2 = smaller of the following = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02907)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02907)*1*0.25
= .276 in^2

N2 16"CF (14"od)

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.447 + 0.276 + 0.063
= 1.786 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02907 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N2 16"CF (14"od)

Applied Loads

Radial load	Pr = 4354 lbf = Pump Wght + Vacuum Force
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Ref. Calc. V049-1-045

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ 2002 psi

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 452. psi

Maximum combined stress = ~~33193 psi~~ 35647 psi
Allowable combined stress = +-3*S = +-44100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~6067 psi~~ 8521 psi
Allowable primary membrane stress = +-1.5*S = +-22050 psi

The maximum primary membrane stress is within allowable limits.

$$\sigma_L = \frac{(14.7\ \text{psi})(15.375\ \text{in})}{2\,(.25\ \text{in})} = 452.0\ \text{psi}$$

$$\sigma_C = \frac{(14.7\ \text{psi})(15.375\ \text{in})}{.25\ \text{in}} = 904.05\ \text{psi} \rightarrow \sigma_C = 2.214(904.05\ \text{psi}) = 2002.\ \text{psi}$$

Max Combined Stress = 33193 psi + 452. psi + 2002 psi
= 35647 psi

Max Primary Membrane Stress = 6067 psi + 452. psi + 2002 psi
= 8521 psi.

N2 16"CF (14"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	1.5557	0.398					-1762	-1762	-1762	-1762
4C*	4.3911	0.398	-4974	-4974	-4974	-4974				
1C	0.0648	0.398					-27085	27085	-27085	27085
2C-1	0.0065	0.398	-2717	2717	-2717	2717				
3A*	1.3830	0.398					-267	-267	267	267
1A	0.0573	0.398					-4079	4079	4079	-4079
3B*	2.5018	0.398	-483	-483	483	483				
1B-1	0.0079	0.398	-562	562	562	-562				
pressure stress*			-2002.	-2002.	-2002.	-2002.	-2002.	-2002.	-2002.	-2002
Total circ stress			-10738	-4180.	-8648.	-4338.	-35195.	27133.	-26503.	19509
Primary membrane circ stress*			-7459.	-7459	-6493	-6493	-4031.	-4031.	-3497.	-3497.
3C*	1.5557	0.398	-1762	-1762	-1762	-1762				
4C*	4.3911	0.398					-4974	-4974	-4974	-4974
1C-1	0.0160	0.398	-6688	6688	-6688	6688				
2C	0.0300	0.398					-12540	12540	-12540	12540
4A*	5.6652	0.398					-1093	-1093	1093	1093
2A	0.0227	0.398					-1616	1616	1616	-1616
4B*	1.4487	0.398	-279	-279	279	279				
2B-1	0.0158	0.398	-1125	1125	1125	-1125				
pressure stress*			-452	-452.	-452.	-452.	-452.	-452.	-452.	-452.
Total long stress			-10306	5320.	-7498	3628.	-20675	7637.	-15257.	6591.
Primary membrane long stress*			-2493.	-2493.	-1935.	-1935	-6519	-6519.	-4333.	-4333.
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-10738.	-7459.	-8648	-6493	-35195.	27133.	-26503.	19509
MEMBRANE STRESS			-452.	-452.	-452.	-452.	-452.	-452.	-452.	-452
MAX COMBINED STRESS			-11190.	-7911.	-9100	-6945.	-35647.	26681.	-26955	19057.
MAX PRIMARY MEMBRANE			-7459.	-7459.	-6493.	-6493.	-6519	-6519.	-4333.	-4333
σ PRIMARY MEMBRANE			-452.	-452.	-452.	-452.	-2002.	-2002.	-2002.	-2002.
MAX TOTAL PRIMARY MEMBRANE			-7911.	-7911.	-6945	-6945.	-8521.	-8521.	-6335	-6335.

N3 8" CF (6"od)

Opening N3 Reinforcement Calculations Per UG-37

Located on:	Spool B-5
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	75.5 degrees
End of nozzle to shell center:	18.125 in
Nozzle offset from center Lo:	4 in
Projection outside vessel Lpr:	3.15 in

```
   tn ->|  |<-
          _         _
         | |<- d ->| |            corrosion allow = 0 in
tw1->|   |<|       | |            noz thick new tn= .125 in
     |/  | | v     | |\           nozzle id. new d= 5.75 in
______.__| |__     | |_.______    fillet weld tw1 = .25 in
______\|_|_tw2     |_|/______     groove weld tw2 = .1875 in
             ^
<---- L ---->|                    To datum L= 74 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 5.965 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .3125 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .3125 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 2.875)/15.3125)
= 63.32211

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 2.875)/15.3125)
= 85.78719

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3125*Sin((85.78719 - 63.32211)/2)
= 5.965 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 119.9299*2.875/(14700*1 - 0.6*119.9299)
= 0.0236 in

Required thickness tr from UG-37(a)

N3 8" CF (6"od)

tr= P*R/(S*E - 0.6*P)
= 119.9299*15.25/(14700*1 - 0.6*119.9299)
= 0.125 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 5.965*0.125*0.5 + 2*0.125*0.125*0.5*(1 - 1)
= .3728 in^2

Area available

A1 = larger of the following = 1.118 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.965*(1*0.25-0.5*0.125) - 2*0.125*(1*0.25-0.5*0.125)*(1-1)
= 1.118 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-0.5*0.125) - 2*0.125*(1*0.25-0.5*0.125)*(1-1)
= .141 in^2

A2 = smaller of the following = 0.063 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.125 - 0.0236)*1*0.25
= .127 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.125 - 0.0236)*1*0.125
= .063 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.118 + 0.063 + 0.063
= 1.244 in^2

As Area > A the reinforcement is adequate for MAWP = 119.9299 at 400 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 5.75*0.125*1 + 2*0.125*0.125*1*(1 - 1)
= .71875 in^2

Area available

N3 8" CF (6"od)

A1 = larger of the following = .719 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.75*(1*0.25-1*0.125) - 2*0.125*(1*0.25-1*0.125)*(1-1)
= .719 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-1*0.125) - 2*0.125*(1*0.25-1*0.125)*(1-1)
= .094 in^2

Area = A1 + A2 + A41
= 0.719 + 0.063 + 0.063
= .845 in^2

As Area > A the reinforcement is adequate for MAWP = 119.9299 at 400 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.125 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.0875 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0236 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.125 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.245 in
The greater of tr2 or tr3:	tr5 = 0.125 in
The lesser of tr4 or tr5:	tr6 = 0.125 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.125 in

Available nozzle wall thickness new, tn = 0.125 in

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*14700 = 10878 psi
Nozzle wall in shear = 0.7*14700 = 10290 psi
Inner fillet weld in shear = 0.49*14700 = 7203 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*6*0.25*7203 = 16963.06 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*5.875*0.125*10290 = 11864.05 lbf

N3 8" CF (6"od)

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*6*0.1875*10878 = 19213.27 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0.71875 - (5.75 - 2*0.125)*(1*0.25 - 1*0.125))*14700
= 459.375 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.063 + 0 + 0.063 + 0)*14700
= 1852.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.063 + 0 + 0.063 + 0 + 2*0.125*0.25*1)*14700
= 2770.95 lbf

Load for path 1-1 lesser of W or W1-1 = 459.375 lbf
Path 1-1 Thru (1) & (3) = 16963.06 + 11864.05 = 28827.11 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 459.375 lbf
Path 2-2 Thru (1), (4) = 16963.06 + 19213.27 = 36176.33 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 5.965 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .3125 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .3125 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 2.875)/15.3125)
= 63.32211

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 2.875)/15.3125)
= 85.78719

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3125*Sin((85.78719 - 63.32211)/2)
= 5.965 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 136.2431*2.875/(16700*1 - 0.6*136.2431)
= 0.0236 in

Required thickness tr from UG-37(a)

N3 8" CF (6"od)

tr = P*R/(S*E - 0.6*P)
= 136.2431*15.25/(16700*1 - 0.6*136.2431)
= 0.125 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 5.965*0.125*0.5 + 2*0.125*0.125*0.5*(1 - 1)
= .3728 in^2

Area available

A1 = larger of the following = 1.118 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.965*(1*0.25-0.5*0.125) - 2*0.125*(1*0.25-0.5*0.125)*(1-1)
= 1.118 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-0.5*0.125) - 2*0.125*(1*0.25-0.5*0.125)*(1-1)
= .141 in^2

A2 = smaller of the following = 0.063 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.125 - 0.0236)*1*0.25
= .127 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.125 - 0.0236)*1*0.125
= .063 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.118 + 0.063 + 0.063
= 1.244 in^2

As Area > A the reinforcement is adequate for MAP = 136.2431 at 0 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 5.75*0.125*1 + 2*0.125*0.125*1*(1 - 1)
= .71875 in^2

Area available

N3 8" CF (6"od)

A1 = larger of the following = .719 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.75*(1*0.25-1*0.125) - 2*0.125*(1*0.25-1*0.125)*(1-1)
= .719 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-1*0.125) - 2*0.125*(1*0.25-1*0.125)*(1-1)
= .094 in^2

Area = A1 + A2 + A41
= 0.719 + 0.063 + 0.063
= .845 in^2

As Area > A the reinforcement is adequate for MAP = 136.2431 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.125 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.0875 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0236 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.125 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.245 in
The greater of tr2 or tr3:	tr5 = 0.125 in
The lesser of tr4 or tr5:	tr6 = 0.125 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.125 in

Available nozzle wall thickness new, tn = 0.125 in

The nozzle neck thickness is adequate for MAP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*6*0.25*8183 = 19270.96 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*5.875*0.125*11690 = 13478.21 lbf

N3 8" CF (6"od)

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*6*0.1875*12358 = 21827.32 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0.71875 - (5.75 - 2*0.125)*(1*0.25 - 1*0.125))*16700
= 521.875 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.063 + 0 + 0.063 + 0)*16700
= 2104.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.063 + 0 + 0.063 + 0 + 2*0.125*0.25*1)*16700
= 3147.95 lbf

Load for path 1-1 lesser of W or W1-1 = 521.875 lbf
Path 1-1 Thru (1) & (3) = 19270.96 + 13478.21 = 32749.17 lbf
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W2-2 = 521.875 lbf
Path 2-2 Thru (1), (4) = 19270.96 + 21827.32 = 41098.28 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 5.965 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .3125 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .3125 in

Determination of Chord Length

Theta1 = ArcCos((Lo + Rn)/Rm)
= ArcCos((4 + 2.875)/15.3214)
= 63.33883

Theta2 = ArcCos((Lo - Rn)/Rm)
= ArcCos((4 - 2.875)/15.3214)
= 85.78963

d = 2*Rm*Sin((Theta2 - Theta1)/2)
= 2*15.3214*Sin((85.78963 - 63.33883)/2)
= 5.965 in

Nozzle required thickness

L/Do = 3.15/6 = .525 Do/t = 6/0.01523 = 393.9593
From table G: A = 0.000333
From table HA-3: B = 4408.2

Pa= 4*B/(3*Do/t)
= 4*4408.2/(3*6/0.01523)

N3 8" CF (6"od)

= 14.9193 psi

Nozzle required thickness trn = .01523 in

Required thickness tr from UG-37(d)(1) = .1428 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(5.965*0.1428*0.5 + 2*0.125*0.1428*0.5*(1 - 1))
= .213 in^2

Area available

A1 = larger of the following = 1.065 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.965*(1*0.25-0.5*0.1428) - 2*0.125*(1*0.25-0.5*0.1428)*(1-1)
= 1.065 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-0.5*0.1428) - 2*0.125*(1*0.25-0.5*0.1428)*(1-1)
= .134 in^2

A2 = smaller of the following = 0.069 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.125 - 0.01523)*1*0.25
= .137 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.125 - 0.01523)*1*0.125
= .069 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.065 + 0.069 + 0.063
= 1.197 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

Reinforcement check in the plane parallel to the long. axis

Area required

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(5.75*0.1428*1 + 2*0.125*0.1428*1*(1 - 1))
= .41055 in^2

N3 8" CF (6"od)

Area available

A1 = larger of the following = .616 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 5.75*(1*0.25-1*0.1428) - 2*0.125*(1*0.25-1*0.1428)*(1-1)
= .616 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.125)*(1*0.25-1*0.1428) - 2*0.125*(1*0.25-1*0.1428)*(1-1)
= .08 in^2

Area = A1 + A2 + A41
= 0.616 + 0.069 + 0.063
= .748 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.01523 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.245 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.125 in

The nozzle neck thickness is adequate for Pe.

NOTE:
N3 8"CF (6"OD) NOZZLE
IS QUALIFIED BY N1 FOR
WRC 107. NO FURTHER
NOZZLE EVALUATION IS REQ'D.

N4 16" CF (14"od)

Opening N4 Reinforcement Calculations Per UG-37

Located on:	Spool B-5
User input vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	0 degrees
End of nozzle to shell center:	18.125 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	2.625 in

```
   tn ->|  |<-
          _            _
         | |<- d ->|  | |
tw1->|   | |<        | |
     |/  | |  v      | |\
_____.-  | | --      | |-.______
______\|_|_tw2       |_|/______
              ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .25 in
nozzle id. new d= 13.5 in
fillet weld tw1 = .25 in
groove weld tw2 = .1875 in

To datum L= 50 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 130.5334*6.75/(14700*1 - 0.6*130.5334)
= 0.0603 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 130.5334*15.25/(14700*1 - 0.6*130.5334)
= 0.1361 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.1361*1 + 2*0.25*0.1361*1*(1 - 1)

N4 16" CF (14"od)

= 1.8373 in^2

Area available

A1 = larger of the following = 1.538 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= 1.538 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
= .114 in^2

A2 = smaller of the following = 0.237 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0603)*1*0.25
= .237 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.538 + 0.237 + 0.063
= 1.838 in^2

As Area > A the reinforcement is adequate for MAWP = 130.5334 at 400 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 >= 1.25*tmin

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0603 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.1361 in
The lesser of tr4 or tr5:	tr6 = 0.1361 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1361 in

Available nozzle wall thickness new, tn = 0.25 in

N4 16" CF (14"od)

The nozzle neck thickness is adequate for MAWP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*14700 = 10878 psi
Nozzle wall in shear = 0.7*14700 = 10290 psi
Inner fillet weld in shear = 0.49*14700 = 7203 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*7203 = 39580.49 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*10290 = 55533.84 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*10878 = 44830.96 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.8373 - (13.5 - 2*0.25)*(1*0.25 - 1*0.1361))*14700
= 5242.018 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.237 + 0 + 0.063 + 0)*14700
= 4410 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.237 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*14700
= 6247.5 lbf

Load for path 1-1 lesser of W or W1-1 = 4410 lbf
Path 1-1 Thru (1) & (3) = 39580.49 + 55533.84 = 95114.33 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 5242.018 lbf
Path 2-2 Thru (1), (4) = 39580.49 + 44830.96 = 84411.45 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations For Nozzle MAP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 148.2763*6.75/(16700*1 - 0.6*148.2763)
= 0.0603 in

N4 16" CF (14"od)

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
 = 148.2763*15.25/(16700*1 - 0.6*148.2763)
 = 0.1361 in

Area required

Allowable stresses: Sn = 16700, Sv = 16700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
 = 13.5*0.1361*1 + 2*0.25*0.1361*1*(1 - 1)
 = 1.8373 in^2

Area available

A1 = larger of the following = 1.538 in^2

 = d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
 = 13.5*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
 = 1.538 in^2

 = 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
 = 2*(0.25+0.25)*(1*0.25-1*0.1361) - 2*0.25*(1*0.25-1*0.1361)*(1-1)
 = .114 in^2

A2 = smaller of the following = 0.237 in^2

 = 5*(tn - trn)*fr2*t
 = 5*(0.25 - 0.0603)*1*0.25
 = .237 in^2

 = 5*(tn - trn)*fr2*tn
 = 5*(0.25 - 0.0603)*1*0.25
 = .237 in^2

A41 = Leg^2*fr2
 = 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
 = 1.538 + 0.237 + 0.063
 = 1.838 in^2

As Area > A the reinforcement is adequate for MAP = 148.2763 at 0 Deg F

Check the welds - From UW-16(d):

tmin = lesser of 0.75 or tn or t, tmin = 0.25 in
t1 or t2(min) = lesser of 0.25 or 0.7*tmin, t1(min) = 0.175 in
t1(actual) = 0.7*Leg = 0.7*0.25 = 0.175 in
t2(actual) = 0.1875 in
t1 + t2 = 0.3625 > = 1.25*tmin

N4 16" CF (14"od)

The weld sizes for t1 and t2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0603 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1361 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.1361 in
The lesser of tr4 or tr5:	tr6 = 0.1361 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1361 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for MAP.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension = 0.74*16700 = 12358 psi
Nozzle wall in shear = 0.7*16700 = 11690 psi
Inner fillet weld in shear = 0.49*16700 = 8183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(Pi/2)*Nozzle O.D.*Leg*Si = 1.57*14*0.25*8183 = 44965.59 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*13.75*0.25*11690 = 63089.47 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*14*0.1875*12358 = 50930.41 lbf

Loading on welds per UG-41(b)(1)

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.8373 - (13.5 - 2*0.25)*(1*0.25 - 1*0.1361))*16700
= 5955.218 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.237 + 0 + 0.063 + 0)*16700
= 5010 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.237 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7097.5 lbf

Load for path 1-1 lesser of W or W1-1 = 5010 lbf
Path 1-1 Thru (1) & (3) = 44965.59 + 63089.47 = 108055.1 lbf
Path 1-1 is stronger than W1-1 so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W2-2 = 5955.218 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 50930.41 = 95896 lbf
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

N4 16" CF (14"od)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 13.5 in
Normal to the vessel wall outside 2.5*(tn-Cn) + te = .625 in
Normal to the vessel wall inside 2.5*(tn-Cn-C) = .625 in

Nozzle required thickness

L/Do = 2.625/14 = .1875   Do/t = 14/0.02907 = 481.5962
From table G: A = 0.000747
From table HA-3:   B = 5338.9

Pa= 4*B/(3*Do/t)
= 4*5338.9/(3*14/0.02907)
= 14.7811 psi

Nozzle required thickness trn = .02907 in

Required thickness tr from UG-37(d)(1) = .1428 in

Area required

Allowable stresses: Sn = 14700, Sv = 14700, psi

fr1 = lesser of 1 or Sn/Sv so fr1 = 1
fr2 = lesser of 1 or Sn/Sv so fr2 = 1

A = 0.5*(d*tr*F + 2*tn*tr*F*(1 - fr1))
= 0.5*(13.5*0.1428*1 + 2*0.25*0.1428*1*(1 - 1))
= .9639 in^2

Area available

A1 = larger of the following   = 1.447 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= 1.447 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.25+0.25)*(1*0.25-1*0.1428) - 2*0.25*(1*0.25-1*0.1428)*(1-1)
= .107 in^2

A2 = smaller of the following   = 0.276 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02907)*1*0.25
= .276 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02907)*1*0.25
= .276 in^2

N4 16" CF (14"od)

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.447 + 0.276 + 0.063
= 1.786 in^2

As Area > A the reinforcement is adequate for Pe = 14.7 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.02907 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0153 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.328125 in
The greater of tr2 or tr3:	tr5 = 0.0625 in
The lesser of tr4 or tr5:	tr6 = 0.0625 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.0625 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

N4 16" CF (14"od)

Applied Loads

Radial load	Pr = 4354 lbf
Circumferential moment	Mc = 378.5 lbf-ft
Circumferential shear	Vc = 126.5 lbf
Longitudinal moment	ML = 378.5 lbf-ft
Longitudinal shear	VL = 126.5 lbf
Torsion moment	Mt = 0 lbf-ft
Internal pressure	P = 0 psi

Stresses at the nozzle OD per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Pressure stress intensity factor, Farr equation 11.5

I = .25*(4 + 3*(r/x)^2 + 3*(r/x)^4)
= .25*(4 + 3*(6.75/7.25)^2 + 3*(6.75/7.25)^4)
= 2.214

Local circ. pressure stress = I*P*Rm/t = ~~0 psi~~ = 2002 psi $= \frac{(14.7)(15.375)}{(.25)} \times 2.214$

Local long. pressure stress = P*Rm/2t = ~~0 psi~~ 452 psi $= \frac{(14.7)(15.375)}{2(.25)}$

Maximum combined stress = ~~33193 psi~~
Allowable combined stress = +-3*S = +- 44100 psi   33193 + 2002 + 452 = 35647 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = ~~6067 psi~~
Allowable primary membrane stress = +-1.5*S = +- 22050 psi   6067 + 2002 + 452 = 8521 psi

The maximum primary membrane stress is within allowable limits.

N4 16" CF (14"od)

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	1.5557	0.398					-1762	-1762	-1762	-1762
✓4C*	4.3911	0.398	-4974	-4974	-4974	-4974				
1C	0.0648	0.398					-27085	27085	-27085	27085
2C-1	0.0065	0.398	-2717	2717	-2717	2717				
3A*	1.3830	0.398					-267	-267	267	267
1A	0.0573	0.398					-4079	4079	4079	-4079
✓3B*	2.5018	0.398	-483	-483	483	483				
1B-1	0.0079	0.398	-562	562	562	-562				
pressure stress* ✓			-2002.	-2002.	-2002.	-2002.	-2002.	-2002.	-2002.	-2002.
Total circ stress			-10738.	-4180.	-8648.	-4338.	-35195.	27133.	-26503.	19509.
Primary membrane circ stress*			-7459.	-7459.	-6493.	-6493.	-4031.	-4031.	-3497.	-3497.
3C*	1.5557	0.398	-1762	-1762	-1762	-1762				
4C*	4.3911	0.398					-4974	-4974	-4974	-4974
1C-1	0.0160	0.398	-6688	6688	-6688	6688				
2C	0.0300	0.398					-12540	12540	-12540	12540
4A*	5.6652	0.398					-1093	-1093	1093	1093
2A	0.0227	0.398					-1616	1616	1616	-1616
4B*	1.4487	0.398	-279	-279	279	279				
2B-1	0.0158	0.398	-1125	1125	1125	-1125				
pressure stress*			-452.	-452.	-452.	-452.	-452.	-452.	-452.	-452.
Total long stress			-10306.	5320.	-7498.	3628.	-20675.	7637.	-15257.	6591.
Primary membrane long stress*			-2493.	-2493.	-1935.	-1935.	-6519.	-6519.	-4333.	-4333.
torsion moment Mt										
Circ shear from Vc			23	23	-23	-23				
Long shear from VL							-23	-23	23	23
Total Shear stress			23	23	-23	-23	-23	-23	23	23
Combined stress			-10738.	-7459.	-8648.	-6493.	-35195.	27133.	-26503.	19509.
MEMBRANE STRESS			-452.	-452.	-452.	-452	-452	-452.	-452.	-452.
MAX COMBINED STRESS			-11190.	-7911.	-9100.	-6945.	-35647.	26681.	-26955.	19057.
MAX PRIMARY MEMBRANE			-7459	-7459.	-6493	-6493	-6519	-6519	-4333.	-4333.
PRIMARY MEMBRANE σ			-452.	-452.	-452.	-452.	-2002.	-2002.	-2002.	-2002.
MAX TOTAL PRIMARY MEMBRANE			-7911.	-7911.	-6945.	-6945.	-8521	-8521.	-6335.	-6335.

Stiffner Rings (A)

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Stiffner Rings (A)
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		64 in
Ring spacing:		117 in
Ring description:		2x2x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	0.938 in^2
Ring moment of inertia:	Ir =	0.348 in^4

Calculations for ring 64 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	58.27083 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 0.938/58.27083))
= 2150.783

From table HA-3 (ring) A = 1.635851E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*58.27083*(0.14281 + 0.938/58.27083)*1.635851E-04)/10.9
= .1335474 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 58.27083 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2

Stiffner Rings (A)

= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 181 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	66 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 0.938/66))
= 2176.604

From table HA-3 (ring) A = 1.655302E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*66*(0.14281 + 0:938/66)*1.655302E-04)/10.9
= .1512443 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 66 in

Stiffner Rings (A)

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Stiffener Rings (B)

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Stiffener Rings (B)
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		292 in
Ring spacing:		108 in
Ring description:		2x2x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	0.938 in^2
Ring moment of inertia:	Ir =	0.348 in^4

Calculations for ring 292 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	52 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 0.938/52))
= 2124.826

From table HA-3 (ring) A = 1.616295E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*52*(0.14281 + 0.938/52)*1.616295E-04)/10.9
= .1191894 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 52 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.25/2

= 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.533/(0.7655676 + 0.938)
= .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
= .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.8440839 - 1.533)^2
= .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 400 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	45.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 0.938/45.5))
= 2091.321

From table HA-3 (ring) A = 1.591049E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*45.5*(0.14281 + 0.938/45.5)*1.591049E-04)/10.9
= .1043065 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 45.5 in

Stiffener Rings (B)

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 1.408 + 0.25/2
 = 1.533 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 0.938*1.533/(0.7655676 + 0.938)
 = .8440839 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*0.8440839^2
 = .5494371 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.348 + 0.938*(0.8440839 - 1.533)^2
 = .7931799 in^4

Total available I = I1 + I2 = 1.342617 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Rings (A)

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Rings (A)
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring to datum line:		112 in
Ring spacing:		236 in
Ring description:		3x3x1/4 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.44 in^2
Ring moment of inertia:	Ir =	1.24 in^4

Calculations for ring 112 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	58.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 1.44/58.5))
= 2041.357

From table HA-3 (ring) A = 1.553394E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*58.5*(0.14281 + 1.44/58.5)*1.553394E-04)/10.9
= .1341392 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 58.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 2.158 + 0.25/2

= 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.44*2.283/(0.7655676 + 1.44)
= 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 3.06227*0.25^3/12 + 0.7655676*1.490555^2
= 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 1.24 + 1.44*(1.490555 - 2.283)^2
= 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 348 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	54 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 1.44/54))
= 2016.649

From table HA-3 (ring) A = 1.534769E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*54*(0.14281 + 1.44/54)*1.534769E-04)/10.9
= .1238351 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 54 in

Support Rings (A)

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
 = 2.158 + 0.25/2
 = 2.283 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 1.44*2.283/(0.7655676 + 1.44)
 = 1.490555 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*1.490555^2
 = 1.70489 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 1.24 + 1.44*(1.490555 - 2.283)^2
 = 2.144275 in^4

Total available I = I1 + I2 = 3.849166 in^4

The 3x3x1/4 Equal Angle vacuum stiffener is satisfactory.

Support Ring (B)

Stiffening Ring Calculations Per UG-29

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Identifier:		Support Ring (B)
Ring material specification:		SA 240 304L HIGH
Number of rings in this group:		1
Distance first ring to datum line:		244 in
Ring description:		3x3x1/2 Equal Angle
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	2.75 in^2
Ring moment of inertia:	Ir =	2.22 in^4

Calculations for ring 244 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.14281 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	31 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	55.5 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*31/(0.14281 + 2.75/55.5))
= 1776.751

From table HA-3 (ring) A = 1.353823E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (31^2*55.5*(0.14281 + 2.75/55.5)*1.353823E-04)/10.9
= .1274282 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 3.06227

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(31*0.25)
= 3.06227 in

W = Ls = 55.5 in

Shell area A1 = W*ts = 0.7655676 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 2.068 + 0.25/2
= 2.193 in

Support Ring (B)

Neutral axis of combined section

NA = As*Y2/(A1 + As)
 = 2.75*2.193/(0.7655676 + 2.75)
 = 1.715441 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 3.06227*0.25^3/12 + 0.7655676*1.715441^2
 = 2.256853 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 2.22 + 2.75*(1.715441 - 2.193)^2
 = 2.847172 in^4

Total available I = I1 + I2 = 5.104024 in^4

The 3x3x1/2 Equal Angle vacuum stiffener is satisfactory.

BELLOWS LUGS

Lug material specification	= SA 206 340L HIGH
Lug allowable stress	= 24000 psi
Top plate width	wp = 2 in
Base plate width	wb = 6 in
Top plate thickness	t = 0.375 in
Base plate thickness	tb = 0.375 in
Lug length circ. direction	L = 6 in
Gusset height	h = 6 in
Gusset thickness	tg = 0.375 in
Number of lugs	= 3
Angular position, first lug	= 120 degrees
Fillet weld size	tw = 0.25 in
Force bearing width	Fb = 3 in
Distance to load	d = 4.5 in

Lug top plate required thickness, Bednar pg 153

ta = 0.75*(VL*d*L)/(Sa*wp^2*h)
= 0.75*(1604*4.5*6)/(24000*2^2*6)
= 0.25 in

Lug gusset required thickness

Sc = 18000/(1 + (1/18000)*(h/(0.289*tg))^2)
= 18000/(1 + (1/18000)*(6/(0.289*0.375))^2)
= 15380.89 psi

tg = VL*(3*d - wb)/(Sc*wb^2*SIN(Alpha)^2)
= 1604*(3*4.5 - 6)/(15380.89*6^2*SIN(56.31)^2)
= 0.0314 in

Lug base plate required thickness

From Escoe table 4-8

fc = VL/(Fb*L) = 89.11111 psi

Mx = Cx*fc*Gs^2
= 0.1085*89.11111*5.25^2 = 266.4896

My = Cy*fc*wb^2
= -.124*89.11111*6^2 = -397.792

tb = Sqr(6*Mmax / Sa)
= Sqr(6*397.792 / 24000)
= 0.3154 in

Check lug attachment stresses

Radial load	Pr = 0 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf
Longitudinal moment	ML = 0 lbf-ft
Longitudinal shear	VL = 1604 lbf

BELLOWS LUGS

Internal pressure P = 0 psi

Stresses at the lug edge per WRC bulletin 107 (psi)

Mean radius Rm = 15.375 in
Rm/t = 61.5

C1 = 3, C2 = 3.375 in

Stress concentration factor Kn (tension) = 1
Stress concentration factor Kb (bending) = 1

Local circ. pressure stress = P*Rm/t = 0 psi

Local long. pressure stress = P*Rm/2t = 0 psi

Maximum combined stress = 950 psi
Allowable combined stress = +-1.5*S = +-22050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 0 psi
Allowable primary membrane stress = +-1.5*S = +-22050 psi

The maximum primary membrane stress is within allowable limits.

BELLOWS LUGS

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	3.9083	0.222								
4C*	7.5544	0.213								
1C	0.0648	0.203								
2C-1	0.0257	0.203								
3A*	2.3818	0.203								
1A	0.0649	0.223								
3B*	5.3623	0.211								
1B-1	0.0191	0.208								
pressure stress*										
Total circ stress										
Primary membrane circ stress*										
3C*	4.1149	0.213								
4C*	7.3854	0.222								
1C-1	0.0500	0.215								
2C	0.0334	0.215								
4A*	5.3293	0.203								
2A	0.0274	0.237								
4B*	2.3936	0.211								
2B-1	0.0268	0.226								
pressure stress*										
Total long stress										
Primary membrane long stress*										
torsion moment Mt										
Circ shear from Vc										
Long shear from VL							-475	-475	475	475
Total Shear stress							-475	-475	475	475
Combined stress							950	950	950	950