VOLUME II ATTACHMENTS

ATTACHMENT 2

I. STRUCTURAL CALCULATIONS

TITLE	DOCUMENT NO.	REV.
80 K Cryopumps		
Short Pump - Outer Shell Analysis	V049-1-081	0
Long Pump - Outer Shell Analysis	[illegible]	[illegible]
Analysis of Pump Resevoir	V049-1-067	0
External Shell Support Design	V049-1-083	0
Adapters and Spools		
Ion Pump	V049-1-045	0
Adapter A-1	V049-1-046	0
Adapter A-5	V049-1-051	0
Adapter A-7	V049-1-052	0
Adapter A-14	V049-1-075	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

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-081 PAGE 1 OF 73
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	131	4/19/96	WDB	RDC	**80K-SHORT Cryopump**	
					BY: W. Bilinsky	DEPT.: 744
PROJECT: LIGO Vacuum Equipment					PROJECT NO: V59049	

PURPOSE:

Determine required shell thickness for the 80K short cryopump. Additionally 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. Vacuum pressure = 14.7 psi
2. "Bakeout" Temperature = 400 deg F.
3. Valve weight = 150.0 lbs
4. Unbalanced Vacuum Load = 1155.0 lbs @ 10" Nozzle

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 Cr-[illegible]

CALCULATIONS:

CONCLUSIONS:

The requirements of the ASME Code are met for 80K short cryopump outer shell.

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

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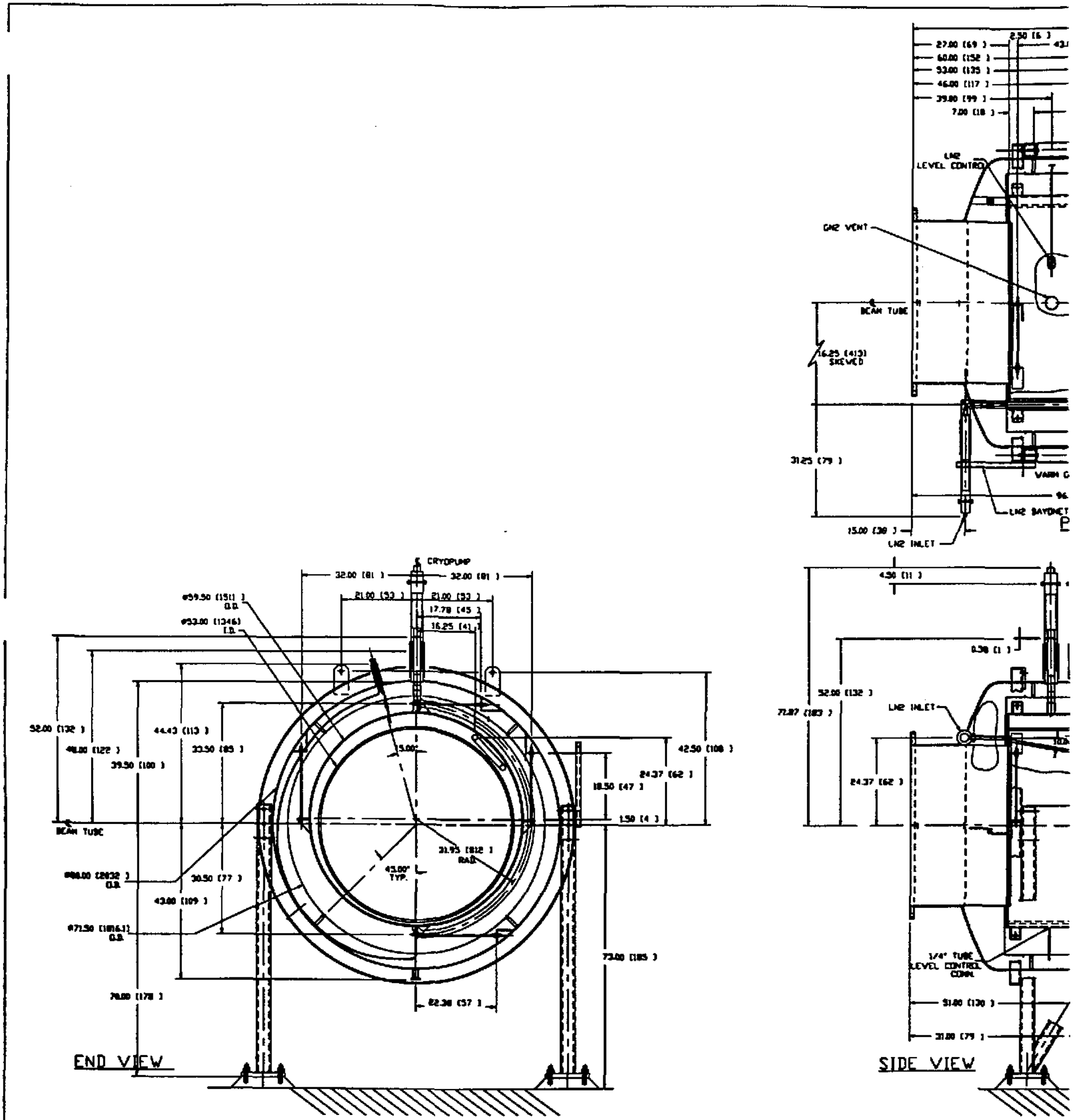


DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION

REFERENCE DRAWINGS

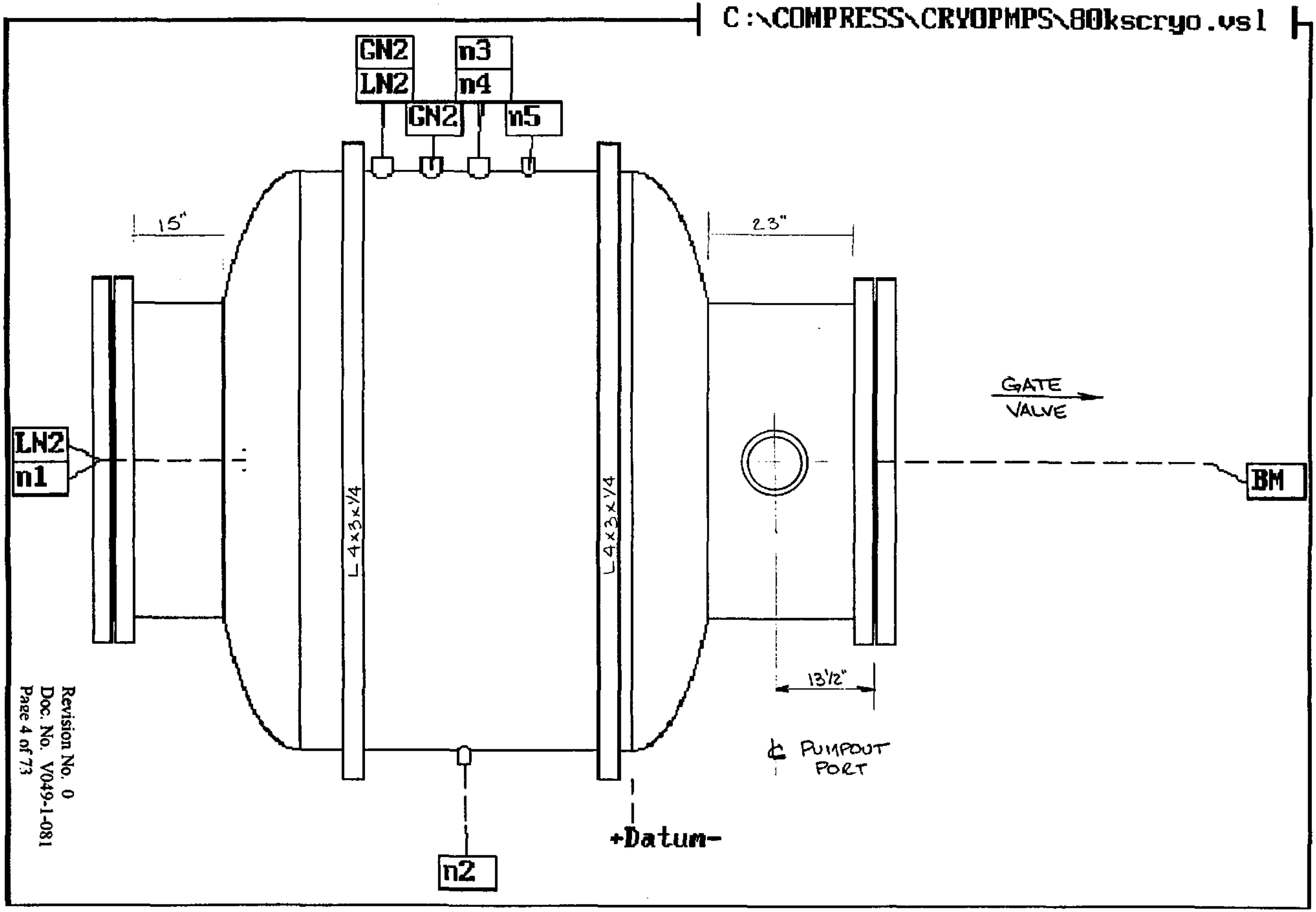
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR ...
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
FINISHED SURFACE ...
BREAK CORNERS ...
REMOVE ALL BURRS

DO NOT SCALE THIS DRAWING

USED ON

NEXT ASS'Y

8 7 6 5


C:\COMPRESS\CRYOPMPS\80kscryo.vsl
GN2
LN2
n3
n4
GN2
n5
15"
23"
LN2
n1
L 4x3x1/4
L 4x3x1/4
GATE VALVE
BM
13 1/2"
℄ PUMPOUT PORT
n2
+Datum-

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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)
80K LFT F&D HD	0.0	0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
80KsJACKET	0.0	0.0	88.9	88.9	20.9	1.000		Not applicable	0.000
80K RT F&D HD	0.0	0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
n1 BEAM TUBE LFT	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
BM BEAM TUBE RT	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n2 Clean Air Vent	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
GN2 GN2 Vent	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
GN2 GN2 Feed	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n3 Burst Disc	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n4 Elec Instrmntion	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n5 Vacuum Gauge	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
LN2 LN2 Lvl Cntrl	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
LN2 LN2 Feed	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
Support Ring					14.7				
LFT BM TUBE FLG	0.0	0.0	5.1	5.1		0.880		Not applicable	0.000
LFT BMTB CVR PLT	0.0	0.0	22.7	19.9		0.880		Not applicable	0.000
RT BM TUBE FLG	0.0	0.0	5.1	5.1		0.880		Not applicable	0.000
RT BMTB CVR PLT	0.0	0.0	22.7	19.9		0.880		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*0.88 = 19.4 psi

Vessel hydrotest pressure is 19.4 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
80k lft f&d hd	667	667	0	0	0	0	0	0	0	0	1432	136
80ksjacket	872	872	0	0	0	0	0	0	251	0	8603	6
80k rt f&d hd	667	667	0	0	0	0	0	0	0	0	1432	218
Lft bm tube flg	426	426	0	0	0	0	0	0	0	0	0	0
Lft bmtb cvr pl	616	616	0	0	0	0	0	0	0	0	0	0
Rt bm tube flg	426	426	0	0	0	0	0	0	0	0	0	0
Rt bmtb cvr plt	616	616	0	0	0	0	0	0	0	0	0	0
	4290	4290	0	0	0	0	0	0	251	0	11467	360

Vessel operating weight, corroded: 4,901 lbs
Vessel empty weight, corroded: 4,901 lbs
Vessel empty weight, new: 4,901 lbs
Vessel test weight, new: 16,368 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 4,902 lbs
Center of gravity to seam: 16 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	45.12	0.2500	0.1001	y	y	0.3750	0.2492		0.0000	105.5
BH	45.12	0.2500	0.1092	y	y	0.3750	0.2492		0.0000	105.3
n2	1.75	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
GN2	3.25	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
GN2	3.25	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
n3	2.75	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
n4	2.75	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
n5	1.75	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
LN2	2.25	0.1250	0.0625	y	y	0.2500	0.1913		0.0000	exempt
LN2	2.62	0.1250	0.0625	y	y	0.3750	0.2492		0.0000	exempt

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	beam tube lft	44.62 IDx0.25	SA 240 304L HIGH	n	n				
BM	beam tube rt	44.62 IDx0.25	SA 240 304L HIGH	n	n				
n2	clean air vent	1.50 IDx0.12	SA 240 304L HIGH	n	n				
GN2	vent	3.00 IDx0.12	SA 240 304L HIGH	n	n				
GN2	feed	3.00 IDx0.12	SA 240 304L HIGH	n	n				
n3	burst disc	2.50 IDx0.12	SA 240 304L HIGH	n	n				
n4	elec instrmntion	2.50 IDx0.12	SA 240 304L HIGH	n	n				
n5	vacuum gauge	1.50 IDx0.12	SA 240 304L HIGH	n	n				
LN2	lvl cntrl	2.00 IDx0.12	SA 240 304L HIGH	n	n				
LN2	feed	2.37 IDx0.12	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)
80k lft f&d hd	79.25		0.3750	0.2492	0.85	external			
80ksjacket	79.50	48.00	0.2500	0.1913	0.85	external			
80k rt f&d hd	79.25		0.3750	0.2492	0.85	external			
Lft bmtb cvr plt			1.0000	0.0000	0.85	internal			
Rt bmtb cvr plt			1.0000	0.0000	0.85	internal			

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

80K LFT F&D HD

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: F&D head
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
Head to shell seam - Spot UW-11(b) type 1

Estimated weight: new = 666.6 corr = 666.6 lb
capacity: new = 171.72 corr = 171.72 US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

External Pressure: (Corroded & at 400 deg F) UG-33(e)

A = .125/(Ro/t)
= .125/(80.375/0.2492)
= 0.000388

From table HA-3: B = 4757.7

Pa= B/(Ro/t)
= 4757.7/(80.375/0.2492)
= 14.7511 psi

Check the external pressure per UG-33(a)(1)

t = 1.67*Pa*Lo*M/(2*S*E + 1.67*Pa*(M-0.2))
= 1.67*14.7511*80.375*1.7706/(2*14700*1 + 1.67*14.7511*(1.7706-0.2))
= 0.119087 in

Design thickness for external pressure Pa = 14.7511 psi:

= t + Corrosion + fa
= 0.2492 + 0 + 0
= 0.2492 in

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa= B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe= 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

80KsJACKET

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 = 871.9	corr = 871.9	lb
capacity:	new = 1031.462	corr = 1031.462	US ga

OD = 80 length Lc= 48 t = 0.25 in (new)

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 16700*0.85*0.25/(40 - 0.4*0.25) - 0
= 88.94111 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-1(a)

P = S*E*t/(Ro - 0.4*t) - Ps
= 16700*0.85*0.25/(40 - 0.4*0.25) - 0
= 88.94111 psi

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

L/Do = 37/80 =0.4625 Do/t = 80/0.19131 = 418.1695
From table G: A = 0.000349
From table HA-3: B = 4622.1

Pa= 4*B/(3*Do/t)
= 4*4622.1/(3*80/0.19131)
= 14.7376 psi

Design thickness for external pressure Pa = 14.7376 psi:

= t + Corrosion
= 0.19131 + 0
= 0.19131 in

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

L/Do = 37/80 =0.4625 Do/t = 80/0.25 = 320
From table G: A = 0.00053
From table HA-3: B = 5026

80KsJACKET

Pa= 4*B/(3*Do/t)
= 4*5026/(3*80/0.25)
= 20.9417 psi

80K RT F&D HD

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: F&D head
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
Head to shell seam - Spot UW-11(b) type 1

Estimated weight:	new = 666.6	corr = 666.6	lb
capacity:	new = 171.72	corr = 171.72	US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

External Pressure: (Corroded & at 400 deg F) UG-33(e)

A = .125/(Ro/t)
= .125/(80.375/0.2492)
= 0.000388

From table HA-3: B = 4757.7

Pa= B/(Ro/t)
= 4757.7/(80.375/0.2492)
= 14.7511 psi

Check the external pressure per UG-33(a)(1)

t = 1.67*Pa*Lo*M/(2*S*E + 1.67*Pa*(M-0.2))
= 1.67*14.7511*80.375*1.7706/(2*14700*1 + 1.67*14.7511*(1.7706-0.2))
= 0.119087 in

Design thickness for external pressure Pa = 14.7511 psi:

= t + Corrosion + fa
= 0.2492 + 0 + 0
= 0.2492 in

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa= B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe= 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

BEAM TUBE LFT

Opening n1 Reinforcement Calculations Per UG-37

Located on:	80K LFT F&D HD
Local vessel thickness:	.375 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 datum line:	75 in
Nozzle calculated as hillside:	no
Projection outside vessel Lpr:	13.275 in

```
   tn ->|  |<-
         _         _
        | |<- d ->| |        corrosion allow = 0 in
 twl->| |<         | |       noz thick new tn= .25 in
      |/ |  v      | |\      nozzle id. new d= 44.625 in
 _____.-| |_       | |-._____  fillet weld twl = .25 in
 _____\|_|_tw2     |_|/_____   groove weld tw2 = .1875 in
           ^
 <--- R --->|                To head center R= 0 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 44.625 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*22.3125/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1.7706/(2*16700*1 - 0.2*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

BEAM TUBE LFT

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 44.625*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 16.734 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= 16.734 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= .469 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.375
= .469 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
= 16.734 + 0.313 + 0.063
= 17.11 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*45.125*0.25*8183 = 144933.7 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*44.875*0.25*11690 = 205901.1 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*45.125*0.1875*12358 = 164159.6 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (44.625 - 2*0.25)*(1*0.375 - 1*0))*16700
=-276332.8 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*0.375*1)*16700
= 9410.45 lbf

Load for path 1-1 lesser of W or W1-1 =-276332.8 lbf
Path 1-1 Thru (1) & (3) = 144933.7 + 205901.1 = 350834.8 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 =-276332.8 lbf
Path 2-2 Thru (1), (4) = 144933.7 + 164159.6 = 309093.3 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 = 44.625 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

BEAM TUBE LFT

Nozzle required thickness

L/Do = 13.275/45.125 = .2942 Do/t = 45.125/0.10015 = 450.5742
From table G: A = 0.000511
From table HA-3: B = 4993.9

Pa= 4*B/(3*Do/t)
= 4*4993.9/(3*45.125/0.10015)
= 14.7779 psi

Nozzle required thickness trn = .10015 in

Required thickness tr from UG-37(d)(1) = .2492 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*(44.625*0.2492*1 + 2*0.25*0.2492*1*(1 - 1))
= 5.5603 in^2

Area available

A1 = larger of the following = 5.614 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= 5.614 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= .157 in^2

A2 = smaller of the following = 0.187 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.10015)*1*0.375
= .281 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.10015)*1*0.25
= .187 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 5.614 + 0.187 + 0.063
= 5.864 in^2

BEAM TUBE LFT

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 = 0.10015 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0708 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 = 0.0708 in
The lesser of tr4 or tr5:	tr6 = 0.0708 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.10015 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

BEAM TUBE RT

Opening BM Reinforcement Calculations Per UG-37

Located on:	80K RT F&D HD
Local vessel thickness:	.375 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 datum line:	-35 in
Nozzle calculated as hillside:	no
Projection outside vessel Lpr:	21.275 in

```
   tn ->| |<-
                                  corrosion allow = 0 in
         |¯|<- d ->|¯|            noz thick new tn= .25 in
twl->| |<|         | |            nozzle id. new d= 44.625 in
     |/| | v       | |\           fillet weld twl = .25 in
_____.-| |—        | |-._____     groove weld tw2 = .1875 in
______\|_|_tw2     |_|/______
           ^
<—— R ——>|                        To head center R= 0 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 44.625 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*22.3125/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1.7706/(2*16700*1 - 0.2*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

BEAM TUBE RT

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 44.625*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 16.734 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= 16.734 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= .469 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.375
= .469 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
= 16.734 + 0.313 + 0.063
= 17.11 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

BEAM TUBE RT

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*45.125*0.25*8183 = 144933.7 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*44.875*0.25*11690 = 205901.1 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*45.125*0.1875*12358 = 164159.6 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (44.625 - 2*0.25)*(1*0.375 - 1*0))*16700
=-276332.8 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*0.375*1)*16700
= 9410.45 lbf

Load for path 1-1 lesser of W or W1-1 =-276332.8 lbf
Path 1-1 Thru (1) & (3) = 144933.7 + 205901.1 = 350834.8 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 =-276332.8 lbf
Path 2-2 Thru (1), (4) = 144933.7 + 164159.6 = 309093.3 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 = 44.625 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

BEAM TUBE RT

Nozzle required thickness

L/Do = 21.275/45.125 = .4715 Do/t = 45.125/0.10929 = 412.8923
From table G: A = 0.000347
From table HA-3: B = 4595.3

Pa= 4*B/(3*Do/t)
= 4*4595.3/(3*45.125/0.10929)
= 14.8394 psi

Nozzle required thickness trn = .10929 in

Required thickness tr from UG-37(d)(1) = .2492 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*(44.625*0.2492*1 + 2*0.25*0.2492*1*(1 - 1))
= 5.5603 in^2

Area available

A1 = larger of the following = 5.614 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= 5.614 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= .157 in^2

A2 = smaller of the following = 0.176 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.10929)*1*0.375
= .264 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.10929)*1*0.25
= .176 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 5.614 + 0.176 + 0.063
= 5.853 in^2

BEAM TUBE RT

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 = 0.10929 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0708 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 = 0.0708 in
The lesser of tr4 or tr5:	tr6 = 0.0708 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.10929 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

Clean Air Vent

Opening n2 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	180 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
         _         _
        | |<- d ->| |
twl->|  |<|       | |
     |/ | |  v    | |\
_____.-| | --     | |-.______
_____\|_|_tw2     |_|/_______
             ^
<--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 1.5 in
fillet weld twl = .125 in
groove weld tw2 = .125 in

To datum L= 24 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
 = 0*0.75/(16700*1 - 0.6*0)
 = 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
 = 0*39.75/(16700*1 - 0.6*0)
 = 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.126875 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

L/Do = 3.25/1.75 = 1.8571 Do/t = 1.75/0.00746 = 234.5845
From table G: A = 0.000197
From table HA-3: B = 2594.7

Pa= 4*B/(3*Do/t)
= 4*2594.7/(3*1.75/0.00746)
= 14.7478 psi

Nozzle required thickness trn = .00746 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00722 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.126875 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Clean Air Vent

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.

Exempt from weld strength calculations per UW-15(b)(2)

GN2 Vent

Opening GN2 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
  tn ->| |<-
        _        _
       | |<- d ->| |           corrosion allow = 0 in
twl->| |<        | |           noz thick new tn= .125 in
     |/|   v     | |\          nozzle id. new d= 3 in
_____.-| |__     | |-.______   fillet weld twl = .125 in
______\|_|_tw2   |_|/_______   groove weld tw2 = .125 in
            ^
<---- L ---->|                 To datum L= 36 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.5/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.189 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

L/Do = 3.25/3.25 = 1	Do/t = 3.25/0.01078 = 301.4842
From table G:	A = 0.000253
From table HA-3:	B = 3340.3

Pa= 4*B/(3*Do/t)
= 4*3340.3/(3*3.25/0.01078)
= 14.7727 psi

Nozzle required thickness trn = .01078 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.01032 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.189 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

GN2 Vent

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.

Exempt from weld strength calculations per UW-15(b)(2)

GN2 Feed

Opening GN2 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
          _         _
twl->| |¯|<- d ->|¯|
     | | |<         |  |
     |/| | v        |  |\
_____.-| | _        |  |-._____
_____\|_|_tw2       |_|/______
           ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 3 in
fillet weld twl = .125 in
groove weld tw2 = .125 in

To datum L= 29 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.5/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

GN2 Feed

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.189 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

L/Do = 3.25/3.25 = 1	Do/t = 3.25/0.01078 = 301.4842
From table G:	A = 0.000253
From table HA-3:	B = 3340.3

Pa= 4*B/(3*Do/t)
= 4*3340.3/(3*3.25/0.01078)
= 14.7727 psi

Nozzle required thickness trn = .01078 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.01032 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.189 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

GN2 Feed

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.

Exempt from weld strength calculations per UW-15(b)(2)

Burst Disc

Opening n3 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
          _ _         _ _
         | |<- d ->| | |
twl->|   | |<        | | |
     |/  | |   v     | | |\
______.-  | |  _      | | |-.______
______\|_| |_tw2     |_|/______
             ^
<---- L ---->|
```

corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2.5 in
fillet weld twl = .125 in
groove weld tw2 = .125 in

To datum L= 22 in

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.25/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Burst Disc

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

L/Do = 3.25/2.75 = 1.1818 Do/t = 2.75/0.00975 = 282.0513
From table G: A = 0.000238
From table HA-3: B = 3140.5

Pa = 4*B/(3*Do/t)
= 4*3140.5/(3*2.75/0.00975)
= 14.846 psi

Nozzle required thickness trn = .00975 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00938 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Burst Disc

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.

Exempt from weld strength calculations per UW-15(b)(2)

Elec Instrmntion

Opening n4 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	15 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->|  |<-
          _         _
         | |<- d ->| |
twl->|  |<|       | |
     |/ | |   v   | |\
_____.-| | --    | |-._____
_____\|_|_tw2    |_|/_____
           ^
<--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2.5 in
fillet weld twl = .125 in
groove weld tw2 = .125 in

To datum L= 22 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
 = 0*1.25/(16700*1 - 0.6*0)
 = 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
 = 0*39.75/(16700*1 - 0.6*0)
 = 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Elec Instrmntion

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

L/Do = 3.25/2.75 = 1.1818 Do/t = 2.75/0.00975 = 282.0513
From table G: A = 0.000238
From table HA-3: B = 3140.5

Pa= 4*B/(3*Do/t)
= 4*3140.5/(3*2.75/0.00975)
= 14.846 psi

Nozzle required thickness trn = .00975 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00938 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Elec Instrmntion

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.

Exempt from weld strength calculations per UW-15(b)(2)

Vacuum Gauge

Opening n5 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
         _         _
        | |<- d ->| |           corrosion allow = 0 in
twl->|  |<        | |           noz thick new tn= .125 in
     |/ | v       | |\          nozzle id. new d= 1.5 in
_____.-| |-       |-._____      fillet weld twl = .125 in
______\|_|_tw2    |_|/______    groove weld tw2 = .125 in
           ^
<---- L ---->|                  To datum L= 15 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*0.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Vacuum Gauge

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.126875 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

L/Do = 3.25/1.75 = 1.8571 Do/t = 1.75/0.00746 = 234.5845
From table G: A = 0.000197
From table HA-3: B = 2594.7

Pa= 4*B/(3*Do/t)
= 4*2594.7/(3*1.75/0.00746)
= 14.7478 psi

Nozzle required thickness trn = .00746 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00722 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.126875 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Vacuum Gauge

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.

Exempt from weld strength calculations per UW-15(b)(2)

Opening LN2 Reinforcement Calculations Per UG-37

Located on:	80KsJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	345 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
         _         _
        | |<- d ->| |          corrosion allow = 0 in
twl->|  | |       | |          noz thick new tn= .125 in
     |  |<|       | |          nozzle id. new d= 2 in
     |/ | |   v   | |\         fillet weld twl = .125 in
 ____.-_| |  __   | |-.____    groove weld tw2 = .125 in
 _____\|_|_|_tw2  |_|/_____
              ^
<---- L ---->|                 To datum L= 36 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.13475 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2 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

Nozzle required thickness

L/Do = 3.25/2.25 = 1.4444 Do/t = 2.25/0.00869 = 258.9183
From table G: A = 0.000219
From table HA-3: B = 2887.4

Pa= 4*B/(3*Do/t)
= 4*2887.4/(3*2.25/0.00869)
= 14.869 psi

Nozzle required thickness trn = .00869 in

Required thickness tr from UG-37(d)(1) = .1913 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00869 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.13475 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

LN2 Lvl Cntrl

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.

Exempt from weld strength calculations per UW-15(b)(2)

LN2 Feed

Opening LN2 Reinforcement Calculations Per UG-37

Located on:	80K LFT F&D HD
Local vessel thickness:	.375 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	90 degrees
End of nozzle to datum line:	55.91607 in
Nozzle calculated as hillside:	*no*
Projection outside vessel Lpr:	0.001 in

```
   tn ->|  |<-
         _       _
        | |<- d ->| |          corrosion allow = 0 in
twl->|  |<|       | |          noz thick new tn= .125 in
     |/ | |  v    | |\         nozzle id. new d= 2.375 in
_____.-|  | __    |  -.____    fillet weld twl = .125 in
_____\|_|_tw2     |_|/_____    groove weld tw2 = .125 in
            ^
<---- R ---->|                 To head center R= 30 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.375 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.1875/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)(1)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1/(2*16700*1 - 0.2*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

LN2 Feed

t2(actual) = 0.125 in
t1 + t2 = 0.2125 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.375 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

Nozzle required thickness

L/Do = .001/2.625 = .0004 Do/t = 2.625/0.00437 = 600.6865
From table G: A = 0.002696
From table HA-3: B = 6661.5

Pa= 4*B/(3*Do/t)
= 4*6661.5/(3*2.625/0.00437)
= 14.7864 psi

Nozzle required thickness trn = .00437 in

Required thickness tr from UG-37(d)(1) = .2492 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00301 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.04 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

LN2 Feed

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.

Exempt from weld strength calculations per UW-15(b)(2)

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:		2
Distance first ring to datum line:		4 in
Ring spacing:		37 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 4 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.19131 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	22.72495 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*80/(0.19131 + 1.69/22.72495))
= 3319.813

From table HA-3 (ring) A = 2.514604E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (80^2*22.72495*(0.19131 + 1.69/22.72495)*2.514604E-04)/10.9
= .891417 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(80*0.25)
= 4.91935 in

W = Ls = 22.72495 in

Shell area A1 = W*ts = 1.229837 in^2

Distance to the ring neutral axis

Support Ring

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/(1.229837 + 1.69)
= 1.669836 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*1.669836^2
= 3.435626 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.669836 - 2.885)^2
= 5.265493 in^4

Total available I = I1 + I2 = 8.701118 in^4

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

Calculations for ring 41 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.19131 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	24.22495 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*80/(0.19131 + 1.69/24.22495))
= 3378.368

From table HA-3 (ring) A = 2.558532E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (80^2*24.22495*(0.19131 + 1.69/24.22495)*2.558532E-04)/10.9
= .9500989 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)

Support Ring

= 1.1*Sqr(80*0.25)
= 4.91935 in

W = Ls = 24.22495 in

Shell area A1 = W*ts = 1.229837 in^2

Distance to the ring neutral axis

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/(1.229837 + 1.69)
= 1.669836 in

Inertia of the shell about the combined section NA

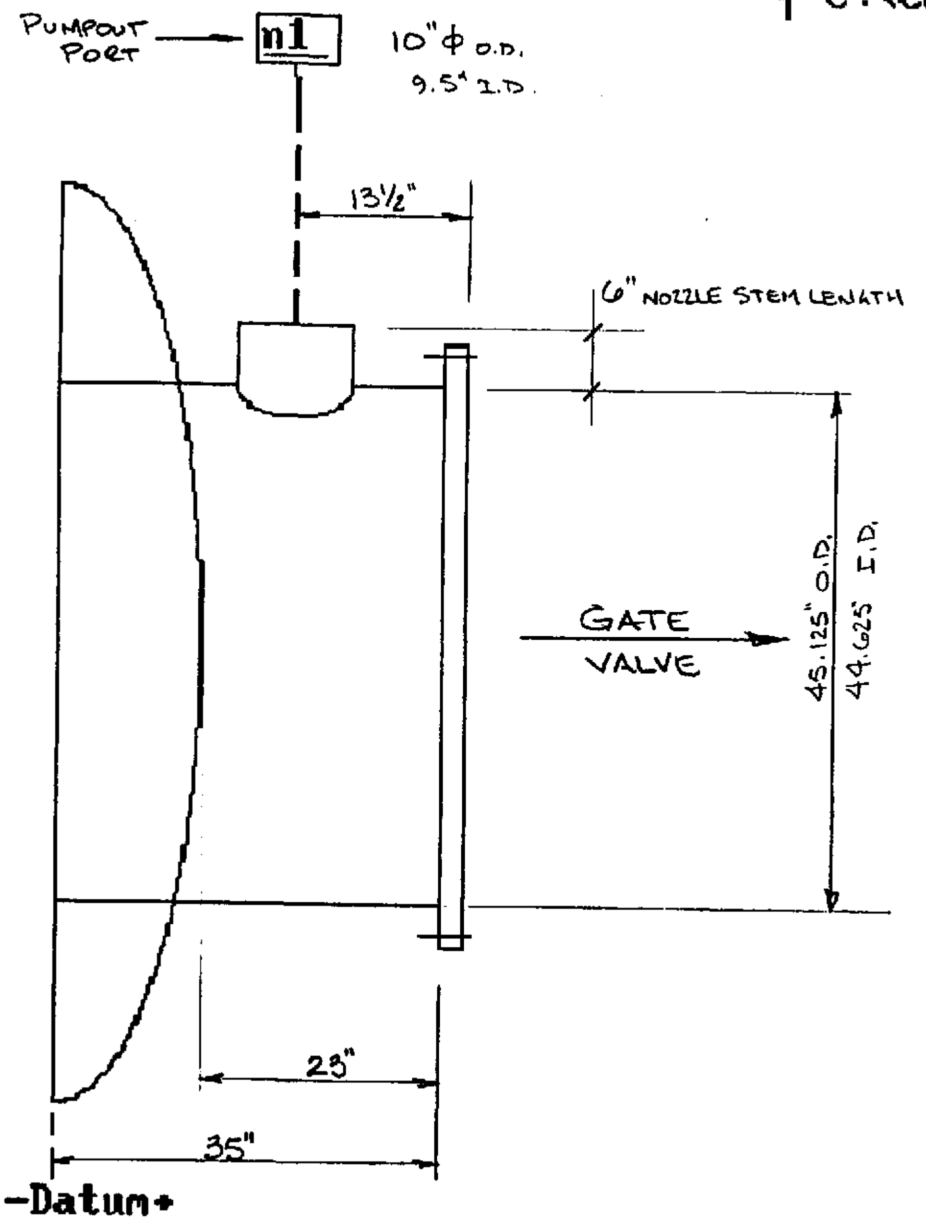
I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*1.669836^2
= 3.435626 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.669836 - 2.885)^2
= 5.265493 in^4

Total available I = I1 + I2 = 8.701118 in^4

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


PUMPOUT PORT
n1
10" ϕ O.D.
9.5" I.D.
13½"
6" NOZZLE STEM LENGTH
GATE VALVE
45.125" O.D.
44.625" I.D.
23"
35"
-Datum+

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3.21.1996

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	Nozzle Status (UG-45)	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)
HD 80Ks	.	0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
Beam Tube RT		0.0	157.9	157.9	56.3	1.000		Not applicable	0.000
n1 Pumpout Port	ok	0.0	105.7	105.7	38.4	1.000		Not applicable	0.000
FLG RT BMTUBE		0.0	0.0	0.0		0.880		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 23.85 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*0.88 = 31.5 psi

Vessel hydrotest pressure is 31.5 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
Hd 80ks	667	667	0	0	0	0	0	0	0	0	1432	0
Beam tube rt	358	358	0	0	0	0	0	0	0	0	1976	14
Flg rt bmtube	223	223	0	0	0	0	0	0	0	0	0	0
	1248	1248	0	0	0	0	0	0	0	0	3408	14

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded:	1,262 lbs
Vessel empty weight, corroded:	1,262 lbs
Vessel empty weight, new:	1,262 lbs
Vessel test weight, new:	4,670 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	1,262 lbs
Center of gravity to seam:	19.4 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	10.50	0.2500	0.1418	y	y	0.2500	0.1867		0.0000	100.0

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	pumpout port	10.00 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)
Hd 80ks	79.25		0.3750	0.3750	0.85				
Beam tube rt	44.62	35.00	0.2500	0.2500	0.85				

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

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Component:	F&D head
Material specification:	SA 240 304L HIGH

Corrosion allowance: Inner C = 0 Outer = 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Head to shell seam - Spot UW-11(b) type 1

Estimated weight:	new = 666.6	corr = 666.6	lb
capacity:	new = 171.72	corr = 171.72	US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa = B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe = 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

Beam Tube RT

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder
Material specification:	SA 240 304L HIGH

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 = 357.7	corr = 357.7	lb
capacity:	new = 236.975	corr = 236.975	US ga

ID = 44.625 length Lc = 35 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/(22.3125 + 0.6*0.25) - 0
= 157.9855 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/(22.3125 + 0.6*0.25) - 0
= 157.9855 psi

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

L/Do = 5.71875/45.125 = 0.1267 Do/t = 45.125/0.25 = 180.5
From table G: A = 0.005954
From table HA-3: B = 7630.7

Pa = 4*B/(3*Do/t)
= 4*7630.7/(3*45.125/0.25)
= 56.3671 psi

Pumpout Port

Opening n1 Reinforcement Calculations Per UG-37

Located on:	Beam Tube RT
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	90 degrees
End of nozzle to shell center:	28.5625 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	6 in

```
   tn ->| |<-
         _          _
twl->| | |<- d ->| | |
     |/ |<|       | |\
        | | v     | |
_____.-| |_       | |-.______
_____\|_|_tw2     |_|/______
            ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .25 in
nozzle id. new d= 10 in
fillet weld twl = .25 in
groove weld tw2 = .1875 in

To datum L= 21.5 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 10 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)
 = 105.729*5/(16700*1 - 0.6*105.729)
 = 0.0318 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
 = 105.729*22.3125/(16700*1 - 0.6*105.729)
 = 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

Pumpout Port

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
 = 10*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
 = 1.418 in^2

Area available

A1 = larger of the following = 1.082 in^2

 = d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
 = 10*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
 = 1.082 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

A2 = smaller of the following = 0.273 in^2

 = 5*(tn - trn)*fr2*t
 = 5*(0.25 - 0.0318)*1*0.25
 = .273 in^2

 = 5*(tn - trn)*fr2*tn
 = 5*(0.25 - 0.0318)*1*0.25
 = .273 in^2

A41 = Leg^2*fr2
 = 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
 = 1.082 + 0.273 + 0.063
 = 1.418 in^2

As Area > A the reinforcement is adequate for MAWP = 105.729 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 = 0.0318 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

Pumpout Port

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*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*10.5*0.25*8183 = 33724.19 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*10.25*0.25*11690 = 47030.33 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10.5*0.1875*12358 = 38197.81 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
 = (1.418 - (10 - 2*0.25)*(1*0.25 - 1*0.1418))*16700
 = 6514.67 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
 = (0.273 + 0 + 0.063 + 0)*16700
 = 5611.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
 = (0.273 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
 = 7698.7 lbf

Load for path 1-1 lesser of W or W1-1 = 5611.2 lbf
Path 1-1 Thru (1) & (3) = 33724.19 + 47030.33 = 80754.52 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 = 6514.67 lbf
Path 2-2 Thru (1), (4) = 33724.19 + 38197.81 = 71922 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 = 10 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

Pumpout Port

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 105.7486*5/(16700*1 - 0.6*105.7486)
= 0.0318 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 105.7486*22.3125/(16700*1 - 0.6*105.7486)
= 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)
= 10*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
= 1.418 in^2

Area available

A1 = larger of the following = 1.082 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 10*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= 1.082 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

A2 = smaller of the following = 0.273 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.082 + 0.273 + 0.063
= 1.418 in^2

As Area > A the reinforcement is adequate for MAP = 105.7486 at 0 Deg F

Pumpout Port

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 = 0.0318 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*10.5*0.25*8183 = 33724.19 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*10.25*0.25*11690 = 47030.33 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10.5*0.1875*12358 = 38197.81 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.418 - (10 - 2*0.25)*(1*0.25 - 1*0.1418))*16700
= 6514.67 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.273 + 0 + 0.063 + 0)*16700
= 5611.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv

Pumpout Port

= (0.273 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7698.7 lbf

Load for path 1-1 lesser of W or W1-1 = 5611.2 lbf
Path 1-1 Thru (1) & (3) = 33724.19 + 47030.33 = 80754.52 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 = 6514.67 lbf
Path 2-2 Thru (1), (4) = 33724.19 + 38197.81 = 71922 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 = 10 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 = 6/10.5 = .5714 Do/t = 10.5/0.05481 = 191.5709
From table G: A = 0.000926
From table HA-3: B = 5544.5

Pa= 4*B/(3*Do/t)
= 4*5544.5/(3*10.5/0.05481)
= 38.5897 psi

Nozzle required thickness trn = .05481 in

Required thickness tr from UG-37(d)(1) = .1867 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*(10*0.1867*1 + 2*0.25*0.1867*1*(1 - 1))
= .9335 in^2

Area available

A1 = larger of the following = .633 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 10*(1*0.25-1*0.1867) - 2*0.25*(1*0.25-1*0.1867)*(1-1)
= .633 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)

Pumpout Port

= 2*(0.25+0.25)*(1*0.25-1*0.1867) - 2*0.25*(1*0.25-1*0.1867)*(1-1)
= .063 in^2

A2 = smaller of the following = 0.244 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.05481)*1*0.25
= .244 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.05481)*1*0.25
= .244 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 0.633 + 0.244 + 0.063
= .94 in^2

As Area > A the reinforcement is adequate for Pe = 38.44917 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.05481 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0585 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.

Pumpout Port

Applied Loads

Radial load	Pr = 1155 lbf
Circumferential moment	Mc = 75 lbf-ft
Circumferential shear	Vc = 150 lbf
Longitudinal moment	ML = 23.8 lbf-ft
Longitudinal shear	VL = 10 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 = 22.4375 in
Rm/t = 89.75

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*(5/5.5)^2 + 3*(5/5.5)^4)
= 2.132

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

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

Maximum combined stress =-9257 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-2349 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Pumpout Port

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	4.8569	0.205					-1000	-1000	-1000	-1000
4C*	10.044	0.205	-2068	-2068	-2068	-2068				
1C	0.0633	0.205					-7019	7019	-7019	7019
2C-1	0.0189	0.205	-2096	2096	-2096	2096				
3A*	3.0844	0.205					-108	-108	108	108
1A	0.0601	0.205					-1130	1130	1130	-1130
3B*	6.8590	0.205	-76	-76	76	76				
1B-1	0.0148	0.205	-88	88	88	-88				
pressure stress*										
Total circ stress			-4328	40	-4000	16	-9257	7041	-6781	4997
Primary membrane circ stress*			-2144	-2144	-1992	-1992	-1108	-1108	-892	-892
3C*	4.8569	0.205	-1000	-1000	-1000	-1000				
4C*	10.044	0.205					-2068	-2068	-2068	-2068
1C-1	0.0427	0.205	-4735	4735	-4735	4735				
2C	0.0338	0.205					-3748	3748	-3748	3748
4A*	8.0408	0.205					-281	-281	281	281
2A	0.0265	0.205					-498	498	498	-498
4B*	3.2169	0.205	-36	-36	36	36				
2B-1	0.0207	0.205	-124	124	124	-124				
pressure stress*										
Total long stress			-5895	3823	-5575	3647	-6595	1897	-5037	1463
Primary membrane long stress*			-1036	-1036	-964	-964	-2349	-2349	-1787	-1787
torsion moment Mt										
Circ shear from Vc			36	36	-36	-36				
Long shear from VL							-2	-2	2	2
Total Shear stress			36	36	-36	-36	-2	-2	2	2
Combined stress			-5896	3823	-5576	3647	-9257	7041	-6781	4997

NOZZLE LOADS @ PUMPOUT PORT

P_R = 1155. lbs = UNBALANCED VACUUM FORCE

$= P_R = P A$

$= (14.7\ lb/in^2)\left(\pi\,(10\,in\,\phi)^2/4\right)$

$= 1155$ lbs

$M_C = W(M.A.)$
$M_L = (\text{SEISMIC } g)(W)(M.A.)$
V_C = wt of Valve
V_L = wt of valve (g.)

WGHT OF VALVE = 150 lbs

$g = 0.05625$

V_L = 150 lbs (0.05625) = 8.4375 lbs ≈ 10 lbs

V_C = 150 lbs.

M_L

MOMENT ARM (CONS.) = $\dfrac{(45.125\text{ in O.D.})}{2} + 6$ IN

= 28.5625 in

M_L = 10 lbs (28.5625 in)

ULTRA-CONSERVATIVE → = 285.625 IN-lbs = 23.8 FT-lbs.

M_C = 150 lbs (6 in) = 900 in-lbs

= 75 FT-lbs.

Single 4.00 x 3.00 x 0.250 Angle in 80.00 OD x .2500 Thk Shell
Metal Density = .2836 Lbs./Cu.In.

Eff. Shl Wdth, One Ring, based on SQR(R*T)	=	5.169 In.
Radius Of Ring Centroid, Inches,	=	38.239
I, for Ring plus Eff. Shell,	=	8.884 In.^4
A, for Ring plus Eff. Shell,	=	2.980 In.^2
CF1, Extreme Inner Fiber (ring) from Centroid,	=	2.489 In.
C2, Extreme Outer Fiber (shell) from Centroid,	=	1.761 In.
Weight of Ring only,	=	113 Lbs.

Weight of full or empty inner vessel at one ring	2168 pounds
Strap ctrline from tank vertical ctrline	32 inches
Strap angle (from bottom)	123.21 degrees
Weight of jacket at 1 ring, may incl. saddle	2320 pounds
Angle from dead bottom ctrline to saddle or lifting lug	90 degrees
Horizontal Force at 1 ring	1084 pounds
Offset of Horiz. force above centerline	0 inches
Side force angle above centerline at 1 ring	0 degrees
Seismic vertical factor used on ring weight	0
External Pressure or Vacuum	14.7 Psi

Maximum Stresses

Inner Fiber Max. Tension	=	0 psi	at	0.00	degrees.
Inner Fiber Max. Compression	=	-4,384 psi	at	99.00	degrees.
Outer Fiber Max. Tension	=	0 psi	at	0.00	degrees.
Outer Fiber Max. Compression	=	-1,619 psi	at	123.21	degrees.

NOTE:
SEE CALC. No. V049-1-083
External Shell Support Design

LIGORING CALCULATES STRESSES DUE TO INTERNAL / EXTERNAL LOADING AT THE STIFFENER RING. SEE REFERENCED CALC FOR LOADING DIAGRAM ON SUPPORT RING.

Angle from bottom	Inner fiber stress	Outer fiber stress
0.00	-2,784	-1,151
5.00	-2,779	-1,152
10.00	-2,767	-1,155
15.00	-2,746	-1,161
20.00	-2,720	-1,168
25.00	-2,689	-1,174
30.00	-2,656	-1,180
35.00	-2,623	-1,182
40.00	-2,594	-1,179
45.00	-2,573	-1,168
50.00	-2,563	-1,149
55.00	-2,568	-1,117
60.00	-2,592	-1,071
61.00	-2,600	-1,060
63.00	-2,618	-1,035
65.00	-2,640	-1,007
70.00	-2,717	-924
75.00	-2,826	-818
80.00	-2,973	-687
85.00	-3,160	-529
90.00	-3,393	-340
90.00	-3,393	-340
90.00	-4,170	-1,078
90.00	-4,147	-1,094
90.00	-4,147	-1,094
95.00	-4,333	-936
100.00	-4,383	-867
105.00	-4,302	-885
110.00	-4,096	-986
115.00	-3,772	-1,166
119.00	-3,432	-1,363
120.00	-3,337	-1,419
122.00	-3,133	-1,540
123.21	-3,002	-1,619
123.21	-2,698	-1,315
126.00	-2,707	-1,293
130.00	-2,709	-1,268
135.00	-2,699	-1,249
140.00	-2,677	-1,239

Angle from bottom	Inner fiber stress	Outer fiber stress
145.00	-2,648	-1,236
150.00	-2,616	-1,238
155.00	-2,583	-1,243
160.00	-2,552	-1,250
165.00	-2,525	-1,257
170.00	-2,505	-1,262
175.00	-2,492	-1,266
180.00	-2,488	-1,267
0.00	0	0

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-082 PAGE 1 OF 73
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	131	4/19/96	WDB	RPC	**80K-LONG Cryopump**	
					BY: W. Billingsley	DEPT.: 744
PROJECT: LIGO Vacuum Equipment					**PROJECT NO:** V59049	

PURPOSE:

Determine required shell thickness for the 80K long cryopump. Additionally, 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. Vacuum pressure = 14.7 psi
2. "Bakeout" Temperature = 400 deg F.
3. Valve weight = 150.0 lbs
4. Unbalanced Vacuum Load = 1155.0 lbs @ 10" Nozzle

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:

CONCLUSIONS:

The requirements of the ASME Code are met for 80K long cryopump outer shell.

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

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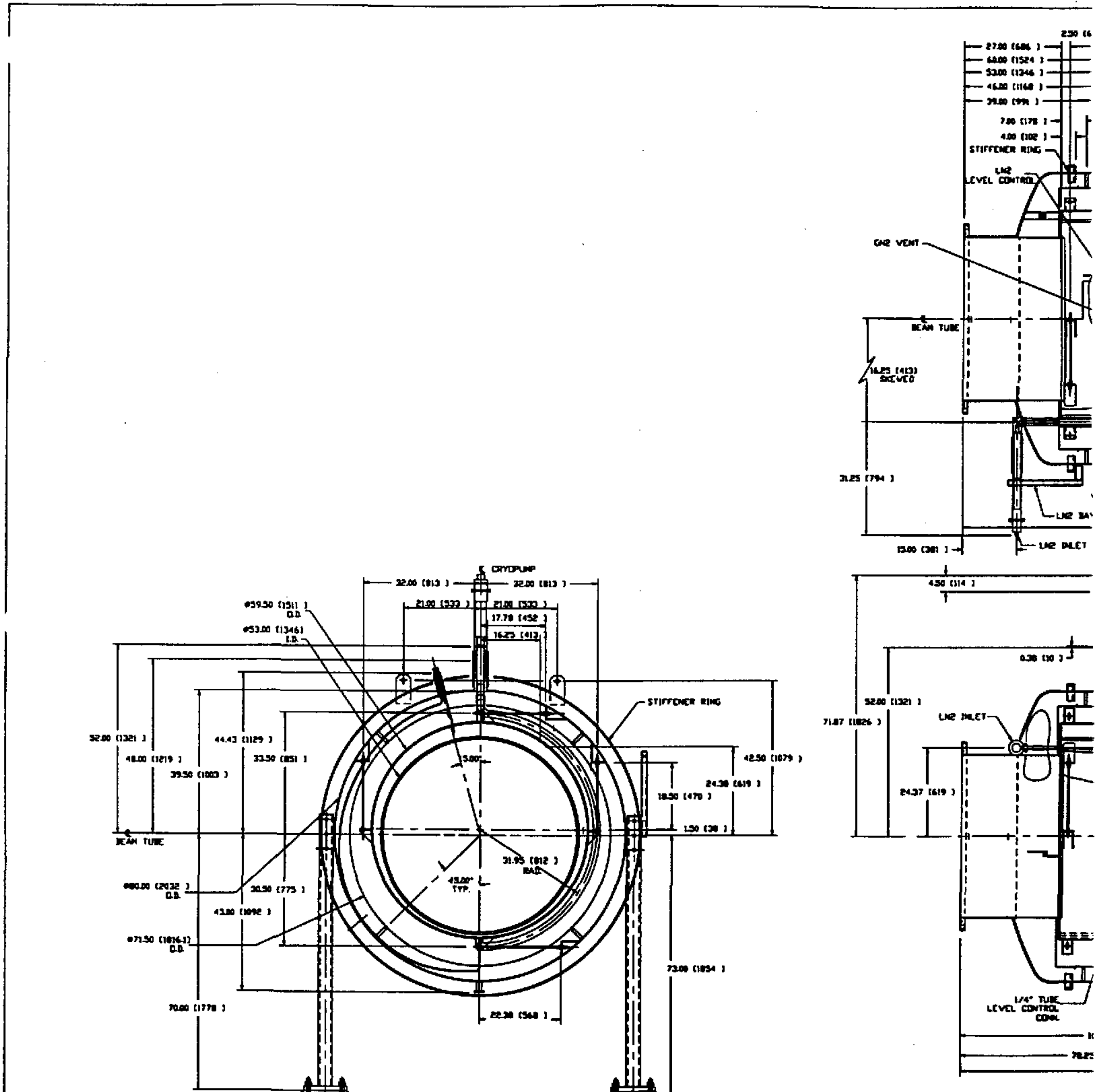

END VIEW

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ANGULAR[illegible]
TWO PLACE DECIMAL ± .[illegible]
THREE PLACE DECIMAL ± .[illegible]
FINISHED SURFACE [illegible]
BREAK CORNERS [illegible]
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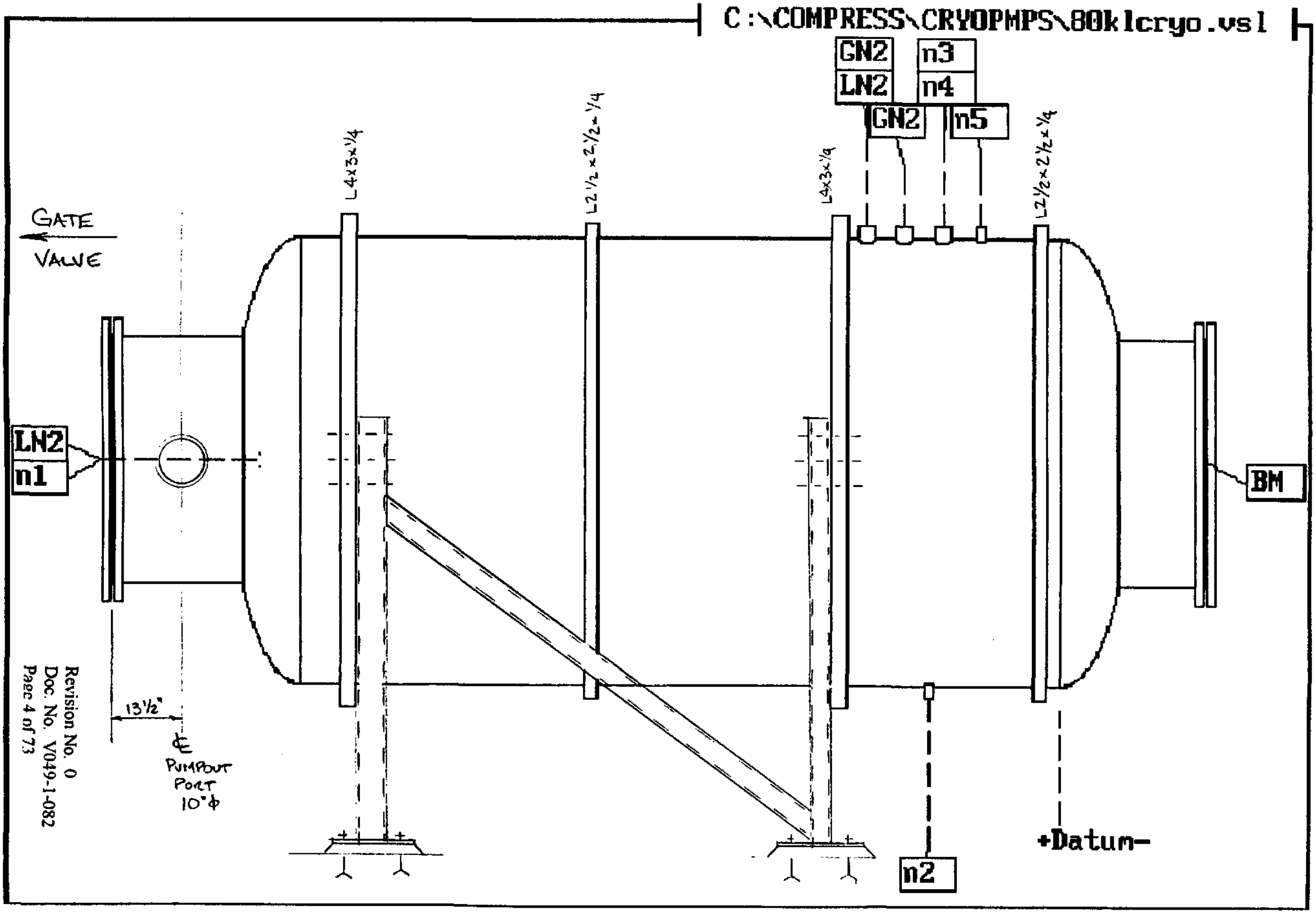

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Pressure Summary

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)
80K LFT F&D HD	0.0	0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
80KLJACKET	0.0	0.0	88.9	88.9	20.1	1.000		Not applicable	0.000
80K RT F&D HD	0.0	0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
n1 BEAM TUBE LFT	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
BM BEAM TUBE RT	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n2 Clean Air Vent	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
GN2 GN2 Vent	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
GN2 GN2 Feed	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n3 Burst Disc	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n4 Elec Instrmntion	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
n5 Vacuum Gauge	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
LN2 LN2 Lvl Cntrl	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
LN2 LN2 Feed	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
Support Rings					14.7				
LFT BM TUBE FLG	0.0	0.0	31.9	31.9		1.000		Not applicable	0.000
LFT BMTB CVR PLT	0.0	0.0	22.7	22.7		1.000		Not applicable	0.000
RT BM TUBE FLG	0.0	0.0	31.9	31.9		1.000		Not applicable	0.000
RT BMTB CVR PLT	0.0	0.0	22.7	22.7		1.000		Not applicable	0.000
Stiffner Rings					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
80k lft f&d hd	667	667	0	0	0	0	0	0	0	0	1432	218
80kljacket	2579	2579	0	0	0	0	0	0	427	0	25450	6
80k rt f&d hd	667	667	0	0	0	0	0	0	0	0	1432	136
Lft bm tube flg	426	426	0	0	0	0	0	0	0	0	0	0
Lft bmtb cvr pl	616	616	0	0	0	0	0	0	0	0	0	0
Rt bm tube flg	426	426	0	0	0	0	0	0	0	0	0	0
Rt bmtb cvr plt	616	616	0	0	0	0	0	0	0	0	0	0
	5997	5997	0	0	0	0	0	0	427	0	28314	360

Vessel operating weight, corroded:	6,784 lbs
Vessel empty weight, corroded:	6,784 lbs
Vessel empty weight, new:	6,784 lbs
Vessel test weight, new:	35,098 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	6,786 lbs
Center of gravity to seam:	60 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	45.12	0.2500	0.1092	y	y	0.3750	0.2492		0.0000	105.3
BM	45.12	0.2500	0.1001	y	y	0.3750	0.2492		0.0000	105.5
n2	1.75	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
GN2	3.25	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
GN2	3.25	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
n3	2.75	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
n4	2.75	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
n5	1.75	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
LN2	2.25	0.1250	0.0625	y	y	0.2500	0.2094		0.0000	exempt
LN2	2.62	0.1250	0.0625	y	y	0.3750	0.2492		0.0000	exempt

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	beam tube lft	44.62 IDx0.25	SA 240 304L HIGH	n	n				
BM	beam tube rt	44.62 IDx0.25	SA 240 304L HIGH	n	n				
n2	clean air vent	1.50 IDx0.12	SA 240 304L HIGH	n	n				
GN2	vent	3.00 IDx0.12	SA 240 304L HIGH	n	n				
GN2	feed	3.00 IDx0.12	SA 240 304L HIGH	n	n				
n3	burst disc	2.50 IDx0.12	SA 240 304L HIGH	n	n				
n4	elec instrmntion	2.50 IDx0.12	SA 240 304L HIGH	n	n				
n5	vacuum gauge	1.50 IDx0.12	SA 240 304L HIGH	n	n				
LN2	lvl cntrl	2.00 IDx0.12	SA 240 304L HIGH	n	n				
LN2	feed	2.37 IDx0.12	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)
80k lft f&d hd	79.25		0.3750	0.2492	0.85	external			
80klJacket	79.50	142.00	0.2500	0.2093	0.85	external			
80k rt f&d hd	79.25		0.3750	0.2492	0.85	external			
Lft bmtb cvr plt			1.0000	0.0000	0.85	internal			
Rt bmtb cvr plt			1.0000	0.0000	0.85	internal			

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

80K LFT F&D HD

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	F&D head
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
Head to shell seam - Spot UW-11(b) type 1

Estimated weight:	new = 666.6	corr = 666.6	lb
capacity:	new = 171.72	corr = 171.72	US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

External Pressure: (Corroded & at 400 deg F) UG-33(e)

A = .125/(Ro/t)
= .125/(80.375/0.2492)
= 0.000388

From table HA-3: B = 4757.7

Pa= B/(Ro/t)
= 4757.7/(80.375/0.2492)
= 14.7511 psi

Check the external pressure per UG-33(a)(1)

t = 1.67*Pa*Lo*M/(2*S*E + 1.67*Pa*(M-0.2))
= 1.67*14.7511*80.375*1.7706/(2*14700*1 + 1.67*14.7511*(1.7706-0.2))
= 0.119087 in

Design thickness for external pressure Pa = 14.7511 psi:

= t + Corrosion + fa
= 0.2492 + 0 + 0
= 0.2492 in

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa= B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe= 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

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 = 2579.3	corr = 2579.3	lb
capacity:	new = 3051.407	corr = 3051.407	US ga

OD = 80 length Lc= 142 t = 0.25 in (new)

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 16700*0.85*0.25/(40 - 0.4*0.25) - 0
= 88.94111 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-1(a)

P = S*E*t/(Ro - 0.4*t) - Ps
= 16700*0.85*0.25/(40 - 0.4*0.25) - 0
= 88.94111 psi

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

L/Do = 46/80 =0.575 Do/t = 80/0.20938 = 382.0804
From table G: A = 0.000322
From table HA-3: B = 4261.2

Pa= 4*B/(3*Do/t)
= 4*4261.2/(3*80/0.20938)
= 14.8702 psi

Design thickness for external pressure Pa = 14.8702 psi:

= t + Corrosion
= 0.20938 + 0
= 0.20938 in

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

L/Do = 46/80 =0.575 Do/t = 80/0.25 = 320
From table G: A = 0.000421
From table HA-3: B = 4826.5

Pa= 4*B/(3*Do/t)
 = 4*4826.5/(3*80/0.25)
 = 20.1104 psi

= t + Corrosion + fa
= 0.2492 + 0 + 0
= 0.2492 in

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa= B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe= 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

Opening n1 Reinforcement Calculations Per UG-37

Located on:	80K LFT F&D HD
Local vessel thickness:	.375 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 datum line:	177 in
Nozzle calculated as hillside:	no
Projection outside vessel Lpr:	21.275 in

```
   tn ->|  |<-
          _                _
         | |<- d ->|  |    |      corrosion allow = 0 in
twl->|   | |<      |  |    |      noz thick new tn= .25 in
     |/  |   v     |  |    |\     nozzle id. new d= 44.625 in
_____.-  |  --     |  |    -.____  fillet weld twl = .25 in
______\|_|_tw2     |_ |/_______    groove weld tw2 = .1875 in
            ^
<---- R ---->|                    To head center R= 0 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 44.625 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*22.3125/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1.7706/(2*16700*1 - 0.2*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

BEAM TUBE LFT

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 44.625*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 16.734 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= 16.734 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= .469 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.375
= .469 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
= 16.734 + 0.313 + 0.063
= 17.11 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*45.125*0.25*8183 = 144933.7 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*44.875*0.25*11690 = 205901.1 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*45.125*0.1875*12358 = 164159.6 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (44.625 - 2*0.25)*(1*0.375 - 1*0))*16700
=-276332.8 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*0.375*1)*16700
= 9410.45 lbf

Load for path 1-1 lesser of W or W1-1 =-276332.8 lbf
Path 1-1 Thru (1) & (3) = 144933.7 + 205901.1 = 350834.8 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 =-276332.8 lbf
Path 2-2 Thru (1), (4) = 144933.7 + 164159.6 = 309093.3 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 = 44.625 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

BEAM TUBE LFT

Nozzle required thickness

L/Do = 21.275/45.125 = .4715 Do/t = 45.125/0.10929 = 412.8923
From table G: A = 0.000347
From table HA-3: B = 4595.3

Pa= 4*B/(3*Do/t)
= 4*4595.3/(3*45.125/0.10929)
= 14.8394 psi

Nozzle required thickness trn = .10929 in

Required thickness tr from UG-37(d)(1) = .2492 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*(44.625*0.2492*1 + 2*0.25*0.2492*1*(1 - 1))
= 5.5603 in^2

Area available

A1 = larger of the following = 5.614 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= 5.614 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= .157 in^2

A2 = smaller of the following = 0.176 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.10929)*1*0.375
= .264 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.10929)*1*0.25
= .176 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 5.614 + 0.176 + 0.063
= 5.853 in^2

BEAM TUBE LFT

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 = 0.10929 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0708 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 = 0.0708 in
The lesser of tr4 or tr5:	tr6 = 0.0708 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.10929 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

80K RT F&D HD

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	F&D head			
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
Head to shell seam - Spot UW-11(b) type 1

Estimated weight:	new = 666.6	corr = 666.6	lb
capacity:	new = 171.72	corr = 171.72	US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

External Pressure: (Corroded & at 400 deg F) UG-33(e)

A = .125/(Ro/t)
= .125/(80.375/0.2492)
= 0.000388

From table HA-3: B = 4757.7

Pa= B/(Ro/t)
= 4757.7/(80.375/0.2492)
= 14.7511 psi

Check the external pressure per UG-33(a)(1)

t = 1.67*Pa*Lo*M/(2*S*E + 1.67*Pa*(M-0.2))
= 1.67*14.7511*80.375*1.7706/(2*14700*1 + 1.67*14.7511*(1.7706-0.2))
= 0.119087 in

Design thickness for external pressure Pa = 14.7511 psi:

BEAM TUBE RT

Opening BM Reinforcement Calculations Per UG-37

Located on:	80K RT F&D HD
Local vessel thickness:	.375 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 datum line:	-27 in
Nozzle calculated as hillside:	no
Projection outside vessel Lpr:	13.275 in

```
    tn ->| |<-
                                 corrosion allow = 0 in
         _|<- d ->|_             noz thick new tn= .25 in
twl->| |<|        | |            nozzle id. new d= 44.625 in
     |/| | v      | |\           fillet weld twl = .25 in
_____.-| | -      | |-._____     groove weld tw2 = .1875 in
_____\|_|_tw2     |_|/______
          ^
<---- R ---->|                   To head center R= 0 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 44.625 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*22.3125/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1.7706/(2*16700*1 - 0.2*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

BEAM TUBE RT

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 44.625*0*1 + 2*0.25*0*1*(1 - 1)
= 0 in^2

Area available

A1 = larger of the following = 16.734 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= 16.734 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0) - 2*0.25*(1*0.375-1*0)*(1-1)
= .469 in^2

A2 = smaller of the following = 0.313 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0)*1*0.375
= .469 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
= 16.734 + 0.313 + 0.063
= 17.11 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*45.125*0.25*8183 = 144933.7 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*44.875*0.25*11690 = 205901.1 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*45.125*0.1875*12358 = 164159.6 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (0 - (44.625 - 2*0.25)*(1*0.375 - 1*0))*16700
=-276332.8 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*0.375*1)*16700
= 9410.45 lbf

Load for path 1-1 lesser of W or W1-1 =-276332.8 lbf
Path 1-1 Thru (1) & (3) = 144933.7 + 205901.1 = 350834.8 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 =-276332.8 lbf
Path 2-2 Thru (1), (4) = 144933.7 + 164159.6 = 309093.3 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 = 44.625 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

BEAM TUBE RT

Nozzle required thickness

L/Do = 13.275/45.125 = .2942 Do/t = 45.125/0.10015 = 450.5742
From table G: A = 0.000511
From table HA-3: B = 4993.9

Pa= 4*B/(3*Do/t)
= 4*4993.9/(3*45.125/0.10015)
= 14.7779 psi

Nozzle required thickness trn = .10015 in

Required thickness tr from UG-37(d)(1) = .2492 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*(44.625*0.2492*1 + 2*0.25*0.2492*1*(1 - 1))
= 5.5603 in^2

Area available

A1 = larger of the following = 5.614 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 44.625*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= 5.614 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.2492) - 2*0.25*(1*0.375-1*0.2492)*(1-1)
= .157 in^2

A2 = smaller of the following = 0.187 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.10015)*1*0.375
= .281 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.10015)*1*0.25
= .187 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 5.614 + 0.187 + 0.063
= 5.864 in^2

BEAM TUBE RT

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 = 0.10015 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0708 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 = 0.0708 in
The lesser of tr4 or tr5:	tr6 = 0.0708 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.10015 in

Available nozzle wall thickness new, tn = 0.25 in

The nozzle neck thickness is adequate for Pe.

Clean Air Vent

Opening n2 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	180 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
         _           _
        | |<- d ->| | |
twl->|  | |<|       | | |
     |/ | |  v      | | |\
_____.-| | --       | | |-._____
_____\|_|_tw2       |_|/______
          ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 1.5 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

To datum L= 24 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*0.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Clean Air Vent

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.126875 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

L/Do = 3.25/1.75 = 1.8571 Do/t = 1.75/0.00745 = 234.8993
From table G: A = 0.000197
From table HA-3: B = 2594.7

Pa= 4*B/(3*Do/t)
= 4*2594.7/(3*1.75/0.00745)
= 14.728 psi

Nozzle required thickness trn = .00745 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00745 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.126875 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Clean Air Vent

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.

Exempt from weld strength calculations per UW-15(b)(2)

GN2 Vent

Opening GN2 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
    tn ->| |<-
          _          _
         | |<- d ->| |
twl->|   |<|       | |
     |/  | |  v    | |\
_____.-  | | _     | | -._____
_____\|_ |_|_tw2   |_|/_______
             ^
<--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 3 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

To datum L= 36 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.5/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

GN2 Vent

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.189 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

L/Do = 3.25/3.25 = 1	Do/t = 3.25/0.0108 = 300.9259
From table G:	A = 0.000253
From table HA-3:	B = 3340.3

Pa= 4*B/(3*Do/t)
= 4*3340.3/(3*3.25/0.0108)
= 14.8001 psi

Nozzle required thickness trn = .0108 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0108 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.189 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

GN2 Vent

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.

Exempt from weld strength calculations per UW-15(b)(2)

GN2 Feed

Opening GN2 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
    tn ->| |<-
          _         _
         | |<- d ->| |
 twl->| |<|   v    | |\
      |/| |        | | \
 _____.-| | _      | |-.______
 _____\|_|_tw2     |_|/_______
            ^
 <--- L --->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 3 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

To datum L= 29 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.5/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

GN2 Feed

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.189 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 3 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

Nozzle required thickness

L/Do = 3.25/3.25 = 1	Do/t = 3.25/0.0108 = 300.9259
From table G:	A = 0.000253
From table HA-3:	B = 3340.3

Pa= 4*B/(3*Do/t)
= 4*3340.3/(3*3.25/0.0108)
= 14.8001 psi

Nozzle required thickness trn = .0108 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.0108 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.189 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

GN2 Feed

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.

Exempt from weld strength calculations per UW-15(b)(2)

Burst Disc

Opening n3 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
  tn ->| |<-
        _         _
       | |<- d ->| |
twl->| |<|       | |
     |/|  v      | |\
_____.-|  -      | |-._____
______\|_|_tw2   |_|/______
          ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2.5 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

To datum L= 22 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.25/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Burst Disc

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

L/Do = 3.25/2.75 = 1.1818 Do/t = 2.75/0.00976 = 281.7623
From table G: A = 0.000238
From table HA-3: B = 3140.5

Pa= 4*B/(3*Do/t)
= 4*3140.5/(3*2.75/0.00976)
= 14.8612 psi

Nozzle required thickness trn = .00976 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00976 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Burst Disc

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.

Exempt from weld strength calculations per UW-15(b)(2)

Elec Instrmntion

Opening n4 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	15 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->| |<-
          _           _
        | |<- d ->| |       corrosion allow = 0 in
twl->|  |<|        | |      noz thick new tn= .125 in
     |/ | |  v     | |\     nozzle id. new d= 2.5 in
_____.-| | -       | |-._____   fillet weld twl = .125 in
______\|_|_tw2     |_|/______   groove weld tw2 = .0875 in
            ^
<---- L ---->|                  To datum L= 22 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.25/(16700*1 - 0.6*0)
= *0 in*

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Elec Instrmntion

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.5 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

Nozzle required thickness

L/Do = 3.25/2.75 = 1.1818 Do/t = 2.75/0.00976 = 281.7623
From table G: A = 0.000238
From table HA-3: B = 3140.5

Pa = 4*B/(3*Do/t)
= 4*3140.5/(3*2.75/0.00976)
= 14.8612 psi

Nozzle required thickness trn = .00976 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00976 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Elec Instrmntion

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.

Exempt from weld strength calculations per UW-15(b)(2)

Vacuum Gauge

Opening n5 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
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:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
     tn ->| |<-
          _       _
         | |<- d ->| |        corrosion allow = 0 in
twl->|   |<|       | |        noz thick new tn= .125 in
     |/  | |   v   | |\       nozzle id. new d= 1.5 in
_____.-  | |_      | |-.____  fillet weld twl = .125 in
______\|_|_tw2     |_|/_____  groove weld tw2 = .0875 in
              ^
<--- L --->|                  To datum L= 15 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*0.75/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

Vacuum Gauge

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.126875 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 1.5 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

Nozzle required thickness

L/Do = 3.25/1.75 = 1.8571 Do/t = 1.75/0.00745 = 234.8993
From table G: A = 0.000197
From table HA-3: B = 2594.7

Pa= 4*B/(3*Do/t)
= 4*2594.7/(3*1.75/0.00745)
= 14.728 psi

Nozzle required thickness trn = .00745 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00745 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.126875 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

Vacuum Gauge

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.

Exempt from weld strength calculations per UW-15(b)(2)

Opening LN2 Reinforcement Calculations Per UG-37

Located on:	80KLJACKET
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	345 degrees
End of nozzle to shell center:	43.25 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	3.25 in

```
   tn ->|  |<-
          _        _
         | |<- d ->| |
twl->|   |<|        | |
     |/  | |  v     | |\
_____.-| | |-       | |-._____
______\|_|_|_tw2    |_|/______
              ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

To datum L= 36 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 0*39.75/(16700*1 - 0.6*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.13475 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 MAWP

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2 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

Nozzle required thickness

L/Do = 3.25/2.25 = 1.4444 Do/t = 2.25/0.00866 = 259.8152
From table G: A = 0.000218
From table HA-3: B = 2874.1

Pa= 4*B/(3*Do/t)
= 4*2874.1/(3*2.25/0.00866)
= 14.7495 psi

Nozzle required thickness trn = .00866 in

Required thickness tr from UG-37(d)(1) = .2094 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00866 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0398 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.13475 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

LN2 Lvl Cntrl

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

Exempt from weld strength calculations per UW-15(b)(2)

LN2 Feed

Opening LN2 Reinforcement Calculations Per UG-37

Located on:	80K LFT F&D HD
Local vessel thickness:	.375 in
Liquid static head included	0 psi
Flange description:	Not installed
Nozzle material specification	SA 240 304L HIGH
Nozzle orientation:	90 degrees
End of nozzle to datum line:	149.9161 in
Nozzle calculated as hillside:	no
Projection outside vessel Lpr:	0 in

```
     tn ->| |<-
                                        corrosion allow = 0 in
          |‾|<- d ->|‾|                 noz thick new tn= .125 in
  twl->|  |<|       | |                 nozzle id. new d= 2.375 in
       |/ | v       | |\                fillet weld twl = .125 in
  _____.-| |‾       | |-.____           groove weld tw2 = .0875 in
  _____\|_|_tw2     |_|/_____
            ^
  <--- R --->|                          To head center R= 30 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.375 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

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 0*1.1875/(16700*1 - 0.6*0)
= 0 in

Required thickness tr from UG-37(a)(1)

tr= P*L*M/(2*S*E - 0.2*P)
= 0*80*1/(2*16700*1 - 0.2*0)
= 0 in

Opening does not require reinforcement per UG-36(c)(3)(a)

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*0.125 = 0.0875 in

LN2 Feed

t2(actual) = 0.0875 in
t1 + t2 = 0.175 >= 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 = 0.177625 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 MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

Reinforcement Calculations for External Pressure

Limits of reinforcement UG-40

Parallel to the vessel wall d = 2.375 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

Nozzle required thickness

L/Do = 0/2.625 = 0	Do/t = 2.625/0.00436 = 602.0642
From table G:	A = 0.002689
From table HA-3:	B = 6658.6

Pa= 4*B/(3*Do/t)
= 4*6658.6/(3*2.625/0.00436)
= 14.7462 psi

Nozzle required thickness trn = .00436 in

Required thickness tr from UG-37(d)(1) = .2497 in

Opening does not require reinforcement per UG-36(c)(3)(a)

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.00436 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.04 in
Wall thickness per UG-16(b):	tr3 = 0.0625 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.177625 in
The greater of tr2 or tr3:	tr5 = 0.0625 in

LN2 Feed

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.

Exempt from weld strength calculations per UW-15(b)(2)

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:		42 in
Ring spacing:		92 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 42 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20938 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	42 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*80/(0.20938 + 1.69/42))
= 3533.398

From table HA-3 (ring) A = 2.674799E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (80^2*42*(0.20938 + 1.69/42)*2.674799E-04)/10.9
= 1.646531 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(80*0.25)
= 4.91935 in

W = Ls = 42 in

Shell area A1 = W*ts = 1.229837 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/(1.229837 + 1.69)
= 1.669836 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*1.669836^2
= 3.435626 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.669836 - 2.885)^2
= 5.265493 in^4

Total available I = I1 + I2 = 8.701119 in^4

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

Calculations for ring 134 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20938 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	29.22495 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*80/(0.20938 + 1.69/29.22495))
= 3300.808

From table HA-3 (ring) A = 2.500345E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (80^2*29.22495*(0.20938 + 1.69/29.22495)*2.500345E-04)/10.9
= 1.146451 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)

Support Rings

= 1.1*Sqr(80*0.25)
= 4.91935 in

W = Ls = 29.22495 in

Shell area A1 = W*ts = 1.229837 in^2

Distance to the ring neutral axis

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/(1.229837 + 1.69)
= 1.669836 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*1.669836^2
= 3.435626 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.669836 - 2.885)^2
= 5.265493 in^4

Total available I = I1 + I2 = 8.701118 in^4

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

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:		2
Distance first ring to datum line:		4 in
Ring spacing:		84 in
Ring description:		2.5x2.5x1/4 Equal A
Ring is rolled:		leg in (hard way)
Ring cross sectional area:	As =	1.19 in^2
Ring moment of inertia:	Ir =	0.703 in^4

Calculations for ring 4 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20938 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	23.22495 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*80/(0.20938 + 1.19/23.22495))
 = 3384.263

From table HA-3 (ring) A = 2.562953E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (80^2*23.22495*(0.20938 + 1.19/23.22495)*2.562953E-04)/10.9
 = .9108638 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)
 = 1.1*Sqr(80*0.25)
 = 4.91935 in

W = Ls = 23.22495 in

Shell area A1 = W*ts = 1.229837 in^2

Distance to the ring neutral axis

Stiffner Rings

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/(1.229837 + 1.19)
 = .9382945 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
 = 4.91935*0.25^3/12 + 1.229837*0.9382945^2
 = 1.08915 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
 = 0.703 + 1.19*(0.9382945 - 1.908)^2
 = 1.821991 in^4

Total available I = I1 + I2 = 2.911141 in^4

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

Calculations for ring 88 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20938 in
Corroded shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	46 in

B = .75*(P*Do/(t + As/Ls))
 = .75*(14.7*80/(0.20938 + 1.19/46))
 = 3749.21

From table HA-3 (ring) A = 2.836571E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
 = (80^2*46*(0.20938 + 1.19/46)*2.836571E-04)/10.9
 = 1.802328 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 4.91935

W = 1.1*Sqr(Do*ts)

Stiffner Rings

= 1.1*Sqr(80*0.25)
= 4.91935 in

W = Ls = 46 in

Shell area A1 = W*ts = 1.229837 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/(1.229837 + 1.19)
= .9382945 in

Inertia of the shell about the combined section NA

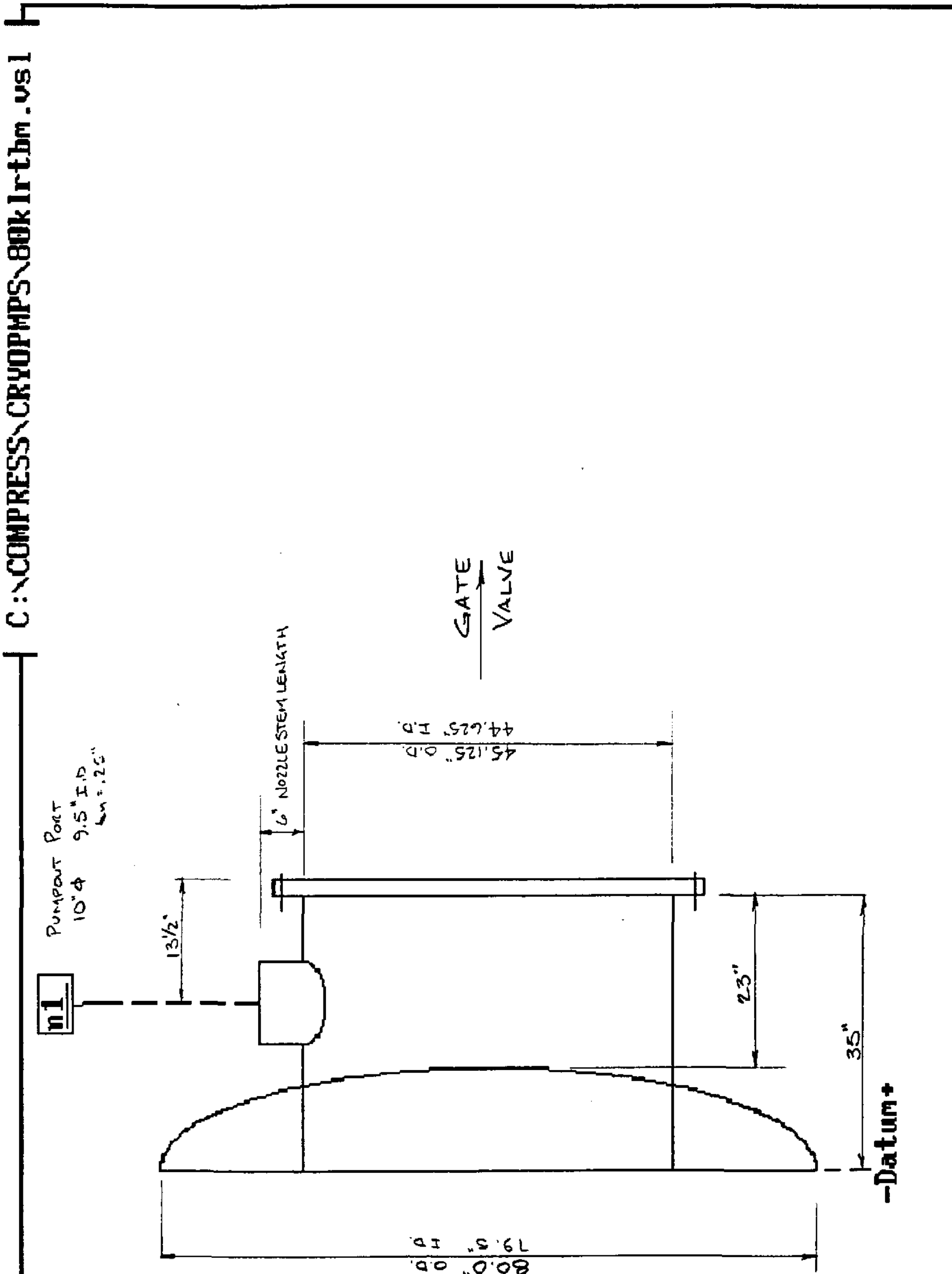
I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*0.9382945^2
= 1.08915 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.703 + 1.19*(0.9382945 - 1.908)^2
= 1.821991 in^4

Total available I = I1 + I2 = 2.911141 in^4

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


C:\COMPRESS\CRYOPMPS\80Klrtbm.vsl
GATE VALVE
6" NOZZLE STEM LENGTH
45.125" O.D.
44.625" I.D.
PUMPOUT PORT
10"Φ 9.5" I.D
tn=.25"
13½"
n1
23"
35"
-Datum+
80.0" O.D.
79.5" I.D.

Pressure Summary

Pressure summary for pressure chamber 1

Identifier	Nozzle Status (UG-45)	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)
HD 80KL		0.0	75.1	75.1	23.8	1.000		Not applicable	0.000
Beam Tube RT		0.0	157.9	157.9	56.3	1.000		Not applicable	0.000
n1 Pumpout Port	ok	0.0	105.7	105.7	38.3	1.000		Not applicable	0.000
FLG RT BMTUBE		0.0	0.0	0.0		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 23.85 psi @ 400 degrees F.

Hydrotest pressure calculation based on Pe

= 1.5*Pe*1 = 35.8 psi

Vessel hydrotest pressure is 35.8 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
Hd 80kl	667	667	0	0	0	0	0	0	0	0	1432	0
Beam tube rt	358	358	0	0	0	0	0	0	0	0	1976	14
Flg rt bmtube	223	223	0	0	0	0	0	0	0	0	0	0
	1248	1248	0	0	0	0	0	0	0	0	3408	14

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded:	1,262 lbs
Vessel empty weight, corroded:	1,262 lbs
Vessel empty weight, new:	1,262 lbs
Vessel test weight, new:	4,670 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	1,262 lbs
Center of gravity to seam:	19.4 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	10.50	0.2500	0.1418	y	y	0.2500	0.1864		0.0000	100.0

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	pumpout port	10.00 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)
Hd 80kl	79.25		0.3750	0.3750	0.85				
Beam tube rt	44.62	35.00	0.2500	0.2500	0.85				

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

HD 80KL

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: F&D head
Material specification: SA 240 304L HIGH

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Spot UW-11(b) type 1
Head to shell seam - Spot UW-11(b) type 1

Estimated weight: new = 666.6 corr = 666.6 lb
capacity: new = 171.72 corr = 171.72 US ga

OD = 80 crown L = 80 knuckle r = 4.8 t = .375 in (min)

Straight flange = 0 forming allowance = 0 in

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

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

MAWP: (Corroded & at 0 deg F) Appendix 1-4(d) Eq 4

P = 2*S*E*t/(M*Lo - t*(M-0.2)) - Ps
= 2*16700*0.85*0.375/(1.7706*80.375 - 0.375*(1.7706-0.2)) - 0
= 75.12013 psi

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

A = .125/(Ro/t)
= .125/(80.375/0.375)
= 0.000583

From table HA-3: B = 5111

Pa= B/(Ro/t)
= 5111/(80.375/0.375)
= 23.846 psi

Check the Maximum External Pressure: UG-33(a)(1) & App. 1-4(d)

Pe= 2*S*E*t/((M*Lo - t*(M-0.2))*1.67)
= 2*14700*1*0.375/((1.7706*80.375 - 0.375*(1.7706-0.2))*1.67)
= 46.58239 psi

The maximum allowable external pressure is 23.846 psi.

Beam Tube RT

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: Cylinder
Material specification: SA 240 304L HIGH

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 = 357.7	corr = 357.7	lb
capacity:	new = 236.975	corr = 236.975	US ga

ID = 44.625 length Lc = 35 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/(22.3125 + 0.6*0.25) - 0
= 157.9855 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/(22.3125 + 0.6*0.25) - 0
= 157.9855 psi

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

L/Do = 5.71875/45.125 =0.1267 Do/t = 45.125/0.25 = 180.5
From table G: A = 0.005954
From table HA-3: B = 7630.7

Pa = 4*B/(3*Do/t)
= 4*7630.7/(3*45.125/0.25)
= 56.3671 psi

Pumpout Port

Opening n1 Reinforcement Calculations Per UG-37

Located on:	Beam Tube RT
Local vessel thickness:	.25 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle material specification:	SA 240 304L HIGH
Nozzle orientation:	90 degrees
End of nozzle to shell center:	28.5625 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	6 in

```
   tn ->| |<-
         _          _
        | |<- d ->| |       corrosion allow = 0 in
twl->|  |<|       | |       noz thick new tn= .25 in
     |/ | |  v    | |\      nozzle id. new d= 10 in
_____.-| | _     | |-._____ fillet weld twl = .25 in
_____\|_|_tw2    |_|/______ groove weld tw2 = .1875 in
            ^
<--- L --->|                To datum L= 21.5 in
```

Reinforcement Calculations For Nozzle MAWP

Limits of reinforcement UG-40

Parallel to the vessel wall d = 10 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)
= 105.729*5/(16700*1 - 0.6*105.729)
= 0.0318 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 105.729*22.3125/(16700*1 - 0.6*105.729)
= 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

Pumpout Port

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 10*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
= 1.418 in^2

Area available

A1 = larger of the following = 1.082 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 10*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= 1.082 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

A2 = smaller of the following = 0.273 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.082 + 0.273 + 0.063
= 1.418 in^2

As Area > A the reinforcement is adequate for MAWP = 105.729 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 = 0.0318 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

Pumpout Port

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*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*10.5*0.25*8183 = 33724.19 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*10.25*0.25*11690 = 47030.33 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10.5*0.1875*12358 = 38197.81 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.418 - (10 - 2*0.25)*(1*0.25 - 1*0.1418))*16700
= 6514.67 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.273 + 0 + 0.063 + 0)*16700
= 5611.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.273 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7698.7 lbf

Load for path 1-1 lesser of W or W1-1 = 5611.2 lbf
Path 1-1 Thru (1) & (3) = 33724.19 + 47030.33 = 80754.52 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 = 6514.67 lbf
Path 2-2 Thru (1), (4) = 33724.19 + 38197.81 = 71922 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 = 10 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

Pumpout Port

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 105.7486*5/(16700*1 - 0.6*105.7486)
= 0.0318 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 105.7486*22.3125/(16700*1 - 0.6*105.7486)
= 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)
= 10*0.1418*1 + 2*0.25*0.1418*1*(1 - 1)
= 1.418 in^2

Area available

A1 = larger of the following = 1.082 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 10*(1*0.25-1*0.1418) - 2*0.25*(1*0.25-1*0.1418)*(1-1)
= 1.082 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

A2 = smaller of the following = 0.273 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0318)*1*0.25
= .273 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.082 + 0.273 + 0.063
= 1.418 in^2

As Area > A the reinforcement is adequate for MAP = 105.7486 at 0 Deg F

Pumpout Port

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 = 0.0318 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*10.5*0.25*8183 = 33724.19 lbf

(3) Nozzle wall in shear
(Pi/2)*Mean nozzle dia.*tn*Sn = 1.57*10.25*0.25*11690 = 47030.33 lbf

(4) Groove weld in tension
(Pi/2)*Nozzle O.D.*tw*Sg = 1.57*10.5*0.1875*12358 = 38197.81 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.418 - (10 - 2*0.25)*(1*0.25 - 1*0.1418))*16700
= 6514.67 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.273 + 0 + 0.063 + 0)*16700
= 5611.2 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv

= (0.273 + 0 + 0.063 + 0 + 2*0.25*0.25*1)*16700
= 7698.7 lbf

Load for path 1-1 lesser of W or W1-1 = 5611.2 lbf
Path 1-1 Thru (1) & (3) = 33724.19 + 47030.33 = 80754.52 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 = 6514.67 lbf
Path 2-2 Thru (1), (4) = 33724.19 + 38197.81 = 71922 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 = 10 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 = 6/10.5 = .5714	Do/t = 10.5/0.05468 = 192.0263
From table G:	A = 0.000922
From table HA-3:	B = 5540.3

Pa= 4*B/(3*Do/t)
= 4*5540.3/(3*10.5/0.05468)
= 38.469 psi

Nozzle required thickness trn = .05468 in

Required thickness tr from UG-37(d)(1) = .1864 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*(10*0.1864*1 + 2*0.25*0.1864*1*(1 - 1))
= .932 in^2

Area available

A1 = larger of the following = .636 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 10*(1*0.25-1*0.1864) - 2*0.25*(1*0.25-1*0.1864)*(1-1)
= .636 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)

Pumpout Port

= 2*(0.25+0.25)*(1*0.25-1*0.1864) - 2*0.25*(1*0.25-1*0.1864)*(1-1)
= .064 in^2

A2 = smaller of the following = 0.244 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.05468)*1*0.25
= .244 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.05468)*1*0.25
= .244 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 0.636 + 0.244 + 0.063
= .943 in^2

As Area > A the reinforcement is adequate for Pe = 38.33908 at 400 Deg F

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	tr1 = 0.05468 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0583 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.

Pumpout Port

Applied Loads

Radial load	Pr = 1155 lbf
Circumferential moment	Mc = 75 lbf-ft
Circumferential shear	Vc = 150 lbf
Longitudinal moment	ML =23.8 lbf-ft
Longitudinal shear	VL = 10 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 = 22.4375 in
Rm/t = 89.75

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*(5/5.5)^2 + 3*(5/5.5)^4)
= 2.132

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

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

Maximum combined stress =-9257 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-2349 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

Pumpout Port

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	4.8569	0.205					-1000	-1000	-1000	-1000
4C*	10.044	0.205	-2068	-2068	-2068	-2068				
1C	0.0633	0.205					-7019	7019	-7019	7019
2C-1	0.0189	0.205	-2096	2096	-2096	2096				
3A*	3.0844	0.205					-108	-108	108	108
1A	0.0601	0.205					-1130	1130	1130	-1130
3B*	6.8590	0.205	-76	-76	76	76				
1B-1	0.0148	0.205	-88	88	88	-88				
pressure stress*										
Total circ stress			-4328	40	-4000	16	-9257	7041	-6781	4997
Primary membrane circ stress*			-2144	-2144	-1992	-1992	-1108	-1108	-892	-892
3C*	4.8569	0.205	-1000	-1000	-1000	-1000				
4C*	10.044	0.205					-2068	-2068	-2068	-2068
1C-1	0.0427	0.205	-4735	4735	-4735	4735				
2C	0.0338	0.205					-3748	3748	-3748	3748
4A*	8.0408	0.205					-281	-281	281	281
2A	0.0265	0.205					-498	498	498	-498
4B*	3.2169	0.205	-36	-36	36	36				
2B-1	0.0207	0.205	-124	124	124	-124				
pressure stress*										
Total long stress			-5895	3823	-5575	3647	-6595	1897	-5037	1463
Primary membrane long stress*			-1036	-1036	-964	-964	-2349	-2349	-1787	-1787
torsion moment Mt										
Circ shear from Vc			36	36	-36	-36				
Long shear from VL							-2	-2	2	2
Total Shear stress			36	36	-36	-36	-2	-2	2	2
Combined stress			-5896	3823	-5576	3647	-9257	7041	-6781	4997

NOZZLE LOADS @ 10" PUMPOUT PORT

P_R = 1155 lbs. = UNBALANCED FORCE

$\Rightarrow P_R = PA$
$= (14.7^{\#}/in^2)(\pi\ (10\ in\ d)^2/4)$
$= 1155$ lbs.

M_C = M.A. X VLV. WEIGHT
= 6" × 150# = 900 in-lbs = 75 FT-lbs.

M_L = M.A. × (VLV WEIGHT × G_{FORCE})
= M.A. × (150 lbs × 0.05625 g)

M.A. = $\left(\frac{45.125\ in\ O.D.}{2}\right) + 6\ in$ = 28.5625 in ULTRA CONSERVATIVE

∴ M_L = (28.5625 in)(150 lbs × 0.05625 g)
≅ (28.5625 in)(10 lbs) = 285.625 in-lbs
= 23.8 FT-lbs.

V_C = WGHT OF VLV
= 150 lbs

V_L = (WGHT OF VLV)(g)
= 150 lbs (0.05625 g)
≅ 10 lbs

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-067 PAGE 1 OF 25
REV.	DEO #	DATE	BY:	CHECK	TITLE: 80K Cryopump -Design of Pump Reservoir	
0	0128	4/17/96	RDC	AGA		
					BY: R. D. Ciatto	DEPT.: 744
PROJECT: LIGO Vacuum Equipment					PROJECT NO: V59049	

PURPOSE:. Design aluminum reservoir of 80k cryopump to meet the requirements of ASME Section VIII, Div. 1.

METHOD: COMPRESS was used for evaluation of shells for internal and external pressure.. A finite element analysis of the discontinuity at the end of the pump reservoir shell was performed using the IMAGES program.

ASSUMPTIONS:

INPUTS: See attachment to this calculation.
SEE ALSO DOC. NO. V049-1-066, LIGO VACUUM EQUIP., STRUCTURAL DESIGN CRITERIA

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels
2. COMPRESS 5.53, Computer Aided Pressure Vessel Design, Code Computer Systems, Inc.
3. IMAGES - 3D, Version 3.0, R. L. Cloud and Associates.

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The requirements of the ASME Code are met. The required material is SB209, 6061, T651 (aluminum)

NOTES: IMAGES computer file: 80KPMPSH.*
COMPRESS files: SHORTPMP.VSL and LONGPMP.VSL

PUMP RESERVOIR - 80K CRYO PUMPS
LONG & SHORT

MATERIAL FOR PUMP RESERVOIR IS 6061 ALUMINUM

GEOMETRY OF RESERVOIR

INNER SHELL

ID = 53 in

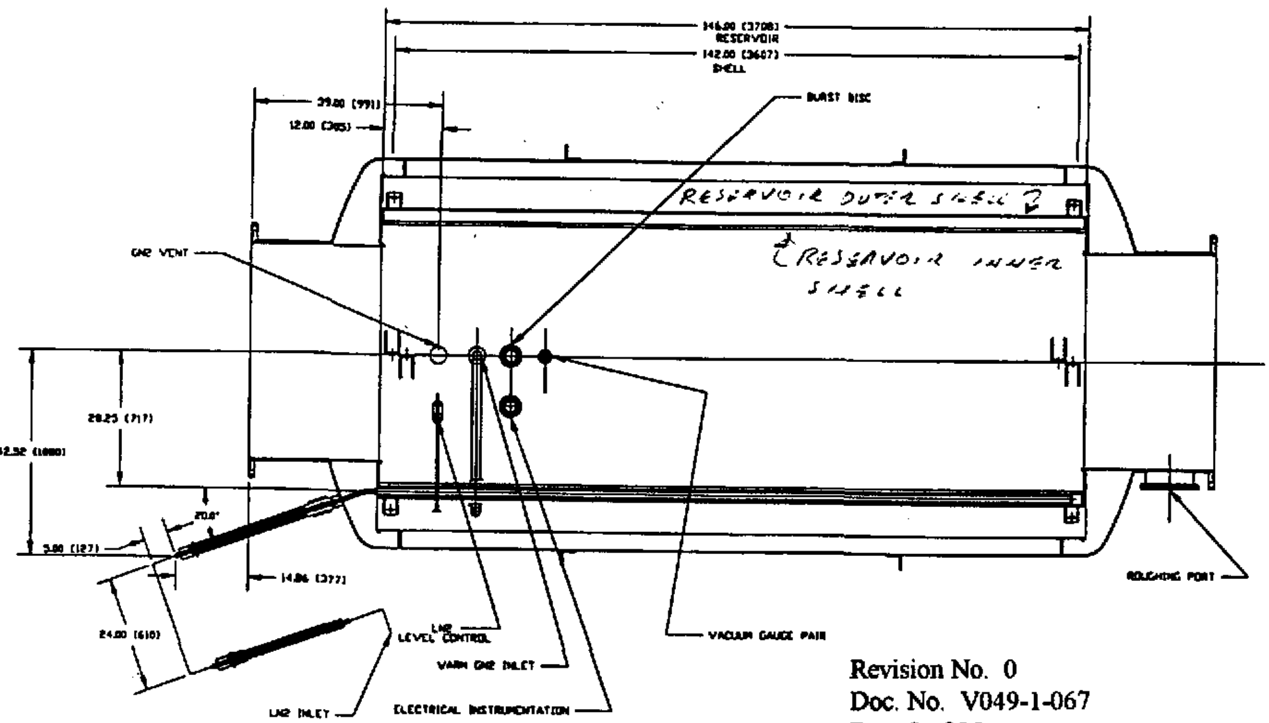
t = .625 in (LONG & SHORT)

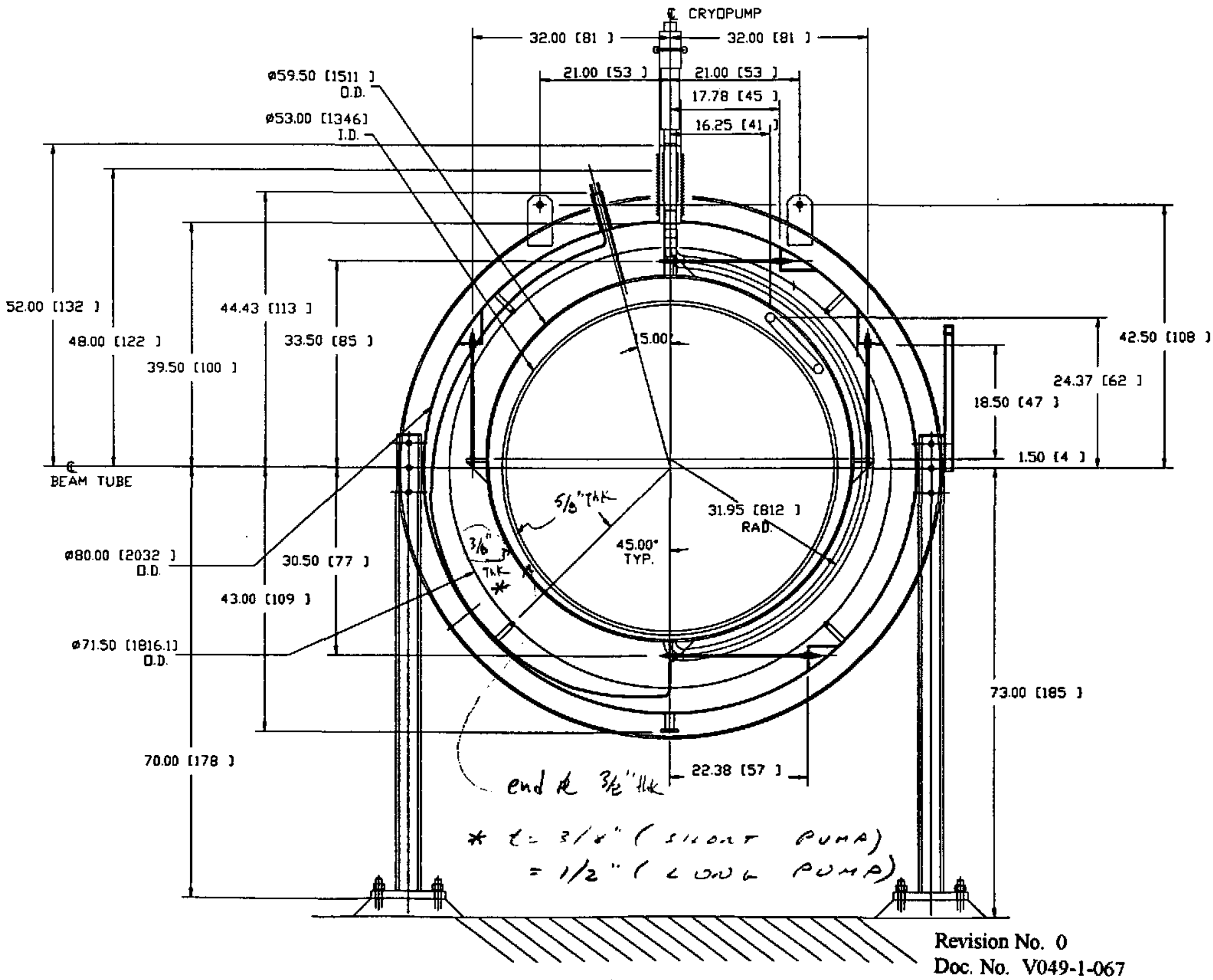
OUTER SHELL

OD = 55.5 in

t = .50 in (LONG)

t = .375 in (SHORT





℄ CRYOPUMP
32.00 [81]
32.00 [81]
21.00 [53]
21.00 [53]
17.78 [45]
16.25 [41]
ø59.50 [1511] O.D.
ø53.00 [1346] I.D.
52.00 [132]
48.00 [122]
44.43 [113]
39.50 [100]
33.50 [85]
15.00°
42.50 [108]
24.37 [62]
18.50 [47]
1.50 [4]
℄ BEAM TUBE
5/8" THK
31.95 [812] RAD.
45.00° TYP.
ø80.00 [2032] O.D.
30.50 [77]
43.00 [109]
ø71.50 [1816.1] O.D.
73.00 [185]
70.00 [178]
22.38 [57]
end ℞ 3/8" thk
* t = 3/8" (SHORT PUMP)
= 1/2" (LONG PUMP)

MATERIAL PROPERTIES

ALUMINUM SB209 6061, T651 FOR WELDED CONSTRUCTION, $t = .25$ TO 5.0 IN

TENSILE STR:

$S_u = 24$ KSI } @ 70°F

YIELD $S_y = 24$ KSI }

REF TABLE 1B, SEC - II, ASME CODE

ALLOWABLE STRESS

$S = 6.0$ KSI $T < -20$ °F

$= 3.5$ KSI @ 400°F

MODULUS OF ELASTICITY

$E = 8.7(10)^6$ @ 400°F

$= 11.1(10)^6$ @ -325°F

REF; TABLE TM-2, PART D SECT II, ASME CODE

Inner Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder		
Material specification:	SB 209 6061 T651 WELDED		
Internal design pressure:	P = 14.7	psi @ 70	deg F
External design pressure:	Pe= 40	psi @ -320	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 = 495.3	corr = 495.3	lb
capacity:	new = 458.427	corr = 458.427	US ga

ID = 53 length Lc= 48 t = 0.625 in (new)

Design thickness: UG-27(c)(1) Circ. stress

t = P*R/(S*E - 0.6*P) + Corrosion
= 14.7*26.5/(6000*0.85 - 0.6*14.7) + 0
= 0.0765 in

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

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

MAWP: (Corroded & at 70 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

External Pressure: (Corroded & at -320 deg F) UG-28

L/Do = 60.83334/54.25 =1.1214 Do/t = 54.25/0.40613 = 133.5779
From table G: A = 0.000777
From table NFA-13: B = 4017.5

Pa= 4*B/(3*Do/t)
= 4*4017.5/(3*54.25/0.40613)
= 40.1014 psi

Design thickness for external pressure Pa = 40.1014 psi:

= t + Corrosion
= 0.40613 + 0
= 0.40613 in

Inner Alum Cyl

Maximum Allowable External Pressure: (Corroded @ -320 deg F)

L/Do = 60.83334/54.25 =1.1214 Do/t = 54.25/0.625 = 86.8
From table G: A = 0.001501
From table NFA-13: B = 6231.1

Pa= 4*B/(3*Do/t)
= 4*6231.1/(3*54.25/0.625)
= 95.7158 psi

Inner Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder			
Material specification:	SB 209 6061 T651 WELDED			
Internal design pressure:	P = 14.7	psi @	70	deg F
External design pressure:	Pe = 25	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 = 495.3	corr = 495.3	lb
capacity:	new = 458.427	corr = 458.427	US ga

ID = 53 length Lc = 48 t = 0.625 in (new)

Design thickness: UG-27(c)(1) Circ. stress

t = P*R/(S*E - 0.6*P) + Corrosion
= 14.7*26.5/(6000*0.85 - 0.6*14.7) + 0
= 0.0765 in

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

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

MAWP: (Corroded & at 70 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

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

L/Do = 60.83334/54.25 = 1.1214 Do/t = 54.25/0.36191 = 149.8992
From table G: A = 0.000644
From table NFA-13: B = 2835.4

Pa = 4*B/(3*Do/t)
= 4*2835.4/(3*54.25/0.36191)
= 25.2205 psi

Design thickness for external pressure Pa = 25.2205 psi:

= t + Corrosion
= 0.36191 + 0
= 0.36191 in

Inner Alum Cyl

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

L/Do = 60.83334/54.25 =1.1214 Do/t = 54.25/0.625 = 86.8
From table G: A = 0.001501
From table NFA-13: B = 4310.7

Pa= 4*B/(3*Do/t)
= 4*4310.7/(3*54.25/0.625)
= 66.2166 psi

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Outer Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder			
Material specification:	SB 209 6061 T651 WELDED			
Internal design pressure:	P = 25	psi @	400	deg F
External design pressure:	Pe= 14.7	psi @	70	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 = 327.7	corr = 327.7	lb
capacity:	new = 563.293	corr = 563.293	US ga

OD = 59.5 length Lc= 48 t = 0.375 in (new)

Design thickness: (At 400 deg F) Appendix 1-1(a)

t = P*Ro/(S*E + 0.4*P) + Corrosion
= 25*29.75/(3500*0.85 + 0.4*25) + 0
= 0.2492 in

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.375/(29.75 - 0.4*0.375) - 0
= 64.61149 psi

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 3500*0.85*0.375/(29.75 - 0.4*0.375) - 0
= 37.69003 psi

External Pressure: (Corroded & at 70 deg F) UG-28

L/Do = 61.79166/59.5 =1.0385 Do/t = 59.5/0.29505 = 201.6607
From table G: A = 0.000447
From table NFA-13: B = 2247.6

Pa= 4*B/(3*Do/t)
= 4*2247.6/(3*59.5/0.29505)
= 14.8606 psi

Design thickness for external pressure Pa = 14.8606 psi:

= t + Corrosion
= 0.29505 + 0
= 0.29505 in

Outer Alum Cyl

Maximum Allowable External Pressure: (Corroded @ 70 deg F)

L/Do = 61.79166/59.5 =1.0385 Do/t = 59.5/0.375 = 158.6667
From table G: A = 0.000655
From table NFA-13: B = 3357.6

Pa= 4*B/(3*Do/t)
= 4*3357.6/(3*59.5/0.375)
= 28.2151 psi

Outer Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder		
Material specification:	SB 209 6061 T651 WELDED		
Internal design pressure:	P = 40	psi @ -320	deg F
External design pressure:	Pe = 14.7	psi @ 70	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 = 327.7	corr = 327.7	lb
capacity:	new = 563.293	corr = 563.293	US ga

OD = 59.5 length Lc = 48 t = 0.375 in (new)

Design thickness: (At -320 deg F) Appendix 1-1(a)

t = P*Ro/(S*E + 0.4*P) + Corrosion
= 40*29.75/(6000*0.85 + 0.4*40) + 0
= 0.2326 in

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.375/(29.75 - 0.4*0.375) - 0
= 64.61149 psi

MAWP: (Corroded & at -320 deg F) Appendix 1-1(a)

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.375/(29.75 - 0.4*0.375) - 0
= 64.61149 psi

External Pressure: (Corroded & at 70 deg F) UG-28

L/Do = 61.79166/59.5 = 1.0385 Do/t = 59.5/0.29505 = 201.6607
From table G: A = 0.000447
From table NFA-13: B = 2247.6

Pa = 4*B/(3*Do/t)
= 4*2247.6/(3*59.5/0.29505)
= 14.8606 psi

Design thickness for external pressure Pa = 14.8606 psi:

= t + Corrosion
= 0.29505 + 0
= 0.29505 in

Outer Alum Cyl

Maximum Allowable External Pressure: (Corroded @ 70 deg F)

L/Do = 61.79166/59.5 =1.0385 Do/t = 59.5/0.375 = 158.6667
From table G: A = 0.000655
From table NFA-13: B = 3357.6

Pa = 4*B/(3*Do/t)
= 4*3357.6/(3*59.5/0.375)
= 28.2151 psi

Inner Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder		
Material specification:	SB 209 6061 T651 WELDED		
Internal design pressure:	P = 14.7	psi @ 70	deg F
External design pressure:	Pe = 40	psi @ -320	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 = 1506.5	corr = 1506.5	lb
capacity:	new = 1394.383	corr = 1394.383	US ga

ID = 53 length Lc = 146 t = 0.625 in (new)

Design thickness: UG-27(c)(1) Circ. stress

t = P*R/(S*E - 0.6*P) + Corrosion
= 14.7*26.5/(6000*0.85 - 0.6*14.7) + 0
= 0.0765 in

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

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

MAWP: (Corroded & at 70 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

External Pressure: (Corroded & at -320 deg F) UG-28

L/Do = 158.8333/54.25 = 2.9278 Do/t = 54.25/0.61646 = 88.0025
From table G: A = 0.000527
From table NFA-13: B = 2671.9

Pa = 4*B/(3*Do/t)
= 4*2671.9/(3*54.25/0.61646)
= 40.4822 psi

Design thickness for external pressure Pa = 40.4822 psi:

= t + Corrosion
= 0.61646 + 0
= 0.61646 in

Inner Alum Cyl

Maximum Allowable External Pressure: (Corroded @ -320 deg F)

L/Do = 158.8333/54.25 =2.9278 Do/t = 54.25/0.625 = 86.8
From table G: A = 0.000537
From table NFA-13: B = 2725.2

Pa= 4*B/(3*Do/t)
= 4*2725.2/(3*54.25/0.625)
= 41.8618 psi

Inner Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder			
Material specification:	SB 209 6061 T651 WELDED			
Internal design pressure:	P = 14.7	psi @	70	deg F
External design pressure:	Pe= 25	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 = 1506.5	corr = 1506.5	lb
capacity:	new = 1394.383	corr = 1394.383	US ga

ID = 53 length Lc= 146 t = 0.625 in (new)

Design thickness: UG-27(c)(1) Circ. stress

t = P*R/(S*E - 0.6*P) + Corrosion
= 14.7*26.5/(6000*0.85 - 0.6*14.7) + 0
= 0.0765 in

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

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

MAWP: (Corroded & at 70 deg F) UG-27(c)(1)

P = S*E*t/(R + 0.6*t) - Ps
= 6000*0.85*0.625/(26.5 + 0.6*0.625) - 0
= 118.6047 psi

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

L/Do = 158.8333/54.25 =2.9278 Do/t = 54.25/0.53843 = 100.7559
From table G: A = 0.000422
From table NFA-13: B = 1905.5

Pa= 4*B/(3*Do/t)
= 4*1905.5/(3*54.25/0.53843)
= 25.2161 psi

Design thickness for external pressure Pa = 25.2161 psi:

= t + Corrosion
= 0.53843 + 0
= 0.53843 in

Inner Alum Cyl

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

L/Do = 158.8333/54.25 =2.9278 Do/t = 54.25/0.625 = 86.8
From table G: A = 0.000537
From table NFA-13: B = 2427.1

Pa= 4*B/(3*Do/t)
= 4*2427.1/(3*54.25/0.625)
= 37.2826 psi

Outer Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder		
Material specification:	SB 209 6061 T651 WELDED		
Internal design pressure:	P = 40	psi @ -320	deg F
External design pressure:	Pe = 14.7	psi @ 70	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 = 1326	corr = 1326	lb
capacity:	new = 1698.799	corr = 1698.799	US ga

OD = 59.5 length Lc = 146 t = 0.5 in (new)

Design thickness: (At -320 deg F) Appendix 1-1(a)

t = P*Ro/(S*E + 0.4*P) + Corrosion
= 40*29.75/(6000*0.85 + 0.4*40) + 0
= 0.2326 in

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.5/(29.75 - 0.4*0.5) - 0
= 86.29442 psi

MAWP: (Corroded & at -320 deg F) Appendix 1-1(a)

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.5/(29.75 - 0.4*0.5) - 0
= 86.29442 psi

External Pressure: (Corroded & at 70 deg F) UG-28

L/Do = 159.75/59.5 = 2.6849 Do/t = 59.5/0.43951 = 135.378
From table G: A = 0.000303
From table NFA-13: B = 1515

Pa = 4*B/(3*Do/t)
= 4*1515/(3*59.5/0.43951)
= 14.9212 psi

Design thickness for external pressure Pa = 14.9212 psi:

= t + Corrosion
= 0.43951 + 0
= 0.43951 in

Outer Alum Cyl

Maximum Allowable External Pressure: (Corroded @ 70 deg F)

L/Do = 159.75/59.5 =2.6849 Do/t = 59.5/0.5 = 119
From table G: A = 0.000367
From table NFA-13: B = 1835

Pa= 4*B/(3*Do/t)
= 4*1835/(3*59.5/0.5)
= 20.5602 psi

Outer Alum Cyl

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component:	Cylinder			
Material specification:	SB 209 6061 T651 WELDED			
Internal design pressure:	P = 25	psi @	400	deg F
External design pressure:	Pe= 14.7	psi @	70	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 = 1326	corr = 1326	lb
capacity:	new = 1698.799	corr = 1698.799	US ga

OD = 59.5 length Lc= 146 t = 0.5 in (new)

Design thickness: (At 400 deg F) Appendix 1-1(a)

t = P*Ro/(S*E + 0.4*P) + Corrosion
= 25*29.75/(3500*0.85 + 0.4*25) + 0
= 0.2492 in

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 6000*0.85*0.5/(29.75 - 0.4*0.5) - 0
= 86.29442 psi

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

P = S*E*t/(Ro - 0.4*t) - Ps
= 3500*0.85*0.5/(29.75 - 0.4*0.5) - 0
= 50.33841 psi

External Pressure: (Corroded & at 70 deg F) UG-28

L/Do = 159.75/59.5 =2.6849 Do/t = 59.5/0.43951 = 135.378
From table G: A = 0.000303
From table NFA-13: B = 1515

Pa= 4*B/(3*Do/t)
= 4*1515/(3*59.5/0.43951)
= 14.9212 psi

Design thickness for external pressure Pa = 14.9212 psi:

= t + Corrosion
= 0.43951 + 0
= 0.43951 in

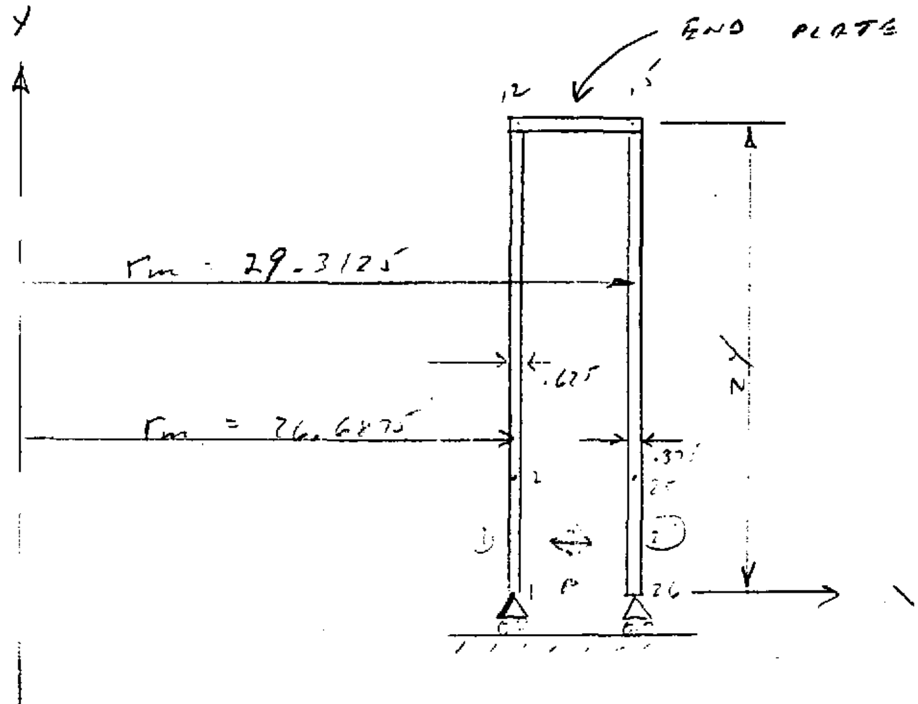
Outer Alum Cyl

Maximum Allowable External Pressure: (Corroded @ 70 deg F)

L/Do = 159.75/59.5 =2.6849 Do/t = 59.5/0.5 = 119
From table G: A = 0.000367
From table NFA-13: B = 1835

Pa= 4*B/(3*Do/t)
= 4*1835/(3*59.5/0.5)
= 20.5602 psi

IMAGES MODEL FOR DISCONTINUITY
AT ENDS OF ALUMINUM PUMP RESERVOIR



AXISYMMETRIC SHELL MODEL

PRESSURE

$p = 37$ psi (PRELIM CASE)*

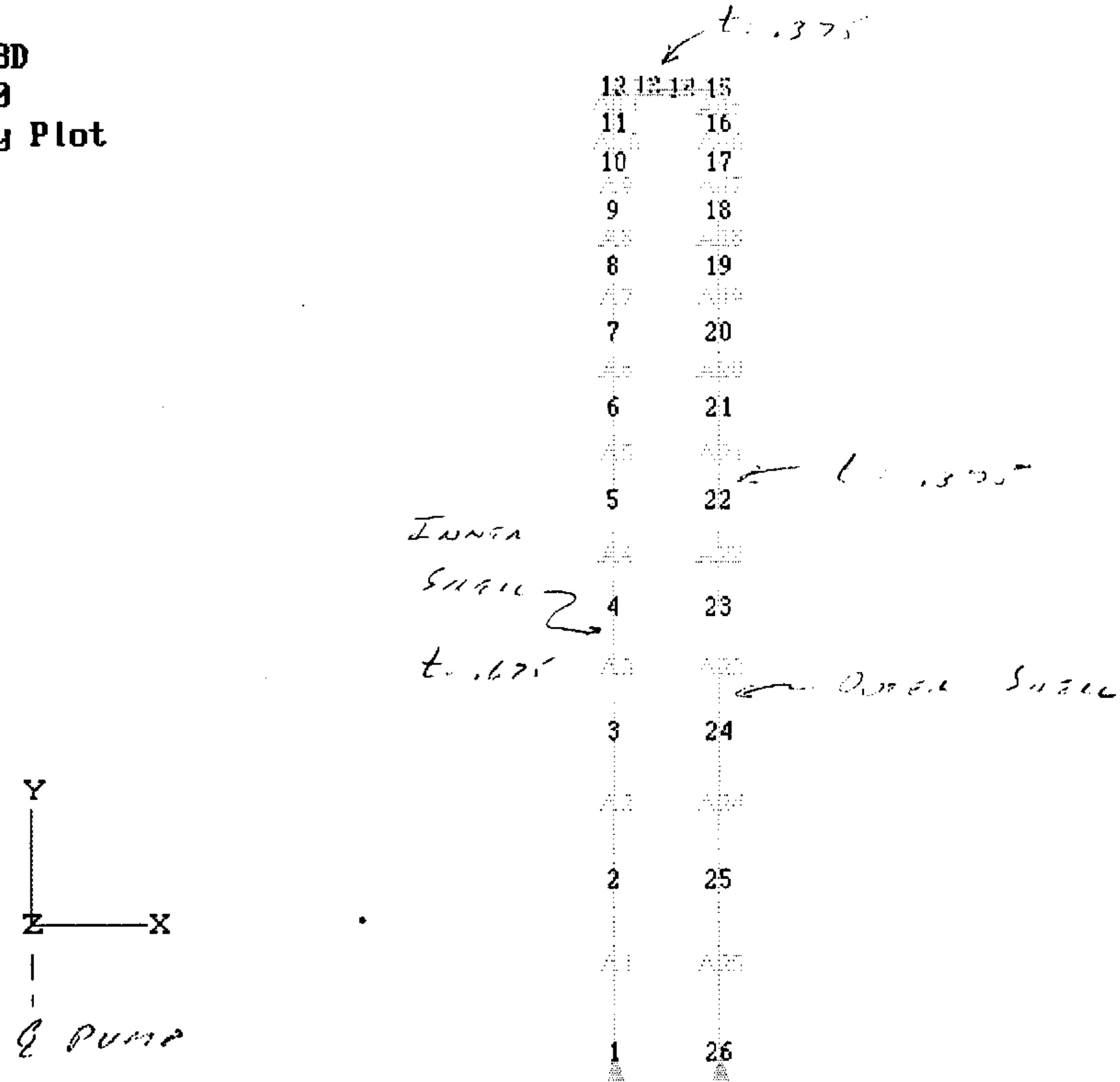
FINAL $p =$ [illegible] psi BUT
$p = 37$ OK TO EVALUATE END PLATE

24 IN LENGTH IS ADEQUATE TO EVALUATE DISCONTINUITY

NOTE: THICKEST INNER SHELL & THINNEST OUTER SHELL MODELED TO BOUND PROBLEM.

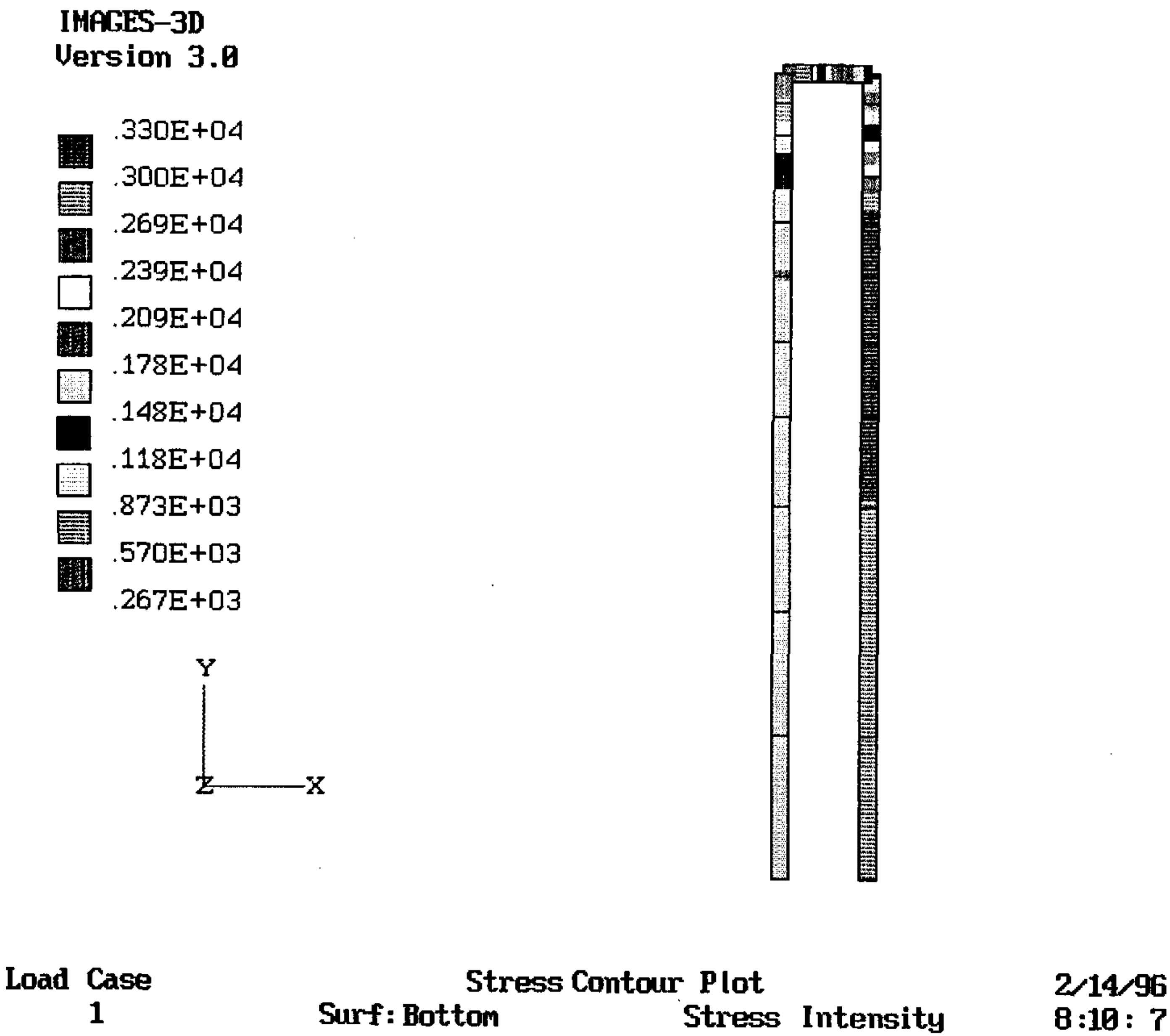
* MODEL CONFORMS TO PRELIM CONFIGURATION BUT IT IS VALID TO SHOW THAT DISCONTINUITY STRESSES ARE ACCEPTABLE AT END PLATE.

IMAGES-3D
Ver. 3.0
Geometry Plot



80k cryopump - short
Wireframe Plot

12/19/95
9: 0:33


IMAGES-3D
Version 3.0
.330E+04
.300E+04
.269E+04
.239E+04
.209E+04
.178E+04
.148E+04
.118E+04
.873E+03
.570E+03
.267E+03
Y
Z
X
Load Case
1
Stress Contour Plot
Surf: Bottom
Stress Intensity
2/14/96
8:10: 7

OUTER SHELL HOOP TENSILE STRESS

$$\sigma_\theta = \frac{pr}{t}$$

$$= \frac{37(29.3125)}{.375}$$

$$= 2890 \text{ psi}$$

AGREES w/ IMAGES OUTPUT

INNER SHELL HOOP COMPRESSIVE STRESS

$$\sigma_\theta = \frac{-37(26.6875)}{.625}$$

$$= -1580 \text{ psi}$$

AGREES w/ IMAGES OUTPUT

FROM PLOT, MAX S_I = 3.3 ksi

$< 1.5 S$

$= 1.5(3.5)$

$= 5.25$ ksi* OK

* CONSERVATIVE - COULD BE LIMITED TO $3 S_m$

DISTRIBUTED
4/3/96

Attachment

MEMORANDUM
LIGO PROJECT

Doc. No. V049-I-056

To: Dave Moore

From: Ray Ciatto RPC

Subject: Design Pressure for 80K Pump Reservoir

Reference: Doc. No. V049-I-55, Memorandum re: Design Pressures, March 29, 1996

Date: April 2, 1996

Our structural design calculation V049-1-067, Analysis of Pump Reservoir, will be updated to include the following design conditions based on the results of your pressure drop calculation which you summarized in the referenced memorandum:

Design Condition ==>	Normal Operation	Regeneration	Leak Check
Absolute Pressure	40 psia	25 psia	14.7 psia
Temperature	-320°F	400°F	70°F
Inner Cyl. Pressure	40 psid (external)	25 psid (external)	14.7 psid (internal)
Outer Cyl. Pressure	40 psid (internal)	25 psid (internal)	14.7 psid (external)
End Plate	40 psid (internal)	25 psid (Internal)	14.7 psid (external)

Please let me know if you disagree with any of the pressures and/or temperatures in the above table.

cc: Rich Bagley, Paul Hendry, Art Roussopoulos, Lynne Long/Project File, Dave McWilliams, Stu Motew, Roberto Than, Tom Starr, Walt Bilynsky, Steve Toth, Dick Curtis

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-083 PAGE 1 OF 90
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0136	4/23/96	WDB	RDC	**80K Cryopump External Shell Support Design**	
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE:

Design an external shell support frame for the 80k short and long cryopump including. baseplates, anchor bolts and bolted connections. The support frame must be able to withstand thermal expansion of the Cryopump's external shell while maintaining structural support integrity

METHOD:

Support frame is designed to AISC standards using hand calculations and STAAD-III computer program release 21.

ASSUMPTIONS:

See calculation

INPUTS:

1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.
3. Unbalanced Vacuum Load = 1155. lbs
4. Full vacuum valve load = 25.4 kips
5. Seismic acceleration = 0.05625 G

REFERENCES:

1. STAAD-III , Research Engineers, Release 21
2. AISC - ASD 9th edition
3. Doc. No. V049-1-066 LIGO Vacuum Equipment Structural Design Criteria

CALCULATIONS:

V049-1-081 80k-Short Pump - Outer Shell Analysis
V049-1-082 80k-Long Pump - Outer Shell Analysis
V049-1-032 Component Interface Loads

CONCLUSIONS:

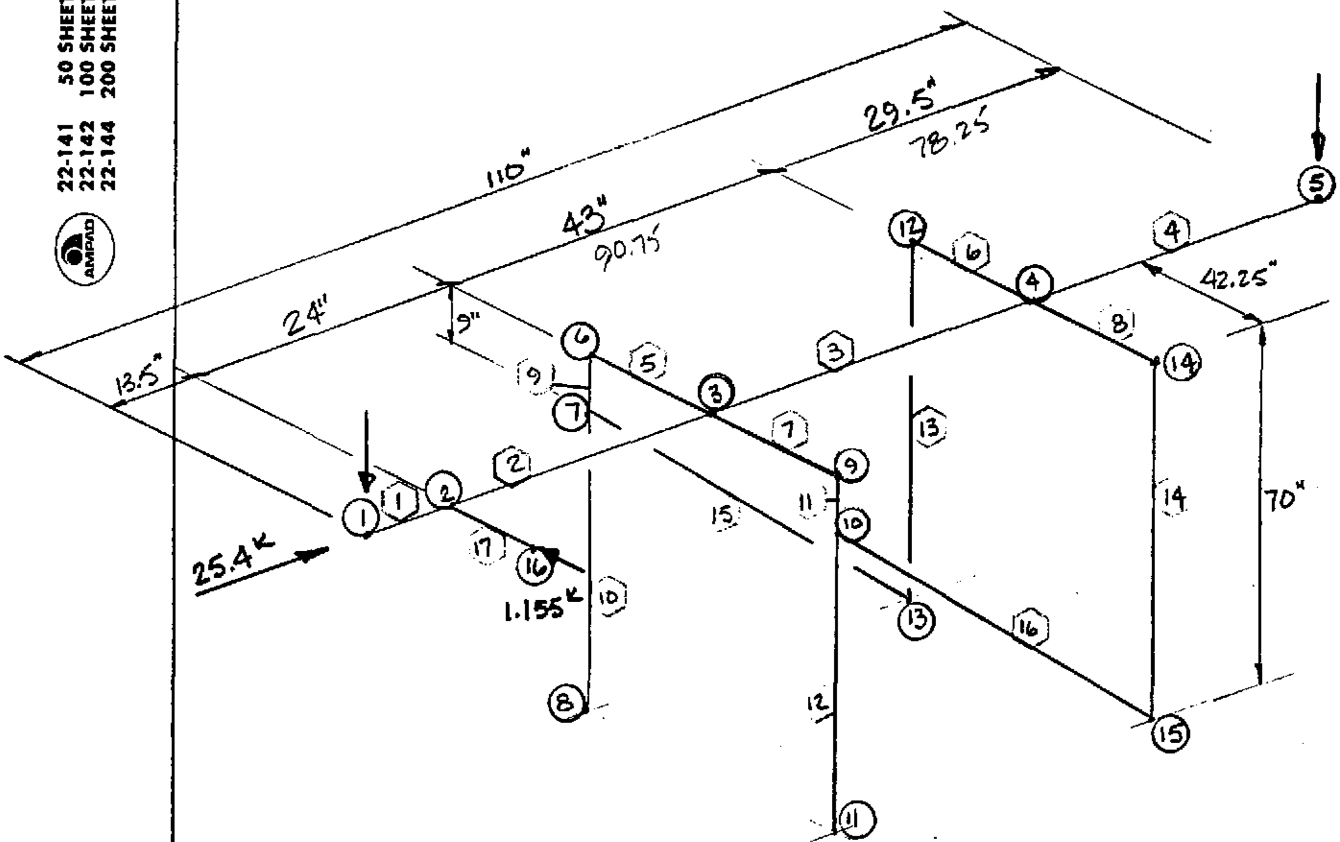
The requirements of AISC Codes and Standards and the Ligo Vacuum Equipment Structural Design Criteria are met.

NOTES: STAAD-III Computer File: 80kshort.* & 80klong.*

TABLE OF CONTENTS

80 K Short Cryopump

Support Frame Model



22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

DESIGN LOADS

DEADWEIGHT

- WEIGHT OF VESSEL
  INTERNAL WEIGHT - 1875. lbs
  EXTERNAL SHELL WEIGHT 2817. lbs
- WEIGHT OF FLANGES. = 426 lbs (ref V049-1-081)
- WEIGHT OF VALVE = 150 lbs (+/-) ASSUME 6" LONG NOZZLE STEM

THERMAL

- VESSEL 'BAKEOUT'

  70°F TO 400°F $\Delta T = 330°F$

  OCCURING ONLY ON EXTERNAL VESSEL SHELL.

VACUUM

- FULL VACUUM LOAD FROM GATE VALVE CLOSING/OPENING

  $F_{VAC} = 25400$ lbs (AXIAL FORCE)
  Doc. No. V049-1-032

- UNBALANCED VACUUM LOAD @ PUMPOUT PORT

$$F = P A$$

$$= (14.7 \text{ \#/in}^2)\frac{(10 \text{ in } \phi)^2 \pi}{4}$$

$$= 1155. \text{ lbs.}$$

SEISMIC AXIAL OR LATERAL ONLY!

$g = 0.05625$

applied as uniform load on Shell.

WEIGHT OF VESSEL

- INTERNALS (REF V049-1-070)

80K LONG CRYOPUMP $W = 5700$ lbs.
$L = 146$ IN.

80K - SHORT

$W = ?$
$L = 48$ IN

$$\frac{W}{48_{IN}} = \frac{5700}{146_{IN}} \Rightarrow W = \frac{(5700\text{ lbs})(48_{IN})}{146_{IN}}$$

WEIGHT OF 80K-SHORT ≅ 1875. lbs.

EXTERNAL SHELL (REF V049-1-081)

VESSEL WEIGHT = 4901.lbs.

$$W_T = (4901\text{ lbs}) - (2)(426\text{ lbs}) - (2)(616\text{ lbs})$$
$$= 2817\text{ lbs.}$$

$$W_{TOT} = 1875\text{ lbs} + 2817.\text{ lbs} = 4692.\text{lbs}$$

SAY 4700 lbs.

APPLY UNIFORM LOAD OVER ENTIRE CRYOPUMP

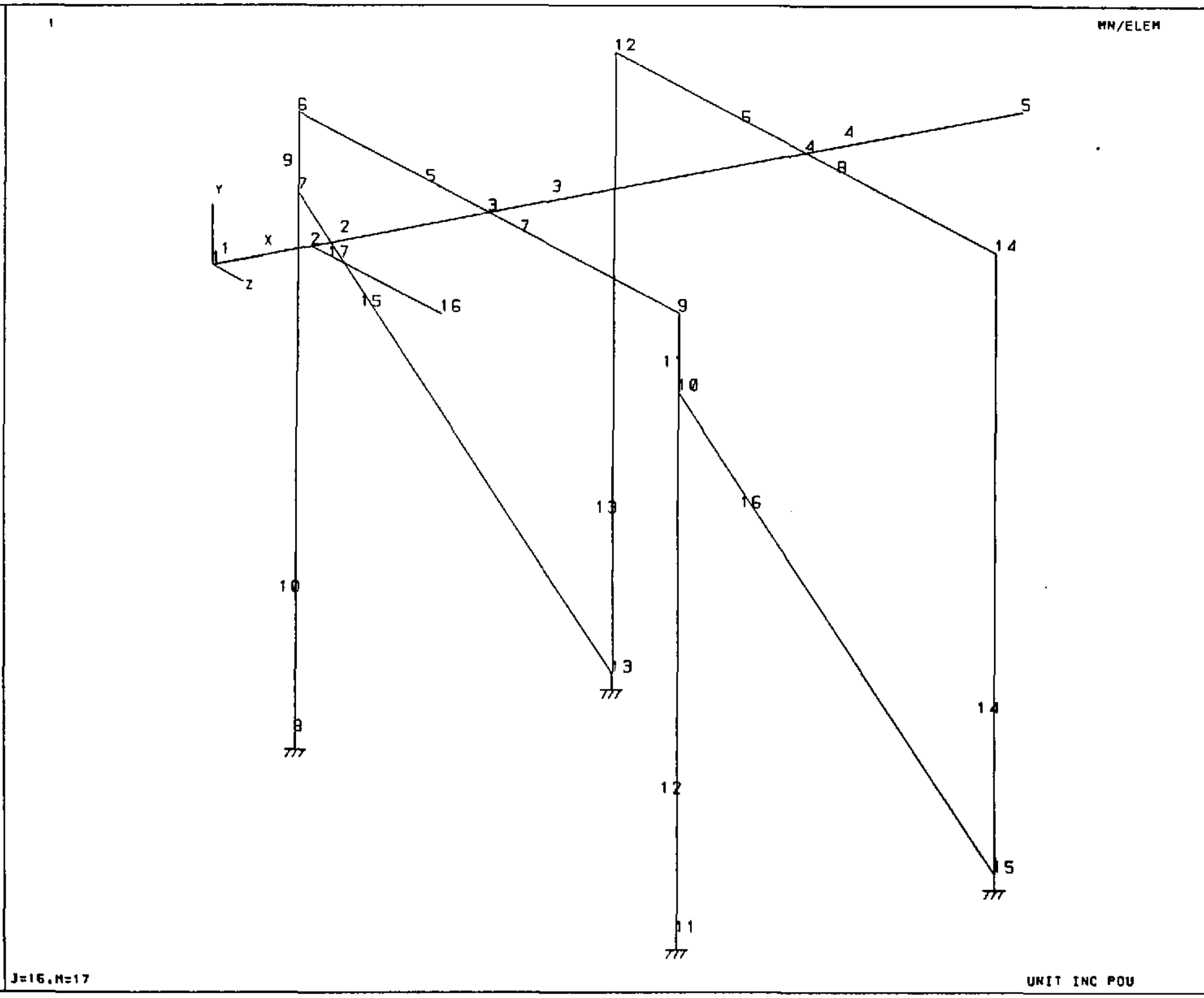
$$w = \frac{4700\text{ lbs}}{110\text{ IN.}}$$

$$w = 42.73\ \frac{\text{lbs}}{\text{IN}} = -Y$$

$$w = (0.05625g)(42.73) = 2.4\text{ lbs/in} = x = z$$

STRUCTURE DATA

TYPE = SPACE
NJ = 16
NM = 17
NE = 0
NS = 4
NL = 5
XMAX= 110.0
YMAX= 70.0
ZMAX= 84.5



USER ID:Process Systems International

S T A A D P O S T - P L O T (REV: 21.0)

TITLE: 80K SHORT CRYOPUMP SUPPORT

DATE: APR 10, 1996

```
**************************************************
*                                                *
*              S T A A D - III                   *
*              Revision 21.0                     *
*              Proprietary Program of            *
*              Research Engineers, Inc.          *
*              Date=    APR 11, 1996             *
*              Time=    15:18:32                 *
*                                                *
*       USER ID: Process Systems International   *
**************************************************
```

```
STAAD SPACE 80K-SHORT CRYOPUMP SUPPORT
*** REV1 REVISED LOADS & MEMBER RELEASE
INPUT WIDTH 72
UNIT INCHES POUND
JOINT COORDINATES
1 0. 0. 0.; 2 13.5 0. 0.; 3 37.5 0. 0.; 4 80.5 0. 0.; 5 110. 0. 0.
6 37.5 0. -42.25; 7 37.5 -9. -42.25; 8 37.5 -70. -42.25; 9 37.5 0. 42.25
10 37.5 -9. 42.25; 11 37.5 -70. 42.25; 12 80.5 0. -42.25
13 80.5 -70. -42.25; 14 80.5 0. 42.25; 15 80.5 -70. 42.25
16 13.5 0. 28.56
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6; 6 4 12; 7 3 9; 8 4 14; 9 7 6; 10 8 7
11 10 9; 12 11 10; 13 13 12; 14 15 14; 15 7 13; 16 10 15; 17 2 16
MEMBER PROPERTY AMER
9 TO 12 15 16 TABLE ST TUB40408
13 14 TABLE ST TUB40203
5 TO 8 TABLE ST TUB80805
1 2 4 TABLE ST PIPE OD 45.12 ID 44.62
3 TABLE ST PIPE OD 80. ID 79.5
17 TABLE ST PIPE OD 10. ID 9.5
MEMBER RELEASE
9 11 13 14 END MX MY MZ
CONSTANTS
E STEEL ALL
POISSON STEEL ALL
DENSITY STEEL ALL
BETA 90. MEMB 13 14
ALPHA 0.00000919 MEMB 1 TO 8
SUPPORTS
8 11 13 15 FIXED
LOAD 1 DEADWEIGHT
JOINT LOAD
1 5 FY -852.
* FLANGE WEIGHT = 2 @ 426 LBS.
16 FY -150.
* VALVE WEIGHT
MEMBER LOAD
1 TO 4 UNI Y -42.73
* UNIFORM  4700.#/110" = 53.18 42.73
* UNIFORM = INTERNAL+EXTERNAL
LOAD 2 DW+TH
```

```
42. JOINT LOAD
43. 1 5 FY -852.
44. 16 FY -150.
45. 16 FZ 1155.
46. * UNBALANCED VACUUM LOAD @ TURBO PMP
47. MEMBER LOAD
48. 1 TO 4 UNI Y -42.73
49. TEMPERATURE LOAD
50. 1 TO 8 17 TEMP 330.
51. LOAD 3 DW+VACUUM
52. JOINT LOAD
53. 1 FX 25400.
54. * FULL VACUUM LOAD @ GATE VALVE
55. 1 5 FY -852.
56. 16 FY -150.
57. 16 FZ 1155.
58. * UNBALANCED VACUUM LOAD @ TURBO PMP
59. MEMBER LOAD
60. 1 TO 4 UNI Y -42.73
61. LOAD 4 DW+TH+SEIS-AXIAL
62. JOINT LOAD
63. 1 5 FY -852.
64. 16 FY -150.
65. 1 5 FX 47.925
66. * FLANGE WEIGHT X 0.05625
67. 16 FX 8.5
68. * VALVE WEIGHT X 0.05625
69. 16 FZ 1155.
70. * UNBALANCED VACUUM LOAD @ TURBO PMP
71. MEMBER LOAD
72. 1 TO 4 UNI Y -42.73
73. 1 TO 4 UNI X 2.4
74. * UNIFORM WEIGHT X 0.05625
75. TEMPERATURE LOAD
76. 1 TO 8 17 TEMP 330.
77. LOAD 5 DW+VACUUM+SEIS-AXIAL
78. JOINT LOAD
79. 1 FX 25400.
80. 1 5 FY -852.
81. 16 FY -150.
82. 1 5 FX 47.925
83. 16 FX 8.5
84. 16 FZ 1155.
85. * UNBALANCED VACUUM LOAD @ TURBO PMP
86. MEMBER LOAD
87. 1 TO 4 UNI Y -42.73
88. 1 TO 4 UNI X 2.4
89. LOAD 6 DW+TH+SEIS-LAT
90. JOINT LOAD
91. 1 5 FY -852.
92. 16 FY -150.
93. 1 5 FZ 47.925
94. 16 FZ 8.5
95. 16 FZ 1155.
96. * UNBALANCED VACUUM LOAD @ TURBO PMP
97. MEMBER LOAD
```

```
 98. 1 TO 4 UNI Y -42.73
 99. 1 TO 4 UNI Z 2.4
100. TEMPERATURE LOAD
101. 1 TO 8 17 TEMP 330.
102. LOAD 7 DW+VACUUM+SEIS-LAT
103. JOINT LOAD
104. 1 FX 25400.
105. 1 5 FY -852.
106. 16 FY -150.
107. 1 5 FZ 47.925
108. 16 FZ 8.5
109. 16 FZ 1155.
110. MEMBER LOAD
111. 1 TO 4 UNI Y -42.73
112. 1 TO 4 UNI Z 2.4
113. LOAD 8 THERMAL "BAKEOUT"
114. TEMPERATURE LOAD
115. 1 TO 8 17 TEMP 330.
116. PERFORM ANALYSIS
```

P R O B L E M   S T A T I S T I C S

```
NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS =     16/    17/     4
ORIGINAL/FINAL BAND-WIDTH =    14/     5
TOTAL PRIMARY LOAD CASES  =     8, TOTAL DEGREES OF FREEDOM =     72
SIZE OF STIFFNESS MATRIX =     2592 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE =  12.05/  480.8 MB,  EXMEM =  1.02 MB

++ PROCESSING ELEMENT STIFFNESS MATRIX.                15:18:33
 · PROCESSING GLOBAL STIFFNESS MATRIX.                 15:18:33
·+ PROCESSING TRIANGULAR FACTORIZATION.                15:18:33
++ CALCULATING JOINT DISPLACEMENTS.                    15:18:33
++ CALCULATING MEMBER  FORCES.                         15:18:33

117. PRINT MATERIAL PROPERTIES ALL
```

MATERIAL PROPERTIES.

\LL UNITS ARE - POUN INCH

MEMBER	E	G	DEN	ALPHA
1	29000000.0	11153846.0	0.28299999	0.00000919
2	29000000.0	11153846.0	0.28299999	0.00000919
3	29000000.0	11153846.0	0.28299999	0.00000919
4	29000000.0	11153846.0	0.28299999	0.00000919
5	29000000.0	11153846.0	0.28299999	0.00000919
6	29000000.0	11153846.0	0.28299999	0.00000919
7	29000000.0	11153846.0	0.28299999	0.00000919
8	29000000.0	11153846.0	0.28299999	0.00000919
9	29000000.0	11153846.0	0.28299999	0.00000000
10	29000000.0	11153846.0	0.28299999	0.00000000
11	29000000.0	11153846.0	0.28299999	0.00000000
12	29000000.0	11153846.0	0.28299999	0.00000000
13	29000000.0	11153846.0	0.28299999	0.00000000
14	29000000.0	11153846.0	0.28299999	0.00000000
15	29000000.0	11153846.0	0.28299999	0.00000000
16	29000000.0	11153846.0	0.28299999	0.00000000
17	29000000.0	11153846.0	0.28299999	0.00000000

************ END OF DATA FROM INTERNAL STORAGE ************

118. PRINT MEMBER INFORMATION ALL

MEMBER INFORMATION

MEMBER	START JOINT	END JOINT	LENGTH (INCH)	BETA (DEG)	RELEASES
1	1	2	13.500	0.00	
2	2	3	24.000	0.00	
3	3	4	43.000	0.00	
4	4	5	29.500	0.00	
5	3	6	42.250	0.00	
6	4	12	42.250	0.00	
7	3	9	42.250	0.00	
8	4	14	42.250	0.00	
9	7	6	9.000	0.00	000000000111
10	8	7	61.000	0.00	
11	10	9	9.000	0.00	000000000111
12	11	10	61.000	0.00	
13	13	12	70.000	90.00	000000000111
14	15	14	70.000	90.00	000000000111
15	7	13	74.632	0.00	
16	10	15	74.632	0.00	
17	2	16	28.560	0.00	

************ END OF DATA FROM INTERNAL STORAGE ************

119. PRINT JOINT COORDINATES ALL

JOINT COORDINATES

COORDINATES ARE INCH UNIT

JOINT	X	Y	Z
1	0.000	0.000	0.000
2	13.500	0.000	0.000
3	37.500	0.000	0.000
4	80.500	0.000	0.000
5	110.000	0.000	0.000
6	37.500	0.000	-42.250
7	37.500	-9.000	-42.250
8	37.500	-70.000	-42.250
9	37.500	0.000	42.250
10	37.500	-9.000	42.250
11	37.500	-70.000	42.250
12	80.500	0.000	-42.250
13	80.500	-70.000	-42.250
14	80.500	0.000	42.250
15	80.500	-70.000	42.250
16	13.500	0.000	28.560

************ END OF DATA FROM INTERNAL STORAGE ************

120. PRINT SUPPORT INFORMATION ALL

SUPPORT INFORMATION (1=FIXED, 0=RELEASED)

UNITS FOR SPRING CONSTANTS ARE POUN INCH DEGREES

JOINT	FORCE-X/ KFX	FORCE-Y/ KFY	FORCE-Z/ KFZ	MOM-X/ KMX	MOM-Y/ KMY	MOM-Z/ KMZ
8	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
11	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
13	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
15	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0

************ END OF DATA FROM INTERNAL STORAGE ************

121. PRINT ANALYSIS RESULTS

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

-INT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	-0.00113	-0.02809	-0.00002	0.00001	0.00000	0.00017
	2	-0.11553	-0.02814	0.10042	0.00000	0.00016	0.00017
	3	0.19925	-0.01474	0.10043	0.00000	0.00016	0.00000
	4	-0.11263	-0.02794	0.10048	0.00000	0.00016	0.00017
	5	0.20214	-0.01455	0.10047	0.00000	0.00016	0.00000
	6	-0.11553	-0.02814	0.12955	0.00000	0.00014	0.00017
	7	0.19925	-0.01474	0.12955	0.00000	0.00014	0.00000
	8	-0.11440	-0.00004	0.00000	0.00000	0.00000	0.00000
2	1	-0.00113	-0.02574	-0.00001	0.00001	0.00000	0.00017
	2	-0.07459	-0.02578	0.09832	0.00000	0.00016	0.00017
	3	0.19891	-0.01463	0.09833	0.00000	0.00016	0.00000
	4	-0.07169	-0.02562	0.09836	0.00000	0.00016	0.00017
	5	0.20181	-0.01447	0.09836	0.00000	0.00016	0.00000
	6	-0.07459	-0.02578	0.12766	0.00000	0.00014	0.00017
	7	0.19891	-0.01463	0.12766	0.00000	0.00014	0.00000
	8	-0.07345	-0.00004	0.00000	0.00000	0.00000	0.00000
3	1	-0.00113	-0.02151	0.00000	0.00001	0.00000	0.00017
	2	-0.00180	-0.02154	0.09449	0.00000	0.00015	0.00017
	3	0.19831	-0.01438	0.09449	0.00000	0.00015	0.00000
	4	0.00109	-0.02143	0.09450	0.00000	0.00016	0.00016
	5	0.20121	-0.01428	0.09450	0.00000	0.00016	0.00000
	6	-0.00180	-0.02154	0.12417	0.00000	0.00014	0.00017
	7	0.19831	-0.01438	0.12418	0.00000	0.00014	0.00000
	8	-0.00067	-0.00002	0.00000	0.00000	0.00000	0.00000
4	1	-0.00113	-0.01449	0.00001	0.00001	0.00000	0.00016
	2	0.12860	-0.01449	0.08784	0.00000	0.00015	0.00016
	3	0.19831	-0.01449	0.08784	0.00000	0.00015	0.00000
	4	0.13150	-0.01449	0.08781	0.00000	0.00016	0.00016
	5	0.20121	-0.01449	0.08780	0.00000	0.00016	0.00000
	6	0.12860	-0.01449	0.11820	0.00000	0.00014	0.00016
	7	0.19831	-0.01449	0.11821	0.00000	0.00014	0.00000
	8	0.12973	0.00000	0.00000	0.00000	0.00000	0.00000
5	1	-0.00113	-0.00989	0.00002	0.00001	0.00000	0.00016
	2	0.21807	-0.00987	0.08328	0.00000	0.00015	0.00016
	3	0.19831	-0.01478	0.08329	0.00000	0.00015	0.00000
	4	0.22096	-0.00994	0.08322	0.00000	0.00016	0.00016
	5	0.20121	-0.01485	0.08322	0.00000	0.00016	-0.00001
	6	0.21807	-0.00987	0.11413	0.00000	0.00014	0.00016
	7	0.19831	-0.01478	0.11413	0.00000	0.00014	0.00000
	8	0.21920	0.00002	0.00000	0.00000	0.00000	0.00000
6	1	-0.00112	-0.00075	0.00000	0.00068	0.00000	0.00017
	2	-0.00362	-0.00100	-0.03362	0.00067	0.00000	0.00017
	3	0.06599	0.00615	0.09441	0.00067	0.00429	0.00000
	4	-0.00263	-0.00090	-0.03360	0.00067	0.00006	0.00016
	5	0.06698	0.00625	0.09442	0.00067	0.00435	0.00000
	6	-0.00339	-0.00098	-0.00395	0.00067	0.00000	0.00017
	7	0.06622	0.00617	0.12408	0.00067	0.00429	0.00000
	8	-0.00023	-0.00002	-0.12803	0.00000	-0.00001	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

INT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
7	1	-0.00092	-0.00065	0.00000	0.00000	0.00000	0.00002
	2	-0.00193	-0.00091	-0.02737	-0.00068	-0.00008	0.00014
	3	0.02632	0.00625	0.07688	0.00190	0.00022	-0.00321
	4	-0.00153	-0.00081	-0.02736	-0.00068	-0.00008	0.00010
	5	0.02672	0.00635	0.07688	0.00190	0.00022	-0.00326
	6	-0.00184	-0.00089	-0.00322	-0.00008	-0.00001	0.00013
	7	0.02641	0.00627	0.10103	0.00250	0.00029	-0.00322
	8	-0.00009	-0.00002	-0.10425	-0.00258	-0.00030	0.00001
8	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	1	-0.00115	-0.00077	0.00000	-0.00068	0.00000	0.00017
	2	0.00088	-0.00057	0.22244	-0.00069	0.00003	0.00017
	3	0.07050	0.00659	0.09441	-0.00069	-0.00426	0.00000
	4	0.00190	-0.00046	0.22245	-0.00069	-0.00003	0.00016
	5	0.07152	0.00669	0.09442	-0.00069	-0.00433	0.00000
	6	0.00066	-0.00059	0.25210	-0.00069	0.00003	0.00017
	7	0.07027	0.00657	0.12408	-0.00069	-0.00427	0.00000
	8	-0.00023	-0.00002	0.12803	0.00000	0.00001	0.00000
10	1	-0.00094	-0.00067	0.00000	0.00000	0.00000	0.00002
	2	-0.00012	-0.00047	0.18112	0.00448	0.00052	-0.00008
	3	0.02813	0.00669	0.07688	0.00190	0.00022	-0.00343
	4	0.00029	-0.00036	0.18113	0.00448	0.00052	-0.00012
	5	0.02854	0.00679	0.07688	0.00190	0.00022	-0.00348
	6	-0.00021	-0.00049	0.20528	0.00507	0.00059	-0.00006
	7	0.02804	0.00667	0.10103	0.00250	0.00029	-0.00342
	8	-0.00009	-0.00002	0.10425	0.00258	0.00030	0.00001
11	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	1	-0.00111	-0.00148	0.00001	0.00043	0.00000	0.00016
	2	0.12167	-0.00149	-0.04029	0.00043	0.00017	0.00016
	3	0.19115	-0.00149	0.08782	0.00043	0.00018	0.00000
	4	0.12451	-0.00149	-0.04032	0.00043	0.00017	0.00016
	5	0.19399	-0.00149	0.08779	0.00043	0.00018	0.00000
	6	0.12233	-0.00149	-0.00993	0.00043	0.00015	0.00016
	7	0.19180	-0.00149	0.11819	0.00043	0.00016	0.00000
	8	0.12930	0.00000	-0.12811	0.00000	0.00001	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

·INT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
13	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	1	-0.00114	-0.00154	0.00001	-0.00043	0.00000	0.00016
	2	0.13467	-0.00152	0.21593	-0.00043	0.00014	0.00016
	3	0.20414	-0.00152	0.08782	-0.00043	0.00013	0.00000
	4	0.13759	-0.00152	0.21590	-0.00043	0.00014	0.00016
	5	0.20707	-0.00152	0.08779	-0.00043	0.00013	0.00000
	6	0.13401	-0.00152	0.24630	-0.00043	0.00012	0.00016
	7	0.20348	-0.00152	0.11819	-0.00043	0.00012	0.00000
	8	0.12930	0.00000	0.12811	0.00000	-0.00001	0.00000
15	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	1	-0.00114	-0.02647	-0.00001	0.00003	0.00000	0.00017
	2	-0.07015	-0.02643	0.09847	0.00003	0.00016	0.00017
	3	0.20335	-0.01528	0.09848	0.00003	0.00016	0.00000
	4	-0.06719	-0.02627	0.09851	0.00003	0.00016	0.00017
	5	0.20631	-0.01512	0.09851	0.00003	0.00016	0.00000
	6	-0.07058	-0.02644	0.12781	0.00003	0.00014	0.00017
	7	0.20291	-0.01529	0.12781	0.00003	0.00014	0.00000
	8	-0.07345	-0.00004	0.00000	0.00000	0.00000	0.00000

SUPPORT REACTIONS -UNIT POUN INCH STRUCTURE TYPE = SPACE

.INT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
8	1	4.32	1977.64	0.01	0.55	0.02	-262.92
	2	-44.68	2746.00	123.83	7733.46	314.66	526.45
	3	1315.74	-18887.53	-347.75	-21718.63	-883.69	-21362.90
	4	-25.34	2438.40	123.77	7730.26	314.53	215.30
	5	1335.10	-19195.47	-347.78	-21720.29	-883.76	-21674.39
	6	-40.23	2676.32	14.56	909.55	37.01	454.76
	7	1320.19	-18957.23	-457.01	-28542.50	-1161.34	-21434.61
	8	-4.55	72.40	471.57	29451.48	1198.33	73.26
11	1	4.44	2030.15	0.01	0.55	0.02	-269.95
	2	44.33	1406.53	-819.31	-51169.73	-2082.00	-912.87
	3	1404.75	-20227.00	-347.75	-21718.64	-883.69	-22802.22
	4	64.27	1089.51	-819.36	-51172.96	-2082.13	-1233.72
	5	1424.71	-20544.42	-347.78	-21720.29	-883.76	-23123.47
	6	39.88	1476.19	-928.58	-57993.67	-2359.66	-841.19
	7	1400.30	-20157.30	-457.01	-28542.50	-1161.34	-22730.50
	8	-4.55	72.34	-471.57	-29451.72	-1198.34	73.20
13	1	-4.31	1248.82	-0.01	-0.55	0.13	-242.72
	2	460.73	480.45	90.69	7282.68	1878.35	3335.14
	3	-13599.64	22113.99	-229.75	-18706.37	-5275.15	-16020.83
	4	260.25	788.05	90.70	7282.95	1877.57	3102.55
	5	-13800.34	22421.92	-229.72	-18704.71	-5275.55	-16253.67
	6	414.63	550.13	15.78	1214.26	220.92	3281.63
	7	-13645.76	22183.68	-304.66	-24774.76	-6932.58	-16074.34
	8	4.52	-72.40	320.43	25988.54	7153.36	3042.22
15	1	-4.45	1297.70	-0.01	-0.55	0.13	-249.20
	2	-460.48	1921.32	-550.18	-44694.55	-12428.42	2257.33
	3	-14520.85	23554.85	-229.75	-18706.37	-5275.15	-17098.63
	4	-667.20	2238.34	-550.17	-44694.28	-12429.20	2017.49
	5	-14727.83	23872.27	-229.72	-18704.71	-5275.56	-17338.77
	6	-414.39	1851.66	-625.09	-50762.97	-14085.86	2310.82
	7	-14474.73	23485.15	-304.66	-24774.76	-6932.58	-17045.11
	8	4.48	-72.34	-320.43	-25988.70	-7153.41	3042.17

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	1	0.00	-851.99	0.00	0.00	0.00	0.01
		2	0.00	1428.85	0.00	0.00	0.00	-15396.01
	2	1	-0.24	-851.99	-0.05	0.00	-0.98	0.02
		2	0.24	1428.85	0.05	0.00	-0.41	-15396.12
	3	1	25400.34	-852.01	0.11	0.00	-0.67	-0.05
		2	-25400.34	1428.87	-0.11	0.00	-0.06	-15395.83
	4	1	47.61	-852.03	0.10	0.00	-0.51	-0.03
		2	-80.08	1428.88	-0.10	0.00	0.17	-15396.04
	5	1	25447.34	-852.00	0.08	0.00	0.07	0.07
		2	-25479.74	1428.86	-0.08	0.00	-0.38	-15395.70
	6	1	0.00	-852.00	47.94	0.00	1.25	0.06
		2	0.00	1428.85	-80.34	0.00	-864.66	-15395.48
	7	1	25400.34	-852.01	48.15	0.00	-0.31	0.01
		2	-25400.34	1428.87	-80.55	0.00	-866.21	-15395.79
	8	1	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.00	0.00	0.00	0.00	0.00	0.00
2	1	2	0.00	-1578.84	0.00	4283.98	0.00	15395.83
		3	0.00	2604.36	0.00	-4283.98	0.00	-65594.73
	2	2	0.24	-1578.84	1155.04	4284.00	-0.19	15395.81
		3	-0.24	2604.36	-1155.04	-4284.00	-27720.74	-65594.48
	3	2	25399.73	-1578.86	1154.99	4284.00	0.33	15395.75
		3	-25399.73	2604.38	-1154.99	-4284.00	-27718.76	-65594.61
	4	2	88.87	-1578.85	1154.89	4284.00	242.68	15395.71
		3	-146.48	2604.37	-1154.89	-4284.00	-27962.12	-65594.63
	5	2	25488.74	-1578.86	1155.01	4284.02	243.05	15395.73
		3	-25546.34	2604.38	-1155.01	-4284.02	-27962.84	-65594.55
	6	2	0.00	-1578.85	1243.61	4284.00	866.33	15395.73
		3	0.00	2604.37	-1301.21	-4284.00	-31407.00	-65594.27
	7	2	25399.73	-1578.86	1243.89	4284.00	863.96	15395.72
		3	-25399.73	2604.38	-1301.49	-4284.00	-31410.60	-65594.61
	8	2	0.24	0.00	0.00	0.00	0.29	0.00
		3	-0.24	0.00	0.00	0.00	-0.24	0.00
3	1	3	-0.74	1427.25	0.02	2050.16	-1.47	65594.91
		4	0.74	410.14	-0.02	-2050.16	0.41	-43726.99
	2	3	84.47	1427.24	172.92	1164.84	-7257.59	65594.34
		4	-84.47	410.15	-172.92	-1164.84	-175.95	-43726.95
	3	3	130.02	1427.25	173.08	1164.86	-7261.75	65594.69
		4	-130.02	410.14	-173.08	-1164.86	-182.08	-43726.72
	4	3	-135.74	1427.24	172.93	1158.86	-7257.29	65594.34
		4	32.71	410.15	-172.93	-1158.86	-179.22	-43726.89
	5	3	-90.98	1427.23	172.79	1158.84	-7253.09	65594.66
		4	-12.22	410.16	-172.79	-1158.84	-177.68	-43726.83

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	6	3	83.98	1427.25	10.90	1253.48	-70.30	65594.63
		4	-83.98	410.14	-114.10	-1253.48	-2615.35	-43726.65
	7	3	130.65	1427.25	10.81	1253.52	-69.22	65594.58
		4	-130.65	410.14	-114.01	-1253.52	-2619.29	-43726.71
	8	3	84.96	0.00	0.05	-0.04	-0.85	0.00
		4	-84.96	0.00	-0.05	0.04	-1.09	0.00
4	1	4	0.00	2112.54	0.00	0.00	0.00	43727.09
		5	0.00	-852.00	0.00	0.00	0.00	-0.04
	2	4	-0.24	2112.53	0.02	0.00	-0.46	43727.08
		5	0.24	-852.00	-0.02	0.00	-1.88	-0.12
	3	4	0.31	2112.54	0.02	0.00	0.63	43726.86
		5	-0.31	-852.00	-0.02	0.00	-0.17	-0.03
	4	4	-118.16	2112.56	0.08	0.00	-0.20	43727.23
		5	47.36	-852.02	-0.08	0.00	-0.74	0.07
	5	4	-118.69	2112.54	0.07	0.00	-1.47	43726.92
		5	47.89	-852.01	-0.07	0.00	0.63	-0.01
	6	4	-0.73	2112.54	-118.62	0.00	2456.04	43727.02
		5	0.73	-852.00	47.82	0.00	0.66	-0.08
	7	4	0.34	2112.54	-118.69	0.01	2456.80	43726.80
		5	-0.34	-852.00	47.89	-0.01	-1.44	0.01
	8	4	-0.49	0.00	0.01	0.00	1.97	0.00
		5	0.49	0.00	-0.01	0.00	-2.34	0.00
5	1	3	0.01	-1989.37	0.35	0.00	-14.92	-84051.05
		6	-0.01	1989.37	-0.35	0.00	0.00	0.00
	2	3	174.93	-1978.90	-456.01	0.00	19266.21	-83608.40
		6	-174.93	1978.90	456.01	0.00	0.05	0.01
	3	3	-490.97	-1978.90	12221.14	0.00	-516342.81	-83608.39
		6	490.97	1978.90	-12221.14	0.00	-0.23	0.00
	4	3	174.80	-1978.83	-275.80	0.00	11652.65	-83605.39
		6	-174.80	1978.83	275.80	0.00	-0.07	0.02
	5	3	-491.01	-1978.83	12401.53	0.00	-523964.88	-83605.38
		6	491.01	1978.83	-12401.53	0.00	-0.03	0.01
	6	3	20.51	-1979.95	-414.58	0.00	17515.75	-83652.72
		6	-20.51	1979.95	414.58	0.00	0.23	-0.01
	7	3	-645.25	-1979.95	12262.59	0.00	-518094.28	-83652.73
		6	645.25	1979.95	-12262.59	0.00	-0.23	0.00
	8	3	665.89	0.00	-42.43	0.00	1792.55	0.02
		6	-665.89	0.00	42.43	0.00	0.30	0.00
6	1	4	-0.01	-1237.08	-0.37	0.00	15.45	-52266.52
		12	0.01	1237.08	0.37	0.00	0.00	0.01
	2	4	39.67	-1247.56	39.95	0.00	-1688.06	-52709.20
		12	-39.67	1247.56	-39.95	0.00	-0.03	-0.01
	3	4	-86.55	-1247.55	62.78	0.00	-2652.05	-52709.19
		12	86.55	1247.55	-62.78	0.00	-0.02	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	4	4	39.73	-1247.63	40.89	0.00	-1727.46	-52712.18
		12	-39.73	1247.63	-40.89	0.00	-0.04	0.01
	5	4	-86.54	-1247.63	63.71	0.00	-2691.41	-52712.20
		12	86.54	1247.63	-63.71	0.00	-0.04	0.00
	6	4	9.83	-1246.51	40.16	0.00	-1697.07	-52664.88
		12	-9.83	1246.51	-40.16	0.00	0.20	0.00
	7	4	-116.40	-1246.51	62.99	0.00	-2661.29	-52664.86
		12	116.40	1246.51	-62.99	0.00	-0.14	0.00
	8	4	126.16	0.00	42.45	0.00	-1793.67	-0.02
		12	-126.16	0.00	-42.45	0.00	0.22	0.00
7	1	3	-0.01	-2042.25	-0.39	0.00	16.38	-86284.87
		9	0.01	2042.25	0.39	0.00	0.00	-0.01
	2	3	1156.74	-2052.72	-371.93	0.00	15714.19	-86727.52
		9	-1156.74	2052.72	371.93	0.00	-0.04	0.00
	3	3	490.97	-2052.72	-13049.07	0.00	551323.25	-86727.53
		9	-490.97	2052.72	13049.07	0.00	0.15	0.00
	4	3	1156.80	-2052.79	-557.76	0.00	23565.15	-86730.52
		9	-1156.80	2052.79	557.76	0.00	0.11	0.01
	5	3	491.01	-2052.79	-13235.11	0.00	559183.63	-86730.55
		9	-491.01	2052.79	13235.11	0.00	0.01	0.02
	6	3	1311.10	-2051.67	-330.49	0.00	13963.31	-86683.22
		9	-1311.10	2051.67	330.49	0.00	-0.05	0.01
	7	3	645.25	-2051.67	-13007.63	0.00	549571.88	-86683.20
		9	-645.25	2051.67	13007.63	0.00	0.25	0.00
	8	3	665.83	0.00	42.40	0.00	-1791.17	-0.02
		9	-665.83	0.00	-42.40	0.00	-0.14	0.00
8	1	4	0.01	-1285.60	0.38	0.00	-15.85	-54316.71
		14	-0.01	1285.60	-0.38	0.00	0.00	0.01
	2	4	212.77	-1275.13	-44.22	0.00	1868.36	-53874.07
		14	-212.77	1275.13	44.22	0.00	-0.02	-0.01
	3	4	86.55	-1275.13	-67.05	0.00	2832.34	-53874.06
		14	-86.55	1275.13	67.05	0.00	0.15	0.00
	4	4	212.71	-1275.05	-45.19	0.00	1909.11	-53871.04
		14	-212.71	1275.05	45.19	0.00	0.07	0.02
	5	4	86.54	-1275.05	-68.00	0.00	2872.81	-53871.04
		14	-86.54	1275.05	68.00	0.00	-0.12	0.00
	6	4	242.74	-1276.17	-43.99	0.00	1858.79	-53918.36
		14	-242.74	1276.17	43.99	0.00	-0.28	0.00
	7	4	116.45	-1276.18	-66.83	0.00	2823.32	-53918.40
		14	-116.45	1276.18	66.83	0.00	0.28	0.00
	8	4	126.28	0.00	-42.45	0.00	1793.72	0.02
		14	-126.28	0.00	42.45	0.00	-0.20	0.00
9	1	7	1989.37	0.35	0.01	0.00	-0.11	3.18
		6	-1989.37	-0.35	-0.01	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

\LL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	7	1978.90	-456.01	174.82	0.00	-1573.41	-4104.09
		6	-1978.90	456.01	-174.82	0.00	0.00	0.00
	3	7	1978.90	12221.11	-490.99	0.00	4418.95	109990.02
		6	-1978.90	-12221.11	490.99	0.00	0.00	0.00
	4	7	1978.82	-275.80	174.76	0.00	-1572.84	-2482.18
		6	-1978.82	275.80	-174.76	0.00	0.00	0.00
	5	7	1978.83	12401.54	-491.01	0.00	4419.15	111613.94
		6	-1978.83	-12401.54	491.01	0.00	0.00	0.00
	6	7	1979.95	-414.57	20.59	0.00	-185.35	-3731.12
		6	-1979.95	414.57	-20.59	0.00	0.00	0.00
	7	7	1979.93	12262.58	-645.22	0.00	5807.06	110363.17
		6	-1979.93	-12262.58	645.22	0.00	0.00	0.00
	8	7	0.00	-42.43	665.76	0.00	-5991.79	-381.90
		6	0.00	42.43	-665.76	0.00	0.00	0.00
10	1	8	1977.64	-4.32	0.01	0.02	-0.55	-262.92
		7	-1977.64	4.32	-0.01	-0.02	0.01	-0.52
	2	8	2746.00	44.68	123.83	314.66	-7733.46	526.45
		7	-2746.00	-44.68	-123.83	-314.66	180.10	2198.86
	3	8	-18887.53	-1315.74	-347.75	-883.69	21718.63	-21362.90
		7	18887.53	1315.74	347.75	883.69	-505.78	-58897.26
	4	8	2438.40	25.34	123.77	314.53	-7730.26	215.30
		7	-2438.40	-25.34	-123.77	-314.53	180.02	1330.36
	5	8	-19195.47	-1335.10	-347.78	-883.76	21720.29	-21674.39
		7	19195.47	1335.10	347.78	883.76	-505.82	-59766.70
	6	8	2676.32	40.23	14.56	37.01	-909.55	454.76
		7	-2676.32	-40.23	-14.56	-37.01	21.18	1999.15
	7	8	-18957.23	-1320.19	-457.01	-1161.34	28542.50	-21434.61
		7	18957.23	1320.19	457.01	1161.34	-664.69	-59097.02
	8	8	72.40	4.55	471.57	1198.33	-29451.48	73.26
		7	-72.40	-4.55	-471.57	-1198.33	685.87	204.48
11	1	10	2042.25	0.39	0.01	0.00	-0.11	3.49
		9	-2042.25	-0.39	-0.01	0.00	0.00	0.00
	2	10	2052.72	371.94	-1156.76	0.00	10410.92	3347.43
		9	-2052.72	-371.94	1156.76	0.00	0.00	0.00
	3	10	2052.72	13049.07	-490.99	0.00	4418.95	117441.63
		9	-2052.72	-13049.07	490.99	0.00	0.00	0.00
	4	10	2052.79	557.75	-1156.83	0.00	10411.49	5019.76
		9	-2052.79	-557.75	1156.83	0.00	0.00	0.00
	5	10	2052.79	13235.12	-491.01	0.00	4419.09	119116.10
		9	-2052.79	-13235.12	491.01	0.00	0.00	0.00
	6	10	2051.67	330.51	-1311.01	0.00	11799.09	2974.56
		9	-2051.67	-330.51	1311.01	0.00	0.00	0.00
	7	10	2051.67	13007.61	-645.24	0.00	5807.06	117068.46
		9	-2051.67	-13007.61	645.24	0.00	0.00	0.00
	8	10	0.00	-42.40	-665.81	0.00	5992.29	-381.61
		9	0.00	42.40	665.81	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

\LL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
12	1	11	2030.15	-4.44	0.01	0.02	-0.55	-269.95
		10	-2030.15	4.44	-0.01	-0.02	0.01	-0.66
	2	11	1406.53	-44.33	-819.31	-2082.00	51169.73	-912.87
		10	-1406.53	44.33	819.31	2082.00	-1191.64	-1791.27
	3	11	-20227.00	-1404.75	-347.75	-883.69	21718.64	-22802.22
		10	20227.00	1404.75	347.75	883.69	-505.77	-62887.37
	4	11	1089.51	-64.27	-819.36	-2082.13	51172.96	-1233.72
		10	-1089.51	64.27	819.36	2082.13	-1191.71	-2686.79
	5	11	-20544.42	-1424.71	-347.78	-883.76	21720.29	-23123.47
		10	20544.42	1424.71	347.78	883.76	-505.81	-63784.00
	6	11	1476.19	-39.88	-928.58	-2359.66	57993.67	-841.19
		10	-1476.19	39.88	928.58	2359.66	-1350.53	-1591.60
	7	11	-20157.30	-1400.30	-457.01	-1161.34	28542.50	-22730.50
		10	20157.30	1400.30	457.01	1161.34	-664.69	-62687.59
	8	11	72.34	4.55	-471.57	-1198.34	29451.72	73.20
		10	-72.34	-4.55	471.57	1198.34	-685.86	204.30
13	1	13	1237.08	-0.01	0.37	0.00	-25.59	-0.86
		12	-1237.08	0.01	-0.37	0.00	0.00	0.00
	2	13	1247.55	39.69	-39.95	0.00	2796.84	2778.32
		12	-1247.55	-39.69	39.95	0.00	0.00	0.00
	3	13	1247.55	-86.52	-62.77	0.00	4393.79	-6056.36
		12	-1247.55	86.52	62.77	0.00	0.00	0.00
	4	13	1247.63	39.72	-40.89	0.00	2862.10	2780.47
		12	-1247.63	-39.72	40.89	0.00	0.00	0.00
	5	13	1247.63	-86.48	-63.70	0.00	4459.12	-6053.73
		12	-1247.63	86.48	63.70	0.00	0.00	0.00
	6	13	1246.51	9.78	-40.17	0.00	2811.94	684.50
		12	-1246.51	-9.78	40.17	0.00	0.00	0.00
	7	13	1246.51	-116.43	-62.98	0.00	4408.89	-8150.19
		12	-1246.51	116.43	62.98	0.00	0.00	0.00
	8	13	0.00	126.21	-42.46	0.00	2972.09	8834.52
		12	0.00	-126.21	42.46	0.00	0.00	0.00
14	1	15	1285.60	-0.01	0.38	0.00	-26.26	-0.86
		14	-1285.60	0.01	-0.38	0.00	0.00	0.00
	2	15	1275.13	-212.72	-44.22	0.00	3095.50	-14890.74
		14	-1275.13	212.72	44.22	0.00	0.00	0.00
	3	15	1275.13	-86.52	-67.03	0.00	4692.45	-6056.36
		14	-1275.13	86.52	67.03	0.00	0.00	0.00
	4	15	1275.05	-212.69	-45.18	0.00	3162.79	-14888.60
		14	-1275.05	212.69	45.18	0.00	0.00	0.00
	5	15	1275.05	-86.48	-68.00	0.00	4759.82	-6053.73
		14	-1275.05	86.48	68.00	0.00	0.00	0.00
	6	15	1276.17	-242.64	-44.01	0.00	3080.40	-16984.57
		14	-1276.17	242.64	44.01	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	7	15	1276.17	-116.43	-66.82	0.00	4677.34	-8150.19
		14	-1276.17	116.43	66.82	0.00	0.00	0.00
	8	15	0.00	-126.21	-42.46	0.00	2972.10	-8834.55
		14	0.00	126.21	42.46	0.00	0.00	0.00
15	1	7	12.29	-2.94	0.00	-0.07	-0.07	-2.66
		13	-12.29	2.94	0.00	0.07	0.34	-217.12
	2	7	-915.46	32.74	-51.00	-1059.97	-957.54	1905.22
		13	915.46	-32.74	51.00	1059.97	4763.81	538.30
	3	7	24854.31	-958.13	143.23	2976.81	2689.14	-51092.91
		13	-24854.31	958.13	-143.23	-2976.81	-13378.67	-20414.62
	4	7	-549.13	18.66	-50.98	-1059.53	-957.14	1151.84
		13	549.13	-18.66	50.98	1059.53	4761.83	240.45
	5	7	25221.04	-972.23	143.24	2977.03	2689.35	-51847.12
		13	-25221.04	972.23	-143.24	-2977.03	-13379.68	-20712.79
	6	7	-831.21	29.50	-6.00	-124.66	-112.61	1731.98
		13	831.21	-29.50	6.00	124.66	560.28	469.69
	7	7	24938.58	-961.37	188.23	3912.10	3534.06	-51266.20
		13	-24938.58	961.37	-188.23	-3912.10	-17582.17	-20483.24
	8	7	-86.25	3.32	-194.23	-4036.69	-3646.60	177.38
		13	86.25	-3.32	194.23	4036.69	18142.11	70.13
16	1	10	12.66	-3.03	0.00	-0.07	-0.07	-2.83
		15	-12.66	3.03	0.00	0.07	0.34	-222.94
	2	10	767.99	-32.08	337.45	7013.44	6335.71	-1556.12
		15	-767.99	32.08	-337.45	-7013.44	-31520.54	-838.17
	3	10	26537.75	-1022.95	143.23	2976.81	2689.14	-54554.24
		15	-26537.75	1022.95	-143.23	-2976.81	-13378.67	-21791.08
	4	10	1145.71	-46.60	337.47	7013.88	6336.10	-2332.94
		15	-1145.71	46.60	-337.47	-7013.88	-31522.51	-1145.30
	5	10	26915.95	-1037.49	143.24	2977.03	2689.35	-55332.03
		15	-26915.95	1037.49	-143.24	-2977.03	-13379.69	-22098.58
	6	10	683.77	-28.84	382.45	7948.75	7180.61	-1382.91
		15	-683.77	28.84	-382.45	-7948.75	-35724.07	-769.58
	7	10	26453.48	-1019.71	188.23	3912.10	3534.05	-54380.95
		15	-26453.48	1019.71	-188.23	-3912.10	-17582.17	-21722.45
	8	10	-86.17	3.31	194.23	4036.72	3646.63	177.22
		15	86.17	-3.31	-194.23	-4036.72	-18142.25	70.06
17	1	2	0.00	150.00	0.00	0.00	0.00	4284.00
		16	0.00	-150.00	0.00	0.00	0.00	0.02
	2	2	-1155.03	150.00	-0.01	0.00	0.08	4283.99
		16	1155.03	-150.00	0.01	0.00	0.25	0.00
	3	2	-1154.99	150.00	-0.01	0.00	0.17	4284.01
		16	1154.99	-150.00	0.01	0.00	0.12	0.01
	4	2	-1154.99	150.00	8.50	0.00	-242.69	4284.01
		16	1154.99	-150.00	-8.50	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
5	2	-1155.04	150.00	8.52	0.00	-242.79	4284.02
	16	1155.04	-150.00	-8.52	0.00	0.03	0.02
6	2	-1163.50	150.00	-0.01	0.00	0.24	4283.99
	16	1163.50	-150.00	0.01	0.00	0.22	-0.02
7	2	-1163.38	150.00	-0.03	0.00	0.34	4284.01
	16	1163.38	-150.00	0.03	0.00	0.26	0.01
8	2	0.00	0.00	0.00	0.00	-0.25	0.00
	16	0.00	0.00	0.00	0.00	0.00	0.00

************** END OF LATEST ANALYSIS RESULT **************

122. PRINT MEMBER STRESSES ALL

MEMBER STRESSES

'LL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
1	1	.0	0.0 T	0.0	0.0	0.0	40.3	0.0
		1.00	0.0 T	0.0	39.2	39.2	67.6	0.0
	2	.0	0.0 T	0.0	0.0	0.0	40.3	0.0
		1.00	0.0 T	0.0	39.2	39.2	67.6	0.0
	3	.0	720.8 C	0.0	0.0	720.8	40.3	0.0
		1.00	720.8 C	0.0	39.2	759.9	67.6	0.0
	4	.0	1.4 C	0.0	0.0	1.4	40.3	0.0
		1.00	2.3 C	0.0	39.2	41.4	67.6	0.0
	5	.0	722.1 C	0.0	0.0	722.1	40.3	0.0
		1.00	723.0 C	0.0	39.2	762.2	67.6	0.0
	6	.0	0.0	0.0	0.0	0.0	40.3	2.3
		1.00	0.0	2.2	39.2	39.2	67.6	3.8
	7	.0	720.8 C	0.0	0.0	720.8	40.3	2.3
		1.00	720.8 C	2.2	39.2	760.0	67.6	3.8
	8	.0	0.0	0.0	0.0	0.0	0.0	0.0
		1.00	0.0	0.0	0.0	0.0	0.0	0.0
2	1	.0	0.0 T	0.0	39.2	39.2	74.7	0.0
		1.00	0.0 T	0.0	166.9	166.9	123.2	0.0
	2	.0	0.0 C	0.0	39.2	39.2	74.7	54.6
		1.00	0.0 C	70.5	166.8	181.1	123.2	54.6
	3	.0	720.7 C	0.0	39.2	759.9	74.7	54.6
		1.00	720.7 C	70.5	166.8	901.9	123.2	54.6
	4	.0	2.5 C	0.6	39.2	41.7	74.7	54.6
		1.00	4.2 C	71.1	166.8	185.5	123.2	54.6
	5	.0	723.3 C	0.6	39.2	762.4	74.7	54.6
		1.00	724.9 C	71.1	166.8	906.3	123.2	54.6
	6	.0	0.0	2.2	39.2	39.2	74.7	58.8
		1.00	0.0	79.9	166.8	185.0	123.2	61.5
	7	.0	720.7 C	2.2	39.2	760.0	74.7	58.8
		1.00	720.7 C	79.9	166.8	905.7	123.2	61.6
	8	.0	0.0 C	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 C	0.0	0.0	0.0	0.0	0.0
3	1	.0	0.0 T	0.0	52.7	52.7	38.0	0.0
		1.00	0.0 T	0.0	35.1	35.1	10.9	0.0
	2	.0	1.3 C	5.8	52.7	54.4	38.0	4.6
		1.00	1.3 C	0.1	35.1	36.5	10.9	4.6
	3	.0	2.1 C	5.8	52.7	55.1	38.0	4.6
		1.00	2.1 C	0.1	35.1	37.2	10.9	4.6
	4	.0	2.2 T	5.8	52.7	55.2	38.0	4.6
		1.00	0.5 T	0.1	35.1	35.6	10.9	4.6
	5	.0	1.5 T	5.8	52.7	54.5	38.0	4.6
		1.00	0.2 T	0.1	35.1	35.3	10.9	4.6
	6	.0	1.3 C	0.1	52.7	54.0	38.0	0.3
		1.00	1.3 C	2.1	35.1	36.5	10.9	3.0
	7	.0	2.1 C	0.1	52.7	54.8	38.0	0.3
		1.00	2.1 C	2.1	35.1	37.3	10.9	3.0

MEMBER STRESSES

-.L UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	8	.0	1.4 C	0.0	0.0	1.4	0.0	0.0
		1.00	1.4 C	0.0	0.0	1.4	0.0	0.0
4	1	.0	0.0 T	0.0	111.2	111.2	99.9	0.0
		1.00	0.0 T	0.0	0.0	0.0	40.3	0.0
	2	.0	0.0 T	0.0	111.2	111.2	99.9	0.0
		1.00	0.0 T	0.0	0.0	0.0	40.3	0.0
	3	.0	0.0 C	0.0	111.2	111.2	99.9	0.0
		1.00	0.0 C	0.0	0.0	0.0	40.3	0.0
	4	.0	3.4 T	0.0	111.2	114.6	99.9	0.0
		1.00	1.3 T	0.0	0.0	1.3	40.3	0.0
	5	.0	3.4 T	0.0	111.2	114.6	99.9	0.0
		1.00	1.4 T	0.0	0.0	1.4	40.3	0.0
	6	.0	0.0 T	6.2	111.2	111.4	99.9	5.6
		1.00	0.0 T	0.0	0.0	0.0	40.3	2.3
	7	.0	0.0 C	6.2	111.2	111.4	99.9	5.6
		1.00	0.0 C	0.0	0.0	0.0	40.3	2.3
	8	.0	0.0 T	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 T	0.0	0.0	0.0	0.0	0.0
5	1	.0	0.0 C	0.7	3698.6	3699.3	397.9	0.1
		1.00	0.0 C	0.0	0.0	0.0	397.9	0.1
	2	.0	18.7 C	847.8	3679.1	4545.6	395.8	91.2
		1.00	18.7 C	0.0	0.0	18.7	395.8	91.2
	3	.0	52.5 T	22721.4	3679.1	26452.9	395.8	2444.2
		1.00	52.5 T	0.0	0.0	52.5	395.8	2444.2
	4	.0	18.7 C	512.8	3679.0	4210.4	395.8	55.2
		1.00	18.7 C	0.0	0.0	18.7	395.8	55.2
	5	.0	52.5 T	23056.8	3679.0	26788.2	395.8	2480.3
		1.00	52.5 T	0.0	0.0	52.5	395.8	2480.3
	6	.0	2.2 C	770.8	3681.1	4454.0	396.0	82.9
		1.00	2.2 C	0.0	0.0	2.2	396.0	82.9
	7	.0	68.9 T	22798.4	3681.1	26548.5	396.0	2452.5
		1.00	68.9 T	0.0	0.0	68.9	396.0	2452.5
	8	.0	71.1 C	78.9	0.0	150.0	0.0	8.5
		1.00	71.1 C	0.0	0.0	71.2	0.0	8.5
6	1	.0	0.0 T	0.7	2300.0	2300.6	247.4	0.1
		1.00	0.0 T	0.0	0.0	0.0	247.4	0.1
	2	.0	4.2 C	74.3	2319.4	2398.0	249.5	8.0
		1.00	4.2 C	0.0	0.0	4.2	249.5	8.0
	3	.0	9.2 T	116.7	2319.4	2445.4	249.5	12.6
		1.00	9.2 T	0.0	0.0	9.2	249.5	12.6
	4	.0	4.2 C	76.0	2319.6	2399.8	249.5	8.2
		1.00	4.2 C	0.0	0.0	4.2	249.5	8.2
	5	.0	9.2 T	118.4	2319.6	2447.2	249.5	12.7
		1.00	9.2 T	0.0	0.0	9.2	249.5	12.7
	6	.0	1.0 C	74.7	2317.5	2393.2	249.3	8.0
		1.00	1.0 C	0.0	0.0	1.1	249.3	8.0

MEMBER STRESSES

L UNITS ARE POUN/SQ INCH

EMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	7	.0	12.4 T	117.1	2317.5	2447.0	249.3	12.6
		1.00	12.4 T	0.0	0.0	12.4	249.3	12.6
	8	.0	13.5 C	78.9	0.0	92.4	0.0	8.5
		1.00	13.5 C	0.0	0.0	13.5	0.0	8.5
7	1	.0	0.0 T	0.7	3796.9	3797.6	408.4	0.1
		1.00	0.0 T	0.0	0.0	0.0	408.4	0.1
	2	.0	123.6 C	691.5	3816.4	4631.5	410.5	74.4
		1.00	123.6 C	0.0	0.0	123.6	410.5	74.4
	3	.0	52.5 C	24260.7	3816.4	28129.5	410.5	2609.8
		1.00	52.5 C	0.0	0.0	52.5	410.5	2609.8
	4	.0	123.6 C	1037.0	3816.5	4977.1	410.6	111.6
		1.00	123.6 C	0.0	0.0	123.6	410.6	111.6
	5	.0	52.5 C	24606.5	3816.5	28475.5	410.6	2647.0
		1.00	52.5 C	0.0	0.0	52.5	410.6	2647.0
	6	.0	140.1 C	614.4	3814.4	4569.0	410.3	66.1
		1.00	140.1 C	0.0	0.0	140.1	410.3	66.1
	7	.0	68.9 C	24183.6	3814.4	28067.0	410.3	2601.5
		1.00	68.9 C	0.0	0.0	68.9	410.3	2601.5
	8	.0	71.1 C	78.8	0.0	150.0	0.0	8.5
		1.00	71.1 C	0.0	0.0	71.1	0.0	8.5
8	1	.0	0.0 C	0.7	2390.2	2390.9	257.1	0.1
		1.00	0.0 C	0.0	0.0	0.0	257.1	0.1
	2	.0	22.7 C	82.2	2370.7	2475.6	255.0	8.8
		1.00	22.7 C	0.0	0.0	22.7	255.0	8.8
	3	.0	9.2 C	124.6	2370.7	2504.6	255.0	13.4
		1.00	9.2 C	0.0	0.0	9.3	255.0	13.4
	4	.0	22.7 C	84.0	2370.6	2477.3	255.0	9.0
		1.00	22.7 C	0.0	0.0	22.7	255.0	9.0
	5	.0	9.2 C	126.4	2370.6	2506.2	255.0	13.6
		1.00	9.2 C	0.0	0.0	9.3	255.0	13.6
	6	.0	25.9 C	81.8	2372.6	2480.4	255.2	8.8
		1.00	25.9 C	0.0	0.0	25.9	255.2	8.8
	7	.0	12.4 C	124.2	2372.6	2509.3	255.2	13.4
		1.00	12.4 C	0.0	0.0	12.5	255.2	13.4
	8	.0	13.5 C	78.9	0.0	92.4	0.0	8.5
		1.00	13.5 C	0.0	0.0	13.5	0.0	8.5
9	1	.0	312.8 C	0.0	0.5	313.3	0.1	0.0
		1.00	312.8 C	0.0	0.0	312.8	0.1	0.0
	2	.0	311.1 C	255.8	667.3	1234.3	114.0	43.7
		1.00	311.1 C	0.0	0.0	311.1	114.0	43.7
	3	.0	311.1 C	718.5	17884.6	18914.2	3055.3	122.7
		1.00	311.1 C	0.0	0.0	311.1	3055.3	122.7
	4	.0	311.1 C	255.7	403.6	970.5	68.9	43.7
		1.00	311.1 C	0.0	0.0	311.1	68.9	43.7
	5	.0	311.1 C	718.6	18148.6	19178.3	3100.4	122.8
		1.00	311.1 C	0.0	0.0	311.1	3100.4	122.8

MEMBER STRESSES

.L UNITS ARE POUN/SQ INCH

..EMB	LD	SECT	AXIAL		BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	6	.0	311.3	C	30.1	606.7	948.1	103.6	5.1
		1.00	311.3	C	0.0	0.0	311.3	103.6	5.1
	7	.0	311.3	C	944.2	17945.2	19200.8	3065.6	161.3
		1.00	311.3	C	0.0	0.0	311.3	3065.6	161.3
	8	.0	0.0	T	974.3	62.1	1036.4	10.6	166.4
		1.00	0.0	T	0.0	0.0	0.0	10.6	166.4
10	1	.0	310.9	C	0.1	42.8	353.8	1.1	0.0
		1.00	310.9	C	0.0	0.1	311.0	1.1	0.0
	2	.0	431.8	C	1257.5	85.6	1774.8	11.2	31.0
		1.00	431.8	C	29.3	357.5	818.6	11.2	31.0
	3	.0	2969.7	T	3531.5	3473.6	9974.9	328.9	86.9
		1.00	2969.7	T	82.2	9576.8	12628.8	328.9	86.9
	4	.0	383.4	C	1257.0	35.0	1675.4	6.3	30.9
		1.00	383.4	C	29.3	216.3	629.0	6.3	30.9
	5	.0	3018.2	T	3531.8	3524.3	10074.2	333.8	86.9
		1.00	3018.2	T	82.2	9718.2	12818.6	333.8	86.9
	6	.0	420.8	C	147.9	73.9	642.6	10.1	3.6
		1.00	420.8	C	3.4	325.1	749.3	10.1	3.6
	7	.0	2980.7	T	4641.1	3485.3	11107.1	330.0	114.3
		1.00	2980.7	T	108.1	9609.3	12698.0	330.0	114.3
	8	.0	11.4	C	4788.9	11.9	4812.2	1.1	117.9
		1.00	11.4	C	111.5	33.2	156.2	1.1	117.9
11	1	.0	321.1	C	0.0	0.6	321.7	0.1	0.0
		1.00	321.1	C	0.0	0.0	321.1	0.1	0.0
	2	.0	322.8	C	1692.8	544.3	2559.9	93.0	289.2
		1.00	322.8	C	0.0	0.0	322.8	93.0	289.2
	3	.0	322.8	C	718.5	19096.2	20137.5	3262.3	122.7
		1.00	322.8	C	0.0	0.0	322.8	3262.3	122.7
	4	.0	322.8	C	1692.9	816.2	2831.9	139.4	289.2
		1.00	322.8	C	0.0	0.0	322.8	139.4	289.2
	5	.0	322.8	C	718.6	19368.5	20409.8	3308.8	122.8
		1.00	322.8	C	0.0	0.0	322.8	3308.8	122.8
	6	.0	322.6	C	1918.6	483.7	2724.8	82.6	327.8
		1.00	322.6	C	0.0	0.0	322.6	82.6	327.8
	7	.0	322.6	C	944.2	19035.5	20302.3	3251.9	161.3
		1.00	322.6	C	0.0	0.0	322.6	3251.9	161.3
	8	.0	0.0	C	974.4	62.1	1036.4	10.6	166.5
		1.00	0.0	C	0.0	0.0	0.0	10.6	166.5
12	1	.0	319.2	C	0.1	43.9	363.2	1.1	0.0
		1.00	319.2	C	0.0	0.1	319.3	1.1	0.0
	2	.0	221.2	C	8320.3	148.4	8689.9	11.1	204.8
		1.00	221.2	C	193.8	291.3	706.2	11.1	204.8
	3	.0	3180.3	T	3531.5	3707.7	10419.5	351.2	86.9
		1.00	3180.3	T	82.2	10225.6	13488.2	351.2	86.9
	4	.0	171.3	C	8320.8	200.6	8692.7	16.1	204.8
		1.00	171.3	C	193.8	436.9	802.0	16.1	204.8

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	5	.0	3230.3 T	3531.8	3759.9	10521.9	356.2	86.9
		1.00	3230.3 T	82.2	10371.4	13683.9	356.2	86.9
	6	.0	232.1 C	9429.9	136.8	9798.8	10.0	232.1
		1.00	232.1 C	219.6	258.8	710.5	10.0	232.1
	7	.0	3169.4 T	4641.1	3696.0	11506.5	350.1	114.3
		1.00	3169.4 T	108.1	10193.1	13470.6	350.1	114.3
	8	.0	11.4 C	4788.9	11.9	4812.2	1.1	117.9
		1.00	11.4 C	111.5	33.2	156.1	1.1	117.9
13	1	.0	612.4 C	19.7	0.4	632.5	0.0	0.7
		1.00	612.4 C	0.0	0.0	612.4	0.0	0.7
	2	.0	617.6 C	2151.4	1424.8	4193.8	26.5	79.9
		1.00	617.6 C	0.0	0.0	617.6	26.5	79.9
	3	.0	617.6 C	3379.8	3105.8	7103.3	57.7	125.5
		1.00	617.6 C	0.0	0.0	617.6	57.7	125.5
	4	.0	617.6 C	2201.6	1425.9	4245.1	26.5	81.8
		1.00	617.6 C	0.0	0.0	617.6	26.5	81.8
	5	.0	617.6 C	3430.1	3104.5	7152.2	57.7	127.4
		1.00	617.6 C	0.0	0.0	617.6	57.7	127.4
	6	.0	617.1 C	2163.0	351.0	3131.1	6.5	80.3
		1.00	617.1 C	0.0	0.0	617.1	6.5	80.3
	7	.0	617.1 C	3391.5	4179.6	8188.1	77.6	126.0
		1.00	617.1 C	0.0	0.0	617.1	77.6	126.0
	8	.0	0.0 C	2286.2	4530.5	6816.7	84.1	84.9
		1.00	0.0 C	0.0	0.0	0.0	84.1	84.9
14	1	.0	636.4 C	20.2	0.4	657.1	0.0	0.8
		1.00	636.4 C	0.0	0.0	636.4	0.0	0.8
	2	.0	631.3 C	2381.2	7636.3	10648.7	141.8	88.4
		1.00	631.3 C	0.0	0.0	631.3	141.8	88.4
	3	.0	631.3 C	3609.6	3105.8	7346.6	57.7	134.1
		1.00	631.3 C	0.0	0.0	631.3	57.7	134.1
	4	.0	631.2 C	2432.9	7635.2	10699.3	141.8	90.4
		1.00	631.2 C	0.0	0.0	631.2	141.8	90.4
	5	.0	631.2 C	3661.4	3104.5	7397.1	57.7	136.0
		1.00	631.2 C	0.0	0.0	631.2	57.7	136.0
	6	.0	631.8 C	2369.5	8710.0	11711.3	161.8	88.0
		1.00	631.8 C	0.0	0.0	631.8	161.8	88.0
	7	.0	631.8 C	3598.0	4179.6	8409.3	77.6	133.6
		1.00	631.8 C	0.0	0.0	631.8	77.6	133.6
	8	.0	0.0 T	2286.2	4530.5	6816.8	84.1	84.9
		1.00	0.0 T	0.0	0.0	0.0	84.1	84.9
15	1	.0	1.9 C	0.0	0.4	2.4	0.7	0.0
		1.00	1.9 C	0.1	35.3	37.3	0.7	0.0
	2	.0	143.9 T	155.7	309.8	609.4	8.2	12.8
		1.00	143.9 T	774.6	87.5	1006.1	8.2	12.8
	3	.0	3907.9 C	437.3	8307.8	12653.0	239.5	35.8
		1.00	3907.9 C	2175.4	3319.4	9402.8	239.5	35.8

MEMBER STRESSES

ᒣL UNITS ARE POUN/SQ INCH

ɱEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	4	.0	86.3 T	155.6	187.3	429.3	4.7	12.7
		1.00	86.3 T	774.3	39.1	899.7	4.7	12.7
	5	.0	3965.6 C	437.3	8430.4	12833.3	243.1	35.8
		1.00	3965.6 C	2175.6	3367.9	9509.1	243.1	35.8
	6	.0	130.7 T	18.3	281.6	430.6	7.4	1.5
		1.00	130.7 T	91.1	76.4	298.2	7.4	1.5
	7	.0	3921.2 C	574.6	8336.0	12831.8	240.3	47.1
		1.00	3921.2 C	2858.9	3330.6	10110.7	240.3	47.1
	8	.0	13.6 T	592.9	28.8	635.3	0.8	48.6
		1.00	13.6 T	2949.9	11.4	2974.9	0.8	48.6
16	1	.0	2.0 C	0.0	0.5	2.5	0.8	0.0
		1.00	2.0 C	0.1	36.2	38.3	0.8	0.0
	2	.0	120.8 C	1030.2	253.0	1404.0	8.0	84.4
		1.00	120.8 C	5125.3	136.3	5382.3	8.0	84.4
	3	.0	4172.6 C	437.3	8870.6	13480.5	255.7	35.8
		1.00	4172.6 C	2175.4	3543.3	9891.3	255.7	35.8
	4	.0	180.1 C	1030.3	379.3	1589.7	11.7	84.4
		1.00	180.1 C	5125.6	186.2	5492.0	11.7	84.4
	5	.0	4232.1 C	437.3	8997.1	13666.4	259.4	35.8
		1.00	4232.1 C	2175.6	3593.3	10000.9	259.4	35.8
	6	.0	107.5 C	1167.6	224.9	1500.0	7.2	95.6
		1.00	107.5 C	5808.8	125.1	6041.4	7.2	95.6
	7	.0	4159.4 C	574.6	8842.4	13576.4	254.9	47.1
		1.00	4159.4 C	2858.9	3532.1	10550.3	254.9	47.1
	8	.0	13.5 T	592.9	28.8	635.3	0.8	48.6
		1.00	13.5 T	2950.0	11.4	2974.9	0.8	48.6
17	1	.0	0.0 T	0.0	235.2	235.2	32.6	0.0
		1.00	0.0 T	0.0	0.0	0.0	32.6	0.0
	2	.0	150.8 T	0.0	235.2	386.1	32.6	0.0
		1.00	150.8 T	0.0	0.0	150.8	32.6	0.0
	3	.0	150.8 T	0.0	235.2	386.1	32.6	0.0
		1.00	150.8 T	0.0	0.0	150.8	32.6	0.0
	4	.0	150.8 T	13.3	235.2	386.5	32.6	1.9
		1.00	150.8 T	0.0	0.0	150.8	32.6	1.9
	5	.0	150.8 T	13.3	235.2	386.5	32.6	1.9
		1.00	150.8 T	0.0	0.0	150.8	32.6	1.9
	6	.0	151.9 T	0.0	235.2	387.2	32.6	0.0
		1.00	151.9 T	0.0	0.0	152.0	32.6	0.0
	7	.0	151.9 T	0.0	235.2	387.2	32.6	0.0
		1.00	151.9 T	0.0	0.0	151.9	32.6	0.0
	8	.0	0.0 C	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 C	0.0	0.0	0.0	0.0	0.0

************** END OF LATEST ANALYSIS RESULT **************

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123. PARAMETER
124. CODE AISC
125. FYLD 45999.969 MEMB 9 TO 16
126. WSTR 21000. MEMB 9 TO 16
127. WMIN 0.188 MEMB 9 TO 16
128. CB 1. MEMB 9 TO 16
129. CMY 1. MEMB 9 TO 16
130. MAIN 0. MEMB 9 TO 16
131. RATIO 1. MEMB 9 TO 16
132. CHECK CODE MEMB 9 TO 16
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STAADD-III CODE CHECKING - (AISC)
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..LL UNITS ARE - POUN INCH (UNLESS OTHERWISE NOTED)

MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
9	ST TUB 40408	PASS	AISC- H1-3	0.696	7
		1979.93 C	5807.06	110363.17	0.00
10	ST TUB 40408	PASS	AISC- H2-1	0.464	5
		19195.47 T	-505.82	-59766.70	61.00
11	ST TUB 40408	PASS	AISC- H1-3	0.740	5
		2052.79 C	4419.09	119116.10	0.00
12	ST TUB 40408	PASS	AISC- H2-1	0.496	5
		20544.42 T	-505.81	-63784.00	61.00
13	ST TUB 40203	PASS	AISC- H1-3	0.311	7
		1246.51 C	4408.89	-8150.19	0.00
14	ST TUB 40203	PASS	AISC- H1-3	0.439	6
		1276.17 C	3080.40	-16984.57	0.00
15	ST TUB 40408	PASS	AISC- H1-1	0.477	5
		25221.04 C	2689.35	-51847.12	0.00
16	ST TUB 40408	PASS	AISC- H1-1	0.510	5
		26915.95 C	2689.35	-55332.03	0.00

133. SELECT WELD MEMB 9 TO 16

STAAD-III WELD DESIGN
****

ALL UNITS ARE - INCH POUN

MEMBER	LOCATION/ LOADING	WELD TYPE/ HOR STRESS	WELD SIZE/ VERT STRESS	COMB STRESS/ DIR STRESS
9	STA	1	5/16	17989.95
	7	129.04	2452.52	17821.52
9	END	1	3/16	4189.34
	5	163.67	4133.85	659.61
10	STA	1	3/16	18824.80
	7	297.51	585.23	18813.35
10	END	1	4/16	16106.25
	5	169.80	416.63	16099.96
11	STA	1	5/16	19125.16
	5	98.20	2647.02	18940.84
11	END	1	3/16	4467.46
	5	163.67	4411.71	684.26
12	STA	1	3/16	19549.20
	7	297.51	611.93	19537.35
12	END	1	4/16	17196.89
	5	169.80	439.03	17190.45
13	STA	1	3/16	6333.72
	7	27.99	51.75	6333.44
13	END	1	3/16	557.12
	7	27.99	51.75	554.00
14	STA	1	3/16	9121.90
	6	19.56	107.84	9121.24
14	END	1	3/16	577.68
	6	19.56	107.84	567.19
15	STA	1	4/16	16542.09
	5	314.91	522.15	16530.85
15	END	1	3/16	17856.10
	7	551.76	809.47	17829.21
16	STA	1	4/16	17619.04
	5	314.91	538.47	17607.99
16	END	1	3/16	18670.55
	7	551.76	828.92	18643.98

STAADD-III WELD DESIGN
****

ALL UNITS ARE - INCH POUN

MEMBER	LOCATION/ LOADING	WELD TYPE/ HOR STRESS	WELD SIZE/ VERT STRESS	COMB STRESS/ DIR STRESS

****************** END OF TABULATED WELD DESIGN ******************

134. FINISH

*************** END OF STAAD-III ***************

**** DATE= APR 11,1996 TIME= 15:18:33 ****

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*********************************************************
*       For questions on  STAAD-III,  contact:          *
*             Research Engineers, Inc at                *
*      Ph: (714) 974-2500   Fax:  (714) 921-2543        *
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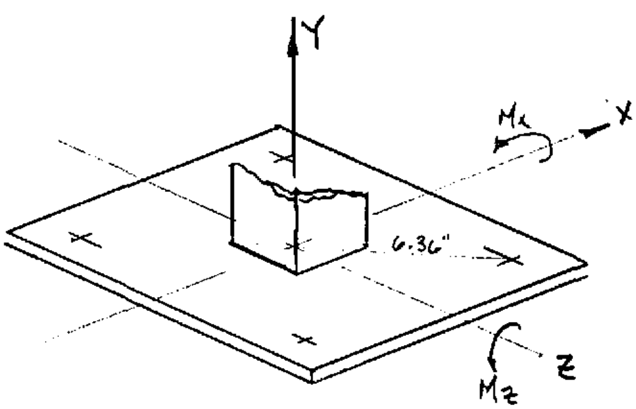
DESIGN ANCHORAGE TRY PL 12"x12"

TRY 1"φ HILTI HVA @ 8 1/4" EMBEDMENT

T_{ALL} = 10960. lbs
V_{ALL} = 7630. lbs
} f'c = 3000 lbs/in^2

SUPPORT REACTIONS

CONSERVATIVELY ENVELOPE ALL LOAD CASES FOR ALL SUPPORT POINTS.



Fx = 14728. lbs   Mx = 57994. in-lbs

FY = 20544. lbs (TENSION)   MY = 14086 in-lbs

Fz = 929. lbs   Mz = 23123 in-lbs

SHEAR

$$V = \frac{14728 + 929}{4 \text{ BOLTS}} + \frac{14086}{(4 \text{ BOLTS})(6.36 \text{ in})}$$

= 4468. lbs.

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$$T = \left(\frac{20544}{4 \text{ BOLTS}} + \frac{57994.}{(2 \text{ BOLTS})(6.5 \text{ in})} + \frac{23123}{(2 \text{ BOLTS})(6.5 \text{ in})} \right) 1.2$$ PRYING FACTOR

= 13651 lbs.

$$\frac{4468}{7630.} + \frac{13651}{10960} = 1.83 > 1.0 \therefore$$ BOLTS N.G.

LOOK AT INDIVIDUAL WORST CASE

JOINT 11 LOADCASE #7

Fx =	1400. lbs	Mx =	28542. in-lbs
Fy =	20157. (TENSION)	My =	1161. in-lbs
Fz =	457. lbs	Mz =	22731. in-lbs

SHEAR

$$V = \frac{1400 + 457}{4 \text{ BOLTS}} + \frac{1161.}{(4 \text{ BOLTS})(6.36 \text{ in})}$$

$$= 510. \text{ lbs/BOLT}$$

TENSION

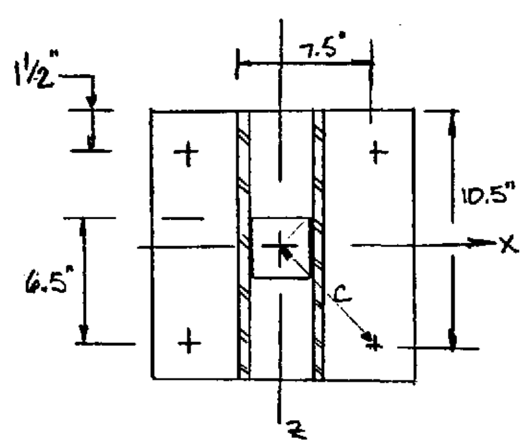
$$T = \left(\frac{28542 \text{ in-lbs}}{(2 \text{ BOLTS})(6.5 \text{ in})} + \frac{22731}{(2 \text{ BOLTS})(6.5 \text{ in})} + \frac{20157}{4 \text{ BOLTS}} \right) 1.2 \text{ PRYING FACTOR}$$

$$= 10780 \text{ lbs/BOLT}$$

BOLT INTERACTION

$$\frac{510}{7630.} + \frac{10780}{10960.} = 0.07 + 0.98 = 1.05 > 1.0$$

TRY STIFFNER PLATES



$$c = \left[(5.5)^2\right](2) = 7.78"$$

$$V = \frac{1400 + 457.}{4 \text{ BOLTS}} + \frac{1161 \text{ in-lbs}}{(4 \text{ BOLTS})(6.36")}$$

$$= 510 \text{ lbs/BOLT}$$

$$T = \frac{28542. \text{ in-lbs}}{(2 \text{ BOLTS})(10.5 \text{ in})} + \frac{22731}{(2 \text{ BOLTS})(7.5 \text{ in})} + \frac{20157}{4 \text{ BOLTS}}$$

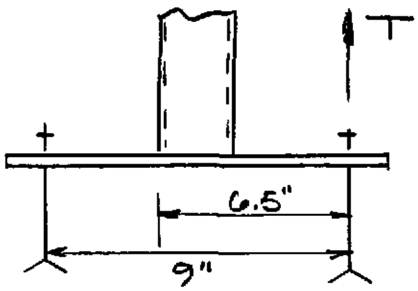
$$T = 7914. \text{ lbs.}$$

PRYING FACTOR

$$\frac{510}{7630} + \frac{7914(1.2)}{10960} = 0.93 \leq 1.0$$

∴ OK.

DETERMINE PLATE THICKNESS



$$T = \left(\frac{7914 \text{ lbs}}{\text{BOLT}}\right) 1.2$$ PRYING FACTOR

$$T = \frac{9497 \text{ lb}}{\text{BOLT}}$$

PL ⇒ $f_y = 36000\#/in^2$

$F_b = .75(f_y) = 27000\#/in^2$

$$f_b = \frac{M}{S} \Rightarrow S_{req'd} = \frac{M}{f_b}$$

$$S_{req'd} = \frac{9497 \text{ lbs}(6.5 \text{ in})}{27000 \text{ lb}/in^2} = 2.286 \text{ in}^3$$

$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{6S}{b}}$$

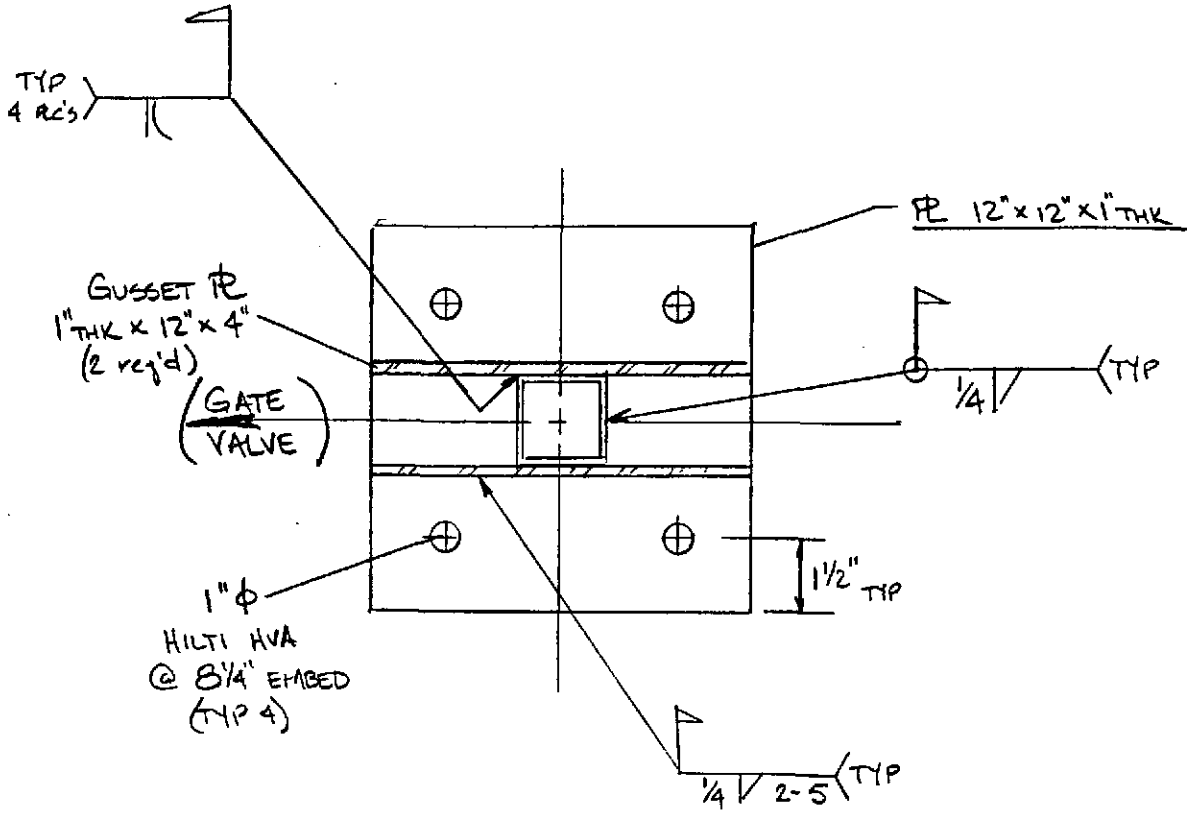
$$d_{req'd} = \sqrt{\frac{6(2.286 \text{ in}^3)}{9 \text{ in}}} = 1.23 \text{ in}$$

USE PL 1 1/4" THK. *

* WITH STIFFNER PL'S

ACCEPTABLE TO USE 1" THK PL.

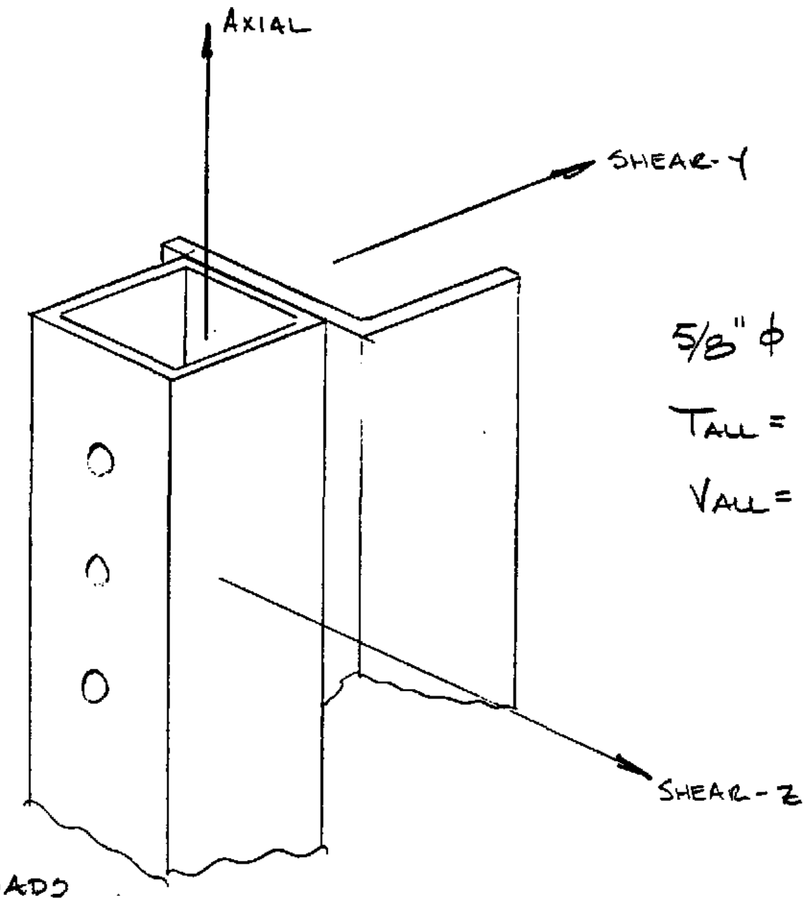
BASE PLATE W/GUSSETS 4. REQ'D



NOTE: STIFFNER PLATES ARE IN LINE WITH CRYOPUMP
I.E. PARALLEL TO THE AXIAL DIRECTION OF THE PUMP.

DESIGN THRU BOLT CONNECTION

@ JOINTS 6, 9, 12 & 14



5/8" φ A307

T_{ALL} = 6100. lbs.

V_{ALL} = 3100 lbs.

ENVELOPE LOADS

AXIAL = 2053. lbs. SHEAR-Y = 13235. lbs. SHEAR-Z = 1311. lbs

$$T = \text{SHEAR-Y} = \frac{13235.\text{ lbs}}{3 \text{ BOLTS}} = 4412.\ \text{lbs/BOLT}$$

$$V = \text{AXIAL} + \text{SHEAR-Z} = \frac{\overset{3364}{2053. + 1311.}}{3 \text{ BOLTS}} = 1121.\ \text{lbs/BOLT}$$

BOLT INTERACTION:

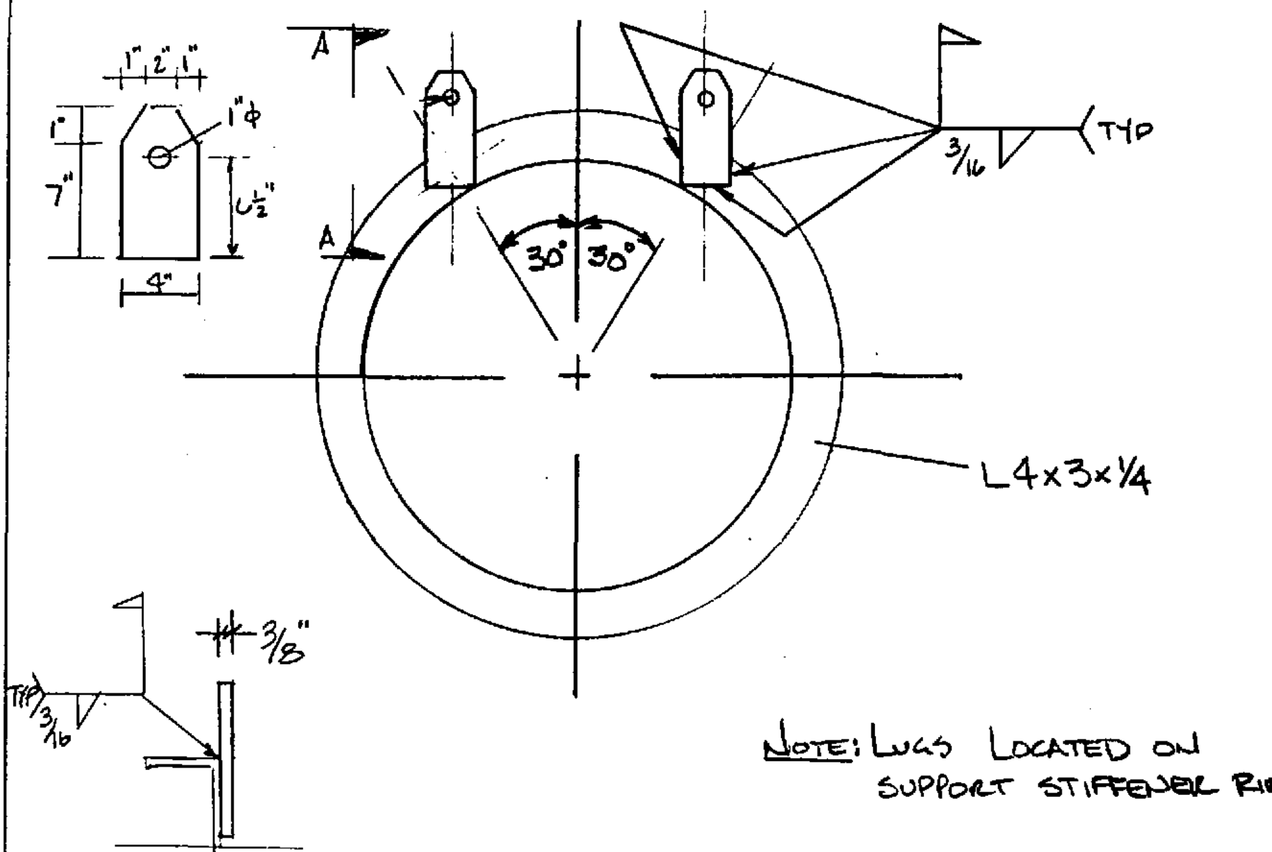
$$\frac{T}{T_{ALL}} + \frac{V}{V_{ALL}} = \frac{4412}{6100} + \frac{1121.}{3100} = 1.08 > 1.0 \ *$$

* ACTUAL WORST LOAD CASE IS @ MEM 11 LOAD # 5 = < 1.0, OK

ALSO, ALLOWABLE LOADS CAN BE INCREASED 33% FOR SEISMIC LOADING ∴ 1.08 < 1.33 O.K.

80K LONG CRYOPUMP - DESIGN IS VALID FOR 80K-SHORT CRYOPUMP

LIFTING LUGS



SECTION A-A

NOTE: LUGS LOCATED ON SUPPORT STIFFENER RINGS

TENSION / LUG = 5700 lbs + 6784 lbs

= 12484 lbs / 4 LUGS = 3121 lbs/LUG

FORCE ALLOWABLE FOR 3/16" WELD PER INCH OF WELD

$$F_{W_{ALL}} = \frac{(3/16 \text{ in})(.707)(21000 \text{ lbs/in})}{1 \text{ in WELD}} = 2784 \text{ lbs/in}$$

∴ WELD AS SHOWN, PROVIDES A MINIMUM OF 10 in OF WELD ∴ $F_{W_{ALL}}$ = 27840 lbs

WELD IS ACCEPTABLE

80K-LONG

WEIGHT OF VESSEL

· INTERNALS (REF V049-1-070)

$W = 5700 \text{ lbs}$

$L = 146 \text{ in.}$

· EXTERNAL SHELL (REF V049-1-082)

$W = 6784 \text{ lbs} - (2)(426 \text{ lbs}) - (2)(616 \text{ lbs})$

$= 4700 \text{ lbs.}$

$W_{TOTAL} = 5700 \text{ lbs} + 4700 \text{ lbs} = 10400 \text{ lbs.}$

Apply Vessel Weight as a uniform load over entire length of 80K Long Cryopump.

$w = \dfrac{10400 \text{ lbs}}{206.5 \text{ in.}}$

$w_{vert.} = 50.36 \text{ lbs/in.}$ (-Y direction)

$w_{hor.} = (0.05625\,g)(50.36 \text{ lbs/in}) = 2.83 \text{ lbs/in}$ X & Z dir.

FOR STAAD MODEL REFER TO 80K - SHORT MODEL

- OVERALL DIMENSION IS 206.5 in VS 110 in
- NODES 3 to 4 increases to 90.75 in VS. 43 in.
- NODES 4 to 5 increases to 78.25 in VS. 29.5 in.

ALL OTHER ELEMENTS, MEMBER INCIDENCES, PROPERTIES AND LOADS REMAIN THE SAME. THE UNIFORM WEIGHT INCREASES TO 50.36 #/in VS. 42.73 #/in.

SAME AS 80K SHORT:

- THERMAL
- VACUUM
- SEISMIC
- DEADWEIGHT : FLANGES, VALVES.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

1

MN/ELEM

STRUCTURE DATA

TYPE = SPACE

NJ = 16

NM = 17

NE = 0

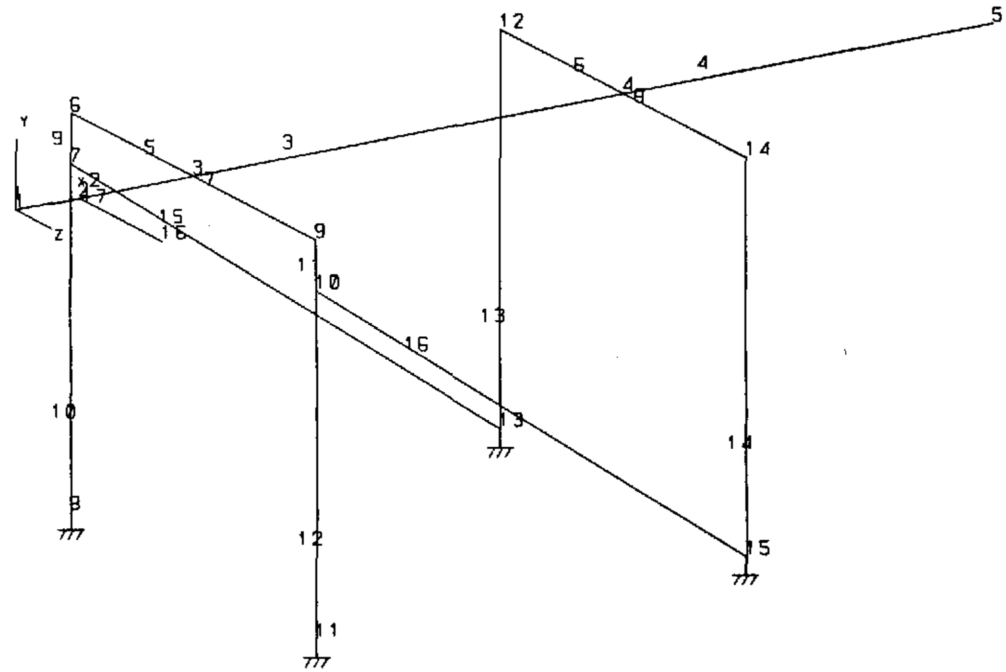
NS = 4

NL = 8

XMAX= 206.5

YMAX= 70.0

ZMAX= 84.5



J=16,M=17

UNIT INC POU

USER ID:Process Systems International

S T A A D P O S T - P L O T (REV: 21.0)

DATE: APR 16, 1996

TITLE: 80K-LONG CRYOPUMP SUPPORT

```
**************************************************
*                                                *
*              S T A A D - III                   *
*              Revision 21.0                     *
*              Proprietary Program of            *
*              Research Engineers, Inc.          *
*              Date=    APR 16, 1996             *
*              Time=    11:48:26                 *
*                                                *
*       USER ID: Process Systems International   *
**************************************************
```

```
 1. STAAD SPACE 80K-LONG CRYOPUMP SUPPORT
 2. *** REV1 REVISED LOADS & MEMBER RELEASE
 3. INPUT WIDTH 72
 4. UNIT INCHES POUND
 5. JOINT COORDINATES
 6. 1 0. 0. 0.; 2 13.5 0. 0.; 3 37.5 0. 0.; 4 128.25 0. 0.; 5 206.5 0. 0.
 7. 6 37.5 0. -42.25; 7 37.5 -9. -42.25; 8 37.5 -70. -42.25; 9 37.5 0. 42.25
 8. 10 37.5 -9. 42.25; 11 37.5 -70. 42.25; 12 128.25 0. -42.25
 9. 13 128.25 -70. -42.25; 14 128.25 0. 42.25; 15 128.25 -70. 42.25
10. 16 13.5 0. 28.56
11. MEMBER INCIDENCES
12. 1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 3 6; 6 4 12; 7 3 9; 8 4 14; 9 7 6; 10 8 7
13. 11 10 9; 12 11 10; 13 13 12; 14 15 14; 15 7 13; 16 10 15; 17 2 16
14. MEMBER PROPERTY AMER
15. 9 TO 12 15 16 TABLE ST TUB40408
16. 13 14 TABLE ST TUB40203
17. 5 TO 8 TABLE ST TUB80805
18. 1 2 4 TABLE ST PIPE OD 45.12 ID 44.62
19. 3 TABLE ST PIPE OD 80. ID 79.5
20. 17 TABLE ST PIPE OD 10. ID 9.5
21. MEMBER RELEASE
22. 9 11 13 14 END MX MY MZ
23. CONSTANTS
24. E STEEL ALL
25. POISSON STEEL ALL
26. DENSITY STEEL ALL
27. BETA 90. MEMB 13 14
28. ALPHA 0.00000919 MEMB 1 TO 8
29. SUPPORTS
30. 8 11 13 15 FIXED
31. LOAD 1 DEADWEIGHT
32. JOINT LOAD
33. 1 5 FY -852.
34. * FLANGE WEIGHT = 2 @ 426 LBS.
35. 16 FY -150.
36. * VALVE WEIGHT
37. MEMBER LOAD
38. 1 TO 4 UNI Y -50.36
39. * UNIFORM  10400#/206.5" = 50.36
40. * UNIFORM = INTERNAL+EXTERNAL
41. LOAD 2 DW+TH
```

```
42. JOINT LOAD
43. 1 5 FY -852.
44. 16 FY -150.
45. 16 FZ 1155.
46. * UNBALANCED VACUUM LOAD @ TURBO PMP
47. MEMBER LOAD
48. 1 TO 4 UNI Y -50.36
49. TEMPERATURE LOAD
50. 1 TO 8 17 TEMP 330.
51. LOAD 3 DW+VACUUM
52. JOINT LOAD
53. 1 FX 25400.
54. * FULL VACUUM LOAD @ GATE VALVE
55. 1 5 FY -852.
56. 16 FY -150.
57. 16 FZ 1155.
58. * UNBALANCED VACUUM LOAD @ TURBO PMP
59. MEMBER LOAD
60. 1 TO 4 UNI Y -50.36
61. LOAD 4 DW+TH+SEIS-AXIAL
62. JOINT LOAD
63. 1 5 FY -852.
64. 16 FY -150.
65. 1 5 FX 47.925
66. * FLANGE WEIGHT X 0.05625
67. 16 FX 8.5
68. * VALVE WEIGHT X 0.05625
69. 16 FZ 1155.
70. * UNBALANCED VACUUM LOAD @ TURBO PMP
71. MEMBER LOAD
72. 1 TO 4 UNI Y -50.36
73. 1 TO 4 UNI X 2.83
74. * UNIFORM WEIGHT X 0.05625
75. TEMPERATURE LOAD
76. 1 TO 8 17 TEMP 330.
77. LOAD 5 DW+VACUUM+SEIS-AXIAL
78. JOINT LOAD
79. 1 FX 25400.
80. 1 5 FY -852.
81. 16 FY -150.
82. 1 5 FX 47.925
83. 16 FX 8.5
84. 16 FZ 1155.
85. * UNBALANCED VACUUM LOAD @ TURBO PMP
86. MEMBER LOAD
87. 1 TO 4 UNI Y -50.36
88. 1 TO 4 UNI X 2.83
89. LOAD 6 DW+TH+SEIS-LAT
90. JOINT LOAD
91. 1 5 FY -852.
92. 16 FY -150.
93. 1 5 FZ 47.925
94. 16 FZ 8.5
95. 16 FZ 1155.
96. * UNBALANCED VACUUM LOAD @ TURBO PMP
97. MEMBER LOAD
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```
 98. 1 TO 4 UNI Y -50.36
 99. 1 TO 4 UNI Z 2.83
100. TEMPERATURE LOAD
101. 1 TO 8 17 TEMP 330.
102. LOAD 7 DW+VACUUM+SEIS-LAT
103. JOINT LOAD
104. 1 FX 25400.
105. 1 5 FY -852.
106. 16 FY -150.
107. 1 5 FZ 47.925
108. 16 FZ 8.5
109. 16 FZ 1155.
110. MEMBER LOAD
111. 1 TO 4 UNI Y -50.36
112. 1 TO 4 UNI Z 2.83
113. LOAD 8 THERMAL "BAKEOUT"
114. TEMPERATURE LOAD
115. 1 TO 8 17 TEMP 330.
116. PERFORM ANALYSIS
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P R O B L E M   S T A T I S T I C S

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NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS =    16/   17/    4
ORIGINAL/FINAL BAND-WIDTH =   14/     5
TOTAL PRIMARY LOAD CASES  =    8, TOTAL DEGREES OF FREEDOM =     72
SIZE OF STIFFNESS MATRIX =     2592 DOUBLE PREC. WORDS
REQRD/AVAIL. DISK SPACE =  12.05/  490.4 MB,  EXMEM =  1.02 MB

++ PROCESSING ELEMENT STIFFNESS MATRIX.          11:48:26
 · PROCESSING GLOBAL STIFFNESS MATRIX.           11:48:26
 + PROCESSING TRIANGULAR FACTORIZATION.          11:48:26
++ CALCULATING JOINT DISPLACEMENTS.              11:48:27
++ CALCULATING MEMBER  FORCES.                   11:48:27

117. PRINT MATERIAL PROPERTIES ALL
```

MATERIAL PROPERTIES.

\LL UNITS ARE - POUN INCH

MEMBER	E	G	DEN	ALPHA
1	29000000.0	11153846.0	0.28299999	0.00000919
2	29000000.0	11153846.0	0.28299999	0.00000919
3	29000000.0	11153846.0	0.28299999	0.00000919
4	29000000.0	11153846.0	0.28299999	0.00000919
5	29000000.0	11153846.0	0.28299999	0.00000919
6	29000000.0	11153846.0	0.28299999	0.00000919
7	29000000.0	11153846.0	0.28299999	0.00000919
8	29000000.0	11153846.0	0.28299999	0.00000919
9	29000000.0	11153846.0	0.28299999	0.00000000
10	29000000.0	11153846.0	0.28299999	0.00000000
11	29000000.0	11153846.0	0.28299999	0.00000000
12	29000000.0	11153846.0	0.28299999	0.00000000
13	29000000.0	11153846.0	0.28299999	0.00000000
14	29000000.0	11153846.0	0.28299999	0.00000000
15	29000000.0	11153846.0	0.28299999	0.00000000
16	29000000.0	11153846.0	0.28299999	0.00000000
17	29000000.0	11153846.0	0.28299999	0.00000000

************ END OF DATA FROM INTERNAL STORAGE ************

118. PRINT MEMBER INFORMATION ALL

MEMBER INFORMATION

MEMBER	START JOINT	END JOINT	LENGTH (INCH)	BETA (DEG)	RELEASES
1	1	2	13.500	0.00	
2	2	3	24.000	0.00	
3	3	4	90.750	0.00	
4	4	5	78.250	0.00	
5	3	6	42.250	0.00	
6	4	12	42.250	0.00	
7	3	9	42.250	0.00	
8	4	14	42.250	0.00	
9	7	6	9.000	0.00	000000000111
10	8	7	61.000	0.00	
11	10	9	9.000	0.00	000000000111
12	11	10	61.000	0.00	
13	13	12	70.000	90.00	000000000111
14	15	14	70.000	90.00	000000000111
15	7	13	109.346	0.00	
16	10	15	109.346	0.00	
17	2	16	28.560	0.00	

************ END OF DATA FROM INTERNAL STORAGE ************

119. PRINT JOINT COORDINATES ALL

JOINT COORDINATES

COORDINATES ARE INCH UNIT

JOINT	X	Y	Z
1	0.000	0.000	0.000
2	13.500	0.000	0.000
3	37.500	0.000	0.000
4	128.250	0.000	0.000
5	206.500	0.000	0.000
6	37.500	0.000	-42.250
7	37.500	-9.000	-42.250
8	37.500	-70.000	-42.250
9	37.500	0.000	42.250
10	37.500	-9.000	42.250
11	37.500	-70.000	42.250
12	128.250	0.000	-42.250
13	128.250	-70.000	-42.250
14	128.250	0.000	42.250
15	128.250	-70.000	42.250
16	13.500	0.000	28.560

************ END OF DATA FROM INTERNAL STORAGE ************

120. PRINT SUPPORT INFORMATION ALL

SUPPORT INFORMATION (1=FIXED, 0=RELEASED)

UNITS FOR SPRING CONSTANTS ARE POUN INCH DEGREES

JOINT	FORCE-X/ KFX	FORCE-Y/ KFY	FORCE-Z/ KFZ	MOM-X/ KMX	MOM-Y/ KMY	MOM-Z/ KMZ
8	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
11	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
13	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0
15	1	1	1	1	1	1
	0.0	0.0	0.0	0.0	0.0	0.0

************ END OF DATA FROM INTERNAL STORAGE ************

121. PRINT ANALYSIS RESULTS

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

INT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	-0.00047	-0.00622	-0.00001	0.00001	0.00000	-0.00034
	2	-0.11553	-0.00626	0.12040	0.00001	0.00019	-0.00034
	3	0.18769	-0.00140	0.12040	0.00001	0.00019	-0.00038
	4	-0.11045	-0.00613	0.12045	0.00001	0.00019	-0.00034
	5	0.19277	-0.00127	0.12046	0.00001	0.00019	-0.00038
	6	-0.11553	-0.00626	0.17907	0.00001	0.00006	-0.00034
	7	0.18769	-0.00140	0.17907	0.00001	0.00006	-0.00038
	8	-0.11505	-0.00003	0.00000	0.00000	0.00000	0.00000
2	1	-0.00047	-0.01078	-0.00001	0.00001	0.00000	-0.00034
	2	-0.07459	-0.01081	0.11788	0.00001	0.00019	-0.00034
	3	0.18735	-0.00647	0.11788	0.00001	0.00019	-0.00038
	4	-0.06951	-0.01069	0.11792	0.00001	0.00019	-0.00034
	5	0.19243	-0.00635	0.11792	0.00001	0.00019	-0.00038
	6	-0.07459	-0.01081	0.17827	0.00001	0.00006	-0.00034
	7	0.18735	-0.00647	0.17828	0.00001	0.00006	-0.00038
	8	-0.07411	-0.00003	0.00000	0.00000	0.00000	0.00000
3	1	-0.00047	-0.01881	0.00000	0.00001	0.00000	-0.00035
	2	-0.00180	-0.01883	0.11329	0.00000	0.00019	-0.00035
	3	0.18676	-0.01540	0.11329	0.00000	0.00019	-0.00038
	4	0.00328	-0.01874	0.11331	0.00000	0.00019	-0.00035
	5	0.19183	-0.01530	0.11331	0.00000	0.00019	-0.00039
	6	-0.00180	-0.01883	0.17675	0.00001	0.00006	-0.00035
	7	0.18676	-0.01540	0.17675	0.00001	0.00006	-0.00038
	8	-0.00133	-0.00002	0.00000	0.00000	0.00000	0.00000
4	1	-0.00047	-0.05015	0.00001	0.00001	0.00000	-0.00035
	2	0.27341	-0.05015	0.09639	0.00000	0.00019	-0.00035
	3	0.18675	-0.05015	0.09639	0.00000	0.00019	-0.00039
	4	0.27850	-0.05015	0.09632	0.00000	0.00019	-0.00035
	5	0.19185	-0.05015	0.09632	0.00000	0.00019	-0.00039
	6	0.27341	-0.05015	0.17162	0.00001	0.00006	-0.00035
	7	0.18675	-0.05015	0.17162	0.00001	0.00006	-0.00039
	8	0.27388	0.00000	0.00000	0.00000	0.00000	0.00000
5	1	-0.00047	-0.08020	0.00002	0.00001	0.00000	-0.00038
	2	0.51072	-0.08018	0.08184	0.00000	0.00019	-0.00038
	3	0.18675	-0.08314	0.08184	0.00000	0.00019	-0.00042
	4	0.51582	-0.08026	0.08170	0.00000	0.00019	-0.00038
	5	0.19186	-0.08322	0.08170	0.00000	0.00019	-0.00042
	6	0.51072	-0.08018	0.16734	0.00001	0.00005	-0.00038
	7	0.18675	-0.08314	0.16735	0.00001	0.00005	-0.00042
	8	0.51119	0.00002	0.00000	0.00000	0.00000	0.00000
6	1	-0.00047	-0.00066	0.00000	0.00059	0.00000	-0.00035
	2	-0.00326	-0.00082	-0.01483	0.00059	-0.00002	-0.00035
	3	0.05427	0.00261	0.11322	0.00059	0.00429	-0.00038
	4	-0.00173	-0.00073	-0.01481	0.00059	0.00009	-0.00035
	5	0.05580	0.00270	0.11324	0.00059	0.00440	-0.00039
	6	-0.00161	-0.00073	0.04858	0.00059	-0.00003	-0.00035
	7	0.05592	0.00271	0.17663	0.00059	0.00428	-0.00038
	8	-0.00041	-0.00002	-0.12805	0.00000	-0.00003	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

INT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
7	1	-0.00038	-0.00057	0.00000	0.00000	0.00000	0.00001
	2	-0.00111	-0.00074	-0.01211	-0.00030	-0.00002	0.00018
	3	0.01387	0.00270	0.09245	0.00226	0.00017	-0.00330
	4	-0.00071	-0.00065	-0.01210	-0.00030	-0.00002	0.00009
	5	0.01427	0.00279	0.09246	0.00226	0.00017	-0.00339
	6	-0.00068	-0.00064	0.03967	0.00097	0.00007	0.00008
	7	0.01430	0.00279	0.14423	0.00353	0.00027	-0.00340
	8	-0.00011	-0.00002	-0.10455	-0.00256	-0.00020	0.00002
8	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	1	-0.00048	-0.00068	0.00000	-0.00060	0.00000	-0.00035
	2	0.00150	-0.00056	0.24126	-0.00060	0.00004	-0.00035
	3	0.05903	0.00287	0.11322	-0.00060	-0.00427	-0.00038
	4	0.00307	-0.00047	0.24128	-0.00060	-0.00008	-0.00035
	5	0.06060	0.00296	0.11324	-0.00060	-0.00439	-0.00039
	6	-0.00015	-0.00066	0.30468	-0.00060	0.00003	-0.00035
	7	0.05738	0.00277	0.17663	-0.00060	-0.00428	-0.00038
	8	-0.00041	-0.00002	0.12805	0.00000	0.00003	0.00000
10	1	-0.00040	-0.00059	0.00000	0.00000	0.00000	0.00001
	2	0.00012	-0.00047	0.19700	0.00482	0.00037	-0.00011
	3	0.01511	0.00296	0.09245	0.00226	0.00017	-0.00359
	4	0.00053	-0.00038	0.19701	0.00482	0.00037	-0.00020
	5	0.01551	0.00305	0.09246	0.00226	0.00017	-0.00368
	6	-0.00031	-0.00057	0.24878	0.00608	0.00047	-0.00001
	7	0.01468	0.00286	0.14423	0.00353	0.00027	-0.00349
	8	-0.00011	-0.00002	0.10455	0.00256	0.00020	0.00002
11	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	1	-0.00046	-0.00519	0.00001	0.00148	0.00000	-0.00035
	2	0.26466	-0.00519	-0.03174	0.00148	0.00022	-0.00035
	3	0.17829	-0.00519	0.09638	0.00148	0.00021	-0.00039
	4	0.26970	-0.00519	-0.03181	0.00148	0.00022	-0.00035
	5	0.18333	-0.00519	0.09631	0.00148	0.00021	-0.00039
	6	0.27012	-0.00519	0.04348	0.00148	0.00009	-0.00035
	7	0.18375	-0.00519	0.17159	0.00148	0.00008	-0.00039
	8	0.27296	0.00000	-0.12811	0.00000	0.00003	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
13	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	1	-0.00048	-0.00524	0.00001	-0.00148	0.00000	-0.00035
	2	0.28032	-0.00524	0.22449	-0.00148	0.00015	-0.00035
	3	0.19395	-0.00524	0.09638	-0.00148	0.00016	-0.00039
	4	0.28544	-0.00524	0.22442	-0.00148	0.00016	-0.00035
	5	0.19907	-0.00524	0.09631	-0.00148	0.00016	-0.00039
	6	0.27486	-0.00524	0.29970	-0.00148	0.00003	-0.00035
	7	0.18849	-0.00524	0.17159	-0.00148	0.00004	-0.00039
	8	0.27296	0.00000	0.12811	0.00000	-0.00003	0.00000
15	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	1	-0.00048	-0.01151	-0.00001	0.00003	0.00000	-0.00034
	2	-0.06925	-0.01149	0.11803	0.00003	0.00019	-0.00034
	3	0.19269	-0.00715	0.11803	0.00003	0.00019	-0.00038
	4	-0.06412	-0.01137	0.11807	0.00003	0.00019	-0.00034
	5	0.19782	-0.00703	0.11807	0.00003	0.00019	-0.00038
	6	-0.07291	-0.01152	0.17842	0.00003	0.00006	-0.00034
	7	0.18903	-0.00718	0.17843	0.00003	0.00006	-0.00038
	8	-0.07411	-0.00003	0.00000	0.00000	0.00000	0.00000

SUPPORT REACTIONS -UNIT POUN INCH STRUCTURE TYPE = SPACE

,INT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
8	1	1.80	1733.37	0.01	0.64	0.02	-109.61
	2	-79.67	2231.93	56.59	3457.63	91.14	1386.05
	3	1595.30	-8150.05	-431.96	-26394.14	-695.76	-29359.75
	4	-34.93	1954.59	56.52	3453.58	91.04	564.84
	5	1640.04	-8427.40	-432.02	-26397.92	-695.86	-30181.02
	6	-31.50	1937.80	-185.36	-11326.03	-298.56	501.74
	7	1643.46	-8444.14	-673.90	-41177.49	-1085.45	-30243.98
	8	-11.79	73.09	488.53	29850.71	786.87	216.46
11	1	1.86	1786.47	0.01	0.64	0.02	-113.10
	2	59.74	1434.10	-920.48	-56244.08	-1482.61	-1175.84
	3	1734.70	-8947.84	-431.96	-26394.15	-695.76	-31921.54
	4	105.19	1152.44	-920.55	-56248.11	-1482.71	-2010.07
	5	1780.16	-9229.55	-432.02	-26397.92	-695.86	-32755.91
	6	11.58	1728.22	-1162.43	-71027.76	-1872.31	-291.52
	7	1686.54	-8653.75	-673.90	-41177.49	-1085.45	-31037.31
	8	-11.79	73.09	-488.54	-29851.00	-786.88	216.46
13	1	-1.77	4342.60	-0.01	-0.64	0.09	-72.79
	2	611.65	3844.05	37.89	3155.97	510.30	7015.38
	3	-13763.32	14226.02	-145.54	-14030.85	-3895.44	-15403.10
	4	225.29	4121.38	37.95	3159.55	509.70	6585.44
	5	-14149.70	14503.37	-145.48	-14027.08	-3896.00	-15833.07
	6	195.71	4138.17	-64.54	-6167.03	-1671.58	6553.20
	7	-14179.21	14520.11	-247.97	-23353.58	-6077.28	-15865.24
	8	11.77	-73.09	183.42	17186.15	4405.58	6418.21
15	1	-1.89	4390.90	-0.01	-0.64	0.09	-75.09
	2	-591.77	4743.27	-328.96	-31216.51	-8300.91	5673.16
	3	-14966.69	15125.21	-145.54	-14030.85	-3895.44	-16745.27
	4	-984.26	5024.93	-328.90	-31212.93	-8301.51	5236.40
	5	-15359.24	15406.92	-145.48	-14027.08	-3896.00	-17182.11
	6	-175.83	4449.14	-431.39	-40539.51	-10482.79	6135.35
	7	-14550.79	14831.12	-247.97	-23353.58	-6077.27	-16283.13
	8	11.77	-73.09	-183.43	-17186.33	-4405.63	6418.21

MEMBER END FORCES STRUCTURE TYPE = SPACE

\LL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	1	0.00	-852.00	0.00	0.00	0.00	-0.16
		2	0.00	1531.86	0.00	0.00	0.00	-16090.66
	2	1	0.00	-852.01	0.09	0.00	-0.33	-0.10
		2	0.00	1531.87	-0.09	0.00	0.13	-16090.93
	3	1	25400.44	-852.00	-0.26	0.00	0.74	-0.06
		2	-25400.44	1531.86	0.26	0.00	0.37	-16090.61
	4	1	47.61	-852.00	0.01	0.00	-1.02	0.02
		2	-85.94	1531.86	-0.01	0.00	-0.57	-16090.73
	5	1	25447.55	-852.00	-0.01	0.00	0.73	-0.12
		2	-25485.75	1531.86	0.01	0.00	-0.03	-16091.03
	6	1	-0.73	-852.00	47.82	0.00	-0.44	-0.15
		2	0.73	1531.86	-86.02	0.00	-904.51	-16090.84
	7	1	25400.59	-852.00	47.87	0.00	0.70	-0.06
		2	-25400.59	1531.86	-86.08	0.00	-905.17	-16090.61
	8	1	-0.49	0.00	0.00	0.00	0.00	0.00
		2	0.49	0.00	0.00	0.00	0.00	0.00
2	1	2	0.00	-1681.86	0.00	4284.05	0.00	16090.76
		3	0.00	2890.50	0.00	-4284.05	0.00	-70959.09
	2	2	0.24	-1681.85	1155.10	4283.97	-0.97	16090.87
		3	-0.24	2890.49	-1155.10	-4283.97	-27720.47	-70959.00
	3	2	25400.43	-1681.86	1155.04	4283.96	1.08	16091.04
		3	-25400.43	2890.50	-1155.04	-4283.96	-27720.98	-70959.07
	4	2	94.73	-1681.86	1155.05	4284.01	243.63	16091.40
		3	-162.60	2890.50	-1155.05	-4284.01	-27964.00	-70959.36
	5	2	25494.16	-1681.87	1154.96	4284.03	243.73	16090.76
		3	-25562.08	2890.51	-1154.96	-4284.03	-27961.84	-70959.59
	6	2	-0.49	-1681.86	1249.78	4284.02	902.86	16091.09
		3	0.49	2890.50	-1317.70	-4284.02	-31708.69	-70959.14
	7	2	25399.45	-1681.86	1249.72	4284.02	904.10	16091.04
		3	-25399.45	2890.50	-1317.64	-4284.02	-31709.54	-70959.07
	8	2	-0.24	0.00	0.00	0.00	0.51	0.00
		3	0.24	0.00	0.00	0.00	-0.39	0.00
3	1	3	-0.31	633.43	0.02	2036.36	-2.30	70958.52
		4	0.31	3936.74	-0.02	-2036.36	0.19	-220846.78
	2	3	179.20	633.42	189.88	1498.85	-17017.93	70960.20
		4	-179.20	3936.75	-189.88	-1498.85	-214.35	-220847.95
	3	3	121.88	633.43	189.85	1498.88	-17013.99	70959.93
		4	-121.88	3936.74	-189.85	-1498.88	-215.91	-220848.28
	4	3	-344.24	633.43	189.76	1496.15	-17003.08	70959.45
		4	87.40	3936.74	-189.76	-1496.15	-219.29	-220847.55
	5	3	-400.60	633.43	189.76	1496.14	-17000.93	70958.64
		4	143.78	3936.74	-189.76	-1496.14	-220.10	-220847.42

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	6	3	179.20	633.43	-188.04	1870.43	17896.32	70959.73
		4	-179.20	3936.74	-68.79	-1870.43	-12486.40	-220847.55
	7	3	122.18	633.43	-188.07	1870.41	17894.03	70960.17
		4	-122.18	3936.74	-68.75	-1870.41	-12481.37	-220848.28
	8	3	179.20	0.00	-0.02	0.00	0.73	0.00
		4	-179.20	0.00	0.02	0.00	1.16	0.00
4	1	4	0.00	4792.66	0.00	-0.01	0.00	220847.19
		5	0.00	-851.99	0.00	0.01	0.00	-0.63
	2	4	0.00	4792.65	0.03	0.00	-3.11	220847.03
		5	0.00	-851.98	-0.03	0.00	1.31	-0.39
	3	4	-0.24	4792.68	0.00	0.00	-0.16	220847.89
		5	0.24	-852.01	0.00	0.00	0.14	0.07
	4	4	-269.04	4792.68	-0.02	0.00	0.71	220847.55
		5	47.61	-852.01	0.02	0.00	-0.43	0.21
	5	4	-269.13	4792.68	-0.02	0.00	0.04	220847.95
		5	47.69	-852.01	0.02	0.00	1.24	0.17
	6	4	0.00	4792.67	-269.42	-0.02	12413.45	220847.50
		5	0.00	-852.00	47.97	0.02	1.92	-0.02
	7	4	-0.48	4792.66	-269.36	-0.01	12413.48	220847.30
		5	0.48	-851.99	47.91	0.01	-1.58	0.02
	8	4	0.49	0.00	0.01	0.00	-1.46	0.00
		5	-0.49	0.00	-0.01	0.00	0.34	0.00
5	1	3	0.01	-1735.36	0.13	0.00	-5.39	-73319.06
		6	-0.01	1735.36	-0.13	0.00	0.00	-0.03
	2	3	63.11	-1729.00	-618.89	0.00	26148.05	-73050.32
		6	-63.11	1729.00	618.89	0.00	0.11	-0.02
	3	3	-482.48	-1729.00	12109.46	0.00	-511624.75	-73050.34
		6	482.48	1729.00	-12109.46	0.00	0.08	-0.02
	4	3	63.17	-1728.97	-278.93	0.00	11785.02	-73048.92
		6	-63.17	1728.97	278.93	0.00	-0.12	0.02
	5	3	-482.57	-1728.97	12449.46	0.00	-525989.63	-73048.90
		6	482.57	1728.97	-12449.46	0.00	-0.04	0.04
	6	3	-207.03	-1733.40	-252.90	0.00	10685.42	-73236.09
		6	207.03	1733.40	252.90	0.00	-0.24	0.00
	7	3	-752.87	-1733.40	12475.41	0.00	-527085.88	-73236.06
		6	752.87	1733.40	-12475.41	0.00	0.14	0.00
	8	3	545.72	0.00	-89.60	0.00	3785.81	0.00
		6	-545.72	0.00	89.60	0.00	-0.05	0.00
6	1	4	-0.01	-4340.61	-0.15	0.00	6.45	-183390.80
		12	0.01	4340.61	0.15	0.00	0.00	-0.03
	2	4	31.31	-4346.97	86.92	0.00	-3672.22	-183659.53
		12	-31.31	4346.97	-86.92	0.00	-0.29	-0.02
	3	4	-94.93	-4346.97	58.55	0.00	-2473.54	-183659.47
		12	94.93	4346.97	-58.55	0.00	0.12	0.01

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	4	4	31.13	-4347.00	88.55	0.00	-3741.39	-183660.91
		12	-31.13	4347.00	-88.55	0.00	0.31	0.00
	5	4	-94.88	-4347.00	60.21	0.00	-2543.74	-183660.81
		12	94.88	4347.00	-60.21	0.00	-0.13	0.04
	6	4	-42.72	-4342.57	88.71	0.00	-3747.84	-183473.77
		12	42.72	4342.57	-88.71	0.00	-0.08	-0.05
	7	4	-169.16	-4342.57	60.33	0.00	-2549.12	-183473.72
		12	169.16	4342.57	-60.33	0.00	0.22	-0.01
	8	4	126.16	0.00	89.63	0.00	-3786.99	0.00
		12	-126.16	0.00	-89.63	0.00	0.01	0.00
7	1	3	-0.01	-1788.56	-0.18	0.00	7.69	-75566.73
		9	0.01	1788.56	0.18	0.00	0.00	-0.03
	2	3	1028.20	-1794.92	-439.97	0.00	18589.12	-75835.44
		9	-1028.20	1794.92	439.97	0.00	-0.32	-0.04
	3	3	482.57	-1794.92	-13168.29	0.00	556360.38	-75835.42
		9	-482.57	1794.92	13168.29	0.00	-0.18	-0.02
	4	3	1028.44	-1794.95	-785.32	0.00	33180.05	-75836.77
		9	-1028.44	1794.95	785.32	0.00	-0.08	0.02
	5	3	482.57	-1794.95	-13513.72	0.00	570954.38	-75836.74
		9	-482.57	1794.95	13513.72	0.00	0.08	0.02
	6	3	1298.64	-1790.53	-74.00	0.00	3126.51	-75649.67
		9	-1298.64	1790.53	74.00	0.00	-0.02	-0.01
	7	3	752.97	-1790.52	-12802.34	0.00	540899.13	-75649.65
		9	-752.97	1790.52	12802.34	0.00	-0.18	0.01
	8	3	545.72	0.00	89.61	0.00	-3786.16	0.00
		9	-545.72	0.00	-89.61	0.00	0.06	0.00
8	1	4	0.01	-4388.81	0.16	0.00	-6.63	-185427.14
		14	-0.01	4388.81	-0.16	0.00	0.00	-0.02
	2	4	221.07	-4382.45	-92.06	0.00	3889.33	-185158.39
		14	-221.07	4382.45	92.06	0.00	0.33	-0.02
	3	4	94.93	-4382.45	-63.69	0.00	2690.82	-185158.39
		14	-94.93	4382.45	63.69	0.00	-0.08	0.01
	4	4	221.01	-4382.41	-93.72	0.00	3960.07	-185157.02
		14	-221.01	4382.41	93.72	0.00	-0.19	-0.02
	5	4	94.88	-4382.41	-65.38	0.00	2761.97	-185156.98
		14	-94.88	4382.41	65.38	0.00	0.08	0.04
	6	4	295.35	-4386.85	-90.26	0.00	3813.47	-185344.17
		14	-295.35	4386.85	90.26	0.00	0.15	-0.02
	7	4	169.06	-4386.84	-61.89	0.00	2614.93	-185344.11
		14	-169.06	4386.84	61.89	0.00	-0.23	0.04
	8	4	126.16	0.00	-89.63	0.00	3787.07	0.00
		14	-126.16	0.00	89.63	0.00	-0.04	0.00
9	1	7	1735.36	0.13	0.01	0.00	-0.10	1.15
		6	-1735.36	-0.13	-0.01	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	7	1729.00	-618.87	63.30	0.00	-569.74	-5569.86
		6	-1729.00	618.87	-63.30	0.00	0.00	0.00
	3	7	1728.99	12109.46	-482.54	0.00	4342.91	108985.16
		6	-1728.99	-12109.46	482.54	0.00	0.00	0.00
	4	7	1728.97	-278.93	63.11	0.00	-568.03	-2510.40
		6	-1728.97	278.93	-63.11	0.00	0.00	0.00
	5	7	1728.97	12449.46	-482.62	0.00	4343.61	112045.18
		6	-1728.97	-12449.46	482.62	0.00	0.00	0.00
	6	7	1733.40	-252.91	-207.07	0.00	1863.65	-2276.20
		6	-1733.40	252.91	207.07	0.00	0.00	0.00
	7	7	1733.39	12475.41	-752.88	0.00	6775.87	112278.68
		6	-1733.39	-12475.41	752.88	0.00	0.00	0.00
	8	7	0.00	-89.62	545.79	0.00	-4912.12	-806.54
		6	0.00	89.62	-545.79	0.00	0.00	0.00
10	1	8	1733.37	-1.80	0.01	0.02	-0.64	-109.61
		7	-1733.37	1.80	-0.01	-0.02	0.00	-0.12
	2	8	2231.93	79.67	56.59	91.14	-3457.63	1386.05
		7	-2231.93	-79.67	-56.59	-91.14	5.84	3473.61
	3	8	-8150.05	-1595.30	-431.96	-695.76	26394.14	-29359.75
		7	8150.05	1595.30	431.96	695.76	-44.50	-67953.69
	4	8	1954.59	34.93	56.52	91.04	-3453.58	564.84
		7	-1954.59	-34.93	-56.52	-91.04	5.85	1565.80
	5	8	-8427.40	-1640.04	-432.02	-695.86	26397.92	-30181.02
		7	8427.40	1640.04	432.02	695.86	-44.49	-69861.62
	6	8	1937.80	31.50	-185.36	-298.56	11326.03	501.74
		7	-1937.80	-31.50	185.36	298.56	-19.12	1419.86
	7	8	-8444.14	-1643.46	-673.90	-1085.45	41177.49	-30243.98
		7	8444.14	1643.46	673.90	1085.45	-69.42	-70007.25
	8	8	73.09	11.79	488.53	786.87	-29850.71	216.46
		7	-73.09	-11.79	-488.53	-786.87	50.32	502.87
11	1	10	1788.56	0.18	0.01	0.00	-0.10	1.64
		9	-1788.56	-0.18	-0.01	0.00	0.00	0.00
	2	10	1794.92	439.98	-1028.23	0.00	9254.14	3959.81
		9	-1794.92	-439.98	1028.23	0.00	0.00	0.00
	3	10	1794.93	13168.29	-482.52	0.00	4342.76	118514.59
		9	-1794.93	-13168.29	482.52	0.00	0.00	0.00
	4	10	1794.95	785.32	-1028.39	0.00	9255.55	7067.92
		9	-1794.95	-785.32	1028.39	0.00	0.00	0.00
	5	10	1794.96	13513.72	-482.62	0.00	4343.61	121623.43
		9	-1794.96	-13513.72	482.62	0.00	0.00	0.00
	6	10	1790.53	73.99	-1298.54	0.00	11686.92	665.90
		9	-1790.53	-73.99	1298.54	0.00	0.00	0.00
	7	10	1790.52	12802.35	-752.86	0.00	6775.71	115221.20
		9	-1790.52	-12802.35	752.86	0.00	0.00	0.00
	8	10	0.00	-89.60	-545.72	0.00	4911.57	-806.41
		9	0.00	89.60	545.72	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
12	1	11	1786.47	-1.86	0.01	0.02	-0.64	-113.10
		10	-1786.47	1.86	-0.01	-0.02	0.00	-0.41
	2	11	1434.10	-59.74	-920.48	-1482.61	56244.08	-1175.84
		10	-1434.10	59.74	920.48	1482.61	-94.81	-2468.40
	3	11	-8947.84	-1734.70	-431.96	-695.76	26394.15	-31921.54
		10	8947.84	1734.70	431.96	695.76	-44.49	-73895.47
	4	11	1152.44	-105.19	-920.55	-1482.71	56248.11	-2010.07
		10	-1152.44	105.19	920.55	1482.71	-94.82	-4406.43
	5	11	-9229.55	-1780.16	-432.02	-695.86	26397.92	-32755.91
		10	9229.55	1780.16	432.02	695.86	-44.49	-75833.83
	6	11	1728.22	-11.58	-1162.43	-1872.31	71027.76	-291.52
		10	-1728.22	11.58	1162.43	1872.31	-119.73	-414.62
	7	11	-8653.75	-1686.54	-673.90	-1085.45	41177.49	-31037.31
		10	8653.75	1686.54	673.90	1085.45	-69.41	-71841.90
	8	11	73.09	11.79	-488.54	-786.88	29851.00	216.46
		10	-73.09	-11.79	488.54	786.88	-50.32	502.87
13	1	13	4340.61	-0.01	0.15	0.00	-10.68	-0.81
		12	-4340.61	0.01	-0.15	0.00	0.00	0.00
	2	13	4346.97	31.27	-86.91	0.00	6083.53	2188.58
		12	-4346.97	-31.27	86.91	0.00	0.00	0.00
	3	13	4346.97	-94.95	-58.55	0.00	4098.33	-6646.27
		12	-4346.97	94.95	58.55	0.00	0.00	0.00
	4	13	4347.00	31.33	-88.56	0.00	6199.36	2193.30
		12	-4347.00	-31.33	88.56	0.00	0.00	0.00
	5	13	4347.00	-94.88	-60.20	0.00	4214.17	-6641.44
		12	-4347.00	94.88	60.20	0.00	0.00	0.00
	6	13	4342.57	-42.83	-88.70	0.00	6209.03	-2998.22
		12	-4342.57	42.83	88.70	0.00	0.00	0.00
	7	13	4342.57	-169.04	-60.34	0.00	4223.81	-11832.89
		12	-4342.57	169.04	60.34	0.00	0.00	0.00
	8	13	0.00	126.21	-89.63	0.00	6274.36	8834.49
		12	0.00	-126.21	89.63	0.00	0.00	0.00
14	1	15	4388.81	-0.01	0.16	0.00	-10.99	-0.81
		14	-4388.81	0.01	-0.16	0.00	0.00	0.00
	2	15	4382.45	-221.15	-92.05	0.00	6443.50	-15480.48
		14	-4382.45	221.15	92.05	0.00	0.00	0.00
	3	15	4382.45	-94.95	-63.69	0.00	4458.29	-6646.27
		14	-4382.45	94.95	63.69	0.00	0.00	0.00
	4	15	4382.41	-221.08	-93.73	0.00	6561.16	-15475.77
		14	-4382.41	221.08	93.73	0.00	0.00	0.00
	5	15	4382.41	-94.88	-65.37	0.00	4575.96	-6641.44
		14	-4382.41	94.88	65.37	0.00	0.00	0.00
	6	15	4386.84	-295.25	-90.26	0.00	6318.01	-20667.28
		14	-4386.84	295.25	90.26	0.00	0.00	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

\LL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	7	15	4386.84	-169.04	-61.90	0.00	4332.80	-11832.89
		14	-4386.84	169.04	61.90	0.00	0.00	0.00
	8	15	0.00	-126.21	-89.63	0.00	6274.36	-8834.58
		14	0.00	126.21	89.63	0.00	0.00	0.00
15	1	7	2.71	-0.58	0.00	-0.10	-0.04	-1.03
		13	-2.71	0.58	0.00	0.10	0.18	-62.11
	2	7	-860.32	27.69	-6.63	-518.18	-238.49	2096.42
		13	860.32	-27.69	6.63	518.18	963.18	931.85
	3	7	16885.20	-553.59	50.59	3955.60	1820.53	-41031.52
		13	-16885.20	553.59	-50.59	-3955.60	-7352.54	-19501.43
	4	7	-386.34	12.17	-6.62	-517.58	-238.22	944.48
		13	386.34	-12.17	6.62	517.58	962.06	386.08
	5	7	17359.20	-569.12	50.60	3956.16	1820.79	-42183.52
		13	-17359.20	569.12	-50.60	-3956.16	-7353.59	-20047.23
	6	7	-350.07	10.98	21.71	1697.40	781.22	856.36
		13	350.07	-10.98	-21.71	-1697.40	-3155.06	344.17
	7	7	17395.39	-570.30	78.93	6171.13	2840.21	-42271.46
		13	-17395.39	570.30	-78.93	-6171.13	-11470.69	-20089.05
	8	7	-124.93	4.09	-57.22	-4473.62	-2058.95	303.63
		13	124.93	-4.09	57.22	4473.62	8315.42	143.86
16	1	10	2.86	-0.60	0.00	-0.10	-0.04	-1.23
		15	-2.86	0.60	0.00	0.10	0.18	-64.10
	2	10	616.03	-20.68	107.81	8429.10	3879.43	-1491.42
		15	-616.03	20.68	-107.81	-8429.10	-15667.74	-770.35
	3	10	18361.48	-601.97	50.59	3955.60	1820.53	-44619.21
		15	-18361.48	601.97	-50.59	-3955.60	-7352.54	-21203.56
	4	10	1097.51	-36.46	107.82	8429.71	3879.70	-2661.60
		15	-1097.51	36.46	-107.82	-8429.71	-15668.86	-1324.76
	5	10	18843.05	-617.74	50.60	3956.16	1820.79	-45789.59
		15	-18843.05	617.74	-50.60	-3956.16	-7353.59	-21758.07
	6	10	105.77	-3.97	136.14	10644.68	4899.13	-251.34
		15	-105.77	3.97	-136.14	-10644.68	-19785.98	-182.66
	7	10	17851.29	-585.25	78.93	6171.13	2840.21	-43379.26
		15	-17851.29	585.25	-78.93	-6171.13	-11470.69	-20615.94
	8	10	-124.93	4.09	57.22	4473.66	2058.97	303.63
		15	124.93	-4.09	-57.22	-4473.66	-8315.50	143.86
17	1	2	0.00	150.00	0.00	0.00	0.00	4284.03
		16	0.00	-150.00	0.00	0.00	0.00	0.03
	2	2	-1154.97	150.00	-0.02	0.00	0.31	4283.99
		16	1154.97	-150.00	0.02	0.00	0.30	-0.02
	3	2	-1155.02	150.00	0.01	0.00	0.08	4283.96
		16	1155.02	-150.00	-0.01	0.00	-0.16	-0.04
	4	2	-1155.01	150.00	8.52	0.00	-243.12	4284.00
		16	1155.01	-150.00	-8.52	0.00	-0.23	0.00

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	5	2	-1155.06	150.00	8.50	0.00	-242.83	4284.02
		16	1155.06	-150.00	-8.50	0.00	0.02	0.02
	6	2	-1163.36	150.00	-0.04	0.00	0.57	4284.01
		16	1163.36	-150.00	0.04	0.00	0.46	0.00
	7	2	-1163.46	150.00	0.01	0.00	-0.24	4284.03
		16	1163.46	-150.00	-0.01	0.00	-0.19	0.02
	8	2	0.00	0.00	0.03	0.00	-0.46	0.00
		16	0.00	0.00	-0.03	0.00	-0.46	0.00

************** END OF LATEST ANALYSIS RESULT **************

122. PRINT MEMBER STRESSES ALL

MEMBER STRESSES

˙.L UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
1	1	.0	0.0 C	0.0	0.0	0.0	40.3	0.0
		1.00	0.0 C	0.0	40.9	40.9	72.4	0.0
	2	.0	0.0	0.0	0.0	0.0	40.3	0.0
		1.00	0.0	0.0	40.9	40.9	72.4	0.0
	3	.0	720.8 C	0.0	0.0	720.8	40.3	0.0
		1.00	720.8 C	0.0	40.9	761.7	72.4	0.0
	4	.0	1.4 C	0.0	0.0	1.4	40.3	0.0
		1.00	2.4 C	0.0	40.9	43.4	72.4	0.0
	5	.0	722.1 C	0.0	0.0	722.1	40.3	0.0
		1.00	723.2 C	0.0	40.9	764.1	72.4	0.0
	6	.0	0.0 T	0.0	0.0	0.0	40.3	2.3
		1.00	0.0 T	2.3	40.9	41.0	72.4	4.1
	7	.0	720.8 C	0.0	0.0	720.8	40.3	2.3
		1.00	720.8 C	2.3	40.9	761.8	72.4	4.1
	8	.0	0.0 T	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 T	0.0	0.0	0.0	0.0	0.0
2	1	.0	0.0 T	0.0	40.9	40.9	79.5	0.0
		1.00	0.0 T	0.0	180.5	180.5	136.7	0.0
	2	.0	0.0 C	0.0	40.9	40.9	79.5	54.6
		1.00	0.0 C	70.5	180.5	193.8	136.7	54.6
	3	.0	720.8 C	0.0	40.9	761.7	79.5	54.6
		1.00	720.8 C	70.5	180.5	914.5	136.7	54.6
	4	.0	2.7 C	0.6	40.9	43.6	79.5	54.6
		1.00	4.6 C	71.1	180.5	198.6	136.7	54.6
	5	.0	723.4 C	0.6	40.9	764.4	79.5	54.6
		1.00	725.4 C	71.1	180.5	919.4	136.7	54.6
	6	.0	0.0 T	2.3	40.9	41.0	79.5	59.1
		1.00	0.0 T	80.7	180.5	197.7	136.7	62.3
	7	.0	720.7 C	2.3	40.9	761.7	79.5	59.1
		1.00	720.7 C	80.7	180.5	918.4	136.7	62.3
	8	.0	0.0 T	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 T	0.0	0.0	0.0	0.0	0.0
3	1	.0	0.0 T	0.0	57.0	57.0	16.9	0.0
		1.00	0.0 T	0.0	177.4	177.4	104.8	0.0
	2	.0	2.9 C	13.7	57.0	61.5	16.9	5.1
		1.00	2.9 C	0.2	177.4	180.3	104.8	5.1
	3	.0	1.9 C	13.7	57.0	60.6	16.9	5.1
		1.00	1.9 C	0.2	177.4	179.3	104.8	5.1
	4	.0	5.5 T	13.7	57.0	64.1	16.9	5.0
		1.00	1.4 T	0.2	177.4	178.8	104.8	5.0
	5	.0	6.4 T	13.7	57.0	65.0	16.9	5.0
		1.00	2.3 T	0.2	177.4	179.7	104.8	5.0
	6	.0	2.9 C	14.4	57.0	61.6	16.9	5.0
		1.00	2.9 C	10.0	177.4	180.5	104.8	1.8
	7	.0	2.0 C	14.4	57.0	60.7	16.9	5.0
		1.00	2.0 C	10.0	177.4	179.6	104.8	1.8

MEMBER STRESSES

'LL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	8	.0	2.9 C	0.0	0.0	2.9	0.0	0.0
		1.00	2.9 C	0.0	0.0	2.9	0.0	0.0
4	1	.0	0.0 T	0.0	561.8	561.8	226.7	0.0
		1.00	0.0 T	0.0	0.0	0.0	40.3	0.0
	2	.0	0.0	0.0	561.8	561.8	226.7	0.0
		1.00	0.0	0.0	0.0	0.0	40.3	0.0
	3	.0	0.0 T	0.0	561.8	561.8	226.7	0.0
		1.00	0.0 T	0.0	0.0	0.0	40.3	0.0
	4	.0	7.6 T	0.0	561.8	569.4	226.7	0.0
		1.00	1.4 T	0.0	0.0	1.4	40.3	0.0
	5	.0	7.6 T	0.0	561.8	569.4	226.7	0.0
		1.00	1.4 T	0.0	0.0	1.4	40.3	0.0
	6	.0	0.0	31.6	561.8	562.6	226.7	12.7
		1.00	0.0	0.0	0.0	0.0	40.3	2.3
	7	.0	0.0 T	31.6	561.8	562.7	226.7	12.7
		1.00	0.0 T	0.0	0.0	0.0	40.3	2.3
	8	.0	0.0 C	0.0	0.0	0.0	0.0	0.0
		1.00	0.0 C	0.0	0.0	0.0	0.0	0.0
5	1	.0	0.0 C	0.2	3226.4	3226.6	347.1	0.0
		1.00	0.0 C	0.0	0.0	0.0	347.1	0.0
	2	.0	6.7 C	1150.6	3214.5	4371.9	345.8	123.8
		1.00	6.7 C	0.0	0.0	6.7	345.8	123.8
	3	.0	51.5 T	22513.7	3214.5	25779.8	345.8	2421.9
		1.00	51.5 T	0.0	0.0	51.6	345.8	2421.9
	4	.0	6.7 C	518.6	3214.5	3739.8	345.8	55.8
		1.00	6.7 C	0.0	0.0	6.8	345.8	55.8
	5	.0	51.6 T	23145.9	3214.5	26411.9	345.8	2489.9
		1.00	51.6 T	0.0	0.0	51.6	345.8	2489.9
	6	.0	22.1 T	470.2	3222.7	3715.0	346.7	50.6
		1.00	22.1 T	0.0	0.0	22.1	346.7	50.6
	7	.0	80.4 T	23194.1	3222.7	26497.2	346.7	2495.1
		1.00	80.4 T	0.0	0.0	80.4	346.7	2495.1
	8	.0	58.3 C	166.6	0.0	224.9	0.0	17.9
		1.00	58.3 C	0.0	0.0	58.3	0.0	17.9
6	1	.0	0.0 T	0.3	8070.0	8070.3	868.1	0.0
		1.00	0.0 T	0.0	0.0	0.0	868.1	0.0
	2	.0	3.3 C	161.6	8081.8	8246.8	869.4	17.4
		1.00	3.3 C	0.0	0.0	3.4	869.4	17.4
	3	.0	10.1 T	108.8	8081.8	8200.8	869.4	11.7
		1.00	10.1 T	0.0	0.0	10.1	869.4	11.7
	4	.0	3.3 C	164.6	8081.9	8249.9	869.4	17.7
		1.00	3.3 C	0.0	0.0	3.3	869.4	17.7
	5	.0	10.1 T	111.9	8081.9	8204.0	869.4	12.0
		1.00	10.1 T	0.0	0.0	10.1	869.4	12.0
	6	.0	4.6 T	164.9	8073.7	8243.1	868.5	17.7
		1.00	4.6 T	0.0	0.0	4.6	868.5	17.7

MEMBER STRESSES

'LL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	7	.0	18.1 T	112.2	8073.7	8203.9	868.5	12.1
		1.00	18.1 T	0.0	0.0	18.1	868.5	12.1
	8	.0	13.5 C	166.6	0.0	180.1	0.0	17.9
		1.00	13.5 C	0.0	0.0	13.5	0.0	17.9
7	1	.0	0.0 T	0.3	3325.3	3325.6	357.7	0.0
		1.00	0.0 T	0.0	0.0	0.0	357.7	0.0
	2	.0	109.9 C	818.0	3337.1	4264.9	359.0	88.0
		1.00	109.9 C	0.0	0.0	109.9	359.0	88.0
	3	.0	51.6 C	24482.3	3337.1	27871.0	359.0	2633.7
		1.00	51.6 C	0.0	0.0	51.6	359.0	2633.7
	4	.0	109.9 C	1460.1	3337.2	4907.1	359.0	157.1
		1.00	109.9 C	0.0	0.0	109.9	359.0	157.1
	5	.0	51.6 C	25124.5	3337.2	28513.2	359.0	2702.7
		1.00	51.6 C	0.0	0.0	51.6	359.0	2702.7
	6	.0	138.7 C	137.6	3328.9	3605.2	358.1	14.8
		1.00	138.7 C	0.0	0.0	138.7	358.1	14.8
	7	.0	80.4 C	23801.9	3328.9	27211.3	358.1	2560.5
		1.00	80.4 C	0.0	0.0	80.5	358.1	2560.5
	8	.0	58.3 C	166.6	0.0	224.9	0.0	17.9
		1.00	58.3 C	0.0	0.0	58.3	0.0	17.9
8	1	.0	0.0 C	0.3	8159.6	8159.9	877.8	0.0
		1.00	0.0 C	0.0	0.0	0.0	877.8	0.0
	2	.0	23.6 C	171.1	8147.8	8342.5	876.5	18.4
		1.00	23.6 C	0.0	0.0	23.6	876.5	18.4
	3	.0	10.1 C	118.4	8147.8	8276.3	876.5	12.7
		1.00	10.1 C	0.0	0.0	10.1	876.5	12.7
	4	.0	23.6 C	174.3	8147.7	8345.6	876.5	18.7
		1.00	23.6 C	0.0	0.0	23.6	876.5	18.7
	5	.0	10.1 C	121.5	8147.7	8279.4	876.5	13.1
		1.00	10.1 C	0.0	0.0	10.1	876.5	13.1
	6	.0	31.6 C	167.8	8156.0	8355.3	877.4	18.1
		1.00	31.6 C	0.0	0.0	31.6	877.4	18.1
	7	.0	18.1 C	115.1	8156.0	8289.1	877.4	12.4
		1.00	18.1 C	0.0	0.0	18.1	877.4	12.4
	8	.0	13.5 C	166.6	0.0	180.1	0.0	17.9
		1.00	13.5 C	0.0	0.0	13.5	0.0	17.9
9	1	.0	272.9 C	0.0	0.2	273.1	0.0	0.0
		1.00	272.9 C	0.0	0.0	272.9	0.0	0.0
	2	.0	271.9 C	92.6	905.7	1270.2	154.7	15.8
		1.00	271.9 C	0.0	0.0	271.9	154.7	15.8
	3	.0	271.9 C	706.2	17721.2	18699.2	3027.4	120.6
		1.00	271.9 C	0.0	0.0	271.9	3027.4	120.6
	4	.0	271.9 C	92.4	408.2	772.4	69.7	15.8
		1.00	271.9 C	0.0	0.0	271.9	69.7	15.8
	5	.0	271.9 C	706.3	18218.7	19196.9	3112.4	120.7
		1.00	271.9 C	0.0	0.0	271.9	3112.4	120.7

MEMBER STRESSES

'.L UNITS ARE POUN/SQ INCH

..EMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	6	.0	272.5 C	303.0	370.1	945.7	63.2	51.8
		1.00	272.5 C	0.0	0.0	272.5	63.2	51.8
	7	.0	272.5 C	1101.8	18256.7	19631.0	3118.9	188.2
		1.00	272.5 C	0.0	0.0	272.5	3118.9	188.2
	8	.0	0.0 T	798.7	131.1	929.9	22.4	136.4
		1.00	0.0 T	0.0	0.0	0.0	22.4	136.4
10	1	.0	272.5 C	0.1	17.8	290.5	0.4	0.0
		1.00	272.5 C	0.0	0.0	272.6	0.4	0.0
	2	.0	350.9 C	562.2	225.4	1138.5	19.9	14.1
		1.00	350.9 C	0.9	564.8	916.7	19.9	14.1
	3	.0	1281.5 T	4291.7	4773.9	10347.1	398.8	108.0
		1.00	1281.5 T	7.2	11049.4	12338.1	398.8	108.0
	4	.0	307.3 C	561.6	91.8	960.7	8.7	14.1
		1.00	307.3 C	1.0	254.6	562.9	8.7	14.1
	5	.0	1325.1 T	4292.3	4907.5	10524.9	410.0	108.0
		1.00	1325.1 T	7.2	11359.6	12691.9	410.0	108.0
	6	.0	304.7 C	1841.6	81.6	2227.9	7.9	46.3
		1.00	304.7 C	3.1	230.9	538.7	7.9	46.3
	7	.0	1327.7 T	6695.5	4917.7	12940.9	410.9	168.5
		1.00	1327.7 T	11.3	11383.3	12722.3	410.9	168.5
	8	.0	11.5 C	4853.8	35.2	4900.5	2.9	122.1
		1.00	11.5 C	8.2	81.8	101.4	2.9	122.1
11	1	.0	281.2 C	0.0	0.3	281.5	0.0	0.0
		1.00	281.2 C	0.0	0.0	281.2	0.0	0.0
	2	.0	282.2 C	1504.7	643.9	2430.8	110.0	257.1
		1.00	282.2 C	0.0	0.0	282.2	110.0	257.1
	3	.0	282.2 C	706.1	19270.7	20259.0	3292.1	120.6
		1.00	282.2 C	0.0	0.0	282.2	3292.1	120.6
	4	.0	282.2 C	1505.0	1149.3	2936.4	196.3	257.1
		1.00	282.2 C	0.0	0.0	282.2	196.3	257.1
	5	.0	282.2 C	706.3	19776.2	20764.7	3378.4	120.7
		1.00	282.2 C	0.0	0.0	282.2	3378.4	120.7
	6	.0	281.5 C	1900.3	108.3	2290.1	18.5	324.6
		1.00	281.5 C	0.0	0.0	281.5	18.5	324.6
	7	.0	281.5 C	1101.7	18735.2	20118.4	3200.6	188.2
		1.00	281.5 C	0.0	0.0	281.5	3200.6	188.2
	8	.0	0.0 T	798.6	131.1	929.8	22.4	136.4
		1.00	0.0 T	0.0	0.0	0.0	22.4	136.4
12	1	.0	280.9 C	0.1	18.4	299.4	0.5	0.0
		1.00	280.9 C	0.0	0.1	281.0	0.5	0.0
	2	.0	225.5 C	9145.4	191.2	9562.1	14.9	230.1
		1.00	225.5 C	15.4	401.4	642.3	14.9	230.1
	3	.0	1406.9 T	4291.7	5190.5	10889.1	433.7	108.0
		1.00	1406.9 T	7.2	12015.5	13429.7	433.7	108.0
	4	.0	181.2 C	9146.0	326.8	9654.1	26.3	230.1
		1.00	181.2 C	15.4	716.5	913.1	26.3	230.1

MEMBER STRESSES

'LL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	5	.0	1451.2 T	4292.3	5326.2	11069.7	445.0	108.0
		1.00	1451.2 T	7.2	12330.7	13789.1	445.0	108.0
	6	.0	271.7 C	11549.2	47.4	11868.4	2.9	290.6
		1.00	271.7 C	19.5	67.4	358.6	2.9	290.6
	7	.0	1360.7 T	6695.5	5046.7	13102.9	421.6	168.5
		1.00	1360.7 T	11.3	11681.6	13053.5	421.6	168.5
	8	.0	11.5 C	4853.8	35.2	4900.5	2.9	122.1
		1.00	11.5 C	8.2	81.8	101.4	2.9	122.1
13	1	.0	2148.8 C	8.2	0.4	2157.5	0.0	0.3
		1.00	2148.8 C	0.0	0.0	2148.8	0.0	0.3
	2	.0	2152.0 C	4679.6	1122.4	7954.0	20.8	173.8
		1.00	2152.0 C	0.0	0.0	2152.0	20.8	173.8
	3	.0	2152.0 C	3152.6	3408.3	8712.9	63.3	117.1
		1.00	2152.0 C	0.0	0.0	2152.0	63.3	117.1
	4	.0	2152.0 C	4768.7	1124.8	8045.5	20.9	177.1
		1.00	2152.0 C	0.0	0.0	2152.0	20.9	177.1
	5	.0	2152.0 C	3241.7	3405.9	8799.5	63.3	120.4
		1.00	2152.0 C	0.0	0.0	2152.0	63.3	120.4
	6	.0	2149.8 C	4776.2	1537.5	8463.5	28.6	177.4
		1.00	2149.8 C	0.0	0.0	2149.8	28.6	177.4
	7	.0	2149.8 C	3249.1	6068.1	11467.0	112.7	120.7
		1.00	2149.8 C	0.0	0.0	2149.8	112.7	120.7
	8	.0	0.0 C	4826.4	4530.5	9356.9	84.1	179.3
		1.00	0.0 C	0.0	0.0	0.0	84.1	179.3
14	1	.0	2172.7 C	8.5	0.4	2181.5	0.0	0.3
		1.00	2172.7 C	0.0	0.0	2172.7	0.0	0.3
	2	.0	2169.5 C	4956.5	7938.7	15064.8	147.4	184.1
		1.00	2169.5 C	0.0	0.0	2169.5	147.4	184.1
	3	.0	2169.5 C	3429.5	3408.3	9007.3	63.3	127.4
		1.00	2169.5 C	0.0	0.0	2169.5	63.3	127.4
	4	.0	2169.5 C	5047.0	7936.3	15152.9	147.4	187.5
		1.00	2169.5 C	0.0	0.0	2169.5	147.4	187.5
	5	.0	2169.5 C	3520.0	3405.9	9095.4	63.3	130.7
		1.00	2169.5 C	0.0	0.0	2169.5	63.3	130.7
	6	.0	2171.7 C	4860.0	10598.6	17630.3	196.8	180.5
		1.00	2171.7 C	0.0	0.0	2171.7	196.8	180.5
	7	.0	2171.7 C	3332.9	6068.1	11572.8	112.7	123.8
		1.00	2171.7 C	0.0	0.0	2171.7	112.7	123.8
	8	.0	0.0 T	4826.4	4530.6	9357.0	84.1	179.3
		1.00	0.0 T	0.0	0.0	0.0	84.1	179.3
15	1	.0	0.4 C	0.0	0.2	0.6	0.1	0.0
		1.00	0.4 C	0.0	10.1	10.6	0.1	0.0
	2	.0	135.3 T	38.8	340.9	514.9	6.9	1.7
		1.00	135.3 T	156.6	151.5	443.4	6.9	1.7
	3	.0	2654.9 C	296.0	6671.8	9622.7	138.4	12.6
		1.00	2654.9 C	1195.5	3171.0	7021.4	138.4	12.6

MEMBER STRESSES

'LL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL		BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	4	.0	60.7	T	38.7	153.6	253.1	3.0	1.7
		1.00	60.7	T	156.4	62.8	280.0	3.0	1.7
	5	.0	2729.4	C	296.1	6859.1	9884.6	142.3	12.6
		1.00	2729.4	C	1195.7	3259.7	7184.9	142.3	12.6
	6	.0	55.0	T	127.0	139.2	321.3	2.7	5.4
		1.00	55.0	T	513.0	56.0	624.0	2.7	5.4
	7	.0	2735.1	C	461.8	6873.4	10070.4	142.6	19.7
		1.00	2735.1	C	1865.2	3266.5	7866.8	142.6	19.7
	8	.0	19.6	T	334.8	49.4	403.8	1.0	14.3
		1.00	19.6	T	1352.1	23.4	1395.1	1.0	14.3
16	1	.0	0.5	C	0.0	0.2	0.7	0.1	0.0
		1.00	0.5	C	0.0	10.4	10.9	0.1	0.0
	2	.0	96.9	C	630.8	242.5	970.2	5.2	27.0
		1.00	96.9	C	2547.6	125.3	2769.7	5.2	27.0
	3	.0	2887.0	C	296.0	7255.2	10438.2	150.5	12.6
		1.00	2887.0	C	1195.5	3447.7	7530.3	150.5	12.6
	4	.0	172.6	C	630.8	432.8	1236.2	9.1	27.0
		1.00	172.6	C	2547.8	215.4	2935.8	9.1	27.0
	5	.0	2962.7	C	296.1	7445.5	10704.3	154.4	12.6
		1.00	2962.7	C	1195.7	3537.9	7696.3	154.4	12.6
	6	.0	16.6	C	796.6	40.9	854.1	1.0	34.0
		1.00	16.6	C	3217.2	29.7	3263.6	1.0	34.0
	7	.0	2806.8	C	461.8	7053.5	10322.2	146.3	19.7
		1.00	2806.8	C	1865.2	3352.2	8024.1	146.3	19.7
	8	.0	19.6	T	334.8	49.4	403.8	1.0	14.3
		1.00	19.6	T	1352.1	23.4	1395.1	1.0	14.3
17	1	.0	0.0	T	0.0	235.2	235.2	32.6	0.0
		1.00	0.0	T	0.0	0.0	0.0	32.6	0.0
	2	.0	150.8	T	0.0	235.2	386.1	32.6	0.0
		1.00	150.8	T	0.0	0.0	150.8	32.6	0.0
	3	.0	150.8	T	0.0	235.2	386.1	32.6	0.0
		1.00	150.8	T	0.0	0.0	150.8	32.6	0.0
	4	.0	150.8	T	13.4	235.2	386.5	32.6	1.9
		1.00	150.8	T	0.0	0.0	150.8	32.6	1.9
	5	.0	150.8	T	13.3	235.2	386.5	32.6	1.8
		1.00	150.8	T	0.0	0.0	150.8	32.6	1.8
	6	.0	151.9	T	0.0	235.2	387.2	32.6	0.0
		1.00	151.9	T	0.0	0.0	151.9	32.6	0.0
	7	.0	151.9	T	0.0	235.2	387.2	32.6	0.0
		1.00	151.9	T	0.0	0.0	151.9	32.6	0.0
	8	.0	0.0	C	0.0	0.0	0.0	0.0	0.0
		1.00	0.0	C	0.0	0.0	0.0	0.0	0.0

************** END OF LATEST ANALYSIS RESULT **************

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123. PARAMETER
124. CODE AISC
125. FYLD 45999.969 MEMB 9 TO 16
126. WSTR 21000. MEMB 9 TO 16
127. WMIN 0.188 MEMB 9 TO 16
128. CB 1. MEMB 9 TO 16
129. CMY 1. MEMB 9 TO 16
130. MAIN 0. MEMB 9 TO 16
131. RATIO 1. MEMB 9 TO 16
132. CHECK CODE MEMB 9 TO 16
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STAAD-III CODE CHECKING - (AISC)
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..LL UNITS ARE - POUN INCH (UNLESS OTHERWISE NOTED)

MEMBER     TABLE          RESULT/   CRITICAL COND/     RATIO/     LOADING/
                            FX            MY             MZ       LOCATION
=======================================================================

     9  ST   TUB 40408     PASS      AISC- H1-3          0.711         7
                     1733.39 C       6775.87       112278.68        0.00
    10  ST   TUB 40408     PASS      AISC- H2-1          0.469         7
                     8444.14 T      41177.49       -30243.98        0.00
    11  ST   TUB 40408     PASS      AISC- H1-3          0.752         5
                     1794.96 C       4343.61       121623.43        0.00
    12  ST   TUB 40408     PASS      AISC- H2-1          0.500         5
                     9229.55 T        -44.49       -75833.83       61.00
    13  ST   TUB 40203     PASS      AISC- H1-3          0.466         7
                     4342.57 C       4223.81       -11832.89        0.00
    14  ST   TUB 40203     PASS      AISC- H1-3          0.689         6
                     4386.84 C       6318.01       -20667.28        0.00
    15  ST   TUB 40408     PASS      AISC- H1-3          0.415         7
                    17395.39 C       2840.21       -42271.46        0.00
    16  ST   TUB 40408     PASS      AISC- H1-1          0.435         5
                    18843.05 C       1820.79       -45789.59        0.00
 133. SELECT WELD MEMB 9 TO 16
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STAAD-III WELD DESIGN
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ALL UNITS ARE - INCH POUN

MEMBER	LOCATION/ LOADING	WELD TYPE/ HOR STRESS	WELD SIZE/ VERT STRESS	COMB STRESS/ DIR STRESS
9	STA 7	1 150.58	5/16 2495.08	18375.66 18204.86
9	END 7	1 250.96	3/16 4158.47	4205.91 577.80
10	STA 7	1 360.32	3/16 683.50	20684.52 20670.08
10	END 7	1 360.32	3/16 683.50	20348.55 20333.88
11	STA 5	1 96.52	5/16 2702.74	19443.06 19254.05
11	END 5	1 160.87	3/16 4504.57	4546.98 598.32
12	STA 7	1 360.32	3/16 697.86	20953.01 20938.28
12	END 5	1 173.24	4/16 510.28	16543.35 16534.57
13	STA 7	1 26.82	3/16 75.13	9077.15 9076.80
13	END 5	1 26.76	3/16 42.17	1932.65 1932.00
14	STA 6	1 40.11	3/16 131.22	13827.59 13826.91
14	END 6	1 40.11	3/16 131.22	1954.53 1949.71
15	STA 7	1 797.70	3/16 961.49	17122.02 17076.38
15	END 7	1 797.70	3/16 961.49	13745.29 13688.40
16	STA 5	1 511.39	3/16 700.43	18204.29 18183.61
16	END 7	1 797.70	3/16 966.48	14028.17 13972.08

STAAD-III WELD DESIGN
****

ALL UNITS ARE - INCH POUN

MEMBER	LOCATION/ LOADING	WELD TYPE/ HOR STRESS	WELD SIZE/ VERT STRESS	COMB STRESS/ DIR STRESS

****************** END OF TABULATED WELD DESIGN ******************

134. FINISH

*************** END OF STAAD-III ***************

**** DATE= APR 16,1996 TIME= 11:48:27 ****

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*********************************************************
*        For questions on  STAAD-III,   contact:        *
*              Research Engineers, Inc at               *
*       Ph: (714) 974-2500   Fax:  (714) 921-2543       *
*********************************************************
```
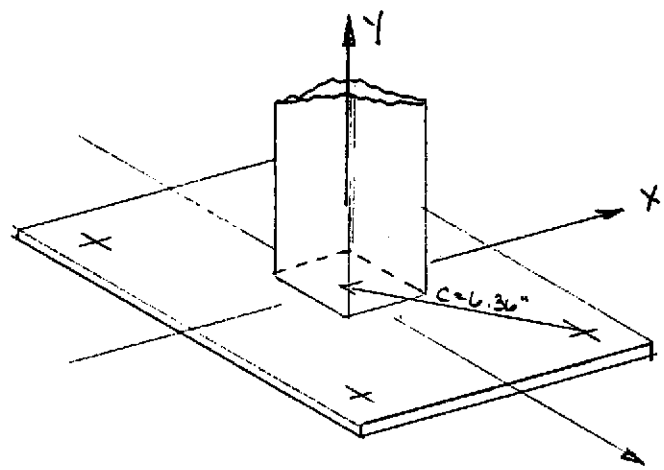

DESIGN ANCHORAGE   TRY PL 12" x 12"

1" φ HILTI HVA @ 8 1/4" EMBEDMENT

$$\left.\begin{array}{l} T_{ALL} = 10960.\text{ lbs} \\ V_{ALL} = 7630.\text{ lbs} \end{array}\right\} f'_c = 3000 \text{ PSI}$$



SUPPORT REACTIONS

CONSERVATIVELY TRY ENVELOPING ALL LOAD CASES FOR ANCHORAGE DESIGN

$F_X = 15359.$ lbs $M_X = 71028$ in-lbs

$F_Y = 9230$ lbs (TENSION) $M_Y = 10483$ in-lbs

$F_Z = 1162.$ lbs. $M_Z = 32756.$ in-lbs.

SHEAR

$$V = \frac{15359 \text{ lbs} + 1162 \text{ lbs}}{4 \text{ BOLTS}} + \frac{10483 \text{ in-lbs}}{(4 \text{ BOLTS})(6.36 \text{ in})}$$

$$= 4542.\text{ lbs/BOLT}$$

TENSION

$$T = \frac{9230 \text{ lbs}}{4 \text{ BOLTS}} + \frac{(71028 + 32756)}{(2 \text{ BOLTS})(6.5 \text{ in})}$$

PRYING FACTOR

$$T = (10291.\text{ lbs})(1.2) = 12349 \text{ lbs/BOLT}$$

$$\text{BOLT INTERACTION} = \frac{T}{T_{ALL}} + \frac{V}{V_{ALL}} = \frac{12349}{10960} + \frac{4542}{7630} = 1.72 > 1.0$$

∴ N.G.

LOOK AT INDIVIDUAL WORST LOAD CASE

JOINT 11 LOADCASE No. 7

$F_X = 1687$ lbs $\quad M_X = 41177.$ in-lbs

$F_Y = 8654$ lbs. (TENSION) $\quad M_Y = 1085.$ in-lbs

$F_Z = 674.$ lbs. $\quad M_Z = 31037.$ in-lbs

SHEAR

$$V = \frac{1687 \text{ lbs} + 674 \text{ lbs}}{4 \text{ BOLTS}} + \frac{1085 \text{ in-lbs}}{(4 \text{ BOLTS})(6.36 \text{ in})}$$

$$= 633 \text{ lbs / BOLT}$$

TENSION

$$T = \frac{8654 \text{ lbs}}{4 \text{ BOLTS}} + \frac{41177 \text{ in-lbs} + 31037 \text{ in-lbs}}{(2 \text{ BOLTS})(6.5 \text{ in})}$$

$$= 7718. \text{ lbs } (1.2) = 9262 \text{ lbs/BOLT}$$

(1.2 = PRYING FACTOR)

BOLT INTERACTION

$$\frac{V}{V_{ALL}} + \frac{T}{T_{ALL}} = \frac{633}{7630} + \frac{9262}{10960} = .93 < 1.0$$

∴ O.K.

1" ϕ HILTI HVA @ 8¼" EMB'T

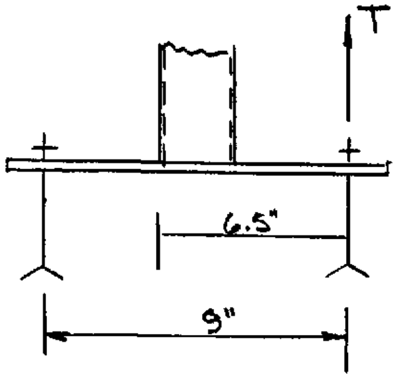
&

PL 12" x 12"

O.K.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

DETERMINE PLATE REQUIRED THICKNESS



$T = 9262$ lbs / BOLT

$F_y = 36000\ \#/in^2$

$F_b = .75\ F_y = 27000\ \#/in^2$

$$f_b = \frac{M}{S} \Rightarrow S_{REQ'D} = \frac{M}{f_b}$$

$$S_{req'd} = \frac{9262\ lbs\ (6.5\ in)}{27000\ \#/in^2} = 2.23\ in^3$$

$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{6\ (S)}{b}}$$

$$d\ req'd = \sqrt{\frac{6\ (2.23\ in^3)}{9\ in}}$$

THKS = 1.22 in

USE PL 1¼" THK

DESIGN THRU-BOLT CONNECTIONS.

MEMBER 9 JOINT 6

MEMBER 11 JOINT 9

MEMBER 13 JOINT 12

MEMBER 14 JOINT 14

5/8" ϕ A307

T_{ALL} = 6100 lbs

V_{ALL} = 3100 lbs

ENVELOPE LOADS

AXIAL = 4389. lbs, SHEAR-Y = 13514. lbs, SHEAR-Z = 1298. lbs

$$T = \text{SHEAR-Y} = \frac{13514 \text{ lbs}}{3 \text{ BOLTS}} = 4505. \text{ lbs/BOLT}$$

$$V = \text{AXIAL} + \text{SHEAR-Z} = \frac{4389 \text{ lbs} + 1298 \text{ lbs}}{3 \text{ BOLTS}} = 1896 \text{ lbs/BOLT}$$

BOLT INTERACTION

$$\frac{T}{T_{ALL}} + \frac{V}{V_{ALL}} = \frac{4505}{6100} + \frac{1896}{3100} = 1.35 > 1.0 \therefore \text{N.G.}$$

LOOK AT WORST INDIVIDUAL CASE
JOINT 11 L.C.# 5

AXIAL = 1795. lbs SHEAR-Y = 13514. lbs SHEAR-Z = 483. lbs

$$T = \frac{13514 \text{ lbs}}{3 \text{ BOLTS}} = 4505 \text{ lbs/BOLT}$$

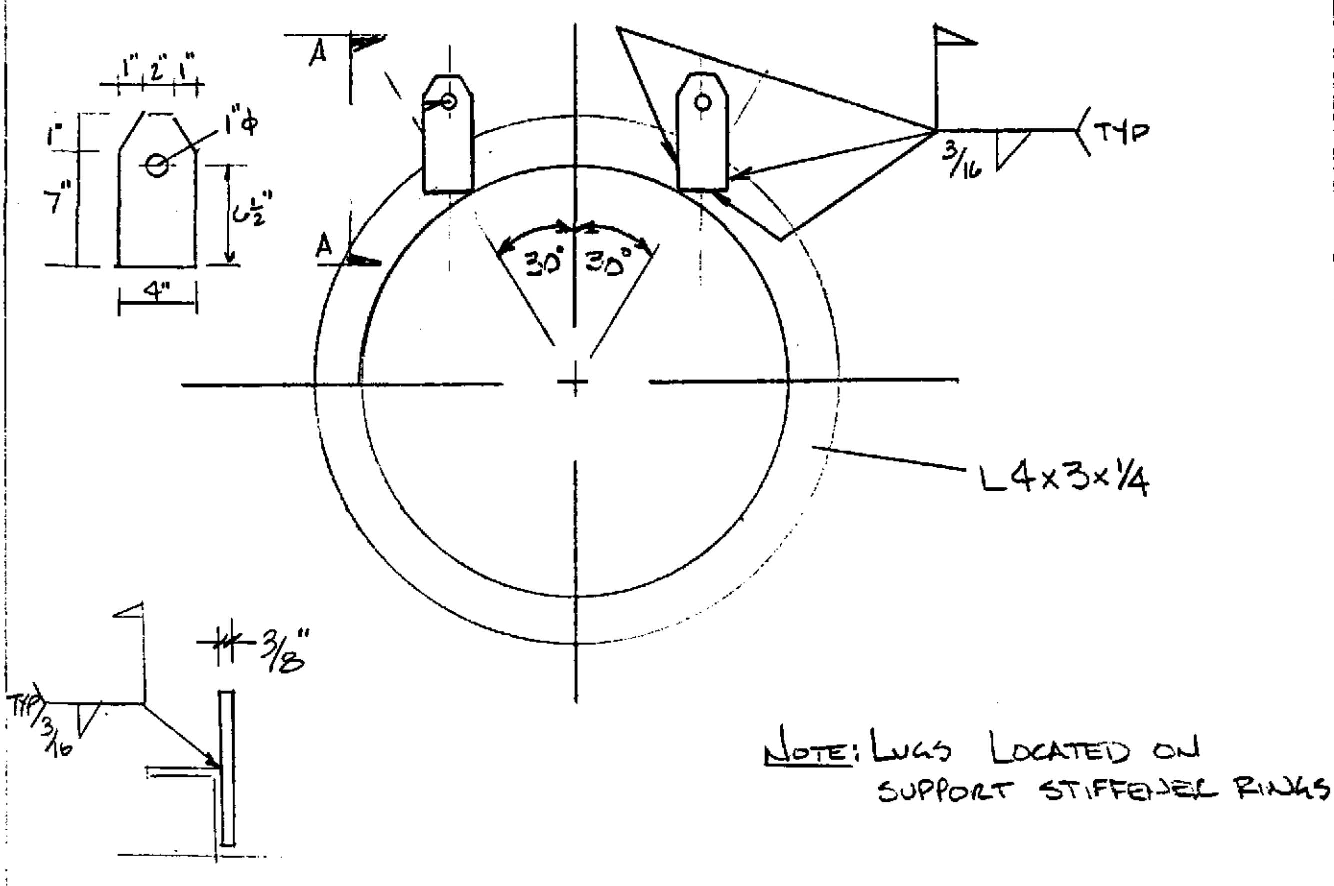
$$V = \frac{1795. \text{ lbs} + 483 \text{ lbs}}{3 \text{ BOLTS}} = 759. \text{ lbs/BOLT}$$

BOLT INTERACTION

$$\frac{T}{T_{ALL}} + \frac{V}{V_{ALL}} = \frac{4505}{6100} + \frac{759}{3100} = .98 < 1.0 \therefore \text{OK.}$$ USE 5/8" ϕ BOLTS A-307

80K LONG CRYOPUMP

LIFTING LUGS



SECTION A-A

TENSION / LUG = 5700 lbs + 6784 lbs

= 12484 lbs / 4 LUGS = 3121 lbs/LUG

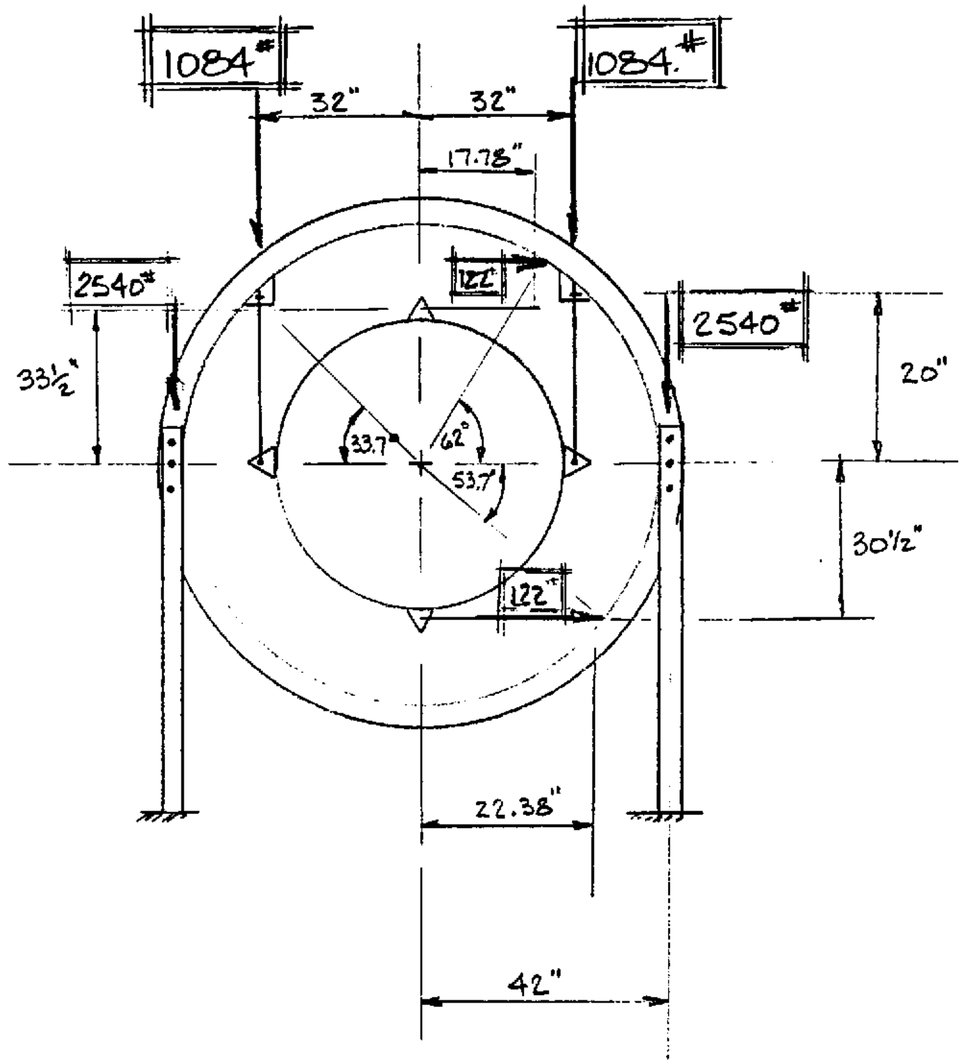
FORCE ALLOWABLE FOR 3/16" WELD PER INCH OF WELD

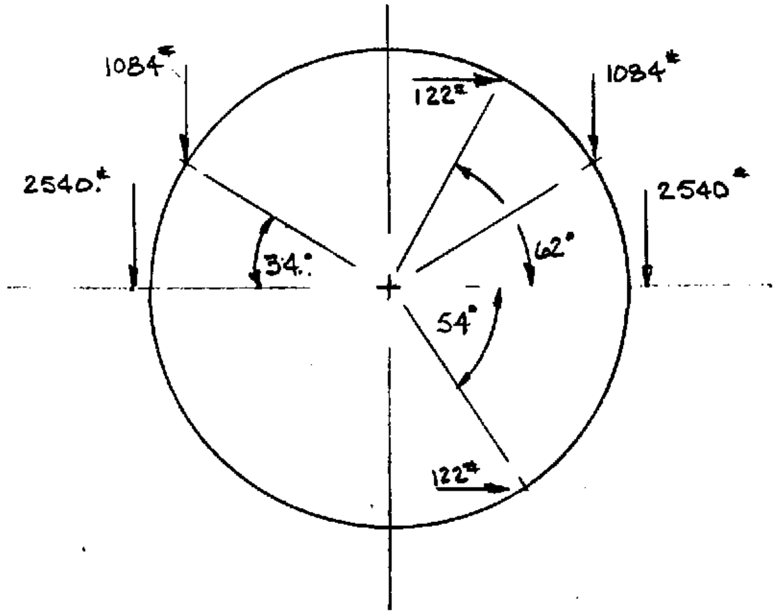
$$F_{W_{ALL}} = \frac{(3/16 \text{ in})(.707)(21000 \text{ lbs/in})}{1 \text{ in WELD}} = 2784 \text{ lbs/in}$$

∴ WELD AS SHOWN, PROVIDES A MINIMUM OF 10 in OF WELD ∴ F_{WALL} = 27840 lbs

WELD IS ACCEPTABLE

CALCULATE STRESSES IN THE OUTER SHELL DUE TO INTERNAL AND EXTERNAL LOADS.



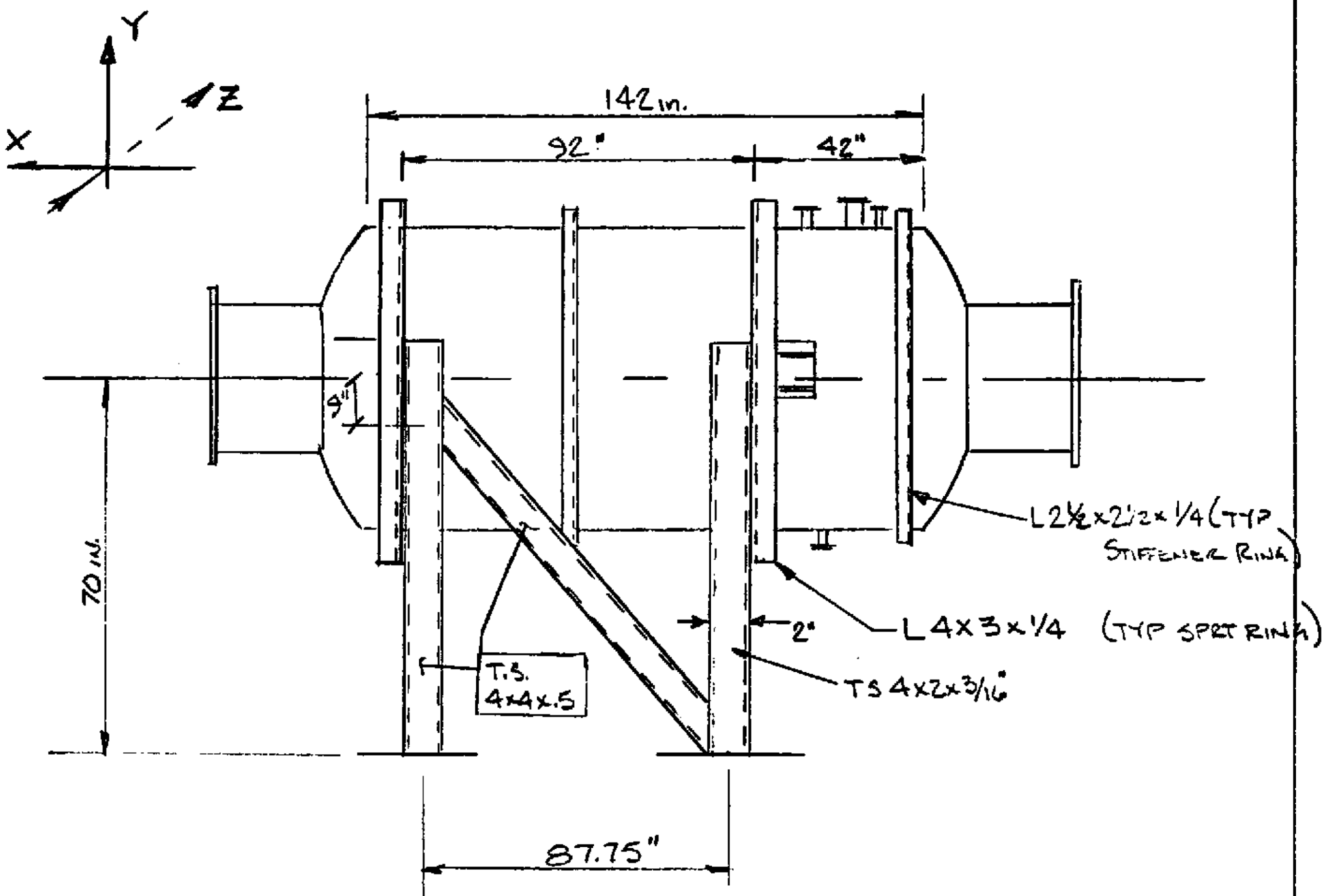


```
     Radius Of Ring Centroid, Inches,                    =  41.511
     I, for Ring plus Eff. Shell,                        =  8.884 In.^4
     A, for Ring plus Eff. Shell,                        =  2.980 In.^2
     CF1. Extreme Inner Fiber (ring) from Centroid,      =   1.761 In.
     C2, Extreme Outer Fiber (shell) from Centroid,      =   2.489 In.
     Weight of Ring only.                                =    113 Lbs.
Weight of full or empty inner vessel at one ring            2168 pounds
Strap ctrline from tank vertical ctrline                    17.78 inches
Strap angle (from bottom)                                   154.6471  degrees
Weight of jacket at 1 ring, may incl. saddle                3025 pounds
Angle from dead bottom ctrline to saddle or lifting lug   90  degrees
Horizontal Force at 1 ring                                  200  pounds
Offset of Horiz. force above centerline                     33.5  inches
Side force angle above centerline at 1 ring                 53.7819 degrees
Seismic vertical factor used on ring weight                 0
External Pressure or Vacuum                                 14.7  Psi
```

Maximum Stresses

```
Inner Fiber Max. Tension      -           0 psi at   0.00 degrees.
Inner Fiber Max. Compression  -      -3,906 psi at 110.00 degrees.
O  er Fiber Max. Tension      -         410 psi at 112.00 degrees.
   er Fiber Max. Compression  -      -1,991 psi at 154.00 degrees.
```

80K - LONG CRYOPUMP - PRELIMINARY DESIGN



WEIGHT OF 80K LONG CRYOPUMP

INTERNALS = 4336 lbs (FULL w/ LIQ. N_2)

SHELL = 5278 lbs (INCLUDES NOZZLES, RINGS, etc)

9614 lbs. = DEADWEIGHT

VALVE CLOSING VACUUM LOAD

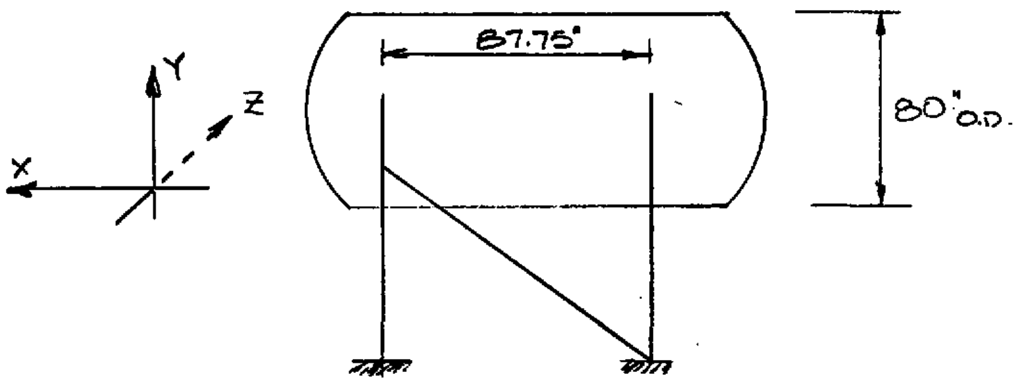
AXIAL FORCE ON VESSEL = 25400. lbs

ref. Calc No. V049-1-032

Seismic Acceleration = 0.05625 G.

MAX THERMAL DISPLACEMENT OF 80K-LONG CRYOPUMP

TEMPERATURE = 400°F
MATERIAL = SA 240-304L HIGH



TEMPERATURE RISE FROM 70°F to 400°F

THERMAL GROWTH @ 87.75" FROM RIGID VERTICAL LEG.

$$\delta = \alpha L \Delta T$$

WHERE α = 9.19 (10^{-6}) IN/IN°F FOR 240-304L
L = 87.75 IN
ΔT = 330°

$$\delta_x = 9.19 (10^{-6}) \frac{IN}{IN °F} (87.75_{IN}) (330°F)$$

$$\delta_x = {}^{-}0.266 \text{ IN}$$

Weight Summary

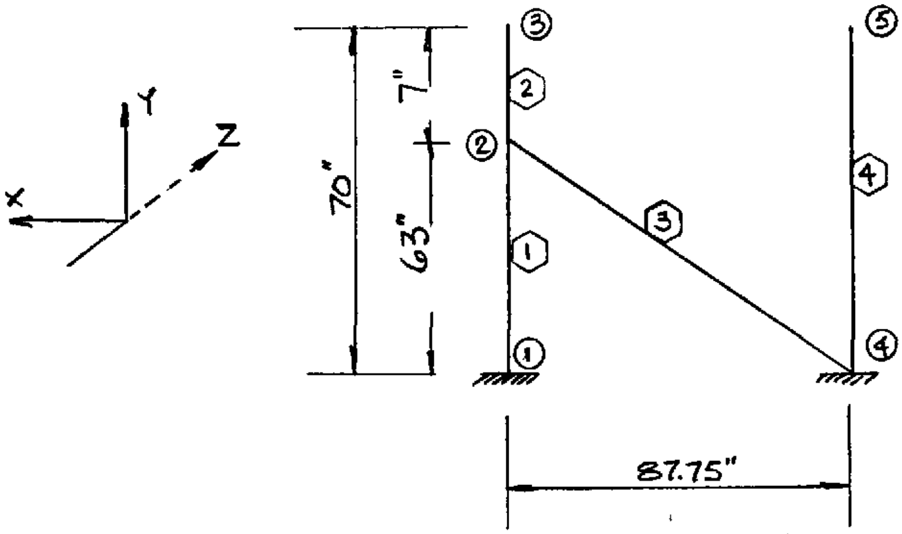
Component	Weight (lbs) Contributed by Vessel Elements										
	Metal New	Metal Corr	Trays	Packed Beds	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
80k lft f&d hd	667	667	0	0	0	0	0	0	0	0	1432	136
80klJacket	2579	2579	0	0	0	0	0	0	427	0	25450	6
80k rt f&d hd	667	667	0	0	0	0	0	0	0	0	1432	136
Lft bm tube flg	329	329	0	0	0	0	0	0	0	0	0	0
Rt bm tube flg	329	329	0	0	0	0	0	0	0	0	0	0
	4571	4571	0	0	0	0	0	0	427	0	28314	278

Vessel operating weight, corroded: 5,276 lbs
Vessel empty weight, corroded: 5,276 lbs
Vessel empty weight, new: 5,276 lbs
Vessel test weight, new: 33,590 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 5,278 lbs
Center of gravity to seam: 70.9 in

STAAD MODEL



LOAD 1 FULL VACUUM + SEISMIC

SELFWEIGHT Y -1.0

JOINT LOAD

3	FX	-13000.	$F_X \doteq .5\left[(25400 \text{ lbs}) + 0.05625(9614 \text{ lbs})\right]$
3	FY	-2540.	$F_Y = (9614 \text{ lbs})(1.05625)/4$
5	FY	-2540	

LOAD 2 LATERAL (SEISMIC) + VERTICAL

3	FZ	135. lbs	$F_Z = 0.05625(9614 \text{ lbs})/4$
5	FZ	135. lbs	$= 135. \text{ lbs}$
3	FY	-2540	
5	FY	-2540	

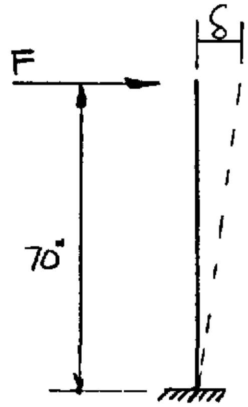
LOAD 3 FULL VACUUM + SEISMIC

3 FX 13000.

3 FY -2540.

5 FY -2540.

CHECK STRESSES FROM BENDING (due to thermal displacment)



T.S. 4x4x.5

$S_y = 5.70\ in^3$ $I_y = 11.4\ in^4$

REF. GERE / WEAVER TABLE B-4

$$M = \frac{6EI\delta}{L^2}$$

$$= \frac{6(29E6)(11.4\ in^4)(0.266\ in)}{(70\ in)^2}$$

$M = 107681.1$ in-lbs

$$f_{by} = \frac{107681.1\ \text{in-lbs}}{5.70\ in^3} = 18891.4\ lb/in^2$$

FOR WEAK AXIS BENDING ALLOWABLE STRESS:

$F_{by} = .66\ F_y$

$F_y = 46$ KSI A500 GR B TUBE STEEL

$F_{by} = .66\ (46\ ksi)$

$= 30.4\ ksi = 30400\ lb/in^2$

$$\frac{f_{by}}{F_{by}} = \frac{18891.4\ lb/in^2}{30400.\ lb/in^2} = .62 < 1.0$$

TO FACILITATE THERMAL FLEXIBILITY CHANGE VERTICAL T.S. 4x4x1/2 TO T.S. 4x2x3/16.

T.S. 4x2x3/16 $I_y = 1.29$ $S_y = 1.29$

∴ STRESSES ARE REDUCE CONSIDERABLY

$M_y = 6(29E6)(1.29\ in^4)(0.266\ in)/(70\ in)^2 = 12185$ in-lbs

$f_{by} = 12185\ \text{in-lbs}/1.29\ in^3 = 9446\ \#/in^2$

CHECK AXIAL LOADING ON TS 4x2x3/16

$$f_a = \frac{P}{A} = \frac{2540 \text{ lbs}}{2.02 \text{ in}^2} = 1257 \text{ \#/in}^2$$

AMPLIFICATION FACTOR

$$\frac{KL_b}{r_{by}} = \frac{1.0(70 \text{ in})}{.798 \text{ in}} = 87.72$$

$$F'e = 19.4 \text{ ksi}$$ TABLE 8 - pg. 5-122

$$\frac{f_a}{F'e} = \frac{1257}{19400} = 0.065$$

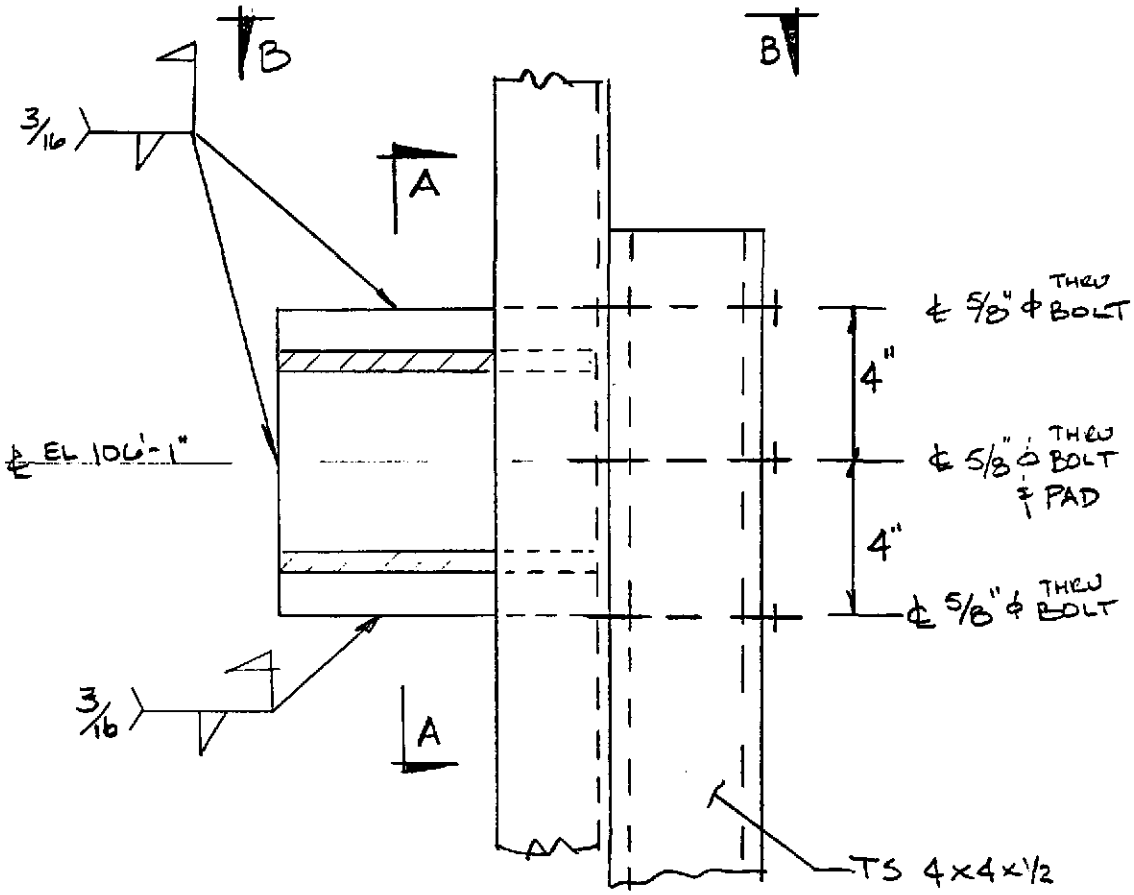
$$1 - \frac{f_a}{F'e_y} = .935 \quad \text{\& } C_{my} = 1.0$$

$$\frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F'e_x}\right) F_{bx}} + \frac{C_{my} f_{by}}{\left(1 - \frac{f_a}{F'e_y}\right) F_{by}} =$$

where: $F_A = 33$ KSI AISC CODE PG. 3-52 4x2x3/16" @ KL = 6 FT.

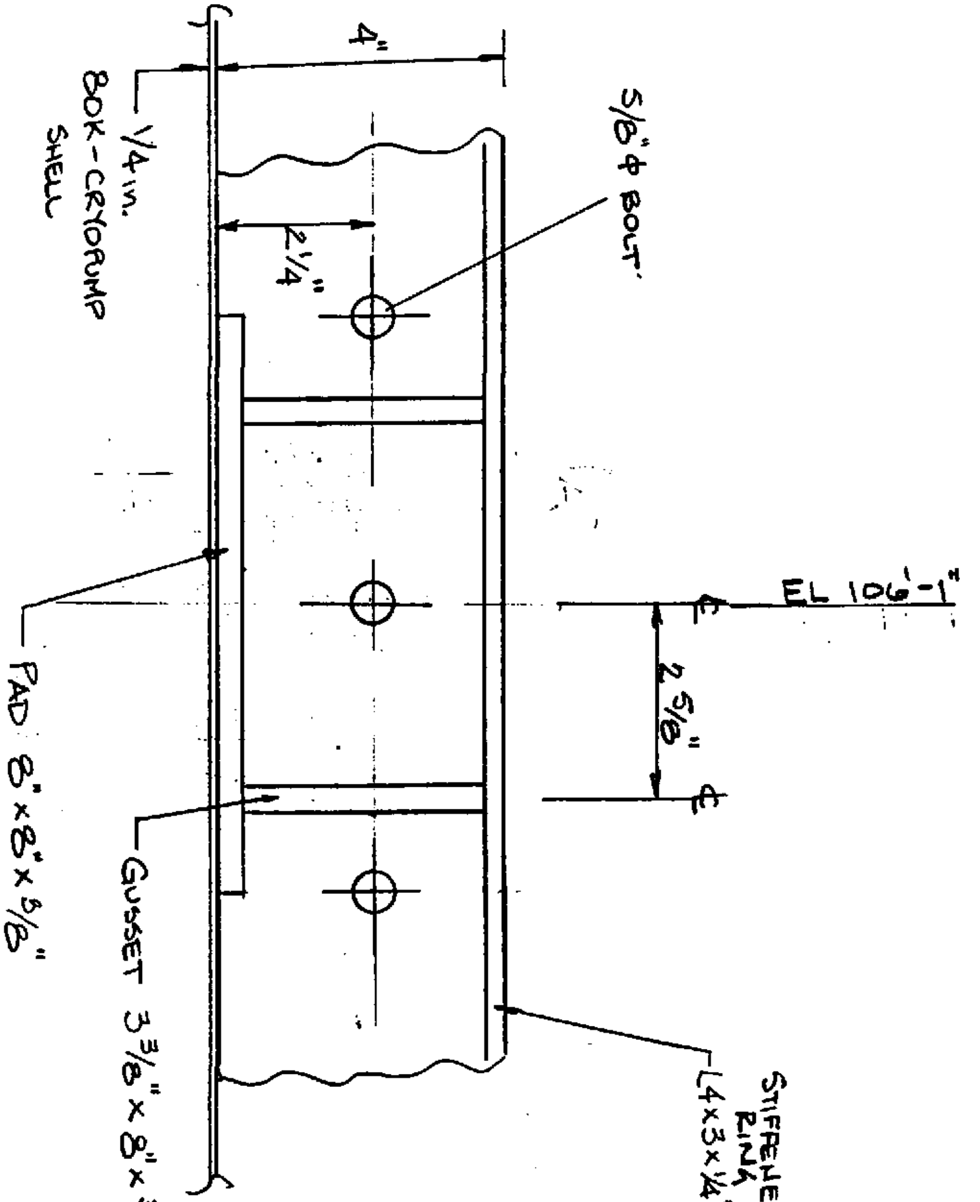
$$\frac{1257 \text{ lbs/in}^2}{33000 \text{ lbs/in}^2} + \phi^{*} + \frac{1.0(9446 \text{ lb/in}^2)}{.935(30400 \text{ lb/in}^2)} = .37 \quad 1.0 \text{ ✓}$$

* No SIDE load for Normal Operations.

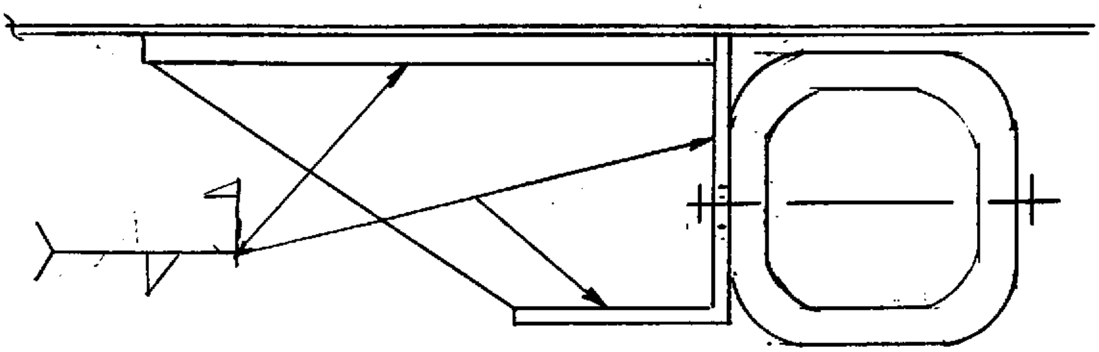


3/16
B
B
A
A
3/16
℄ EL 106'-1"
℄ 5/8" φ THRU BOLT
4"
℄ 5/8" φ THRU BOLT & PAD
4"
℄ 5/8" φ THRU BOLT
TS 4x4x1/2

ELEVATION

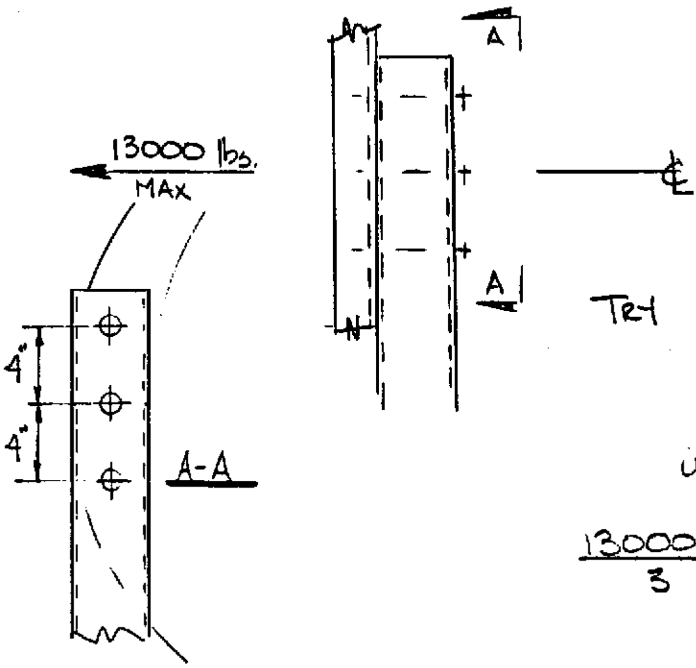

4"
1/4 in.
80K-CRYOPUMP SHELL
5/8" ϕ BOLT
2 1/4"
EL 106'-1"
2 5/8"
PAD 8" x 8" x 5/8"
GUSSET 3 3/8" x 8" x 3/8"
STIFFENER RING
L4 x 3 x 1/4"

SECTION A-A



SECTION B-B

DESIGN THRU BOLT AT FRAME TO SUPPORT RING



TRY 5/8" Φ A-307

T_{allow} = 6.1 KIPS

USE 3 BOLTS

$\frac{13000 \text{ lbs}}{3 \text{ BOLTS}} = 4333. \frac{\text{lbs}}{\text{BOLT}} < 6100 \text{ lbs}$

CHECK SHEAR FOR 5/8" Φ A-307

$F_{V_{ALLOW}}$ = 3.1 KIPS

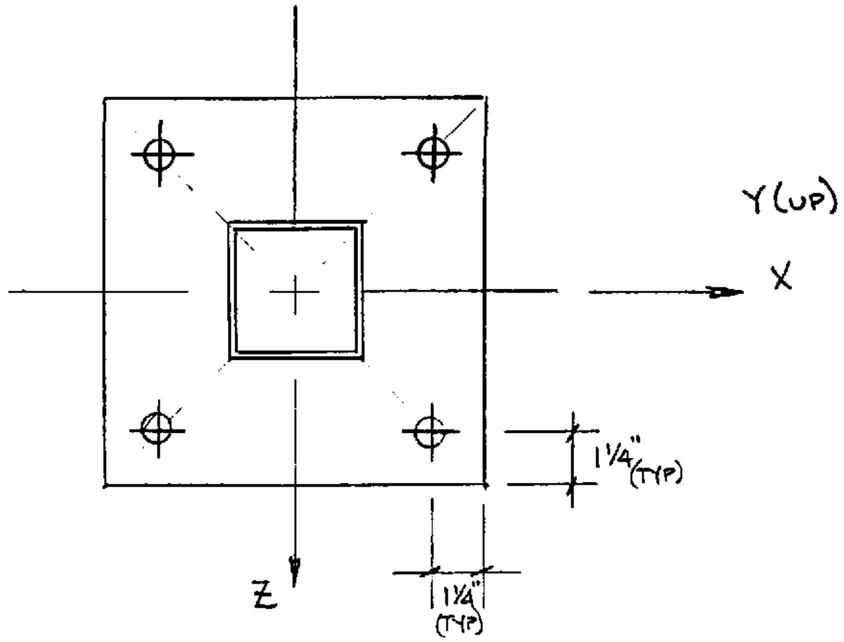
$f_{V_{ACTUAL}}$ = 2540 lbs / 3 BOLTS = 847 lbs / BOLT

$\frac{847 \text{ lbs}}{3100 \text{ lbs}} + \frac{4333. \text{lbs}}{6100. \text{lbs}} = .98 < 1.0 \therefore$ OK.

DESIGN ANCHOR BOLTS & BASEPLATE

TRY PLATE 12" x 12"
w/ 4 - 1"φ HVA HILTI ANCHORS @ 8¼" EMBT

$f'_c = 3000 psi$



REACTIONS @ BP (WORST CASE)

Fx = 13987. lbs.

FY = 13111. lbs (UP)

Fz = 135. lbs.

ANCHOR BOLTS

1"φ HVA HILTIS

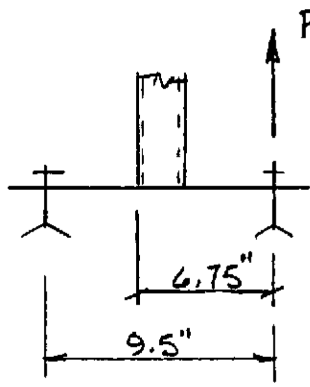
T_{ALL} = 10960 lbs
V_{ALL} = 7630 lbs

BOLT LOADS

V = 13987 lbs / 4 BOLTS = 3497. lbs
T = 13111. lbs / 4 BOLTS = 3278. lbs

$$\frac{3278.}{10960} + \frac{3497.}{7630.} = .76 < 1.0$$ ∴ 1"φ BOLTS O.K.

BASEPLATE - DETERMINE PLATE THICKNESS REQ'D



$P = (3278.\text{ lbs})(2 \text{ BOLTS})$

$= 6556.\text{ lbs.}$

$M = PL = 6556 \text{ lbs}(6.75")$

$M = 44253 \text{ in-lbs}$

$$f_b = \frac{M}{S} \Rightarrow S = \frac{M}{f_b} = \frac{44253.\text{ in-lbs}}{27000 \text{ lb/in}^2} = 1.64 \text{ in}^3$$

$$S = \frac{bd^2}{6} \Rightarrow \frac{1.64 \text{ in}^3 (6)}{b} = d^2$$

$$\sqrt{\frac{1.64 \text{ in}^3 (6)}{9.5 \text{ in}}} = d = 1.02 \text{ in}$$

USE PL 1 1/4 in THK.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-045 PAGE 1 OF 4
REV.	DEO #	DATE	BY:	CHECK	TITLE: ION PUMP	
0	0141	4.25.96	WDB	RJC		
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE:

Provide ion pump design loads for spools pieces:
B-2, B-3, B-5, B-4, & A-7.
Provide misc dimensional information

METHOD:

Hand calculations using 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. *Roark and Young's Formulas for Stress and Strain* fifth edition

CALCULATIONS:

(See Attached)

CONCLUSIONS:

NOTES:

Design Loads

- External Pressure −14.7 PSIA

- Dead Weight ;

Part	Weight	C.G.	W×C.G.
Valve	500#	$6 + \frac{10}{2}$	57,562.5
Pump	1500#	$16 + \frac{44.25}{2}$	55,000
2nd Pump	250#	$60.75 + \frac{20}{2}$	17,697.5
			80,750 in-lb

$\therefore P_T = \underline{2250\#}$

$$C.G. = \frac{80750}{2250} = 35.88''$$

- Seismic $g = .05625$ g's

$$V_c = V_L = (.05625)(2250) = \underline{126.5\#}$$

$$M_c = M_L = (.05625)(80750) = \underline{4542 \text{ in-lb}}$$

Rev. 0
Doc. No. V049-1-045

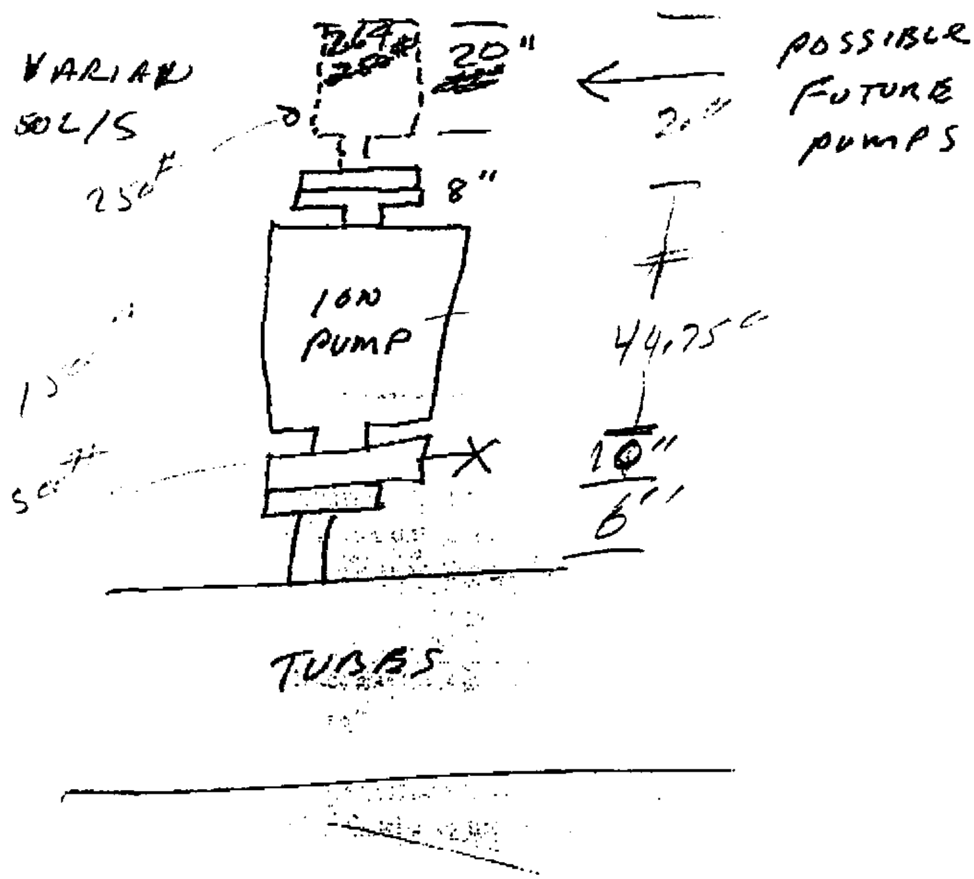
FAX

2/5/96

TO: KYLE MARTINI

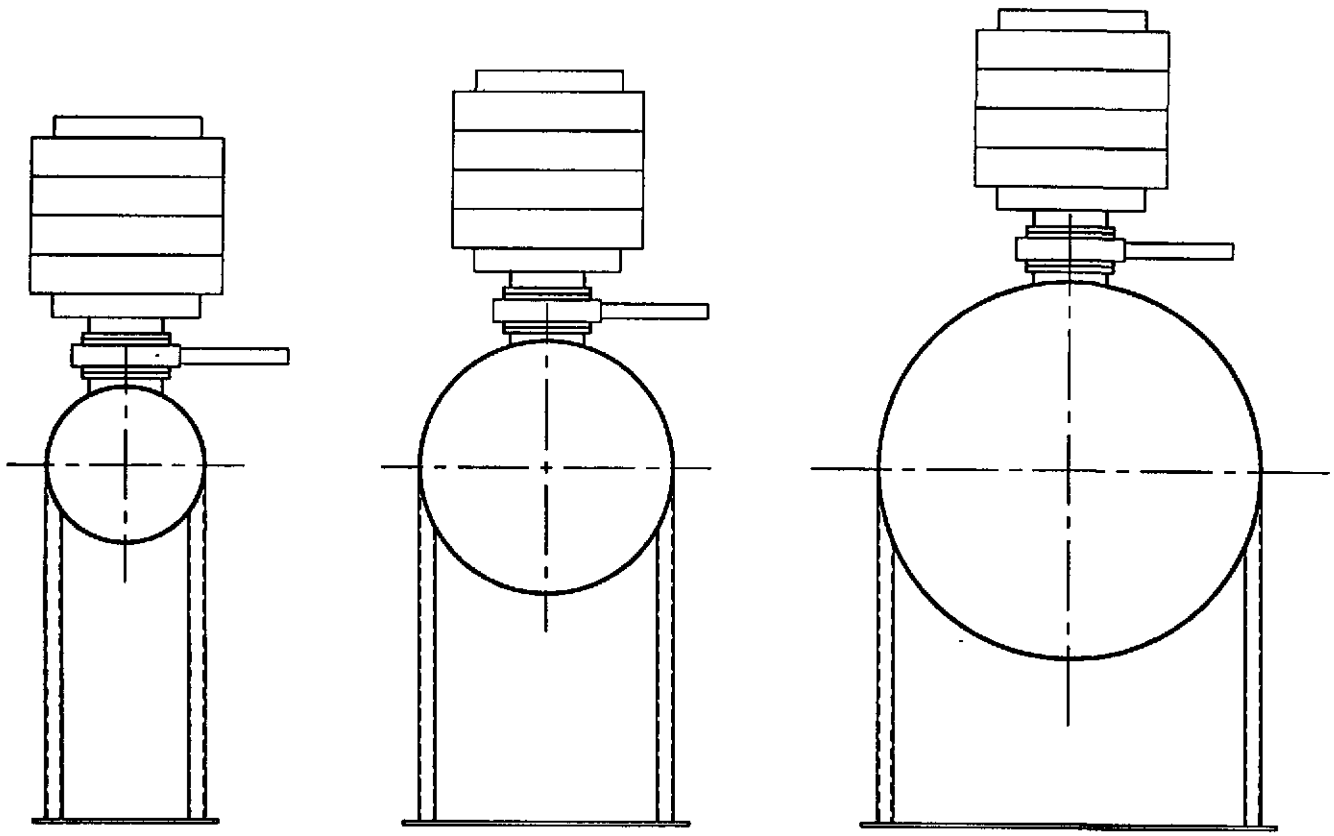
FROM: RAY CIATTO

HERE IS LATEST INFO RE: FUTURE ION PUMP



ION PUMP WEIGHT
FROM MANUFACTURER'S INFO.
(VARIAN)

Rev. O
Doc No V049-1-045
Pg 3 of 4



30 1/4" I.D. PIPE

B2, B3, B5

48 1/4" I.D. PIPE

B-4

72 1/4" I.D. PIPE

A-7

Rev. O
Dr. No. V049-1-045
Pg 4 of 4

B

A

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REV	DESCRIPTION	CHKD	DRWN	DATE	DEO#

ISSUE DESCRIPTION

4 3 2 1

Sept 27, 1995 - 135950

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	GARENA	ROC	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 – V049-1-006

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.

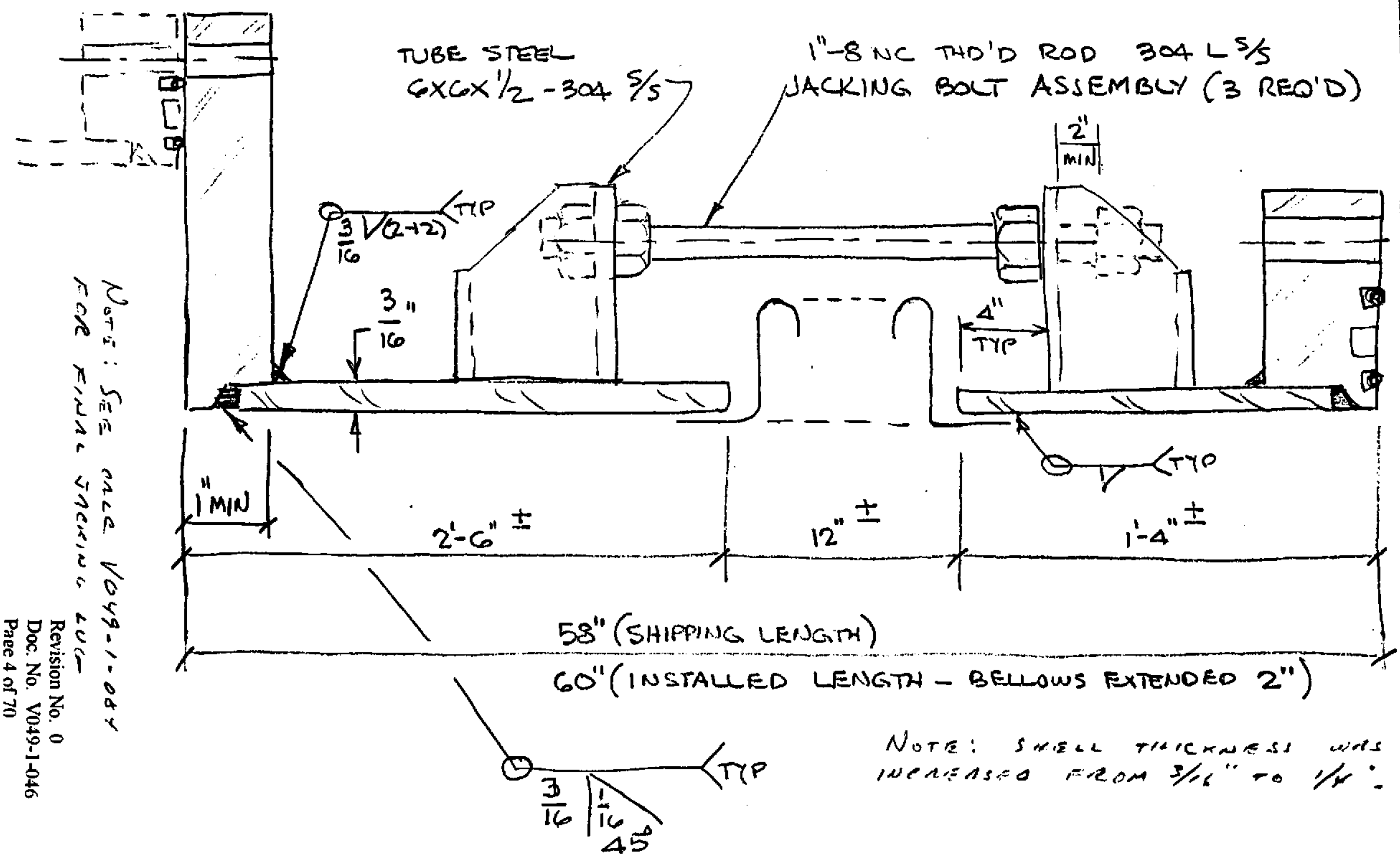
The maximum stress intensity in the flange is 845 psi at node 132.

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.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS

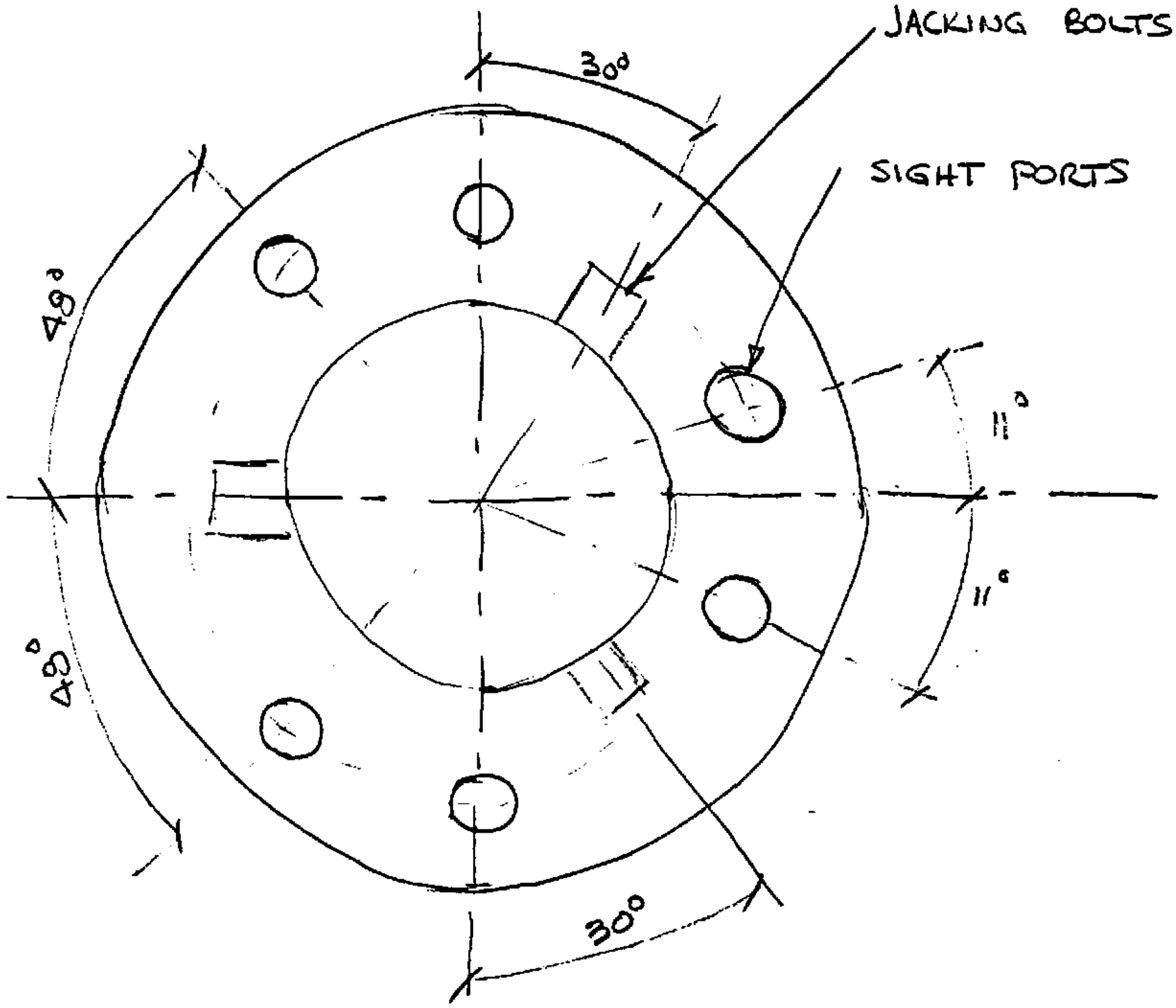
1. ASSEMBLY DETAIL



NOTE: SHELL THICKNESS WAS INCREASED FROM 3/16" TO 1/4".

NOTE: SEE CALC V049-1-084 FOR FINAL JACKING LUG

JACKING BOLT ORIENTATION



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. × 1/4 THK SHELL

SHELL LENGTH PARAMETER $\lambda = \left[\frac{3(1-\nu^2)}{R^2 t^2}\right]^{1/4}$ ROARK 5TH PG 453

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

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

$44\frac{5}{8}$ ID × 3/16 THK SHELL

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

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

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

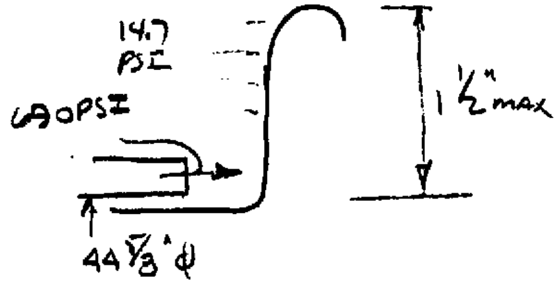
BELLOWS TO BE COLD PULLED 2" AT INSTALLATION

∴ 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

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

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PAGE 15 RUN ID= 05:05:10

=============== I M A G E S - 3 D =============
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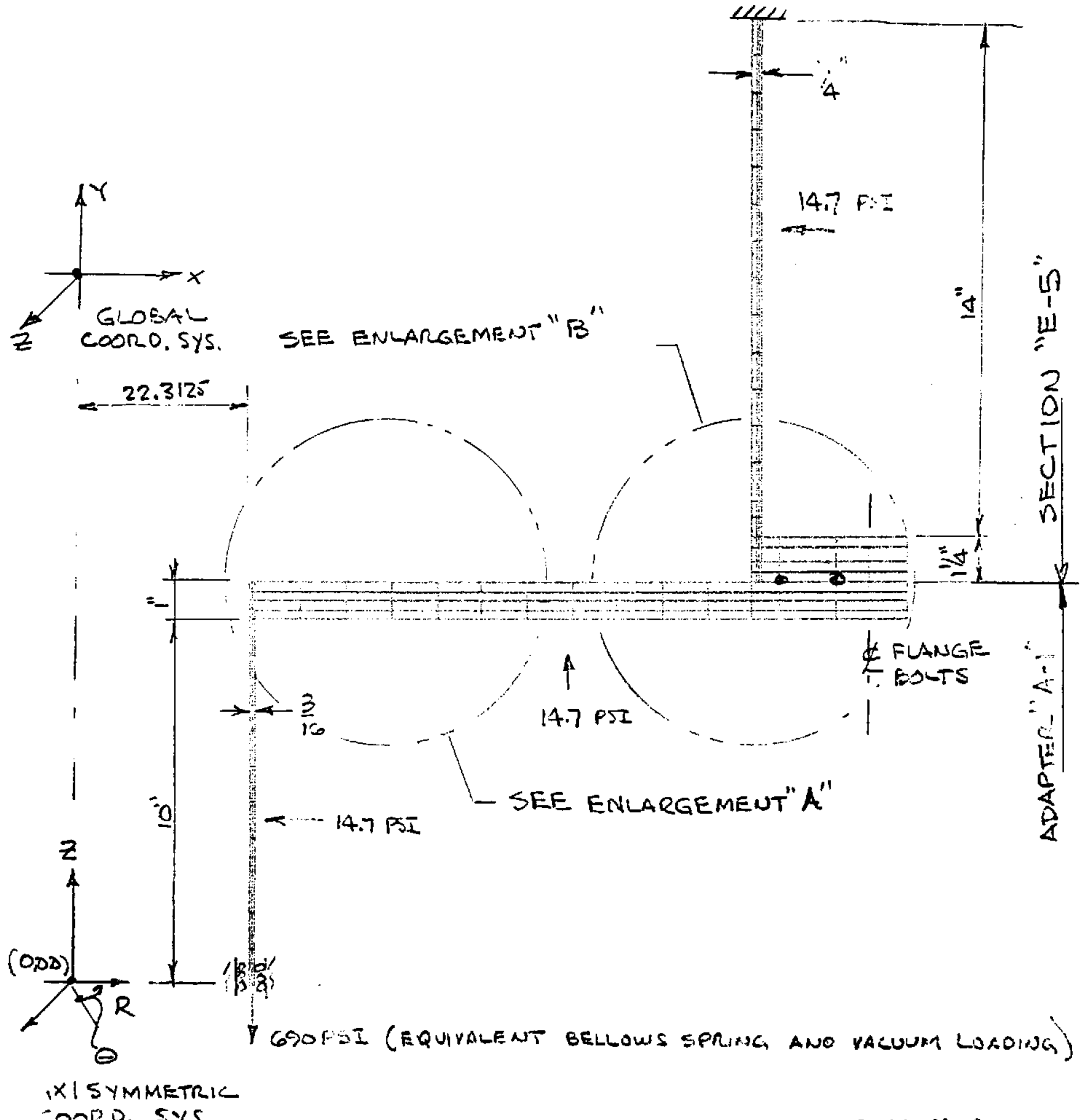
GEOMETRY PLOT Version 2.0

A1 REDUCING FLANGE W/SHELL FILE NAME: C:\IMAGES\LIGO\A1FLG.*



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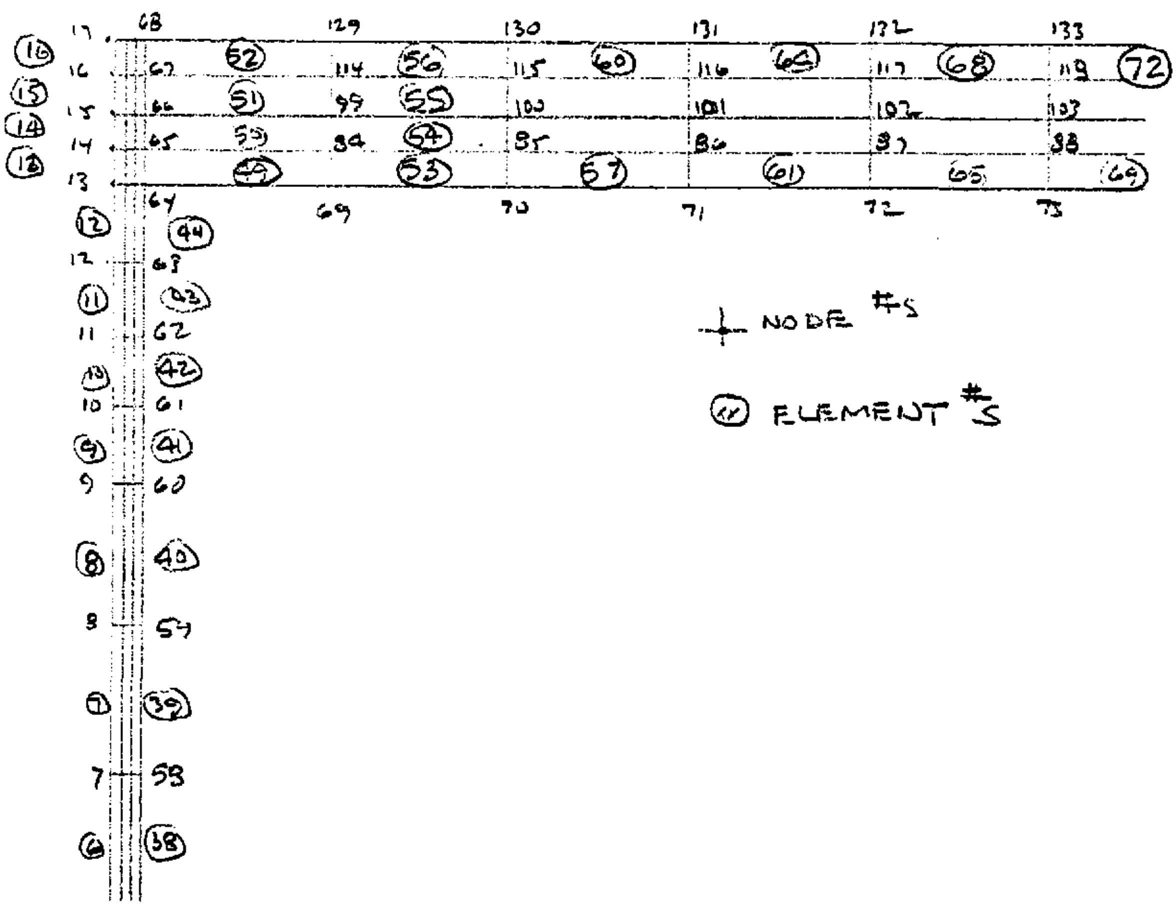
= IMAGES - 3D =

GEOMETRY PLOT Version 2.0

A1 REDUCING FLANGE W/SHELL



ENLARGEMENT "A"

GEOMETRY PLOT Version 2.0

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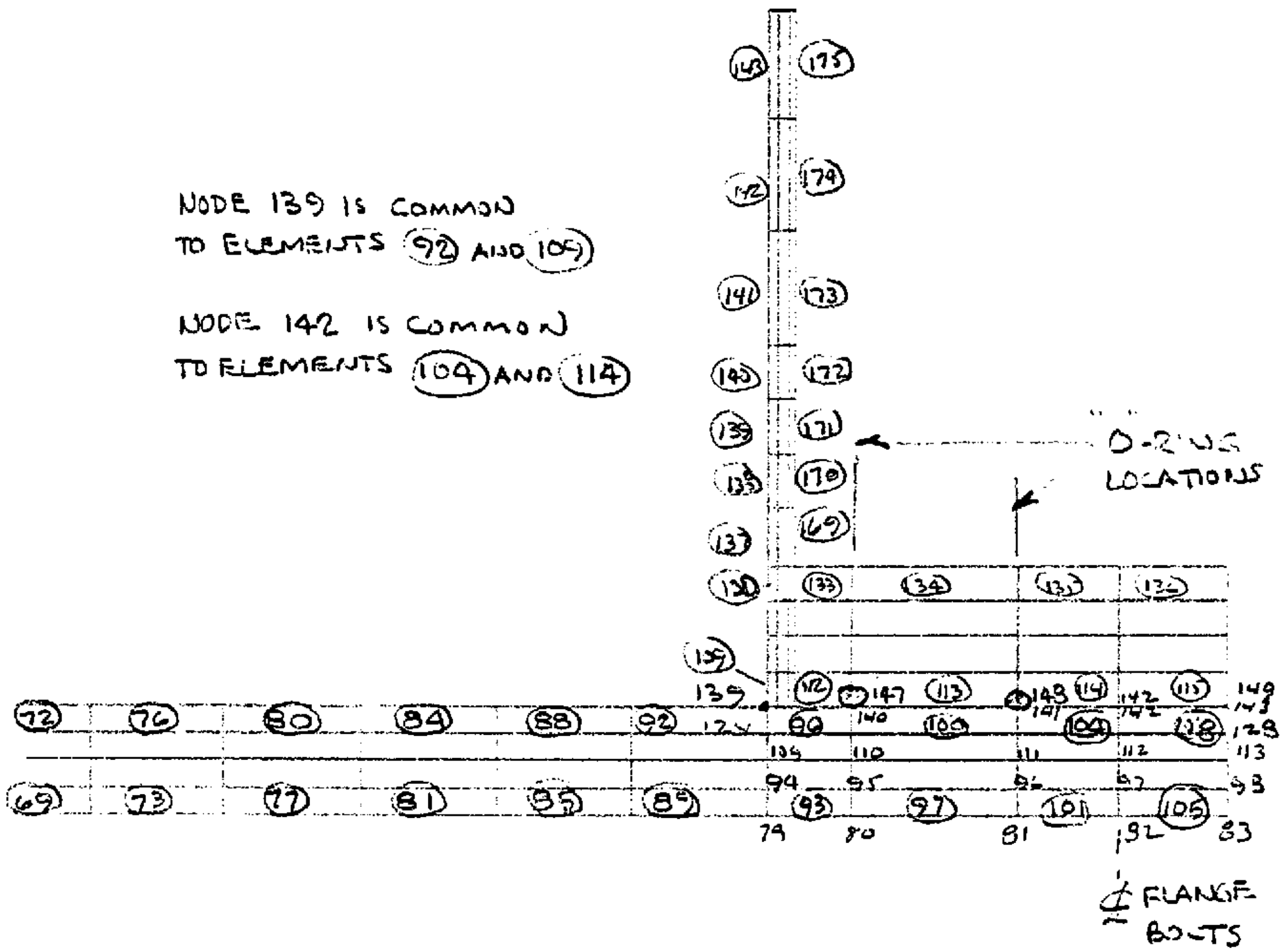

ENLARGEMENT "B"

+ NODE #s

(XX) ELEMENT #s

I M A G E S   3 D

Interactive Microcomputer Analysis & Graphics of Engineering Systems

IMAGES-3D Version 2.0 07/01/90

NOTICE

Celestial Software Inc. assumes no responsibility for the validity, accuracy, or applicability of the results obtained from IMAGES-3D.

Any questions or comments concerning the use of IMAGES-3D or the users manual should be addressed to:

Celestial Software Inc.
125 University Ave.
Berkeley,CA
94710

415-843-0977

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B1 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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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
64	2.25000E+01	1.00000E+01	0.00000E+00
65	2.25000E+01	1.02500E+01	0.00000E+00
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

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A1 REDUCING FLANGE W/SHELL

Node	X-Coord.	Y-Coord.	Z-Coord.
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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
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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

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A1 REDUCING FLANGE W/SHELL

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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

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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
186	3.58750E+01	1.52500E+01	0.00000E+00
187	3.58750E+01	1.62500E+01	0.00000E+00
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

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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

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.	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

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

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

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

CHECK GEOMETRY Version 2.0 07/01/90

A1 REDUCING FLANGE W/SHELL

RESTRAINTS

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

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

KOCH PROCESSOR SYSTEMS S/N:801743A 03/04/96
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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

	Principal Stress			/		
Node	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	-.6522E+03	/	.1143E+04	.1318E+04
10	.5227E+03	-.3411E+02	-.3887E+03	/	.7957E+03	.9113E+03
11	.2384E+03	-.1255E+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+03	-.3642E+03	/	.3608E+03	.3778E+03
17	.1122E+02	-.4802E+01	-.4012E+03	/	.4047E+03	.4124E+03
18	.5616E+03	-.7518E+01	-.2000E+04	/	.2330E+04	.2562E+04
19	.5483E+03	-.5819E+01	-.1953E+04	/	.2275E+04	.2501E+04
20	.5621E+03	.5759E+01	-.1895E+04	/	.2228E+04	.2457E+04
21	.5821E+03	-.4952E+01	-.1828E+04	/	.2176E+04	.2410E+04
22	.6036E+03	-.2802E+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

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	.5037E+03	-.1559E+02	-.1040E+04	/	.1261E+04	.1545E+04
43	.4971E+03	-.4201E+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	/	.8238E+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	.5849E+03	-.1003E+02	-.1981E+04	/	.2326E+04	.2566E+04
53	.5661E+03	-.1481E+02	-.1938E+04	/	.2270E+04	.2504E+04
54	.5402E+03	-.1223E+02	-.1889E+04	/	.2205E+04	.2429E+04
55	.4980E+03	-.8314E+01	-.1834E+04	/	.2124E+04	.2332E+04
56	.4494E+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	-.3260E+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+02	-.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	/	.1862E+03	.2012E+03

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	S1	S2	S3	/	Von Mises	Stress Intensity
	Principal Stress			/		
83	-.4816E+01	-.1074E+02	-.1873E+03	/	.1796E+03	.1825E+03
84	-.3626E+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	-.3087E+01	-.3394E+03	-.4499E+03	/	.3982E+03	.4418E+03
88	-.1103E+02	-.3486E+03	-.4681E+03	/	.4107E+03	.4571E+03
89	-.1008E+02	-.3490E+03	-.4457E-03	/	.3962E+03	.4056E+03
90	-.1000E+02	-.3336E+03	-.3817E+03	/	.3502E+03	.3717E+03
91	-.1155E+02	-.2788E+03	-.3034E+03	/	.2803E+03	.2918E+03
92	-.3399E-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	/	.1926E+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	-.2026E+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

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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	-.2315E+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 FL
133	.7528E+03	-.5578E+02	-.5689E+02	/	.8091E+03	.8097E+03
134	.6665E+03	-.3220E+02	-.5233E+02	/	.7290E+03	.7383E+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	-.5567E+02	/	.1757E+03	.1832E+03
138	.5443E+02	-.1312E+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

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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	.2906E+03	.1006E+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	.9469E+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+03	-.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

KOCH PROCESSOR SYSTEMS S/N:801743A 03/04/96
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A1 REDUCING FLANGE W/SHELL

LOAD CASE 1
EXTERNAL PRESSURE + BELLOWS LOAD

Axi-Solid Elements

Node	Principal Stress S1	S2	S3	/	Von Mises	Stress Intensity
206	.2105E+01	-.2288E+03	-.2140E+04	/	.2036E+04	.2142E+04
207	.3009E+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	-.1344E+03	-.2729E+03	/	.2983E+03	.3393E+03
216	-.7262E+01	-.2718E+03	-.4596E+03	/	.3936E+03	.4523E+03
217	-.7460E+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	/	.1889E+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	-.7227E+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
F[1,1]

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

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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	-2.745E-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

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	-2.342E-04	1.286E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
133	-2.145E-04	1.218E-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	-4.641E-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	7.378E-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	-3.309E-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	6.569E-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	5.354E-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	-2.806E-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

COMBINE RESULTS Version 2.0 07/01/90

Combined Displacements

Node	Dx	Dy	Dz	Rx	Ry	Rz
243	-1.561E-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)

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

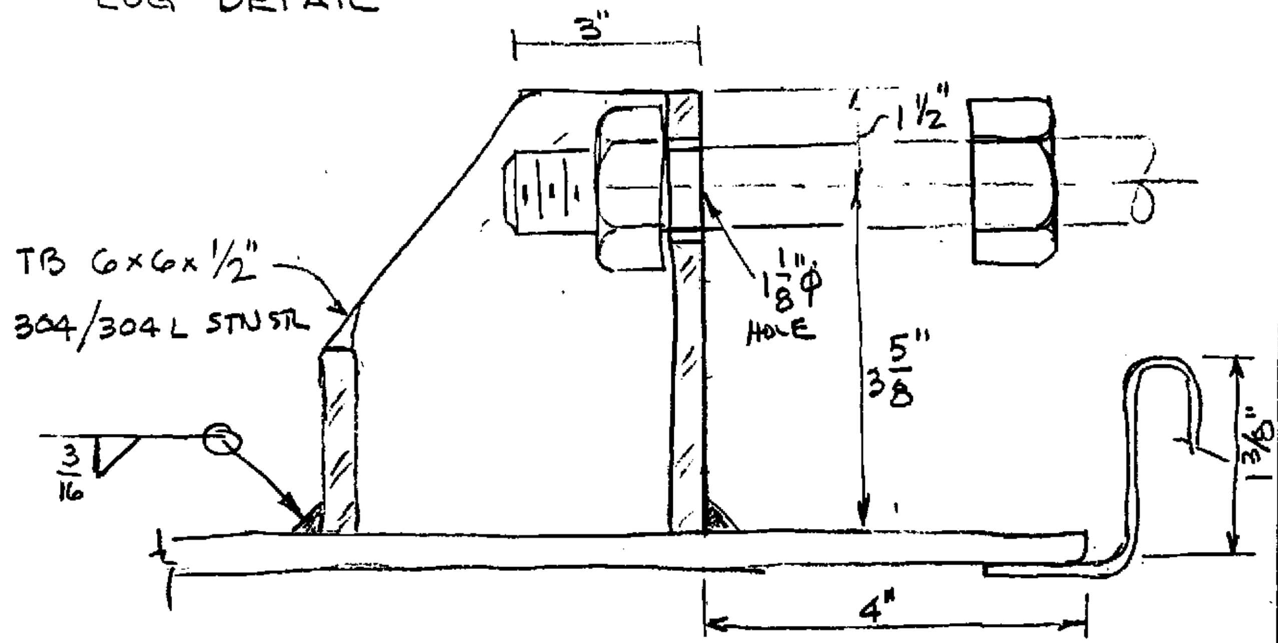
ROD/NUT MATERIAL 304L STN-STL

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

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

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

LUG DETAIL

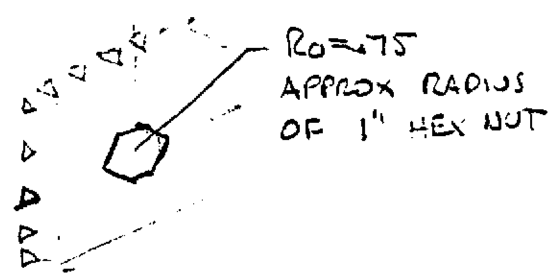


VARIABLE SHEET

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.459)
		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*	9.536	.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:801742A RUN ID= 02/14/96
PAGE 1 13:19:02

I M A G E S - 3 D

GEOMETRY PLOT Version 2.0

ADAPTER A-1 JACKING LUG DEFLECTIONS

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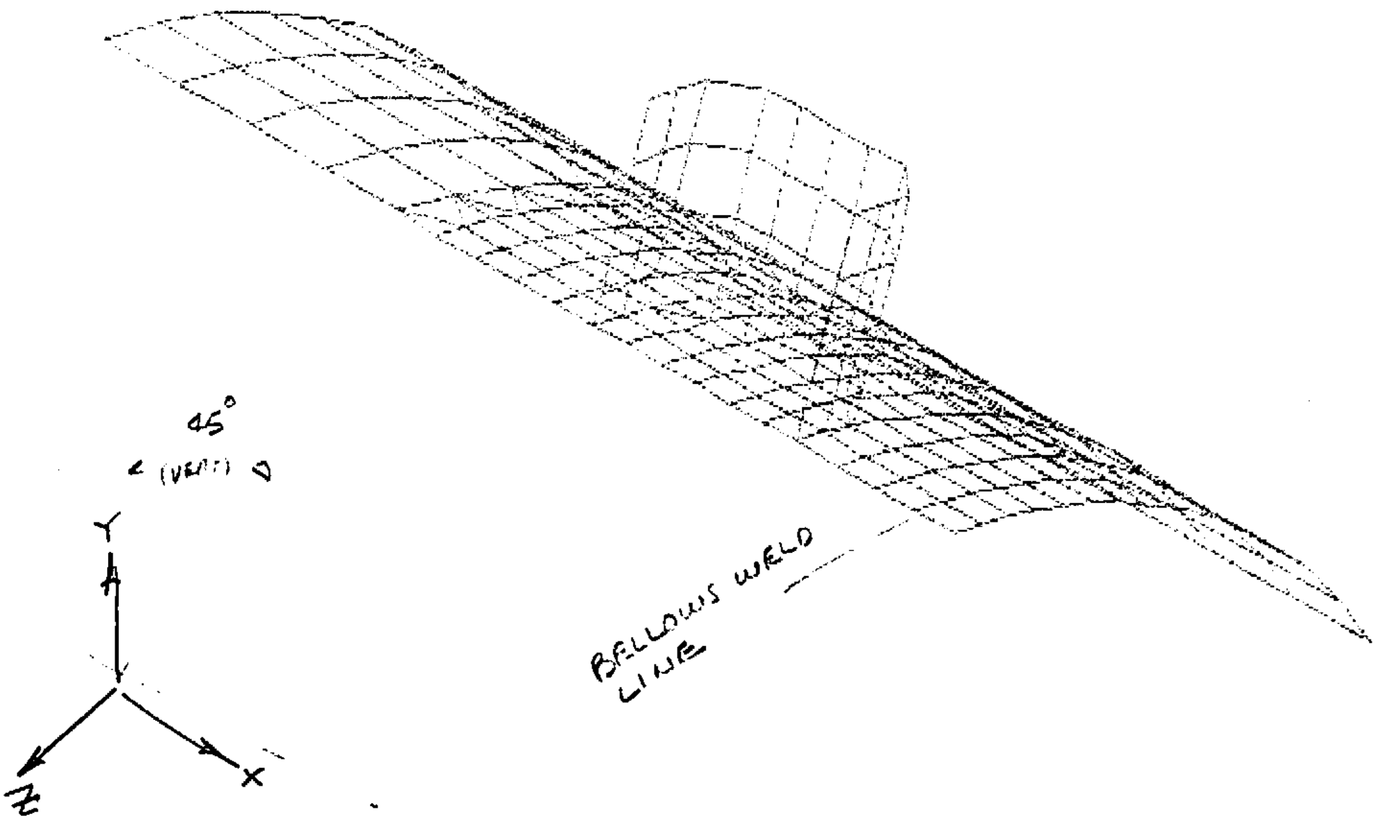
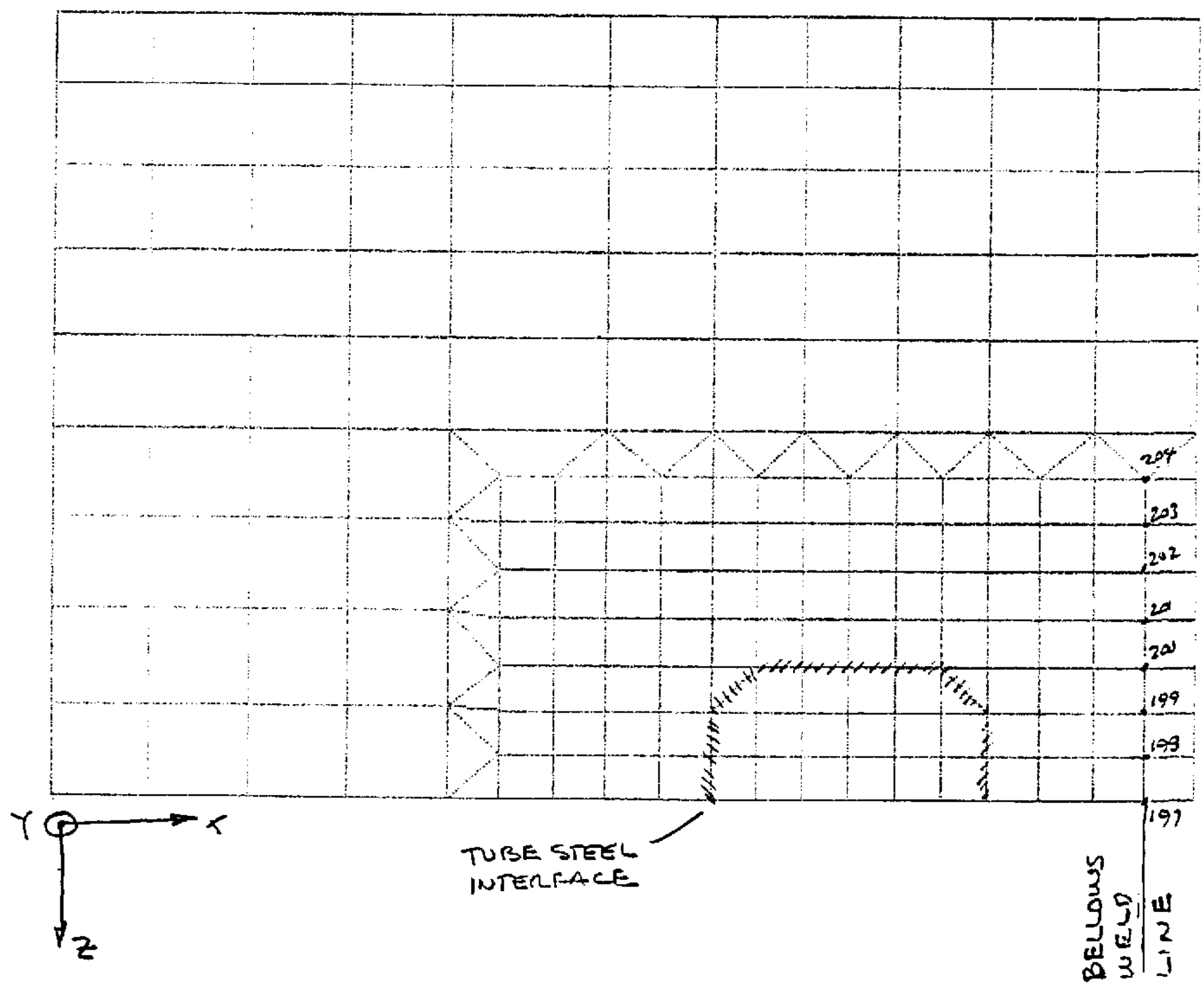


GEOMETRY PLOT Version 2.0

ADAPTER A-1 JACKING LUG DEFLECTIONS



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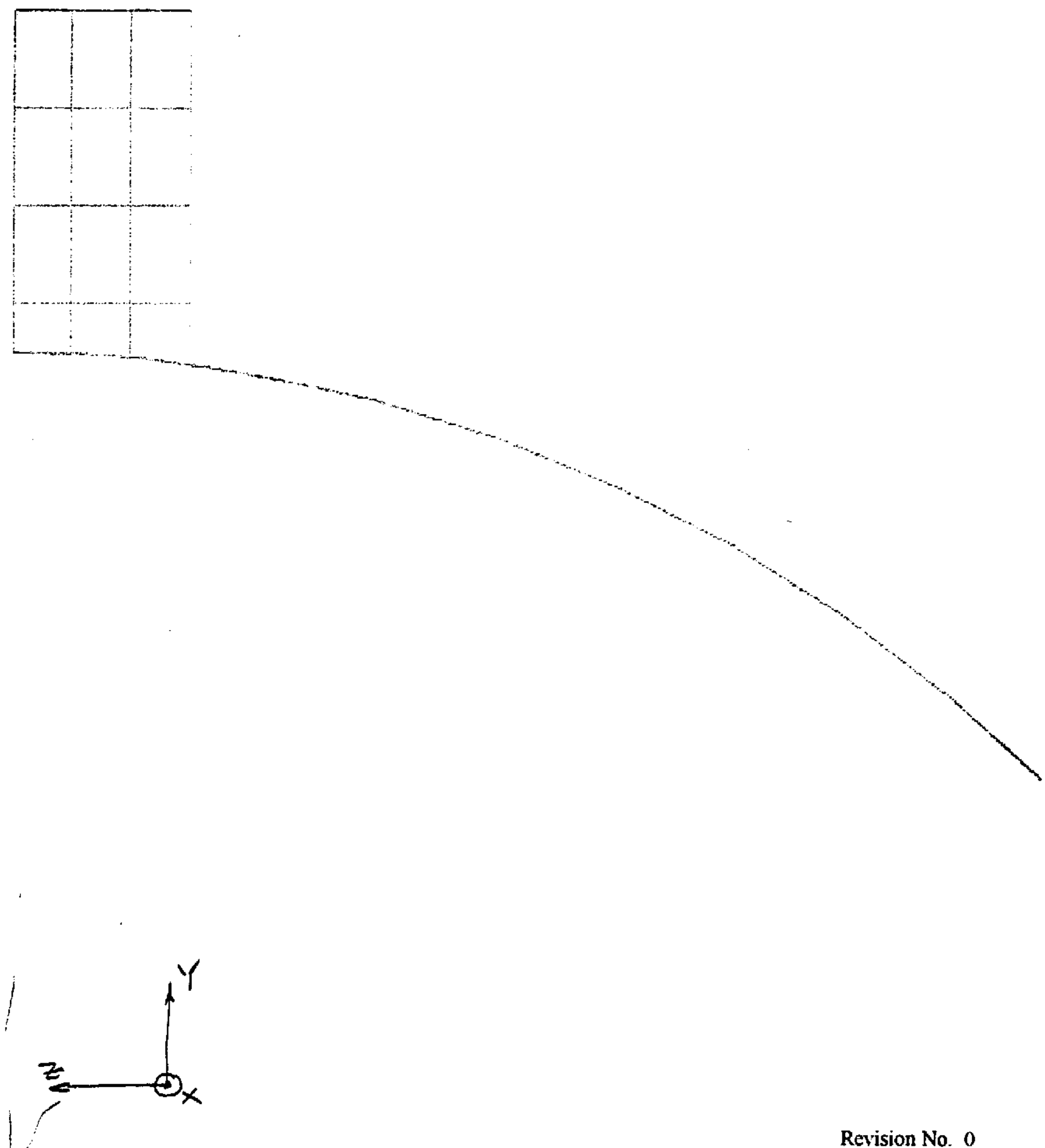
GEOMETRY PLOT Version 2.0

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

CHECK GEOMETRY Version 2.0 07/01/90

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	1.59793E+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
QUAD	33	36	37	47	46	1	1.875E-01	3.993E+00		9.983E-01	M+B
QUAD	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
QUAD	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
AD	74	95	96	104	103	1	1.875E-01	9.708E-01		8.599E-01	M+B
AD	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
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
[illegible]D	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
QU[illegible]	140	170	171	179	178	1	1.875E-01	8.974E-01		1.068E+00	M+B

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	Plate No.	Nodes 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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	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
	197	188	81	196		1	1.875E-01	5.201E-01		2.000E+00	M+B
	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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	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

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

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								

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	7.316E-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	-5.626E-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	-6.543E-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	2.689E-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	-5.359E-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	-2.962E-03	-3.251E-04	-1.891E-03	0.000E+00
85	-3.460E-05	1.070E-03	-9.662E-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	6.012E-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	4.830E-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	9.061E-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	-4.482E-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	-2.586E-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	0.600E+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	1.095E-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	1.685E-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

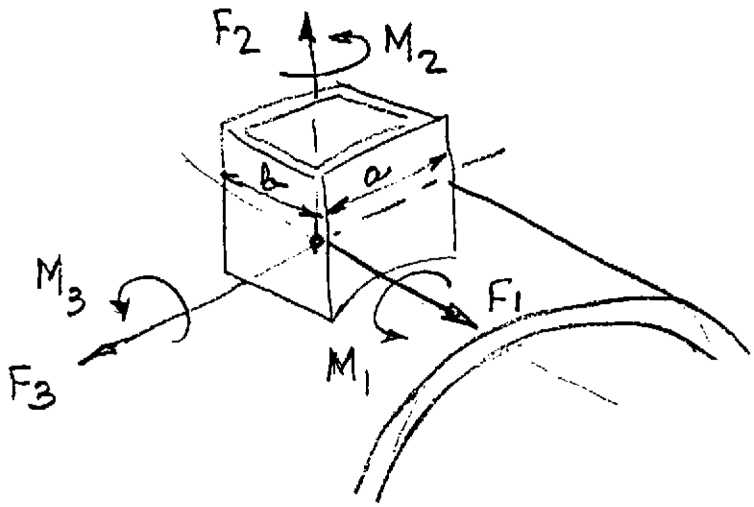
Node	Dx	Dy	Dz	Rx	Ry	Rz
243	1.260E-02	-1.157E-02	1.639E-03	3.876E-04	1.307E-03	-2.958E-03
244	1.676E-02	-1.159E-02	2.295E-03	6.197E-04	1.823E-03	-2.911E-03
245	4.350E-03	-1.448E-02	1.717E-04	-6.024E-05	2.393E-04	-3.375E-03
246	9.421E-03	-1.447E-02	-3.409E-05	3.441E-04	1.374E-03	-3.646E-03
247	1.441E-02	-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	1.632E-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)

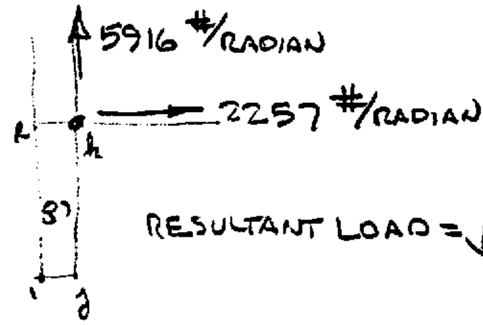
ω
0.041

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 <u>3/16" FILLET WELD x 2" LONG ON 12" CTRS</u>

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:

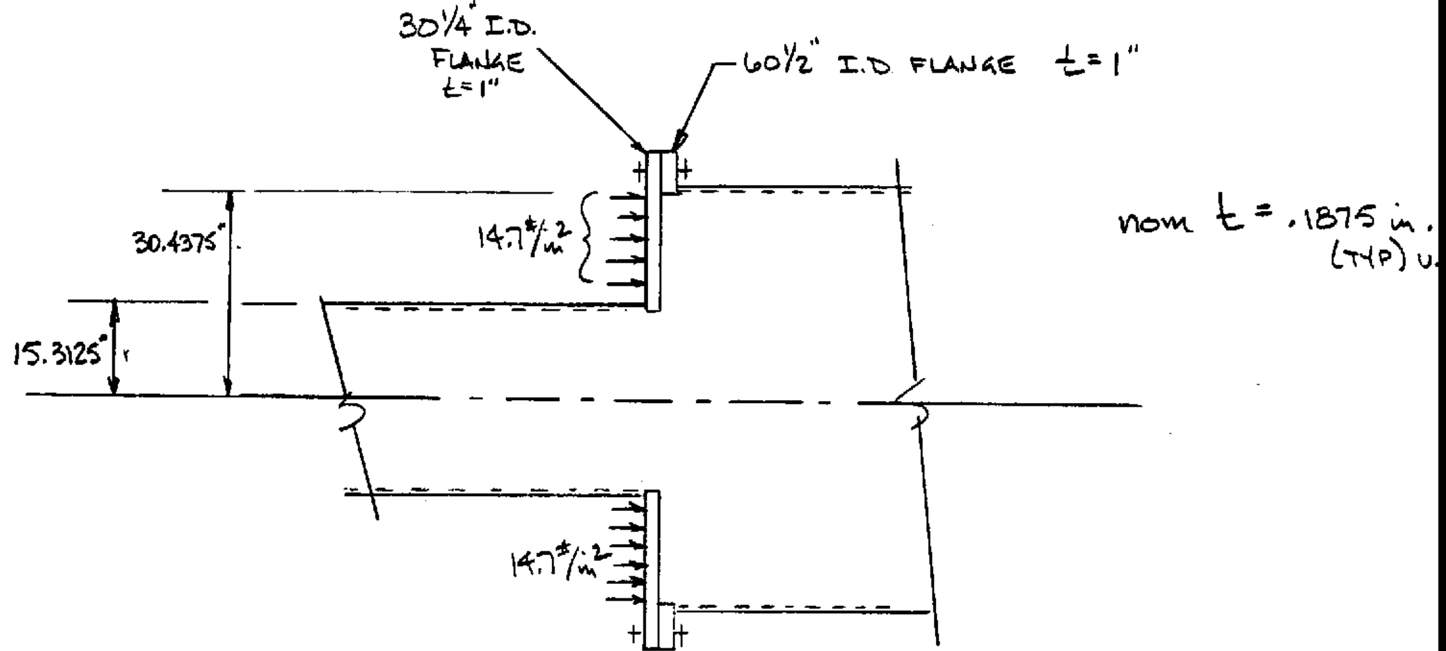
(See Attached)

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.

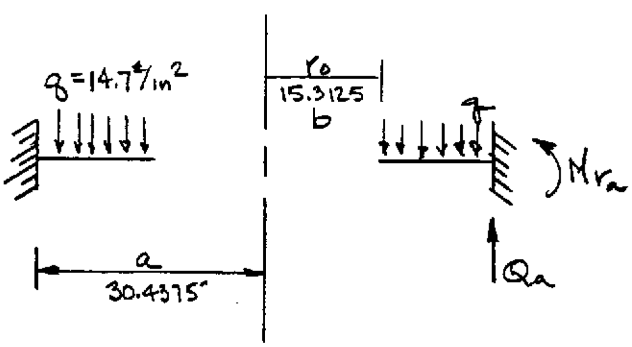
DETERMINE IF EXTERNAL PRESSURE OF 14.7 PSIA ON EXPOSED PORTION OF 30 1/4" FLANGE PRODUCES BENDING STRESSES WITHIN ALLOWABLE LIMITS.



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.



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

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

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

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

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

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

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

$$L_{17} = 0.0733$$

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

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

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

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

$$L_{14} = 0.015$$

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

$$C_4 = 1.023$$

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

$$C_7 = .6755$$

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

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

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

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

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

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

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

FOR TYPE 304L

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

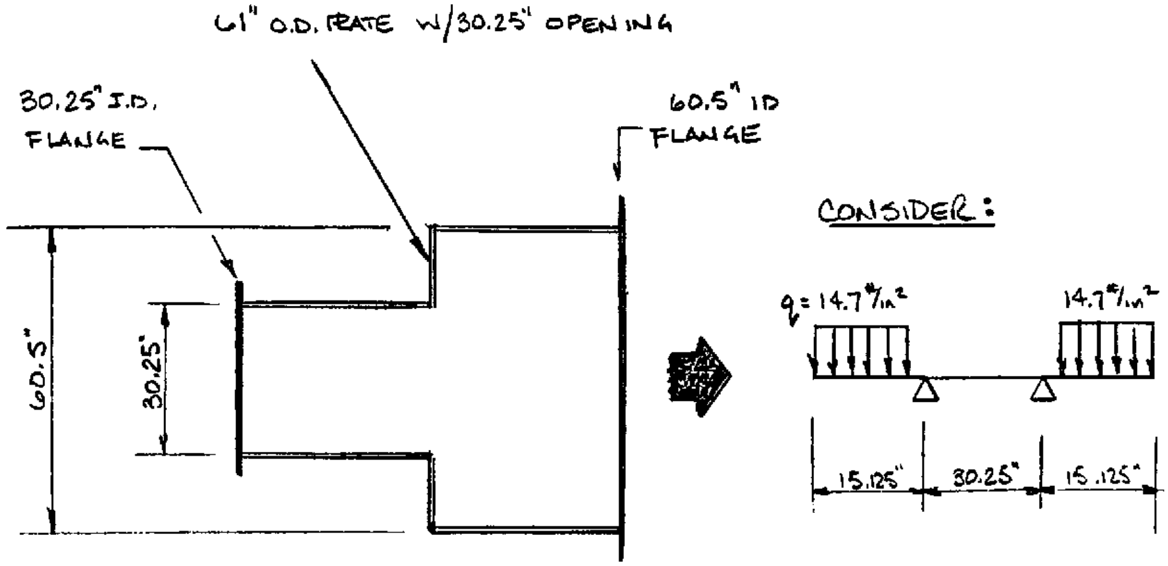
$S = 1.5S = 22$ KSI @ 400°F for membrane + bending stress

$\therefore$ Max $\sigma < S$

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

1" THK PLATE O.K.

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



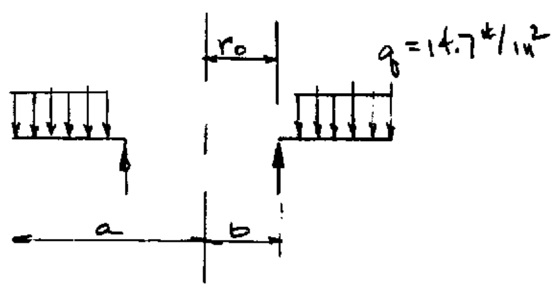
REF. ROARK'S - FORMULAS FOR STRESS & STRAIN

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

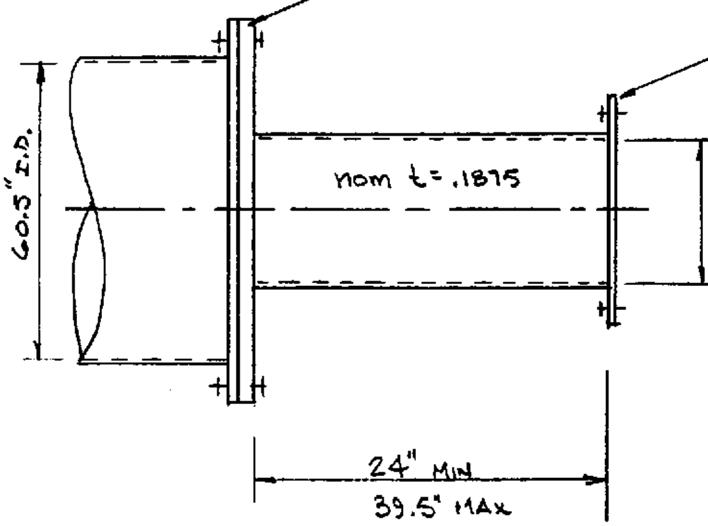
$$= \frac{14.7\#/in^2/in}{2\left(15.125\,in\right)}\left[\left(30.25\,in\right)^2 - \left(15.125\,in\right)^2\right]$$

$$= 333.5 \text{ lbs}$$

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

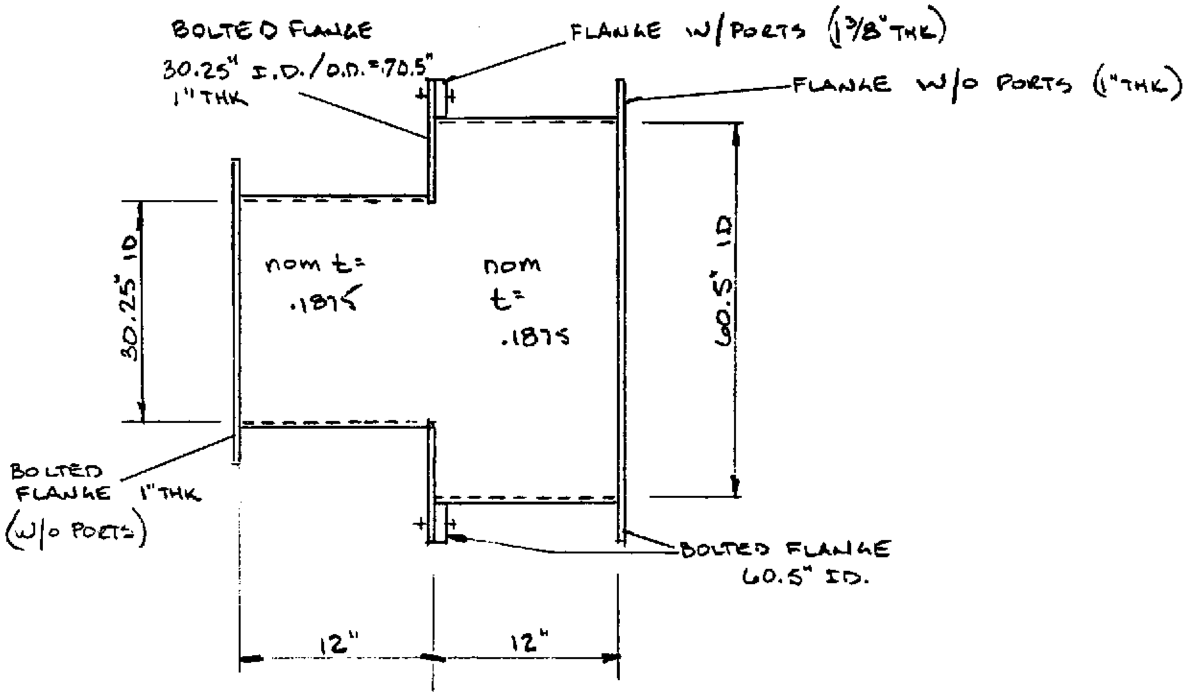
$= 1591\#/in \times \frac{\pi D}{4} = 37794\#$

ADAPTER A-5

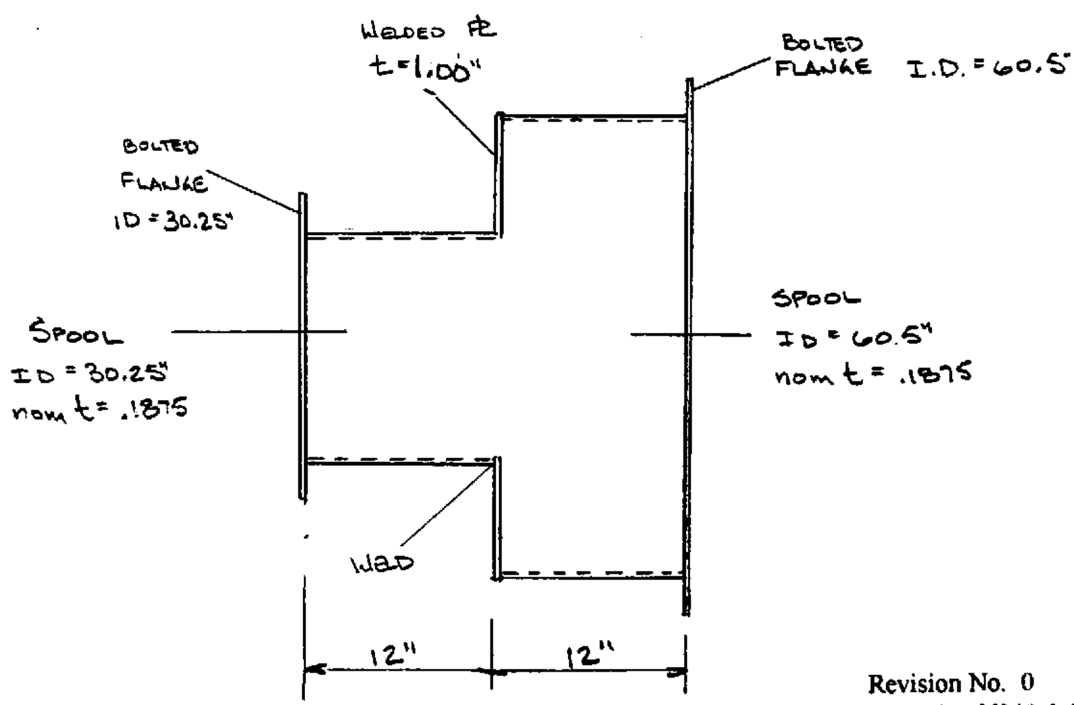

NON-STANDARD 30¼" I.D. FLANGE X 61" O.D. (+/-)
STD 30¼" I.D. FLANGE
60.5" I.D.
nom t = .1875
30¼" I.D.
24" MIN
39.5" MAX

ADAPTER A-5   30" × 60" SPOOL

OPTION   FLANGED SPOOL PIECES



OPTION



PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1- 052 PAGE 1 OF 37
REV.	DEO #	DATE	BY:	CHECK	TITLE: **ADAPTER A-7**	
0	0131	4/19/96	[illegible]	[illegible]		
					BY:	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:

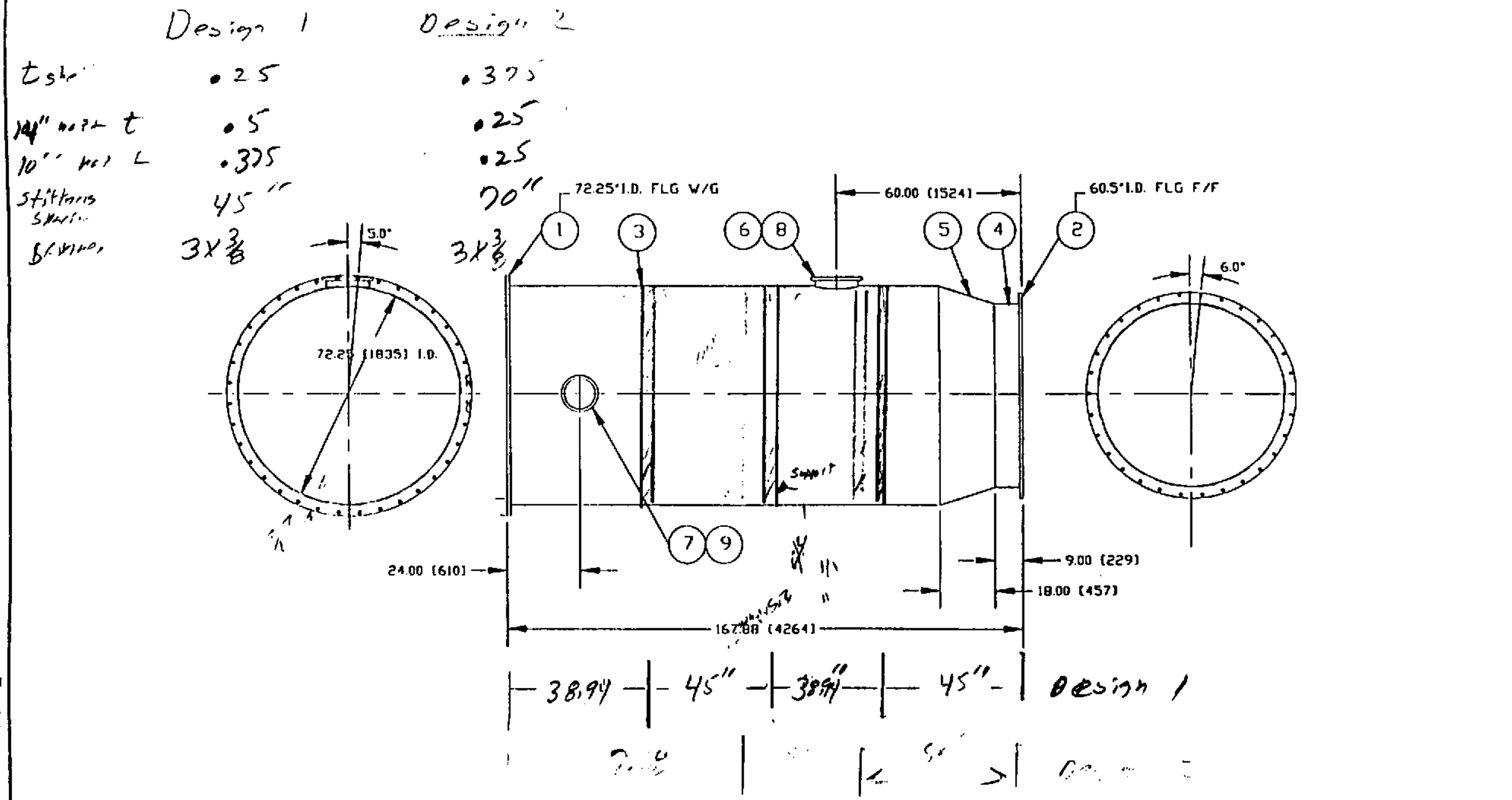
INPUTS:
1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.

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. V049-1-066, LIGO Vacuum Equipment Str. Des. Criteria

CALCULATIONS: (SEE ATTACHED)

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.



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± [illegible]
ANGULAR [illegible]
TWO PLACE DECIMAL ± [illegible]
THREE PLACE DECIMAL ± [illegible]
FINISHED SURFACE [illegible]
BREAK CORNERS [illegible]
REMOVE ALL BURRS

DO NOT SCALE THIS DWG
USED ON
NEXT ASS'Y

REV	DESCRIPTION	CHKD	DRWN	DATE	DEO#
X	X	X	X	X	X

ISSUE DESCRIPTION

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

ADAPTER A-7
72" X 60"
LIGO VACUUM EQUIPMENT

CAD FILE: A7 | SIZE: B | DWG NO: V049-4-A7 | REV: 0
SCALE: 3/8"=1'-0" | SHEET: 1 OF 1

Dec 20 1995 - 10:41:31

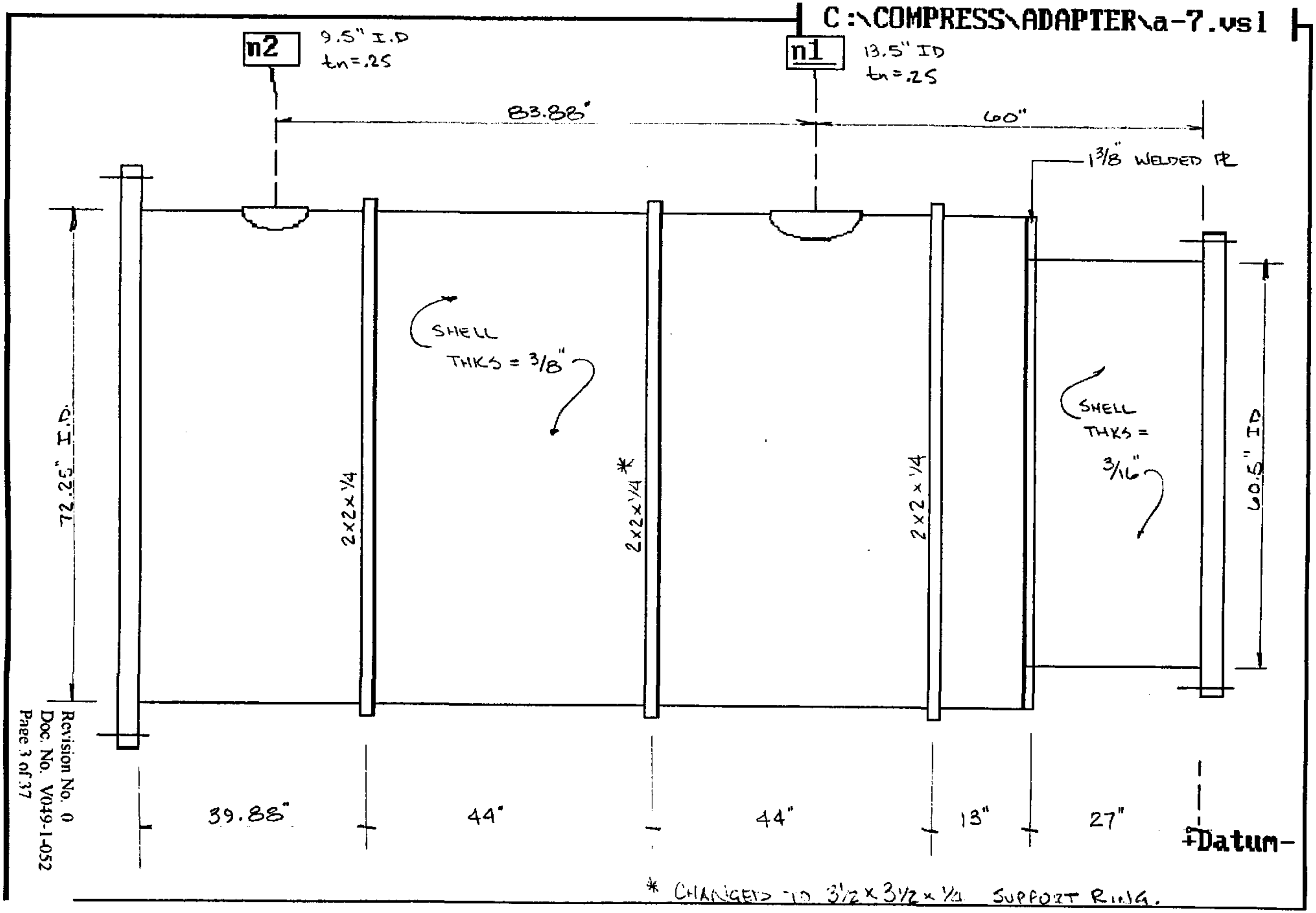

C:\COMPRESS\ADAPTER\a-7.vsl
n2
9.5" I.D
tn=.25
n1
13.5" ID
tn=.25
83.88"
60"
1 3/8" WELDED PL
SHELL
THKS = 3/8"
SHELL
THKS =
3/16"
72.25" I.D.
60.5" I.D.
2x2x1/4
2x2x1/4*
2x2x1/4
39.88"
44"
44"
13"
27"
Datum
* CHANGED TO 3 1/2 x 3 1/2 x 1/4 SUPPORT RING.

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)
A-7 CYLINDER	0.0	0.0	146.4	146.4	36.7	1.000		Not applicable	0.000
n1 NOZZLE #1	0.0	0.0	91.8	92.0	14.7	1.000		Not applicable	0.000
n2 NOZZLE #2	0.0	0.0	94.6	94.4	14.7	1.000		Not applicable	0.000
73.25" CVR PLT	0.0	0.0	19.2	19.2		1.000		Not applicable	0.000
60.5" CYLINDER	0.0	0.0	87.6	87.6	19.7	1.000		Not applicable	0.000
60.5" FLNG	0.0	0.0	18.4	18.4		1.000		Not applicable	0.000
72.25" FLNG	0.0	0.0	10.2	10.2		1.000		Not applicable	0.000
Stiffener Rings					14.7				
Support Ring					14.7				

Vessel MAWP hot & corroded is 10.22 psi @ 0 degrees F.

Vessel MAP new & cold is 10.22 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
A-7 cylinder	3496	3496	0	0	0	0	0	0	241	0	20854	8
73.25" cvr plt	1680	1680	0	0	0	0	0	0	0	0	0	0
60.5" cylinder	280	280	0	0	0	0	0	0	0	0	2802	0
60.5" flng	625	625	0	0	0	0	0	0	0	0	0	0
72.25" flng	1264	1264	0	0	0	0	0	0	0	0	0	0
	7345	7345	0	0	0	0	0	0	241	0	23656	8

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded:	7,594 lbs
Vessel empty weight, corroded:	7,594 lbs
Vessel empty weight, new:	7,594 lbs
Vessel test weight, new:	31,250 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	7,595 lbs
Center of gravity to seam:	81.7 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 (%)
n1	14.00	0.2500	0.1997	y	y	0.3750	0.2008		0.0000	100.0
n2	10.00	0.2500	0.2054	y	y	0.3750	0.2008	0.3750	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
n1	nozzle #1	13.50 IDx0.25	SA 240 304L HIGH	n	n				
n2	nozzle #2	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	Governing Load	Governing Status	Governing Stress	Deflect (in)
A-7 cylinder	72.25	140.88	0.3750	0.2007	0.85	external			
73.25" cvr plt			1.3750	0.0000	0.85	internal			
60.5" cylinder	60.50	27.00	0.1875	0.1587	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

A-7 CYLINDER

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 = 3495.5	corr = 3495.5	lb
capacity:	new = 2500.36	corr = 2500.36	US ga

ID = 72.25 length Lc= 140.88 t = 0.375 in (new)

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

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.375/(36.125 + 0.6*0.375) - 0
= 146.4409 psi

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

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.375/(36.125 + 0.6*0.375) - 0
= 146.4409 psi

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

L/Do = 48/73 =0.6575 Do/t = 73/0.20078 = 363.582
From table G: A = 0.000305
From table HA-3: B = 4034.1

Pa= 4*B/(3*Do/t)
= 4*4034.1/(3*73/0.20078)
= 14.7939 psi

Design thickness for external pressure Pa = 14.7939 psi:

= t + Corrosion
= 0.20078 + 0
= 0.20078 in

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

L/Do = 48/73 =0.6575 Do/t = 73/0.375 = 194.6667
From table G: A = 0.000772
From table HA-3: B = 5369.9

A-7 CYLINDER

Pa= 4*B/(3*Do/t)
= 4*5369.9/(3*73/0.375)
= 36.7801 psi

NOZZLE #1

Opening n1 Reinforcement Calculations Per UG-37

Located on:	A-7 CYLINDER
Local vessel thickness:	.375 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:	38 in
Nozzle offset from center Lo:	0 in
Projection outside vessel Lpr:	1.5 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 = .25 in

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*(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)
= 91.83556*6.75/(16700*1 - 0.6*91.83556)
= 0.0372 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 91.83556*36.125/(16700*1 - 0.6*91.83556)
= 0.1993 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

NOZZLE #1

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 13.5*0.1993*1 + 2*0.25*0.1993*1*(1 - 1)
= 2.6906 in^2

Area available

A1 = larger of the following = 2.372 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.375-1*0.1993) - 2*0.25*(1*0.375-1*0.1993)*(1-1)
= 2.372 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.1993) - 2*0.25*(1*0.375-1*0.1993)*(1-1)
= .22 in^2

A2 = smaller of the following = 0.266 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0372)*1*0.375
= .399 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0372)*1*0.25
= .266 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 2.372 + 0.266 + 0.063
= 2.701 in^2

As Area > A the reinforcement is adequate for MAWP = 91.83556 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) = 0.25 in
t1 + t2 = 0.425 >= 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 = 0.0372 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1993 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 = 0.1993 in
The lesser of tr4 or tr5:	tr6 = 0.1993 in

NOZZLE #1

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1993 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*0.25*12358 = 67907.21 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
 = (2.6906 - (13.5 - 2*0.25)*(1*0.375 - 1*0.1993))*16700
 = 6788.55 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
 = (0.266 + 0 + 0.063 + 0)*16700
 = 5494.3 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
 = (0.266 + 0 + 0.063 + 0 + 2*0.25*0.375*1)*16700
 = 8625.55 lbf

Load for path 1-1 lesser of W or W1-1 = 5494.3 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 = 6788.55 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 67907.21 = 112872.8 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 #1

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 92.03197*6.75/(16700*1 - 0.6*92.03197)
= 0.0373 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 92.03197*36.125/(16700*1 - 0.6*92.03197)
= 0.1997 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*0.1997*1 + 2*0.25*0.1997*1*(1 - 1)
= 2.696 in^2

Area available

A1 = larger of the following = 2.367 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.375-1*0.1997) - 2*0.25*(1*0.375-1*0.1997)*(1-1)
= 2.367 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.1997) - 2*0.25*(1*0.375-1*0.1997)*(1-1)
= .219 in^2

A2 = smaller of the following = 0.266 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.0373)*1*0.375
= .399 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.0373)*1*0.25
= .266 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 2.367 + 0.266 + 0.063
= 2.696 in^2

As Area > A the reinforcement is adequate for MAP = 92.03197 at 0 Deg F

NOZZLE #1

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) = 0.25 in
t1 + t2 = 0.425 >= 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 = 0.0373 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.1997 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 = 0.1997 in
The lesser of tr4 or tr5:	tr6 = 0.1997 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1997 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*0.25*12358 = 67907.21 lbf

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

W = (A - (d - 2*tn)*(E1*t - F*tr))*Sv
= (2.696 - (13.5 - 2*0.25)*(1*0.375 - 1*0.1997))*16700
= 6965.571 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.266 + 0 + 0.063 + 0)*16700
= 5494.3 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv

NOZZLE #1

= (0.266 + 0 + 0.063 + 0 + 2*0.25*0.375*1)*16700
= 8625.55 lbf

Load for path 1-1 lesser of W or W1-1 = 5494.3 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 = 6965.571 lbf
Path 2-2 Thru (1), (4) = 44965.59 + 67907.21 = 112872.8 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 = 1.5/14 = .1071 Do/t = 14/0.02658 = 526.7118
From table G: A = 0.001242
From table HA-3: B = 5832.7

Pa= 4*B/(3*Do/t)
= 4*5832.7/(3*14/0.02658)
= 14.7651 psi

Nozzle required thickness trn = .02658 in

Required thickness tr from UG-37(d)(1) = .2008 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*0.2008*1 + 2*0.25*0.2008*1*(1 - 1))
= 1.3554 in^2

Area available

A1 = larger of the following = 2.352 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 13.5*(1*0.375-1*0.2008) - 2*0.25*(1*0.375-1*0.2008)*(1-1)
= 2.352 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)

NOZZLE #1

= 2*(0.375+0.25)*(1*0.375-1*0.2008) - 2*0.25*(1*0.375-1*0.2008)*(1-1)
= .218 in^2

A2 = smaller of the following = 0.279 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02658)*1*0.375
= .419 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02658)*1*0.25
= .279 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 2.352 + 0.279 + 0.063
= 2.694 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 = 0.02658 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.

NOZZLE #1

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 = 36.3125 in
Rm/t = 96.83334

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 =-9220 psi
Allowable combined stress = +-3*S = +- 50100 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-2445 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

NOZZLE #1

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	6.6652	0.169					-1101	-1101	-1101	-1101
4C*	11.967	0.169	-1977	-1977	-1977	-1977				
1C	0.0610	0.169					-5856	5856	-5856	5856
2C-1	0.0255	0.169	-2448	2448	-2448	2448				
3A*	3.7245	0.169					-203	-203	203	203
1A	0.0651	0.169					-2060	2060	2060	-2060
3B*	8.5978	0.169	-468	-468	468	468				
1B-1	0.0182	0.169	-576	576	576	-576				
pressure stress*										
Total circ stress			-5469	579	-3381	363	-9220	6612	-4694	2898
Primary membrane circ stress*			-2445	-2445	-1509	-1509	-1304	-1304	-898	-898
3C*	6.6652	0.169	-1101	-1101	-1101	-1101				
4C*	11.967	0.169					-1977	-1977	-1977	-1977
1C-1	0.0529	0.169	-5078	5078	-5078	5078				
2C	0.0357	0.169					-3427	3427	-3427	3427
4A*	8.3161	0.169					-453	-453	453	453
2A	0.0300	0.169					-949	949	949	-949
4B*	3.7183	0.169	-202	-202	202	202				
2B-1	0.0241	0.169	-763	763	763	-763				
pressure stress*										
Total long stress			-7144	4538	-5214	3416	-6806	1946	-4002	954
Primary membrane long stress*			-1303	-1303	-899	-899	-2430	-2430	-1524	-1524
torsion moment Mt										
Circ shear from Vc			15	15	-15	-15				
Long shear from VL							-15	-15	15	15
Total Shear stress			15	15	-15	-15	-15	-15	15	15
Combined stress			-7144	4538	-5214	3416	-9220	6612	-4694	2898

NOZZLE #2

Opening n2 Reinforcement Calculations Per UG-37

Located on:	A-7 CYLINDER
User input vessel thickness:	.375 in
Liquid static head included:	0 psi
Flange description:	Not installed
Nozzle 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:	1.5 in

```
   tn ->|  |<-
            _         _
          | |<- d ->|  |          corrosion allow = 0 in
twl->|  |<|           |  |        noz thick new tn= .25 in
     | /|  |  v       |  |\       nozzle id. new d= 9.5 in
_____.-|  |_          |  |-.____  fillet weld twl = .25 in
______\|_|_tw2        |_|/______  groove weld tw2 = .25 in
            ^
<---- L ---->|                    To datum L= 143.88 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*(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)
= 94.63811*4.75/(16700*1 - 0.6*94.63811)
= 0.027 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 94.63811*36.125/(16700*1 - 0.6*94.63811)
= 0.2054 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

NOZZLE #2

A = d*tr*F + 2*tn*tr*F*(1 - fr1)
= 9.5*0.2054*1 + 2*0.25*0.2054*1*(1 - 1)
= 1.9513 in^2

Area available

A1 = larger of the following = 1.611 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.375-1*0.2054) - 2*0.25*(1*0.375-1*0.2054)*(1-1)
= 1.611 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.2054) - 2*0.25*(1*0.375-1*0.2054)*(1-1)
= .212 in^2

A2 = smaller of the following = 0.279 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.027)*1*0.375
= .418 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.027)*1*0.25
= .279 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.611 + 0.279 + 0.063
= 1.953 in^2

As Area > A the reinforcement is adequate for MAWP = 94.63811 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) = 0.25 in
t1 + t2 = 0.425 >= 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 = 0.027 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.2054 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 = 0.2054 in
The lesser of tr4 or tr5:	tr6 = 0.2054 in

NOZZLE #2

Req'd per UG-45 is the larger of tr1 or tr6 = 0.2054 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*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

(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 - (d - 2*tn)*(E1*t - F*tr))*Sv
= (1.9513 - (9.5 - 2*0.25)*(1*0.375 - 1*0.2054))*16700
= 7095.831 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
= (0.279 + 0 + 0.063 + 0)*16700
= 5711.4 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv
= (0.279 + 0 + 0.063 + 0 + 2*0.25*0.375*1)*16700
= 8842.65 lbf

Load for path 1-1 lesser of W or W1-1 = 5711.4 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 = 7095.831 lbf
Path 2-2 Thru (1), (4) = 32118.28 + 48505.15 = 80623.43 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 = 9.5 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 #2

Nozzle required thickness

trn = P*Rn/(Sn*E - 0.6*P)
= 94.44759*4.75/(16700*1 - 0.6*94.44759)
= 0.027 in

Required thickness tr from UG-37(a)

tr= P*R/(S*E - 0.6*P)
= 94.44759*36.125/(16700*1 - 0.6*94.44759)
= 0.205 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)
= 9.5*0.205*1 + 2*0.25*0.205*1*(1 - 1)
= 1.9475 in^2

Area available

A1 = larger of the following = 1.615 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.375-1*0.205) - 2*0.25*(1*0.375-1*0.205)*(1-1)
= 1.615 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 2*(0.375+0.25)*(1*0.375-1*0.205) - 2*0.25*(1*0.375-1*0.205)*(1-1)
= .213 in^2

A2 = smaller of the following = 0.279 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.027)*1*0.375
= .418 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.027)*1*0.25
= .279 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.615 + 0.279 + 0.063
= 1.957 in^2

As Area > A the reinforcement is adequate for MAP = 94.44759 at 0 Deg F

NOZZLE #2

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) = 0.25 in
t1 + t2 = 0.425 >= 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 = 0.027 in (E = 1)
Wall thickness per UG-45(b)(1):	tr2 = 0.205 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 = 0.205 in
The lesser of tr4 or tr5:	tr6 = 0.205 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.205 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

(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 - (d - 2*tn)*(E1*t - F*tr))*Sv
  = (1.9475 - (9.5 - 2*0.25)*(1*0.375 - 1*0.205))*16700
  = 6972.25 lbf

W1-1 = (A2 + A5 + A41 + A42)*Sv
  = (0.279 + 0 + 0.063 + 0)*16700
  = 5711.4 lbf

W2-2 = (A2 + A3 + A41 + A43 + 2*tn*t*fr1)*Sv

NOZZLE #2

= (0.279 + 0 + 0.063 + 0 + 2*0.25*0.375*1)*16700
= 8842.65 lbf

Load for path 1-1 lesser of W or W1-1 = 5711.4 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 = 6972.25 lbf
Path 2-2 Thru (1), (4) = 32118.28 + 48505.15 = 80623.43 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 = 9.5 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 = 1.5/10 = .15 Do/t = 10/0.02006 = 498.5045
From table G: A = 0.0009
From table HA-3: B = 5516.8

Pa= 4*B/(3*Do/t)
= 4*5516.8/(3*10/0.02006)
= 14.7556 psi

Nozzle required thickness trn = .02006 in

Required thickness tr from UG-37(d)(1) = .2008 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*(9.5*0.2008*1 + 2*0.25*0.2008*1*(1 - 1))
= .9538 in^2

Area available

A1 = larger of the following = 1.655 in^2

= d*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)
= 9.5*(1*0.375-1*0.2008) - 2*0.25*(1*0.375-1*0.2008)*(1-1)
= 1.655 in^2

= 2*(t+tn)*(E1*t-F*tr) - 2*tn*(E1*t-F*tr)*(1-fr1)

NOZZLE #2

= 2*(0.375+0.25)*(1*0.375-1*0.2008) - 2*0.25*(1*0.375-1*0.2008)*(1-1)
= .218 in^2

A2 = smaller of the following = 0.287 in^2

= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02006)*1*0.375
= .431 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02006)*1*0.25
= .287 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.655 + 0.287 + 0.063
= 2.005 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 = 0.02006 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.

NOZZLE #2

Applied Loads

Radial load	Pr = 1155 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 = 36.3125 in
Rm/t = 96.83334

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

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

Maximum combined stress =-4635 psi
Allowable combined stress = +-1.5*S = +- 25050 psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress =-1192 psi
Allowable primary membrane stress = +-1.5*S = +- 25050 psi

The maximum primary membrane stress is within allowable limits.

NOZZLE #2

From Fig.	Value read	beta	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
3C*	10.019	0.12					-850	-850	-850	-850
4C*	14.051	0.12	-1192	-1192	-1192	-1192				
1C	0.0768	0.12					-3785	3785	-3785	3785
2C-1	0.0445	0.12	-2193	2193	-2193	2193				
3A*	3.8452	0.12								
1A	0.0776	0.12								
3B*	10.290	0.12								
1B-1	0.0283	0.12								
pressure stress*										
Total circ stress			-3385	1001	-3385	1001	-4635	2935	-4635	2935
Primary membrane circ stress*			-1192	-1192	-1192	-1192	-850	-850	-850	-850
3C*	10.019	0.12	-850	-850	-850	-850				
4C*	14.051	0.12					-1192	-1192	-1192	-1192
1C-1	0.0751	0.12	-3701	3701	-3701	3701				
2C	0.0473	0.12					-2331	2331	-2331	2331
4A*	6.9979	0.12								
2A	0.0391	0.12								
4B*	3.8031	0.12								
2B-1	0.0391	0.12								
pressure stress*										
Total long stress			-4551	2851	-4551	2851	-3523	1139	-3523	1139
Primary membrane long stress*			-850	-850	-850	-850	-1192	-1192	-1192	-1192
torsion moment Mt										
Circ shear from Vc										
Long shear from VL										
Total Shear stress										
Combined stress			-4551	2851	-4551	2851	-4635	2935	-4635	2935

73.25" CVR PLT

ASME Section VIII Division 1, 1992 Edition, A94 Addenda

Component: Flat welded head
Material specification: SA 240 304L HIGH

Corrosion allowance: Inner C = 0 Outer= 0 in

PWHT is not performed

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

Estimated weight: new = 1680.3 corr = 1680.3 lb

OD = 73.25 t = 1.375 in (new)

Factor C = .26

Note: Factor C increased per UG-39(d)

Design thickness: (At 0 deg F) UG-34 eq (1)

t = d*Sqr(C*P/(S*E)) + Corrosion
= 73.25*Sqr(0.26*0/(16700*0.85)) + 0
= 0 in

MAP: (New & at 0 deg F)

P = (S*E/C)*(t/d)^2 - Ps
= (16700*0.85/0.26)*(1.375/73.25)^2 - 0
= 19.2377 psi

MAWP: (Corroded 0 deg F)

P = (S*E/C)*(t/d)^2 - Ps
= (16700*0.85/0.26)*(1.375/73.25)^2 - 0
= 19.2377 psi

60.5" CYLINDER

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 = 279.9	corr = 279.9	lb
capacity:	new = 336.01	corr = 336.01	US ga

ID = 60.5 length Lc= 27 t = 0.1875 in (new)

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

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.1875/(30.25 + 0.6*0.1875) - 0
= 87.65953 psi

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

P = S*E*t/(R + 0.6*t) - Ps
= 16700*0.85*0.1875/(30.25 + 0.6*0.1875) - 0
= 87.65953 psi

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

L/Do = 34.72917/60.875 =0.5705 Do/t = 60.875/0.15876 = 383.4404
From table G: A = 0.000322
From table HA-3: B = 4261.2

Pa= 4*B/(3*Do/t)
= 4*4261.2/(3*60.875/0.15876)
= 14.8174 psi

Design thickness for external pressure Pa = 14.8174 psi:

= t + Corrosion
= 0.15876 + 0
= 0.15876 in

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

L/Do = 34.72917/60.875 =0.5705 Do/t = 60.875/0.1875 = 324.6667
From table G: A = 0.000417
From table HA-3: B = 4818.4

60.5" CYLINDER

Pa= 4*B/(3*Do/t)
 = 4*4818.4/(3*60.875/0.1875)
 = 19.7881 psi

Stiffener Rings

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:		2
Distance first ring to datum line:		40 in
Ring spacing:		88 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 40 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20078 in
Corroded shell thickness:	ts =	0.375 in
Shell outer diameter:	Do =	73 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	30.15625 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*73/(0.20078 + 0.938/30.15625))
= 3470.799

From table HA-3 (ring) A = 2.627857E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (73^2*30.15625*(0.20078 + 0.938/30.15625)*2.627857E-04)/10.9
= .8984013 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 5.755324

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(73*0.375)
= 5.755324 in

W = Ls = 30.15625 in

Shell area A1 = W*ts = 2.158247 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.375/2
= 1.5955 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.5955/(2.158247 + 0.938)
= .4833527 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 5.755324*0.375^3/12 + 2.158247*0.4833527^2
= .5295227 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.4833527 - 1.5955)^2
= 1.508186 in^4

Total available I = I1 + I2 = 2.037708 in^4

The 2x2x1/4 Equal Angle vacuum stiffener is satisfactory.

Calculations for ring 128 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20078 in
Corroded shell thickness:	ts =	0.375 in
Shell outer diameter:	Do =	73 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	39.94 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*73/(0.20078 + 0.938/39.94))
= 3588.719

From table HA-3 (ring) A = 2.716277E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (73^2*39.94*(0.20078 + 0.938/39.94)*2.716277E-04)/10.9
= 1.189497 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 5.755324

W = 1.1*Sqr(Do*ts)

Stiffener Rings

= 1.1*Sqr(73*0.375)
= 5.755324 in

W = Ls = 39.94 in

Shell area A1 = W*ts = 2.158247 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2
= 1.408 + 0.375/2
= 1.5955 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 0.938*1.5955/(2.158247 + 0.938)
= .4833527 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 5.755324*0.375^3/12 + 2.158247*0.4833527^2
= .5295227 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.348 + 0.938*(0.4833527 - 1.5955)^2
= 1.508186 in^4

Total available I = I1 + I2 = 2.037708 in^4

The 2x2x1/4 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:		88 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 88 in from datum

Shell material specification:		SA 240 304L HIGH
Required shell thickness:	t =	0.20078 in
Corroded shell thickness:	ts =	0.375 in
Shell outer diameter:	Do =	73 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
Stiffener supported length:	Ls =	44 in

B = .75*(P*Do/(t + As/Ls))
= .75*(14.7*73/(0.20078 + 1.69/44))
= 3364.806

From table HA-3 (ring) A = 2.548358E-04

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (73^2*44*(0.20078 + 1.69/44)*2.548358E-04)/10.9
= 1.311215 in^4

Available moment of inertia of the combined ring-shell section

Shell width contributing smaller of = 5.755324

W = 1.1*Sqr(Do*ts)
= 1.1*Sqr(73*0.375)
= 5.755324 in

W = Ls = 44 in

Shell area A1 = W*ts = 2.158247 in^2

Distance to the ring neutral axis

Y2 = Ring NA + ts/2

= 2.76 + 0.375/2
= 2.9475 in

Neutral axis of combined section

NA = As*Y2/(A1 + As)
= 1.69*2.9475/(2.158247 + 1.69)
= 1.294427 in

Inertia of the shell about the combined section NA

I1 = W*ts^3/12 + A1*NA^2
= 5.755324*0.375^3/12 + 2.158247*1.294427^2
= 3.641525 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.294427 - 2.9475)^2
= 7.388177 in^4

Total available I = I1 + I2 = 11.0297 in^4

The 4x3x1/4 Un Equal Ang 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:

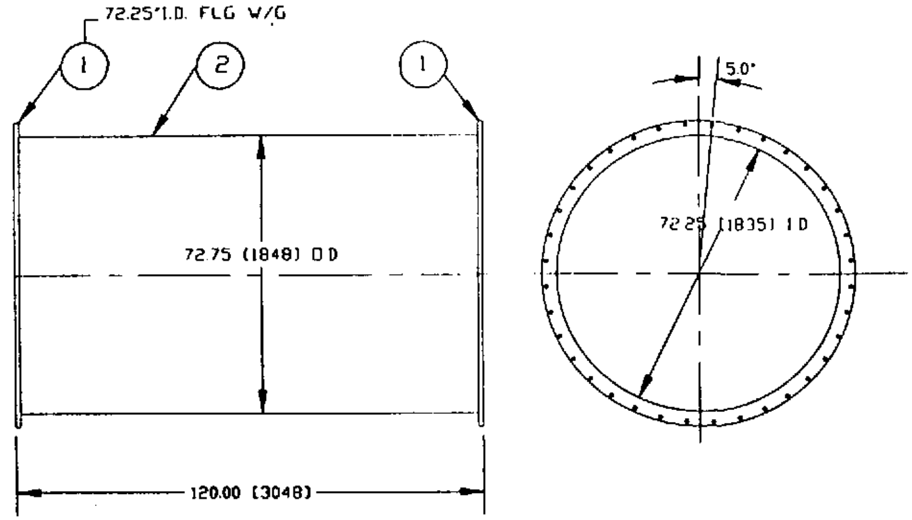
INPUTS:
1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.

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.



Revision No. 0
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Page 2 of 10

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					CHKD	DRWN	DATE	DCO#
X	X					X	X	X	X

ISSUE DESCRIPTION

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

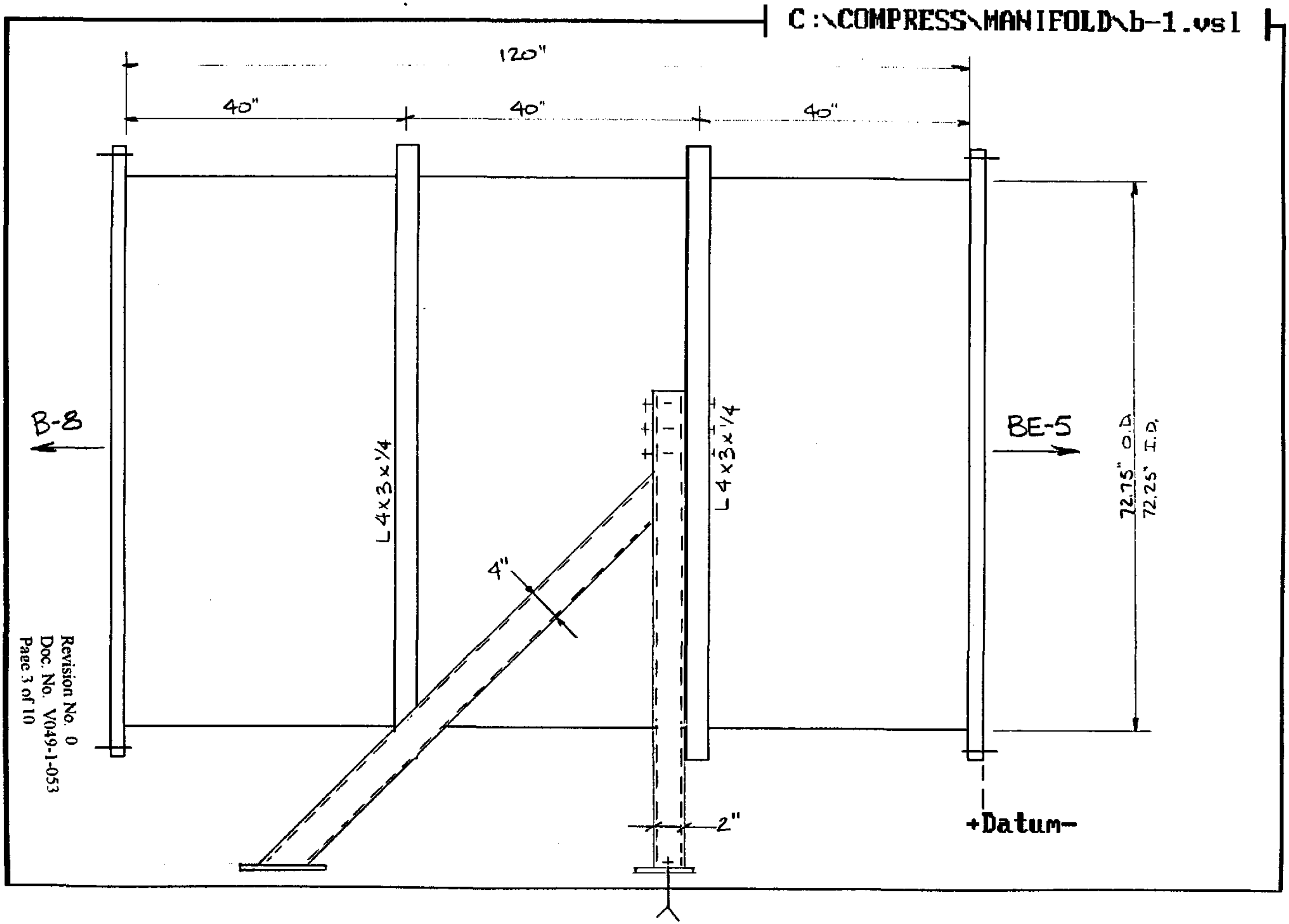
SPOOL B-1
72"
LIGO VACUUM EQUIPMENT

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

4 3 2 1

B A

Jan 17, 1996 - 14:34:15



Revision No. 0
Doc. No. V049-1-053
Page 3 of 10

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

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- 053 PAGE 1 OF 10
REV.	DEO #	DATE	BY:	CHECK	TITLE: SPOOL B-1 (72 in)	
0	0131	4/19/96	WDB	RDC		
					BY: W. Blyinky	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.

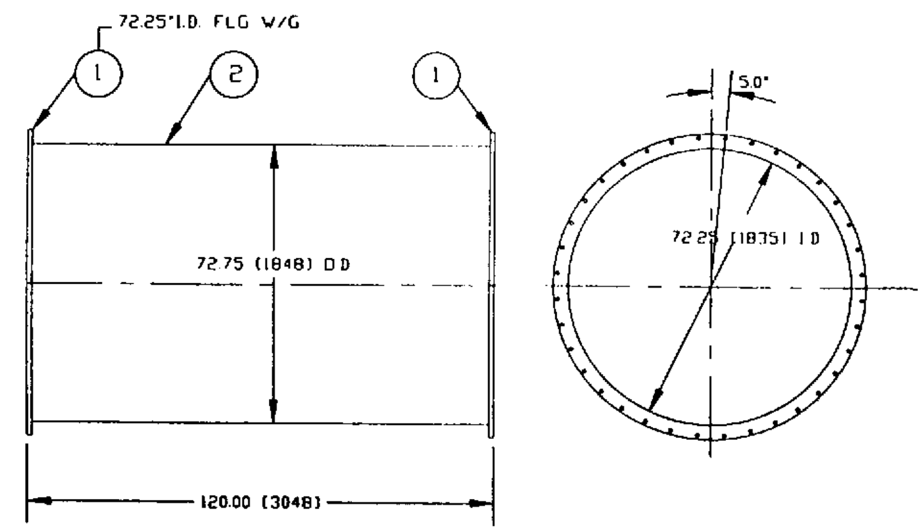
REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.31, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-001, LIGO Vacuum Equip. Struct. Design Criteria

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.

Revision No. 0
Doc. No. V049-1-053
Page 2 of 10



12 REQ'D

PROPRIETARY AND CONFIDENTIAL

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	CHKD	DRWN	DATE	DEO#
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

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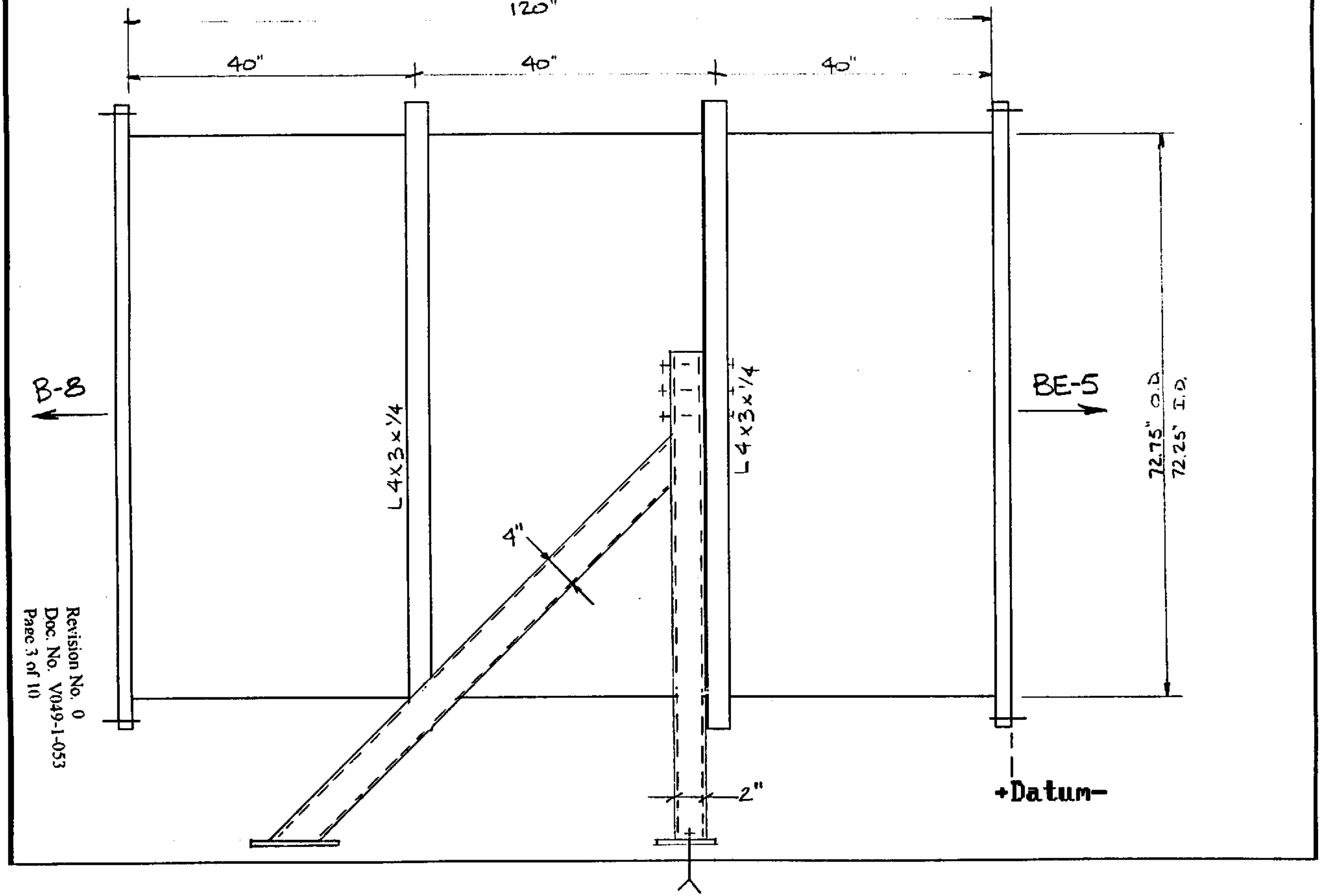

120"
40"
40"
40"
B-8
BE-5
L 4x3x¼
L 4x3x¼
4"
2"
72.75" O.D.
72.25" I.D.
+Datum-

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)
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	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-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

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: **SPOOL B-2 (30 in)**	
0	0131	4/19/96	WDB	RDC		
					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:

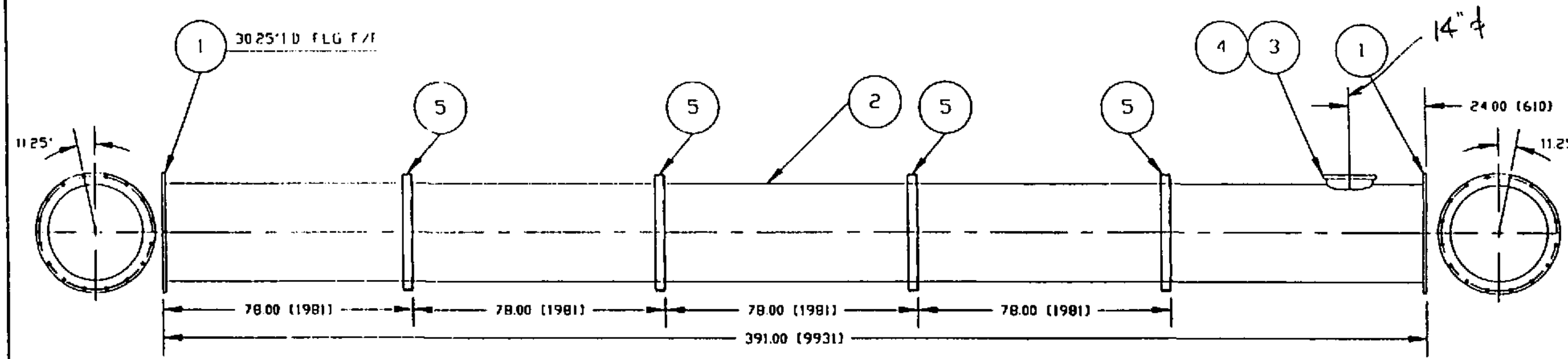
1. ASME Boiler & Pressure Vessel Code, Section VIII, Div. 1, Pressure Vessels.
2. COMPRESS 5.31, Computer Aided Pressure Vessel Design, Codeware Computer Systems, Inc.
3. V049-1-066, LIGO Vac. Equip. Struct. Design Criteria

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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PROPRIETARY AND CONFIDENTIAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE THIS DWG

USED ON

NEXT ASS'Y

REV	DESCRIPTION	CHKD	DRWN	DATE	DCO#

ISSUE DESCRIPTION

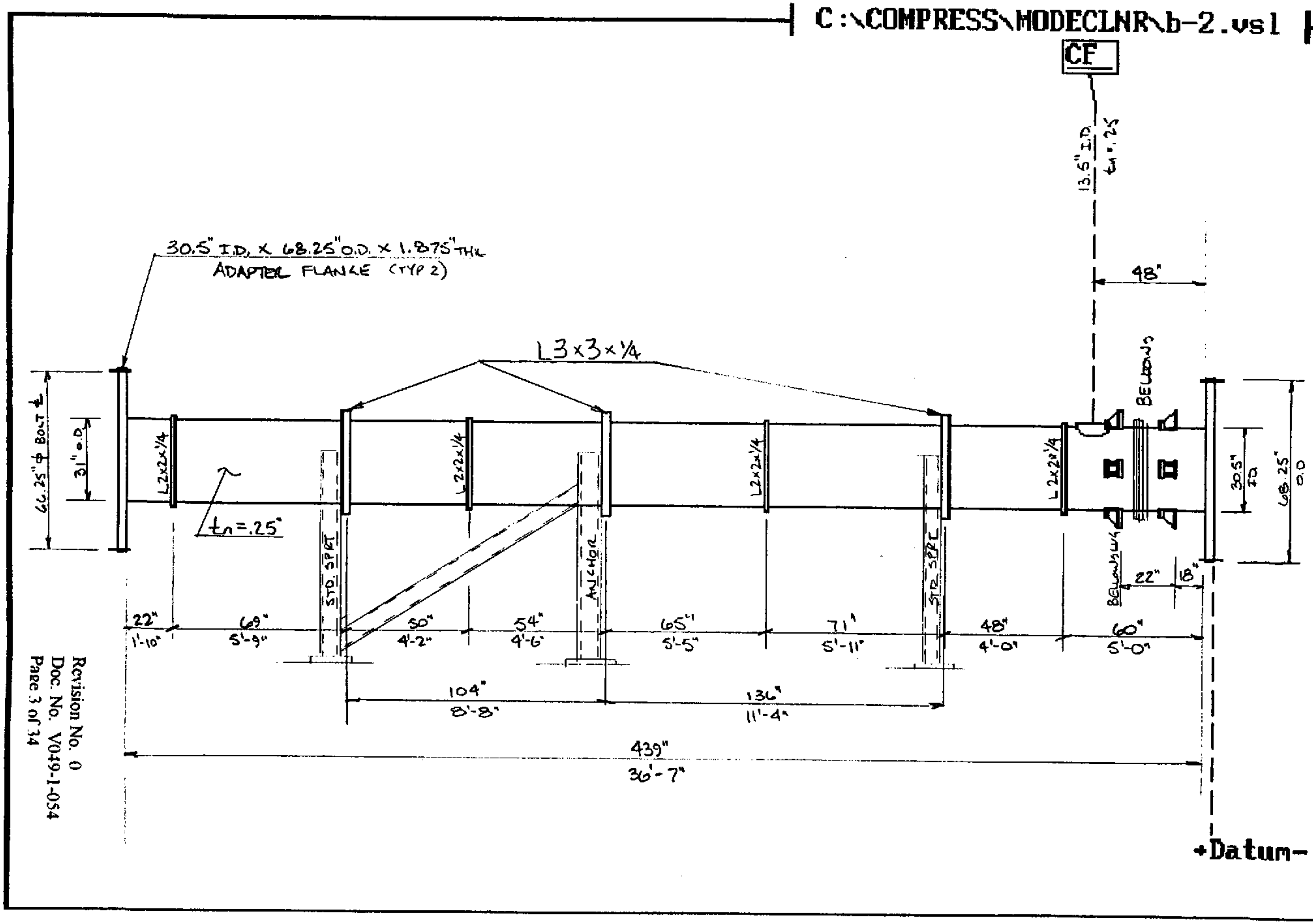
PROCESS SYSTEMS INTERNATIONAL, INC.

SPOOL B-2
30"
LIGO VACUUM EQUIPMENT

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

SHEET 1 OF 1

Dec 19, 1995 - 08:36:09



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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-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

Weight (lbs) Contributed by Vessel Elements

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

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

Stiffener Rings

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)

= 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 V049-1-044 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

REFER TO CALCULATION V049-1-064 FOR FINAL DESIGN OF 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

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	4/15/96	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

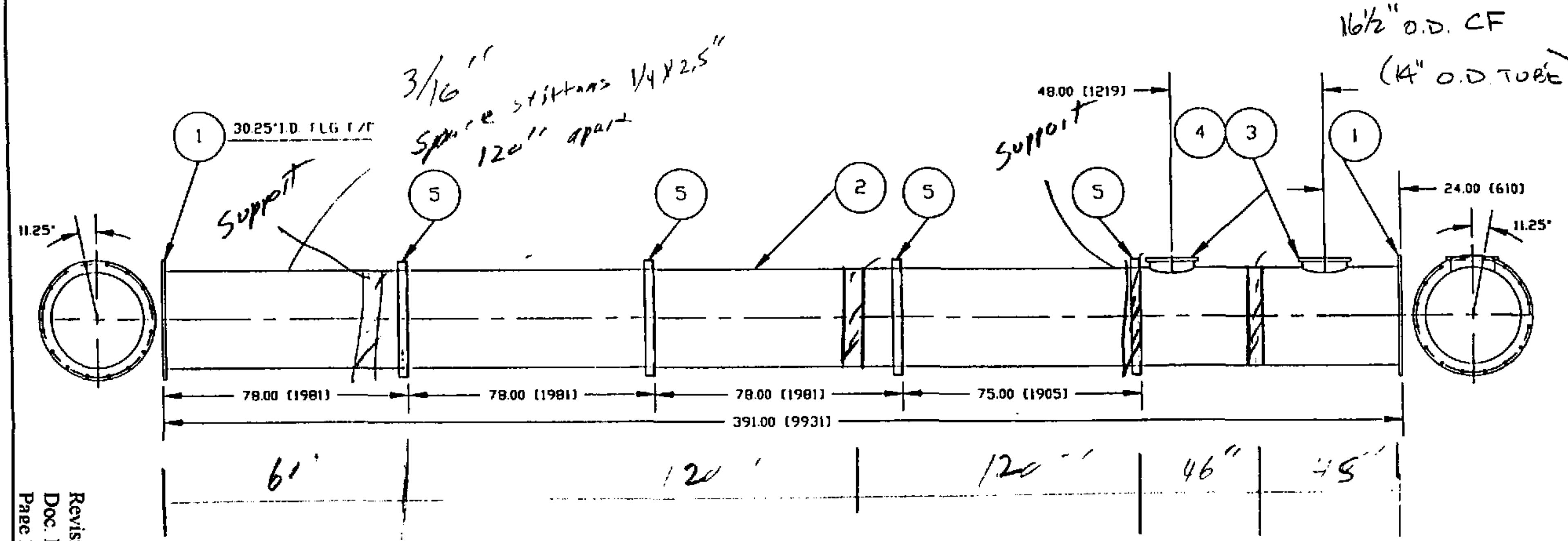
REFERENCES:

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 ±1°
TWO PLACE DECIMAL ± .XX
THREE PLACE DECIMAL ± .XXX
FINISHED SURFACE XXX
BREAK CORNERS .XX OUT-
REMOVE ALL BURRS

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

REV	DESCRIPTION	CHKD	DRWN	DATE	DEO#
X	X		X	X	X

ISSUE DESCRIPTION

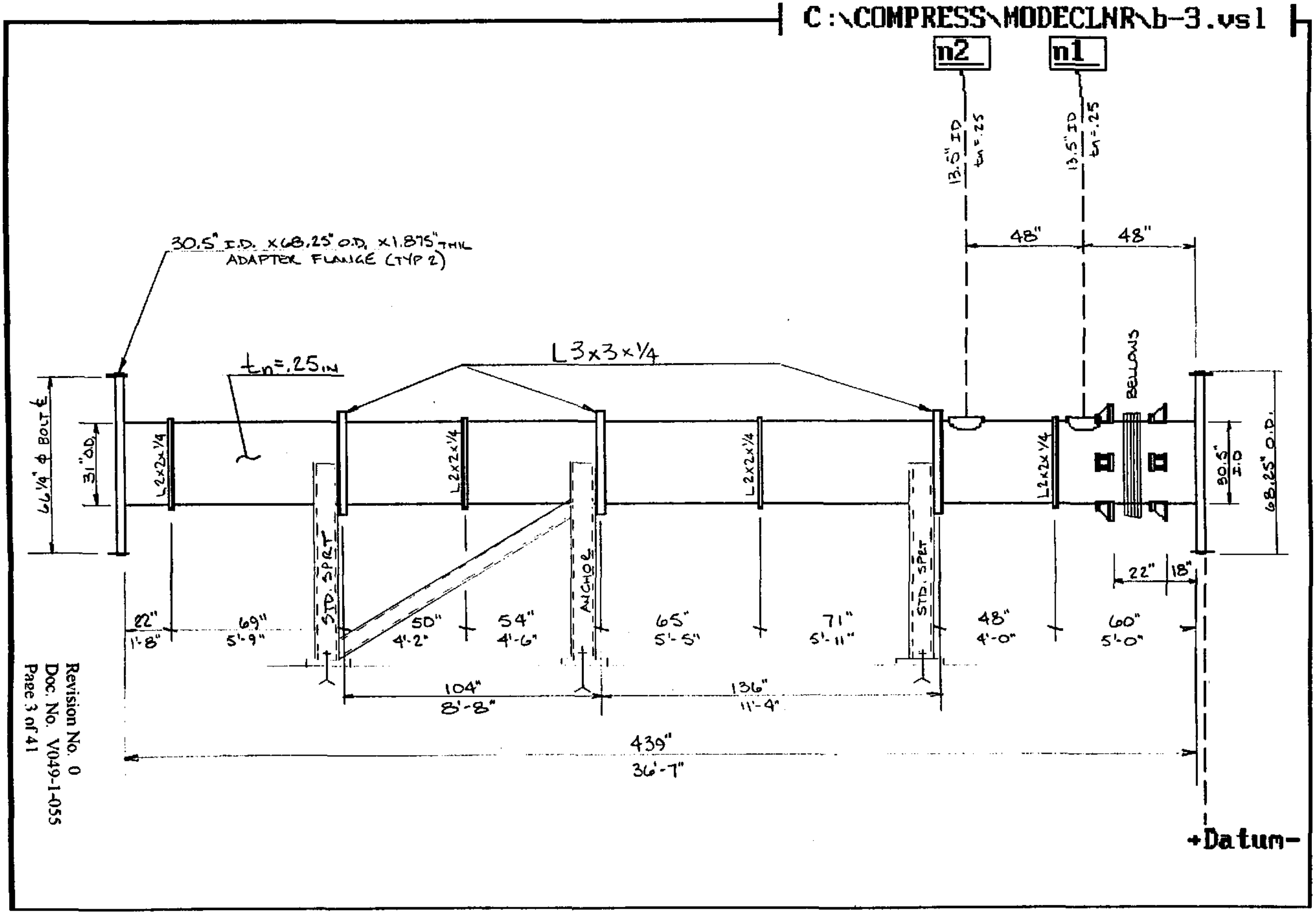
PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

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

Dec 19, 1995 - 10:33:27



C:\COMPRESS\MODECLNR\b-3.vsl
n2
n1
13.5" ID
tn=.25
13.5" ID
tn=.25
48"
48"
30.5" I.D. x 68.25" O.D. x 1.875" THK
ADAPTER FLANGE (TYP 2)
L3x3x1/4
tn=.25IN
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	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											
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 ->|  |<-
                                        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 = .1875 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) = 0.1875 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

16-1/2"od CF

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

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 ->| |
 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= 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

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

16-1/2"od CF

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

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

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

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 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

Refer to Calculation V049-1-044 for final design of 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								
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1A	0.0649	0.223								
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pressure stress*										
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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 18
REV.	DEO #	DATE	BY:	CHECK	TITLE: **SPOOL B-4 (48 in)**	
0	0136	4/23/96	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 5.53.

ASSUMPTIONS:

INPUTS:

1. Vacuum pressure = 14.7 psi
2. Design Temperature = 400 F.
3. Nozzle Loads per Calc 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 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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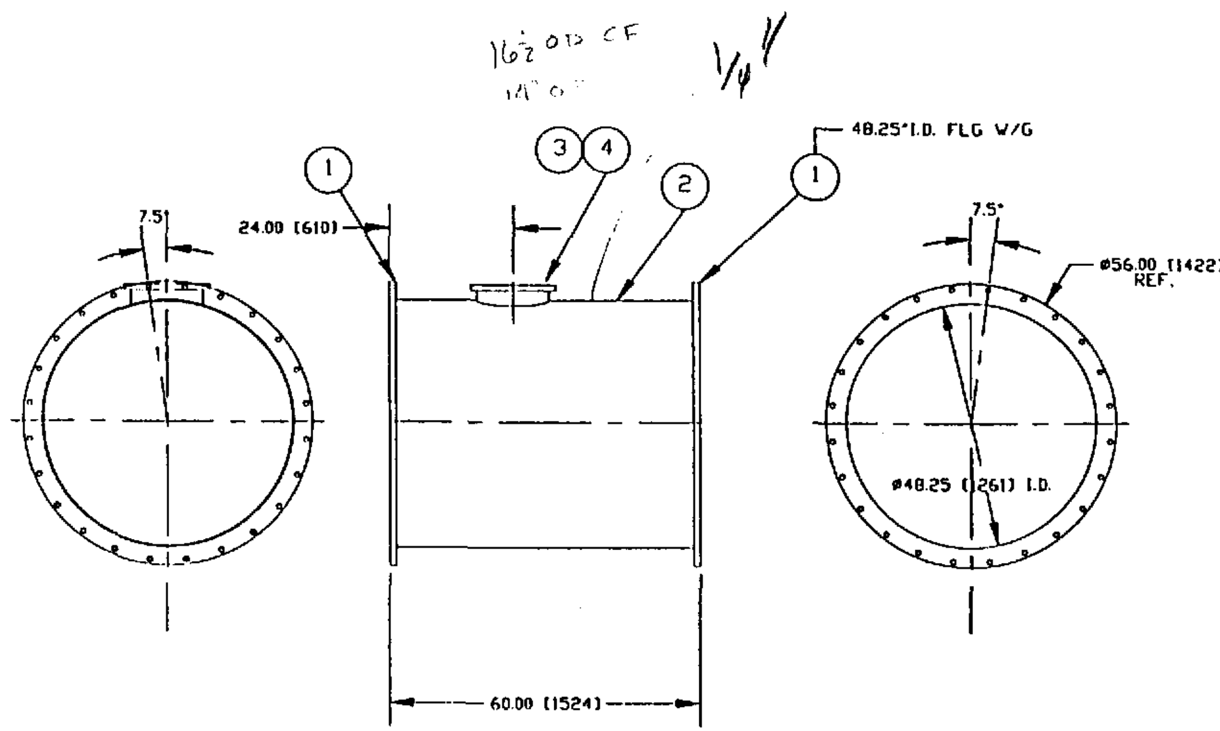

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UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
FINISHED SURFACE
BREAK CORNERS
REMOVE ALL BURRS

DO NOT SCALE THIS DWG.

USED ON

NEXT ASS'Y.

REV	DESCRIPTION	CHKD	DRWN	DATE	DCDD
X	X	X	X	X	X

ISSUE DESCRIPTION

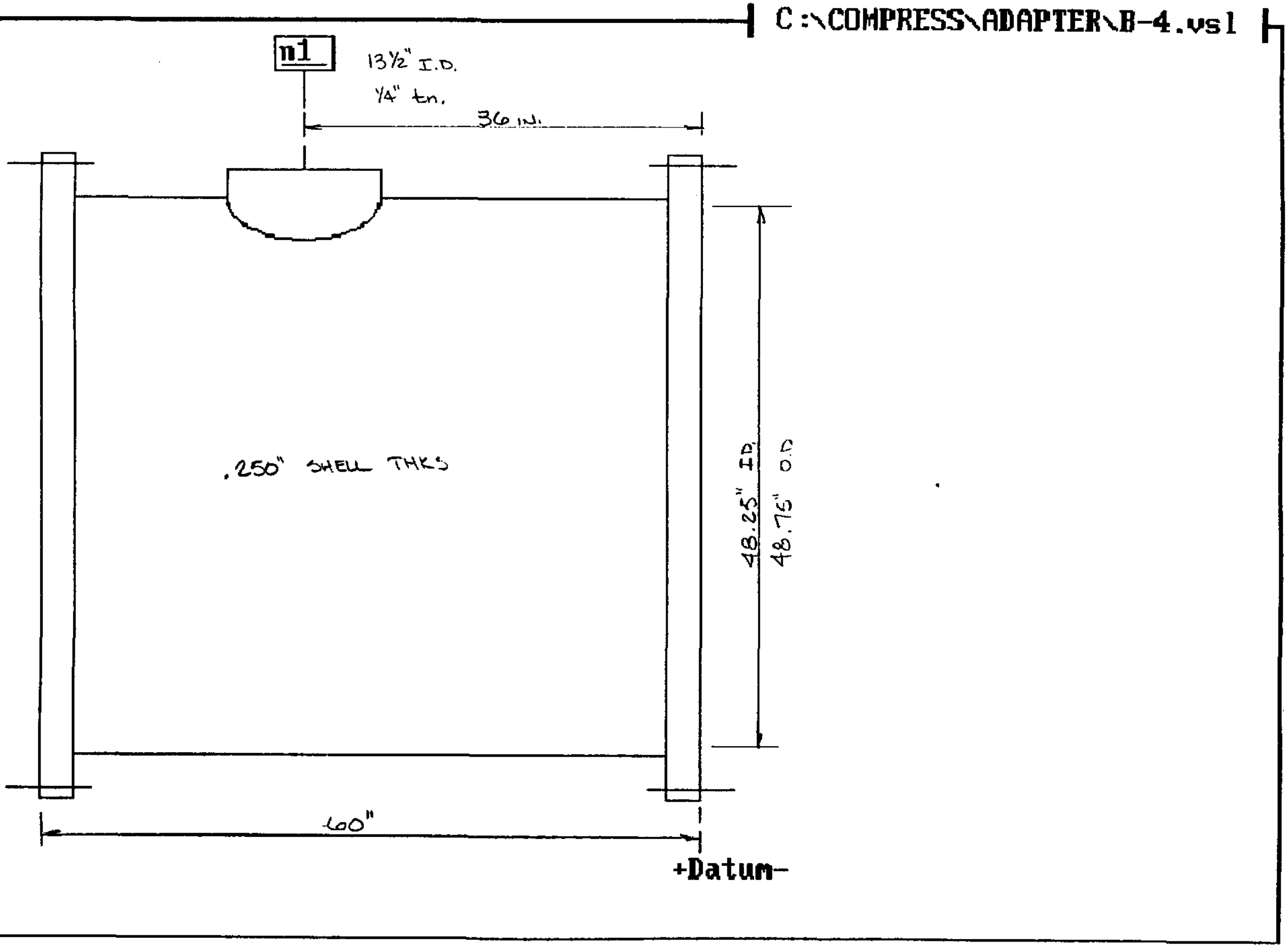
PROCESS SYSTEMS INTERNATIONAL, INC.
30 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

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
n1
13½" I.D.
¼" tn.
36 IN.
.250" SHELL THKS
48.25" ID
48.75" O.D
60"
+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)
Spool B-4	0.0	0.0	146.1	146.1	32.6	1.000		Not applicable	0.000
n1 16-1/2" CF 14"tu	0.0	0.0	0.0	0.0	14.7	1.000		Not applicable	0.000
48.25" id Flange	0.0	0.0	53.4	53.4		1.000		Not applicable	0.000
48.25" id Flange	0.0	0.0	53.4	53.4		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	506	506	0	0	0	0	0	0	0	0	0	0
48.25" id flang	506	506	0	0	0	0	0	0	0	0	0	0
	1675	1675	0	0	0	0	0	0	0	0	3961	9

Weight (lbs) Contributed by Vessel Elements

Vessel operating weight, corroded:	1,684 lbs
Vessel empty weight, corroded:	1,684 lbs
Vessel empty weight, new:	1,684 lbs
Vessel test weight, new:	5,645 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new:	1,684 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	113.1

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
n1	16-1/2" of 14"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-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

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 ->|  |<-
         _        _               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 = .1875 in
_____\|_|_tw2     |_|/_____
          ^
<---- L ---->|                    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

16-1/2" CF 14"tube

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

16-1/2" CF 14"tube

Nozzle required thickness

L/Do = 3/14 = .2143 Do/t = 14/0.02962 = 472.6536
From table G: A = 0.000667
From table HA-3: B = 5233.5

Pa= 4*B/(3*Do/t)
= 4*5233.5/(3*14/0.02962)
= 14.7635 psi

Nozzle required thickness trn = .02962 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 = 0.275 in^2

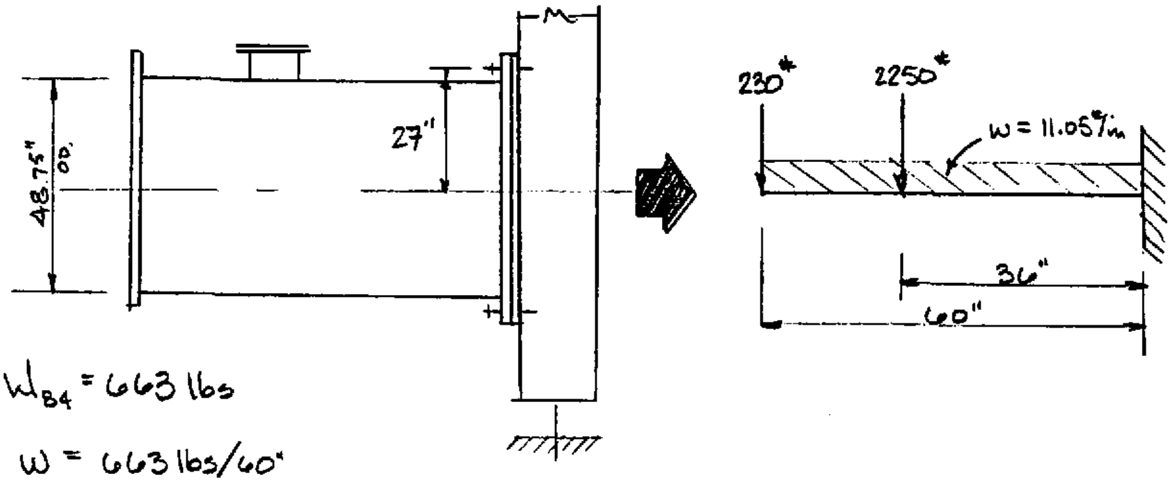
= 5*(tn - trn)*fr2*t
= 5*(0.25 - 0.02962)*1*0.25
= .275 in^2

= 5*(tn - trn)*fr2*tn
= 5*(0.25 - 0.02962)*1*0.25
= .275 in^2

A41 = Leg^2*fr2
= 0.25^2*1 = .063 in^2

Area = A1 + A2 + A41
= 1.003 + 0.275 + 0.063
= 1.341 in^2

Check Bolts @ Gate Valve's Flange Connection



W_{B4} = 663 lbs

w = 663 lbs/60"
= 11.05#/in

$$M = \frac{(11.05\#/in^2)(60\,in)^2}{2} + (2250\text{ lbs})(36\,in) + (230\text{ lbs})(60\,in)$$

M = 114690 in-lbs ⇒ SAY 115000 in-lbs.

Bolts 7/8" φ A307

T_{ALL} = 12000 lbs V_{ALL} = 6000 lbs

Assume all shear & tension @ 1 bolt

$$\text{Tension} = \frac{115000\text{ in-lbs}}{27\text{ in}} = 4259\text{ lbs}$$

$$\text{Shear} = \frac{663\text{ lbs} + 2250\text{ lbs} + 230\text{ lbs}}{1\text{ bolt}} = 3143\text{ lbs.}$$

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.