VOLUME II ATTACHMENTS

ATTACHMENT 2 Part I

LIGO-C960964-01-V

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

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. Bilynsky	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 Criteria

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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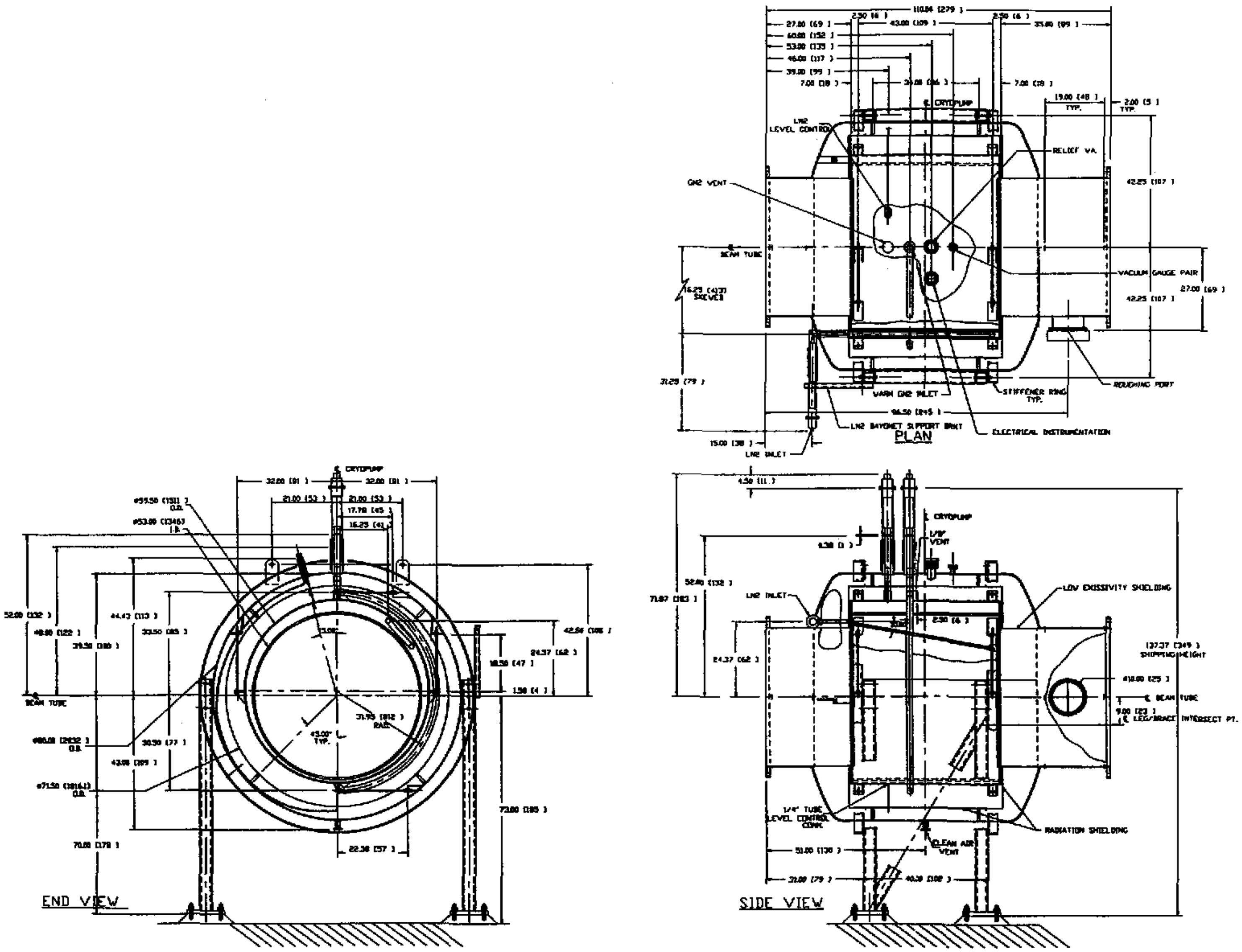

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DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION
REFERENCE DRAWINGS			

DO NOT SCALE THIS DRAWING

REV	DESCRIPTION	CHKD	DRWN	DATE	DECN
P1	PRELIMINARY DESIGN UPDATE		GV	3/8/96	

PROCESS SYSTEMS INTERNATIONAL, INC.

80K CRYO PUMP, SHORT
LIGO VACUUM EQUIPMENT

SIZE: D — DWG. NO.: V049-4-005 — REV.: P1

SHEET 1 OF 1

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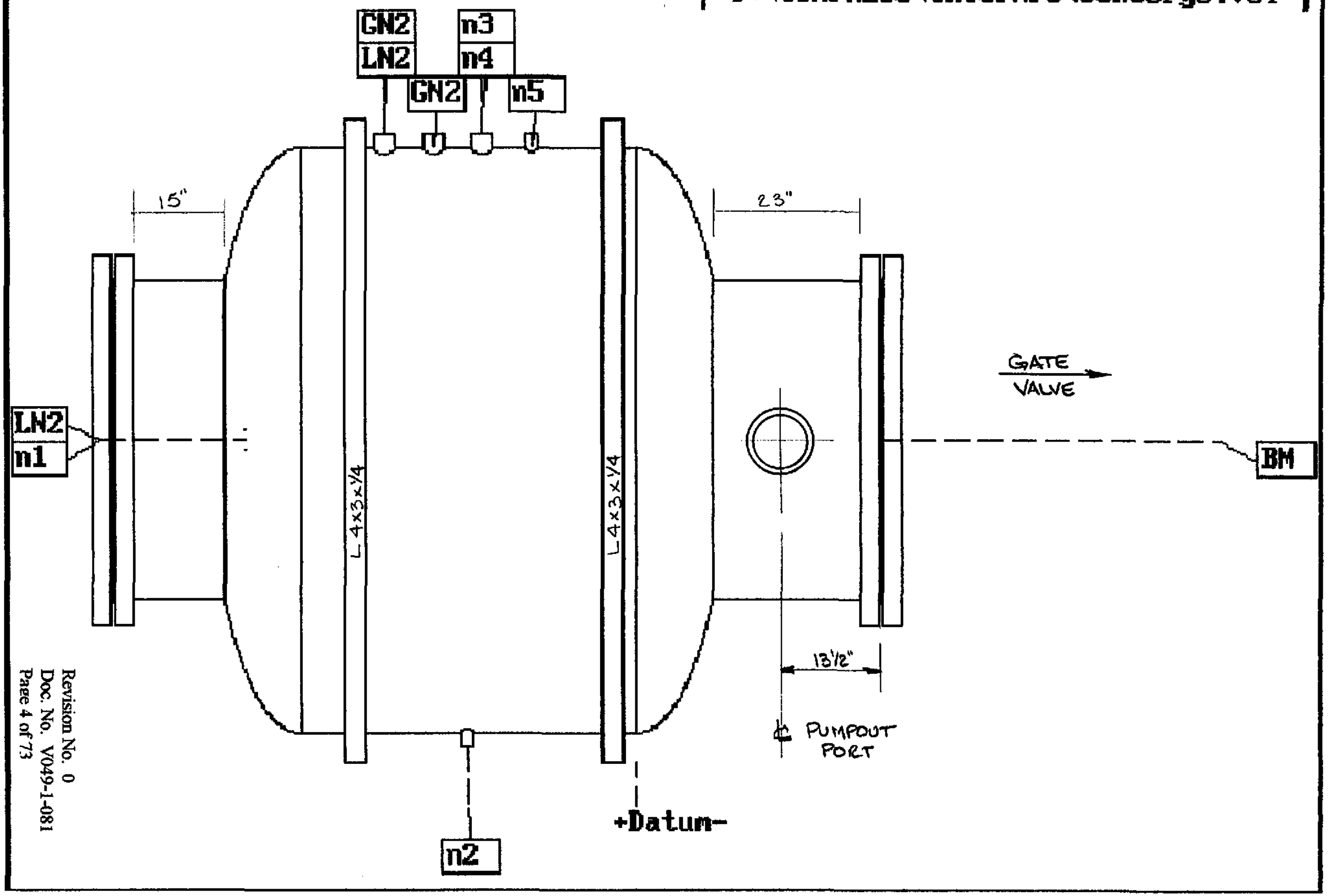

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3.21.1996

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	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
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
BM	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.

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
   tw1->|  |<            |  |       noz thick new tn= .25 in
        |/ |   v         |  |\      nozzle id. new d= 44.625 in
   _____.-| |-           |  |-.____ fillet weld tw1 = .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 ->| |<-
          _          _
         | |<- d ->| |
twl->|   | |<        | |
     |/  | |  v      | |\
 ____.-  | |  --     | |-.____
 _____\|_|_|_tw2     |_|/_____
              ^
<---- R ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .25 in
nozzle id. new d= 44.625 in
fillet weld twl = .25 in
groove weld tw2 = .1875 in

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 ->| |             corrosion allow = 0 in
twl->|  |<|       | |             noz thick new tn= .125 in
     |/ | | v     | |\            nozzle id. new d= 1.5 in
     |  | |       | |             fillet weld twl = .125 in
_____.-| |--      | |-._____      groove weld tw2 = .125 in
_____\|_|_tw2     |_|/______
          ^
<---- L ---->|                    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) = 0.125 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 ->| |<-
                                      corrosion allow = 0 in
         |¯|<- d ->|¯|                noz thick new tn= .125 in
twl->|   |<         | |               nozzle id. new d= 3 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 = 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) = 0.125 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 ->| |<-
        _   _       _  _           corrosion allow = 0 in
       | | |<- d ->| | |           noz thick new tn= .125 in
twl->| | |<        | | |           nozzle id. new d= 3 in
     |/| | v       | | |\          fillet weld twl = .125 in
_____.-| | _       | | |-._____    groove weld tw2 = .125 in
_____\|_|_tw2      |_|_|/_____
            ^
<--- L --->|                       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

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 ->| |<-
                                      corrosion allow = 0 in
       _|<- d ->|_|                   noz thick new tn= .125 in
twl->| |<|        |  |                nozzle id. new d= 2.5 in
     |/ | |  v    |  |\               fillet weld twl = .125 in
_____._| |__      |  |-.______        groove weld tw2 = .125 in
______\|_|_tw2    |_|/______
           ^
<---- 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) = 0.125 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 ->| |<-
         _         _                corrosion allow = 0 in
        | |<- d ->| |               noz thick new tn= .125 in
twl->|  |<|       | |               nozzle id. new d= 1.5 in
     |/ | |   v   | |\              fillet weld twl = .125 in
_____.-_| |--     | |-._____        groove weld tw2 = .125 in
_____\|_|_tw2     |_|/_____
          ^
<---- 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 ->| |
 tw1->| |<          |  \
      |/ |  v       | |  \
______.-|  |  _     | |-.______
______\|_|_tw2      |_|/______
            ^
<---- L ---->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2 in
fillet weld tw1 = .125 in
groove weld tw2 = .125 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) = 0.125 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 ->| |
twl->|   |<|       | |
     |/| | v       | |\
 _____.-| |_      | |-._____
 ______\|_|_tw2   |_|/______
           ^
<--- R --->|
```

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2.375 in
fillet weld twl = .125 in
groove weld tw2 = .125 in

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

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)

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

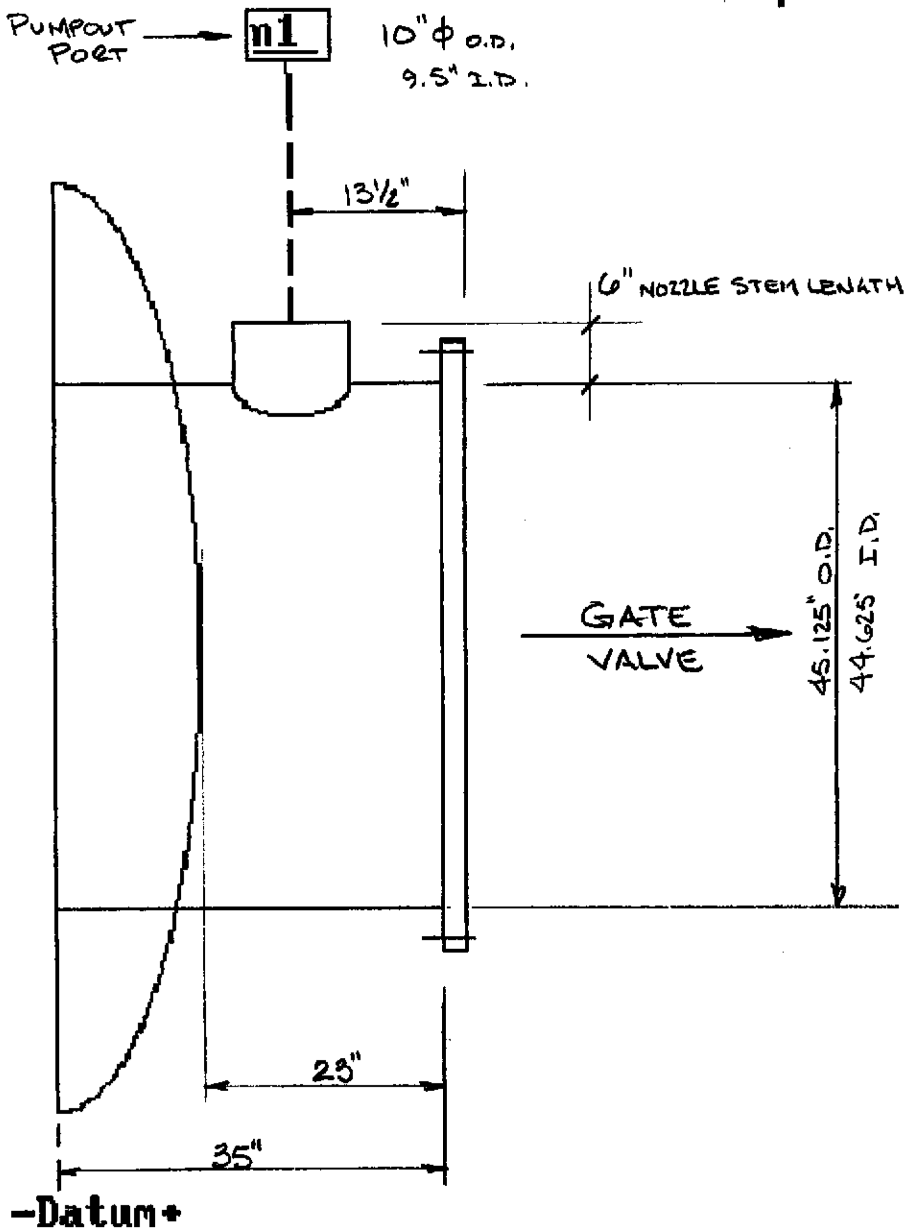
I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.229837*1.669836^2
= 3.435626 in^4

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 ------------------------ Weight (lbs) Contributed by Vessel Elements ----------------------------

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

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

HD 80Ks

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 ->| |<-
                                       corrosion allow = 0 in
         |¯|<- d ->|¯|                 noz thick new tn= .25 in
 twl->| |<|        | |                 nozzle id. new d= 10 in
      |/| |  v     | |\                fillet weld twl = .25 in
 -----.-| |--      | |-.-----          groove weld tw2 = .1875 in
 ------\|_|_tw2    |_|/------
            ^
 <--- 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

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

$= P_R = PA$

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

$= 1155$ lbs

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

WEIGHT OF VALVE = 150 lbs

$g = 0.05625$

$V_L = 150\ lbs\ (0.05625) = 8.4375\ lbs \approx 10\ lbs$

$V_C = 150$ lbs.

M_L

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

$= 28.5625$ 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

REV. O
Doc No. V049-1-081

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. B[illegible]	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 Eq., 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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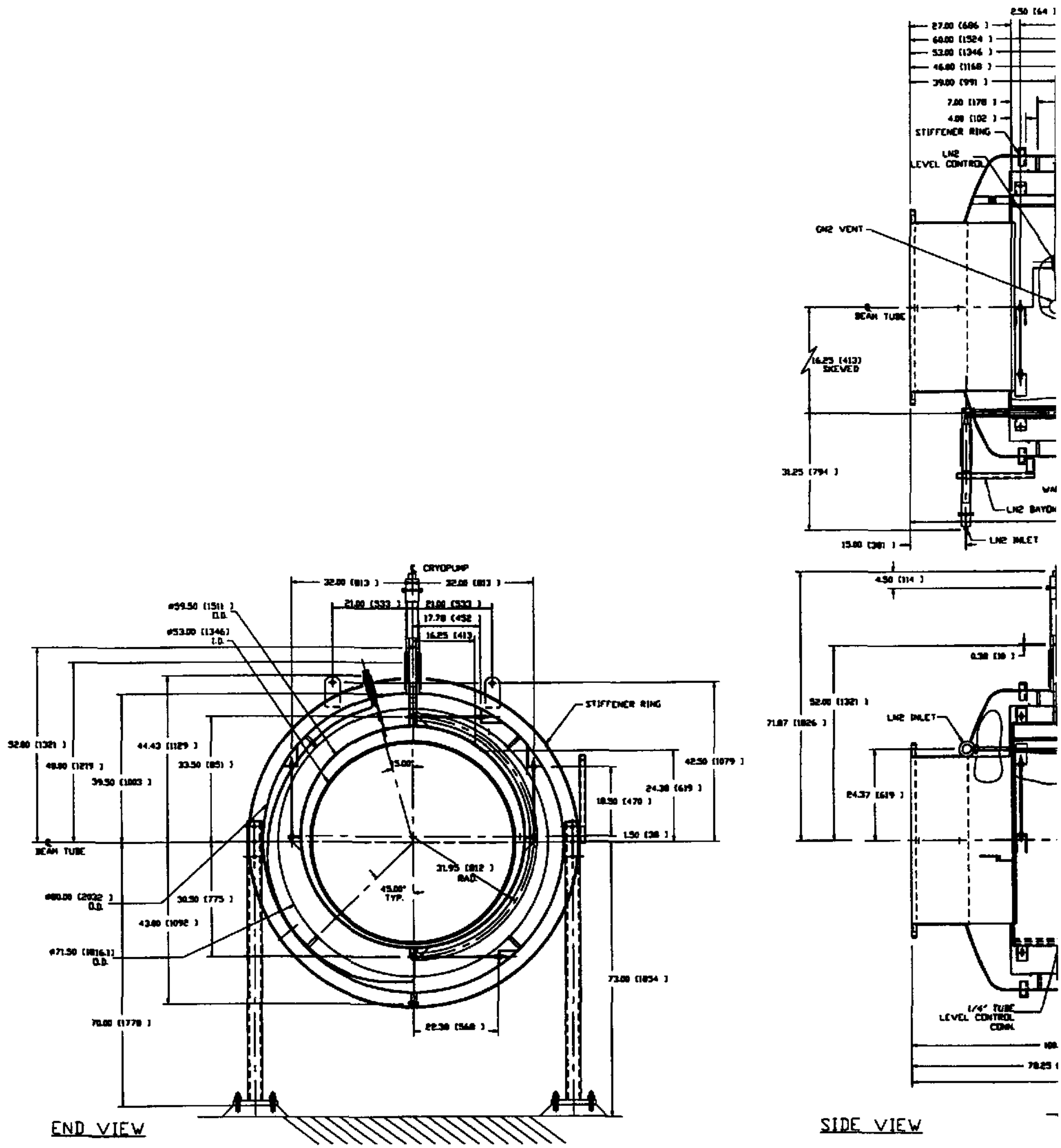

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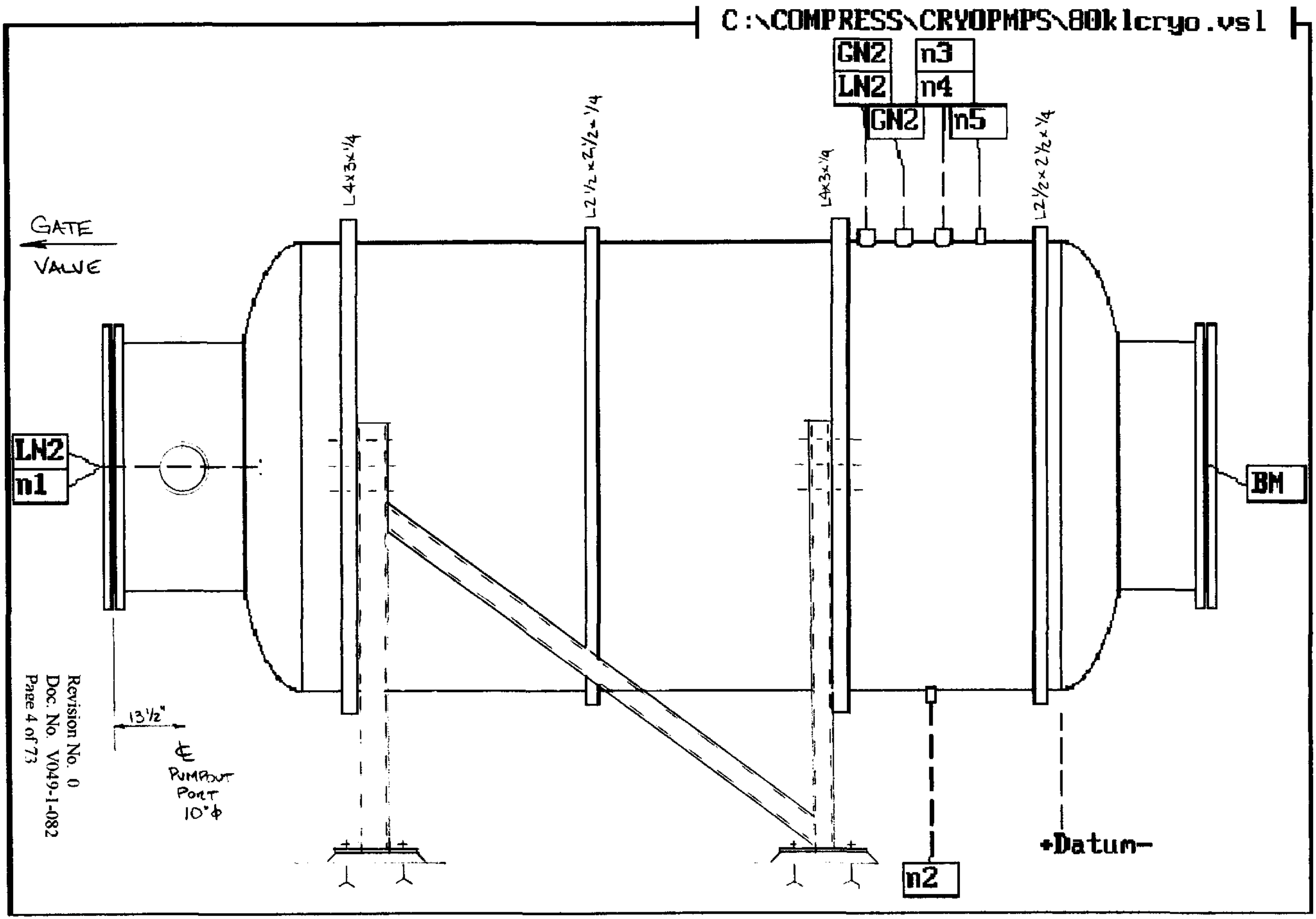
DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION

REFERENCE DRAWINGS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH ...
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005
FINISHED SURFACE ...
BREAK CORNERS ... OUT.
REMOVE ALL BURRS

DO NOT SCALE THIS DRAWING | P1
USED ON | REV
NEXT ASSY.

8 | 7 | 6 | 5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GN2
LN2
n3
n4
GN2
n5
L4x3x1/4
L2 1/2 x 2 1/2 x 1/4
L4x3x1/4
L2 1/2 x 2 1/2 x 1/4
GATE
VALVE
LN2
n1
BM
13 1/2"
℄
PUMPOUT
PORT
10"ϕ
n2
+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)
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.

80KLJACKET

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

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 LFT

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:

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 ->| |<-
         _          _
        | |<- 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 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 ->| |<-
                                      corrosion allow = 0 in
        |‾|<- d ->|‾|                 noz thick new tn= .125 in
twl->| |<                             nozzle id. new d= 3 in
     |/| |  v     | |\                fillet weld twl = .125 in
_____.-| |—       | |-._____          groove weld tw2 = .0875 in
_____\|_|_tw2     |_|/_____
           ^
<—— 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) = 0.0875 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)

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 ->| |<-
                                          corrosion allow = 0 in
          |¯|<- d ->|¯|                   noz thick new tn= .125 in
twl->|    | |<      | |                   nozzle id. new d= 3 in
     |/   | | v     | |\                  fillet weld twl = .125 in
______.-  | |—      | |-.______           groove weld tw2 = .0875 in
______\|_|_|_tw2    |_|/______
              ^
<—— L ——>|                                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

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 ->| |       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

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

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 ->| |
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= 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)

LN2 Lvl Cntrl

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 ->| |<-
                                corrosion allow = 0 in
        |‾|<- d ->|‾|           noz thick new tn= .125 in
twl->|  |<|       | |           nozzle id. new d= 2 in
     |/ | | v     | |\          fillet weld twl = .125 in
_____.-| |—       | |-.______   groove weld tw2 = .0875 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) = 0.0875 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) = .2[illegible] 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:	140.9161 in
Nozzle calculated as hillside:	no
Projection outside vessel I.D.:	0 in

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

```
corrosion allow = 0 in
noz thick new tn= .125 in
nozzle id. new d= 2.375 in
fillet weld twl = .125 in
groove weld tw2 = .0875 in

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(a)(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

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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 = 1.2298[illegible]

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/(1.229[illegible]
= 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 + 1.229[illegible]
= 3.435626 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 2.77 + 1.69*(1.669[illegible]
= 5.265493 in^4

Total available I = I1 + I2 = 8.70[illegible]

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-0[illegible]

Required moment of inertia of the combined ring-shell section

Is= (Do^2*Ls*(t + As/Ls)*A)/10.9
= (80^2*29.22495*(0.2[illegible]
= 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 = 8.701119 in^4

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

Stiffner Rings

...ffening Ring Calculations Per UG 29

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Identifier:		Stiffner Rings
Ring material spec...:		SA 240 304L HIGH
Number of rings in this group:		2
Distance first ring ...:		4 in
Ring spacing:		84 in
Ring description		2.5x2.5x1/4 Equal ...
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
... shell thickness:	ts =	0.25 in
Shell outer diameter:	Do =	80 in
Design temperature:	=	400 deg F
External design pressure:	P =	14.7 psi
... 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 = 1.229... 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/(1.229[illegible] + 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 + 1.229827*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 = 1.2298[illegible]

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/(1.2298[illegible] + 1.19)
= .9382945 in

Inertia of the shell about the combined section NA

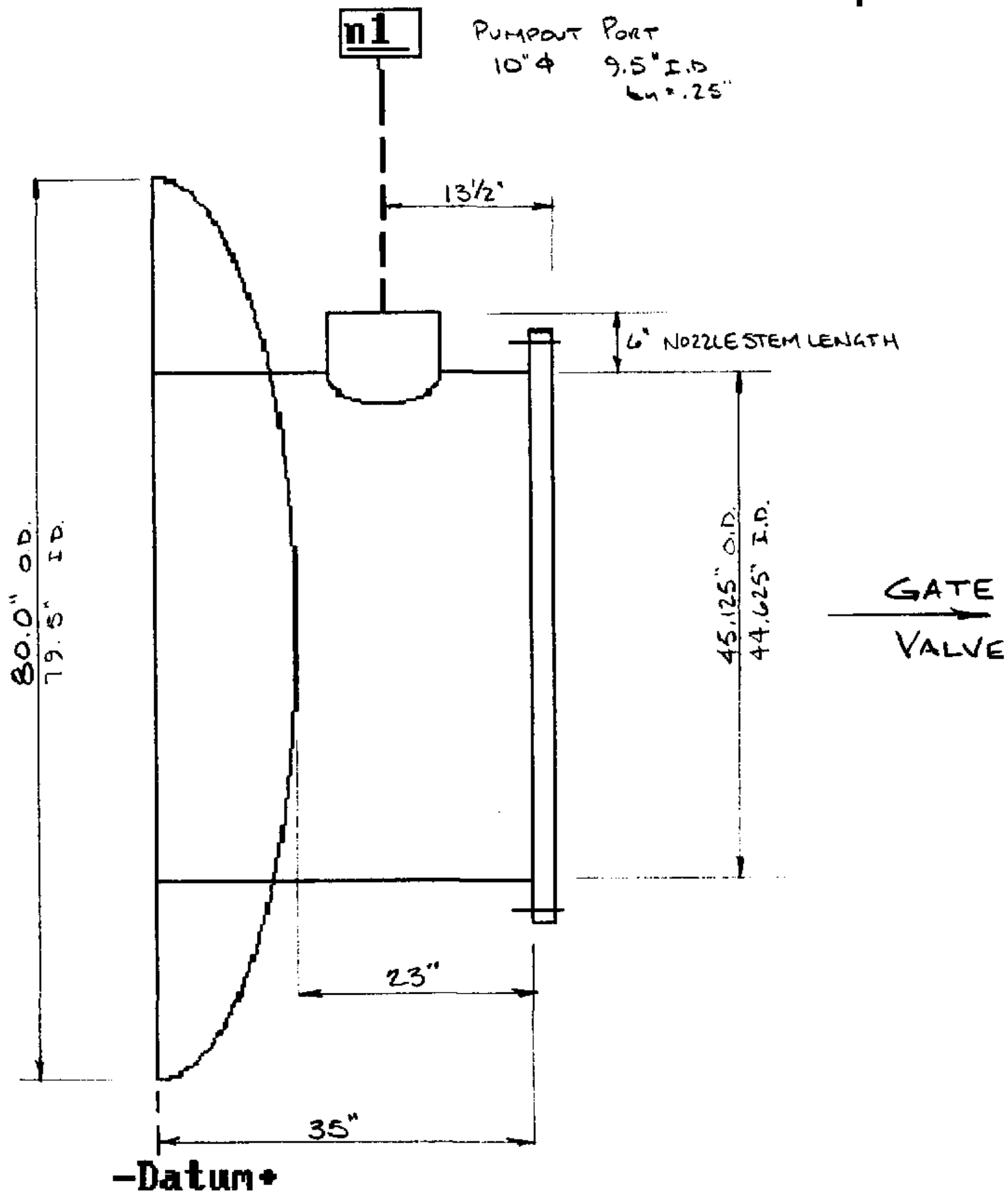
I1 = W*ts^3/12 + A1*NA^2
= 4.91935*0.25^3/12 + 1.22983[illegible]
= 1.08915 in^4

Inertia of the ring about the combined section NA

I2 = Ir + As*(NA - Y2)^2
= 0.703 + 1.19*(0.938[illegible])^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.


n1
PUMPOUT PORT
10"φ 9.5" I.D
tn=.25"
13½"
6" NOZZLE STEM LENGTH
80.0" O.D
79.5" I.D
45.125" O.D.
44.625" I.D.
GATE VALVE
23"
35"
-Datum+

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

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

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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

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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
 tw1->| |<        | |            noz thick new tn= .25 in
      |/| |  v    | |\           nozzle id. new d= 10 in
 _____.-| | --    | |-._____     fillet weld tw1 = .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

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 = 10.5/0.05468 = 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" PUMPOOT PORT

$PR = 1155$ lbs. = UNBALANCED FORCE

$\Rightarrow PR = PA$
$= (14.7^{\#}/in^2)(\pi\,(10_{in}\,\phi)^2/4)$
$= 1155$ lbs.

$M_C =$ M.A. X VLV. WEIGHT

$= 6'' \times 150^{\#} = 900$ in-lbs $= 75$ FT-lbs.

$M_L = M.A. \times (\text{VLV WEIGHT} \times G_{FORCE})$

$= M.A. \times (150\,lbs \times 0.05625\,g)$

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

$\therefore M_L = (28.5625\,in)(150\,lbs \times 0.05625\,g)$
$\cong (28.5625\,in)(10\,lbs) = 285.625\,in\text{-}lbs$
$= 23.8$ FT-lbs.

$V_C =$ WGHT OF VLV

$= 150$ lbs

$V_L = (\text{WGHT OF VLV})(g)$

$= 150\,lbs\,(0.05625\,g)$

$\cong 10$ lbs

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 CRYOPUMPS
LONG & SHORT

MATERIAL FOR PUMP RESERVOIR IS 6061 ALUMINUM

GEOMETRY OF RESERVOIR

INNER SHELL

ID = 53 in

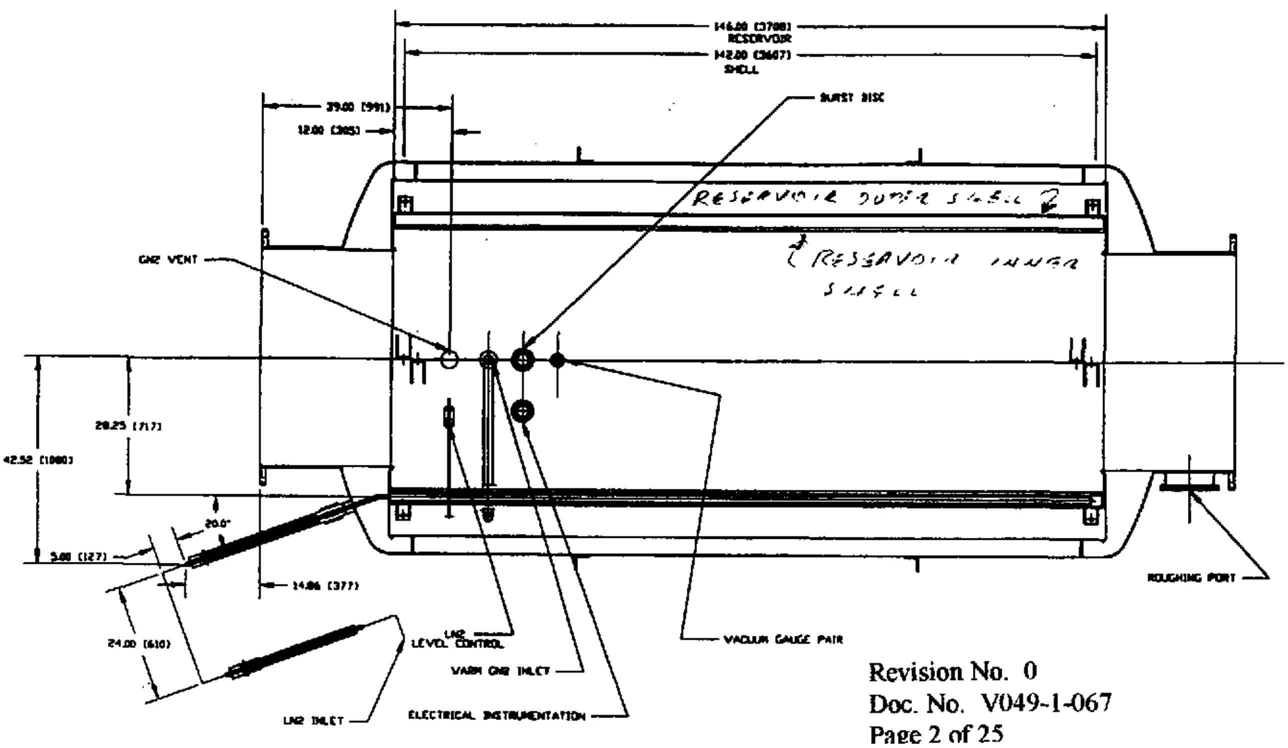
t .625 in (LONG & SHORT)

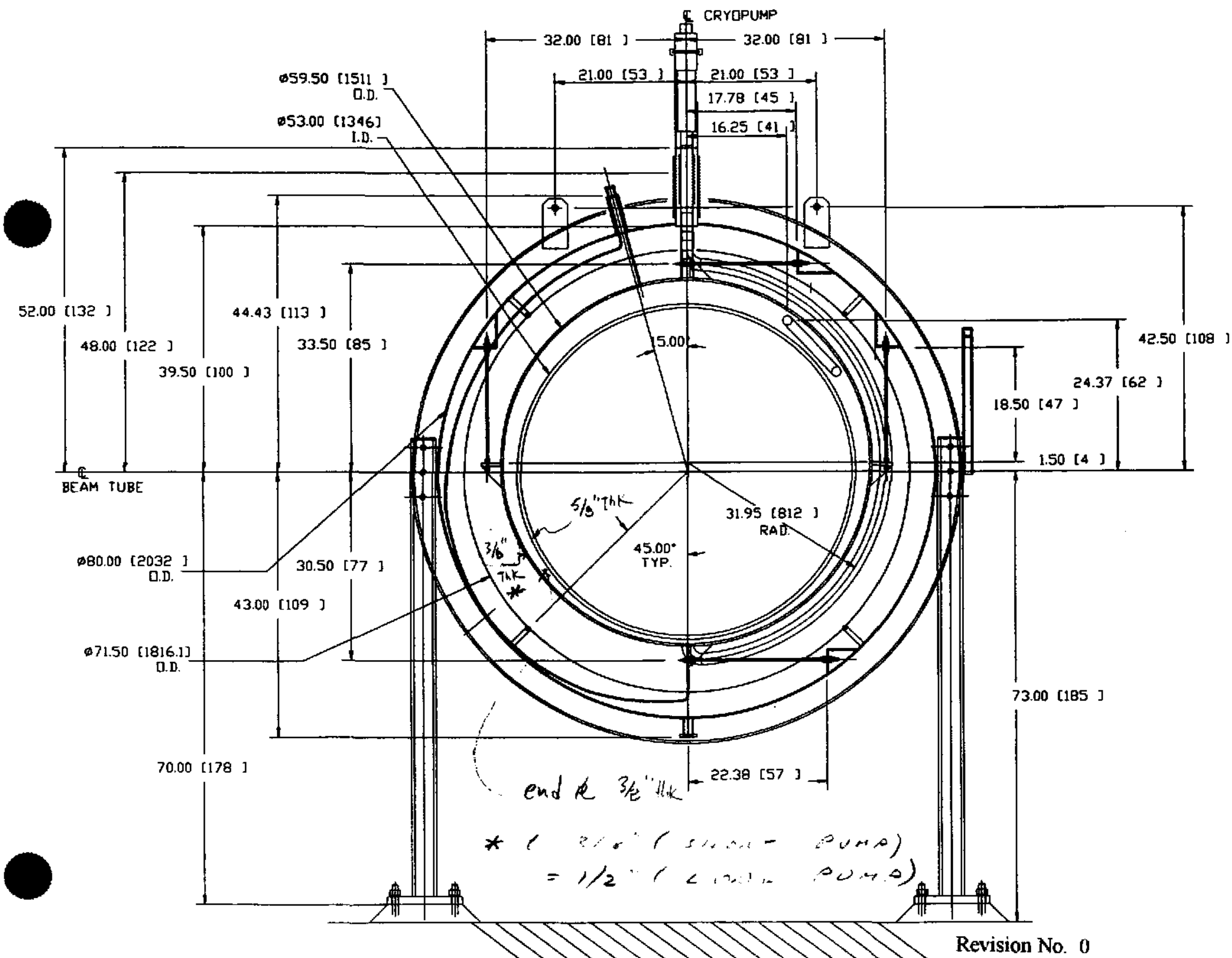
OUTER SHELL

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
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]

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 = [illegible] 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

$E = 8.7(10)^6$ @ [illegible]

$= 11.1(10)^6$ @ -325 °F

Ref: Table TM-2, Part D, Sec 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

Rev 0

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

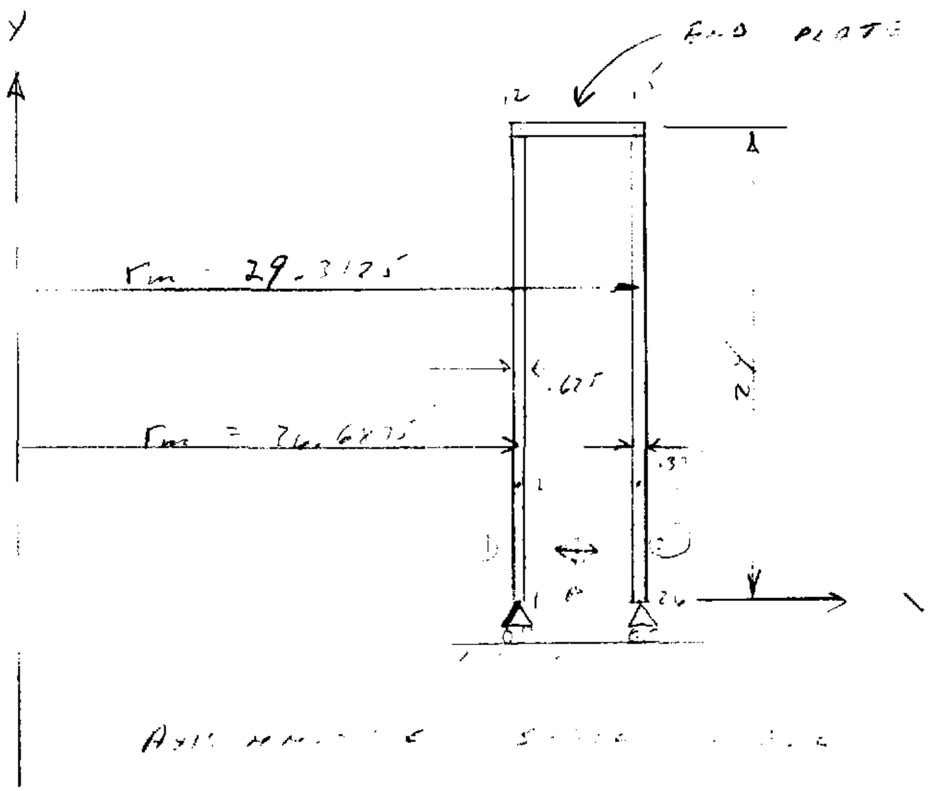
Outer Alum Cyl

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

TANKS MODEL FOR DISCONTINUITY
AT ENDS OF ALUMINUM PUMP RESERVOIR



AXISYMMETRIC [illegible]

PRESSURE

$P = 37$ psi (PRELIM CASE)*

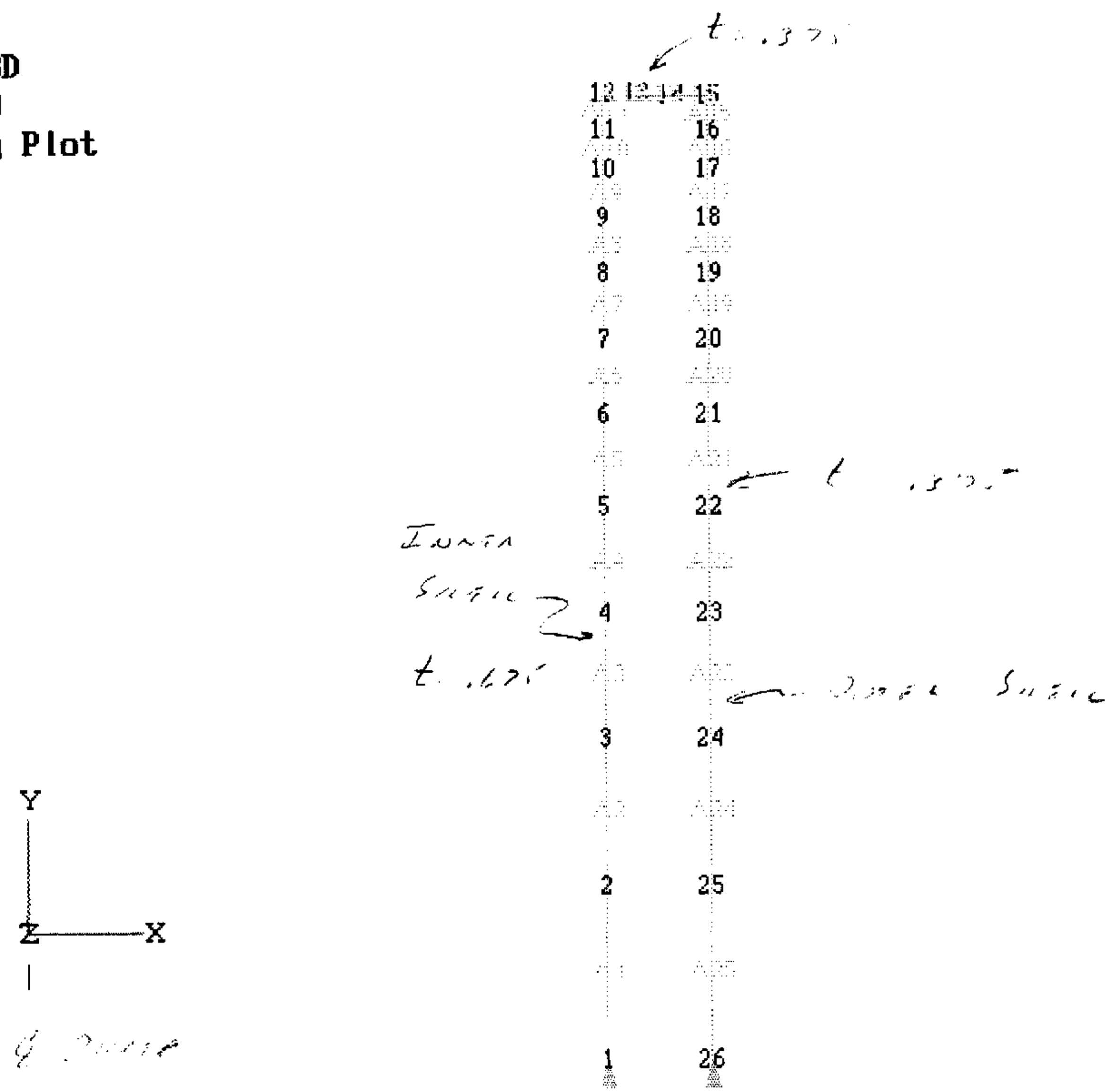
FINAL $P = 6$ psi BUT
$P = 37$ OK TO EVALUATE END PLATE

2Y [illegible] AVERAGE TO EVALUATE DISCONTINUITY

NOTE: [illegible] OUTER SHELL MODELED TO BOUND PROBLEM.

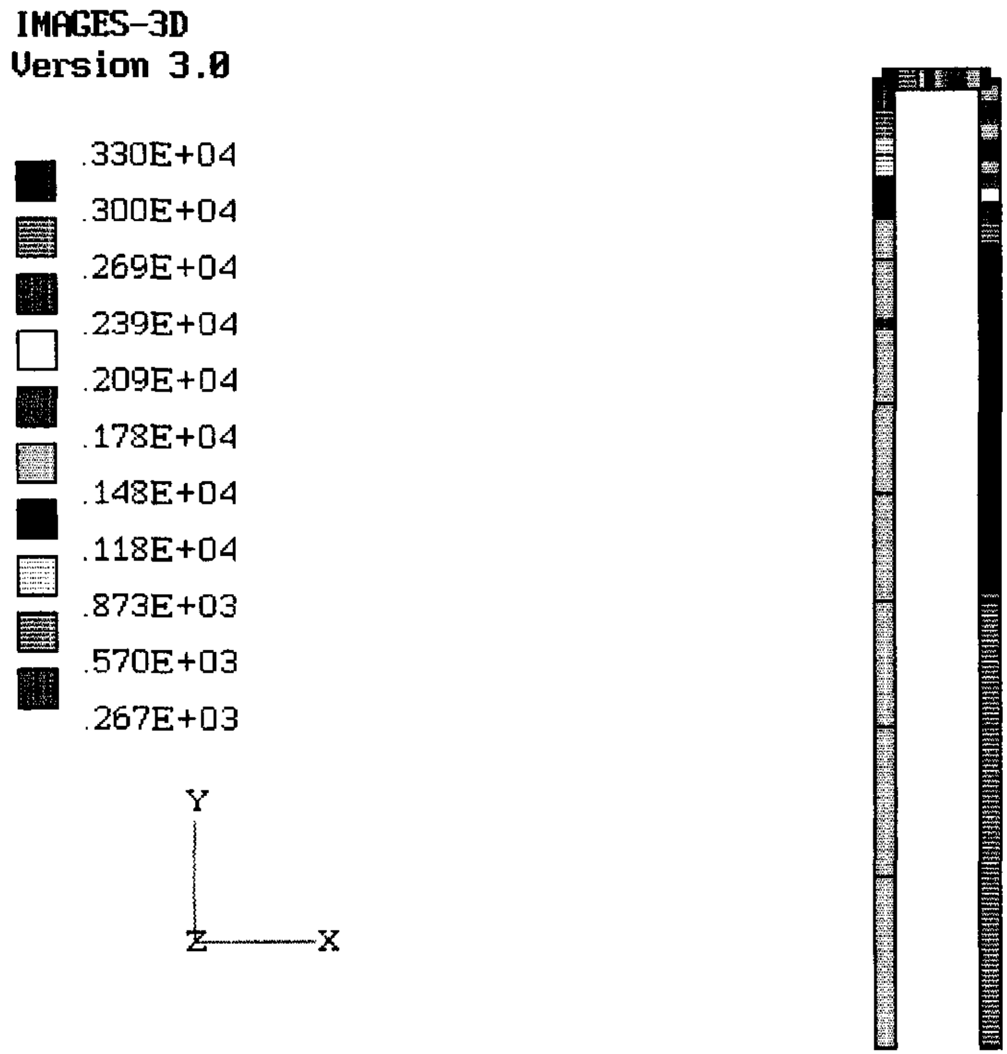
* MODEL COMPARED TO PRELIM CONFIGURATION BUT IT IS VALID TO SHOW THAT DISCONTINUITY STRESSES ARE ACCEPTABLE AT END PLATE.

IMAGES-3D
Ver. 3.0
Geometry Plot



80k cryopump - short
Wireframe Plot

12/19/95
9: 0:33



Load Case 1 | Stress Contour Plot | Surf: Bottom | Stress Intensity | 2/14/96 8:10: 7

OUTER SHELL HOOP TENSILE STRESS

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

$$= \frac{21(25.3125)}{.3125}$$

$$= [illegible] \text{ psi}$$

AGREES W/ [illegible]

INNER SHELL HOOP COMPRESSIVE STRESS

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

$$= -15[illegible] \text{ psi}$$

AGREES W/ [illegible]

FROM PLOT, MAX SI = 3.3 KSI

$< 1.5 S$

$= 1.5(3.5)$

$= 5.75$ 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: [redacted]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, Dave McWilliams, Tom Starr, Dick Curtis, Paul Hendry, Stu Motew, Walt Bilynsky, Art Roussopoulos, Roberto Than, Steve Toth, Lynne Long/Project File

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-070 / PAGE 1 OF 34
REV.	DEO #	DATE	BY:	CHECK	TITLE: 80k Cryopump Reservoir Support Rods and Brackets	
0	0293	7/18/96	RDC	WDB		
					BY: R. D. Ciatto	DEPT.: 744
PROJECT: LIGO Vacuum Equipment					PROJECT NO: V59049	

PURPOSE: Design Support Rods and Brackets for the long and short aluminum reservoirs of the 80k croypumps.

METHOD: Hand calculation methods.

ASSUMPTIONS: See attached.

INPUTS: LIGO project drawings and sketches.
Cryopump drawings V049-4-004 and V049-4-005.

REFERENCES:
1. ASME Boiler & Pressure Vessel Code, Section III, Div. 1, Subsection NF, Component Supports for buckling rules of stainless steel rods.
2. WRC 107, Local Stresses in Shells.
3. Doc. No. V049-1-066, Structural Design Criteria.

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: Design Criteria are met for the reservoir supports. Permanent support rods result in a fundamental natural frequency of the reservoir/support rod system which is less than 10 hz. This ensures vibration isolation for the pump shell.

NOTES:

TABLE OF CONTENTS

1. - <u>SCOPE:</u>

- 80K LONG PUMP
- SUPPORT DESIGN FOR INTERNAL CYLINDERS

2. - <u>DESIGN CRITERIA:</u>

- T = 400°F
- SEISMIC LOAD = .05625 g LATERAL ONLY - SINGLE DIRECTION

3. - <u>MATERIALS:</u>

- CYLINDERS / RAD SHIELD
  - ALCAD 6061 T6 / SB 209
- SUPPORT RODS
  - A 479 TYPE 304 L
- <u>PHYSICAL PROPERTIES:</u>
  - <u>ALCAD 6061 T6 / SB 209:</u>

    DENSITY = .098 #/IN^3 (REF: ASME II, PART D, TABLE NF-2)
    E = 8.7×10^6 PSI (REF: ASME II, PART D, TABLE TM-2)

  - <u>A 479 TYPE 304L</u>

    E = 26.5×10^6 PSI (REF ASME II, PART D, TABLE TM-1)

  - <u>LIQUID NITROGEN</u>

    DENSITY = 50.4 #/FT^3 (REF: MARKS, P. 18-36

4. - <u>ALLOWABLE STRESSES: (REF: ASME II, PART D)</u>

- <u>ALCAD 6061 T6 / SB 209</u>

  S AT 400°F = 3,500 PSI
  S_y AT 400°F = 13,300 PSI

- <u>A 479 TYPE 304 L</u>

  S AT 400°F = 14,700 PSI
  S_y AT 400°F = 17,500 PSI

5. - DEADWEIGHT CALC

- OUTER CYLINDER: 59.5" OD × 58.5" ID × 146" LG

  $V = \pi/4 (59.5^2 - 58.5^2)(146) = 13{,}531 \text{ IN}^3$

  $W_T = 13{,}531 \times .098 = 1{,}326\#$

- INNER CYLINDER: 54 1/4" O.D × 53" ID × 146" LG

  $V = \pi/4 (54.25^2 - 53^2)(146) = 15{,}373 \text{ IN}^3$

  $W_T = 15{,}373 \times .098 = 1{,}507\#$

- END CAPS - 3/8" THK END CAP
  59 1/2" OD × 45 1/8" ID × 3/8" THK - QTY 2

  $V = 2 \times \pi/4 (59.5^2 - 45.125^2)(.375) = 886 \text{ IN}^3$

  $W_T = 886 \times .098 = 87\#$

- RAD SHIELD: (SUPPORTED BY ...)

  - CYLINDER: 71 1/2" OD × .060" THK × 146" LG

    $V = \pi(71.5)(.06)(146) = 1{,}968 \text{ IN}^3$

    $W_T = 1968 \times .098 = 193\#$

  - END CAPS - 71 1/2" OD × 45 1/8" ID × .060" THK
    QTY 2

    $V = 2 \times \pi/4 (71.5^2 - 45.125^2)(.060) = 145 \text{ IN}^3$

    $W_T = 145 \times .098 = 14\#$

- PIPING: 1 1/2" (ASSUME SCH 160) OD = 1.9", ID = 1.338"

  PIPE LENGTH: $L_{PIPE} = 1/2\, \pi(64) + 2.25 + 18.5 + 20.75 = 142"$

  $V = \pi/4 (1.9^2 - 1.338^2)(142) = 203 \text{ IN}^3$

  $W_T = 203 \times .098 = 20\#$

5. – CON'T

- LIQUID NITROGEN

  - CYLINDERS ANNULUS: 59.5" I.D. X 54¼" OD X 146" LG

    $V = \pi/4\,(59.5^2 - 54.25^2)(146) = 68{,}478\ IN^3$

    $W_T = (68478\ /1728)(50.46) = 2{,}000\#$

  - PIPE: 1.9" OD X 1.338" ID X 142" LG

    $V = \pi/4\,(1.338^2)(142) = 200\ IN^3$

    $W_T = (200/1728)(50.46) = 6\#$

- TOTAL WEIGHT:

  $\Sigma W_T = 1326 + 1507 + 87 + 193 + 14 + 20 + 2000 + 6 =$

  $\Sigma W_T = 5153 \longrightarrow 5200\#$ FOR DESIGN*

6. – ROD SUPPORT SIZING – A487 TYPE 304L

6.1 • VERTICAL SEISMIC ROD SIZING – QTY 4 RODS

$\sigma = F/A$; $A = F/\sigma$; $\pi/4\,D^2 = F/\sigma$

$$D = \sqrt{\frac{4}{\pi}\left(\frac{F}{\sigma}\right)} = \sqrt{\frac{4}{\pi}\left(\frac{1300}{14{,}700}\right)} = .3356"$$

WHERE: $F = \Sigma W_T/4 = 5{,}200/4 = 1300\#$

$\sigma = 14{,}700$ PSI AT 400°F

ROOT DIA FOR A ½" - 20 UNF THREAD IS .435" (REF: B1.1) > .3356" REQ. ∴ OK

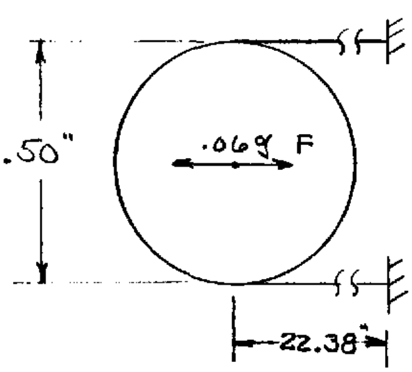
∴ SPECIFY ½" OD ROD WITH ½-20 UNF THDS. FOR VERTICAL SUPPORT

NOTE: VERTICAL SUPPORT LOADING IS TENSILE ONLY ∴ NO BUCKLING.

* SAY WT = 5000 W/O RAD. SHIELD

6.2 – LATERAL SEISMIC ROD SIZING

6.2.1 • TRANSVERSE - QTY 4 RODS



LOAD PER ROD

$F = (\Sigma W / 4) .06$

$F = (5200/4)(.06) = 78^{\#}$

REF: ASME III, NF 3322 C (2) :, P.62

• $\frac{KL}{r} = \frac{(1.0)(22.38)}{.1257} = 178 > 120$ ∴ EQ 6b OF NF 3322.1 APPLIES

WHERE: K = 1.0 (PIVOT BOTH ENDS)

$r = \sqrt{I/A} = \sqrt{(.0031)/(.1963)} = .1257"$

$I = \pi/64 (.5)^4 = .0031 IN^4$

$A = \pi/4 (.5)^2 = .1963 IN^2$

• ALLOWABLE STRESS PER EQ. 6b:

EQ. 6b: $F_a = S_y \left(.40 - \frac{KL/r}{600} \right)$

$F_a = 17{,}500 \left(.40 - \frac{178}{600} \right) = 1{,}808 PSI$

• ACTUAL CALCULATED STRESS,

$\sigma = \frac{F}{A} = \frac{78}{.1963} = 397$ PSI < 1,808 PSI ∴ OK

• TRY 3/8" OD ROD FOR LATERAL SUPPORT.

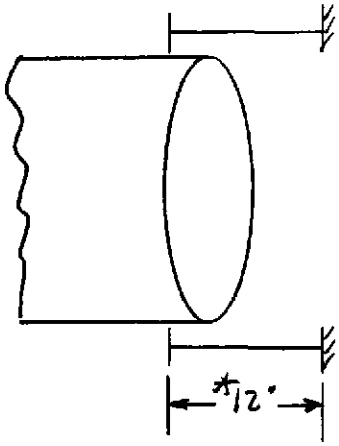
$F_a = 17{,}500 (.40 - 238.7/600) = 38 PSI < 438 PSI$ ∴ N.G.

WHERE: NEW $KL/r = (1)(22.38)/.0937 =$

$r = \sqrt{(\pi/64)(.375)^4/(\pi/4)(.375)^2} = .0937"$

CONCLUSION: 1/2" DIA DIA ROD IS REQUIRED FOR BOTH VERTICAL + LATERAL SUPPORT.

6.2.2 - AXIAL - QTY 2 RODS



LOAD PER ROD:

$F = (5200/2)(.06) = 156^{\#}$

* ASSUMED LENGTH

- $\frac{KL}{r} = \frac{(1.0)(12)}{.1257} = 95.5 < 120$ ∴ EQ 6a OF NF3322.1 APPLIES

- ALLOWABLE STRESS PER EQ 6a:

EQ. 6a: $F_a = S_y\left(.47 - \frac{KL/r}{444}\right)$

$$F_a = 17{,}500\left(.47 - \frac{95.5}{444}\right) = 4461 \text{ PSI}$$

- ACTUAL CALCULATED STRESS:

$\sigma = \frac{F}{A} = \frac{156}{.1963} = 795 \text{ PSI} < 4461 \text{ PSI}$ ∴ OK

7.0 ROD SIZE CHECK FOR SHIPPING REQUIREMENTS

- SHIPPING REQUIREMENTS – REF DOC. NO. V049-1-066

SHIPPING ACCELERATION:

- VERTICAL – 1.0 G
- HORIZONTAL – 0.5 G

7.1 SHIPPING WEIGHT

- NEW CYLINDER DEADWEIGHT WITH NO NITROGEN (EMPTY WHEN SHIPPING)

TOTAL WT. WITH N_2: = 5200#

NEW WT. WITHOUT N_2: = 5200 – 2000 = 3200#

7.2 SEISMIC LOADS

- VERTICAL: $F_{VS} = 1.0(3200) = 3200\#$
- HORIZONTAL: $F_{HS} = .5(3200) = 1600\#$

7.3 VERTICAL RODS – QTY 4 RODS L=18.5"

– SHIPPING LOAD = $F_{DW} + F_{VS} = 3200 + 3200 = 6400\#$

– LOAD PER ROD = $6400/4 = 1600\#$

7.3.1 • TENSILE SHIPPING STRESS:

$$\sigma_{ST} = \frac{F}{A_R} = \frac{1600}{.1257} = 12{,}729 \text{ PSI} < 16{,}700 \text{ PSI} \therefore \text{OK}$$

WHERE: S ALLOWABLE AT 100°F = 16,700 PSI FOR 304L

$A_R = .1257 \text{ IN}^2$ – ROOT AREA FOR 1/2-13 THD

7.3.2 • BUCKLING STRESS IF CYL IS SHIPPED UPSIDE DOWN

$KL/r = (1.0)(18.5)/.1257 = 147 < 120 \therefore$ EQ. 6b APPLIES

$F_a = 25{,}000(.40 - 147/600) = 3875 \text{ PSI}$

ACTUAL: $\sigma_{ACT} = 6400/.196 = 32{,}595 \text{ PSI} >>> 3875 \text{ PSI} \therefore$ N.G.! (← 1600 #/ROD)

$= \frac{1600}{.196} = 8160 \text{ psi} > 3875$

7.4 LATERAL SEISMIC LOADS

7.4.1 - TRANSVERSE LATERAL - QTY 4 RODS

- SHIPPING LOAD = F_{HS} = 1600#

- LOAD PER ROD = 1600/4 = 400#

L = 22.38"

$\frac{KL}{r} = \frac{1.0\,(22.38)}{.1257} = 178 > 120$ ∴ 6b OF NF3322.1 APPLIES

• ALLOWABLE STRESS PER EQ. 6b:

EQ. 6b: $F_a = S_y\left(.40 - \frac{KL/r}{600}\right)$

$F_a = 25000\left(.40 - \frac{178}{600}\right) = 2{,}583$ PSI

• ACTUAL SHIPPING STRESS:

$\sigma = \frac{F}{A} = \frac{400}{.1963} = 2{,}038$ PSI $< 2{,}583$ PSI ∴ OK

WHERE: S_y AT 1000°F = 25,000 PSI FOR 304L

A = .1963 IN³ - TENSILE / COMPRESSIVE AREA FOR ½ DIA ROD

7.4.2 - AXIAL LATERAL - QTY 2 RODS

- LOAD PER ROD = 1600/2 = 800#

L = 12" (ASSUMED LENGTH)

$\frac{KL}{r} = \frac{1.0\,(12)}{.1257} = 95.5 < 120$ ∴ EQ. 6a OF NF3322.1 APPLIES

• ALLOWABLE STRESS PER EQ. 6a:

EQ. 6a: $F_a = S_y\left(.47 - \frac{KL/r}{444}\right)$

∴ $F_a = 25000\left(.47 - \frac{95.5}{444}\right) = 6{,}373$ PSI

7.4.2 CON'T

• ACTUAL SHIPPING STRESS

$$\sigma = \frac{F}{A} = \frac{800}{.1963} = 4{,}075 \text{ PSI} < 6370 \text{ PSI} \therefore OK$$

8. - MANUFACTURING BUCKLING LOADS

8.1 - TIP SHELL/CYLINDER ASSEMBLY UPSIDE DOWN SUBJECTING VERTICAL RODS TO DEADWEIGHT BUCKLING - QTY 4 RODS

- VERTICAL ROD LENGTH = 18.5"

- $\frac{KL}{r} = \frac{(1.0)(18.5)}{.1257} = 147.2 > 120$ ∴ EQ 6b OF NF 3322.1 APPLIES.

• ALLOWABLE STRESS PER EQ 6b:

EQ. 6b: $F_a = S_y\left(.40 - \frac{KL/r}{600}\right)$

$$F_a = 25000\left(.40 - \frac{147.2}{600}\right) = 3,867 \text{ PSI}$$

• ACTUAL MAX STRESS BASED ON DW LOAD OF 3200# $F = 3200/4 = 800\#$

$$\sigma_{ACTUAL} = \frac{F}{A} = \frac{800}{.1963} = 4,075 \text{ PSI}$$

WHICH IS > 3,867 PSI ~ 4,075 PSI

∴ SAFETY FACTOR WILL PROVIDE AMPLE MARGIN TO PRECLUDE BUCKLING DURING MANUFACTURING OPERATIONS.

8.2 - ROTATE SHELL CYLINDER ASSEMBLEY 90° ABOUT AXIAL/LONGITUDINAL AXIS SUBJECTING TRANSVERSE/LATERAL RODS TO DEADWEIGHT BUCKLING - QTY 4 RODS

- TRAVERSE/LATERAL ROD LENGTH = 22.38"

- $\frac{KL}{r} = \frac{(1.0)(22.38)}{.1257} = 178 > 120$ ∴ E6b OF NF 3322.1 APPLIES.

8.2 CON'T

- ALLOWABLE STRESS PER EQ. 6b:

$$\text{EQ. 6b: } F_a = S_Y\left(.40 - \frac{KL/r}{600}\right)$$

$$F_a = 25000\left(.40 - \frac{179}{600}\right) = 2583 \text{ PSI}$$

- ACTUAL MAX STRESS BASED ON DW LOAD OF 3200# F=3200/4 = 800#

$$\sigma_{ACTUAL} = \frac{F}{A} = \frac{800}{.1963} = 4{,}075 \text{ PS} > 2{,}593 \text{ PSI} \therefore \text{N.G.}$$

8.3 - STAND SHELL/CYLINDER ASSEMBLY ON END SUBJECTING THE TWO (2) AXIAL/LONGITUDINAL RODS TO DEADWEIGHT BUCKLING

- AXIAL/LONGITUDINAL ROD LENGTH = 12" (ASSUMED)

- $\frac{KL}{r} = \frac{(1.0)(12)}{.1257} = 95.5 < 120 \therefore$ EQ. 6a OF NF3322.1 APPLIES

- ALLOWABLE STRESS PER EQ 6a:

$$\text{EQ. 6a: } F_a = S_Y\left(.47 - \frac{KL/r}{444}\right)$$

$$F_a = 25000\left(.47 - \frac{95.5}{444}\right) = 6{,}373 \text{ PSI}$$

- ACTUAL MAX STRESS BASED ON A DW LOAD OF 3200# F=3200/2 = 1600#

$$\sigma_{ACTUAL} = \frac{F}{A} = \frac{1600}{.1963} = 8{,}150 \text{ PSI} > 6{,}373 \text{ PSI} \therefore \text{N.G.}$$

8.4 CONCLUSION: NEXT SIZE 304L ROD (5/8" DIA.) IS REQUIRED TO PRECLUDE BUCKLING WHEN EXPOSED TO COMPRESSIVE LOADS DURING MANUFACTURING OPERATIONS.

8.5 - SUMMARY OF 304L 1/2" & 5/8" RODS SUBJECTED TO BUCKLING AND TENSILE LOADS DURING MANUFACTURING OPERATIONS

8.5.1 - 1/2" DIA 304 L RODS Sy = 25000 PSI

		Buckling Loads		Tensile Stress
		Allowable	Actual	
8.1	Cylinder Upside Down	3867	*4075	6364
8.2	Cyl Rot. 90°	2583	*4075	6364
8.3	Cylinder On End	6373	*8150	*12,728

NOTE: TENSILE STRESS IS BASED ON 1/2-13 UNC ROOT DIA OF THREAD

* ACTUALS EXCEED ALLOWABLES ∴ N.G.

8.5.2 - 5/8" DIA 304 L RODS Sy = 25,000 PSI

		Buckling Loads		Tensile Stress
		Allowable	Actual	
8.1	Cylinder Upside Down	5068	2608	3960
8.2	Cyl. Rot 90°	4034	2608	3960
8.3	Cylinder On End	7427	5215	7921

NOTE: • TENSILE STRESS IS BASED ON 5/8-11 UNC ROOT DIA. OF THREAD.

• ACTUALS ARE LESS THAN ALLOWABLES ∴ 5/8" DIA RODS FOR MANUFACTURING LOADS ARE OK

9.0 - TOTAL LOAD SUMMARY FOR 304L 5/8" DIA RODS

9.1 - OPERATIONAL LOADS

		BUCKLING LOADS		① TENSILE STRESS
		ALLOWABLE	ACTUAL	
6.1	VERTICAL DEADWEIGHT LOAD	—	—	6,436
6.2.1	LATERAL/TRANSVERSE SEISMIC LOAD	5,254	254	386
6.2.2	LONGITUDINAL/AXIAL SEISMIC LOAD	6,602	508	772

9.2 - SHIPPING LOADS

		BUCKLING LOADS		① TENSILE STRESS
		ALLOWABLE	ACTUAL	
7.3.1	VERTICAL DEADWEIGHT + SEISMIC LOADS (RIGHT SIDE UP)	—	—	7,921
7.3.2	VERTICAL BUCKLING IF CYL IS SHIPPED 90° RIGHT OR LEFT	7,507	② 5,267	—
7.4.1	TRANSVERSE LATERAL SEISMIC LOAD (RIGHT SIDE UP)	7,507	1,304	1,980
7.4.2	LONGITUDINAL LATERAL SEISMIC LOAD	9,474	2,608	3,960

9.3 - MANUFACTURING LOADS

		BUCKLING LOADS		① TENSILE STRESS
		ALLOWABLE	ACTUAL	
8.1	CYLINDER UPSIDE DOWN	5068	2068	3960
8.2	CYLINDER ROTATED 90°	4034	2068	3960
8.3	CYLINDER ON END	7427	③ 5215	7921

① - TENSILE LOADS ARE BASED ON 5/8-11 UNC ROOT AREA

② - THIS IS THE WORSE CASE SHIPPING CONDITION, i.e. LATERAL RODS HAVE LONGEST LENGTH = 22 3/8". ∴ SHIPPING CAN BE ANY POSITION.

③ - THIS IS THE WORSE CASE MANUFACTURING CONDITION.

10.- SUPPORT ROD LUG DESIGN

10.1- DESIGN CRITERIA:

- OPERATIONAL:

  F = 1300# (MAX LUG LOAD - VERTICAL RODS)

  T = 400°F

- SHIPPING:

  F = 1600# (MAX LUG LOAD - VERTICAL OR LATERAL RODS)

  T = 100°F

- MANUFACTURING:

  F = 1600# (MAX LUG LOAD - LONGITUDINAL/AXIAL RODS)

  T = 100°F

10.2- MATERIALS / ALLOWABLE STRESSES:

- MATERIAL: SB 209 6061 T6

- ALLOWABLE STRESSES

  S_{ALLOW} AT 100°F = 6000 PSI

  S_{ALLOW} AT 400°F = 3500 PSI

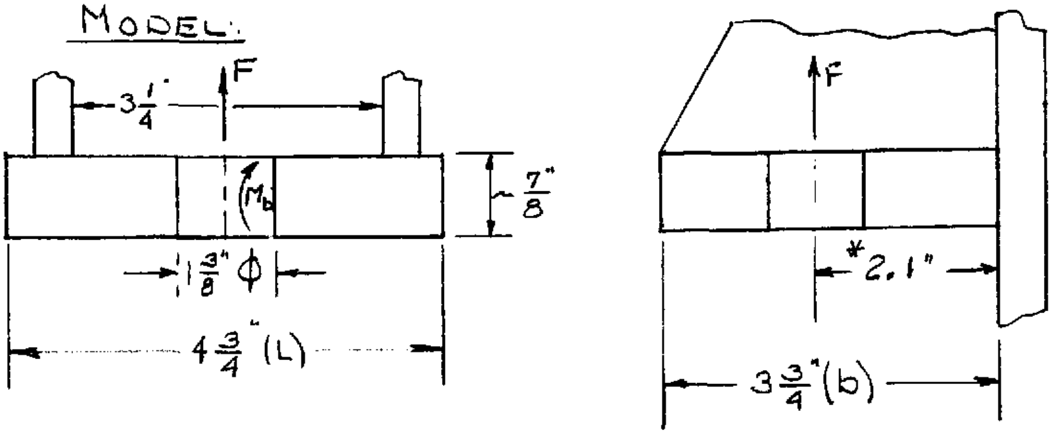
  S_y AT 100°F = 35,000 PSI

  S_y AT 400°F = 13,300 PSI

10.3 - LUG DESIGN

10.3.1 • BASE PLATE WITH DOUBLE GUSSETS
REF: MOSS, P. 122

MODEL:



$M_b = \frac{FL}{6}$ $t_b = \sqrt{\frac{6 M_b}{(b-\phi) F_b}}$

- FOR OPERATIONAL LOADS F = 1300#, T = 400°F

$M_b = \frac{1300 (4.75)}{6} = 1029$ IN-#

$t_b = \sqrt{\frac{6(1029)}{(3.75 - 1.375)(3500)}} = .862" < .875"$ ∴ OK

WHERE: $\phi = 1\,3/8"$ (HOLE DIAMETER)

$F_b = 3500$ PSI = S_{ALLOW} AT 400°F

- FOR MANUFACTURING/SHIPPING LOADS F=1600#, T=100°F

$M_b = \frac{1600 (4.75)}{6} = 1,267$ IN-#

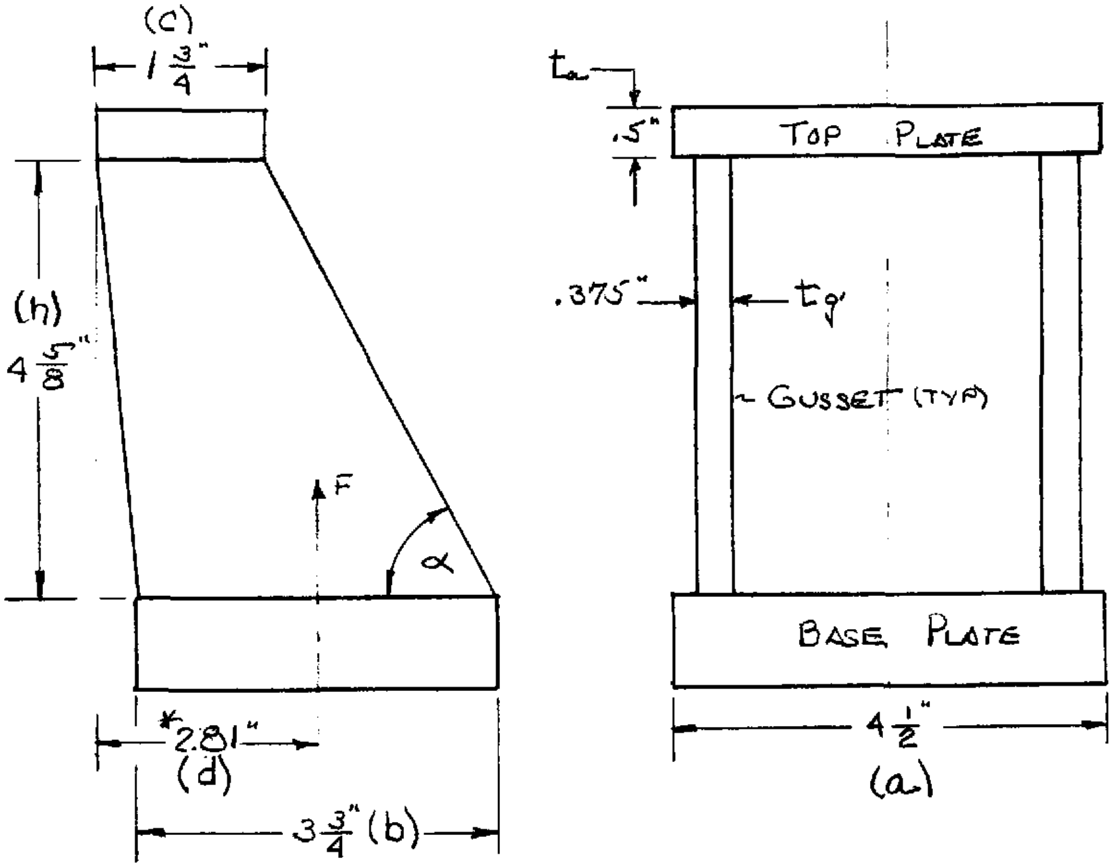
$t_b = \sqrt{\frac{6(1267)}{(3.75 - 1.375)(6000)}} = .730" < .875"$ ∴ OK

WHERE: $F_b = 6000$ PSI AT 100°F

* MEASURED FROM ACTUAL LAYOUT (MAX)

10.3.2 • <u>TOP PLATE</u>
REF. BEDNAR P.154

<u>MODEL:</u>



$$t_a = \frac{.75\,(F d a)}{S_b C^2 h}$$

- <u>FOR OPERATIONAL LOADS:</u>

$$t_a = \frac{.75(1300)(2.81)(4.5)}{3500(1.75)^2(4.625)} = .25" < .5" \therefore \text{ OK}$$

WHERE: S_b = 3500 PSI = SALLOW AT 400°F
F = 1300# MAX

- <u>FOR MANUFACTURING / SHIPPING LOADS:</u>

$$t_a = \frac{.75(1600)(2.81)(4.5)}{6000(1.75)^2(4.625)} = .179 < .5" \therefore \text{ OK}$$

WHERE: S_b = 6000 PSI = SALLOW AT 100°F
F = 1600# MAX

10.3.3 – GUSSETS
REF. BEDNAR P.154

MODEL: SAME AS 10.3.3

$$t_g = \frac{F(3d-b)}{S_a b^2 \sin^2 \alpha^*}$$

– FOR OPERATIONAL LOADS : F = 1300# T = 400°F

$$t_g = \frac{1300(3 \times 2.81 - 3.75)}{3500(3.375)^2 \sin^2(65.69)} = .184" < .375" \therefore OK$$

WHERE: S_a = 3500 PSI = S_{ALLOW} AT 400°F

– FOR MANUFACTURING/SHIPPING LOADS :

$$t_g = \frac{1600(3 \times 2.81 - 3.75)}{6000(3.375)^2 \sin^2(65.69)} = .132" < .375" \therefore OK$$

WHERE: S_a = 6000 PSI = S_{ALLOW} AT 100°F

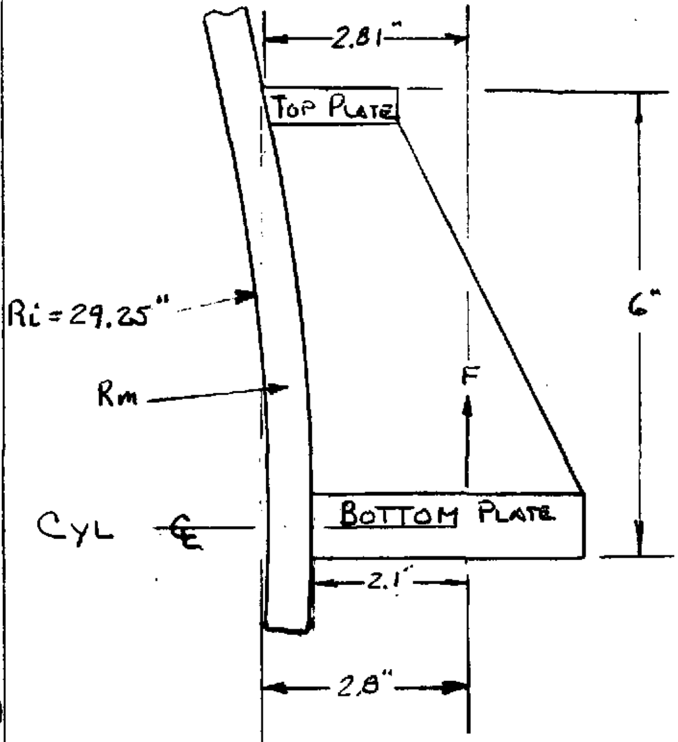
* DETERMINATION OF α:
REF. MODEL IN 10.3.1 + 10.3.2

$$\tan \alpha = \frac{6}{3.75 + (2.81 - 2.10) - 1.75} = 2.21$$

$$\alpha = \tan^{-1} 2.21 = 65.69°$$

11. - LUG DESIGN QUALIFICATION

11.1 TYPICAL LUG LAYOUT



$$R_m = \frac{(R_i + .5) + R_i}{2}$$

$$R_m = \frac{(29.25 + .5) + 29.25}{2}$$

$$R_m = 29.5"$$

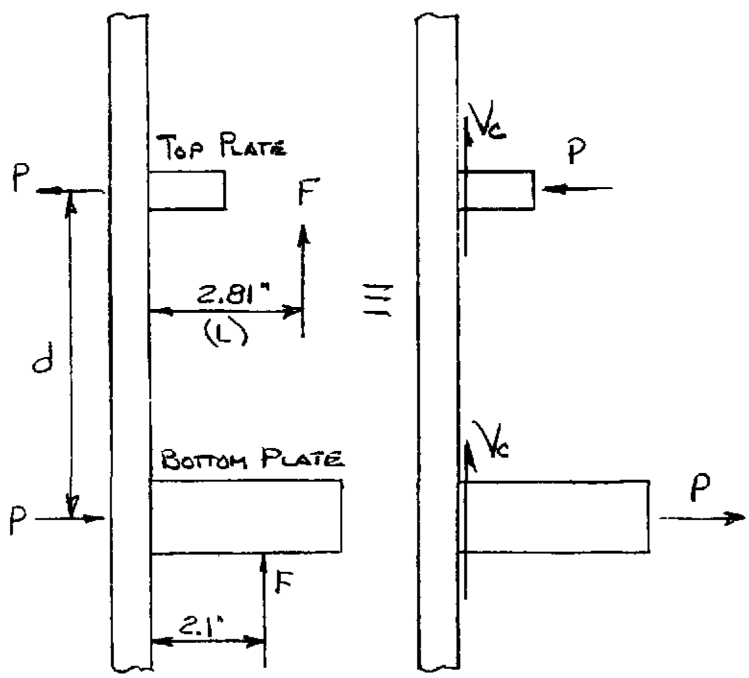
$$C_1 = \frac{.5}{2} = .25"$$

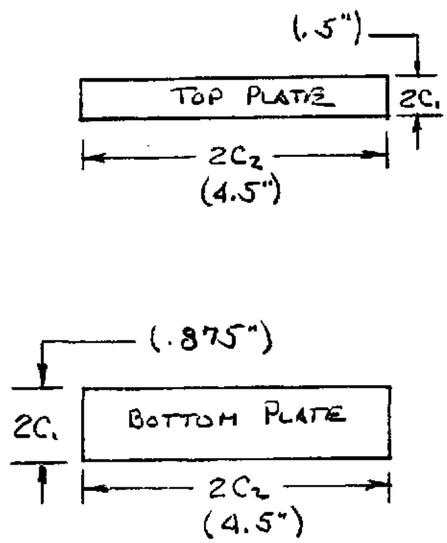
$$C_2 = \frac{4.5}{2} = 2.25"$$

$$d = 6 - \left(\frac{.5 + .875}{2}\right) = 5.3125"$$

MODEL:

TOP PLATE





11.2 — WRC 107 QUALIFICATION / ANALYSIS

THE ANALYSIS WILL BE APPLIED TO THE WORSE CASE (HIGHEST LOADED) LUG TO SHELL CONDITION - WHICH IS THE TOP PLATE. (SMALLER SHELL BEARING SURFACE WITH LARGER MOMENT LOAD.)

- LOADS - OPERATIONAL AT 400°F (WORSE CASE)
  - F = 1300#
  - COMPRESSIVE RADIAL ATTACHMENT TO SHELL LOAD: P

$$P = FL/d = (1300)(2.81)/5.3125 = 688\#$$

  - CIRCUMFERENTIAL ATTACHMENT TO SHELL SHEAR LOAD

$$V_c = \frac{F}{2} = \frac{1300}{2} = 650\#$$

- SECTION 4.2.2.3 (WRC 107) "RECTANGULAR ATTACHMENT SUBJECT TO RADIAL LOAD P"
  - SHELL PARAMETER: γ

$$\gamma = \frac{R_m}{T} = \frac{29.5}{.5} = 59$$

  - ATTACHMENT PARAMETER: β

$$\beta_1 = \frac{C_1}{R_m} = \frac{.25}{29.5} = .0085$$

$$\beta_2 = \frac{C_2}{R_m} = \frac{2.25}{29.5} = .0763$$

$$\frac{\beta_1}{\beta_2} = \frac{.0085}{.0763} = .111 < 1$$

$$\therefore \quad \beta = \left[1 - \frac{4}{3}\left(1 - \frac{\beta_1}{\beta_2}\right)(1 - K_2)\right]\sqrt{\beta_1 \beta_2}$$

$$\beta = \left[1 - \frac{4}{3}\left(1 - \frac{.0085}{.0763}\right)(1-K_2)\right]\sqrt{(.0085)(.0763)}$$

$$\beta = [1 - 1.1848(1-K_2)].0257$$

$$\beta = .0257 - .03017(1-K_2)$$

- STRESSES DUE TO RADIAL LOAD P

- FOR CIRCUMFERENTIAL STRESS:
  - $K_2 = 1.48$
  - $\beta = .0257 - .03017(1-1.48) = .0402$
  - $\gamma = 59$
  - FROM FIG 3C : $\frac{N\phi}{P/R_m} = 12.5$
  - $\sigma_c = \left(\frac{N\phi}{P/R_m}\right)\left(\frac{P}{R_m T}\right) = (12.5)\left(\frac{688}{29.5 \times .5}\right)$

  $\sigma_c = 583\ PSI < 3500\ PSI \therefore OK$

- FOR LONGITUDINAL STRESS:
  - $K_2 = 1.2$
  - $\beta = .0257 - .03017(1-1.2) = .03173$
  - $\gamma = 59$
  - FROM FIG. 4C $\frac{N_x}{P/R_m} = 11.2$

  $\sigma_L = \left(\frac{N_x}{P/R_m}\right)\left(\frac{P}{R_m T}\right) = (11.2)\left(\frac{688}{29.5 \times .5}\right)$

  $\sigma_L = 522\ PSI < 3500\ PSI \therefore OK$

- SECT. 4.3.5 "STRESSES RESULTING FROM SHEAR LOADS"

4.3.5.2 "RECTANGULAR ATTACHMENT

$$\tau = \frac{V_c}{4C_1T} = \frac{650}{4(.25)(.5)} = 1300 \text{ PSI} < 3500 \text{ PSI} \therefore \text{OK}$$

- STRESSES DUE TO INTERNAL PRESSURE

- MAX INTERNAL CYLINDER PRESSURE: $P_{MAX} = 40 \text{PSI}$

REF: ROARK, 5TH. ED., CASE 1C, P. 448

- CIRCUMFERENTIAL:

$$\sigma_C = \frac{P_{MAX} R_m}{T} = \frac{40(29.5)}{(.5)} = 2360 \text{ PSI} < 3500 \text{ PSI} \therefore \text{OK}$$

- LONGITUDINAL:

$$\sigma_L = \frac{P_{MAX} R_m}{2T} = \frac{40(29.5)}{2(.5)} = 1180 \text{ PSI} < 3500 \text{ PSI} \therefore \text{OK}$$

- RADIAL - ON OUTSIDE SURFACE (ATTACHMENT SIDE)

$\sigma_R = 0$ PSI

- COMBINING STRESSES

$\sigma_{C\,TOTAL} = 583 + 2360 = 2{,}943$ PSI

$\sigma_{L\,TOTAL} = 522 + 1180 = 1{,}702$ PSI

$$\sigma_1, \sigma_2 = \left(\frac{2943+1702}{2}\right) \pm \sqrt{\left(\frac{2943-1702}{2}\right)^2 + (1300)^2}$$

$\sigma_1, \sigma_2 = 2323 \pm 1441$

$\sigma_1 = 3{,}764$ PSI

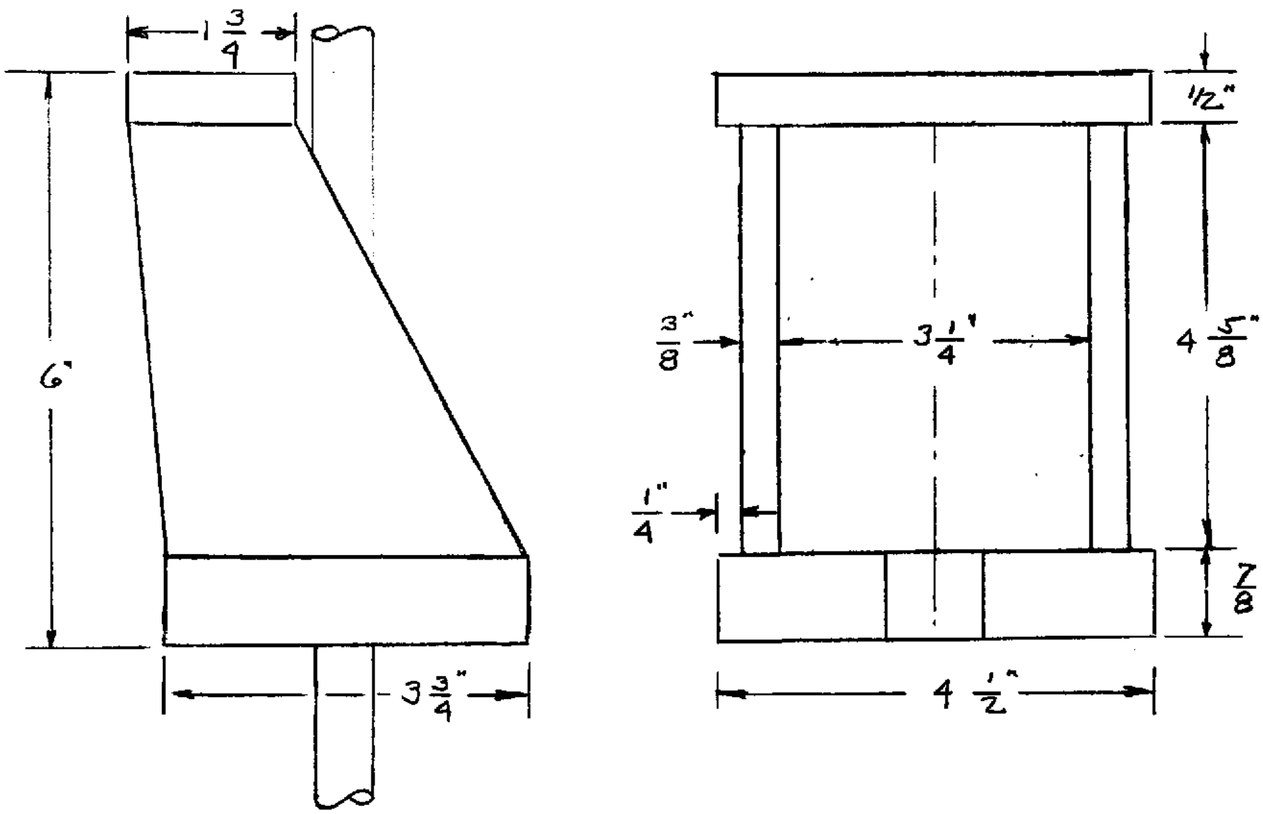
$\sigma_2 = 882$ PSI

$\sigma_3 = 0$

MAX STRESS INTENSITY = $3764 - 0 = 3764$ PSI
$< 1.5S = 1.5(3500) = 5250$ PSI $\therefore$ OK

DESIGN SKETCH

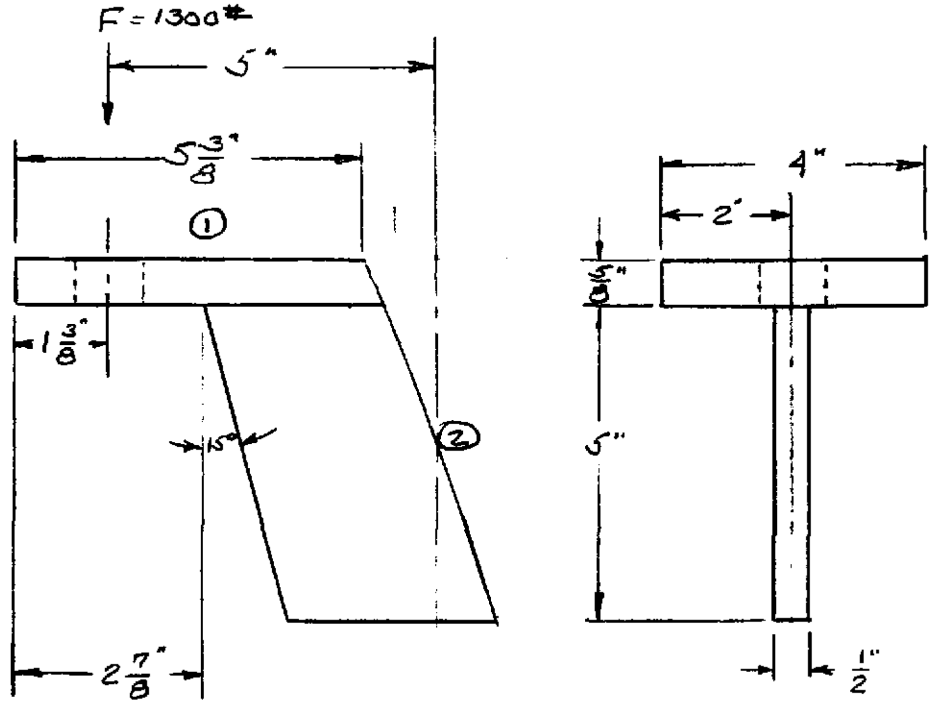
SK-V049-1-070, REV 0; SHEET 1 OF 3

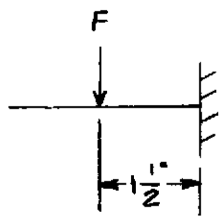


NOTE: THIS IS THE GENERIC DESIGN FOR VERTICAL (WITHOUT LONGITUDINAL ATTACHMENTS) AND ALL LATERAL SUPPORTS.

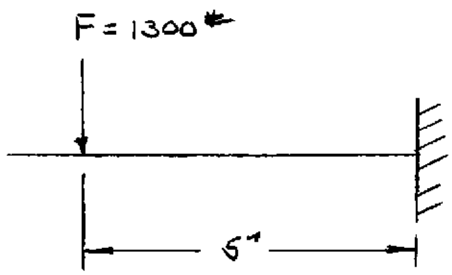
- FOR VERTICAL SUPPORT DESIGN, WITH THE LONGITUDINAL ROD ATTACHMENT SEE SHEET 2 FOR THE VERTICAL SUPPORT DESIGN AND SHEET 3 FOR THE MATING LONGITUDINAL TIE ROD DESIGN.

11.4 - Shell Side Support Bracket (A240 TP 304 L)





① $\sigma_1 = \frac{M_1}{Z_1} = \frac{1.5(1300)}{\frac{(4)(.625)^2}{6}} = 7{,}488 \text{ PSI} < S = 14.7 \text{ KSI} \therefore \text{OK}$



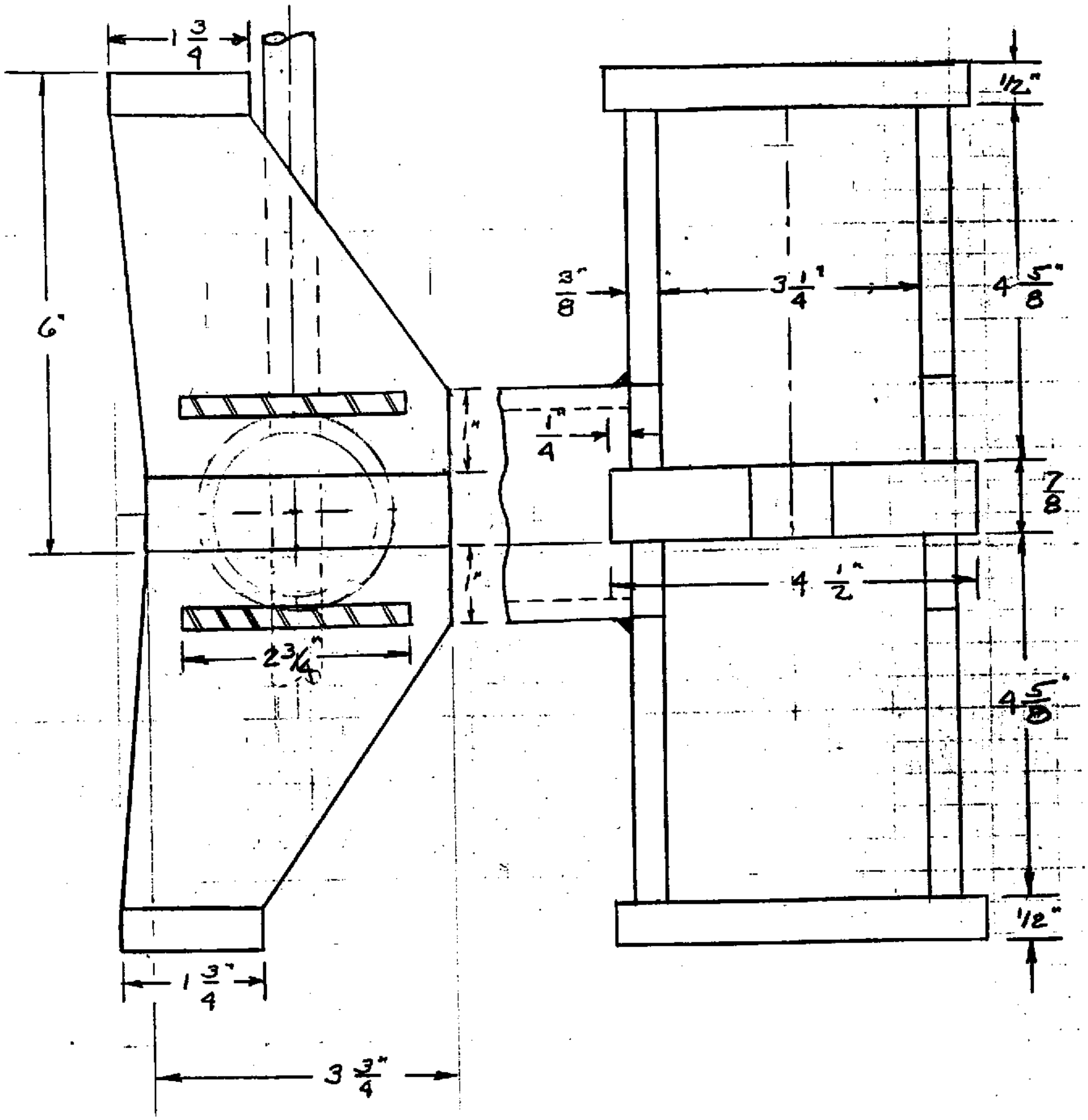
② $\sigma_2 = \frac{M_2}{Z_2} = \frac{(1300)(5)}{(.5)(5)^2/6} = 3{,}120 \text{ PSI} < S = 14.7 \text{KSI} \therefore \text{OK}$

Where: S = 14,700 PSI is the allowable stress at 400°F for 304L (Ref: Doc. No. V049-1-66)

12. LONGITUDINAL SUPPORT / LUG DESIGN

12.1 - DESIGN SKETCH

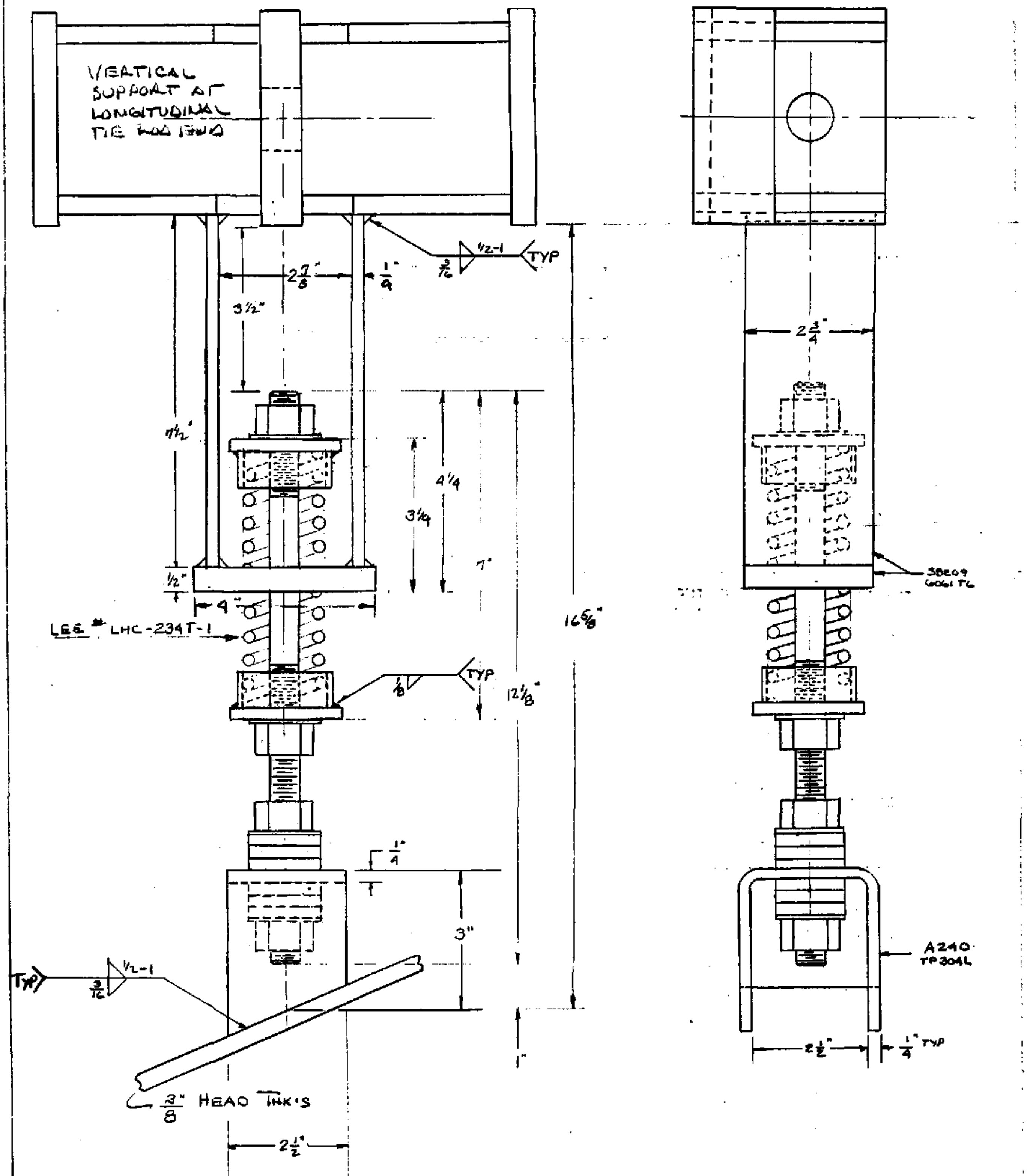
SK-V049-1-070, REV 0; SHEET 2 OF 3



VERTICAL SUPPORT DESIGN WITH LONGITUDINAL TIE ROD ATTACHMENT (SEE SHEET 3 OF 3)

12.2 - DESIGN SKETCH

SK-V049-1-070, REV0; SHEET 3 OF 3

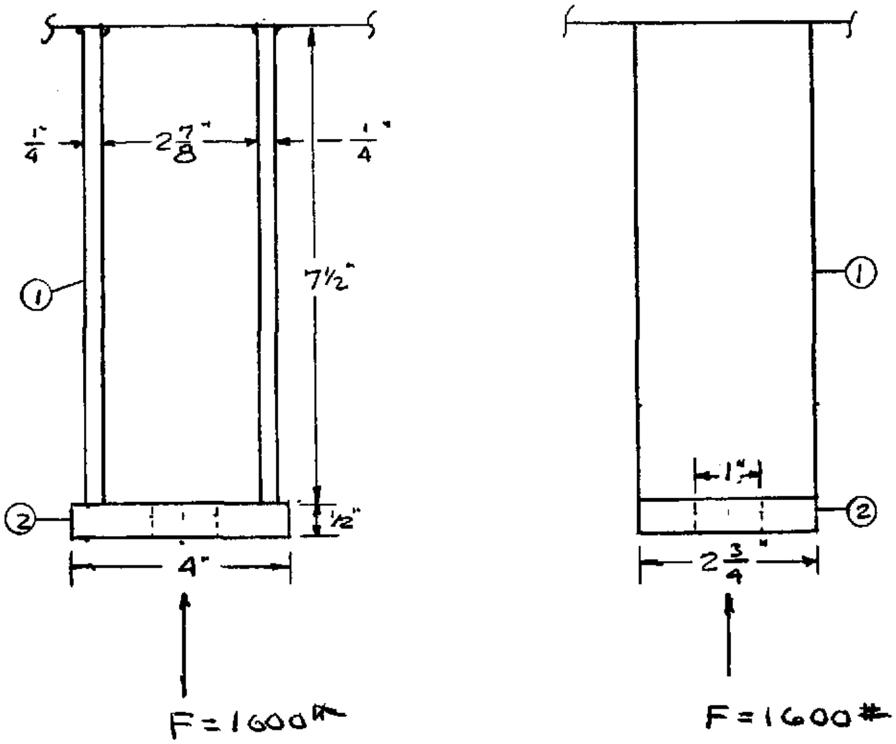


LONGITUDINAL TIE ROD ATTACHMENT

NOTE: SPRING ARRANGEMENT WAS MODIFIED.

12.3– DESIGN QUALIFICATIONS

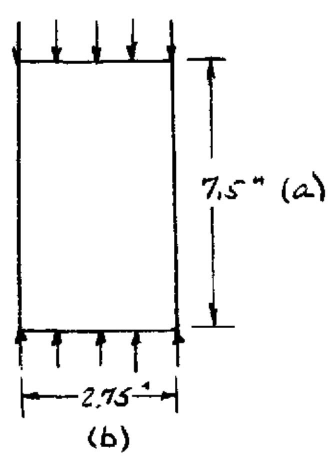
- ATTACHMENT TO VERTICAL LUG
  SB209 6061 T6



- F=1600# IS THE WORSE CASE MANUFACTURING BUCKLING LOAD (SEE 8.3)

① CHECK FOR BUCKLING REF: BLODGETT, SECT 2.12, P. 2.12-1

MODEL



$$\sigma_{CR} = \frac{K\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$$

$$\sigma_{CR} = \frac{(4)\pi^2(8.7\times10^6)}{12(1-.33^2)}\left(\frac{.25}{2.75}\right)^2$$

$$\sigma_{CR} = 265{,}452 \text{ PSI} > 1163 \text{ PSI} \therefore \text{OK}$$

WHERE: $E = 8.7\times10^6$ (400°F - WORSE CASE)
REF: TABLE TM-2, ASME II, PART D

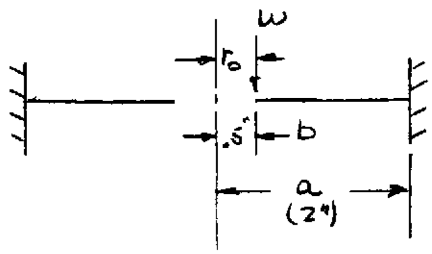
$\nu = .33$ REF: TABLE NF-1, ASME II, PART D

$$\sigma_{ACT} = \frac{F}{A} = \frac{800}{(.25)(2.75)} = 1{,}163 \text{ PSI}$$

12.3 CONT

② CHECK STRESS

MODEL: REF: ROARK, CASE 1e, P. 336



$w = 1600\ \pi(1) = 503\ \#/\text{IN}$

$\frac{b}{a} = \frac{.5}{2} = .25$; $K_{Mrb} = .2308$

$M = K_M w a$

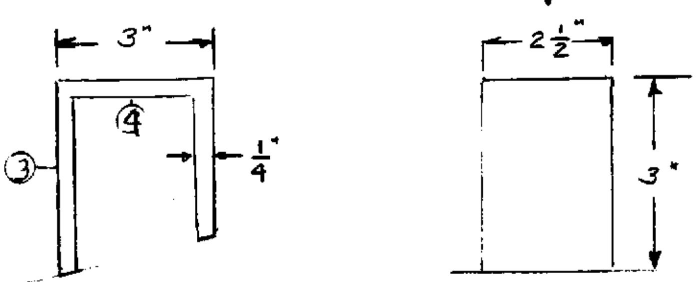
$M = (.2308)(503)(2) = 232$

$\sigma = \frac{6M}{t^2}$

$t = \sqrt{\frac{6M}{\sigma}} = \sqrt{\frac{6(232)}{6000}} = .481" < \frac{1}{2}"$ ACTUAL ∴ OK

• ATTACHMENT TO SHELL SIDE
A240 TP304L

$F = 1600\#/2 = 800\#$ PER LEG



$\sigma_{ACT} = \frac{800}{(2.5)(.25)}$

$\sigma_{ACT} = 1280\ PSI$

③ - CHECK BUCKLING (SAME AS ①)

$\sigma_{CR} = \frac{(4)\ \pi^2\ (26.5\times10^6)}{12(1-.3^2)}\left(\frac{.25}{2.5}\right)^2 = 958{,}000\ PSI > 1280\ PSI\ ∴\ OK$

WHERE: $E = 26.5\times10^6$ PSI REF: TABLE TM-1, ASME II, PART D
$\nu = .3$ (ASSUMED)

12.3 CONT

④ - CHECK STRESS (SAME AS ②)

$\omega = 503$ #/IN

$\frac{b}{a} = \frac{.50}{1.5} = .33$; $K_{Mra} = .1791$

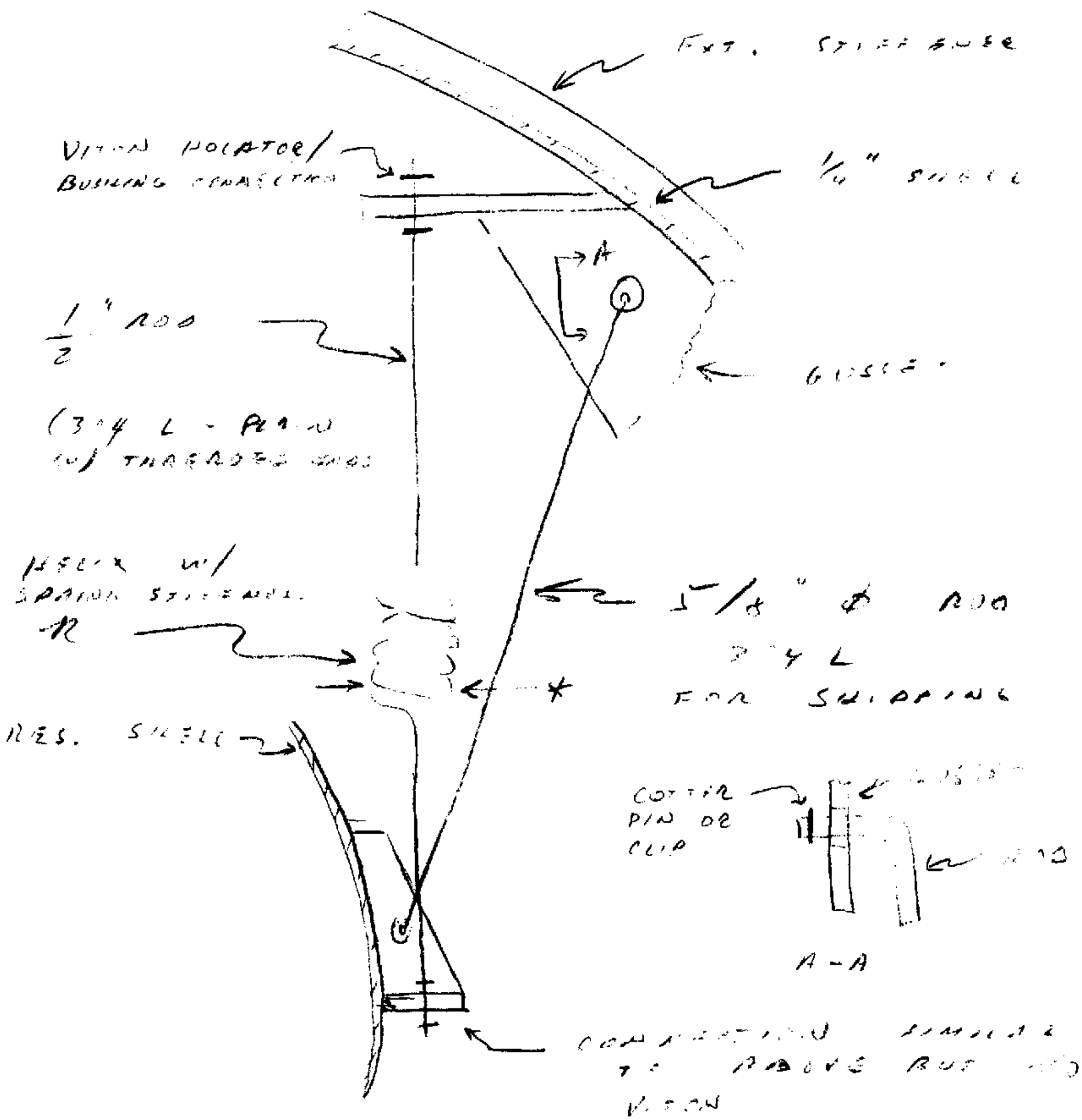
$M = (.1791)(503)(1.5) = 135$

$\sigma = \frac{6M}{t^2}$

$t = \sqrt{\frac{6(135)}{(16,700)}} = .22" < .25"$ ∴ OK

13.1

TYPICAL SUPPORT AND CONNECTION
FOR 80K PUMP RESERVOIR



* LIMIT SPRING DIAM TO CLEAR RESERVOIR & SHIELD

LONG PUMP: K_{max} = 12500 #/in
K_{min} = 11,500

SHORT PUMP: K_{max} = 4200
K_{min} = 3400

13.2 HELIX ROD WITH SPRING STIFFNESS

ROD / SPRING FOR LONG PUMP

MAX FREQUENCY OF SINGLE DOF SYSTEM CONSISTING OF PUMP/RESERVOIR ON SPRING SUPPORT IS 10 HZ

$$w = \frac{1}{2\pi}\sqrt{\frac{k}{M}} = 10 \text{ Hz MAX}$$

k = STIFFNESS OF 4 SPRINGS

M = MASS OF RESERVOIR INCLUDING NITROGEN

$$= \frac{W}{g}$$

$W \cong 5000$ LBS FOR LONG PUMP W/ NITROGEN (SEE FOLLOWING SHEETS)

$g = 386.4 \ \frac{in}{sec^2}$

$$M = \frac{5000}{386.4} = 12.94 \ \frac{\# \, sec^2}{in}$$

$$10 = \frac{1}{2\pi}\left(\frac{k}{12.94}\right)^{\frac{1}{2}}$$

$k = 51100$ #/in FOR 4 SPRINGS

$= \frac{51100}{4} = 12800$ #/in FOR A SINGLE SPRING

SAY ALLOWABLE RANGE OF SPRING RATE

$11500 < k < 12500$ #/in FOR LONG PUMP

SHORT PUMP

CALCULATE WEIGHT

LENGTH OF SHORT PUMP RESERVOIR IS 48"
LONG PUMP RESERVOIR IS 146 IN LONG.
SEE FOLLOWING SHEETS FOR LONG PUMP WT & RATIO

OUTER CYL $W_1 = 1326 \times \frac{48}{146} =$ 436

INNER CYL $W_2 = 1507 \times \frac{48}{146} =$ 495

END CAPS $W_3 = 87$ 87

PIPING, ETC $W_4 = 20$ 20

NITROGEN $W_5 = 2000 \times \frac{48}{146} =$ 658

TOTAL 1696 SAY 1700#

$$M = \frac{1700}{386.4} = 4.389 \ \frac{\# \ SEC^2}{IN}$$

$$10 = \frac{1}{2\pi}\left(\frac{k}{4.389}\right)^{\frac{1}{2}}$$

$k = 17330$ #/IN FOR 4 SPRINGS

$= 4330$ #/IN FOR 1 SPRING

SAY ALLOWABLE RANGE OF SPRING RATE

$3800 < k \leq 4200$ #/IN

5/8" SHIPPING ROD

$I = \frac{\pi}{64}(.625)^4 = .007490$

$A = \frac{\pi}{4}(.625)^2 = .3068$

$r = \sqrt{\frac{I}{A}} = .1563$

$l = 22.38$ MAX FOR LAT REST.

SHIPPING CONDITION

$S_y = 25$ KSI @ 70°

$\frac{Kl}{r} = \frac{1(22.38)}{.1563} = 143 > 120$

$F_a = S_y\left(.40 - \frac{\frac{Kl}{r}}{600}\right)$ FOR CB OF SECT III, NF 3322.1

$= 25\left(.40 - \frac{143}{600}\right) = 4.0$ KSI

MAX LOAD DUE TO SHIPPING

W - LONG PUMP
$W = 5000 - 2000 = 3000$ # ← N.

W + 1 G VERT ACCEL (UNIT TURNED 90° SO THAT LAT ROD IS IN COMP.)

$F = 3000 + 3000 = 6000$

$= \frac{6000}{4} = 1500$ #/ROD

MAX COMP STRESS DUE TO SHIPPING

$$\sigma = \frac{F}{A} = \frac{1500}{.3068} = 4890 \text{ psi}$$

> 4.0 KSI BUT SAY OK FOR SHIPPING

NOTE: FACTOR OF SAFETY GIVES SUFFICIENT MARGIN AGAINST BUCKLING FOR THIS TEMP CONDITION.

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**	
1	0243	9/27/96	WDB	RDC		
					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 = 27.57 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: 80K-S-R1.* & 80K-L-R1.*

TABLE OF CONTENTS

REVISION HISTORY

Rev. 0 Original Issue
April 23, 1996

Rev. 1 Issue Date
September 27, 1996

- Revised the unbalanced vacuum load at the gate valve (27.57kip).
- Recreated body of calc to reflect changes due to revised vacuum load.
- Modified the baseplate thickness.
- Modified the anchor bolts.
- Added weld calculations.
- Revised anchorage design details.

80K-SHORT CRYOPUMP

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

$F_{VAC} = 27.57$ KIPS (see page 6 of 90)

- UNBALANCED VACUUM LOAD @ PUMPOUT PORT

$$F = PA$$

$$= (14.7\ \#/\text{in}^2)\frac{(10\ \text{in}\ \phi)^2 \pi}{4}$$

$$= 1155.\ \text{lbs.}$$

SEISMIC AXIAL OR LATERAL ONLY!

$g = 0.05625$

applied as uniform load on Shell.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

UNBALANCED FORCE AT 80K PUMP

44" GATE VALVE IS ATTACHED TO PUMP

D_m = 45.964 in (HYSPAN CALC 7/5/96)

VACUUM FORCE

$$F = \pi \frac{D_m^2}{4} (14.7)$$

$$= \pi \frac{(45.964)^2}{4} (14.7)$$

$$= 24.39 \text{ K}$$

PURGE PRESSURE = 2 psig

$$F' = \pi \frac{G^2}{4} (2)$$

G = INNER O-RING DIAM

= 45.0 in

$$F' = \pi \frac{(45)^2}{4} (2)$$

$$= 3.18 \text{ K}$$

TOTAL FORCE

$$F = 24.39 + 3.18 = 27.57^K$$

WEIGHT OF VESSEL

- INTERNALS (REF V049-1-070)

80K LONG CRYOPUMP W = 5700 lbs.
L = 146 IN.

80K - SHORT

W = ?
L = 48 IN

$$\frac{W}{48_{IN}} = \frac{5700}{146_{IN}} \Rightarrow W = \frac{(5700\ lbs)(48_{IN})}{146_{IN}}$$

WEIGHT OF 80K-SHORT ≅ 1875. lbs.

EXTERNAL SHELL (REF V049-1-081)

VESSEL WEIGHT = 4901.lbs.

$$W_T = (4901\ lbs) - (2)(426\ lbs) - (2)(616^{*}\ lbs)$$

$$= 2817\ lbs.$$

← FLANGE NOT INCL. IN STAAD [illegible] (P. 13, LINE 34)

$$W_{TOT} = 1875\ lbs + 2817.\ lbs = 4692.\ lbs$$

SAY 4700 lbs.

APPLY UNIFORM LOAD OVER ENTIRE CRYOPUMP

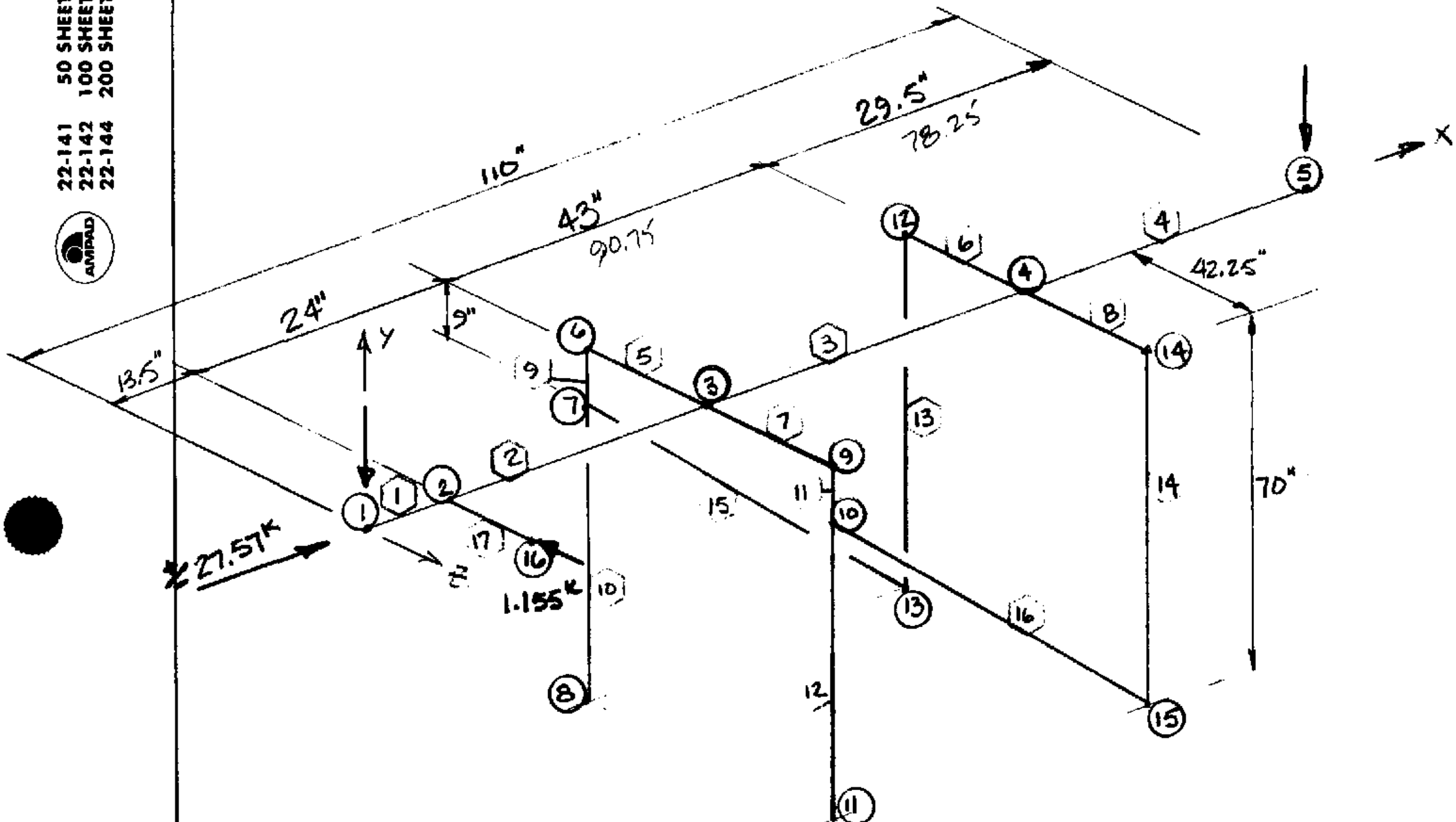
$$w = \frac{4700\ lbs}{110\ IN.}$$

$$w = 42.73\ \frac{lbs}{IN} = -Y$$

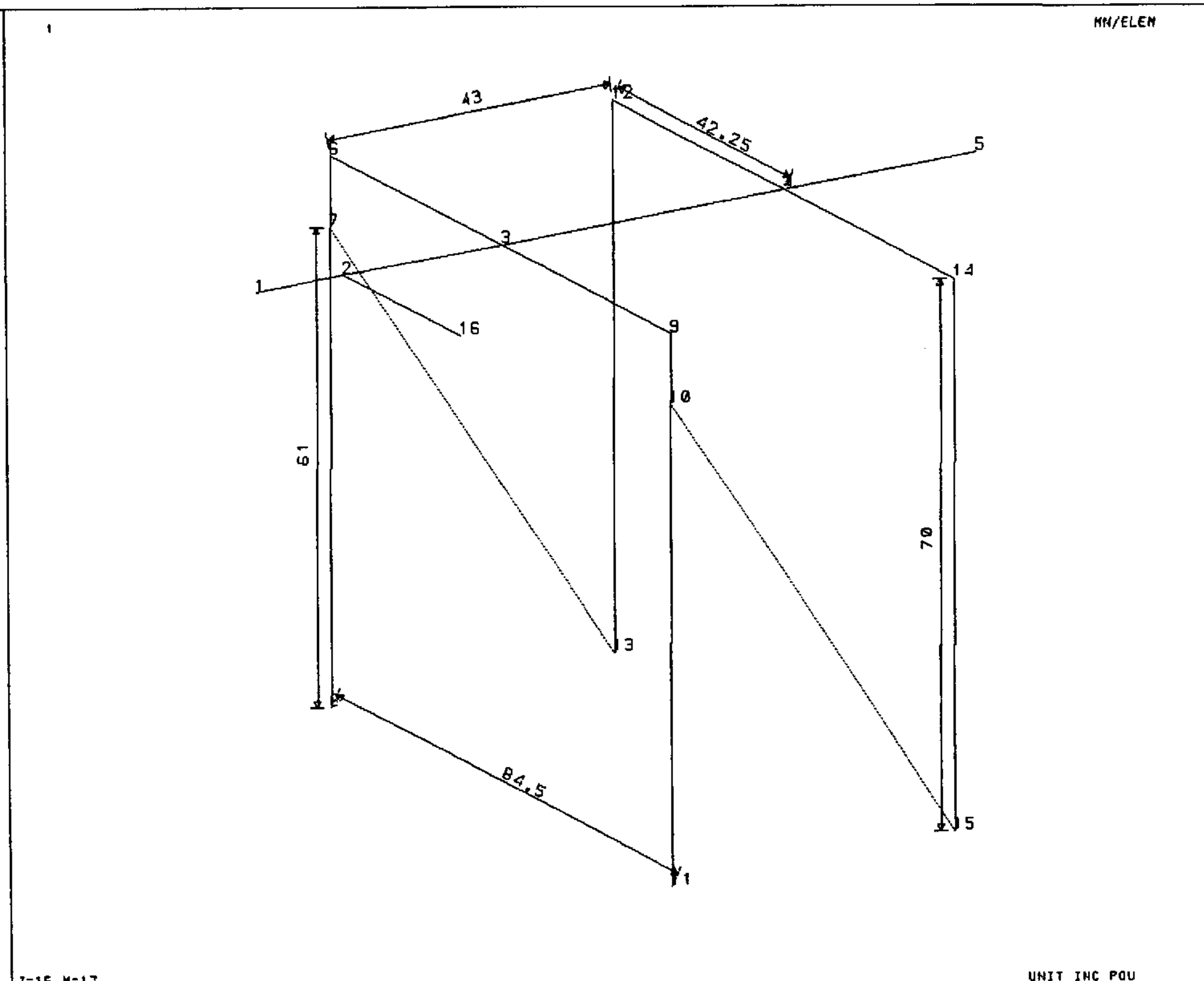
$$w = (0.05625g)(42.73) = 2.4\ lbs/in = x = z$$

* FICTITIOUS COMPONENTS IN [illegible] ANALYSIS

80 K Short Cryopump
Support Frame Model



Note: Vacuum Force From 44" Gate Valve Acts in either direction.



STRUCTURE DATA

TYPE = SPACE
NJ = 16
NM = 17
NE = 0
NS = 4
NL = 8
XMAX= 110.0
YMAX= 70.0
ZMAX= 84.5

S T A A D   P O S T - P L O T (REV: 21.0)   DATE: SEP 27, 1996

USER ID:PROCESS SYSTEMS INTERNATIONAL IN   TITLE: 80K-SHORT CRYOPUMP SUPPORT

```
**************************************************
*                                                *
*            S T A A D - III                     *
*            Revision 21.0                       *
*            Proprietary Program of              *
*            Research Engineers, Inc.            *
*            Date=    SEP 24, 1996               *
*            Time=    15:30:46                   *
*                                                *
*      USER ID: PROCESS SYSTEMS INTERNATIONAL IN *
**************************************************
```

```
STAAD SPACE 80K-SHORT CRYOPUMP SUPPORT
INPUT WIDTH 72
*** REV1 REVISED LOADS
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" = 42.73
* UNIFORM = INTERNAL+EXTERNAL
```

```
**********************************
LOAD 2 DW+TH+VACUUM(+)
JOINT LOAD
1 FX 27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -42.73
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
**********************************
LOAD 3 DW+TH+VACUUM(-)
JOINT LOAD
1 FX -27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -42.73
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
**********************************
LOAD 4 DW+TH+VACUUM(+)+SEIS-AXIAL(+)
JOINT LOAD
1 FX 27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FX 47.925
* FLANGE WEIGHT X 0.05625
16 FX 8.5
* VALVE WEIGHT X 0.05625
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -42.73
1 TO 4 UNI X 2.4
* UNIFORM WEIGHT X 0.05625
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
**********************************
LOAD 5 DW+TH+VACUUM(-)+SEIS-AXIAL(-)
JOINT LOAD
1 FX -27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FX -47.925
16 FX -8.5
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
```

```
 98. MEMBER LOAD
 99. 1 TO 4 UNI Y -42.73
100. 1 TO 4 UNI X -2.4
101. **********************************
102. LOAD 6 DW+TH+VACUUM(+)+SEIS-LAT(+)
103. JOINT LOAD
104. 1 FX 27569.998
105. * UNBALANCED VACUUM LOAD @ 44" GATE VALVE
106. 1 5 FY -852.
107. 16 FY -150.
108. 1 5 FZ 47.925
109. 16 FZ 8.5
110. 16 FZ 1155.
111. * UNBALANCED VACUUM LOAD @ TURBO PMP
112. MEMBER LOAD
113. 1 TO 4 UNI Y -42.73
114. 1 TO 4 UNI Z 2.4
115. TEMPERATURE LOAD
116. 1 TO 8 17 TEMP 330.
117. **********************************
118. LOAD 7 DW+VACUUM(-)+SEIS-LAT(-)
119. JOINT LOAD
120. 1 FX -27569.998
121. * UNBALANCED VACUUM LOAD @ 44" GATE VALVE
122. 1 5 FY -852.
123. 16 FY -150.
124. 1 5 FZ -47.925
125. 16 FZ -8.5
126. 16 FZ 1155.
127. MEMBER LOAD
128. 1 TO 4 UNI Y -42.73
129. 1 TO 4 UNI Z -2.4
130. **********************************
131. LOAD 8 THERMAL "BAKEOUT"
132. TEMPERATURE LOAD
133. 1 TO 8 17 TEMP 330.
134. **********************************
135. 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/   952.7 MB,  EXMEM = 14.83 MB

++ PROCESSING ELEMENT STIFFNESS MATRIX.              15:30:48
++ PROCESSING GLOBAL STIFFNESS MATRIX.               15:30:48
++ PROCESSING TRIANGULAR FACTORIZATION.              15:30:48
++ CALCULATING JOINT DISPLACEMENTS.                  15:30:48
++ CALCULATING MEMBER  FORCES.                       15:30:48


 136. PRINT MATERIAL PROPERTIES ALL
```

MATERIAL PROPERTIES.

ALL 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 ************

137. 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 ************

138. 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 ************

139. 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 ************

140. PRINT ANALYSIS RESULTS

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	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	0.10197	-0.01365	0.10043	0.00000	0.00016	-0.00001
	3	-0.33303	-0.04263	0.10043	0.00000	0.00016	0.00035
	4	0.10486	-0.01345	0.10048	0.00000	0.00016	-0.00001
	5	-0.22152	-0.04278	0.10038	0.00000	0.00015	0.00035
	6	0.10197	-0.01365	0.12955	0.00000	0.00014	-0.00001
	7	-0.21863	-0.04258	0.07130	0.00000	0.00017	0.00035
	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	0.14255	-0.01372	0.09833	0.00000	0.00016	-0.00001
	3	-0.29172	-0.03784	0.09833	0.00000	0.00016	0.00035
	4	0.14544	-0.01356	0.09836	0.00000	0.00016	-0.00001
	5	-0.22116	-0.03797	0.09829	0.00000	0.00015	0.00035
	6	0.14254	-0.01372	0.12765	0.00000	0.00014	-0.00001
	7	-0.21826	-0.03780	0.06900	0.00000	0.00017	0.00035
	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	0.21468	-0.01380	0.09449	0.00000	0.00015	-0.00001
	3	-0.21829	-0.02928	0.09449	0.00000	0.00015	0.00035
	4	0.21757	-0.01369	0.09450	0.00000	0.00016	-0.00002
	5	-0.22051	-0.02936	0.09448	0.00000	0.00015	0.00035
	6	0.21468	-0.01380	0.12417	0.00000	0.00014	-0.00001
	7	-0.21762	-0.02925	0.06480	0.00000	0.00017	0.00035
	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	0.34508	-0.01449	0.08784	0.00000	0.00015	-0.00002
	3	-0.08788	-0.01449	0.08784	0.00000	0.00015	0.00034
	4	0.34798	-0.01449	0.08780	0.00000	0.00016	-0.00002
	5	-0.22051	-0.01449	0.08788	0.00000	0.00015	0.00035
	6	0.34508	-0.01449	0.11820	0.00000	0.00014	-0.00002
	7	-0.21761	-0.01449	0.05747	0.00000	0.00017	0.00034
	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	0.43455	-0.01518	0.08329	0.00000	0.00015	-0.00002
	3	0.00158	-0.00456	0.08329	0.00000	0.00015	0.00034
	4	0.43745	-0.01525	0.08322	0.00000	0.00016	-0.00002
	5	-0.22051	-0.00451	0.08336	0.00000	0.00015	0.00034
	6	0.43455	-0.01518	0.11412	0.00000	0.00014	-0.00002
	7	-0.21761	-0.00458	0.05245	0.00000	0.00017	0.00034
	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	0.07169	0.00674	-0.03361	0.00067	0.00464	-0.00001
	3	-0.07893	-0.00875	-0.03362	0.00067	-0.00464	0.00035
	4	0.07268	0.00684	-0.03361	0.00067	0.00471	-0.00002
	5	-0.07969	-0.00882	0.09441	0.00067	-0.00469	0.00035
	6	0.07191	0.00676	-0.00396	0.00067	0.00464	-0.00001
	7	-0.07892	-0.00874	0.06475	0.00067	-0.00463	0.00035
	8	-0.00023	-0.00002	-0.12803	0.00000	-0.00001	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	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	0.02863	0.00683	-0.02737	-0.00068	-0.00008	-0.00348
	3	-0.03249	-0.00865	-0.02737	-0.00068	-0.00008	0.00377
	4	0.02903	0.00693	-0.02736	-0.00068	-0.00008	-0.00353
	5	-0.03280	-0.00873	0.07687	0.00190	0.00022	0.00381
	6	0.02872	0.00685	-0.00322	-0.00008	-0.00001	-0.00349
	7	-0.03249	-0.00865	0.05272	0.00130	0.00015	0.00377
	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	0.07619	0.00717	0.22244	-0.00069	-0.00462	-0.00001
	3	-0.07443	-0.00831	0.22244	-0.00069	0.00467	0.00035
	4	0.07721	0.00728	0.22245	-0.00069	-0.00468	-0.00002
	5	-0.07521	-0.00839	0.09441	-0.00069	0.00472	0.00035
	6	0.07596	0.00715	0.25210	-0.00069	-0.00462	-0.00001
	7	-0.07396	-0.00826	0.06475	-0.00069	0.00466	0.00035
	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	0.03044	0.00727	0.18113	0.00448	0.00052	-0.00370
	3	-0.03068	-0.00821	0.18112	0.00448	0.00052	0.00355
	4	0.03085	0.00738	0.18113	0.00448	0.00052	-0.00375
	5	-0.03100	-0.00829	0.07687	0.00190	0.00022	0.00359
	6	0.03035	0.00725	0.20527	0.00507	0.00059	-0.00369
	7	-0.03049	-0.00816	0.05272	0.00130	0.00015	0.00353
	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	0.33743	-0.00149	-0.04028	0.00043	0.00019	-0.00002
	3	-0.09408	-0.00149	-0.04029	0.00043	0.00014	0.00034
	4	0.34027	-0.00149	-0.04032	0.00043	0.00019	-0.00002
	5	-0.22622	-0.00149	0.08786	0.00043	0.00013	0.00035
	6	0.33808	-0.00149	-0.00993	0.00043	0.00018	-0.00002
	7	-0.22403	-0.00149	0.05746	0.00043	0.00014	0.00034
	8	0.12930	0.00000	-0.12811	0.00000	0.00001	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	-0.00114	-0.00154	0.00001	-0.00043	0.00000	0.00016
	2	0.35042	-0.00152	0.21594	-0.00043	0.00012	-0.00002
	3	-0.08109	-0.00152	0.21594	-0.00043	0.00016	0.00034
	4	0.35335	-0.00152	0.21590	-0.00043	0.00012	-0.00002
	5	-0.21332	-0.00152	0.08786	-0.00043	0.00018	0.00035
	6	0.34976	-0.00152	0.24630	-0.00043	0.00010	-0.00002
	7	-0.20973	-0.00152	0.05746	-0.00043	0.00019	0.00034
	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	0.14699	-0.01437	0.09848	0.00003	0.00016	-0.00001
	3	-0.28728	-0.03849	0.09848	0.00003	0.00016	0.00035
	4	0.14994	-0.01421	0.09851	0.00003	0.00016	-0.00001
	5	-0.21678	-0.03861	0.09844	0.00003	0.00015	0.00035
	6	0.14655	-0.01438	0.12780	0.00003	0.00014	-0.00001
	7	-0.21339	-0.03844	0.06914	0.00003	0.00017	0.00035
	8	-0.07345	-0.00004	0.00000	0.00000	0.00000	0.00000

SUPPORT REACTIONS -UNIT POUN INCH STRUCTURE TYPE = SPACE

JOINT	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	1427.02	-20657.18	123.81	7732.46	314.62	-23153.46
	3	-1516.40	26149.59	123.82	7732.87	314.64	24206.79
	4	1446.37	-20964.96	123.78	7730.83	314.55	-23464.80
	5	-1531.19	26384.75	-347.73	-21716.97	-883.62	24444.66
	6	1431.46	-20726.61	14.57	910.06	37.03	-23224.92
	7	-1516.28	26146.52	-238.49	-14894.77	-606.04	24204.88
	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	1516.03	-21996.60	-819.33	-51170.74	-2082.04	-24592.75
	3	-1427.39	24810.08	-819.32	-51170.32	-2082.03	22767.43
	4	1535.98	-22313.87	-819.36	-51172.38	-2082.11	-24913.85
	5	-1442.79	25054.77	-347.73	-21716.98	-883.62	23015.10
	6	1511.57	-21926.74	-928.57	-57993.14	-2359.64	-24520.87
	7	-1418.37	24667.66	-238.49	-14894.77	-606.04	22622.13
	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	-14795.96	23883.63	90.68	7281.79	1878.10	-14372.35
	3	15717.69	-22923.14	90.68	7282.18	1878.20	21042.94
	4	-14996.56	24191.41	90.71	7283.46	1877.71	-14605.07
	5	15913.63	-23158.31	-229.77	-18708.03	-5274.75	18233.29
	6	-14841.91	23953.07	15.78	1214.72	221.04	-14425.68
	7	15759.05	-22920.07	-154.83	-12637.98	-3617.73	18053.97
	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	-15717.14	25324.45	-550.19	-44695.45	-12428.66	-15450.13
	3	14796.45	-21482.23	-550.18	-44695.05	-12428.56	19965.10
	4	-15924.02	25641.72	-550.16	-44693.78	-12429.06	-15690.15
	5	14998.69	-21726.92	-229.77	-18708.03	-5274.75	17162.78
	6	-15670.92	25254.59	-625.08	-50762.51	-14085.73	-15396.48
	7	14745.60	-21339.82	-154.83	-12637.98	-3617.73	16869.12
	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	27570.07	-851.99	-0.11	0.00	0.50	-0.01
		2	-27570.07	1428.85	0.11	0.00	0.95	-15395.79
	3	1	-27569.82	-851.98	-0.06	0.00	0.35	-0.63
		2	27569.82	1428.83	0.06	0.00	0.26	-15396.25
	4	1	27618.16	-851.99	0.01	0.00	-0.67	-0.03
		2	-27650.63	1428.85	-0.01	0.00	-0.01	-15395.78
	5	1	-27618.52	-851.95	-0.08	0.00	0.94	0.44
		2	27650.92	1428.80	0.08	0.00	0.93	-15395.13
	6	1	27569.82	-852.02	47.91	0.00	0.78	0.06
		2	-27569.82	1428.87	-80.31	0.00	-864.70	-15395.74
	7	1	-27570.38	-852.03	-47.93	0.00	-0.15	0.08
		2	27570.38	1428.88	80.33	0.00	865.29	-15395.12
	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	27569.58	-1578.85	1154.95	4284.00	0.95	15395.73
		3	-27569.58	2604.37	-1154.95	-4284.00	-27718.72	-65594.48
	3	2	-27570.07	-1578.83	1155.00	4284.02	1.33	15395.98
		3	27570.07	2604.35	-1155.00	-4284.02	-27720.28	-65594.29
	4	2	27659.18	-1578.87	1154.95	4284.00	242.49	15395.79
		3	-27716.79	2604.39	-1154.95	-4284.00	-27962.71	-65594.63
	5	2	-27657.93	-1578.84	1155.01	4283.96	-242.34	15395.67
		3	27715.53	2604.36	-1155.01	-4283.96	-27477.53	-65593.70
	6	2	27569.58	-1578.85	1243.78	4283.99	866.66	15395.79
		3	-27569.58	2604.37	-1301.38	-4283.99	-31408.55	-65594.56
	7	2	-27570.53	-1578.85	1066.23	4284.01	-865.87	15395.89
		3	27570.53	2604.37	-1008.63	-4284.01	-24031.15	-65594.10
	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	226.07	1427.24	173.07	1164.88	-7259.67	65594.47
		4	-226.07	410.15	-173.07	-1164.88	-182.18	-43726.96
	3	3	-56.64	1427.25	173.03	1164.84	-7260.74	65595.27
		4	56.64	410.14	-173.03	-1164.84	-180.77	-43727.87
	4	3	5.86	1427.25	172.84	1158.86	-7254.12	65594.53
		4	-108.89	410.14	-172.84	-1158.86	-177.01	-43726.74
	5	3	77.65	1427.22	173.21	1170.86	-7265.78	65594.72
		4	25.55	410.17	-173.21	-1170.86	-181.86	-43726.64

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	225.59	1427.24	10.83	1253.49	-71.71	65594.63
		4	-225.59	410.15	-114.03	-1253.49	-2617.75	-43727.08
	7	3	-142.37	1427.26	335.18	1076.21	-14451.60	65595.65
		4	142.37	410.13	-231.98	-1076.21	2258.54	-43727.78
	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	0.73	2112.54	-0.01	-0.01	1.15	43726.86
		5	-0.73	-852.00	0.01	0.01	-1.82	0.00
	3	4	0.24	2112.55	0.04	0.00	-1.37	43726.86
		5	-0.24	-852.01	-0.04	0.00	0.11	-0.11
	4	4	-118.16	2112.53	0.02	0.00	-2.17	43726.85
		5	47.36	-852.00	-0.02	0.00	-0.15	-0.21
	5	4	119.00	2112.53	-0.07	-0.02	0.46	43726.44
		5	-48.20	-852.00	0.07	0.02	0.55	0.17
	6	4	-0.49	2112.55	-118.74	0.01	2456.38	43727.03
		5	0.49	-852.01	47.94	-0.01	2.55	0.05
	7	4	0.52	2112.54	118.70	-0.01	-2457.79	43727.34
		5	-0.52	-852.01	-47.90	0.01	0.41	-0.03
	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	13258.14	0.00	-560156.19	-83608.41
		6	-174.93	1978.90	-13258.14	0.00	-0.17	0.02
	3	3	174.87	-1978.90	-14170.38	0.00	598698.81	-83608.41
		6	-174.87	1978.90	14170.38	0.00	-0.28	-0.02
	4	3	174.68	-1978.83	13438.44	0.00	-567774.56	-83605.40
		6	-174.68	1978.83	-13438.44	0.00	-0.02	0.00
	5	3	-490.98	-1978.97	-14308.15	0.00	604519.56	-83611.40
		6	490.98	1978.97	14308.15	0.00	0.05	0.02
	6	3	20.63	-1979.95	13299.42	0.00	-561900.81	-83652.70
		6	-20.63	1979.95	-13299.42	0.00	0.02	0.00
	7	3	-336.75	-1977.85	-14169.19	0.00	598648.69	-83564.07
		6	336.75	1977.85	14169.19	0.00	-0.22	0.01
	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	-1247.55	110.82	0.00	-4681.60	-52709.18
		12	-39.67	1247.55	-110.82	0.00	-0.19	0.00
	3	4	39.67	-1247.56	-30.89	0.00	1305.21	-52709.20
		12	-39.67	1247.56	30.89	0.00	-0.06	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	39.61	-1247.63	111.74	0.00	-4720.68	-52712.20
		12	-39.61	1247.63	-111.74	0.00	0.11	-0.01
	5	4	-86.57	-1247.48	-74.27	0.00	3138.34	-52706.17
		12	86.57	1247.48	74.27	0.00	-0.16	0.00
	6	4	9.89	-1246.51	111.01	0.00	-4690.57	-52664.87
		12	-9.89	1246.51	-111.01	0.00	0.00	0.01
	7	4	-56.59	-1248.60	-73.57	0.00	3108.02	-52753.52
		12	56.59	1248.60	73.57	0.00	-0.13	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	1156.80	-2052.72	-14086.06	0.00	595135.81	-86727.52
		9	-1156.80	2052.72	14086.06	0.00	0.40	-0.01
	3	3	1156.80	-2052.72	13342.41	0.00	-563717.25	-86727.55
		9	-1156.80	2052.72	-13342.41	0.00	0.34	-0.01
	4	3	1156.86	-2052.79	-14272.00	0.00	602992.19	-86730.53
		9	-1156.86	2052.79	14272.00	0.00	0.16	0.01
	5	3	490.98	-2052.65	13485.85	0.00	-569777.31	-86724.52
		9	-490.98	2052.65	-13485.85	0.00	0.12	0.00
	6	3	1310.97	-2051.67	-14044.49	0.00	593379.94	-86683.21
		9	-1310.97	2051.67	14044.49	0.00	-0.19	0.01
	7	3	336.70	-2053.77	13258.35	0.00	-560165.44	-86771.87
		9	-336.70	2053.77	-13258.35	0.00	0.13	-0.03
	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	212.71	-1275.13	-115.08	0.00	4862.02	-53874.07
		14	-212.71	1275.13	115.08	0.00	0.44	0.00
	3	4	212.71	-1275.12	26.62	0.00	-1124.96	-53874.04
		14	-212.71	1275.12	-26.62	0.00	0.10	0.00
	4	4	212.71	-1275.05	-116.02	0.00	4902.16	-53871.06
		14	-212.71	1275.05	116.02	0.00	-0.09	0.00
	5	4	86.52	-1275.20	70.04	0.00	-2959.46	-53877.08
		14	-86.52	1275.20	-70.04	0.00	0.18	0.00
	6	4	242.61	-1276.17	-114.84	0.00	4852.43	-53918.36
		14	-242.61	1276.17	114.84	0.00	-0.20	0.01
	7	4	56.59	-1274.08	68.87	0.00	-2909.67	-53829.73
		14	-56.59	1274.08	-68.87	0.00	0.20	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

ALL UNITS ARE -- POUN INCH

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	2	7	1978.89	13258.13	174.77	0.00	-1572.91	119323.21
		6	-1978.89	-13258.13	-174.77	0.00	0.00	0.00
	3	7	1978.90	-14170.40	174.83	0.00	-1573.46	-127533.60
		6	-1978.90	14170.40	-174.83	0.00	0.00	0.00
	4	7	1978.82	13438.44	174.80	0.00	-1573.17	120945.96
		6	-1978.82	-13438.44	-174.80	0.00	0.00	0.00
	5	7	1978.97	-14308.15	-490.95	0.00	4418.56	-128773.38
		6	-1978.97	14308.15	490.95	0.00	0.00	0.00
	6	7	1979.95	13299.43	20.59	0.00	-185.29	119694.88
		6	-1979.95	-13299.43	-20.59	0.00	0.00	0.00
	7	7	1977.83	-14169.20	-336.72	0.00	3030.48	-127522.77
		6	-1977.83	14169.20	336.72	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	-20657.18	-1427.02	123.81	314.62	-7732.46	-23153.46
		7	20657.18	1427.02	-123.81	-314.62	180.09	-63894.96
	3	8	26149.59	1516.40	123.82	314.64	-7732.87	24206.79
		7	-26149.59	-1516.40	-123.82	-314.64	180.10	68293.85
	4	8	-20964.96	-1446.37	123.78	314.55	-7730.83	-23464.80
		7	20964.96	1446.37	-123.78	-314.55	180.03	-64763.98
	5	8	26384.75	1531.19	-347.73	-883.62	21716.97	24444.66
		7	-26384.75	-1531.19	347.73	883.62	-505.74	68957.81
	6	8	-20726.61	-1431.46	14.57	37.03	-910.06	-23224.92
		7	20726.61	1431.46	-14.57	-37.03	21.21	-64094.02
	7	8	26146.52	1516.28	-238.49	-606.04	14894.77	24204.88
		7	-26146.52	-1516.28	238.49	606.04	-346.87	68288.13
	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	2052.70	14086.06	-1156.79	0.00	10411.18	126774.58
		9	-2052.70	-14086.06	1156.79	0.00	0.00	0.00
	3	10	2052.71	-13342.41	-1156.78	0.00	10410.96	-120081.70
		9	-2052.71	13342.41	1156.78	0.00	0.00	0.00
	4	10	2052.81	14272.00	-1156.80	0.00	10411.36	128448.04
		9	-2052.81	-14272.00	1156.80	0.00	0.00	0.00
	5	10	2052.64	-13485.86	-490.95	0.00	4418.56	-121372.66
		9	-2052.64	13485.86	490.95	0.00	0.00	0.00
	6	10	2051.67	14044.49	-1311.01	0.00	11798.95	126400.45
		9	-2051.67	-14044.49	1311.01	0.00	0.00	0.00
	7	10	2053.74	-13258.37	-336.73	0.00	3030.49	-119325.31
		9	-2053.74	13258.37	336.73	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

ALL 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	-21996.60	-1516.03	-819.33	-2082.04	51170.74	-24592.75
		10	21996.60	1516.03	819.33	2082.04	-1191.65	-67884.99
	3	11	24810.08	1427.39	-819.32	-2082.03	51170.32	22767.43
		10	-24810.08	-1427.39	819.32	2082.03	-1191.64	64303.62
	4	11	-22313.87	-1535.98	-819.36	-2082.11	51172.38	-24913.85
		10	22313.87	1535.98	819.36	2082.11	-1191.69	-68781.19
	5	11	25054.77	1442.79	-347.73	-883.62	21716.98	23015.10
		10	-25054.77	-1442.79	347.73	883.62	-505.74	64994.87
	6	11	-21926.74	-1511.57	-928.57	-2359.64	57993.14	-24520.87
		10	21926.74	1511.57	928.57	2359.64	-1350.53	-67684.74
	7	11	24667.66	1418.37	-238.49	-606.04	14894.77	22622.13
		10	-24667.66	-1418.37	238.49	606.04	-346.86	63898.45
	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	-110.80	0.00	7756.23	2778.01
		12	-1247.55	-39.69	110.80	0.00	0.00	0.00
	3	13	1247.56	39.69	30.89	0.00	-2162.64	2778.17
		12	-1247.56	-39.69	-30.89	0.00	0.00	0.00
	4	13	1247.63	39.72	-111.74	0.00	7821.53	2780.64
		12	-1247.63	-39.72	111.74	0.00	0.00	0.00
	5	13	1247.48	-86.56	74.29	0.00	-5199.99	-6058.98
		12	-1247.48	86.56	-74.29	0.00	0.00	0.00
	6	13	1246.51	9.78	-111.02	0.00	7771.28	684.65
		12	-1246.51	-9.78	111.02	0.00	0.00	0.00
	7	13	1248.60	-56.61	73.57	0.00	-5149.76	-3962.53
		12	-1248.60	56.61	-73.57	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	-212.73	-115.07	0.00	8054.88	-14891.05
		14	-1275.13	212.73	115.07	0.00	0.00	0.00
	3	15	1275.13	-212.73	26.63	0.00	-1863.97	-14890.90
		14	-1275.13	212.73	-26.63	0.00	0.00	0.00
	4	15	1275.05	-212.69	-116.03	0.00	8122.22	-14888.43
		14	-1275.05	212.69	116.03	0.00	0.00	0.00
	5	15	1275.20	-86.56	70.05	0.00	-4903.37	-6058.98
		14	-1275.20	86.56	-70.05	0.00	0.00	0.00
	6	15	1276.17	-242.63	-114.85	0.00	8039.74	-16984.41
		14	-1276.17	242.63	114.85	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	1274.08	-56.61	68.87	0.00	-4820.89	-3962.53
		14	-1274.08	56.61	-68.87	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	26962.30	-1039.18	-50.99	-1059.83	-957.42	-55428.20
		13	-26962.30	1039.18	50.99	1059.83	4763.19	-22128.58
	3	7	-28793.71	1104.68	-51.00	-1059.89	-957.47	59239.65
		13	28793.71	-1104.68	51.00	1059.89	4763.45	23205.57
	4	7	27328.84	-1053.28	-50.98	-1059.61	-957.21	-56182.04
		13	-27328.84	1053.28	50.98	1059.61	4762.19	-22426.60
	5	7	-29073.75	1115.45	143.22	2976.58	2688.94	59815.61
		13	29073.75	-1115.45	-143.22	-2976.58	-13377.64	23433.27
	6	7	27046.26	-1042.41	-6.00	-124.74	-112.69	-55600.87
		13	-27046.26	1042.41	6.00	124.74	560.60	-22196.96
	7	7	-28791.30	1104.59	98.23	2041.51	1844.23	59234.69
		13	28791.30	-1104.59	-98.23	-2041.51	-9175.17	23203.73
	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	28645.70	-1104.00	337.46	7013.58	6335.82	-58889.45
		15	-28645.70	1104.00	-337.46	-7013.58	-31521.15	-23505.01
	3	10	-27110.21	1039.86	337.46	7013.52	6335.77	55778.22
		15	27110.21	-1039.86	-337.46	-7013.52	-31520.89	21829.07
	4	10	29023.71	-1118.54	337.47	7013.80	6336.02	-59666.86
		15	-29023.71	1118.54	-337.47	-7013.80	-31522.17	-23812.37
	5	10	-27401.77	1051.07	143.22	2976.58	2688.93	56377.85
		15	27401.77	-1051.07	-143.22	-2976.58	-13377.65	22066.14
	6	10	28561.23	-1100.75	382.45	7948.67	7180.55	-58715.74
		15	-28561.23	1100.75	-382.45	-7948.67	-35723.75	-23436.22
	7	10	-26939.32	1033.29	98.23	2041.51	1844.23	55426.76
		15	26939.32	-1033.29	-98.23	-2041.51	-9175.17	21690.01
	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	-0.01	4283.99
		16	1155.03	-150.00	-0.01	0.00	-0.15	0.01
	3	2	-1155.09	150.00	0.02	0.00	-0.17	4284.04
		16	1155.09	-150.00	-0.02	0.00	-0.41	0.04
	4	2	-1155.00	150.00	8.51	0.00	-242.85	4284.00
		16	1155.00	-150.00	-8.51	0.00	-0.19	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	-1155.08	150.00	-8.51	0.00	243.15	4283.97
		16	1155.08	-150.00	8.51	0.00	0.21	-0.01
	6	2	-1163.53	150.00	0.00	0.00	-0.18	4283.99
		16	1163.53	-150.00	0.00	0.00	-0.06	-0.02
	7	2	-1146.49	150.00	-0.01	0.00	0.19	4284.01
		16	1146.49	-150.00	0.01	0.00	0.15	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 **************

141. PRINT MEMBER STRESSES ALL

MEMBER STRESSES

ALL 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	782.3 C	0.0	0.0	782.3	40.3	0.0
		1.00	782.3 C	0.0	39.2	821.5	67.6	0.0
	3	.0	782.3 T	0.0	0.0	782.3	40.3	0.0
		1.00	782.3 T	0.0	39.2	821.5	67.6	0.0
	4	.0	783.7 C	0.0	0.0	783.7	40.3	0.0
		1.00	784.6 C	0.0	39.2	823.8	67.6	0.0
	5	.0	783.7 T	0.0	0.0	783.7	40.3	0.0
		1.00	784.6 T	0.0	39.2	823.8	67.6	0.0
	6	.0	782.3 C	0.0	0.0	782.3	40.3	2.3
		1.00	782.3 C	2.2	39.2	821.5	67.6	3.8
	7	.0	782.3 T	0.0	0.0	782.3	40.3	2.3
		1.00	782.3 T	2.2	39.2	821.6	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	782.3 C	0.0	39.2	821.5	74.7	54.6
		1.00	782.3 C	70.5	166.8	963.5	123.2	54.6
	3	.0	782.3 T	0.0	39.2	821.5	74.7	54.6
		1.00	782.3 T	70.5	166.8	963.5	123.2	54.6
	4	.0	784.9 C	0.6	39.2	824.0	74.7	54.6
		1.00	786.5 C	71.1	166.8	967.9	123.2	54.6
	5	.0	784.8 T	0.6	39.2	824.0	74.7	54.6
		1.00	786.5 T	69.9	166.8	967.4	123.2	54.6
	6	.0	782.3 C	2.2	39.2	821.5	74.7	58.8
		1.00	782.3 C	79.9	166.8	967.3	123.2	61.5
	7	.0	782.3 T	2.2	39.2	821.6	74.7	50.4
		1.00	782.3 T	61.1	166.8	960.0	123.2	47.7
	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	3.6 C	5.8	52.7	56.6	38.0	4.6
		1.00	3.6 C	0.1	35.1	38.7	10.9	4.6
	3	.0	0.9 T	5.8	52.7	53.9	38.0	4.6
		1.00	0.9 T	0.1	35.1	36.0	10.9	4.6
	4	.0	0.1 C	5.8	52.7	53.1	38.0	4.6
		1.00	1.7 C	0.1	35.1	36.9	10.9	4.6
	5	.0	1.2 C	5.8	52.7	54.3	38.0	4.6
		1.00	0.4 C	0.1	35.1	35.5	10.9	4.6
	6	.0	3.6 C	0.1	52.7	56.3	38.0	0.3
		1.00	3.6 C	2.1	35.1	38.8	10.9	3.0
	7	.0	2.3 T	11.6	52.7	56.2	38.0	8.9
		1.00	2.3 T	1.8	35.1	37.4	10.9	6.2

MEMBER STRESSES

ALL 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 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
	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 C	0.0	111.2	114.6	99.9	0.0
		1.00	1.4 C	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	6.3	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	24649.3	3679.1	28347.2	395.8	2651.6
		1.00	18.7 C	0.0	0.0	18.7	395.8	2651.6
	3	.0	18.7 C	26345.4	3679.1	30043.2	395.8	2834.1
		1.00	18.7 C	0.0	0.0	18.7	395.8	2834.1
	4	.0	18.7 C	24984.6	3679.0	28682.2	395.8	2687.7
		1.00	18.7 C	0.0	0.0	18.7	395.8	2687.7
	5	.0	52.5 T	26601.5	3679.3	30333.2	395.8	2861.6
		1.00	52.5 T	0.0	0.0	52.5	395.8	2861.6
	6	.0	2.2 C	24726.1	3681.1	28409.4	396.0	2659.9
		1.00	2.2 C	0.0	0.0	2.2	396.0	2659.9
	7	.0	36.0 T	26343.2	3677.2	30056.3	395.6	2833.8
		1.00	36.0 T	0.0	0.0	36.0	395.6	2833.8
	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	206.0	2319.4	2529.7	249.5	22.2
		1.00	4.2 C	0.0	0.0	4.2	249.5	22.2
	3	.0	4.2 C	57.4	2319.4	2381.1	249.5	6.2
		1.00	4.2 C	0.0	0.0	4.2	249.5	6.2
	4	.0	4.2 C	207.7	2319.6	2531.5	249.5	22.3
		1.00	4.2 C	0.0	0.0	4.2	249.5	22.3
	5	.0	9.2 T	138.1	2319.3	2466.7	249.5	14.9
		1.00	9.2 T	0.0	0.0	9.3	249.5	14.9
	6	.0	1.1 C	206.4	2317.5	2524.9	249.3	22.2
		1.00	1.1 C	0.0	0.0	1.1	249.3	22.2

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	7	.0	6.0 T	136.8	2321.4	2464.2	249.7	14.7
		1.00	6.0 T	0.0	0.0	6.1	249.7	14.7
	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	26188.6	3816.4	30128.6	410.5	2817.2
		1.00	123.6 C	0.0	0.0	123.6	410.5	2817.2
	3	.0	123.6 C	24806.0	3816.4	28746.0	410.5	2668.5
		1.00	123.6 C	0.0	0.0	123.6	410.5	2668.5
	4	.0	123.6 C	26534.3	3816.5	30474.4	410.6	2854.4
		1.00	123.6 C	0.0	0.0	123.6	410.6	2854.4
	5	.0	52.5 C	25072.7	3816.3	28941.4	410.5	2697.2
		1.00	52.5 C	0.0	0.0	52.5	410.5	2697.2
	6	.0	140.1 C	26111.3	3814.4	30065.8	410.3	2808.9
		1.00	140.1 C	0.0	0.0	140.1	410.3	2808.9
	7	.0	36.0 C	24649.7	3818.3	28504.1	410.8	2651.7
		1.00	36.0 C	0.0	0.0	36.0	410.8	2651.7
	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	214.0	2370.7	2607.4	255.0	23.0
		1.00	22.7 C	0.0	0.0	22.7	255.0	23.0
	3	.0	22.7 C	49.5	2370.7	2442.9	255.0	5.3
		1.00	22.7 C	0.0	0.0	22.7	255.0	5.3
	4	.0	22.7 C	215.7	2370.6	2609.0	255.0	23.2
		1.00	22.7 C	0.0	0.0	22.7	255.0	23.2
	5	.0	9.2 C	130.2	2370.8	2510.3	255.0	14.0
		1.00	9.2 C	0.0	0.0	9.3	255.0	14.0
	6	.0	25.9 C	213.5	2372.6	2612.1	255.2	23.0
		1.00	25.9 C	0.0	0.0	25.9	255.2	23.0
	7	.0	6.0 C	128.0	2368.7	2502.8	254.8	13.8
		1.00	6.0 C	0.0	0.0	6.1	254.8	13.8
	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	19402.1	19969.1	3314.5	43.7
		1.00	311.1 C	0.0	0.0	311.1	3314.5	43.7
	3	.0	311.1 C	255.8	20737.2	21304.2	3542.6	43.7
		1.00	311.1 C	0.0	0.0	311.1	3542.6	43.7
	4	.0	311.1 C	255.8	19666.0	20232.9	3359.6	43.7
		1.00	311.1 C	0.0	0.0	311.1	3359.6	43.7
	5	.0	311.2 C	718.5	20938.8	21968.4	3577.0	122.7
		1.00	311.2 C	0.0	0.0	311.2	3577.0	122.7

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	6	.0	311.3 C	30.1	19462.6	19804.0	3324.9	5.1
		1.00	311.3 C	0.0	0.0	311.3	3324.9	5.1
	7	.0	311.0 C	492.8	20735.4	21539.2	3542.3	84.2
		1.00	311.0 C	0.0	0.0	311.0	3542.3	84.2
	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	3248.0 T	1257.3	3764.8	8270.1	356.8	31.0
		1.00	3248.0 T	29.3	10389.4	13666.7	356.8	31.0
	3	.0	4111.6 C	1257.4	3936.1	9305.0	379.1	31.0
		1.00	4111.6 C	29.3	11104.7	15245.5	379.1	31.0
	4	.0	3296.4 T	1257.0	3815.4	8368.8	361.6	30.9
		1.00	3296.4 T	29.3	10530.7	13856.4	361.6	30.9
	5	.0	4148.5 C	3531.2	3974.7	11654.5	382.8	86.9
		1.00	4148.5 C	82.2	11212.7	15443.4	382.8	86.9
	6	.0	3258.9 T	148.0	3776.4	7183.3	357.9	3.6
		1.00	3258.9 T	3.4	10421.8	13684.1	357.9	3.6
	7	.0	4111.1 C	2421.9	3935.8	10468.8	379.1	59.6
		1.00	4111.1 C	56.4	11103.8	15271.3	379.1	59.6
	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	1692.9	20613.8	22629.4	3521.5	289.2
		1.00	322.8 C	0.0	0.0	322.8	3521.5	289.2
	3	.0	322.8 C	1692.8	19525.5	21541.1	3335.6	289.2
		1.00	322.8 C	0.0	0.0	322.8	3335.6	289.2
	4	.0	322.8 C	1692.9	20885.9	22901.5	3568.0	289.2
		1.00	322.8 C	0.0	0.0	322.8	3568.0	289.2
	5	.0	322.7 C	718.5	19735.4	20776.6	3371.5	122.7
		1.00	322.7 C	0.0	0.0	322.7	3371.5	122.7
	6	.0	322.6 C	1918.5	20552.9	22794.0	3511.1	327.8
		1.00	322.6 C	0.0	0.0	322.6	3511.1	327.8
	7	.0	322.9 C	492.8	19402.5	20218.2	3314.6	84.2
		1.00	322.9 C	0.0	0.0	322.9	3314.6	84.2
	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	3458.6 T	8320.4	3998.8	15777.9	379.0	204.8
		1.00	3458.6 T	193.8	11038.2	14690.6	379.0	204.8
	3	.0	3901.0 C	8320.4	3702.0	15923.4	356.8	204.8
		1.00	3901.0 C	193.8	10455.9	14550.6	356.8	204.8
	4	.0	3508.5 T	8320.7	4051.0	15880.2	384.0	204.8
		1.00	3508.5 T	193.8	11183.9	14886.2	384.0	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	3939.4 C	3531.2	3742.3	11212.9	360.7	86.9
		1.00	3939.4 C	82.2	10568.3	14589.9	360.7	86.9
	6	.0	3447.6 T	9429.8	3987.1	16864.5	377.9	232.1
		1.00	3447.6 T	219.6	11005.6	14672.8	377.9	232.1
	7	.0	3878.6 C	2421.9	3678.4	9978.9	354.6	59.6
		1.00	3878.6 C	56.4	10390.0	14325.0	354.6	59.6
	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	5966.3	1424.6	8008.6	26.5	221.6
		1.00	617.6 C	0.0	0.0	617.6	26.5	221.6
	3	.0	617.6 C	1663.6	1424.7	3705.9	26.5	61.8
		1.00	617.6 C	0.0	0.0	617.6	26.5	61.8
	4	.0	617.6 C	6016.6	1426.0	8060.2	26.5	223.5
		1.00	617.6 C	0.0	0.0	617.6	26.5	223.5
	5	.0	617.6 C	4000.0	3107.2	7724.7	57.7	148.6
		1.00	617.6 C	0.0	0.0	617.6	57.7	148.6
	6	.0	617.1 C	5977.9	351.1	6946.1	6.5	222.0
		1.00	617.1 C	0.0	0.0	617.1	6.5	222.0
	7	.0	618.1 C	3961.4	2032.1	6611.5	37.7	147.1
		1.00	618.1 C	0.0	0.0	618.1	37.7	147.1
	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	6196.1	7636.4	14463.8	141.8	230.1
		1.00	631.3 C	0.0	0.0	631.3	141.8	230.1
	3	.0	631.3 C	1433.8	7636.4	9701.4	141.8	53.3
		1.00	631.3 C	0.0	0.0	631.3	141.8	53.3
	4	.0	631.2 C	6247.9	7635.1	14514.2	141.8	232.1
		1.00	631.2 C	0.0	0.0	631.2	141.8	232.1
	5	.0	631.3 C	3771.8	3107.2	7510.3	57.7	140.1
		1.00	631.3 C	0.0	0.0	631.3	57.7	140.1
	6	.0	631.8 C	6184.4	8710.0	15526.1	161.8	229.7
		1.00	631.8 C	0.0	0.0	631.8	161.8	229.7
	7	.0	630.7 C	3708.4	2032.1	6371.2	37.7	137.7
		1.00	630.7 C	0.0	0.0	630.7	37.7	137.7
	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	4239.4 C	155.7	9012.7	13407.7	259.8	12.7
		1.00	4239.4 C	774.5	3598.1	8612.0	259.8	12.7
	3	.0	4527.3 T	155.7	9632.5	14315.5	276.2	12.7
		1.00	4527.3 T	774.5	3773.3	9075.1	276.2	12.7

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	4	.0	4297.0 C	155.6	9135.3	13587.9	263.3	12.7
		1.00	4297.0 C	774.3	3646.6	8717.9	263.3	12.7
	5	.0	4571.3 T	437.2	9726.1	14734.7	278.9	35.8
		1.00	4571.3 T	2175.2	3810.3	10556.9	278.9	35.8
	6	.0	4252.6 C	18.3	9040.8	13311.7	260.6	1.5
		1.00	4252.6 C	91.2	3609.3	7953.0	260.6	1.5
	7	.0	4526.9 T	299.9	9631.7	14458.5	276.1	24.6
		1.00	4526.9 T	1491.9	3773.0	9791.8	276.1	24.6
	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	4504.0 C	1030.2	9575.5	15109.8	276.0	84.4
		1.00	4504.0 C	5125.4	3822.0	13451.4	276.0	84.4
	3	.0	4262.6 T	1030.2	9069.6	14362.4	260.0	84.4
		1.00	4262.6 T	5125.3	3549.4	12937.4	260.0	84.4
	4	.0	4563.5 C	1030.2	9701.9	15295.7	279.6	84.4
		1.00	4563.5 C	5125.6	3871.9	13561.0	279.6	84.4
	5	.0	4308.5 T	437.2	9167.1	13912.8	262.8	35.8
		1.00	4308.5 T	2175.2	3588.0	10071.7	262.8	35.8
	6	.0	4490.8 C	1167.6	9547.3	15205.6	275.2	95.6
		1.00	4490.8 C	5808.7	3810.8	14110.3	275.2	95.6
	7	.0	4235.7 T	299.9	9012.5	13548.1	258.3	24.6
		1.00	4235.7 T	1491.9	3526.8	9254.5	258.3	24.6
	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	150.9	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	13.4	235.2	386.5	32.6	1.9
		1.00	150.8 T	0.0	0.0	150.9	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	151.9	32.6	0.0
	7	.0	149.7 T	0.0	235.2	385.0	32.6	0.0
		1.00	149.7 T	0.0	0.0	149.7	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 **************

```
142. PARAMETER
143. CODE AISC
144. FYLD 45999.969 MEMB 9 TO 16
145. WSTR 21000. MEMB 9 TO 16
146. WMIN 0.188 MEMB 9 TO 16
147. CB 1. MEMB 9 TO 16
148. CMY 1. MEMB 9 TO 16
149. MAIN 0. MEMB 9 TO 16
150. RATIO 1. MEMB 9 TO 16
151. CHECK CODE MEMB 9 TO 16
```

STAAD-III CODE CHECKING - (AISC)
****

ALL 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	0.796	5
		1978.97 C	4418.56	-128773.38	0.00
10	ST TUB 40408	PASS	AISC- H1-2	0.560	5
		26384.75 C	-505.74	68957.81	61.00
11	ST TUB 40408	PASS	AISC- H1-3	0.830	4
		2052.81 C	10411.36	128448.04	0.00
12	ST TUB 40408	PASS	AISC- H2-1	0.611	6
		21926.74 T	57993.14	-24520.87	0.00
13	ST TUB 40203	PASS	AISC- H1-3	0.306	4
		1247.63 C	7821.53	2780.64	0.00
14	ST TUB 40203	PASS	AISC- H1-3	0.577	6
		1276.17 C	8039.74	-16984.41	0.00
15	ST TUB 40408	PASS	AISC- H2-1	0.534	5
		29073.75 T	2688.94	59815.61	0.00
16	ST TUB 40408	PASS	AISC- H1-1	0.574	4
		29023.71 C	6336.02	-59666.86	0.00

152. 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 5	1 98.19	5/16 2861.63	20574.80 20374.59
9	END 5	1 163.65	3/16 4769.38	4817.57 659.66
10	STA 5	1 226.36	3/16 620.85	20346.06 20335.33
10	END 5	1 169.77	4/16 465.64	19626.87 19620.61
11	STA 4	1 192.80	6/16 2378.67	17859.72 17699.56
11	END 4	1 385.60	3/16 4757.33	4821.74 684.27
12	STA 6	1 453.36	4/16 599.11	20966.53 20953.06
12	END 4	1 400.04	4/16 579.19	18711.63 18698.38
13	STA 4	1 49.66	3/16 17.65	6136.43 6136.20
13	END 4	1 49.66	3/16 17.65	557.00 554.50
14	STA 6	1 51.05	3/16 107.84	11955.69 11955.09
14	END 6	1 51.05	3/16 107.84	579.60 567.19
15	STA 5	1 314.86	4/16 557.92	18998.84 18988.04
15	END 5	1 419.81	3/16 743.89	18913.28 18893.98
16	STA 4	1 741.91	4/16 937.18	19667.82 19631.47
16	END 6	1 840.80	4/16 1020.38	18280.68 18232.80

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                    STAADD-III WELD DESIGN
                    *********************

ALL UNITS ARE - INCH POUN

MEMBER   LOCATION/     WELD TYPE/      WELD SIZE/      COMB STRESS/
         LOADING       HOR STRESS     VERT STRESS       DIR STRESS
=====================================================================


****************** END OF TABULATED WELD DESIGN ******************


153. FINISH

          *************** END OF STAAD-III ***************

            **** DATE= SEP 24,1996   TIME= 15:30:50 ****

      *********************************************************
      *        For questions on  STAAD-III,   contact:       *
      *              Research Engineers, Inc at               *
      *       Ph: (714) 974-2500   Fax:  (714) 921-2543       *
      *********************************************************
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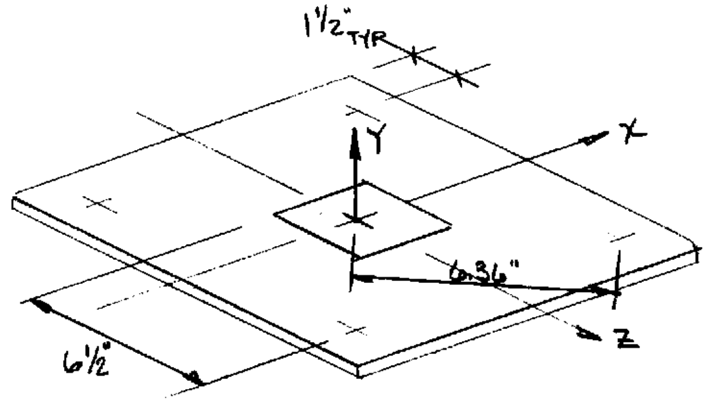
DESIGN ANCHORAGE   TRY PL 12"x12" w/ 1"Φ HILTI HVA
USE THKS = 1 3/8"



SUPPORT REACTIONS - JTS 13 & 15 (SEE PAGE 20 of 90)

WORST CASE LOADING OCCURS @ JOINT 15 L.C. #3

F_X = 14796 lbs M_X = 44695 in-lbs

F_Y = 21482 lbs (TENSION) M_Y = 12429 in-lbs

F_Z = 550 lbs M_Z = 19965 in-lbs.

SHEAR

$$V = \frac{14796 \text{ lbs} + 550 \text{ lbs}}{4 \text{ BOLTS}} + \frac{12429 \text{ in-lbs}}{4 \text{ BOLTS } (6.36 \text{ in})}$$

= 4325 lbs/BOLT

TENSION

$$T = \frac{21482 \text{ lbs}}{4 \text{ BOLTS}} + \frac{44695 \text{ in-lbs} + 19965 \text{ in-lbs}}{2 \text{ BOLT } (6.95 \text{ in})}$$

L (see following page FOR DETAIL)

T = 5370.5 lbs/BOLT + 4652. lbs/BOLT

T = 10023. lbs/BOLT   (NOTE: NO PRYING FACTOR DUE TO THICK PL)

BOLT INTERACTION (PER HILTI SPEC.)

1" ϕ HILTI HVA @ 12 3/8" EMB'T (HAS STD - SAE 1018)

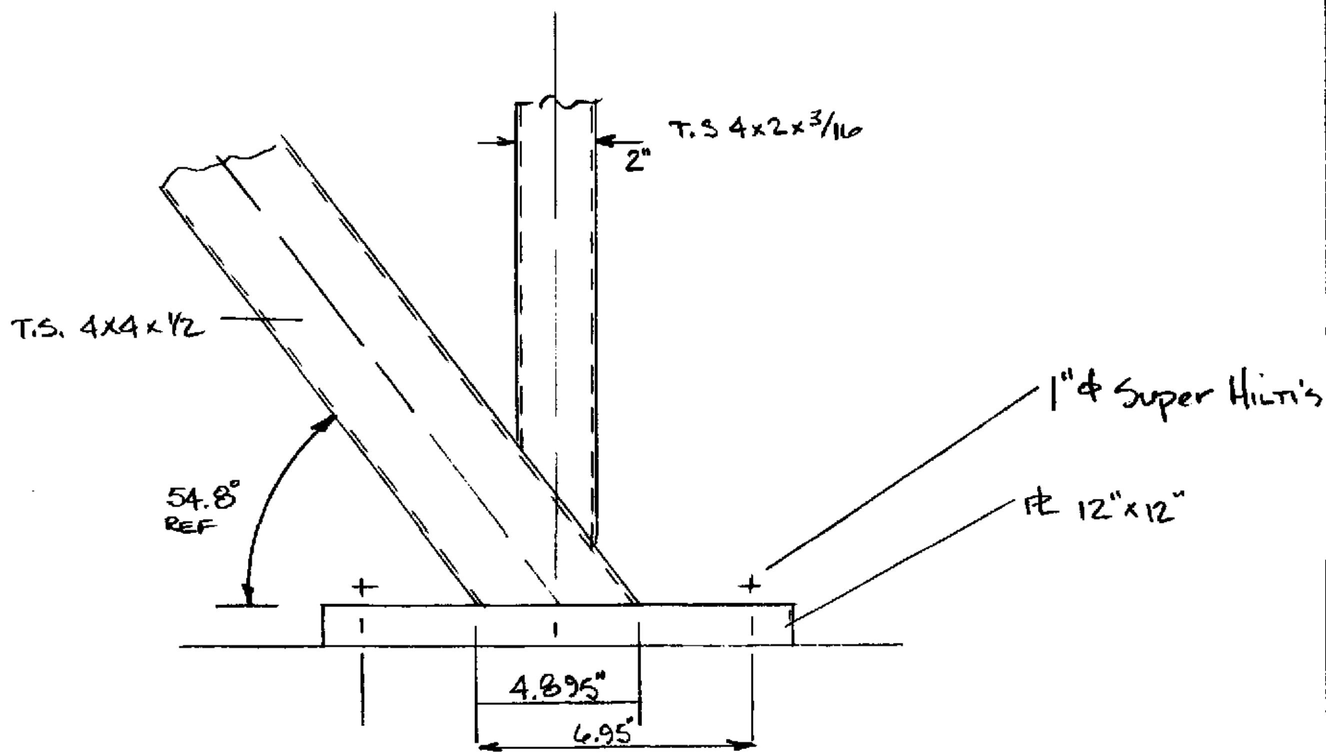
T_{ALL} = 12120 lbs V_{ALL} = 7630 lbs

$$\left(\frac{4325 \text{ lb/BOLT}}{7630 \text{ lb/BOLT}}\right)^{5/3} + \left(\frac{10023 \text{ lbs/BOLT}}{12120 \text{ lbs/BOLT}}\right)^{5/3} = 1.11 > 1.0 \therefore NG$$

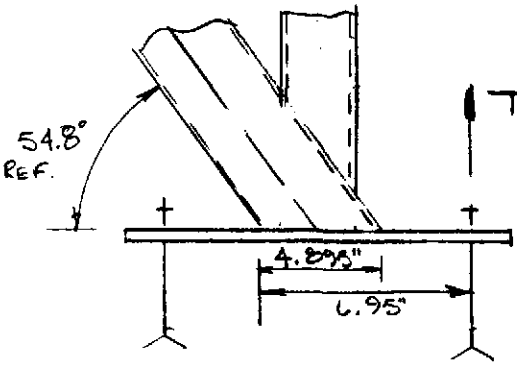
TRY 1" ϕ HAS SUPER SAE 4140 @ 12 3/8" EMB'T

T_{ALL} = 16450 lbs V_{ALL} = 13760 lbs

$$\left(\frac{4325 \text{ lb/BOLT}}{13760 \text{ lb/BOLT}}\right)^{5/3} + \left(\frac{10344 \text{ lb/BOLT}}{16450 \text{ lb/BOLT}}\right)^{5/3} = .61 < 1.0 \therefore O.K.$$



DETERMINE PL PLATE THICKNESS



T = 10344 lbs/BOLT

PL ⇒ $f_y = 36000 \#/in^2$

$F_b = .75(f_y) = 27000 \#/in^2$

$$f_b = \frac{M}{S} \Rightarrow S_{req'd} = \frac{M}{f_b}$$

$$S_{req'd} = \frac{10344 \text{ lbs} (6.95 \text{ in})}{27000 \text{ lb/in}^2} = 2.66 \text{ in}^3$$

$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{6S}{b}}$$

$$d_{req'd} = \sqrt{\frac{6(2.66 \text{ in}^3)}{12 \text{ in}}} = 1.15 \text{ in}$$

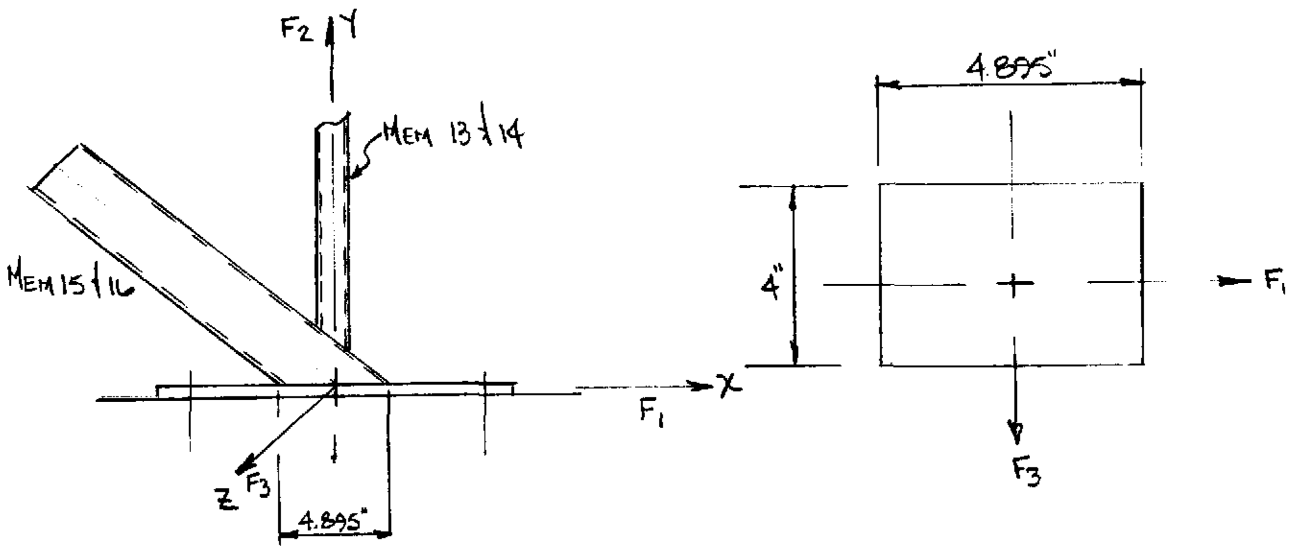
USE PL 1 3/8" THK.

USE PL 12" x 12" x 1 3/8" THK
W/4 - 1"φ HILTI HAS SUPER SAE 4140
ANCHOR BOLTS @ 12 3/8" EMBT

Filename: 80K-SHRT PMP

ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part Jts. 13 & 15 and BASEPLTS



LOAD INPUT (LBS., INCH-LBS.)

F1	F2	F3	M1	M2	M3
14796.00	21482.00	550.00	44695.00	12429.00	19965.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90ø>á<120ø)
4.000	4.895	21000	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
17.790	24.913	27.567	117.297	2.000	2.448

EFFECTIVE THROAT CORRECTION FACTOR

Mf
1.00

MAXIMUM WELD LOAD (f) - #/INCH

f=
3880

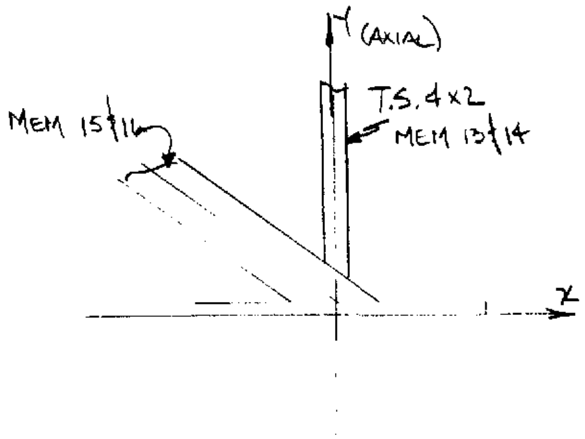
REQUIRED FILLET WELD SIZE (INCHES)

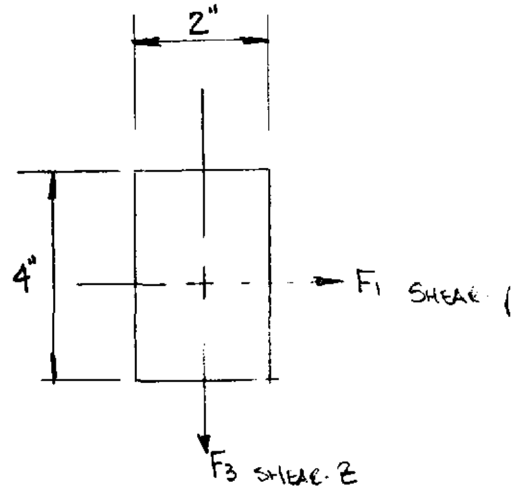
w=
0.261 USE 1/4" fillet on 3 sides & full Penetration on the 4th side

Filename: 80K-SHRT PMP

ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part Jts.13 & 15 and BASEPLTS
(END OF MEMBERS 13 & 14)





LOAD INPUT (LBS., INCH-LBS.) (SEE PGS 25&26 of 90)

F1	F2	F3	M1	M2	M3
243.00	1276.00	116.00	8040.00		16984.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90ø>á<120ø)
4.000	2.000	21000	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
12.000	13.333	9.333	36.000	2.000	1.000

EFFECTIVE THROAT CORRECTION FACTOR

Mf
1.00

MAXIMUM WELD LOAD (f) - #/INCH

f=
2529

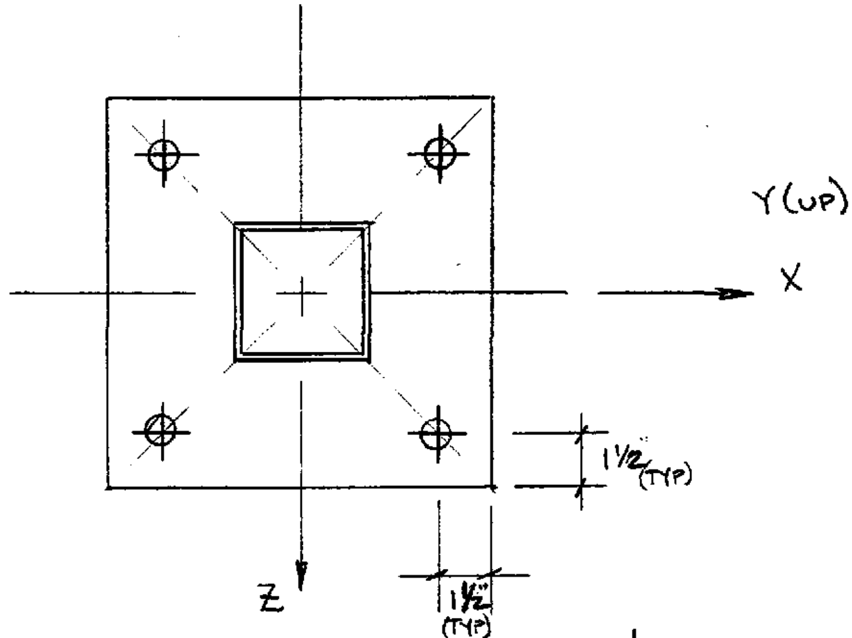
REQUIRED FILLET WELD SIZE (INCHES)

w=
0.170

DESIGN ANCHOR BOLTS & BASEPLATE

TRY PLATE 12" x 12"
w/ 4 - 1" φ HVA HILTI ANCHORS.

$f'_c = 3000 \text{ psi}$



REACTIONS @ BP (WORST CASE) @ 11. JTS 8 & 11 (see page 20 of 90)

Fx = 1512. lbs.	Mx = 57993. in-lbs
FY = 21927. lbs (UP)	MY = 2360. in-lbs
Fz = 929. lbs.	Mz = 24521. in-lbs.

TENSION

$$T = \frac{21927 \text{ lbs}}{4 \text{ bolts}} + \frac{57993 \text{ in-lbs} + 24521 \text{ in-lbs}}{2\ (6.5 \text{ in})}$$

$$= 11829 \text{ lbs}$$

Revision No. 1
Doc. No. V049-1-083
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SHEAR

$$V = \frac{1512 \text{ lbs} + 929 \text{ lbs}}{4 \text{ bolts}} + \frac{2360 \text{ in-lbs}}{4 \text{ bolts}\ (6.364 \text{ in})}$$

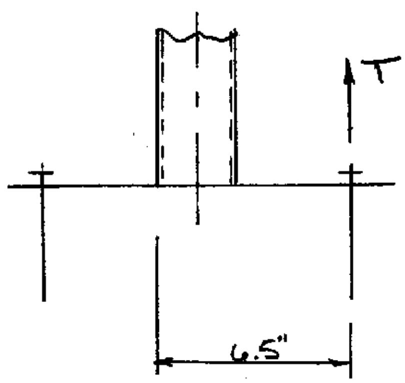
$$V = 703 \text{ lbs.}$$

TRY 1"Φ HILTI HVA @ 12 3/8" EMB'T

T_{ALL} = 12120 V_{ALL} = 7630

$$\left(\frac{11829\ lbs}{12120\ lbs}\right)^{5/3} + \left(\frac{703\ lbs}{7630\ lbs}\right)^{5/3} = .98 < 1.0 \therefore O.K.$$

BASEPLATE



T = 11829 lbs

F_y = 36000 #/in²

F_b = .75 F_y = 27000 #/in²

$$f_b = \frac{M}{S} \therefore S_{req'd} = \frac{M}{f_b}$$

$$S_{req'd} = \frac{6.5\ in\ (11829\ lbs)}{27000\ \#/in^2} = 2.85\ in^3$$

$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{S(6)}{b}}$$

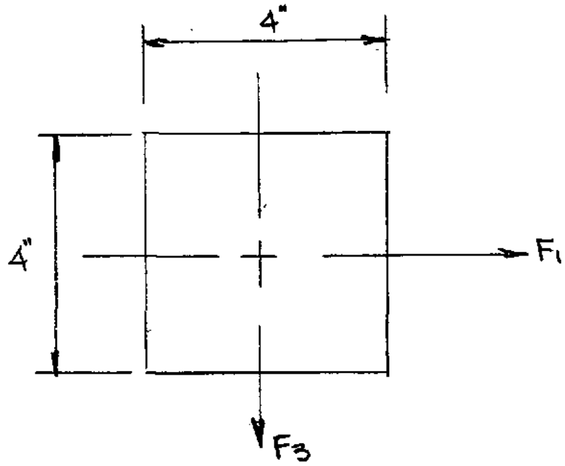
$$d = \sqrt{\frac{2.85(6)}{12\ in}} = 1.19\ in$$ USE 1 3/8" PL

USE PL 12" x 12" x 1 3/8"
w/ 4 - 1"Φ HILTI HVA
HAS SUPER (SAE 4140) @ 12 3/8" EMB'T

Filename: 80K-SHRT PMP

ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part Jts. 8 & 11 and BASEPLTS
(END OF MEMBERS 10 & 12)



LOAD INPUT (LBS., INCH-LBS.) (SEE PAGE 20 of 90)

F1	F2	F3	M1	M2	M3
1512.00	21927.00	929.00	57993.00	2360.00	24521.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90ø>â<120ø)
4.000	4.000	21000	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
16.000	21.333	21.333	85.333	2.000	2.000

EFFECTIVE THROAT CORRECTION FACTOR

Mf
1.00

MAXIMUM WELD LOAD (f) - #/INCH

f=
5242

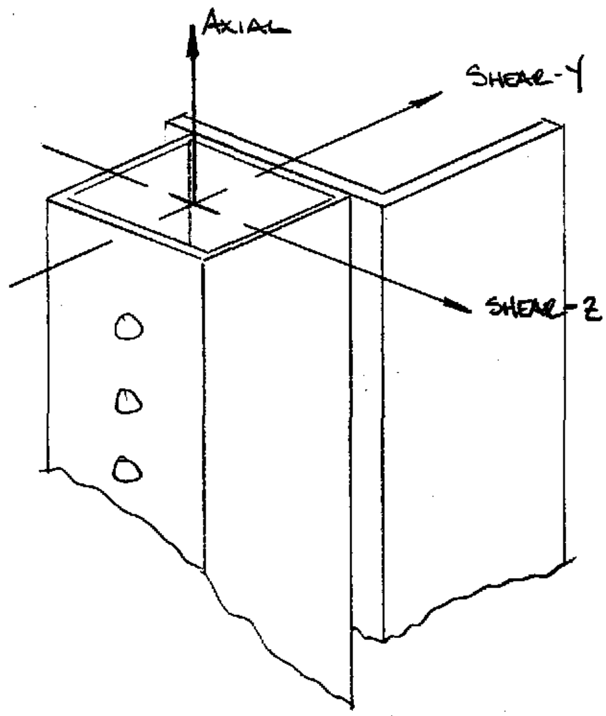
REQUIRED FILLET WELD SIZE (INCHES)

w=
0.353

DESIGN THRU BOLT CONNECTION. (SEE PAGES 23 to 26)

		Axial	Shear-Y	Shear-Z
@ Member 9	Joint 6	1989.	14308.	666.
Member 13	Joint 12	1249	126.	112.
Member 11	Joint 9	2054.	14272.	1311.
Member 14	Joint 14	1286.	243.	116.

ENVELOPE LOADS PER MEMBER



5/8" ϕ A325 BOLTS

T_{ALL} = 13508. lbs

V_{ALL} = 5219. lbs

TENSION

$$T = \frac{14308 \text{ lbs}}{3 \text{ BOLTS}} = 4769.33 \text{ \#/BOLT}$$

SHEAR

$$V = \frac{1989. \text{ lbs} + 666 \text{ lbs}}{3 \text{ BOLTS}} = 885 \text{ \#/BOLT}$$

BOLT INTERACTION

PRYING FACTOR

$$\frac{(4769.33 \text{ \#/BOLT})(1.2)}{13508 \text{ \#/BOLT}} + \frac{885 \text{ \#/BOLT}}{5219 \text{ \#/BOLT}} = .59 < 1.0 \quad \therefore \text{O.K.}$$

CHECK PUNCHING SHEAR @ BOLT

A500 GR. B F_y = 42 KSI

$F_v = .4(F_y) = 16.8$ KSI

ASSUME ENTIRE LOAD @ ONE BOLT HOLE

$A = \pi D \times \text{thks.}$
$= \pi(.6875 \text{ in})(.5 \text{ in})$
$= 1.08 \text{ in}^2$

$F_v = P/A =$
$= 14308 \text{ lbs} / 1.08 \text{ in}^2$
$= 13.3 \text{ KSI} < 16.8 \text{ KSI}$
$\therefore$ OK.

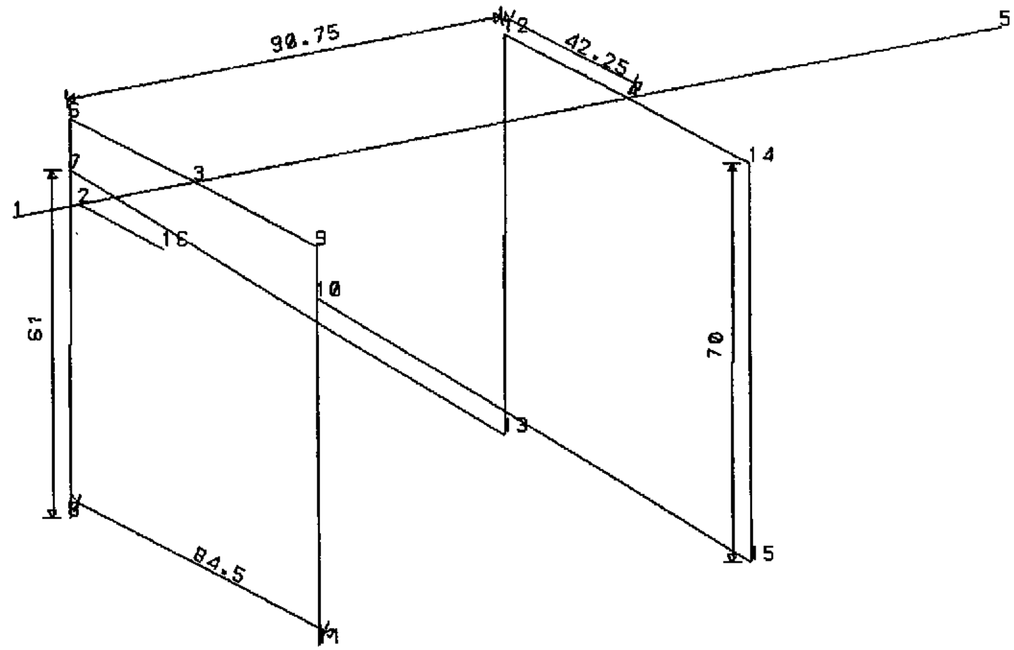
80K-LONG CRYOPUMP

1

NN/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

S T A A D P O S T - P L O T (REV: 21.0)

DATE: SEP 27, 1996

USER ID:PROCESS SYSTEMS INTERNATIONAL IN

TITLE: 80K-LONG CRYOPUMP SUPPORT

80K-LONG

WEIGHT OF VESSEL

· INTERNALS (REF V049-1-070)

$W = 5700\ lbs$
$L = 146\ in.$

· EXTERNAL SHELL (REF V049-1-082)

$W = 6784\ lbs - (2)(426\ lbs) - (2)(616\ lbs)$

$= 4700\ lbs.$

$W_{TOTAL} = 5700\ lbs + 4700\ lbs = 10400\ lbs.$

Apply Vessel Weight as a uniform load over entire length of 80K Long Cryopump.

$$w = \frac{10400\ lbs}{206.5\ ins}$$

$w_{vert.} = 50.36\ lbs/in.$ (−Y direction)

$w_{hor.} = (0.05625\ g)(50.36\ lbs/in) = 2.83\ lbs/in$ X & Z dir.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

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

```
**************************************************
*                                                *
*            S T A A D - III                     *
*            Revision 21.0                       *
*            Proprietary Program of              *
*            Research Engineers, Inc.            *
*            Date=    SEP 27, 1996               *
*            Time=    10:54:20                   *
*                                                *
*      USER ID: PROCESS SYSTEMS INTERNATIONAL IN *
**************************************************
```

```
STAAD SPACE 80K-LONG CRYOPUMP SUPPORT
INPUT WIDTH 72
*** REV1 REVISED LOADS & MEMBER RELEASE
UNIT INCHES POUND
JOINT COORDINATES
1 0. 0. 0.; 2 13.5 0. 0.; 3 37.5 0. 0.; 4 128.25 0. 0.; 5 206.5 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; 12 128.25 0. -42.25
13 128.25 -70. -42.25; 14 128.25 0. 42.25; 15 128.25 -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 -50.36
* UNIFORM  10400#/206.5" = 50.36
* UNIFORM = INTERNAL+EXTERNAL
```

```
***********************************
LOAD 2 DW+TH+VACUUM(+)
JOINT LOAD
1 FX 27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 3 DW+TH+VACUUM(-)
JOINT LOAD
1 FX -27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 4 DW+TH+VACUUM(+)+SEIS-AXIAL(+)
JOINT LOAD
1 FX 27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FX 47.925
* FLANGE WEIGHT X 0.05625
16 FX 8.5
* VALVE WEIGHT X 0.05625
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
1 TO 4 UNI X 2.83
* UNIFORM WEIGHT X 0.05625
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 5 DW+TH+VACUUM(-)+SEIS-AXIAL(-)
JOINT LOAD
1 FX -27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FX -47.925
* FLANGE WEIGHT X 0.05625
16 FX -8.5
* VALVE WEIGHT X 0.05625
```

```
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
1 TO 4 UNI X -2.83
* UNIFORM WEIGHT X 0.05625
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 6 DW+TH+VACUUM(+)+SEIS-LAT(+)
JOINT LOAD
1 FX 27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FZ 47.925
16 FZ 8.5
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
1 TO 4 UNI Z 2.83
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 7 DW+TH+VACUUM(-)+SEIS-LAT(-)
JOINT LOAD
1 FX -27569.998
* UNBALANCED VACUUM LOAD @ 44" GATE VALVE
1 5 FY -852.
16 FY -150.
1 5 FZ -47.925
16 FZ -8.5
16 FZ 1155.
* UNBALANCED VACUUM LOAD @ TURBO PMP
MEMBER LOAD
1 TO 4 UNI Y -50.36
1 TO 4 UNI Z -2.83
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
LOAD 8 THERMAL "BAKEOUT"
TEMPERATURE LOAD
1 TO 8 17 TEMP 330.
***********************************
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/  951.7 MB,  EXMEM = 14.83 MB

++ PROCESSING ELEMENT STIFFNESS MATRIX.              10:54:22
++ PROCESSING GLOBAL STIFFNESS MATRIX.               10:54:22
++ PROCESSING TRIANGULAR FACTORIZATION.              10:54:22
++ CALCULATING JOINT DISPLACEMENTS.                  10:54:22
++ CALCULATING MEMBER  FORCES.                       10:54:22

144. PRINT MATERIAL PROPERTIES ALL
```

MATERIAL PROPERTIES.

ALL 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 ************

145. 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 ************

146. 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 ************

147. 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 ************

148. PRINT ANALYSIS RESULTS

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	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	0.08871	-0.00103	0.12040	0.00001	0.00019	-0.00038
	3	-0.31977	-0.01149	0.12041	0.00001	0.00019	-0.00030
	4	0.09379	-0.00090	0.12045	0.00001	0.00019	-0.00038
	5	-0.32485	-0.01162	0.12035	0.00001	0.00019	-0.00030
	6	0.08871	-0.00103	0.17907	0.00001	0.00006	-0.00038
	7	-0.31977	-0.01149	0.06174	0.00000	0.00031	-0.00030
	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	0.12929	-0.00613	0.11788	0.00001	0.00019	-0.00038
	3	-0.27846	-0.01549	0.11789	0.00001	0.00019	-0.00030
	4	0.13437	-0.00601	0.11792	0.00001	0.00019	-0.00038
	5	-0.28354	-0.01560	0.11784	0.00001	0.00019	-0.00030
	6	0.12929	-0.00613	0.17827	0.00001	0.00006	-0.00038
	7	-0.27846	-0.01549	0.05749	0.00000	0.00031	-0.00030
	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	0.20143	-0.01513	0.11329	0.00000	0.00019	-0.00039
	3	-0.20503	-0.02253	0.11330	0.00000	0.00019	-0.00031
	4	0.20650	-0.01504	0.11331	0.00000	0.00019	-0.00039
	5	-0.21011	-0.02262	0.11328	0.00000	0.00018	-0.00030
	6	0.20143	-0.01513	0.17674	0.00001	0.00006	-0.00039
	7	-0.20503	-0.02253	0.04984	0.00000	0.00031	-0.00031
	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	0.47663	-0.05015	0.09639	0.00000	0.00019	-0.00039
	3	0.07019	-0.05015	0.09640	0.00000	0.00019	-0.00031
	4	0.48172	-0.05015	0.09632	0.00000	0.00019	-0.00040
	5	0.06509	-0.05015	0.09646	0.00000	0.00018	-0.00031
	6	0.47663	-0.05015	0.17161	0.00001	0.00006	-0.00039
	7	0.07019	-0.05015	0.02117	0.00000	0.00032	-0.00031
	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	0.71394	-0.08337	0.08184	0.00000	0.00019	-0.00042
	3	0.30749	-0.07699	0.08185	0.00000	0.00019	-0.00034
	4	0.71904	-0.08345	0.08170	0.00000	0.00019	-0.00042
	5	0.30239	-0.07691	0.08199	0.00000	0.00018	-0.00034
	6	0.71394	-0.08337	0.16734	0.00001	0.00005	-0.00042
	7	0.30749	-0.07699	-0.00366	0.00000	0.00032	-0.00034
	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	0.05874	0.00288	-0.01483	0.00059	0.00462	-0.00039
	3	-0.06527	-0.00452	-0.01482	0.00059	-0.00467	-0.00031
	4	0.06028	0.00297	-0.01481	0.00059	0.00474	-0.00039
	5	-0.06681	-0.00462	-0.01485	0.00059	-0.00479	-0.00030
	6	0.06039	0.00298	0.04858	0.00059	0.00462	-0.00039
	7	-0.06692	-0.00462	-0.07824	0.00059	-0.00466	-0.00031
	8	-0.00041	-0.00002	-0.12805	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
7	1	-0.00038	-0.00057	0.00000	0.00000	0.00000	0.00001
	2	0.01504	0.00296	-0.01211	-0.00030	-0.00002	-0.00357
	3	-0.01726	-0.00444	-0.01210	-0.00030	-0.00002	0.00393
	4	0.01544	0.00305	-0.01209	-0.00030	-0.00002	-0.00366
	5	-0.01766	-0.00453	-0.01212	-0.00030	-0.00002	0.00402
	6	0.01547	0.00306	0.03967	0.00097	0.00007	-0.00367
	7	-0.01769	-0.00454	-0.06388	-0.00156	-0.00012	0.00403
	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	0.06351	0.00314	0.24126	-0.00060	-0.00461	-0.00039
	3	-0.06050	-0.00426	0.24127	-0.00060	0.00468	-0.00031
	4	0.06507	0.00323	0.24128	-0.00060	-0.00472	-0.00039
	5	-0.06206	-0.00436	0.24125	-0.00060	0.00480	-0.00030
	6	0.06186	0.00304	0.30467	-0.00060	-0.00461	-0.00039
	7	-0.05885	-0.00417	0.17785	-0.00061	0.00469	-0.00031
	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	0.01627	0.00323	0.19700	0.00482	0.00037	-0.00386
	3	-0.01603	-0.00418	0.19700	0.00482	0.00037	0.00364
	4	0.01668	0.00332	0.19701	0.00482	0.00037	-0.00395
	5	-0.01644	-0.00427	0.19699	0.00482	0.00037	0.00373
	6	0.01584	0.00313	0.24878	0.00608	0.00047	-0.00376
	7	-0.01560	-0.00408	0.14522	0.00355	0.00027	0.00354
	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	0.46719	-0.00519	-0.03173	0.00148	0.00024	-0.00039
	3	0.06212	-0.00519	-0.03173	0.00148	0.00019	-0.00031
	4	0.47223	-0.00519	-0.03180	0.00148	0.00024	-0.00040
	5	0.05708	-0.00519	-0.03166	0.00148	0.00019	-0.00031
	6	0.47265	-0.00519	0.04347	0.00148	0.00011	-0.00039
	7	0.05666	-0.00520	-0.10694	0.00148	0.00032	-0.00031
	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	0.48285	-0.00524	0.22449	-0.00148	0.00013	-0.00039
	3	0.07778	-0.00524	0.22450	-0.00148	0.00018	-0.00031
	4	0.48797	-0.00524	0.22442	-0.00148	0.00013	-0.00040
	5	0.07266	-0.00524	0.22456	-0.00148	0.00018	-0.00031
	6	0.47739	-0.00524	0.29970	-0.00148	0.00000	-0.00039
	7	0.08324	-0.00523	0.14928	-0.00148	0.00031	-0.00031
	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	0.13462	-0.00681	0.11803	0.00003	0.00019	-0.00038
	3	-0.27313	-0.01617	0.11803	0.00003	0.00019	-0.00030
	4	0.13976	-0.00669	0.11807	0.00003	0.00019	-0.00038
	5	-0.27827	-0.01629	0.11799	0.00003	0.00018	-0.00030
	6	0.13096	-0.00684	0.17842	0.00003	0.00006	-0.00038
	7	-0.26947	-0.01613	0.05764	0.00003	0.00031	-0.00030
	8	-0.07411	-0.00003	0.00000	0.00000	0.00000	0.00000

SUPPORT REACTIONS -UNIT POUN INCH STRUCTURE TYPE = SPACE

JOINT	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	1725.60	-8957.68	56.58	3457.30	91.13	-31751.53
	3	-1884.94	13421.59	56.56	3455.73	91.09	34523.80
	4	1770.32	-9234.89	56.51	3453.11	91.02	-32572.37
	5	-1929.68	13698.91	56.64	3460.89	91.23	35344.97
	6	1773.76	-9251.77	-185.35	-11325.19	-298.54	-32635.73
	7	-1933.11	13715.72	298.51	18239.57	480.80	35408.11
	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	1865.00	-9755.47	-920.49	-56244.42	-1482.62	-34313.30
	3	-1745.54	12623.82	-920.51	-56245.99	-1482.66	31962.06
	4	1910.44	-10037.08	-920.55	-56248.60	-1482.73	-35147.36
	5	-1790.99	12905.48	-920.43	-56240.82	-1482.52	32796.31
	6	1816.85	-9461.40	-1162.41	-71026.91	-1872.29	-33429.16
	7	-1697.38	12329.71	-678.56	-41462.16	-1092.95	31077.79
	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	-14978.65	15033.66	37.89	3155.71	510.25	-10351.85
	3	16202.03	-7345.62	37.88	3154.79	510.02	24382.71
	4	-15364.84	15310.86	37.95	3159.30	509.63	-10781.59
	5	16588.38	-7622.94	37.83	3151.84	510.78	24812.62
	6	-15394.53	15327.74	-64.53	-6166.47	-1671.45	-10813.98
	7	16617.97	-7639.74	140.32	12477.86	2691.93	24844.89
	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	-16182.01	15932.84	-328.96	-31216.77	-8300.96	-11694.02
	3	14998.68	-6446.45	-328.97	-31217.68	-8301.19	23040.56
	4	-16574.42	16214.45	-328.90	-31213.18	-8301.58	-12130.69
	5	15391.18	-6728.12	-329.02	-31220.64	-8300.43	23477.33
	6	-15766.15	15638.77	-431.39	-40538.95	-10482.67	-11231.92
	7	14582.76	-6152.34	-226.53	-21894.62	-6119.29	22578.40
	8	11.77	-73.09	-183.43	-17186.33	-4405.63	6418.21

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	-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	27569.82	-852.00	0.01	0.00	-0.32	-0.26
		2	-27569.82	1531.86	-0.01	0.00	0.15	-16090.60
	3	1	-27568.60	-852.00	0.05	0.00	-0.54	-0.20
		2	27568.60	1531.86	-0.05	0.00	-0.58	-16091.21
	4	1	27617.92	-852.00	0.09	0.00	0.53	-0.08
		2	-27656.25	1531.86	-0.09	0.00	1.47	-16090.97
	5	1	-27617.19	-851.99	0.07	0.00	-0.16	-0.28
		2	27655.52	1531.85	-0.07	0.00	-0.01	-16091.02
	6	1	27569.58	-852.00	47.85	0.00	-1.33	-0.13
		2	-27569.58	1531.86	-86.05	0.00	-905.35	-16090.87
	7	1	-27570.31	-851.99	-47.97	0.00	0.26	0.20
		2	27570.31	1531.85	86.17	0.00	904.47	-16090.54
	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	27570.07	-1681.86	1155.03	4284.01	0.55	16091.31
		3	-27570.07	2890.50	-1155.03	-4284.01	-27720.23	-70959.74
	3	2	-27569.33	-1681.85	1155.01	4283.98	-0.66	16091.24
		3	27569.33	2890.49	-1155.01	-4283.98	-27721.57	-70959.59
	4	2	27665.04	-1681.86	1154.97	4284.04	241.10	16091.03
		3	-27732.91	2890.50	-1154.97	-4284.04	-27964.43	-70959.66
	5	2	-27664.55	-1681.86	1155.07	4284.00	-242.44	16090.99
		3	27732.42	2890.50	-1155.07	-4284.00	-27478.39	-70959.09
	6	2	27569.82	-1681.86	1249.62	4284.00	906.51	16090.87
		3	-27569.82	2890.50	-1317.54	-4284.00	-31712.47	-70958.98
	7	2	-27571.29	-1681.86	1060.37	4283.96	-904.65	16090.91
		3	27571.29	2890.50	-992.45	-4283.96	-23729.01	-70959.27
	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	312.01	633.42	189.85	1498.93	-17013.95	70959.66
		4	-312.01	3936.75	-189.85	-1498.93	-215.84	-220847.38
	3	3	45.41	633.43	189.80	1498.89	-17010.72	70959.23
		4	-45.41	3936.74	-189.80	-1498.89	-212.94	-220847.48
	4	3	-209.96	633.43	189.72	1496.13	-17000.87	70959.05
		4	-46.87	3936.74	-189.72	-1496.13	-218.86	-220847.13
	5	3	568.36	633.42	189.97	1501.68	-17028.53	70958.51
		4	-311.52	3936.75	-189.97	-1501.68	-211.10	-220848.38

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	312.01	633.42	-188.24	1870.39	17897.56	70959.15
		4	-312.01	3936.75	-68.58	-1870.39	-12473.13	-220847.77
	7	3	45.41	633.41	567.93	1127.40	-51932.24	70959.26
		4	-45.41	3936.76	-311.11	-1127.40	12044.72	-220848.53
	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	0.49	4792.67	0.02	-0.01	-0.70	220847.63
		5	-0.49	-852.00	-0.02	0.01	-1.26	0.08
	3	4	-0.24	4792.67	0.00	-0.01	-0.70	220847.38
		5	0.24	-852.00	0.00	0.01	0.77	-0.20
	4	4	-269.04	4792.68	-0.01	0.00	1.30	220847.67
		5	47.61	-852.01	0.01	0.00	-0.54	0.06
	5	4	269.53	4792.67	0.04	0.00	-3.24	220847.83
		5	-48.10	-852.00	-0.04	0.00	-0.29	-0.07
	6	4	0.24	4792.68	-269.30	0.01	12411.52	220847.75
		5	-0.24	-852.01	47.85	-0.01	-3.52	0.19
	7	4	-0.24	4792.69	269.38	0.00	-12414.64	220848.23
		5	0.24	-852.02	-47.93	0.00	-0.27	0.23
	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	63.17	-1729.00	13099.64	0.00	-553459.50	-73050.30
		6	-63.17	1729.00	-13099.64	0.00	-0.24	0.03
	3	3	63.29	-1729.00	-14337.51	0.00	605759.44	-73050.34
		6	-63.29	1729.00	14337.51	0.00	0.42	-0.02
	4	3	63.17	-1728.97	13439.45	0.00	-567816.56	-73048.92
		6	-63.17	1728.97	-13439.45	0.00	-0.26	0.00
	5	3	63.17	-1729.03	-14677.44	0.00	620122.00	-73051.69
		6	-63.17	1729.03	14677.44	0.00	-0.29	0.00
	6	3	-207.03	-1733.40	13465.55	0.00	-568919.75	-73236.02
		6	207.03	1733.40	-13465.55	0.00	-0.28	0.05
	7	3	333.50	-1724.61	-14703.48	0.00	621221.81	-72864.56
		6	-333.50	1724.61	14703.48	0.00	0.26	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	31.25	-4346.97	153.40	0.00	-6481.45	-183659.44
		12	-31.25	4346.97	-153.40	0.00	0.41	0.04
	3	4	31.31	-4346.97	20.39	0.00	-861.79	-183659.50
		12	-31.31	4346.97	-20.39	0.00	0.12	-0.04

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	31.25	-4347.00	155.07	0.00	-6551.69	-183660.84
		12	-31.25	4347.00	-155.07	0.00	0.10	0.04
	5	4	31.25	-4346.94	18.75	0.00	-792.02	-183658.05
		12	-31.25	4346.94	-18.75	0.00	-0.02	0.02
	6	4	-42.97	-4342.57	155.19	0.00	-6556.92	-183473.70
		12	42.97	4342.57	-155.19	0.00	0.61	0.05
	7	4	105.35	-4351.37	18.61	0.00	-786.25	-183845.20
		12	-105.35	4351.37	-18.61	0.00	-0.06	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	1028.26	-1794.92	-14158.45	0.00	598194.56	-75835.39
		9	-1028.26	1794.92	14158.45	0.00	-0.11	0.02
	3	3	1028.20	-1794.92	13278.71	0.00	-561024.88	-75835.43
		9	-1028.20	1794.92	-13278.71	0.00	-0.47	-0.02
	4	3	1028.26	-1794.95	-14503.75	0.00	612783.19	-75836.79
		9	-1028.26	1794.95	14503.75	0.00	0.36	-0.01
	5	3	1028.14	-1794.89	13624.06	0.00	-575616.13	-75834.04
		9	-1028.14	1794.89	-13624.06	0.00	-0.25	0.01
	6	3	1298.34	-1790.52	-13792.52	0.00	582734.13	-75649.63
		9	-1298.34	1790.52	13792.52	0.00	0.29	0.05
	7	3	758.00	-1799.32	12912.72	0.00	-545562.19	-76021.20
		9	-758.00	1799.32	-12912.72	0.00	-0.48	-0.04
	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	221.19	-4382.44	-158.55	0.00	6698.83	-185158.36
		14	-221.19	4382.44	158.55	0.00	-0.19	0.04
	3	4	221.19	-4382.45	-25.53	0.00	1078.90	-185158.42
		14	-221.19	4382.45	25.53	0.00	-0.16	-0.02
	4	4	221.07	-4382.41	-160.24	0.00	6770.08	-185156.98
		14	-221.07	4382.41	160.24	0.00	-0.03	0.01
	5	4	221.37	-4382.48	-23.86	0.00	1007.96	-185159.75
		14	-221.37	4382.48	23.86	0.00	-0.06	0.04
	6	4	295.29	-4386.84	-156.75	0.00	6623.01	-185344.06
		14	-295.29	4386.84	156.75	0.00	-0.41	0.07
	7	4	147.09	-4378.05	-27.34	0.00	1154.98	-184972.59
		14	-147.09	4378.05	27.34	0.00	0.10	0.07
	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	13099.62	63.21	0.00	-568.86	117896.59
		6	-1729.00	-13099.62	-63.21	0.00	0.00	0.00
	3	7	1729.02	-14337.48	63.21	0.00	-568.87	-129037.30
		6	-1729.02	14337.48	-63.21	0.00	0.00	0.00
	4	7	1728.97	13439.43	63.11	0.00	-567.94	120954.88
		6	-1728.97	-13439.43	-63.11	0.00	0.00	0.00
	5	7	1729.04	-14677.44	63.35	0.00	-570.12	-132096.97
		6	-1729.04	14677.44	-63.35	0.00	0.00	0.00
	6	7	1733.39	13465.57	-207.04	0.00	1863.36	121190.20
		6	-1733.39	-13465.57	207.04	0.00	0.00	0.00
	7	7	1724.62	-14703.46	333.46	0.00	-3001.15	-132331.16
		6	-1724.62	14703.46	-333.46	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	-8957.68	-1725.60	56.58	91.13	-3457.30	-31751.53
		7	8957.68	1725.60	-56.58	-91.13	5.82	-73510.15
	3	8	13421.59	1884.94	56.56	91.09	-3455.73	34523.80
		7	-13421.59	-1884.94	-56.56	-91.09	5.83	80457.79
	4	8	-9234.89	-1770.32	56.51	91.02	-3453.11	-32572.37
		7	9234.89	1770.32	-56.51	-91.02	5.83	-75417.09
	5	8	13698.91	1929.68	56.64	91.23	-3460.89	35344.97
		7	-13698.91	-1929.68	-56.64	-91.23	5.82	82365.49
	6	8	-9251.77	-1773.76	-185.35	-298.54	11325.19	-32635.73
		7	9251.77	1773.76	185.35	298.54	-19.08	-75563.66
	7	8	13715.72	1933.11	298.51	480.80	-18239.57	35408.11
		7	-13715.72	-1933.11	-298.51	-480.80	30.73	82511.53
	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	1794.93	14158.43	-1028.31	0.00	9254.83	127425.86
		9	-1794.93	-14158.43	1028.31	0.00	0.00	0.00
	3	10	1794.91	-13278.69	-1028.31	0.00	9254.82	-119508.20
		9	-1794.91	13278.69	1028.31	0.00	0.00	0.00
	4	10	1794.96	14503.75	-1028.42	0.00	9256.03	130533.71
		9	-1794.96	-14503.75	1028.42	0.00	0.00	0.00
	5	10	1794.89	-13624.05	-1028.18	0.00	9253.57	-122616.42
		9	-1794.89	13624.05	1028.18	0.00	0.00	0.00
	6	10	1790.53	13792.53	-1298.58	0.00	11687.21	124132.72
		9	-1790.53	-13792.53	1298.58	0.00	0.00	0.00
	7	10	1799.31	-12912.71	-758.04	0.00	6822.34	-116214.41
		9	-1799.31	12912.71	758.04	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	-9755.47	-1865.00	-920.49	-1482.62	56244.42	-34313.30
		10	9755.47	1865.00	920.49	1482.62	-94.81	-79451.90
	3	11	12623.82	1745.54	-920.51	-1482.66	56245.99	31962.06
		10	-12623.82	-1745.54	920.51	1482.66	-94.80	74516.13
	4	11	-10037.08	-1910.44	-920.55	-1482.73	56248.60	-35147.36
		10	10037.08	1910.44	920.55	1482.73	-94.82	-81389.54
	5	11	12905.48	1790.99	-920.43	-1482.52	56240.82	32796.31
		10	-12905.48	-1790.99	920.43	1482.52	-94.80	76454.21
	6	11	-9461.40	-1816.85	-1162.41	-1872.29	71026.91	-33429.16
		10	9461.40	1816.85	1162.41	1872.29	-119.73	-77398.52
	7	11	12329.71	1697.38	-678.56	-1092.95	41462.16	31077.79
		10	-12329.71	-1697.38	678.56	1092.95	-69.89	72462.48
	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	31.26	-153.42	0.00	10739.12	2188.42
		12	-4346.97	-31.26	153.42	0.00	0.00	0.00
	3	13	4346.97	31.26	-20.40	0.00	1427.92	2187.95
		12	-4346.97	-31.26	20.40	0.00	0.00	0.00
	4	13	4347.00	31.33	-155.07	0.00	10854.90	2193.19
		12	-4347.00	-31.33	155.07	0.00	0.00	0.00
	5	13	4346.94	31.19	-18.74	0.00	1312.10	2183.55
		12	-4346.94	-31.19	18.74	0.00	0.00	0.00
	6	13	4342.57	-42.83	-155.21	0.00	10864.60	-2997.90
		12	-4342.57	42.83	155.21	0.00	0.00	0.00
	7	13	4351.37	105.35	-18.61	0.00	1302.43	7374.78
		12	-4351.37	-105.35	18.61	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	-158.56	0.00	11099.08	-15480.64
		14	-4382.45	221.15	158.56	0.00	0.00	0.00
	3	15	4382.45	-221.16	-25.54	0.00	1787.87	-15481.12
		14	-4382.45	221.16	25.54	0.00	0.00	0.00
	4	15	4382.41	-221.08	-160.24	0.00	11216.71	-15475.88
		14	-4382.41	221.08	160.24	0.00	0.00	0.00
	5	15	4382.48	-221.22	-23.86	0.00	1670.21	-15485.52
		14	-4382.48	221.22	23.86	0.00	0.00	0.00
	6	15	4386.84	-295.24	-156.77	0.00	10973.60	-20666.97
		14	-4386.84	295.24	156.77	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	4378.05	-147.06	-27.33	0.00	1913.36	-10294.29
		14	-4378.05	147.06	27.33	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	18265.66	-598.81	-6.63	-518.13	-238.46	-44386.52
		13	-18265.66	598.81	6.63	518.13	963.09	-21090.97
	3	7	-19986.39	654.20	-6.62	-517.90	-238.36	48579.60
		13	19986.39	-654.20	6.62	517.90	962.65	22954.79
	4	7	18739.42	-614.33	-6.62	-517.51	-238.18	-45537.93
		13	-18739.42	614.33	6.62	517.51	961.92	-21636.49
	5	7	-20460.35	669.73	-6.63	-518.67	-238.71	49731.48
		13	20460.35	-669.73	6.63	518.67	964.09	23500.53
	6	7	18775.84	-615.52	21.71	1697.27	781.15	-45626.43
		13	-18775.84	615.52	-21.71	-1697.27	-3154.82	-21678.58
	7	7	-20496.64	670.92	-34.96	-2733.50	-1258.07	49819.66
		13	20496.64	-670.92	34.96	2733.50	5080.94	23542.46
	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	19741.93	-647.19	107.81	8429.15	3879.45	-47974.19
		15	-19741.93	647.19	-107.81	-8429.15	-15667.83	-22793.09
	3	10	-18510.14	605.83	107.81	8429.39	3879.56	44991.98
		15	18510.14	-605.83	-107.81	-8429.39	-15668.27	21252.69
	4	10	20223.32	-662.96	107.82	8429.78	3879.74	-49144.14
		15	-20223.32	662.96	-107.82	-8429.78	-15669.00	-23347.40
	5	10	-18991.64	621.60	107.80	8428.61	3879.20	46162.20
		15	18991.64	-621.60	-107.80	-8428.61	-15666.83	21807.12
	6	10	19231.78	-630.47	136.14	10644.55	4899.07	-46734.36
		15	-19231.78	630.47	-136.14	-10644.55	-19785.75	-22205.53
	7	10	-17999.92	589.11	79.47	6213.79	2859.85	43751.98
		15	17999.92	-589.11	-79.47	-6213.79	-11549.99	20665.04
	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	-1155.03	150.00	0.01	0.00	-0.22	4284.01
		16	1155.03	-150.00	-0.01	0.00	0.03	0.01
	3	2	-1155.07	150.00	0.01	0.00	-0.04	4283.98
		16	1155.07	-150.00	-0.01	0.00	-0.17	-0.02
	4	2	-1155.05	150.00	8.50	0.00	-242.61	4284.03
		16	1155.05	-150.00	-8.50	0.00	0.01	0.03

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	-1155.03	150.00	-8.48	0.00	242.50	4283.98
		16	1155.03	-150.00	8.48	0.00	-0.35	-0.03
	6	2	-1163.68	150.00	0.00	0.00	0.01	4284.00
		16	1163.68	-150.00	0.00	0.00	0.01	0.00
	7	2	-1146.47	150.00	0.01	0.00	-0.27	4283.97
		16	1146.47	-150.00	-0.01	0.00	-0.15	-0.04
	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 **************

149. PRINT MEMBER STRESSES ALL

MEMBER STRESSES

ALL 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	782.3 C	0.0	0.0	782.3	40.3	0.0
		1.00	782.3 C	0.0	40.9	823.3	72.4	0.0
	3	.0	782.3 T	0.0	0.0	782.3	40.3	0.0
		1.00	782.3 T	0.0	40.9	823.2	72.4	0.0
	4	.0	783.7 C	0.0	0.0	783.7	40.3	0.0
		1.00	784.8 C	0.0	40.9	825.7	72.4	0.0
	5	.0	783.7 T	0.0	0.0	783.7	40.3	0.0
		1.00	784.8 T	0.0	40.9	825.7	72.4	0.0
	6	.0	782.3 C	0.0	0.0	782.3	40.3	2.3
		1.00	782.3 C	2.3	40.9	823.3	72.4	4.1
	7	.0	782.3 T	0.0	0.0	782.3	40.3	2.3
		1.00	782.3 T	2.3	40.9	823.3	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	782.3 C	0.0	40.9	823.3	79.5	54.6
		1.00	782.3 C	70.5	180.5	976.1	136.7	54.6
	3	.0	782.3 T	0.0	40.9	823.2	79.5	54.6
		1.00	782.3 T	70.5	180.5	976.1	136.7	54.6
	4	.0	785.0 C	0.6	40.9	826.0	79.5	54.6
		1.00	787.0 C	71.1	180.5	981.0	136.7	54.6
	5	.0	785.0 T	0.6	40.9	825.9	79.5	54.6
		1.00	786.9 T	69.9	180.5	980.5	136.7	54.6
	6	.0	782.3 C	2.3	40.9	823.3	79.5	59.1
		1.00	782.3 C	80.7	180.5	980.0	136.7	62.3
	7	.0	782.4 T	2.3	40.9	823.4	79.5	50.1
		1.00	782.4 T	60.4	180.5	972.7	136.7	46.9
	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	5.0 C	13.7	57.0	63.6	16.9	5.1
		1.00	5.0 C	0.2	177.4	182.4	104.8	5.1
	3	.0	0.7 C	13.7	57.0	59.3	16.9	5.1
		1.00	0.7 C	0.2	177.4	178.1	104.8	5.1
	4	.0	3.4 T	13.7	57.0	62.0	16.9	5.0
		1.00	0.7 T	0.2	177.4	178.1	104.8	5.0
	5	.0	9.1 C	13.7	57.0	67.7	16.9	5.1
		1.00	5.0 C	0.2	177.4	182.4	104.8	5.1
	6	.0	5.0 C	14.4	57.0	63.8	16.9	5.0
		1.00	5.0 C	10.0	177.4	182.7	104.8	1.8
	7	.0	0.7 C	41.7	57.0	71.4	16.9	15.1
		1.00	0.7 C	9.7	177.4	178.4	104.8	8.3

MEMBER STRESSES

ALL 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 C	0.0	561.8	561.8	226.7	0.0
		1.00	0.0 C	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 C	0.0	561.8	569.4	226.7	0.0
		1.00	1.4 C	0.0	0.0	1.4	40.3	0.0
	6	.0	0.0 C	31.6	561.8	562.7	226.7	12.7
		1.00	0.0 C	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	24354.7	3214.5	27575.9	345.8	2619.9
		1.00	6.7 C	0.0	0.0	6.8	345.8	2619.9
	3	.0	6.8 C	26656.1	3214.5	29877.4	345.8	2867.5
		1.00	6.8 C	0.0	0.0	6.8	345.8	2867.5
	4	.0	6.7 C	24986.4	3214.5	28207.7	345.8	2687.9
		1.00	6.7 C	0.0	0.0	6.8	345.8	2687.9
	5	.0	6.7 C	27288.1	3214.6	30509.4	345.8	2935.5
		1.00	6.7 C	0.0	0.0	6.8	345.8	2935.5
	6	.0	22.1 T	25035.0	3222.7	28279.8	346.7	2693.1
		1.00	22.1 T	0.0	0.0	22.1	346.7	2693.1
	7	.0	35.6 C	27336.5	3206.4	30578.5	344.9	2940.7
		1.00	35.6 C	0.0	0.0	35.6	344.9	2940.7
	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	285.2	8081.8	8370.4	869.4	30.7
		1.00	3.3 C	0.0	0.0	3.4	869.4	30.7
	3	.0	3.3 C	37.9	8081.8	8123.1	869.4	4.1
		1.00	3.3 C	0.0	0.0	3.4	869.4	4.1
	4	.0	3.3 C	288.3	8081.9	8373.5	869.4	31.0
		1.00	3.3 C	0.0	0.0	3.3	869.4	31.0
	5	.0	3.3 C	34.9	8081.8	8120.0	869.4	3.7
		1.00	3.3 C	0.0	0.0	3.3	869.4	3.7
	6	.0	4.6 T	288.5	8073.7	8366.8	868.5	31.0
		1.00	4.6 T	0.0	0.0	4.6	868.5	31.0

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	7	.0	11.3 C	34.6	8090.0	8135.9	870.3	3.7
		1.00	11.3 C	0.0	0.0	11.3	870.3	3.7
	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	26323.2	3337.1	29770.1	359.0	2831.7
		1.00	109.9 C	0.0	0.0	109.9	359.0	2831.7
	3	.0	109.9 C	24687.6	3337.1	28134.5	359.0	2655.7
		1.00	109.9 C	0.0	0.0	109.9	359.0	2655.7
	4	.0	109.9 C	26965.2	3337.2	30412.2	359.0	2900.7
		1.00	109.9 C	0.0	0.0	109.9	359.0	2900.7
	5	.0	109.8 C	25329.6	3337.0	28776.5	359.0	2724.8
		1.00	109.8 C	0.0	0.0	109.9	359.0	2724.8
	6	.0	138.7 C	25642.9	3328.9	29110.5	358.1	2758.5
		1.00	138.7 C	0.0	0.0	138.7	358.1	2758.5
	7	.0	81.0 C	24007.1	3345.3	27433.4	359.9	2582.5
		1.00	81.0 C	0.0	0.0	81.0	359.9	2582.5
	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	294.8	8147.8	8466.2	876.5	31.7
		1.00	23.6 C	0.0	0.0	23.6	876.5	31.7
	3	.0	23.6 C	47.5	8147.8	8218.9	876.5	5.1
		1.00	23.6 C	0.0	0.0	23.6	876.5	5.1
	4	.0	23.6 C	297.9	8147.7	8469.3	876.5	32.0
		1.00	23.6 C	0.0	0.0	23.6	876.5	32.0
	5	.0	23.7 C	44.4	8147.8	8215.8	876.5	4.8
		1.00	23.7 C	0.0	0.0	23.7	876.5	4.8
	6	.0	31.5 C	291.4	8156.0	8478.9	877.4	31.3
		1.00	31.5 C	0.0	0.0	31.6	877.4	31.3
	7	.0	15.7 C	50.8	8139.6	8206.1	875.6	5.5
		1.00	15.7 C	0.0	0.0	15.7	875.6	5.5
	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	92.5	19170.2	19534.5	3274.9	15.8
		1.00	271.9 C	0.0	0.0	271.9	3274.9	15.8
	3	.0	271.9 C	92.5	20981.7	21346.0	3584.4	15.8
		1.00	271.9 C	0.0	0.0	271.9	3584.4	15.8
	4	.0	271.9 C	92.3	19667.5	20031.7	3359.9	15.8
		1.00	271.9 C	0.0	0.0	271.9	3359.9	15.8
	5	.0	271.9 C	92.7	21479.2	21843.7	3669.4	15.8
		1.00	271.9 C	0.0	0.0	271.9	3669.4	15.8

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL		BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	6	.0	272.5	C	303.0	19705.7	20281.3	3366.4	51.8
		1.00	272.5	C	0.0	0.0	272.5	3366.4	51.8
	7	.0	271.2	C	488.0	21517.3	22276.4	3675.9	83.4
		1.00	271.2	C	0.0	0.0	271.2	3675.9	83.4
	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	1408.4	T	562.2	5162.8	7133.5	431.4	14.1
		1.00	1408.4	T	0.9	11952.9	13362.3	431.4	14.1
	3	.0	2110.3	C	561.9	5613.6	8285.8	471.2	14.1
		1.00	2110.3	C	0.9	13082.6	15193.8	471.2	14.1
	4	.0	1452.0	T	561.5	5296.3	7309.8	442.6	14.1
		1.00	1452.0	T	0.9	12262.9	13715.9	442.6	14.1
	5	.0	2153.9	C	562.7	5747.1	8463.8	482.4	14.2
		1.00	2153.9	C	0.9	13392.8	15547.6	482.4	14.2
	6	.0	1454.7	T	1841.5	5306.6	8602.8	443.4	46.3
		1.00	1454.7	T	3.1	12286.8	13744.6	443.4	46.3
	7	.0	2156.6	C	2965.8	5757.4	10879.8	483.3	74.6
		1.00	2156.6	C	5.0	13416.5	15578.1	483.3	74.6
	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	1504.9	20719.7	22506.7	3539.6	257.1
		1.00	282.2	C	0.0	0.0	282.2	3539.6	257.1
	3	.0	282.2	C	1504.8	19432.2	21219.3	3319.7	257.1
		1.00	282.2	C	0.0	0.0	282.2	3319.7	257.1
	4	.0	282.2	C	1505.0	21225.0	23012.3	3625.9	257.1
		1.00	282.2	C	0.0	0.0	282.2	3625.9	257.1
	5	.0	282.2	C	1504.6	19937.6	21724.5	3406.0	257.0
		1.00	282.2	C	0.0	0.0	282.2	3406.0	257.0
	6	.0	281.5	C	1900.4	20184.2	22366.1	3448.1	324.6
		1.00	281.5	C	0.0	0.0	281.5	3448.1	324.6
	7	.0	282.9	C	1109.3	18896.7	20288.9	3228.2	189.5
		1.00	282.9	C	0.0	0.0	282.9	3228.2	189.5
	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	1533.9	T	9145.4	5579.4	16258.7	466.3	230.1
		1.00	1533.9	T	15.4	12919.0	14468.3	466.3	230.1
	3	.0	1984.9	C	9145.7	5197.1	16327.6	436.4	230.1
		1.00	1984.9	C	15.4	12116.4	14116.7	436.4	230.1
	4	.0	1578.2	T	9146.1	5715.0	16439.3	477.6	230.1
		1.00	1578.2	T	15.4	13234.1	14827.6	477.6	230.1

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL		BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	5	.0	2029.2	C	9144.8	5332.7	16506.7	447.7	230.1
		1.00	2029.2	C	15.4	12431.6	14476.2	447.7	230.1
	6	.0	1487.6	T	11549.1	5435.6	18472.4	454.2	290.6
		1.00	1487.6	T	19.5	12585.1	14092.2	454.2	290.6
	7	.0	1938.6	C	6741.8	5053.3	13733.7	424.3	169.6
		1.00	1938.6	C	11.4	11782.5	13732.5	424.3	169.6
	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	8260.9	1122.3	11535.1	20.8	306.8
		1.00	2152.0	C	0.0	0.0	2152.0	20.8	306.8
	3	.0	2152.0	C	1098.4	1122.0	4372.4	20.8	40.8
		1.00	2152.0	C	0.0	0.0	2152.0	20.8	40.8
	4	.0	2152.0	C	8349.9	1124.7	11626.6	20.9	310.1
		1.00	2152.0	C	0.0	0.0	2152.0	20.9	310.1
	5	.0	2151.9	C	1009.3	1119.8	4281.0	20.8	37.5
		1.00	2151.9	C	0.0	0.0	2151.9	20.8	37.5
	6	.0	2149.8	C	8357.4	1537.4	12044.6	28.6	310.4
		1.00	2149.8	C	0.0	0.0	2149.8	28.6	310.4
	7	.0	2154.1	C	1001.9	3781.9	6937.9	70.2	37.2
		1.00	2154.1	C	0.0	0.0	2154.1	70.2	37.2
	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	8537.8	7938.8	18646.1	147.4	317.1
		1.00	2169.5	C	0.0	0.0	2169.5	147.4	317.1
	3	.0	2169.5	C	1375.3	7939.0	11483.8	147.4	51.1
		1.00	2169.5	C	0.0	0.0	2169.5	147.4	51.1
	4	.0	2169.5	C	8628.2	7936.3	18734.1	147.4	320.5
		1.00	2169.5	C	0.0	0.0	2169.5	147.4	320.5
	5	.0	2169.5	C	1284.8	7941.3	11395.6	147.5	47.7
		1.00	2169.5	C	0.0	0.0	2169.5	147.5	47.7
	6	.0	2171.7	C	8441.2	10598.4	21211.4	196.8	313.5
		1.00	2171.7	C	0.0	0.0	2171.7	196.8	313.5
	7	.0	2167.4	C	1471.8	5279.1	8918.3	98.0	54.7
		1.00	2167.4	C	0.0	0.0	2167.4	98.0	54.7
	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	2872.0	C	38.8	7217.3	10128.1	149.7	1.7
		1.00	2872.0	C	156.6	3429.4	6458.0	149.7	1.7
	3	.0	3142.5	T	38.8	7899.1	11080.4	163.6	1.7
		1.00	3142.5	T	156.5	3732.5	7031.5	163.6	1.7

MEMBER STRESSES

ALL UNITS ARE POUN/SQ INCH

MEMB	LD	SECT	AXIAL	BEND-Y	BEND-Z	COMBINED	SHEAR-Y	SHEAR-Z
	4	.0	2946.4 C	38.7	7404.5	10389.7	153.6	1.7
		1.00	2946.4 C	156.4	3518.1	6621.0	153.6	1.7
	5	.0	3217.0 T	38.8	8086.4	11342.3	167.4	1.7
		1.00	3217.0 T	156.8	3821.2	7195.0	167.4	1.7
	6	.0	2952.2 C	127.0	7418.9	10498.1	153.9	5.4
		1.00	2952.2 C	513.0	3525.0	6990.1	153.9	5.4
	7	.0	3222.7 T	204.6	8100.8	11528.1	167.7	8.7
		1.00	3222.7 T	826.2	3828.0	7877.0	167.7	8.7
	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	3104.1 C	630.8	7800.7	11535.6	161.8	27.0
		1.00	3104.1 C	2547.6	3706.2	9357.9	161.8	27.0
	3	.0	2910.4 T	630.8	7315.8	10857.0	151.5	27.0
		1.00	2910.4 T	2547.7	3455.7	8913.8	151.5	27.0
	4	.0	3179.8 C	630.9	7990.9	11801.5	165.7	27.0
		1.00	3179.8 C	2547.8	3796.3	9523.9	165.7	27.0
	5	.0	2986.1 T	630.8	7506.0	11122.9	155.4	27.0
		1.00	2986.1 T	2547.5	3545.9	9079.4	155.4	27.0
	6	.0	3023.9 C	796.6	7599.1	11419.5	157.6	34.0
		1.00	3023.9 C	3217.2	3610.7	9851.7	157.6	34.0
	7	.0	2830.2 T	465.0	7114.1	10409.3	147.3	19.9
		1.00	2830.2 T	1878.0	3360.2	8068.4	147.3	19.9
	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	13.3	235.2	386.5	32.6	1.8
		1.00	150.8 T	0.0	0.0	150.8	32.6	1.8
	5	.0	150.8 T	13.3	235.2	386.5	32.6	1.8
		1.00	150.8 T	0.0	0.0	150.9	32.6	1.8
	6	.0	152.0 T	0.0	235.2	387.2	32.6	0.0
		1.00	152.0 T	0.0	0.0	152.0	32.6	0.0
	7	.0	149.7 T	0.0	235.2	385.0	32.6	0.0
		1.00	149.7 T	0.0	0.0	149.7	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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150. PARAMETER
151. CODE AISC
152. FYLD 45999.969 MEMB 9 TO 16
153. WSTR 21000. MEMB 9 TO 16
154. WMIN 0.188 MEMB 9 TO 16
155. CB 1. MEMB 9 TO 16
156. CMY 1. MEMB 9 TO 16
157. MAIN 0. MEMB 9 TO 16
158. RATIO 1. MEMB 9 TO 16
159. CHECK CODE MEMB 9 TO 16
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STAAD-III CODE CHECKING - (AISC)
****

ALL 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	0.807	7
		1724.62 C	-3001.15	-132331.16	0.00
10	ST TUB 40408	PASS	AISC- H1-3	0.578	7
		13715.72 C	30.73	82511.53	61.00
11	ST TUB 40408	PASS	AISC- H1-3	0.834	4
		1794.96 C	9256.03	130533.71	0.00
12	ST TUB 40408	PASS	AISC- H2-1	0.669	6
		9461.40 T	71026.91	-33429.16	0.00
13	ST TUB 40203	PASS	AISC- H1-3	0.486	6
		4342.57 C	10864.60	-2997.90	0.00
14	ST TUB 40203	PASS	AISC- H1-3	0.819	6
		4386.84 C	10973.60	-20666.97	0.00
15	ST TUB 40408	PASS	AISC- H1-1	0.427	6
		18775.84 C	781.15	-45626.43	0.00
16	ST TUB 40408	PASS	AISC- H1-1	0.483	4
		20223.32 C	3879.74	-49144.14	0.00

160. 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	20853.26
	7	66.69	2940.69	20644.77
9	END	1	3/16	4936.00
	7	111.15	4901.15	574.87
10	STA	1	3/16	17998.33
	7	159.60	704.47	17983.82
10	END	1	4/16	18913.36
	7	119.70	528.35	18905.60
11	STA	1	6/16	17937.33
	4	171.40	2417.29	17772.88
11	END	1	3/16	4883.51
	4	342.81	4834.58	598.32
12	STA	1	5/16	17571.87
	6	372.90	503.79	17560.69
12	END	1	4/16	17802.10
	4	369.14	616.62	17787.59
13	STA	1	3/16	9337.81
	6	68.98	19.03	9337.54
13	END	1	3/16	1934.53
	7	8.27	46.82	1933.94
14	STA	1	3/16	16487.79
	6	69.67	131.22	16487.12
14	END	1	3/16	1955.36
	6	69.67	131.22	1949.71
15	STA	1	3/16	19612.98
	7	353.34	565.33	19601.64
15	END	1	3/16	14003.94
	7	353.34	565.33	13988.06
16	STA	1	3/16	20067.27
	4	1089.66	1274.71	19997.08
16	END	1	3/16	17034.13
	6	1375.95	1540.73	16908.41

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                     STAAD-III WELD DESIGN
                     *********************

ALL UNITS ARE - INCH POUN

MEMBER   LOCATION/     WELD TYPE/       WELD SIZE/      COMB STRESS/
         LOADING       HOR STRESS      VERT STRESS       DIR STRESS
======================================================================


****************** END OF TABULATED WELD DESIGN ******************

161. FINISH

          *************** END OF STAAD-III ***************

            **** DATE= SEP 27,1996   TIME= 10:54:24 ****

      *********************************************************
      *        For questions on  STAAD-III,   contact:        *
      *              Research Engineers, Inc at               *
      *       Ph: (714) 974-2500   Fax:  (714) 921-2543       *
      *********************************************************
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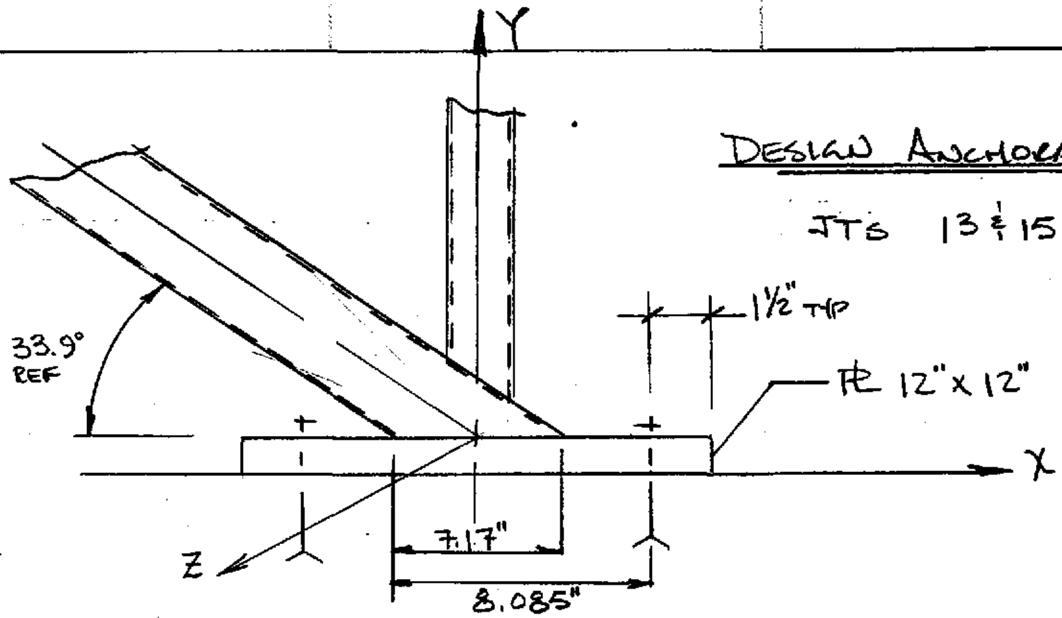
DESIGN ANCHORAGE

JTS 13 & 15



WORST DESIGN LOADING OCCURS @ JT 15 L.C.# 5 (SEE PG 62 of 90)

F_x = 15391. lbs M_x = 31221. in-lbs

F_y = 6728. lbs (TENSION) M_y = 8300. in-lbs.

F_z = 329. lbs. M_z = 23477. in-lbs.

ANCHOR BOLTS TRY 1" φ HILTI'S

TENSION

$$T = \frac{6728 \text{ lbs}}{4 \text{ BOLTS}} + \frac{31221 \text{ in-lbs}}{2 \text{ BOLTS} (6.5 \text{ in})} + \frac{23477 \text{ in-lbs}}{2 \text{ BOLTS} (8.085 \text{ in})}$$

T = 5536. lbs.

SHEAR

$$V = \frac{15391 \text{ lbs} + 329 \text{ lbs}}{4 \text{ BOLTS}} + \frac{8300 \text{ in-lbs}}{4 \text{ BOLTS} (6.364 \text{ in})}$$

= 4256 lbs.

BOLTS – TRY 1" φ @ 8¼" EMB'T

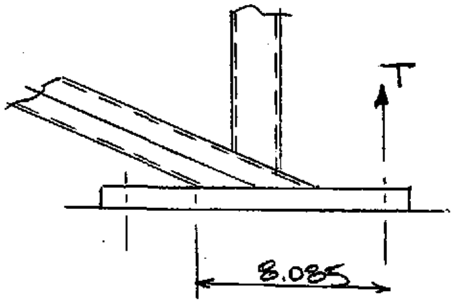
WHERE:

T_{ALL} = 10960 lbs

V_{ALL} = 7630 lbs

$$\left(\frac{5536 \text{ lbs}}{10960 \text{ lbs}}\right)^{5/3} + \left(\frac{4256 \text{ lbs}}{7630 \text{ lbs}}\right)^{5/3} = .70 < 1.0 \therefore \text{OK.}$$

DETERMINE PLATE THICKNESS



$T = 5536 \text{ lbs}$

$F_y = 36000 \ \#/in^2$

$F_b = .75 F_y = 27000 \ \#/in^2$

$f_b = \frac{M}{S} \qquad S_{REQ'D} = \frac{M}{f_b}$

$$S_{req'd} = \frac{5536 \text{ lbs } (8.065 \text{ in})}{27000 \text{ lb/in}^2} = 1.65 \text{ in}^3$$

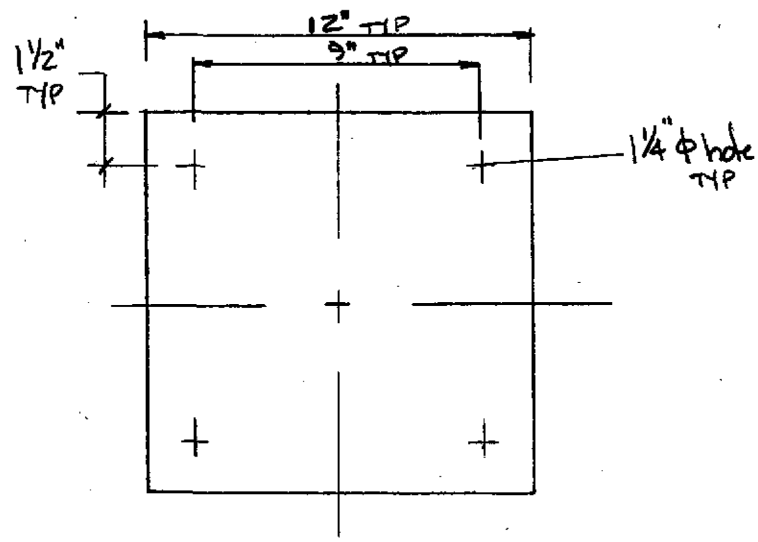
$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{6S}{b}}$$

$$d_{req'd} = \sqrt{\frac{6(1.65 \text{ in}^3)}{12 \text{ in}}}$$

$$= 0.91 \text{ in}$$

USE 1 3/8" THICK PL

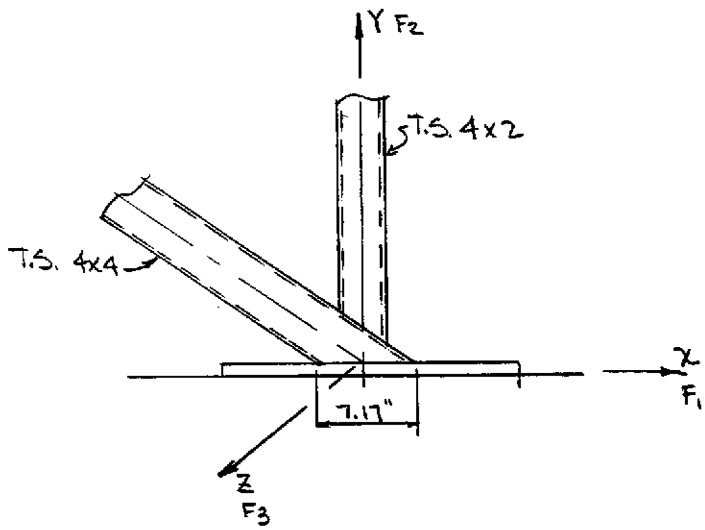
∴ USE PL 12"×12"×1 3/8" THK w/ 4-1"φ HILTI HVA @ 8 1/4" EMBT

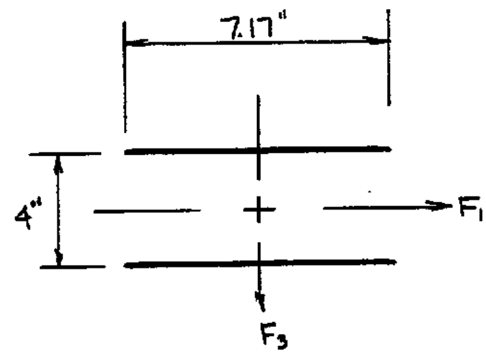


filename: 80K-LONG PMP

HORIZONTAL FILLET WELDS PARALLEL TO F1 AXIS

Between part BASEPLATE & JT 13 & 15





LOAD INPUT (LBS., INCH-LBS.) (SEE PG 62 OF 90)

F1	F2	F3	M1	M2	M3
15391.00	6728.00	329.00	31221.00	8300.00	23477.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)
4.000	7.170	21000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
14.340	28.680	17.136	118.794	2.000	3.585

MAXIMUM WELD LOAD (f) - #/INCH

f
3181

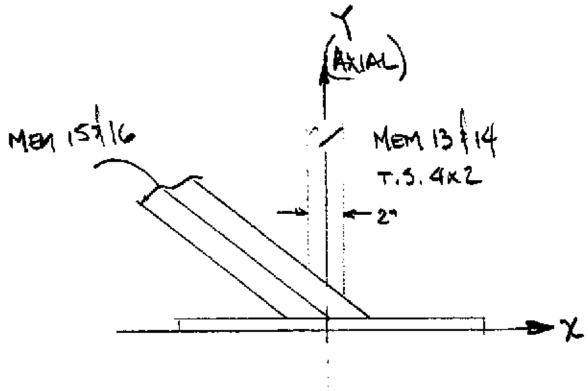
REQUIRED FILLET WELD SIZE (INCHES)

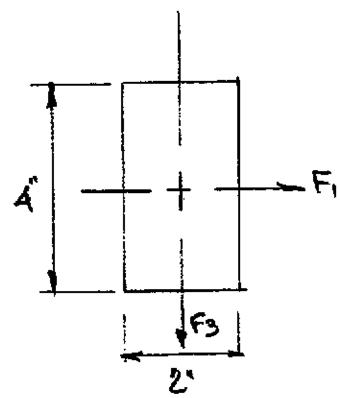
w
0.214

Filename: 80K-LONG PMP

ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part Jts. 13 & 15 and BASEPLTS
(END OF MEMBERS 13 & 14)





LOAD INPUT (LBS., INCH-LBS.) (SEE PG. 67 OF 90)

F1	F2	F3	M1	M2	M3
295.00		160.00	10974.00		20667.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90ø>á<120ø)
4.000	2.000	21000	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
12.000	13.333	9.333	36.000	2.000	1.000

EFFECTIVE THROAT CORRECTION FACTOR

Mf
1.00

MAXIMUM WELD LOAD (f) - #/INCH

f=
3038

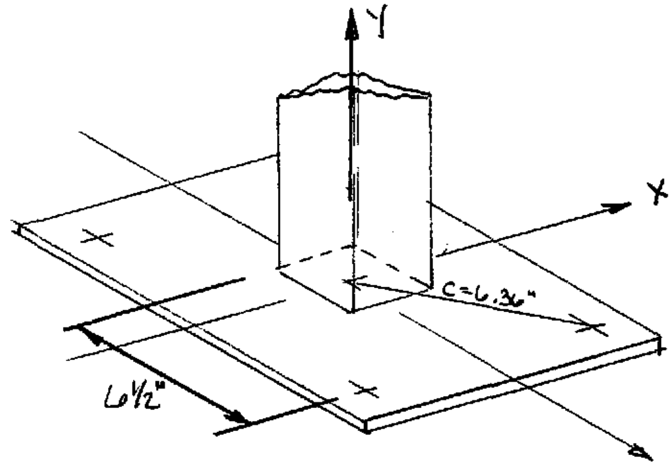
REQUIRED FILLET WELD SIZE (INCHES)

w=
0.205

DESIGN ANCHORAGE   TRY PL 12" x 12"   (JTS 8 & 11)

1" φ HILTI HVA @ 8 1/4" EMBEDMENT

T_{ALL} = 10960. lbs
V_{ALL} = 7630. lbs
} f'_c = 3000 PSI



SUPPORT REACTIONS

WORST LOAD/DESIGN CONDITIONS (SEE PG. 62 of 90)

JT-11 LOADCASE-6

Fx = 1817.0 lbs   Mx = 71027. in-lbs

FY = 9461. lbs (TENSION)   MY = 1872. in-lbs

Fz = 1162. lbs.   Mz = 33429. in-lbs.

SHEAR

$$V = \frac{1817.\text{ lbs} + 1162\text{ lbs}}{4\text{ BOLTS}} + \frac{1872.\text{ in-lbs}}{(4\text{ BOLTS})(6.36\text{ in})}$$

= 818. lbs/BOLT

TENSION

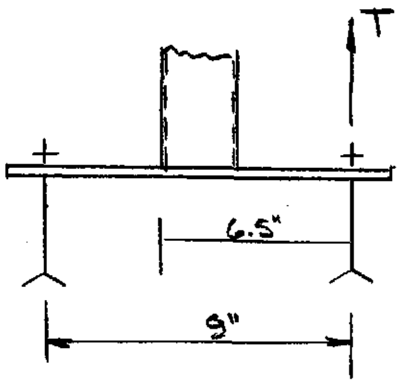
$$T = \frac{9461\text{ lbs}}{4\text{ BOLTS}} + \frac{(71027 + 33429)}{(2\text{ BOLTS})(6.5\text{ in})}$$

T = 10400. lbs/BOLT

$$\text{BOLT INTERACTION} = \left(\frac{T}{T_{ALL}}\right)^{5/3} + \left(\frac{V}{V_{ALL}}\right)^{5/3} = \left(\frac{10400}{10960}\right)^{5/3} + \left(\frac{818}{7630}\right)^{5/3} = 0.94 < 1.0$$

∴ OK

DETERMINE PLATE REQUIRED THICKNESS



T = 9461 lbs/BOLT

$F_y = 36000\ \#/in^2$

$F_b = .75\ F_y = 27000\ \#/in^2$

$$f_b = \frac{M}{S} \Rightarrow S_{REQD} = \frac{M}{f_b}$$

$$S_{req'd} = \frac{9461\ lbs\ (6.5\ in)}{27000\ \#/in^2} = 2.28\ in^3$$

$$S = \frac{bd^2}{6} \Rightarrow d = \sqrt{\frac{6(S)}{b}}$$

$$d\ req'd = \sqrt{\frac{6\ (2.28\ in^3)}{12\ in}}$$

THKS = 1.07 in

USE PL 1 3/8" THK

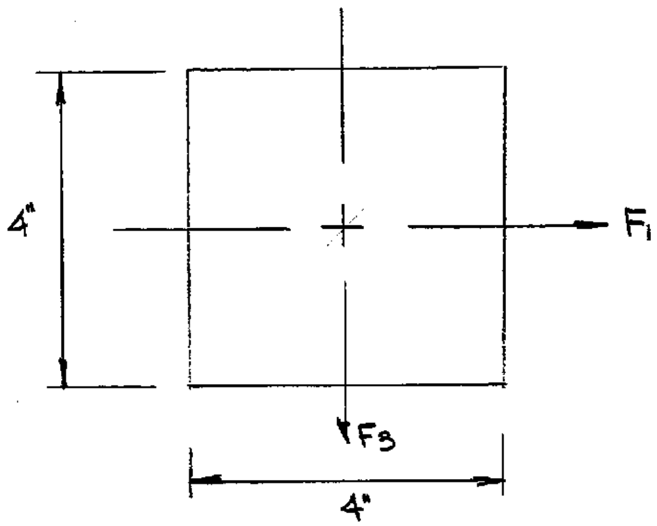
USE PL 12" x 12" x 1 3/8" THK

W - 4 - 1" φ HILTI HVA
@ 8 1/4" EMB'T

Filename: 80K LONG PMP

ALL AROUND RECTANGULAR OR SQUARE FILLET WELD

Between part Jts. 11 & 8 and BASEPLTS END OF MEMBERS 10 & 12



LOAD INPUT (LBS., INCH-LBS.) (SEE PG. 66 & 67 OF 90)

F1	F2	F3	M1	M2	M3
1817.00	9461.00	1162.00	71027.00	1872.00	33429.00

GEOMETRIC DIMENSIONS

a	b	WELD STRESS (PSI)	SKEWED ANGLE(90ø>á<120ø)
4.000	4.000	21000	90.000

SECTION PROPERTIES

A	Sw1	Sw3	J	C1	C3
16.000	21.333	21.333	85.333	2.000	2.000

EFFECTIVE THROAT CORRECTION FACTOR

Mf

1.00

MAXIMUM WELD LOAD (f) - #/INCH

f=

5491

REQUIRED FILLET WELD SIZE (INCHES)

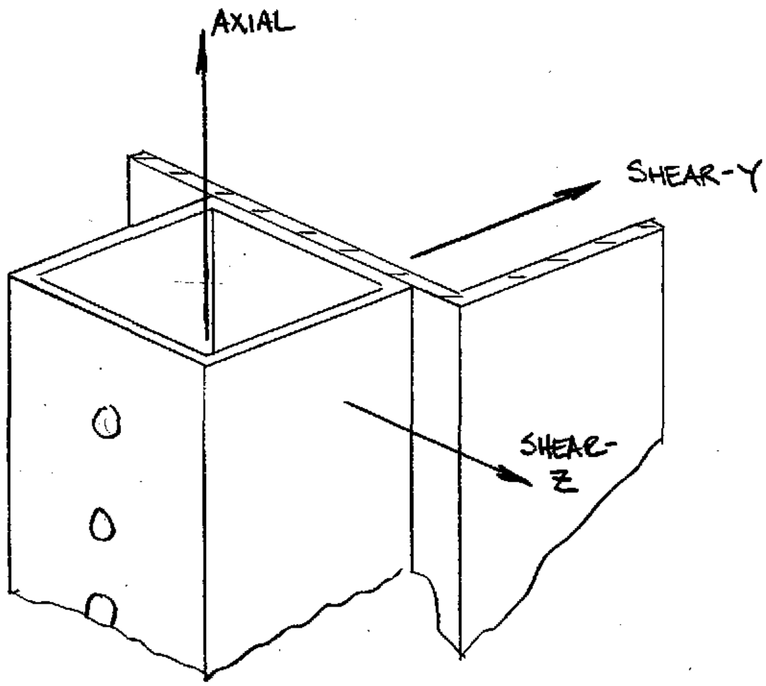
w=

0.370 USE 3/8" all-around fillet Weld.

80K-LONG

DESIGN BOLTED CONNECTION AT STIFFENER RING

@ MEMBER 9 JOINT 6, MEMBER 11 JOINT 9
MEMBER 13 JOINT 12, MEMBER 14 JOINT 14



SEE PG 46 OF 90 FOR PUNCHING SHEAR @ BOLT.

WORST DESIGN BASIS LOADING OCCURS @ MEMBER 11 L.C.#4
(SEE PG. 65 TO 68 OF 90)

AXIAL = 1795 lbs ; SHEAR-Y = 14504. lbs ; SHEAR-Z = 1028. lbs.

TENSION

$$T = \frac{14504\text{ lbs}}{3\text{ BOLTS}} = 4835\text{ lbs}\,(1.2) = 5802\text{ lbs/BOLT}$$

(1.2 = PRYING)

SHEAR

$$V = \frac{1795\text{ lbs} + 1028\text{ lbs}}{3\text{ BOLTS}} = 941\text{ lbs/BOLT}$$

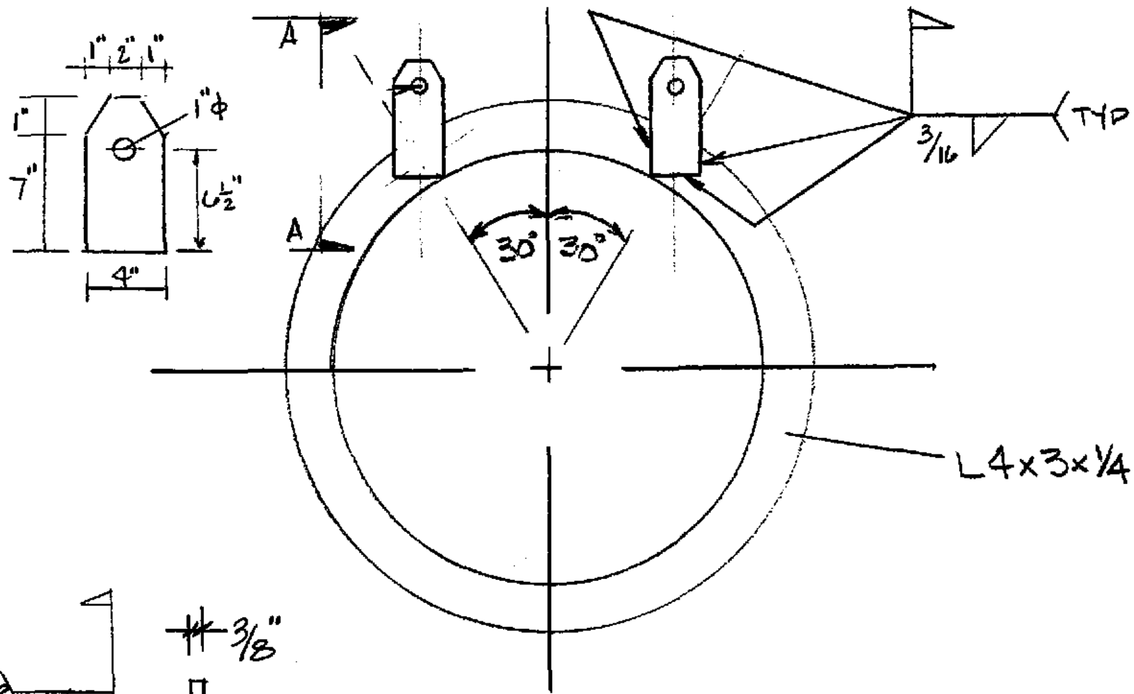
5/8" ⌀ A325 T_{ALL} = 13500 lbs V_{ALL} = 5220 lbs

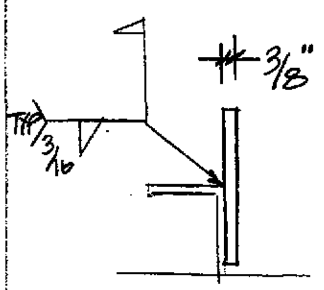
$$\frac{5802}{13500} + \frac{941}{5220} = .61 < 1.0 \therefore OK.$$

USE 5/8" A325 BOLTS

80K LONG 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

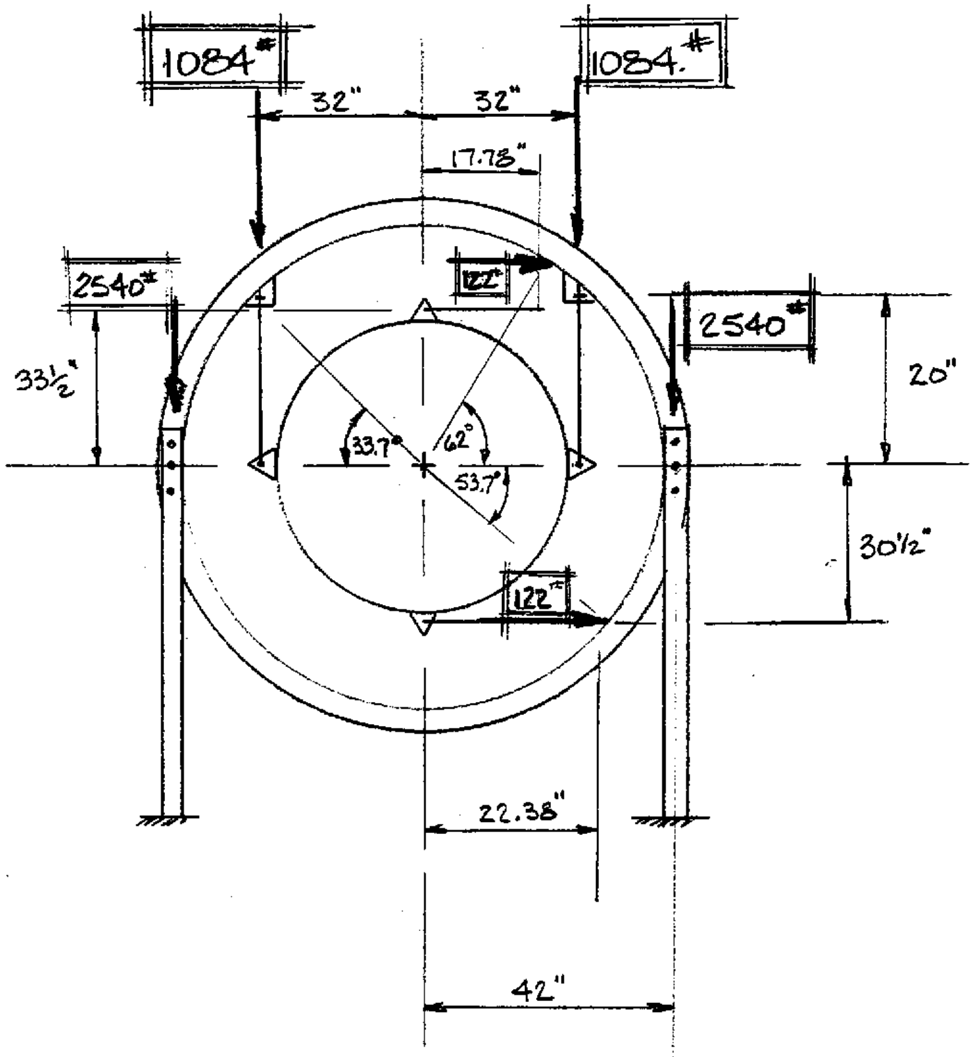
FORCE ALLOWABLE FOR 3/16" WELD PER INCH OF WELD

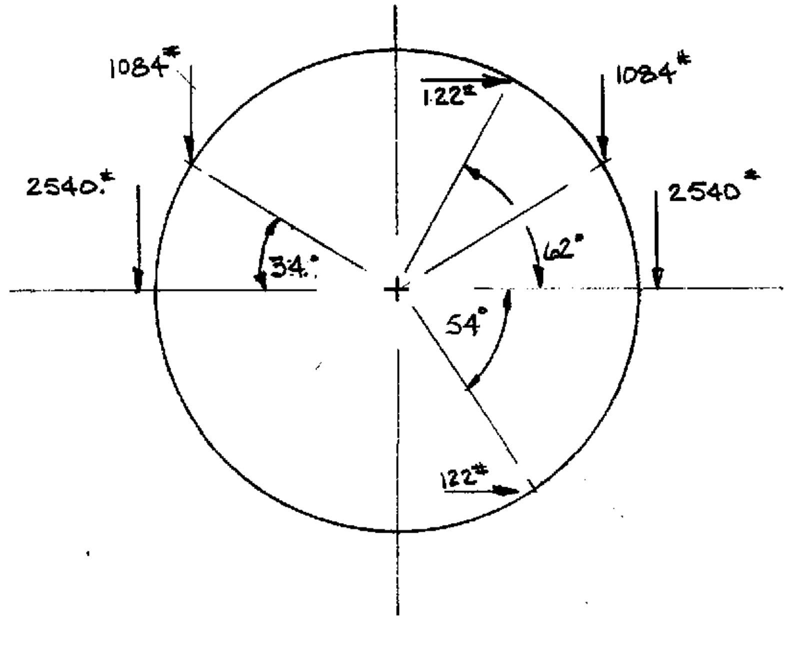
$$F_{W_{ALL}} = \frac{(3/16\ in)(.707)(21000\ lbs/in)}{1\ in\ WELD} = 2784\ lbs/in$$

∴ WELD AS SHOWN, PROVIDES A MINIMUM OF 10 in OF WELD ∴ $F_{W_{ALL}}$ = 27840 lbs

WELD IS ACCEPTABLE

CALCULATE STRESSES IN THE OUTER SHELL DUE TO INTERNAL AND EXTERNAL LOADS.



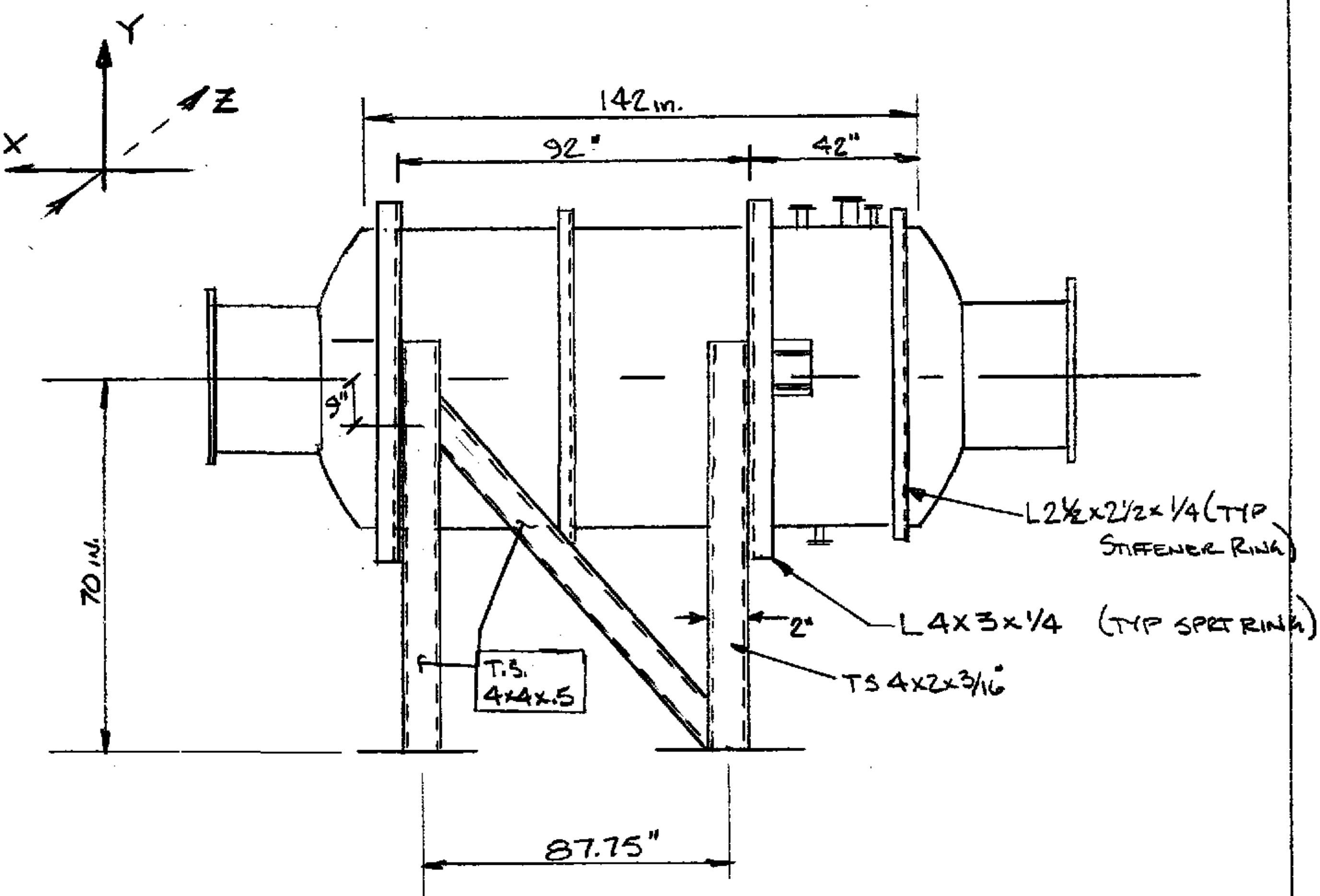


Radius Of Ring Centroid, Inches,	= 41.511
I, for Ring plus Eff. Shell,	= 8.884 In.^4
A, for Ring plus Eff. Shell,	= 2.980 In.^2
CF1, Extreme Inner Fiber (ring) from Centroid,	= 1.761 In.
C2, Extreme Outer Fiber (shell) from Centroid,	= 2.489 In.
Weight of Ring only,	= 113 Lbs.
Weight of full or empty 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	53.78818 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	=	-3,968 psi	at 110.00 degrees.
Outer Fiber Max. Tension	=	430 psi	at 112.00 degrees.
Outer Fiber Max. Compression	=	-3,991 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

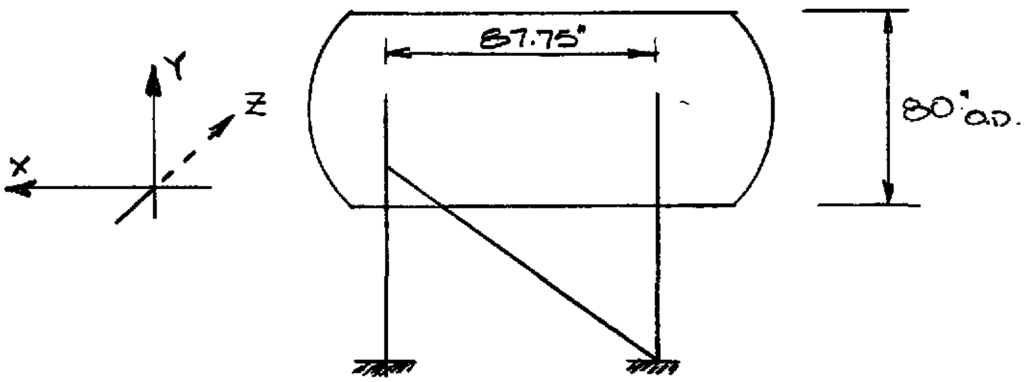
AXIAL FORCE ON VESSEL = 25400. lbs

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 $\alpha = 9.19(10^{-6})$ IN/IN°F FOR 240-304L
$L = 87.75$ IN
$\Delta T = 330°$

$$\delta_x = 9.19(10^{-6}) \frac{IN}{IN\,°F} (87.75\,IN)(330°F)$$

$$\delta_x = {}^{-}0.266\,IN$$

Weight Summary

Component	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

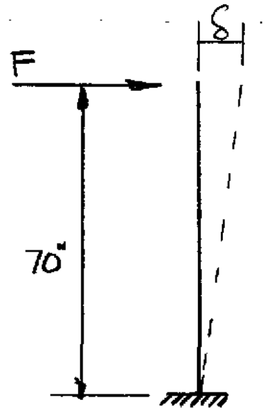
Weight (lbs) Contributed by Vessel Elements

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

CHECK STRESSES FROM BENDING (due to thermal displacement)



T.S. 4×4×.5

$S_y = 5.70\ in^3$ $I_y = 11.4\ in^4$

REF. GERE & WEAVER TABLE B-4

$$M = \frac{6EI\delta}{L^2}$$

$$= \frac{6(29E6)(11.4\ in^4)(0.266\ in)}{(70\ in)^2}$$

$$M = 107681.1\ in\text{-}lbs$$

$$f_{by} = \frac{107681.1\ in\text{-}lbs}{5.70\ in^3} = 18891.4\ lb/in^2$$

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. 4×4×1/2 TO T.S. 4×2×3/16.

T.S. 4×2×3/16 $I_y = 1.29$ $S_y = 1.29$

∴ STRESSES ARE REDUCE CONSIDERABLY

$M_y = 6(29E6)(1.29\ in^4)(0.266\ in)/(70\ in)^2 = 12185\ in\text{-}lbs$

$f_{by} = 12185\ in\text{-}lbs / 1.29\ in^3 = 9446\ \#/in^2$

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

$$\frac{f_a}{F'_e} = \frac{1257}{19400} = 0.065$$

$$1 - \frac{f_a}{F'_{ey}} = .935 \quad \& \quad C_{my} = 1.0$$

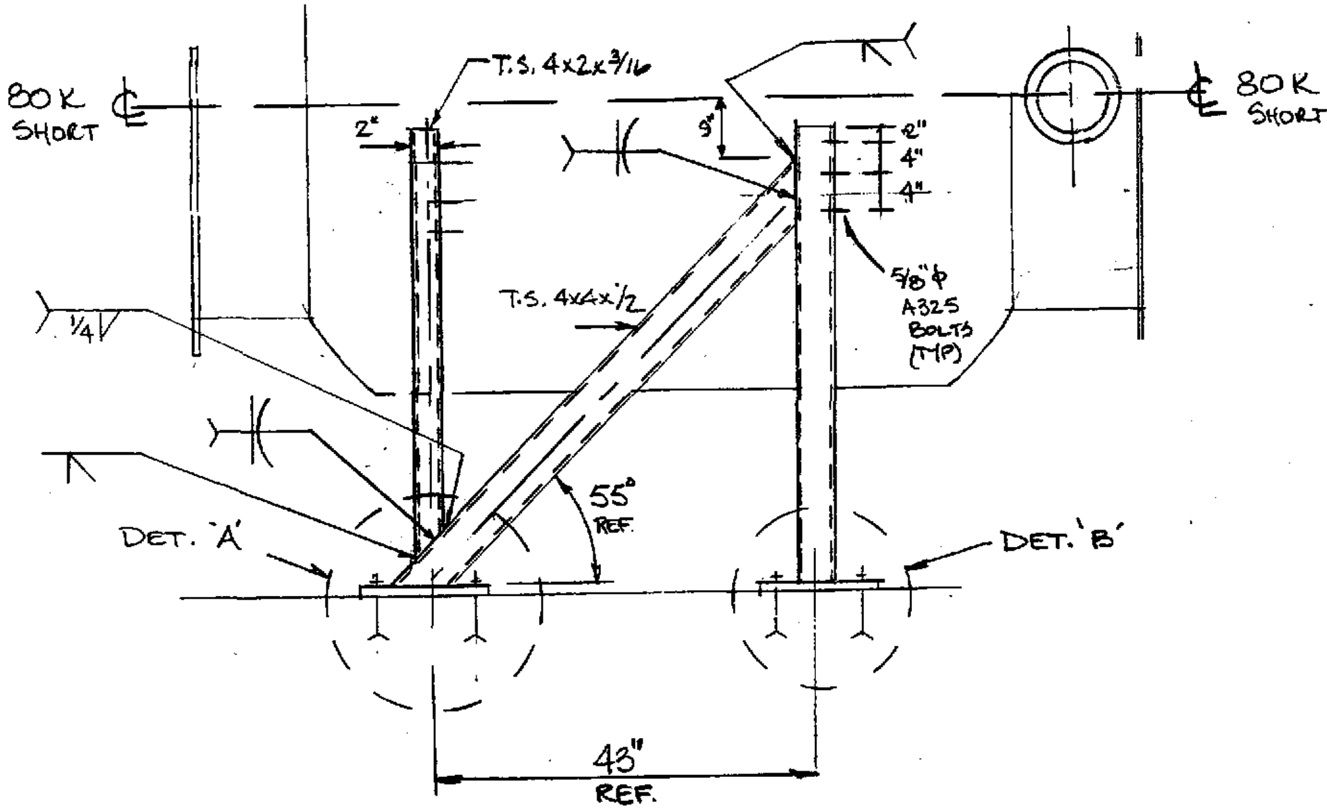
$$\frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}}\right) F_{bx}} + \frac{C_{my} f_{by}}{\left(1 - \frac{f_a}{F'_{ey}}\right) F_{by}} =$$

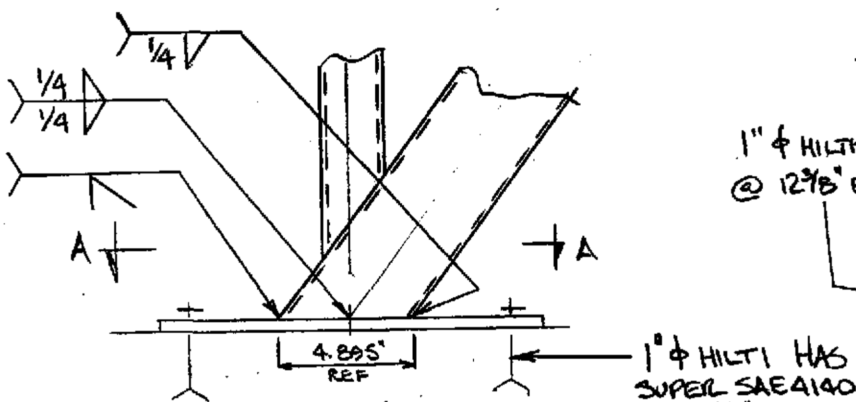
where: $F_A = 33$ KSI AISC CODE PG. 3-52 4x2x3/16" @ KL = 6 FT.

$$\frac{1257 \text{ lbs/in}^2}{33000 \text{ lbs/in}^2} + \not{0}^{*} + \frac{1.0(9446 \text{ lb/in}^2)}{.935(30400 \text{ lb/in}^2)} = .37 < 1.0 \checkmark$$

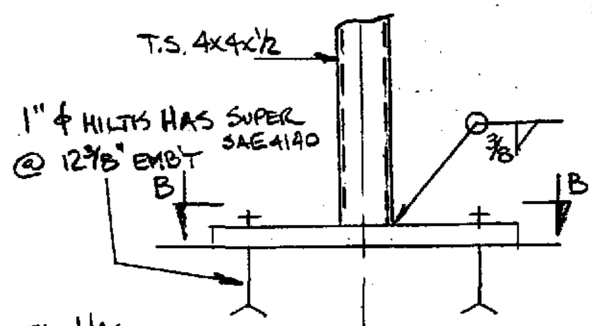
* No SIDE load for Normal Operations.

80 K-SHORT

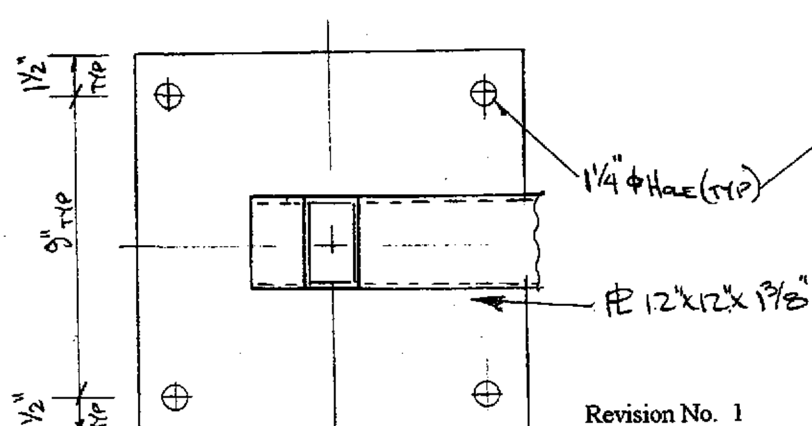




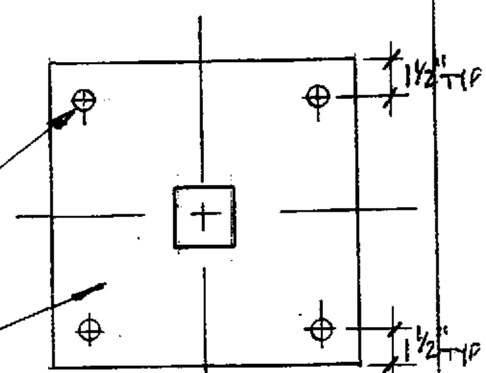
DET. 'A'



DET 'B'

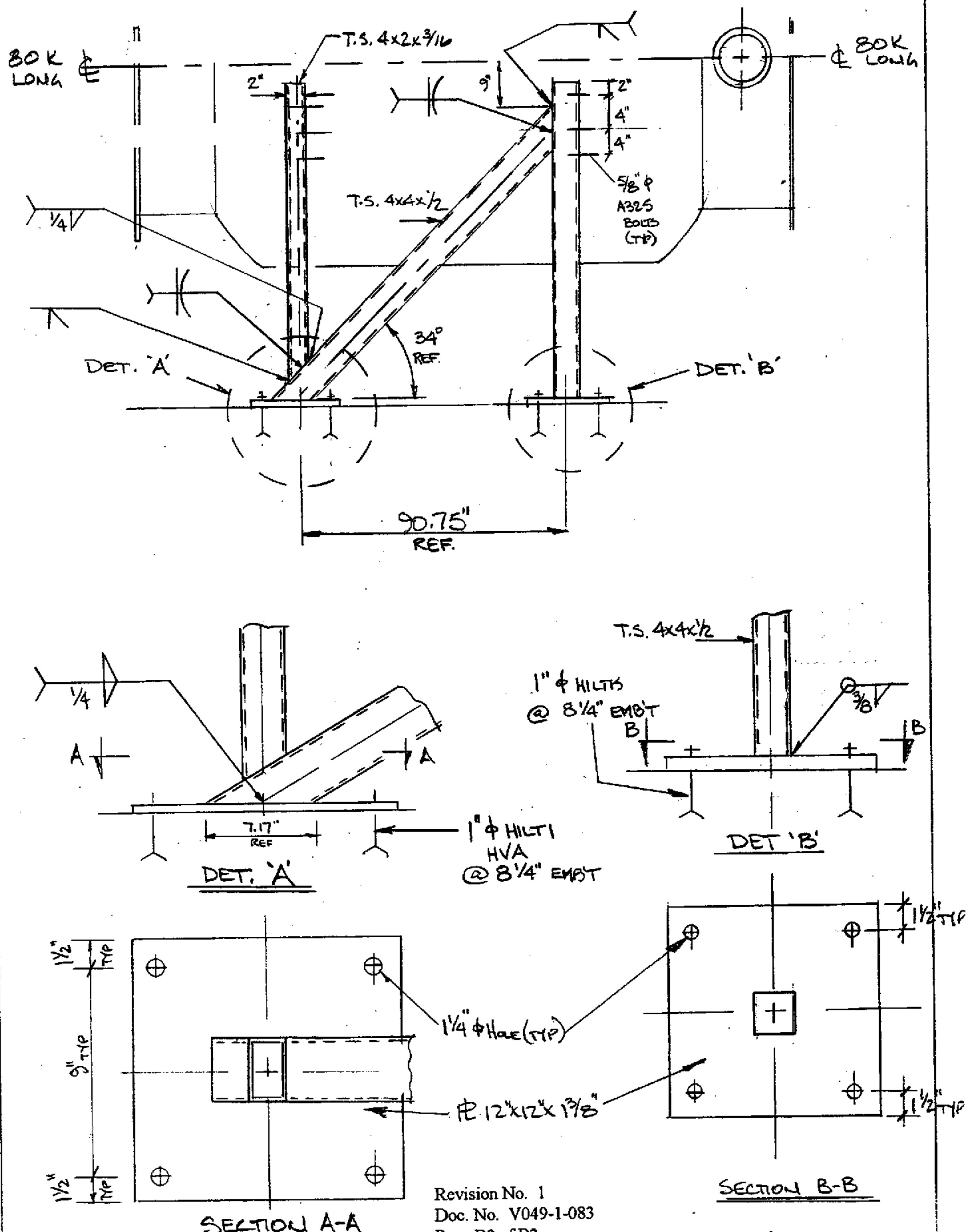


SECTION A-A



SECTION B-B

80K-LONG



80K LONG ℄
T.S. 4x2x3/16
2"
9"
2"
4"
4"
5/8" φ A325 BOLTS (TYP)
℄ 80K LONG
1/4
T.S. 4x4x1/2
34° REF.
DET. 'A'
DET. 'B'
90.75" REF.
1/4
A
A
7.17" REF
1" φ HILTI HVA @ 8 1/4" EMB'T
DET. 'A'
T.S. 4x4x1/2
1" φ HILTI @ 8 1/4" EMB'T
3/8
B
B
DET 'B'
1 1/2" TYP
9" TYP
1 1/2" TYP
1 1/4" φ HOLE (TYP)
PL 12"x12"x1 3/8"
1 1/2" TYP
1 1/2" TYP
SECTION A-A
SECTION B-B

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-114 PAGE 1 OF 54
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	349	11/15/96	WDB	RDC	**1-1/2" ∅ GN_2 Regeneration Piping**	
					BY: W. Bilynsky	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE:

Design/analyze the 1-1/2" ∅ GN_2 Regeneration piping for the 80K cryopumps (Long & Short). The piping will be designed to B31.1 Power Piping standards for the normal operating condition regeneration process and the regasification condition/state.

METHOD:

Piping is designed to the ASME Code Standards for B31.1 Power Piping using hand calculations and the ALGOR® *PIPEPLUS* Pipe Stress computer program version 5.06-3H

ASSUMPTIONS: See calculation

INPUTS: See calculation

REFERENCES:

1. ALGOR® *PIPEPLUS* Pipe Stress Analysis and Design System (version 5.06-3H)
2. NAVCO Piping Datalog
3. Doc. No. V049-1-066 LIGO Vacuum Equipment Structural Design Criteria
4. Memorandum - Design Pressure for 80K Pump Reservoir, Doc. No. V049-1-056
5. ASME B31.1 Power Piping, 1995 Edition
6. A V049-2-037 rev.3 Specification for Piping Design and Material

CALCULATIONS:
V049-1-081 80k-Short Pump - Outer Shell Analysis
V049-1-082 80k-Long Pump - Outer Shell Analysis
V067-1-067 Analysis of Pump Reservoir

CONCLUSIONS:

The requirements of the B31.1 ASME Code for Pressure Piping and the Ligo Vacuum Equipment Structural Design Criteria are met.

NOTES: *PIPEPLUS* Computer File: GN2OPR-C.*, GN2GAS-H.* & GN2REGEN

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA	ENGINEERING CALCULATIONS	NO: V049-1-114 Rev. No. 0 Page 2 of 54
PROJECT: LIGO VACUUM EQUIPMENT	PROJECT NO: V59049	
CALCULATION TITLE: 80K Cryopump 1-1/2" Ø GN2 Regeneration Piping		

TABLE OF CONTENTS

REVISION HISTORY

Rev. 0 Original Issue
November 15, 1996

PREFACE

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

The 1-1/2" ∅ GN_2 regeneration piping is the supply pipe for the 80K pump reservoir. During normal operating conditions the temperature of the 80K pump reservoir is -320^0 F (at 40 psia). The piping temperature ranges from -320^0 F at the reservoir to 70^0 F at the bellows and beyond (the pipe is insulated). During regeneration, nitrogen is pumped into the pump reservoir at 302^0F (150^0 C) and 25 psi. The reservoir's temperature will rise from -320^0 F to 302^0F. When the reservoir reaches 302^0F (150^0 C) the system is in a regasification state, the reservoir and attached piping are at a constant temperature as the system *"cleans"* itself.

The 1-1/2" ∅ GN_2 regeneration piping is therefore designed for three conditions;

- Normal Operating Condition
- Regeneration Process
- ReGasification Condition/State

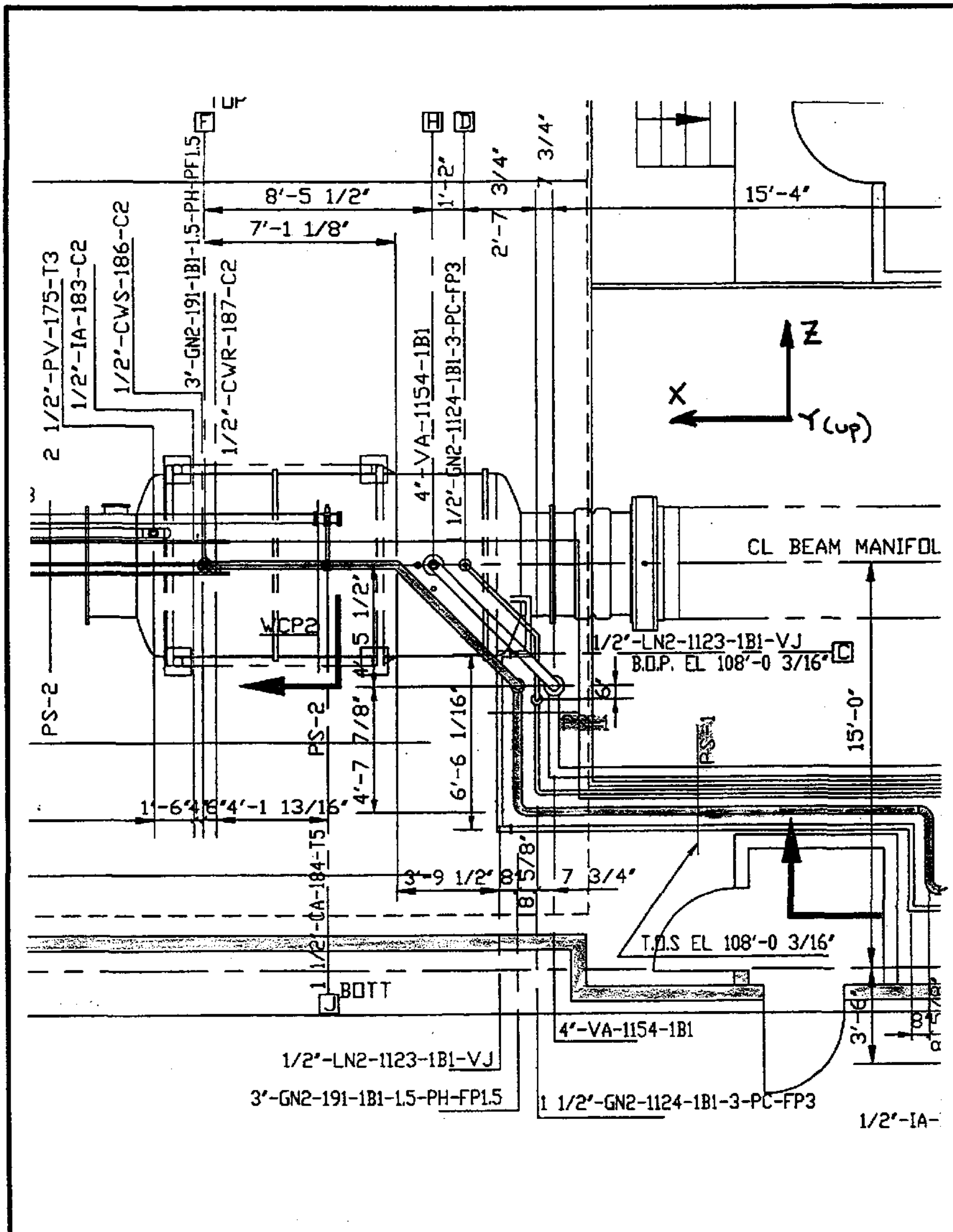
During normal operating conditions the temperature of the 80k pump reservoir is consistently at -320^0 F and 40 psi. The regen pipe is at $-320.^0$F from the reservoir to where it leaves the building at which point it is heat traced. The pipe is at 40 psi from the pump reservoir to the bellows and at 25 psi from the bellows to the analytical model's termination point. At -320^0 F the reservoir *contracts* in the axial and radial directions. Additionally at this temperature, the pump reservoir is filled with LN_2 which increases the deadweight of the reservoir and produces a downward displacement. The regen pipe's nozzle (anchor), which is located at the bottom of the reservoir, will be displaced relative to the pump reservoir. An unbalanced vacuum load due to the differing internal and external pressures acts at the bellows to regen pipe interface.

During the regeneration process, GN_2 is pumped into the reservoir at 302^0 F (150^0 C) and 25 psi. The regen pipe temperature goes through a temperature gradient of $302.^0$F and 25 psi to 70^0F and 40 psi at the bellows to -320^0 F and 40 psi at the reservoir.

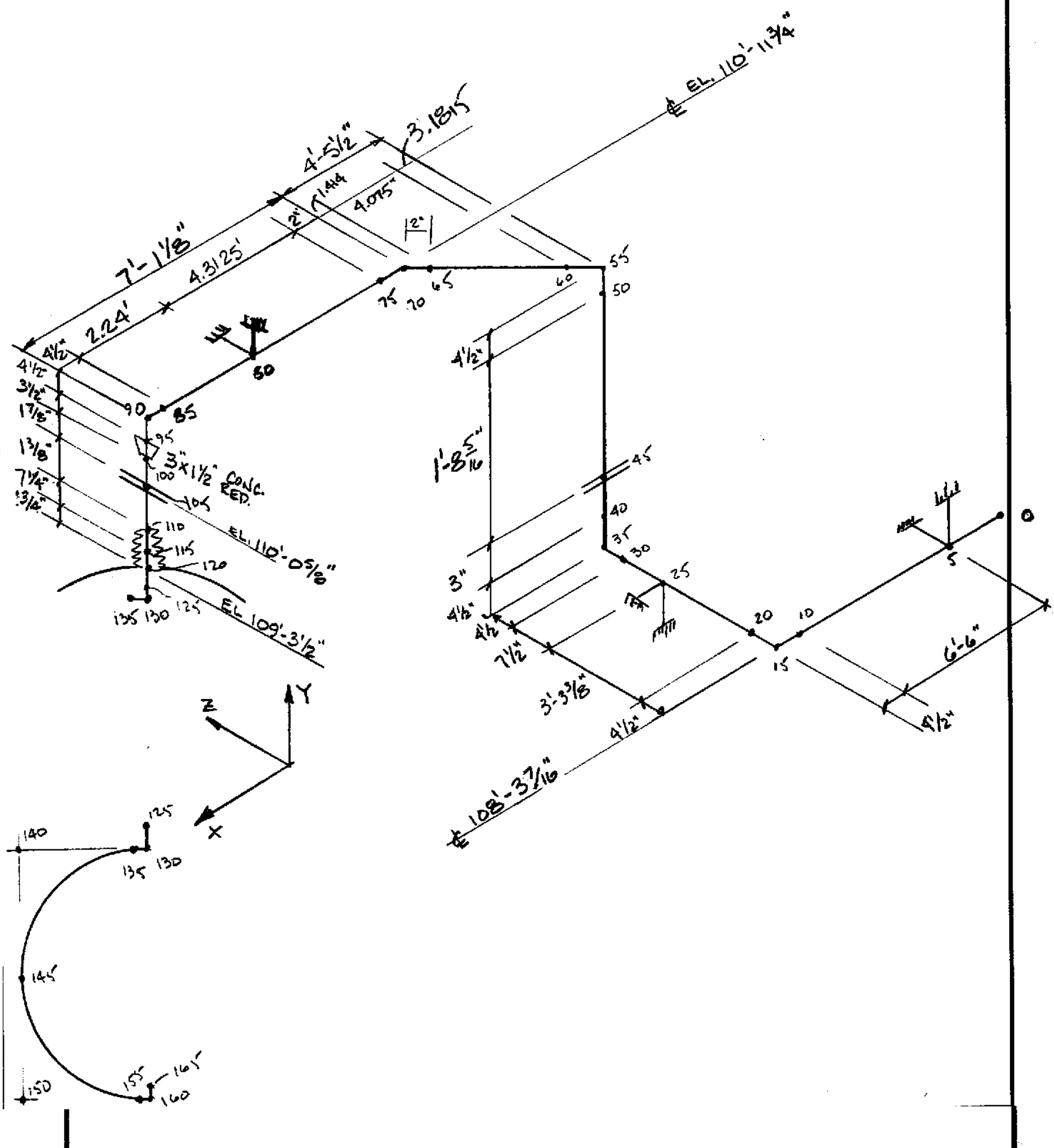
During regasification, the reservoir is at *302^0 F (150^0 C) and 25 psi*. At $302.^0$F the reservoir *expands* in the axial and radial directions. The pump reservoir is filled with GN_2 which reduces the deadweight of the reservoir resulting in lower displacements from the reservoir's weight. The regen pipe is analyzed at $302.^0$F and displaced relative to the pump reservoir. The unbalanced vacuum force is present at the bellows to regen pipe interface.

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

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA	ENGINEERING CALCULATIONS	NO: V049-1-114 Rev. No. 0 Page 5 of 54
PROJECT: LIGO VACUUM EQUIPMENT	PROJECT NO:	V59049
CALCULATION TITLE: 1-1/2" Ø GN_2 Regeneration Piping		



PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA	ENGINEERING CALCULATIONS	NO: V049-1- 114 Rev. No. 0 Page 6 of 54
PROJECT: LIGO VACUUM EQUIPMENT	PROJECT NO:	V59049
CALCULATION TITLE:	1-1/2" Ø GN_2 Regeneration Piping	



Pipe Properties

Aluminum

1-1/2″ Ø GN_2

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

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

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

Austentic Stainless Steel

1-1/2″ Ø GN_2

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

3″ Ø GN2

SA-312 TP304L CMTR, Seamless, SCH 10S
OD = 3.50 in ID = 3.26 in
Thks = 0.120 in
Contents (Nitrogen) S.G. = 0.9714
Density = 0.784 #/ft^3

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

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

Design Operating Conditions

Normal Operation *Pump reservoir operates at -320.^{0}F.*
Regen piping temperature is at −320.^{0}F.
Pump reservoir is at it's heaviest (filled with LN_2)
Reservoir is contracting radially and longitudinally (-320.^{0}F.)

Regeneration Process *Purging of pump reservoir with nitrogen gas GN_2 at 302.^{0}F.*
Regen piping temperature is at 302.^{0}F.
Pump reservoir's weight is decreasing (liquid is being displaced by gas)
Reservoir is expanding radially and longitudinally (as it goes to 302.^{0}F.)

ReGasification *Pump reservoir is at 302.^{0}F*
Regen piping temperature is at 302.^{0}F
Pump reservoir is at it's lightest weight (filled with GN_2).
Reservoir has expanded radially and longitudinally (302.^{0}F.).

Thermal Displacements at Nozzle (Node Pt. 110)

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

where:

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

Longitudinal Direction

Normal Operation @ −320.^{0}F
$\delta_{thermal} = \alpha\ \Delta T\ L$
= (0.0000099 in/in/^{0}F) (−320.^{0}F − 70.^{0}F) (124. in)
= **−0.479 in.** (contracting towards reservoirs axial restraints)

Regeneration/ReGasification Process @ 302.^{0}F
$\delta_{thermal} = \alpha\ \Delta T\ L$
= (0.00001328 in/in/^{0}F) (302.^{0}F − 70.^{0}F) (124. in)
= **0.382 in.** (expanding away from reservoirs axial restraints)

Radial Direction

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

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

- Displacement of Filled 80K Long Cryopump Reservoir

Per Reference: Doc. No. V049-I-104

Measured Weight of Short Cryopump Reservoir

(The spring stiffness rates are relative for the Long and Short pumps i.e. δ is =)

Deflection upon loading of LN_2 = –0.078″ (short pump)

Per manufacturers specification the spring stiffness has a margin of 30% +/–

$$\delta_{deadweight} = -0.078'' \,(1.33\%) = \mathbf{-0.10374''}$$

$$\delta_{deadweight} = -0.078'' \,(66\%) = \mathbf{-0.05148''}$$

- Anchor Displacements (Node Pt 160)

Normal Operating Condition @ –320.°F *(pump reservoir's deadweight is at it's greatest)*

Longitudinal Direction

$$\delta_{Thermal\ X\text{-}X} = \mathbf{-0.479\ in.}$$

Radial Direction

$\delta_{Thermal\ Y\text{-}Y}$ =	**+0.11490 in.**	$\delta_{Thermal\ Y\text{-}Y}$ =	**+0.11490 in.**
$\delta_{DW\ Y\text{-}Y}$ =	**–0.10374 in.**	$\delta_{DW\ Y\text{-}Y}$ =	**–0.05148 in.**
$\delta_{Total\ Y\text{-}Y}$ =	**+0.01116 in.**	$\delta_{Total\ Y\text{-}Y}$ =	**+0.06342 in.**

Regeneration Process @ 302.°F (*Purging of pump reservoir with GN_2 at 302.°F., Pump reservoir's deadweight is decreasing i.e. $\delta_{DW\ Y\text{-}Y} \Rightarrow 0.0$ in*)

Longitudinal Direction

$$\delta_{Thermal\ X\text{-}X} = \mathbf{+0.382\ in.}$$

Radial Direction

$$\delta_{Thermal\ Y\text{-}Y} = \mathbf{-0.0911\ in.}$$

ReGasification Condition/State @ 302.°F (*Pump reservoir's deadweight is at it's least)*

Longitudinal Direction

$$\delta_{Thermal\ X\text{-}X} = \mathbf{+0.382\ in.}$$

Radial Direction

$$\delta_{Thermal\ Y\text{-}Y} = \mathbf{-0.0911\ in.}$$

- Unbalanced Vacuum Force At Bellows (Node Pt. 95)

$$F_{UV} = P\,A$$

where:

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

A = Net Area = $\pi/4\,[(D_M \text{ in.})^2 - (D_I \text{ in.})^2]$

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

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

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

$$F_{UV} = (14.7\ \#/in^2)\,(\pi/4\,[(3.50 \text{ in.})^2 - (1.90 \text{ in.})^2]) = 99.75 \text{ lbs.} \approx 100.0 \text{ lbs.}$$

Load Combinations

Normal Operating Condition *pump reservoir is filled with LN_2*

- Deadweight + Pressure

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

- Thermal

  $-320.^0$F. Temperature is constant at $-320.^0$F up to the wall penetration (beyond which it is heat traced.)

- Thermal + Displacement

  $\Delta T = -320.^0F.$
  δ_{thrm} = −0.479 in. (reservoir's longitudinal direction)
  δ_{thrm} = +0.1149 in. (reservoir's radial inward/contraction direction)
  Displacement (δ_{DW}) from loading of LN_2 = −0.10374 in.
  = −0.05148 in

- Deadweight + Pressure + Thermal + Displacement

- Deadweight + Pressure + Seismic

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

Load Combinations

Regeneration Process *Purging of pump reservoir with nitrogen gas GN_2 at 302.^{0}F., Pump reservoir's deadweight is decreasing*

- Deadweight + Pressure

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

- Thermal

  302.^{0}F (temperature is constant)

- Thermal + Displacement

  $\Delta T = 302.^0F$
  δ_{thm} = 0.382 in. (reservoir's longitudinal direction)
  δ_{thm} = 0.0911 in. (reservoir's radial inward/contraction direction)
  Pump Reservoir's displacement (δ) due to purging of LN_2 with GN_2 ⇒ 0.00 in.

- Deadweight + Pressure + Thermal + Displacement

- Deadweight + Pressure + Seismic

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

Load Combinations

ReGasification *Pump reservoir is at 302.^{0}F, filled with GN_2*

- Deadweight + Pressure

  Pressure = 25.0 psia + 14.7 psia ≈ 40.0 psia (from the reservoir to the bellows)
  Pressure = 25.0 psia (piping beyond the bellows connection)
  Displacement δ = 0.0 in. (filled with GN_2)

- Thermal

  302.^{0}F (temperature remains constant)

- Thermal + Displacement (pipe at reservoir)

  ΔT = 302.^{0}F.
  δ_{thrm} = 0.3820 in. (reservoir's longitudinal direction)
  δ_{thrm} = 0.0911 in. (reservoir's radial outward/expansion direction)

- Deadweight + Pressure + Thermal + Displacement

- Deadweight + Pressure + Seismic

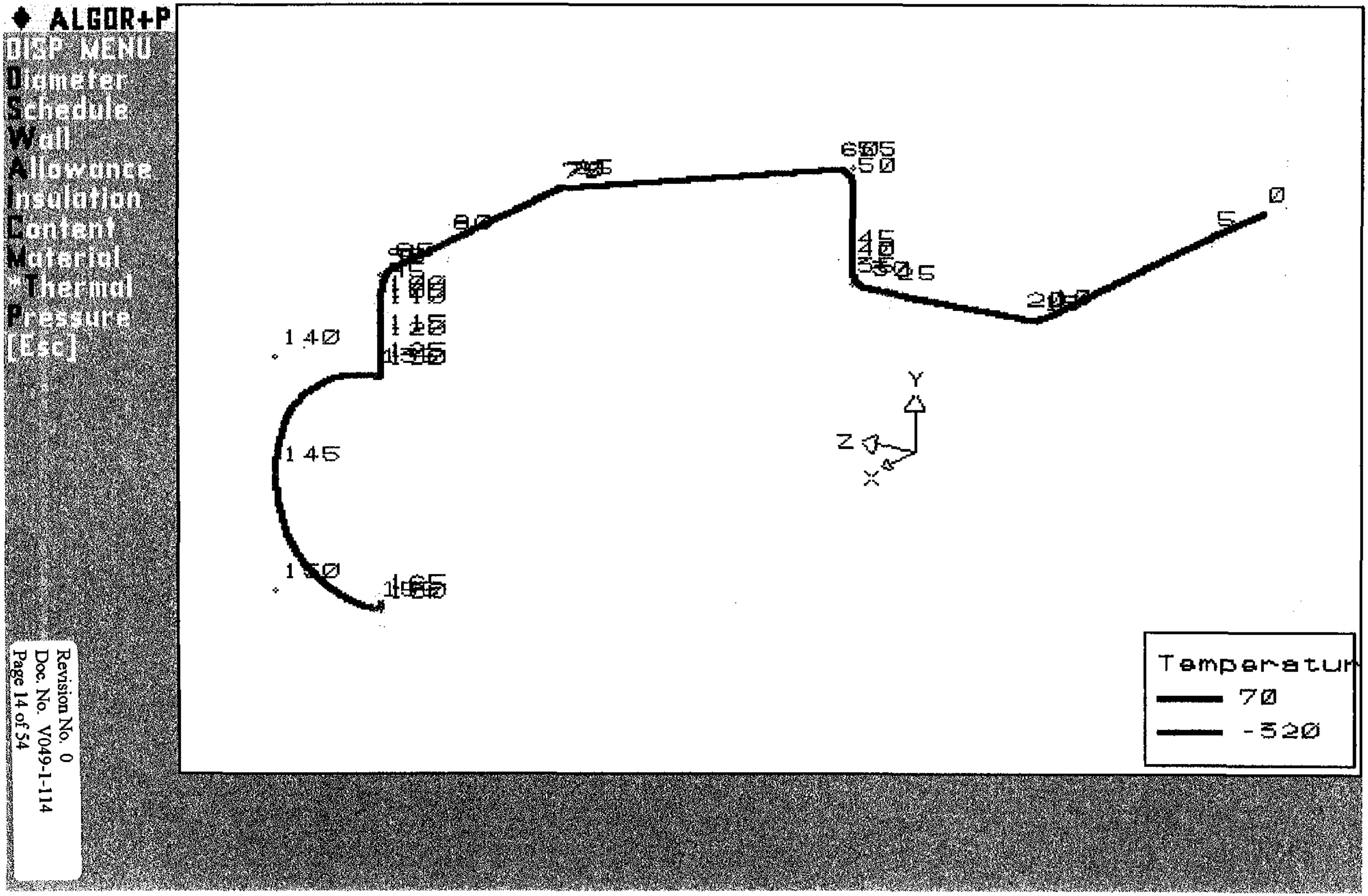
  $\delta_{seismic}$ = 0.05625 g (horizontal directions)

Summary

Normal Operasting Condition

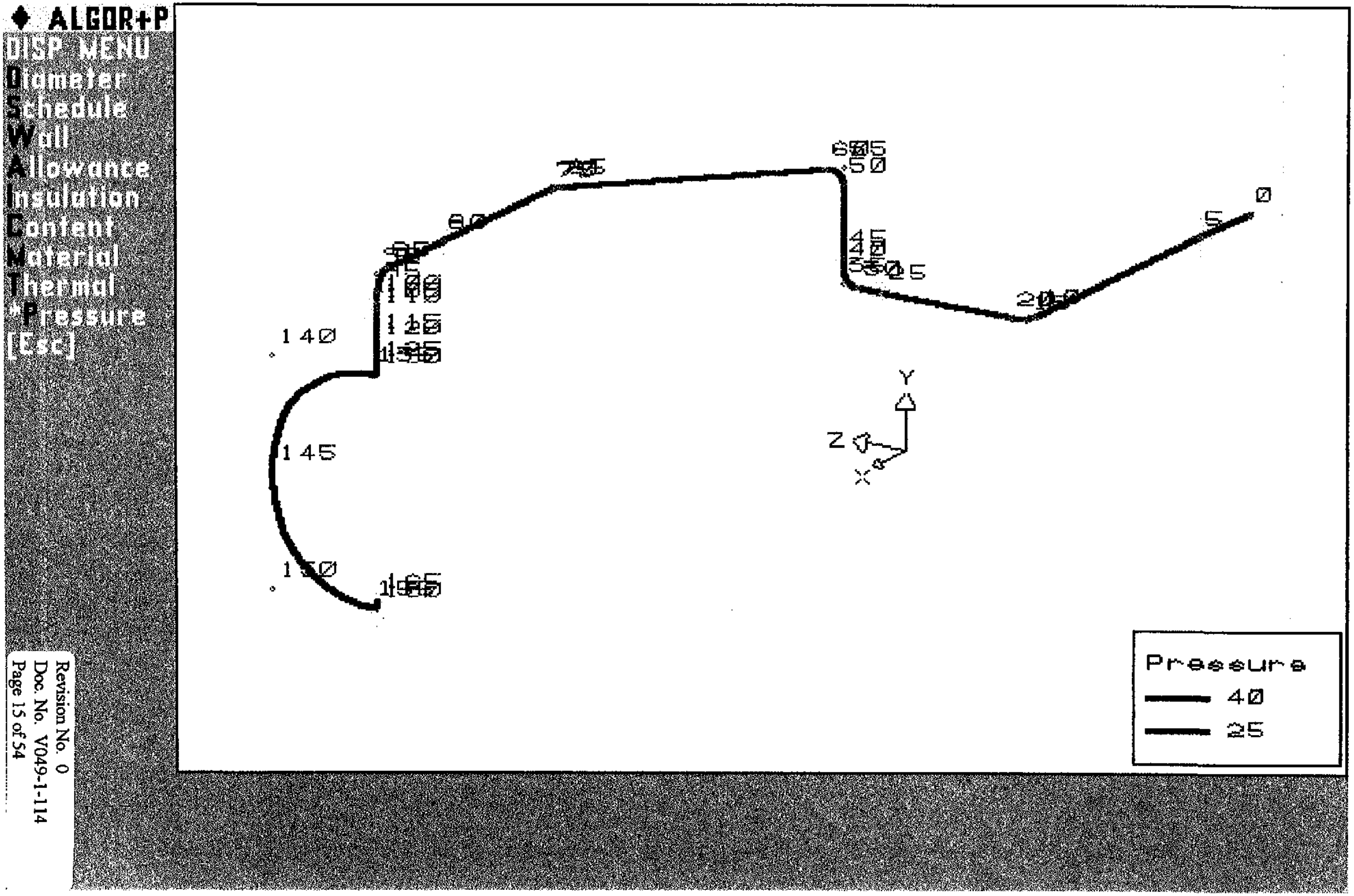
GN_2 Regen Piping

Normal Operating Condition



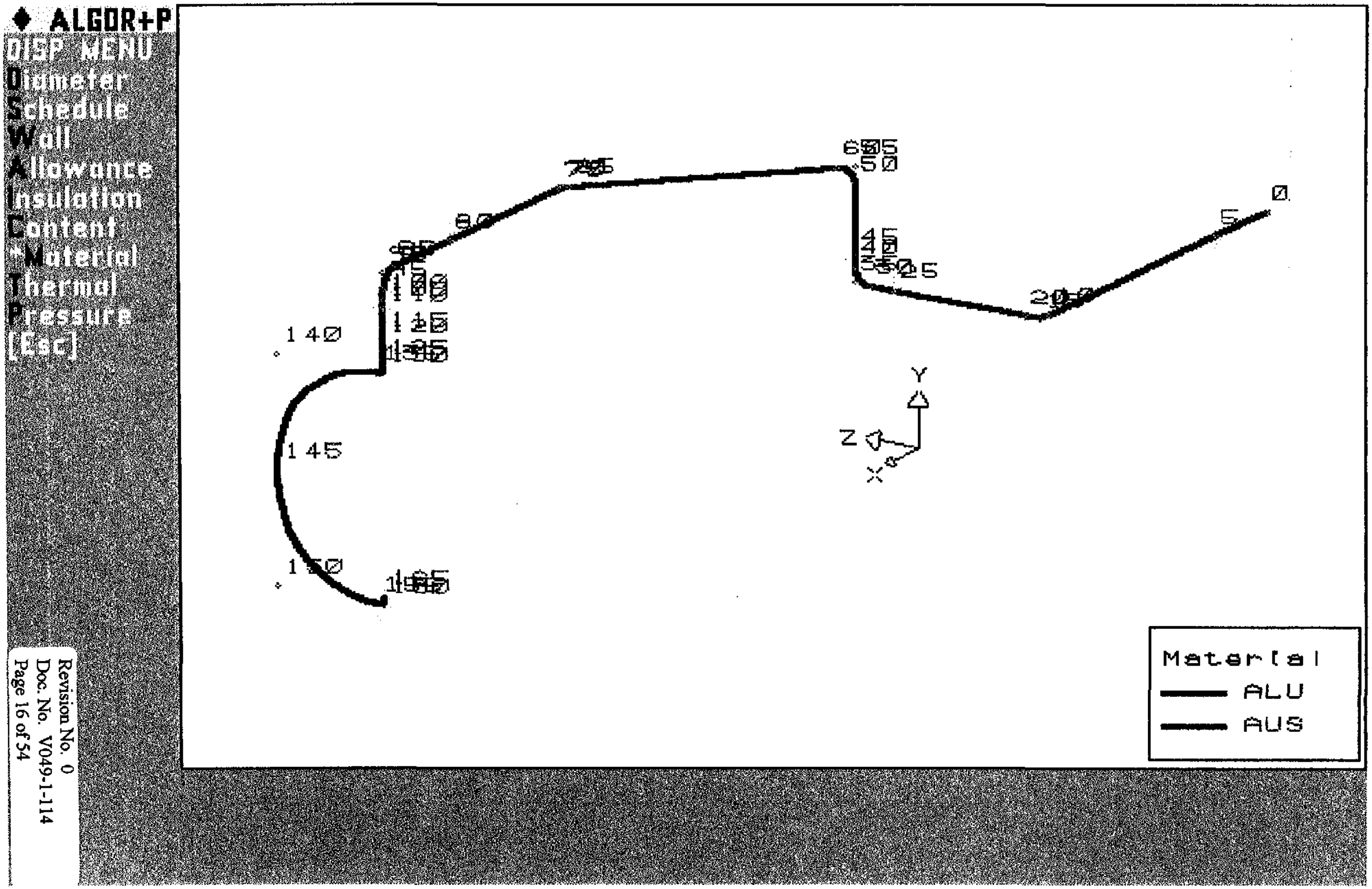
GN_2 Regen Piping

Normal Operating Condition



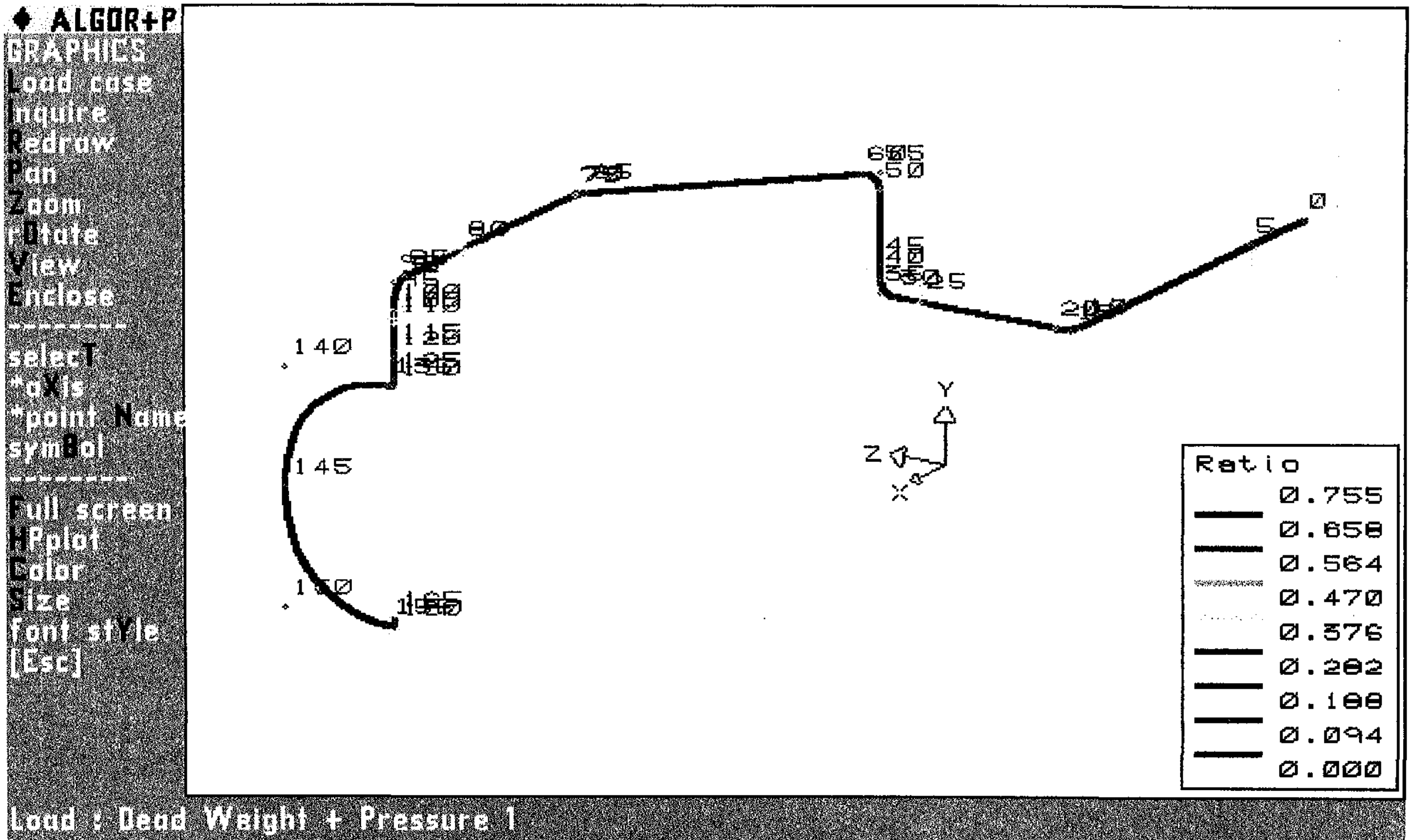
GN_2 Regen Piping

Normal Operating Condition



GN_2 Regen Piping

Normal Operating Condition



*** System Maxima ***

Maximum X displacement = 0.137 inch at point 55.Far
Maximum Y displacement = -0.448 inch at point 10
Maximum Z displacement = -0.267 inch at point 55.Far

Maximum X rotation = -0.628 degree at point 15.Far
Maximum Y rotation = -0.157 degree at point 65
Maximum Z rotation = -0.343 degree at point 5

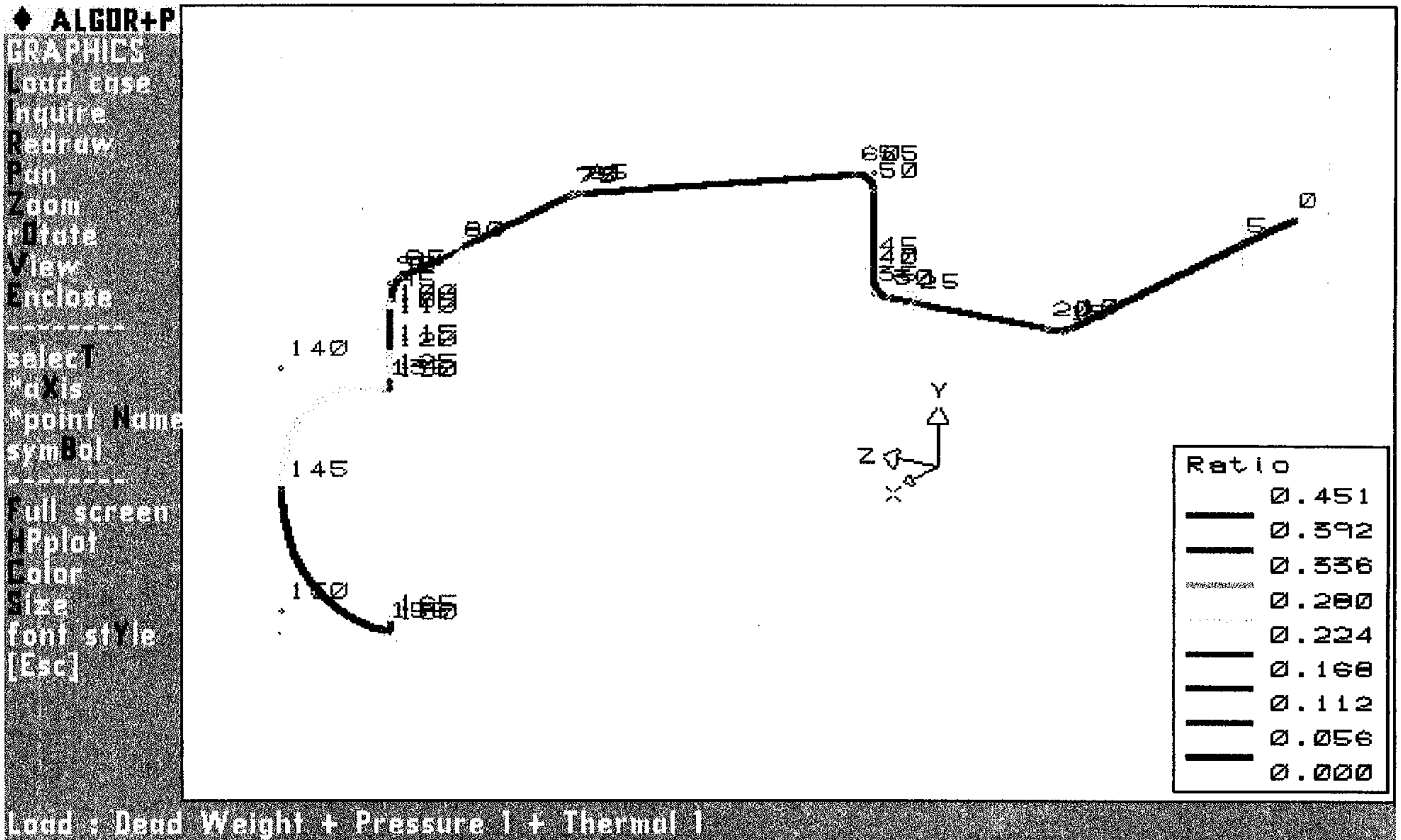
Maximum X force = -9 lb at point 80
Maximum Y force = 108 lb at point 80
Maximum Z force = 18 lb at point 80

Maximum X moment = 1866 inch-lb at point 20
Maximum Y moment = 767 inch-lb at point 80
Maximum Z moment = -2377 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 5639 psi at point 95
Maximum principal stress = 5670 psi at point 95
Maximum code stress = 4532 psi at point 150.Far
Maximum stress ratio (code/allowable) = 0.76 at point 150.Far

GN_2 Regen Piping

Normal Operating Condition



Load : Dead Weight + Pressure 1 + Thermal 1

*** System Maxima ***

Maximum X displacement = -0.199 inch at point 130.Far
Maximum Y displacement = -0.599 inch at point 10
Maximum Z displacement = -0.342 inch at point 55.Far

Maximum X rotation = -0.836 degree at point 15.Far
Maximum Y rotation = -0.200 degree at point 65
Maximum Z rotation = -0.514 degree at point 85

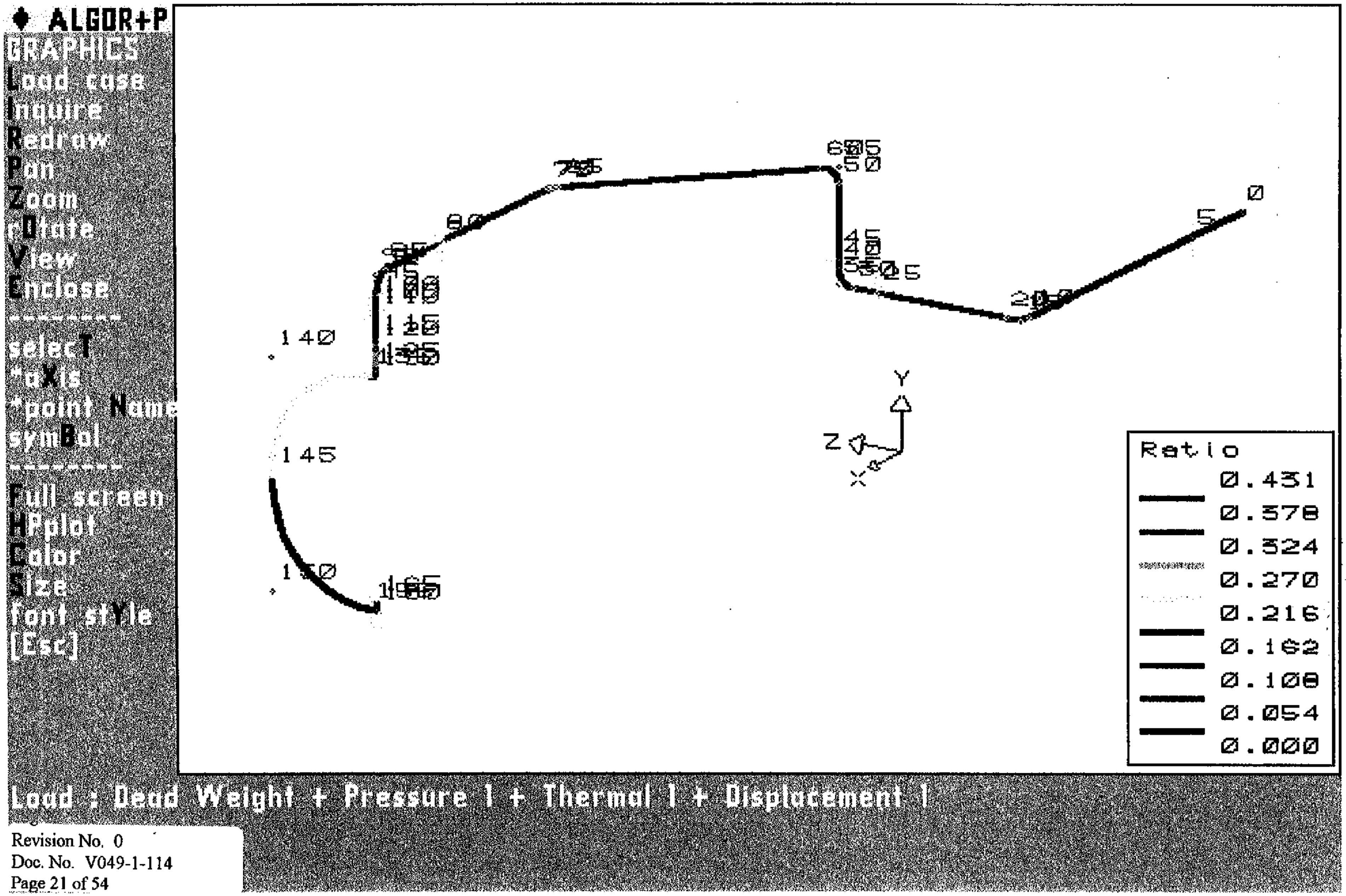
Maximum X force = -14 lb at point 80
Maximum Y force = 144 lb at point 80
Maximum Z force = 14 lb at point 80

Maximum X moment = 1800 inch-lb at point 20
Maximum Y moment = 758 inch-lb at point 80
Maximum Z moment = -3207 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 9941 psi at point 95
Maximum principal stress = 9977 psi at point 95
Maximum code stress = 8941 psi at point 95
Maximum stress ratio (code/allowable) = 0.45 at point 150.Far

GN2 Regen Piping

Normal Operating Condition



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

*** System Maxima ***

Maximum X displacement = -0.479 inch at point 150.Far
Maximum Y displacement = -0.749 inch at point 10
Maximum Z displacement = -0.347 inch at point 55.Far

Maximum X rotation = -1.044 degree at point 0
Maximum Y rotation = -0.214 degree at point 70.Far
Maximum Z rotation = -0.645 degree at point 85

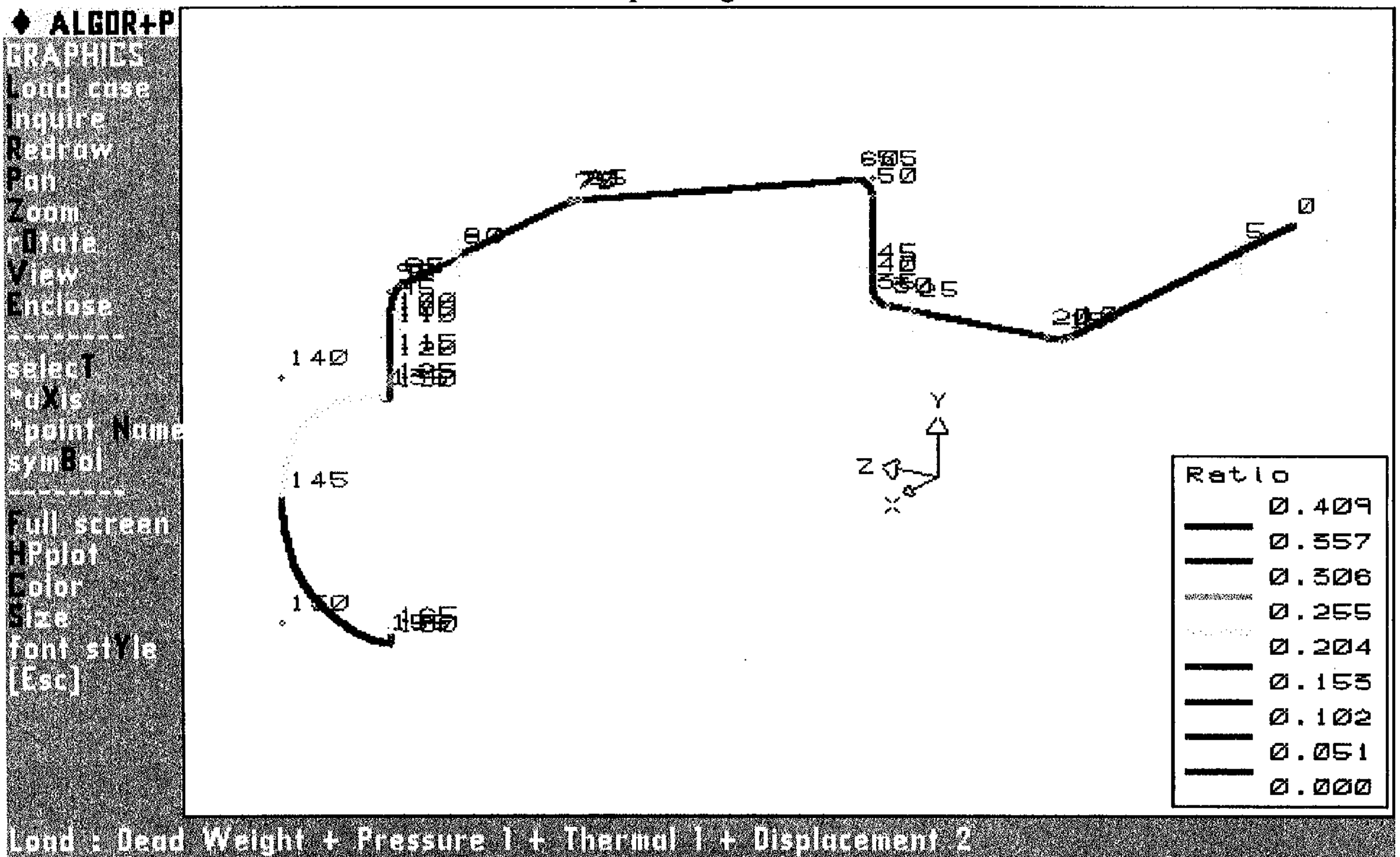
Maximum X force = -8 lb at point 25
Maximum Y force = 144 lb at point 80
Maximum Z force = 20 lb at point 80

Maximum X moment = 1884 inch-lb at point 20
Maximum Y moment = 776 inch-lb at point 80
Maximum Z moment = -3618 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 10648 psi at point 95
Maximum principal stress = 10656 psi at point 95
Maximum code stress = 10788 psi at point 95
Maximum stress ratio (code/allowable) = 0.43 at point 150.Far

GN2 Regen Piping

Normal Operating Condition



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

*** System Maxima ***

Maximum X displacement = -0.479 inch at point 150.Far
Maximum Y displacement = -0.717 inch at point 10
Maximum Z displacement = -0.331 inch at point 55.Far

Maximum X rotation = -1.001 degree at point 0
Maximum Y rotation = -0.206 degree at point 75
Maximum Z rotation = -0.609 degree at point 85

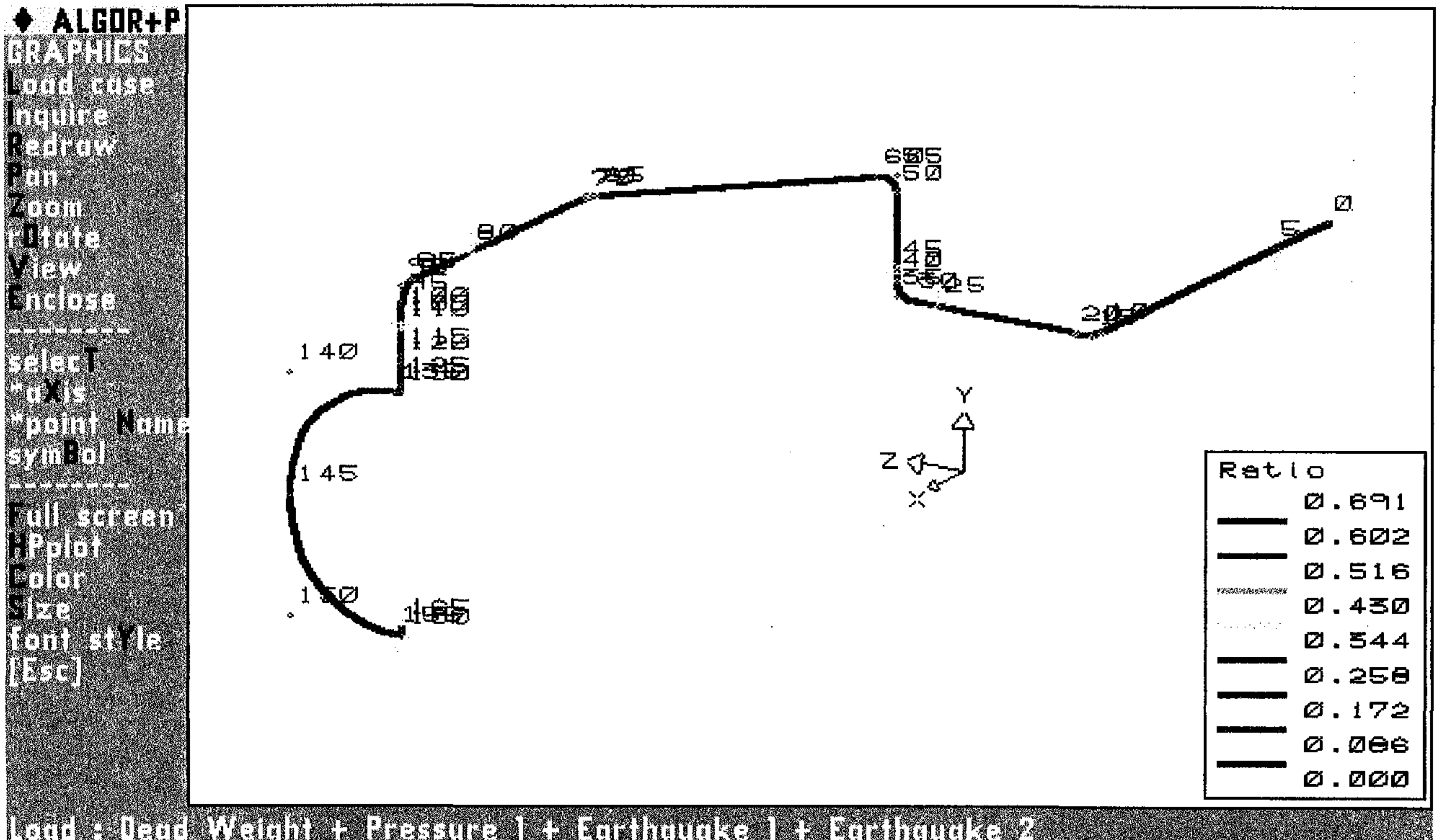
Maximum X force = -9 lb at point 25
Maximum Y force = 137 lb at point 80
Maximum Z force = 21 lb at point 80

Maximum X moment = 1897 inch-lb at point 20
Maximum Y moment = 778 inch-lb at point 80
Maximum Z moment = -3442 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 9694 psi at point 95
Maximum principal stress = 9701 psi at point 95
Maximum code stress = 10023 psi at point 95
Maximum stress ratio (code/allowable) = 0.41 at point 150.Far

GN_2 Regen Piping

Normal Operating Condition



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

*** System Maxima ***

Maximum X displacement = -0.184 inch at point 130.Far
Maximum Y displacement = -0.520 inch at point 10
Maximum Z displacement = -0.338 inch at point 55.Far

Maximum X rotation = -0.730 degree at point 0
Maximum Y rotation = -0.199 degree at point 65
Maximum Z rotation = -0.393 degree at point 5

Maximum X force = 19 lb at point 25
Maximum Y force = 110 lb at point 80
Maximum Z force = 24 lb at point 80

Maximum X moment = 1951 inch-lb at point 20
Maximum Y moment = -1171 inch-lb at point 20
Maximum Z moment = -2478 inch-lb at point 80

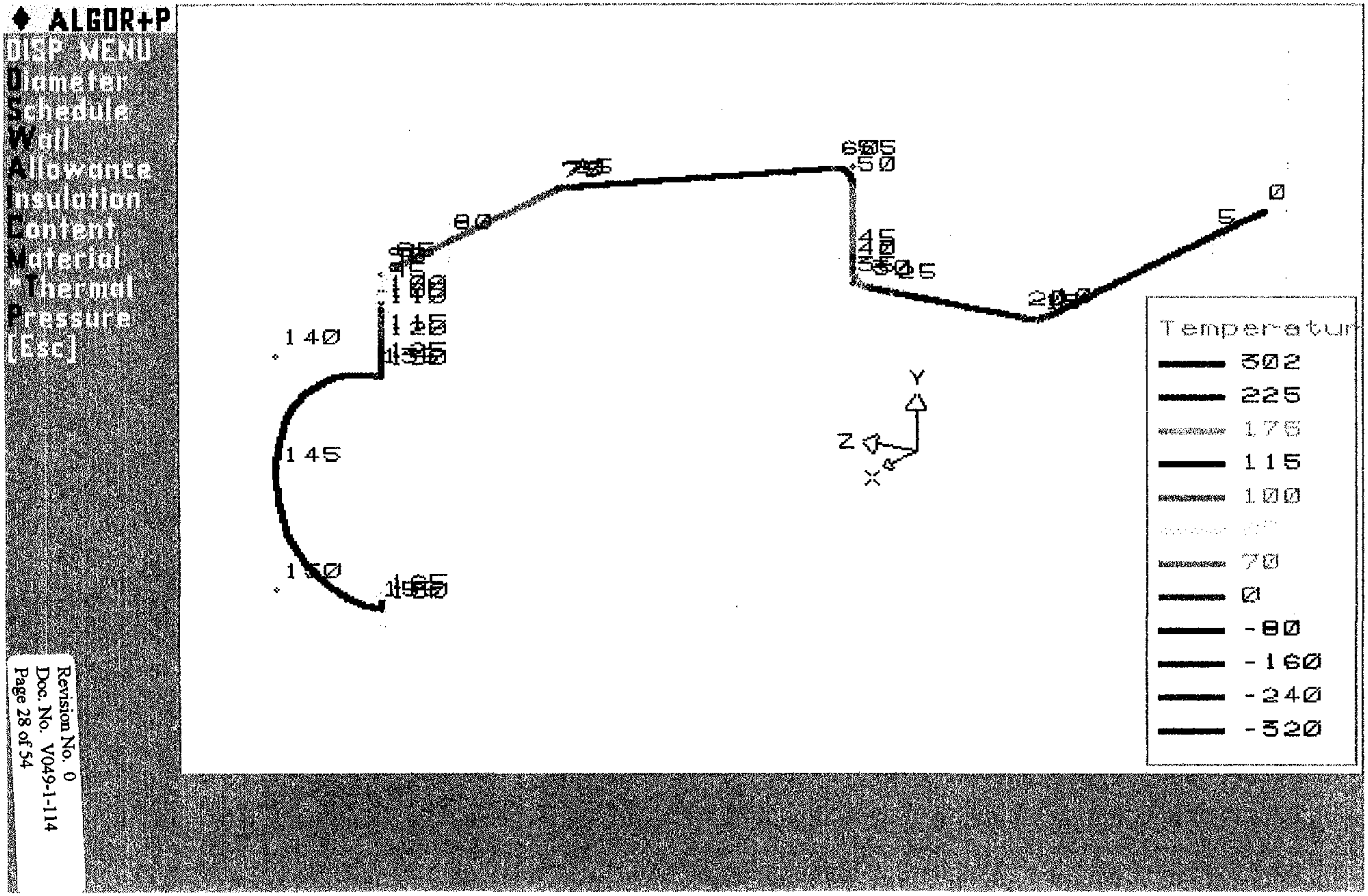
Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 6375 psi at point 95
Maximum principal stress = 6411 psi at point 95
Maximum code stress = 4978 psi at point 95
Maximum stress ratio (code/allowable) = 0.69 at point 150.Far

Summary

Regeneration Process

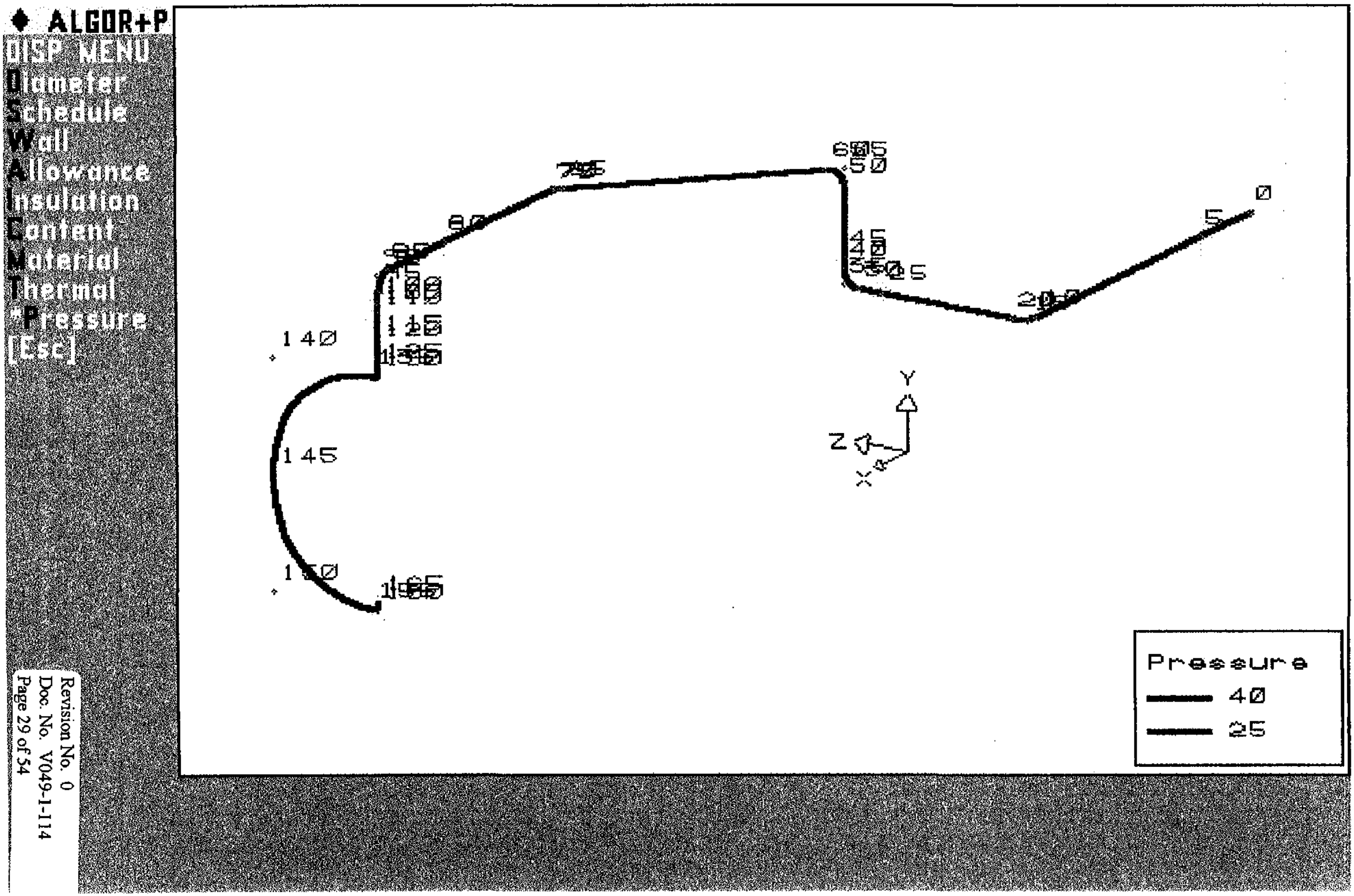
GN_2 Regen Piping

Regeneration Process



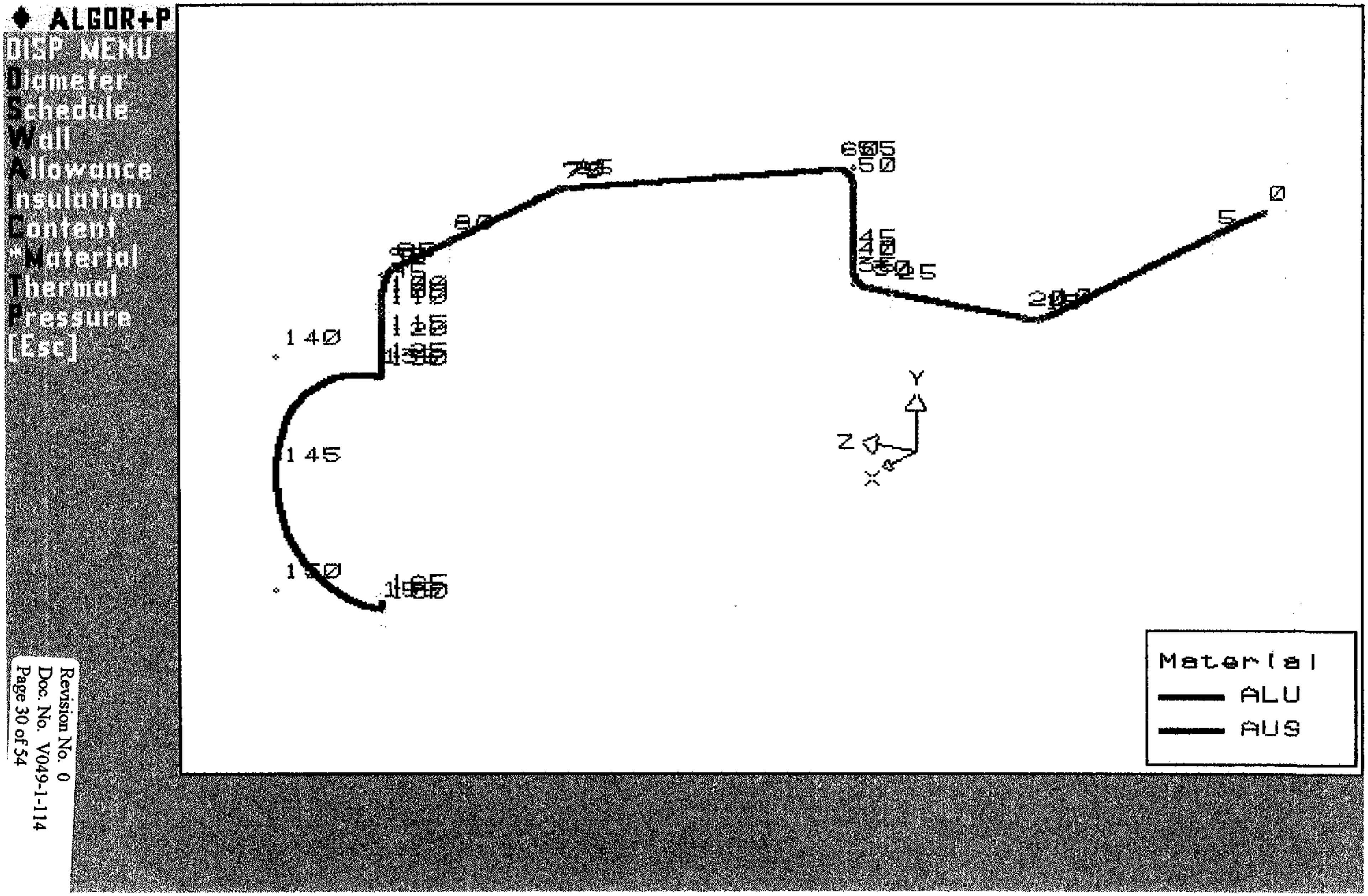
GN_2 Regen Piping

Regeneration Process



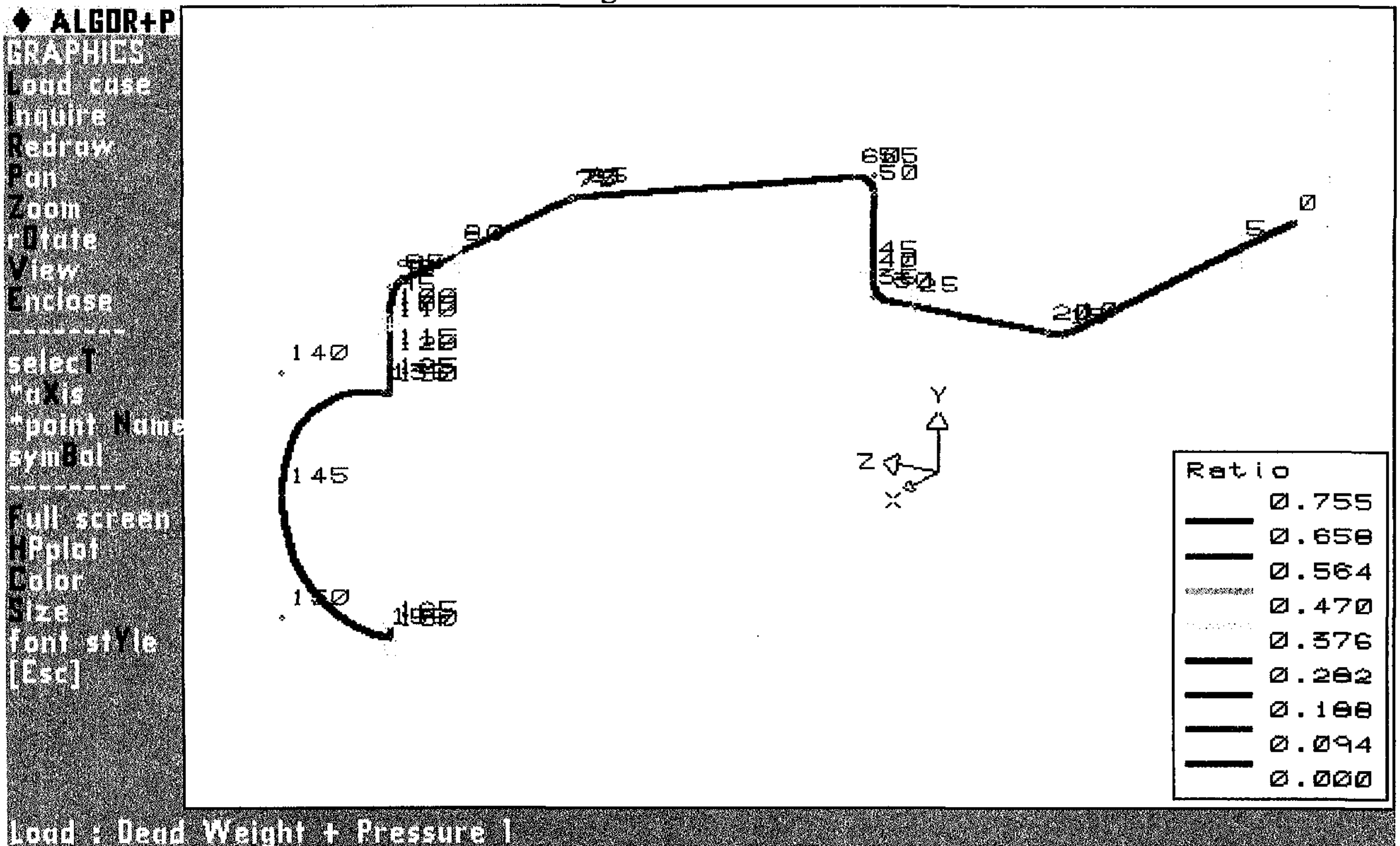
GN_2 Regen Piping

Regeneration Process



GN_2 Regen Piping

Regeneration Process



Load : Dead Weight + Pressure 1

*** System Maxima ***

Maximum X displacement = 0.137 inch at point 55.Far
Maximum Y displacement = -0.448 inch at point 10
Maximum Z displacement = -0.267 inch at point 55.Far

Maximum X rotation = -0.628 degree at point 15.Far
Maximum Y rotation = -0.157 degree at point 65
Maximum Z rotation = -0.343 degree at point 5

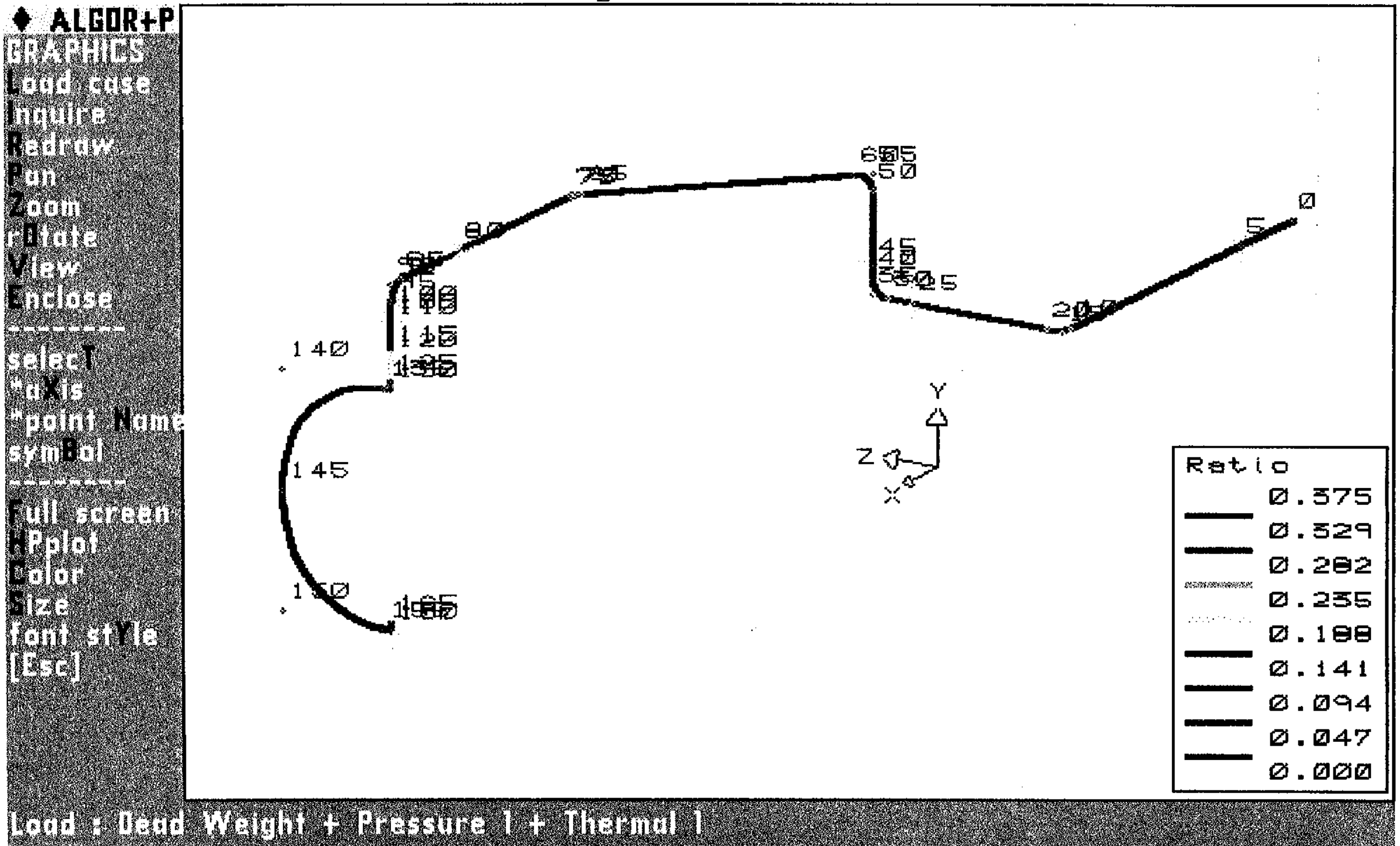
Maximum X force = -9 lb at point 80
Maximum Y force = 108 lb at point 80
Maximum Z force = 18 lb at point 80

Maximum X moment = 1866 inch-lb at point 20
Maximum Y moment = 767 inch-lb at point 80
Maximum Z moment = -2377 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 5639 psi at point 95
Maximum principal stress = 5670 psi at point 95
Maximum code stress = 4532 psi at point 150.Far
Maximum stress ratio (code/allowable) = 0.76 at point 150.Far

GN$_2$ Regen Piping

Regeneration Process



Load : Dead Weight + Pressure 1 + Thermal 1

*** System Maxima ***

Maximum X displacement = -0.163 inch at point 0
Maximum Y displacement = -0.548 inch at point 10
Maximum Z displacement = -0.285 inch at point 55.Far

Maximum X rotation = -0.764 degree at point 15.Far
Maximum Y rotation = -0.170 degree at point 55.Far
Maximum Z rotation = -0.472 degree at point 85

Maximum X force = 16 lb at point 25
Maximum Y force = 128 lb at point 80
Maximum Z force = 17 lb at point 80

Maximum X moment = 1779 inch-lb at point 20
Maximum Y moment = -944 inch-lb at point 15.Near
Maximum Z moment = -2867 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 8116 psi at point 95
Maximum principal stress = 8141 psi at point 95
Maximum code stress = 7121 psi at point 95
Maximum stress ratio (code/allowable) = 0.38 at point 150.Far

*** System Maxima ***

Maximum X displacement = 0.382 inch at point 150.Far
Maximum Y displacement = -0.583 inch at point 10
Maximum Z displacement = -0.304 inch at point 55.Far

Maximum X rotation = -0.815 degree at point 0
Maximum Y rotation = -0.181 degree at point 65
Maximum Z rotation = -0.492 degree at point 85

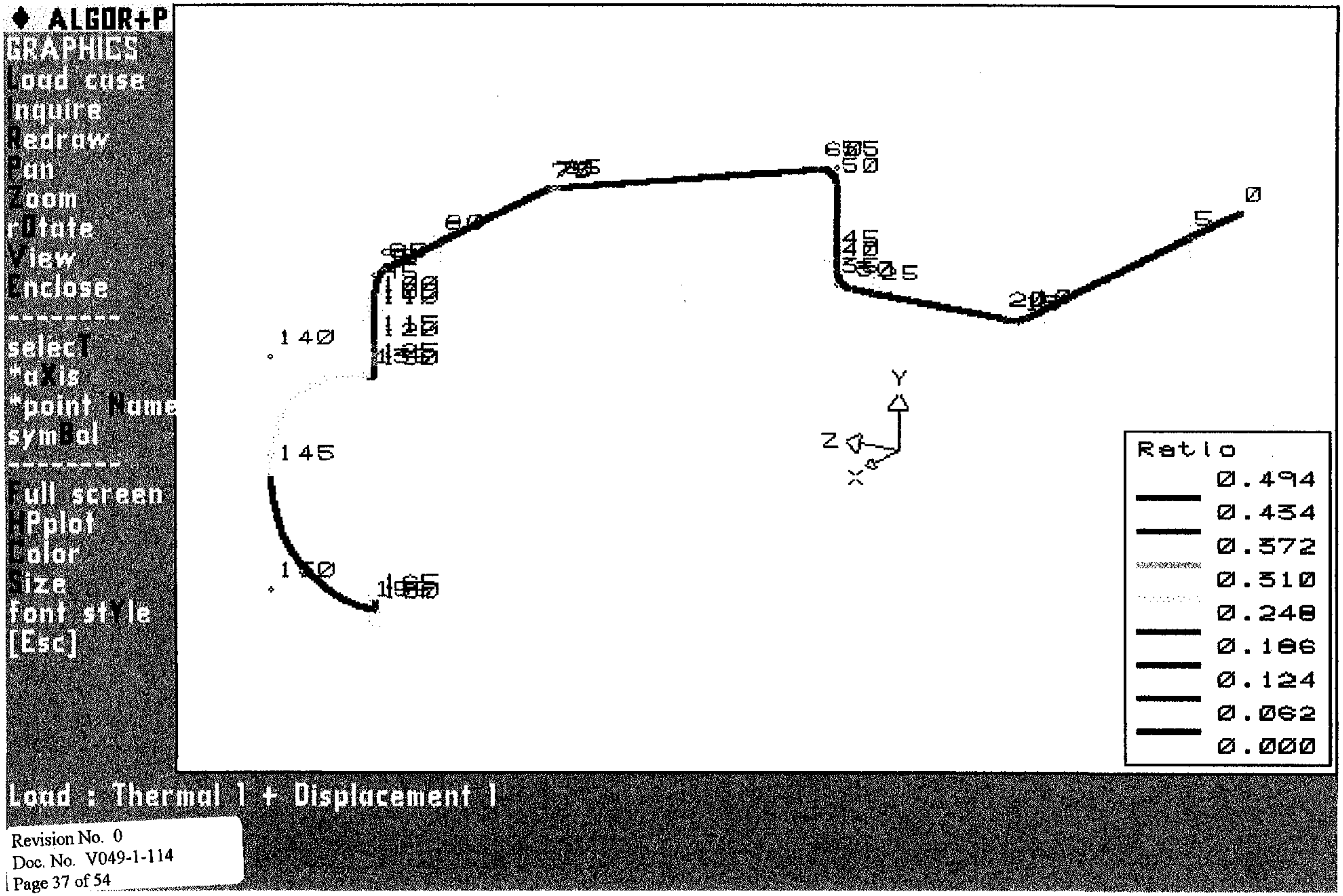
Maximum X force = -24 lb at point 80
Maximum Y force = 161 lb at point 80
Maximum Z force = -13 lb at point 25

Maximum X moment = 1872 inch-lb at point 20
Maximum Y moment = 825 inch-lb at point 80
Maximum Z moment = -3226 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 12884 psi at point 95
Maximum principal stress = 12954 psi at point 95
Maximum code stress = 11899 psi at point 95
Maximum stress ratio (code/allowable) = 0.55 at point 150.Far

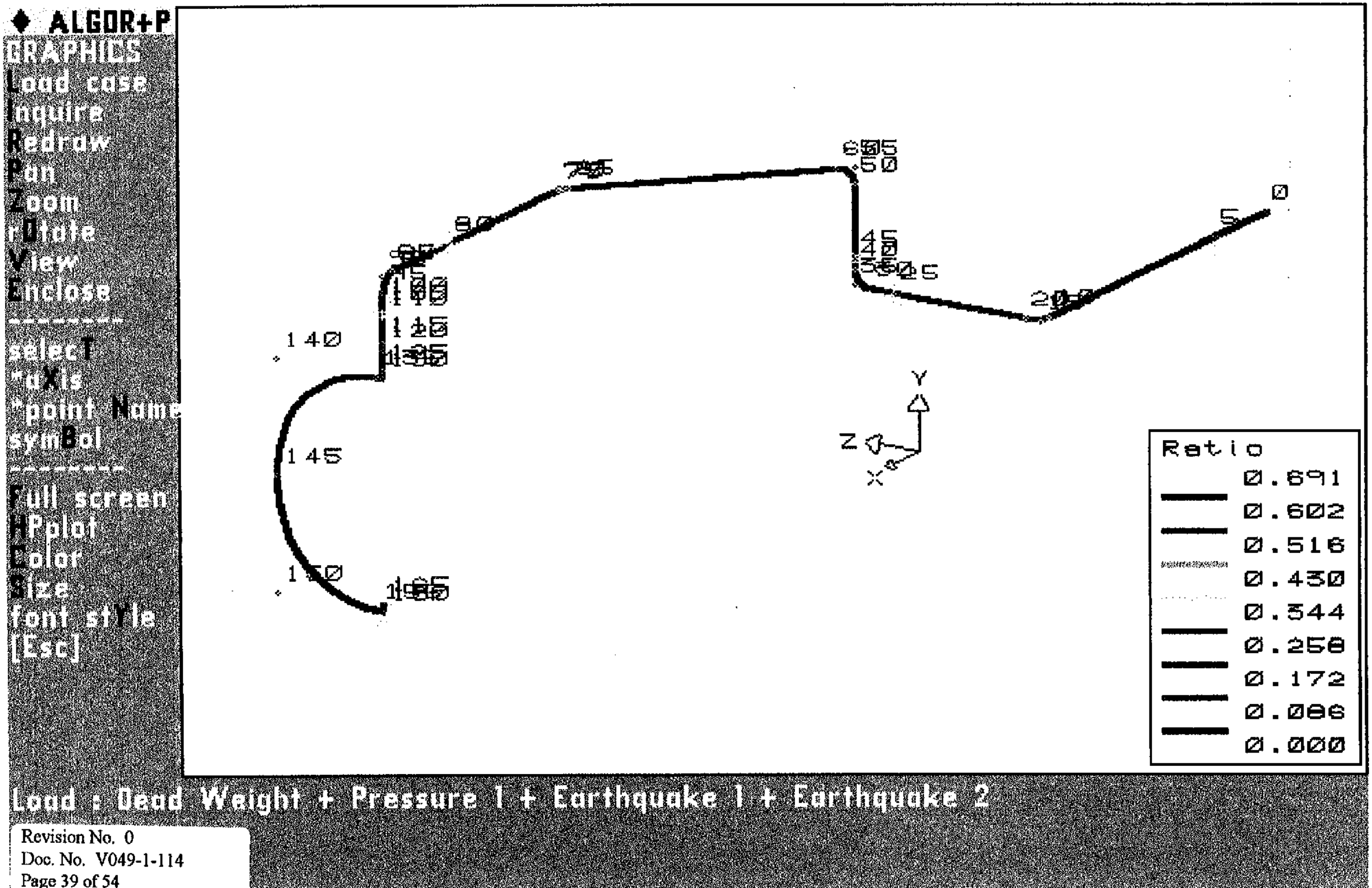
GN2 Regen Piping

Regeneration Process



GN_2 Regen Piping

Regeneration Process



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

*** System Maxima ***

Maximum X displacement = -0.184 inch at point 130.Far
Maximum Y displacement = -0.520 inch at point 10
Maximum Z displacement = -0.338 inch at point 55.Far

Maximum X rotation = -0.730 degree at point 0
Maximum Y rotation = -0.199 degree at point 65
Maximum Z rotation = -0.393 degree at point 5

Maximum X force = 19 lb at point 25
Maximum Y force = 110 lb at point 80
Maximum Z force = 24 lb at point 80

Maximum X moment = 1951 inch-lb at point 20
Maximum Y moment = -1171 inch-lb at point 20
Maximum Z moment = -2478 inch-lb at point 80

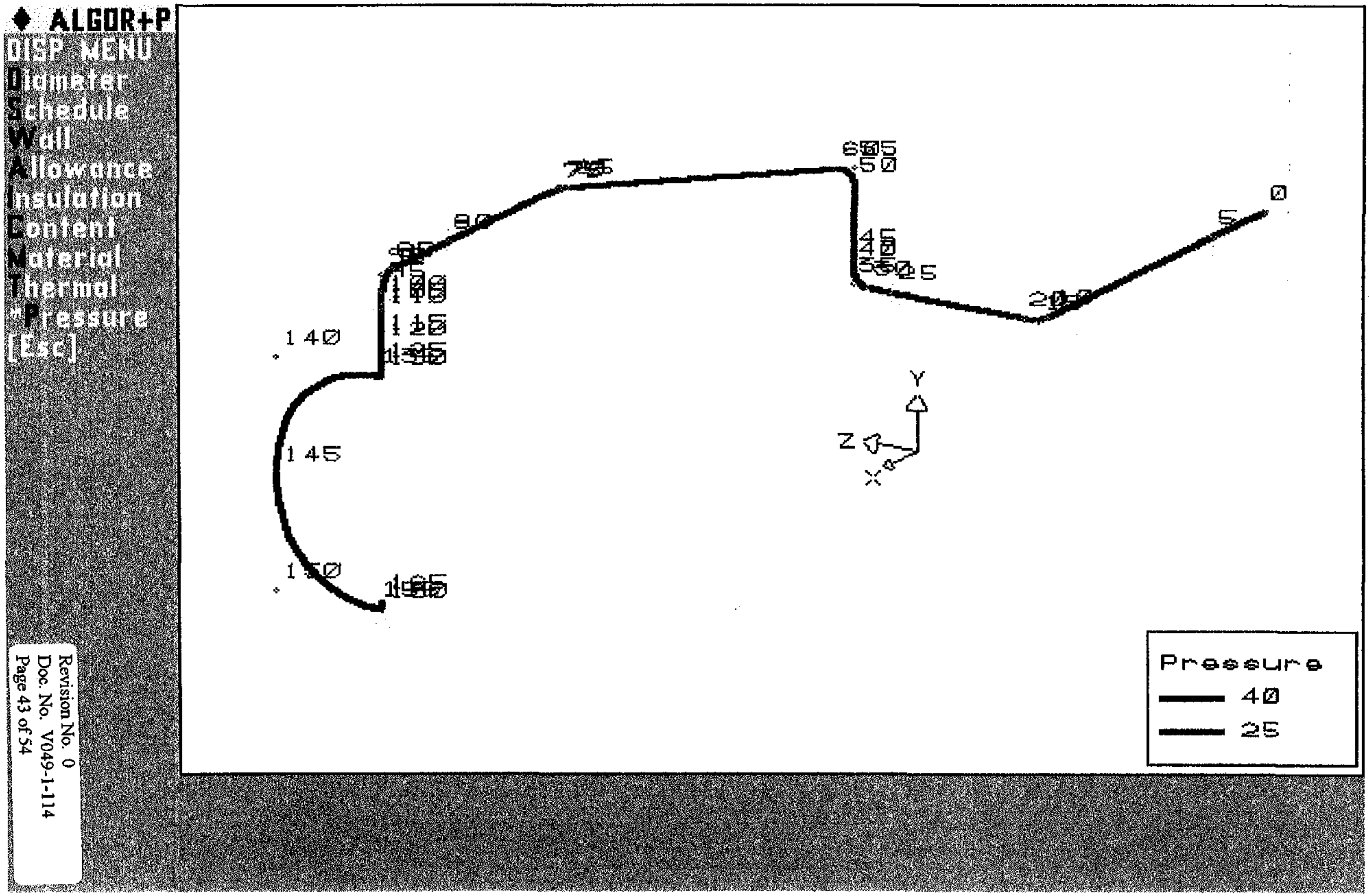
Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 6375 psi at point 95
Maximum principal stress = 6411 psi at point 95
Maximum code stress = 4978 psi at point 95
Maximum stress ratio (code/allowable) = 0.69 at point 150.Far

Summary

ReGasification Condition

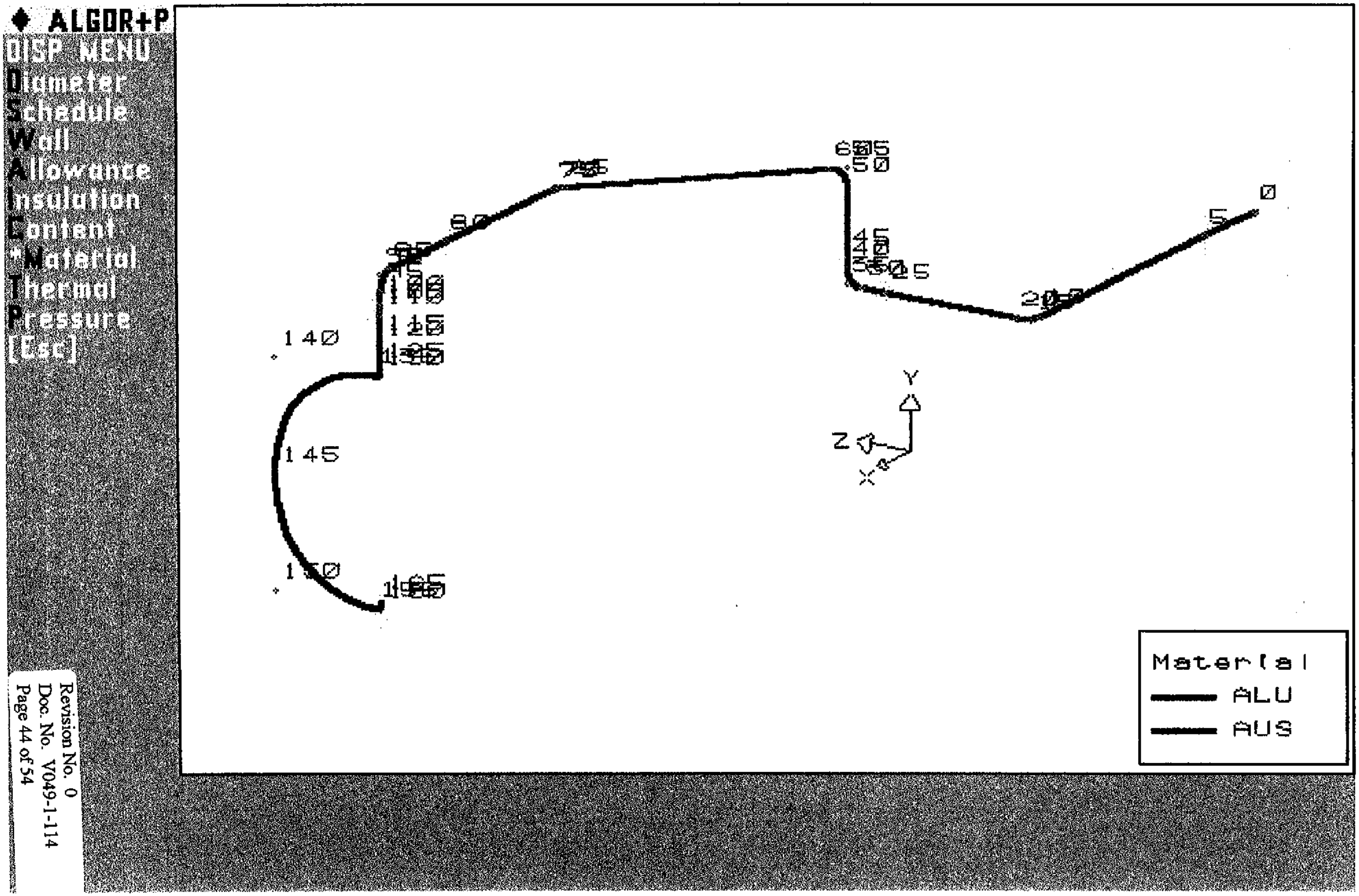
GN_2 Regen Piping

ReGasification Condition



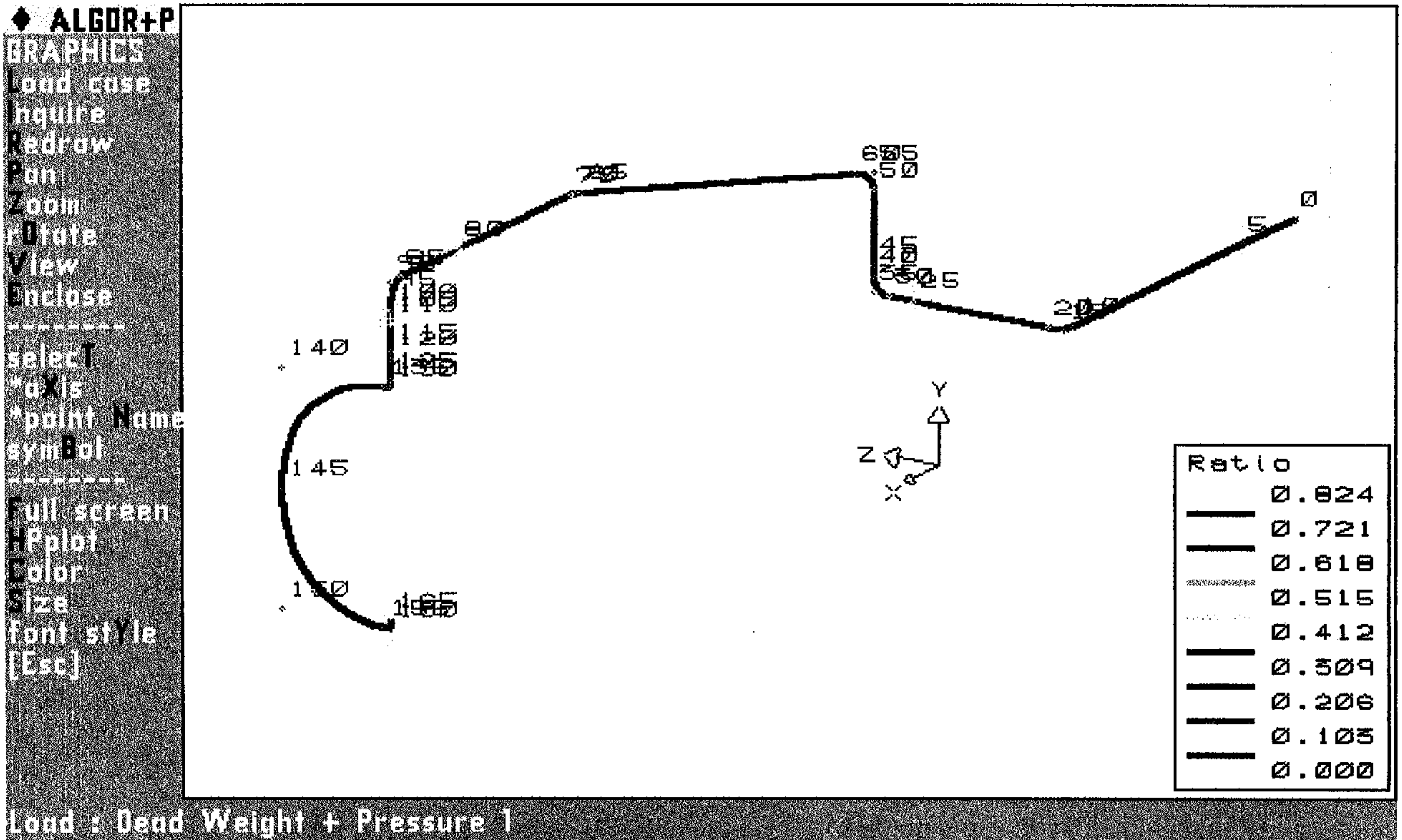
GN_2 Regen Piping

ReGasification Condition



GN_2 Regen Piping

ReGasification Condition



Load : Dead Weight + Pressure 1

*** System Maxima ***

Maximum X displacement = 0.137 inch at point 55.Far
Maximum Y displacement = -0.448 inch at point 10
Maximum Z displacement = -0.267 inch at point 55.Far

Maximum X rotation = -0.628 degree at point 15.Far
Maximum Y rotation = -0.157 degree at point 65
Maximum Z rotation = -0.343 degree at point 5

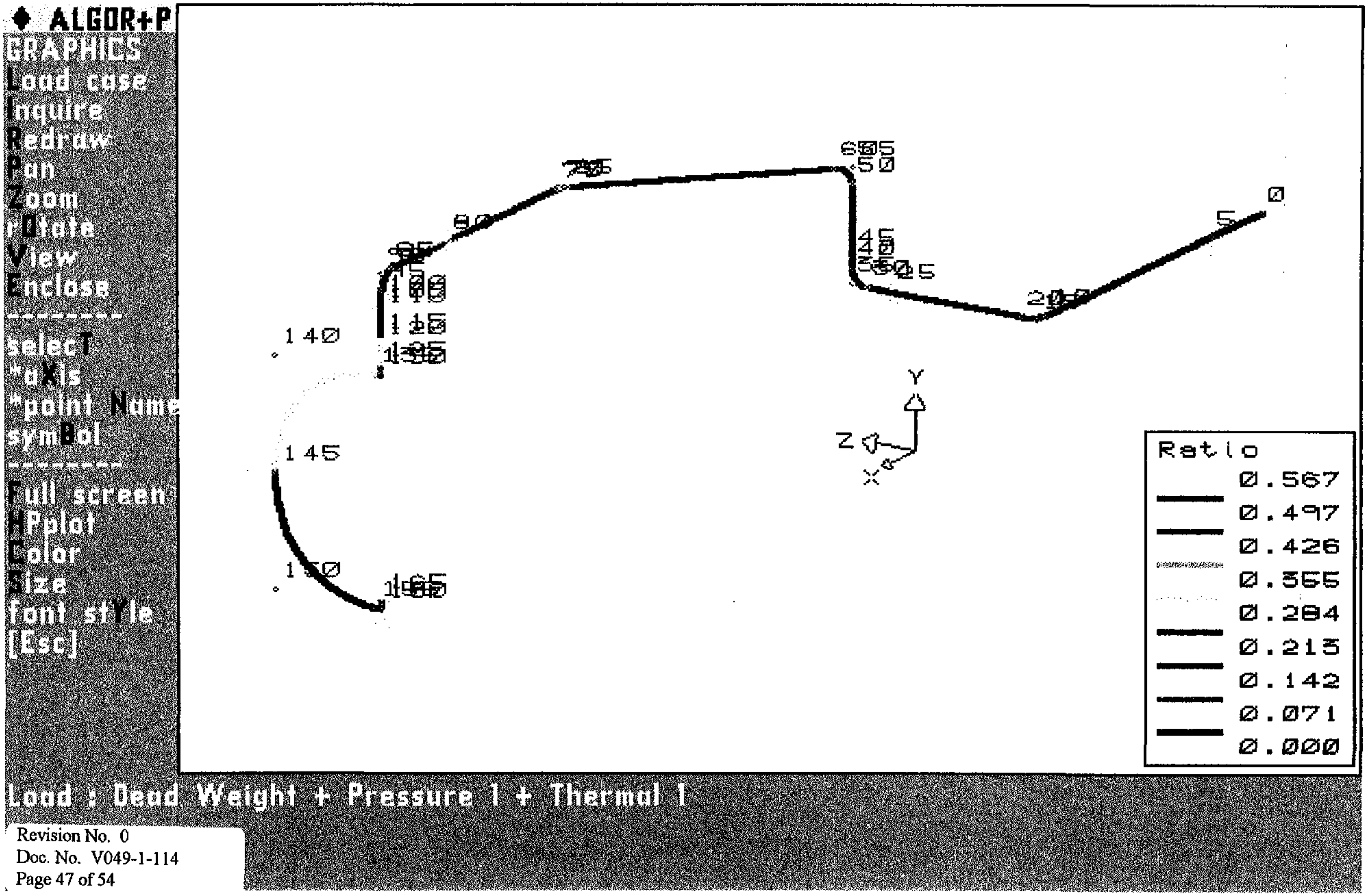
Maximum X force = -9 lb at point 80
Maximum Y force = 108 lb at point 80
Maximum Z force = 18 lb at point 80

Maximum X moment = 1866 inch-lb at point 20
Maximum Y moment = 767 inch-lb at point 80
Maximum Z moment = -2377 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 5639 psi at point 95
Maximum principal stress = 5670 psi at point 95
Maximum code stress = 4532 psi at point 150.Far
Maximum stress ratio (code/allowable) = 0.82 at point 150.Far

GN$_2$ Regen Piping

ReGasification Condition



Load : Dead Weight + Pressure 1 + Thermal 1

*** System Maxima ***

Maximum X displacement = 0.357 inch at point 85
Maximum Y displacement = -0.370 inch at point 10
Maximum Z displacement = 0.339 inch at point 140.Far

Maximum X rotation = -0.519 degree at point 15.Far
Maximum Y rotation = 0.081 degree at point 0
Maximum Z rotation = -0.285 degree at point 5

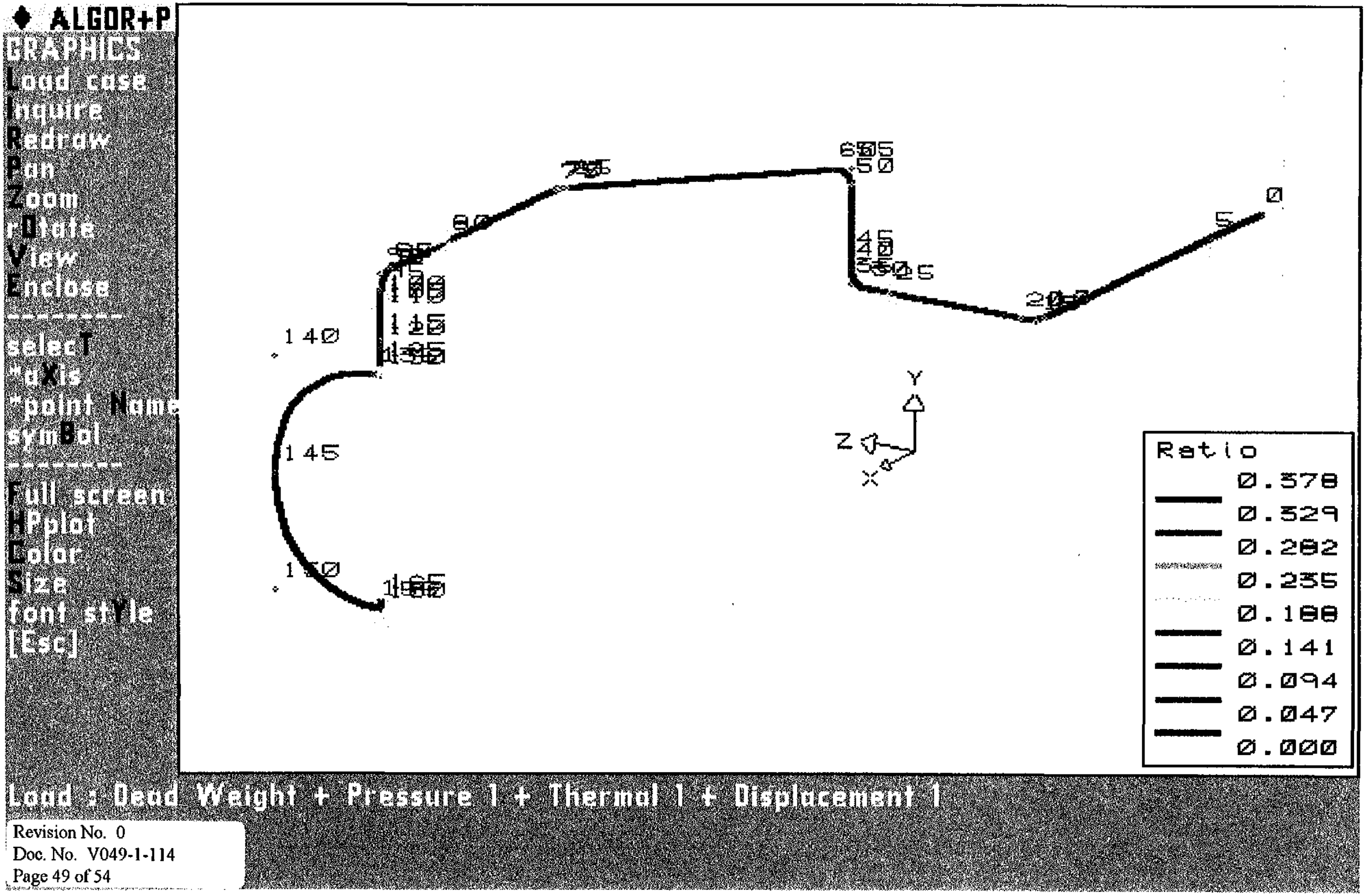
Maximum X force = 16 lb at point 25
Maximum Y force = 100 lb at point 150.Far
Maximum Z force = 25 lb at point 80

Maximum X moment = -2454 inch-lb at point 150.Far
Maximum Y moment = -798 inch-lb at point 15.Near
Maximum Z moment = -1487 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 7658 psi at point 150.Far
Maximum principal stress = 7677 psi at point 150.Far
Maximum code stress = 10847 psi at point 95
Maximum stress ratio (code/allowable) = 0.57 at point 150.Far

GN$_2$ Regen Piping

ReGasification Condition



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

*** System Maxima ***

Maximum X displacement = 0.382 inch at point 150.Far
Maximum Y displacement = -0.395 inch at point 10
Maximum Z displacement = 0.252 inch at point 140.Far

Maximum X rotation = -0.555 degree at point 0
Maximum Y rotation = 0.109 degree at point 130.Far
Maximum Z rotation = -0.303 degree at point 5

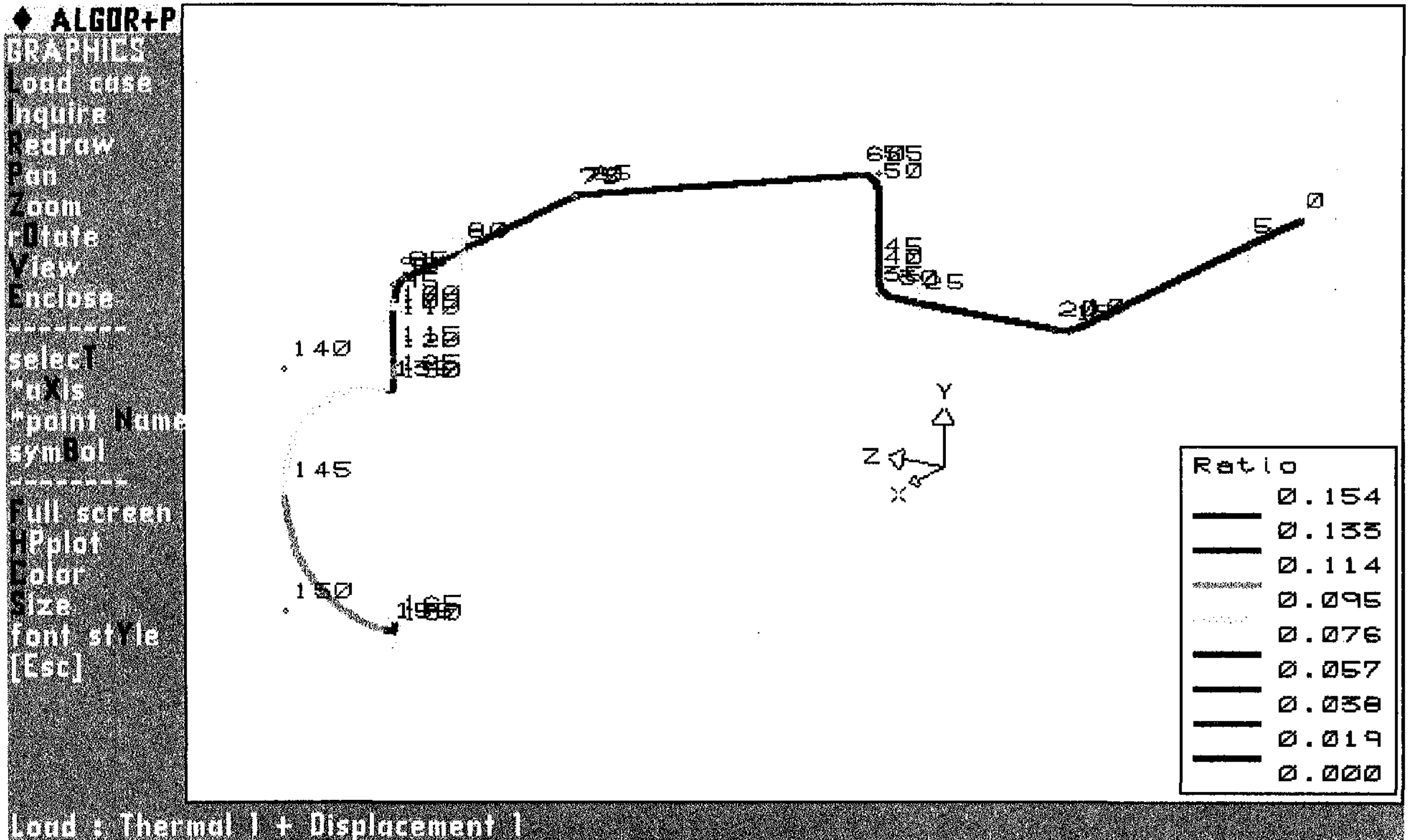
Maximum X force = 13 lb at point 5
Maximum Y force = 91 lb at point 80
Maximum Z force = 18 lb at point 80

Maximum X moment = 1884 inch-lb at point 20
Maximum Y moment = -841 inch-lb at point 10
Maximum Z moment = -1821 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 5341 psi at point 150.Far
Maximum principal stress = 5380 psi at point 150.Far
Maximum code stress = 6451 psi at point 95
Maximum stress ratio (code/allowable) = 0.38 at point 150.Far

GN_2 Regen Piping

ReGasification Condition



Load : Thermal 1 + Displacement 1

*** System Maxima ***

Maximum X displacement = 0.382 inch at point 150.Far
Maximum Y displacement = -0.091 inch at point 150.Far
Maximum Z displacement = 0.085 inch at point 70.Near

Maximum X rotation = -0.102 degree at point 130.Far
Maximum Y rotation = 0.094 degree at point 80
Maximum Z rotation = 0.056 degree at point 125

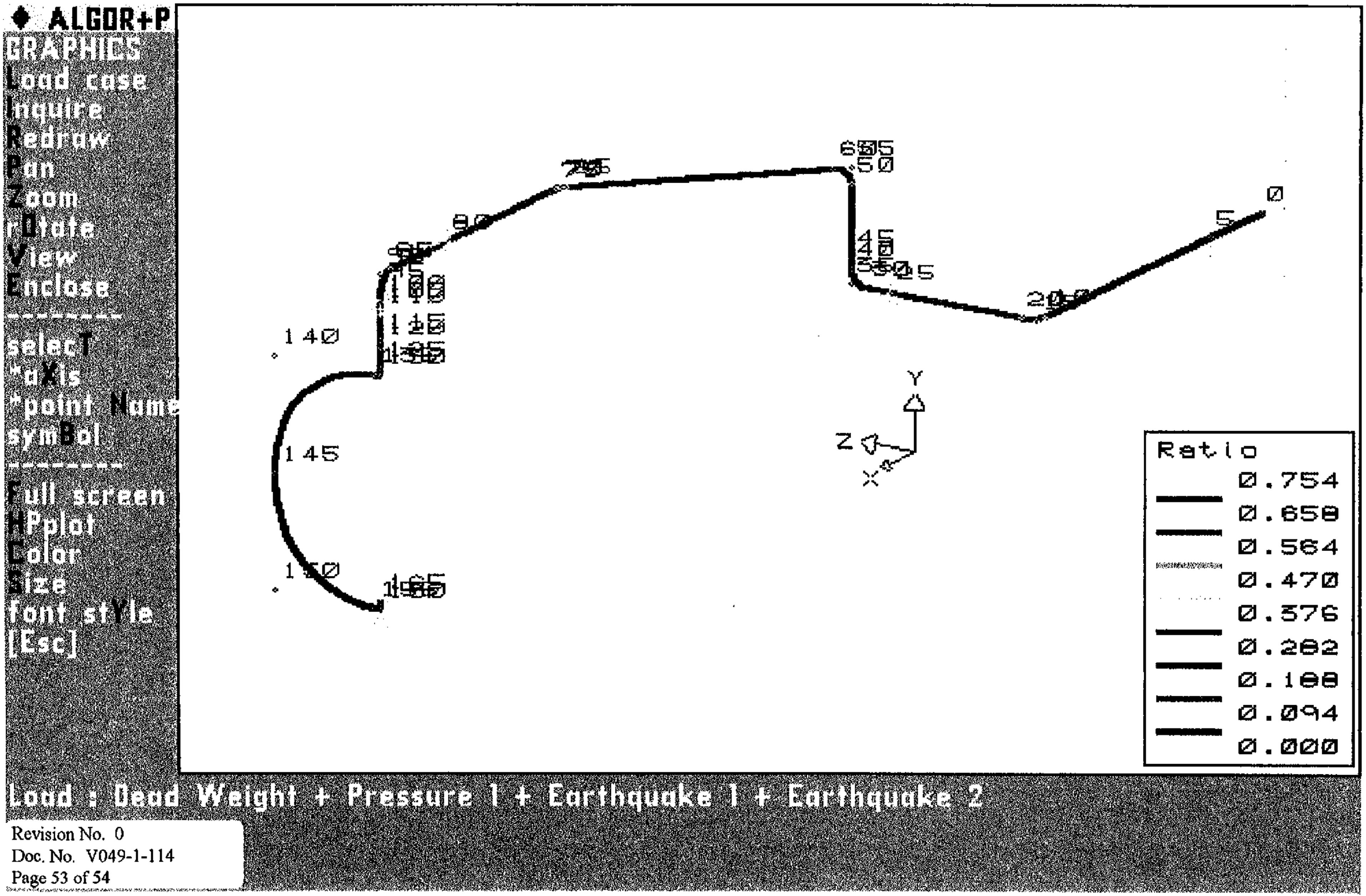
Maximum X force = 16 lb at point 5
Maximum Y force = -17 lb at point 80
Maximum Z force = 5 lb at point 25

Maximum X moment = -289 inch-lb at point 150.Far
Maximum Y moment = -401 inch-lb at point 10
Maximum Z moment = 556 inch-lb at point 80

Maximum hoop stress = 0 psi at point
Maximum longitudinal stress = 2069 psi at point 95
Maximum principal stress = 2070 psi at point 95
Maximum code stress = 2056 psi at point 95
Maximum stress ratio (code/allowable) = 0.15 at point 125

GN_2 Regen Piping

ReGasification Condition



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

*** System Maxima ***

Maximum X displacement = -0.184 inch at point 130.Far
Maximum Y displacement = -0.520 inch at point 10
Maximum Z displacement = -0.338 inch at point 55.Far

Maximum X rotation = -0.730 degree at point 0
Maximum Y rotation = -0.199 degree at point 65
Maximum Z rotation = -0.393 degree at point 5

Maximum X force = 19 lb at point 25
Maximum Y force = 110 lb at point 80
Maximum Z force = 24 lb at point 80

Maximum X moment = 1951 inch-lb at point 20
Maximum Y moment = -1171 inch-lb at point 20
Maximum Z moment = -2478 inch-lb at point 80

Maximum hoop stress = 355 psi at point 0
Maximum longitudinal stress = 6375 psi at point 95
Maximum principal stress = 6411 psi at point 95
Maximum code stress = 4978 psi at point 95
Maximum stress ratio (code/allowable) = 0.75 at point 150.Far

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1-123 PAGE 1 OF 118
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	345	11/12/96	WDB	RDC	**80K Cryopump 1-1/2" Ø GN_2 Vent Piping**	
					BY: W. Bilynsky	DEPT.: 744
PROJECT: LIGO Vacuum Equipment					PROJECT NO: V59049	

PURPOSE:

Design/analyze the 1-1/2" Ø GN_2 Vent piping for the 80K cryopumps (Long & Short). The piping will be designed to B31.1 Power Piping standards for the normal operating design conditions and the regeneration process design conditions.

METHOD:

Piping is designed to the ASME Code Standards for B31.1 Power Piping using hand calculations and the ALGOR® *PIPEPLUS* Pipe Stress computer program version 5.06-3H

ASSUMPTIONS: See calculation

INPUTS: See calculation

REFERENCES:

1. ALGOR® *PIPEPLUS* Pipe Stress Analysis and Design System (version 5.06-3H)
2. NAVCO Piping Datalog
3. Doc. No. V049-1-066 LIGO Vacuum Equipment Structural Design Criteria
4. Memorandum - Design Pressure for 80K Pump Reservoir, Doc. No. V049-1-056
5. ASME B31.1 Power Piping, 1995 Edition
6. A V049-2-037 rev.3 Specification for Piping Design and Material

CALCULATIONS:

V049-1-081 80k-Short Pump - Outer Shell Analysis
V049-1-082 80k-Long Pump - Outer Shell Analysis
V067-1-067 Analysis of Pump Reservoir

CONCLUSIONS:

The requirements of the B31.1 ASME Code for Pressure Piping and the Ligo Vacuum Equipment Structural Design Criteria are met.

NOTES: *PIPEPLUS* Computer File: GN2VENTO.* & GN2VENTR.*