STYRENE PARK OFFSITE

Document Title:

Strength Calculation-Active Carbon Filter

Please refer to comments on the related general arrangement document.

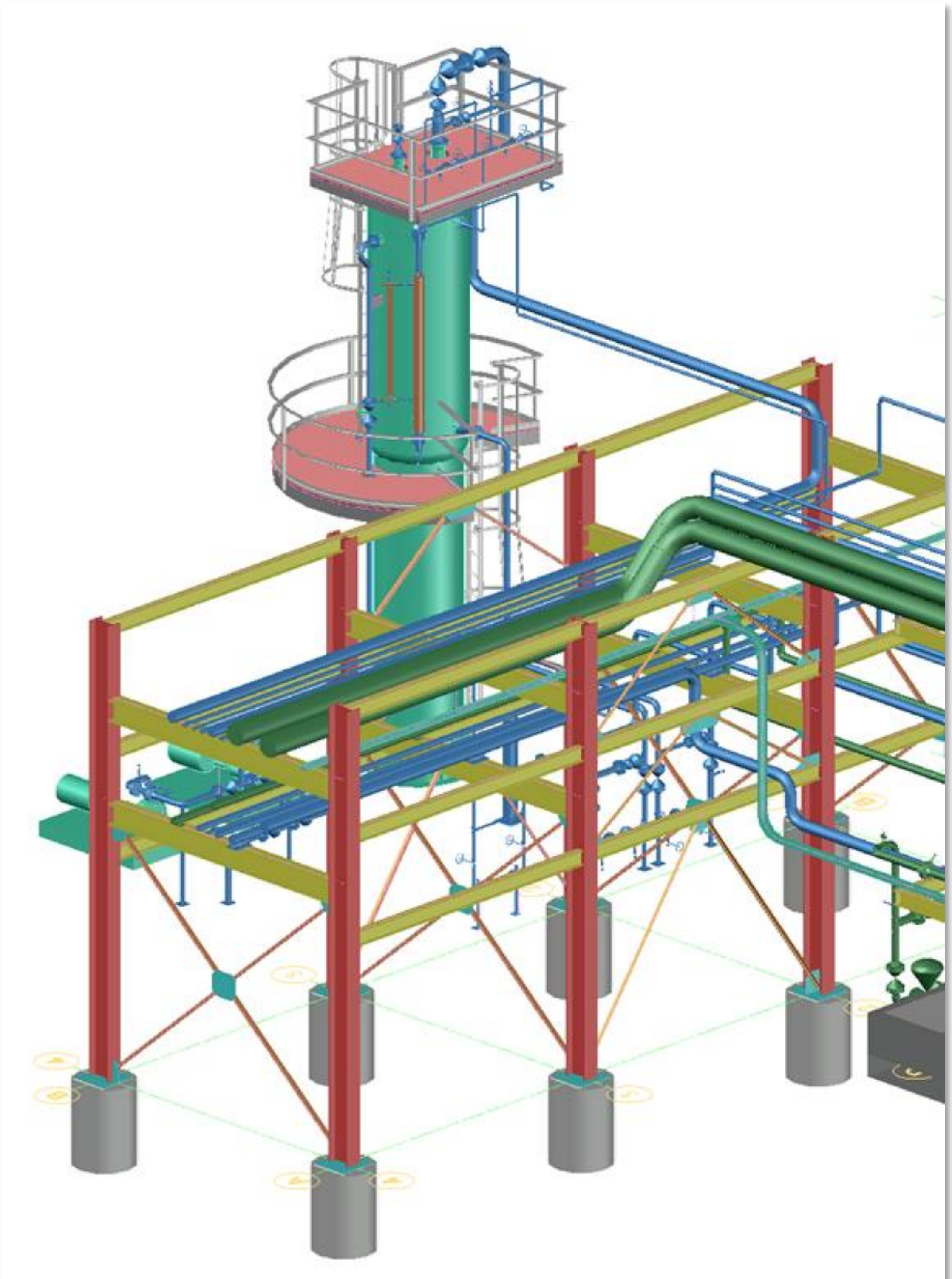
Please add one totally view of modeled vessel

See other comments on the body of document

00	2024 / Feb. / 27	Issued for Approval	A. Azodi	E. Malek	M. Shariati
Rev.	**Issued Date**	**DESCRIPTION**	**PREPARED**	**CHECKED**	**APPROVED**

Page	Revisions								Page	Revisions						
	00	01	02	03	04	05	06			00	01	02	03	04	05	06
1	x								41	x						
2	x								42	x						
3	x								43	x						
4	x								44	x						
5	x								45	x						
6	x								46	x						
7	x								47	x						
8	x								48	x						
9	x								49	x						
10	x								50	x						
11	x								51	x						
12	x								52	x						
13	x								53	x						
14	x								54	x						
15	x								55	x						
16	x								56	x						
17	x								57	x						
18	x								58	x						
19	x								59	x						
20	x								60	x						
21	x								61	x						
22	x								62	x						
23	x								63	x						
24	x								64	x						
25	x								65	x						
26	x								66	x						
27	x								67	x						
28	x								68	x						
29	x								69	x						
30	x								70	x						
31	x								71	x						
32	x								72	x						
33	x								73	x						
34	x								74	x						
35	x								75	x						
36	x								76	x						
37	x								.	x						
38	x								.	x						
39	x								.	x						
40	x								155	x						

Project Data Page:



Strength Calculation-Active Carbon Filter
Design by A. Azodi
Rev.00

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Cover Page

Strength Calculation-Active Carbon Filter
Design by A. Azodi
Rev.00

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File : C:\USERS\A.AZODI\DESKTOP\EI0127-HRC-VD-ME-CAL-00

Date of Analysis : Feb 27,2024 11:11am

PV Elite 2019 SP1, March 2019

Title Page

Note:
PV Elite performs all calculations internally in Imperial Units
to remain compliant with the ASME Code and any built in assumptions
in the ASME Code formulas. The finalized results are reflected to show
the user's set of selected units.

```
Class From To : Basic Element Checks.
==========================================================================
Note  10   20    The wind diameter multiplier is very big.
Note  20   30    The wind diameter multiplier is very big.
Note  30   40    The wind diameter multiplier is very big.
Note  40   50    The wind diameter multiplier is very big.
Note  50   60    The wind diameter multiplier is very big.
Note  60   70    The wind diameter multiplier is very big.

Class From To: Check of Additional Element Data
==========================================================================

There were no geometry errors or warnings.
```

- **PV Elite Vessel Analysis Program: Input Data**

Strength Calculation-Active Carbon Filter
Design by A. Azodi
Rev.00

Design Internal Pressure (for Hydrotest)	0.2	bars
Design Internal Temperature	85.0	°C
Type of Hydrotest	User Entered Pressure	
Hydrotest Position	Horizontal	Please recheck
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	-5.0	°C
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT-1	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

Wind Design Code	UBC-94/97	
UBC Design Wind Speed	125	Km/hr
UBC Exposure Constant	C: Open Terrain	
UBC Importance Factor	1.15	
UBC Base Elevation	0	mm.
UBC Percent Wind for Hydrotest	33.0	
Using User defined Wind Press. Vs Elev.	N	
Damping Factor (Beta) for Wind (Ope)	0.0100	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	

Seismic Design Code	ASCE/SEI 7-16

Seismic Load Reduction Scale Factor		0.714
Importance Factor		1.250
Table Value Fa		1.050
Table Value Fv		1.100
Max. Mapped Res. Acceleration	[Ss]	1.310
Max. Eff. Ground Acceleration	[S]	0.460
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.920
User Value of Sd1 (used if > 0)		0.340
Moment Reduction Factor Tau		1.000

Design Pressure + Static Head	Y
Consider MAP New and Cold in Noz. Design	N
Consider External Loads for Nozzle Des.	Y
Use ASME VIII-1 Appendix 1-9	N

Material Database Year Current w/Addenda or Code Year

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No
Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	No

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	Lower Head	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	2100	mm.
Element Thickness	4.8	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	

Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	N./mm²
Allowable Stress, Operating	137.9	N./mm²
Allowable Stress, Hydrotest	235.8	N./mm²
Material Density	0.00775	kg./cm³
P Number Thickness	30.988	mm.
Yield Stress, Operating	241.8	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	-525	mm.
Height/Length of Liquid	575	mm.
Liquid Density	0.12995E-05	kg./cm³

Element From Node	10	
Detail Type	Nozzle	
Detail ID	Drain - 3"	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	STD	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	9.7876	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	10	
Detail Type	For./Mom.	
Detail ID	Drain - 3"	
Dist. from "FROM" Node / Offset dist	-525	mm.
Force in X Direction	95.452	Kgf
Force in Y Direction	-76.28	Kgf
Force in Z Direction	95.452	Kgf
Moment about X Axis	30.182	Kg-m.
Moment about Y Axis	0	Kg-m.
Moment about Z Axis	30.182	Kg-m.
Force/Moment Combination Method	SRSS	

Element From Node	10	
Detail Type	For./Mom.	
Detail ID	Gas Inlet - 6"	
Dist. from "FROM" Node / Offset dist	50	mm.
Force in X Direction	144.4	Kgf
Force in Y Direction	-180.71	Kgf
Force in Z Direction	144.4	Kgf
Moment about X Axis	163.47	Kg-m.
Moment about Y Axis	0	Kg-m.

Moment about Z Axis	163.47	Kg-m.
Force/Moment Combination Method	SRSS	

Element From Node	10	
Detail Type	For./Mom.	
Detail ID	Utility - 2" T	
Dist. from "FROM" Node / Offset dist	50	mm.
Force in X Direction	51.805	Kgf
Force in Y Direction	-64.858	Kgf
Force in Z Direction	51.805	Kgf
Moment about X Axis	21.046	Kg-m.
Moment about Y Axis	0	Kg-m.
Moment about Z Axis	21.046	Kg-m.
Force/Moment Combination Method	SRSS	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Shell #1	
Distance "FROM" to "TO"	1200	mm.
Inside Diameter	2100	mm.
Element Thickness	8	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	8	mm.
External Corrosion Allowance	0	mm. Shall be considered
Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Packing	
Detail ID	Carbon Active	
Dist. from "FROM" Node / Offset dist	400	mm.
Height of Packed Section	800	mm.
Density	0.00045	kg./cm³
Percent Volume Holdup	0.0	
Specific Gravity of Packing Liquid	0.0	

Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.12995E-05	kg./cm³

Element From Node	20	
Detail Type	Nozzle	
Detail ID	MH1 - 24"	
Dist. from "FROM" Node / Offset dist	800	mm.

Nozzle Diameter	24	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	327.07	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Gas Inlet - 6"	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	150	
Layout Angle	75.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	101.05	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Utility - 2"	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	80	
Nozzle Class	150	
Layout Angle	105.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	5.9665	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	600	mm.
Diameter at Leg Centerline	2292	mm.
Leg Orientation	1	
Number of Legs	4	
Section Identifier	HE160B	
Length of Legs	1750	mm.

Element From Node	30	
Element To Node	40	
Element Type	Cylinder	
Description	Shell #2	
Distance "FROM" to "TO"	1500	mm.
Inside Diameter	2100	mm.
Element Thickness	6	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.

Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Weld is pre-Heated	No	

Element From Node	30	
Detail Type	Packing	
Detail ID	Carbon Active	
Dist. from "FROM" Node / Offset dist	0	mm.
Height of Packed Section	1500	mm.
Density	0.00045	kg./cm³
Percent Volume Holdup	0.0	
Specific Gravity of Packing Liquid	0.0	

Element From Node	30	
Detail Type	Liquid	
Detail ID	Liquid: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1500	mm.
Liquid Density	0.12995E-05	kg./cm³

Element From Node	30	
Detail Type	Ring	
Detail ID	Ring #1	
Dist. from "FROM" Node / Offset dist	800	mm.
Inside Diameter of Ring	2112	mm.
Thickness of Ring	6	mm.
Outside Diameter of Ring	2232	mm.
Material Name	SA-516 70	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	Shell #3	
Distance "FROM" to "TO"	1100	mm.
Inside Diameter	2100	mm.
Element Thickness	6	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	

Weld is pre-Heated	No	
Element From Node	40	
Detail Type	Packing	
Detail ID	Carbon Active	
Dist. from "FROM" Node / Offset dist	0	mm.
Height of Packed Section	1100	mm.
Density	0.00045	kg./cm³
Percent Volume Holdup	0.0	
Specific Gravity of Packing Liquid	0.0	
Element From Node	40	
Detail Type	Liquid	
Detail ID	Liquid: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1100	mm.
Liquid Density	0.0004498	kg./cm³

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description	Shell #4	
Distance "FROM" to "TO"	1500	mm.
Inside Diameter	2100	mm.
Element Thickness	6	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Weld is pre-Heated	No	
Element From Node	50	
Detail Type	Packing	
Detail ID	Carbon Active	
Dist. from "FROM" Node / Offset dist	0	mm.
Height of Packed Section	1100	mm.
Density	0.00045	kg./cm³
Percent Volume Holdup	0.0	
Specific Gravity of Packing Liquid	0.0	
Element From Node	50	
Detail Type	Liquid	
Detail ID	Liquid: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1500	mm.
Liquid Density	0.12995E-05	kg./cm³
Element From Node	50	

Detail Type	Ring	
Detail ID	Ring #2	
Dist. from "FROM" Node / Offset dist	500	mm.
Inside Diameter of Ring	2112	mm.
Thickness of Ring	6	mm.
Outside Diameter of Ring	2232	mm.
Material Name	SA-516 70	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	50	
Detail Type	Nozzle	
Detail ID	Gas Outlet - 6"	
Dist. from "FROM" Node / Offset dist	1300	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	STD	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	26.179	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	50	
Detail Type	For./Mom.	
Detail ID	Gas Outlet - 6"	
Dist. from "FROM" Node / Offset dist	1300	mm.
Force in X Direction	144.4	Kgf
Force in Y Direction	-180.71	Kgf
Force in Z Direction	144.4	Kgf
Moment about X Axis	136.23	Kg-m.
Moment about Y Axis	0	Kg-m.
Moment about Z Axis	136.23	Kg-m.
Force/Moment Combination Method	SRSS	

Element From Node	60	
Element To Node	70	
Element Type	Elliptical	
Description	Upper Head	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	2100	mm.
Element Thickness	4.8	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	6	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.2	bars
Design Temperature Internal Pressure	85	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	85	°C
Effective Diameter Multiplier	1.6	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	60	
Detail Type	Platform	
Detail ID	TOP PLATFORM	
Dist. from "FROM" Node / Offset dist	750	mm.
Platform Start Angle (degrees)	0.0	
Platform End Angle (degrees)	0.0	
Platform Wind Area	35750	cm^2
Platform Weight	853.62	Kgf
Platform Railing Weight	0.003	Kgf/mm.
Platform Grating Weight	0.015	Kgs/cm^2
Platform Width	2200	mm.
Platform Height	1100	mm.
Platform Clearance or End Offset	1250	mm.
Platform Force Coefficient	1.3	
Ladder Layout Angle	0.0	
Ladder Start Elevation	0	mm.
Ladder End Elevation	0	mm.
Unit Weight of Ladder	0	Kgf/mm.
Platform Length (top head platform)	2500	mm.

Element From Node	60	
Detail Type	Platform	
Detail ID	TOP LADDER	
Dist. from "FROM" Node / Offset dist	1700	mm.
Platform Start Angle (degrees)	0.0	
Platform End Angle (degrees)	0.0	
Platform Wind Area	0	cm^2
Platform Weight	244.5	Kgf
Platform Railing Weight	0	Kgf/mm.
Platform Grating Weight	0	Kgs/cm^2
Platform Width	0	mm.
Platform Height	0	mm.
Platform Clearance or End Offset	0	mm.
Platform Force Coefficient	1.3	
Ladder Layout Angle	0.0	
Ladder Start Elevation	0	mm.
Ladder End Elevation	8150	mm.
Unit Weight of Ladder	0.03	Kgf/mm.
Platform Length (top head platform)	0	mm.

Element From Node	60	
Detail Type	Liquid	
Detail ID	Liquid: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	575	mm.
Liquid Density	0.12995E-05	$kg./cm^3$

Element From Node	60	
Detail Type	Nozzle	
Detail ID	MH2 - 24"	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	24	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	Y	

Weight of Nozzle (Used if > 0)	347.24	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	

Element From Node	60	
Detail Type	Nozzle	
Detail ID	PSV - 2"	
Dist. from "FROM" Node / Offset dist	750	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	80	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	8.2712	Kgf
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	60	
Detail Type	For./Mom.	
Detail ID	PSV - 2"	
Dist. from "FROM" Node / Offset dist	400	mm.
Force in X Direction	64.858	Kgf
Force in Y Direction	-51.805	Kgf
Force in Z Direction	64.858	Kgf
Moment about X Axis	13.868	Kg-m.
Moment about Y Axis	0	Kg-m.
Moment about Z Axis	13.868	Kg-m.
Force/Moment Combination Method	SRSS	

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Lower Head		...	50	...	50
Shell #1		...	1250	...	1200
Shell #2		...	2750	...	1500
Shell #3		...	3850	...	1100
Shell #4		...	5350	...	1500
Upper Head		...	5400	...	50

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
Lower Head		0.2492	6	3	2100	117.21
Shell #1		0.2491	8	3	2100	117.21
Shell #2		0.249	6	3	2100	117.21
Shell #3		0.2488	6	3	2100	117.21
Shell #4		0.2003	6	3	2100	117.21
Upper Head		0.2001	6	3	2100	117.21

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
Lower Head		0.2	1.56359	5.35564	4.8	4.5
Shell #1		0.2	5.5005	8.88951	8	4.5
Shell #2		0.2	3.28459	6.67473	6	4.5
Shell #3		0.2	3.28478	6.67473	6	4.5
Shell #4		0.2	3.3333	6.67473	6	4.5
Upper Head		0.2	1.61272	5.35564	4.8	4.5
Minimum			1.564	5.356		

MAWP: 1.564 bars, limited by: Lower Head.

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 85 °C

Lower Head

Material UNS Number: K02700

Appendix 1-4(f) was also used in determining the required thickness of this head. The required thickness for this geometry is shown below. The required thickness is determined by iteration.

Required thickness per Appendix 1-4(f) : 0.586 mm.
The value of ts/L : 0.000951

Appendix 1-4(f) does not govern the design of this head.

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (0.249*2106.0*0.996)/(2*137.9*0.85-0.2*0.249)
= 0.2230 + 3.0000 = 3.2230 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.049 bars
```
 = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
 = (2*137.9*0.85*1.8)/(0.996*2106.0+0.2*1.8)
 = 1.613 - 0.049 = 1.564  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
 = (2*137.9*0.85*4.8)/(1.0*2100.0+0.2*4.8)
 = 5.356 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(Kcor*D+0.2*t))/(2*E*t)
 = (0.249*(0.996*2106.0+0.2*1.8))/(2*0.85*1.8)
 = 17.090 N./mm²
```

Straight Flange Required Thickness:
```
 = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
 = (0.249*1053.0)/(137.9*0.85-0.6*0.249)+3.0
 = 3.224 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.049 bars
```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9 * 0.85 * 3.0)/(1053.0 + 0.6 * 3.0 )
 = 3.334 - 0.049 = 3.284  bars
```

Factor K, corroded condition [Kcor]:
```
 = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^(2))/6
 = ( 2 + ( 2106.0/( 2 * 528.0 ))^(2))/6
 = 0.996217
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 1.250 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 4.8, tr = 1.5, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.708, Temp. Reduction = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -45 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 6.0, tr = 1.45, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.411, Temp. Reduction = 48 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
```

<u>Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 85 °C</u>

Shell #1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (0.249*1053.0)/(137.9*0.85-0.6*0.249)
= 0.2238 + 3.0000 = 3.2238 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.049 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*5.0)/(1053.0+0.6*5.0)
= 5.550 - 0.049 = 5.501 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*8.0)/(1050.0+0.6*8.0)
= 8.890 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (0.249*(1053.0+0.6*5.0))/(0.85*5.0)
= 6.190 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.380 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 8.0, tr = 1.5, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.255, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Cylindrical Shell From 30 To 40 SA-516 70 , UCS-66 Crv. B at 85 °C

Shell #2

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (0.249*1053.0)/(137.9*0.85-0.6*0.249)
= 0.2237 + 3.0000 = 3.2237 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.049 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*3.0)/(1053.0+0.6*3.0)
= 3.334 - 0.049 = 3.285 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9*0.85*6.0)/(1050.0+0.6*6.0)
 = 6.675 bars

Actual stress at given pressure and thickness, corroded [Sact]:
 = (P*(R+0.6*t))/(E*t)
 = (0.249*(1053.0+0.6*3.0))/(0.85*3.0)
 = 10.299 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.285 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 6.0, tr = 1.5, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.425, Temp. Reduction = 45 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. B at 85 °C

Shell #3

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
 = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
 = (0.249*1053.0)/(137.9*0.85-0.6*0.249)
 = 0.2235 + 3.0000 = 3.2235 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.049 bars
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9*0.85*3.0)/(1053.0+0.6*3.0)
 = 3.334 - 0.049 = 3.285 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9*0.85*6.0)/(1050.0+0.6*6.0)
 = 6.675 bars

Actual stress at given pressure and thickness, corroded [Sact]:
 = (P*(R+0.6*t))/(E*t)
 = (0.249*(1053.0+0.6*3.0))/(0.85*3.0)
 = 10.291 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.285 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 6.0, tr = 1.5, c = 3.0 mm., E* = 0.85

Thickness Ratio = tr * (E*)/(tg - c) = 0.425, Temp. Reduction = 45 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

Cylindrical Shell From 50 To 60 SA-516 70 , UCS-66 Crv. B at 85 °C

Shell #4

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
 = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
 = (0.2*1053.0)/(137.9*0.85-0.6*0.2)
 = 0.1799 + 3.0000 = 3.1799 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.000 bars

```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9*0.85*3.0)/(1053.0+0.6*3.0)
 = 3.334 - 0.000 = 3.333  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9*0.85*6.0)/(1050.0+0.6*6.0)
 = 6.675 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
 = (P*(R+0.6*t))/(E*t)
 = (0.2*(1053.0+0.6*3.0))/(0.85*3.0)
 = 8.284 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 0.285 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 6.0, tr = 1.5, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.425, Temp. Reduction = 45 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

Elliptical Head From 60 To 70 SA-516 70 , UCS-66 Crv. B at 85 °C

Upper Head

Material UNS Number: K02700

Appendix 1-4(f) was also used in determining the required thickness of this head. The required thickness for this geometry is shown below. The required thickness is determined by iteration.

Required thickness per Appendix 1-4(f) : 0.529 mm.
The value of ts/L : 0.000951

Appendix 1-4(f) does not govern the design of this head.

Required Thickness due to Internal Pressure [tr]:
```
 = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
 = (0.2*2106.0*0.996)/(2*137.9*0.85-0.2*0.2)
 = 0.1791 + 3.0000 = 3.1791 mm.
```

Note: The thickness required was less than the Code Minimum, therefore
the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.000 bars
```
 = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
 = (2*137.9*0.85*1.8)/(0.996*2106.0+0.2*1.8)
 = 1.613 - 0.000 = 1.613  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
 = (2*137.9*0.85*4.8)/(1.0*2100.0+0.2*4.8)
 = 5.356 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(Kcor*D+0.2*t))/(2*E*t)
 = (0.2*(0.996*2106.0+0.2*1.8))/(2*0.85*1.8)
 = 13.720 N./mm²
```

Straight Flange Required Thickness:
```
 = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
 = (0.2*1053.0)/(137.9*0.85-0.6*0.2)+3.0
 = 3.180 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.000 bars
```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9 * 0.85 * 3.0)/(1053.0 + 0.6 * 3.0 )
 = 3.334 - 0.000 = 3.334  bars
```

Factor K, corroded condition [Kcor]:
```
 = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^(2))/6
 = ( 2 + ( 2106.0/( 2 * 528.0 ))^(2))/6
 = 0.996217
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 1.250 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 4.8, tr = 1.5, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.708, Temp. Reduction = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -45 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 6.0, tr = 1.406, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.398, Temp. Reduction = 51 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
```

Note: Heads and Shells Exempted to -20F (-29C) by paragraph UG-20F

Hydrostatic Test Pressure Results:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S         2.033  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S      0.260  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)      6.756  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S         1.720  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    0.286  bars
Pressure per App 27-4  = M.A.W.P.                       1.564  bars
User Defined Hydrostatic Test Pressure at High Point    2.468  bars
```

Horizontal Test performed per: User Hydro Pressure

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure (N./mm² & bars):

From To	Stress	Allowable	Ratio	Pressure
Lower Head	183.4	235.8	0.778	2.67
Shell #1	66.4	235.8	0.282	2.67
Shell #2	110.6	235.8	0.469	2.67
Shell #3	110.6	235.8	0.469	2.67
Shell #4	110.6	235.8	0.469	2.67
Upper Head	183.4	235.8	0.778	2.67

Stress ratios for Nozzle and Pad Materials (N./mm²):

Description	Pad/Nozzle	Ambient	Operating	Ratio
Drain - 3"	Nozzle	117.90	117.90	1.000
Drain - 3"	Pad	137.90	137.90	1.000
MH1 - 24"	Nozzle	137.90	137.90	1.000
Gas Inlet - 6"	Nozzle	117.90	117.90	1.000
Utility - 2"	Nozzle	117.90	117.90	1.000
Gas Outlet - 6"	Nozzle	117.90	117.90	1.000
Gas Outlet - 6"	Pad	137.90	137.90	1.000
MH2 - 24"	Nozzle	137.90	137.90	1.000
MH2 - 24"	Pad	137.90	137.90	1.000
PSV - 2"	Nozzle	117.90	117.90	1.000
PSV - 2"	Pad	137.90	137.90	1.000

Minimum 1.000

Stress ratios for Stiffening Ring Materials (N./mm²):

Description	Ambient	Operating	Ratio
Ring #1	137.90	137.90	1.000
Ring #2	137.90	137.90	1.000

Minimum 1.000

Stress ratios for Pressurized Vessel Elements (N./mm²):

Description	Ambient	Operating	Ratio
Lower Head	137.90	137.90	1.000
Shell #1	137.90	137.90	1.000
Shell #2	137.90	137.90	1.000
Shell #3	137.90	137.90	1.000
Shell #4	137.90	137.90	1.000
Upper Head	137.90	137.90	1.000

Minimum 1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm²):

Description	Ambient	Operating	Ratio
Drain - 3"	6.49	217.19	0.030
MH1 - 24"	40.64	235.81	0.172
Gas Inlet - 6"	3.30	217.19	0.015
Utility - 2"	4.26	217.19	0.020
Gas Outlet - 6"	6.87	217.19	0.032
MH2 - 24"	40.64	235.81	0.172
PSV - 2"	4.26	217.19	0.020

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	20	No Calc	2109.6	1.8	0.00011851	11.8479
20	30	2225	2116	5	0.00014515	14.5112
30	Ring	2225	2112	3	0.67961E-04	6.79459
Ring	40	2300	2112	3	0.65695E-04	6.56798
40	50	2300	2112	3	0.65695E-04	6.56798
50	Ring	2300	2112	3	0.65695E-04	6.56798
Ring	60	1225	2112	3	0.00012544	12.5416
60	70	No Calc	2109.6	1.8	0.00011851	11.8479

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	4.8	4.69848	0.1	0.11232
20	30	8	5.72741	0.1	0.45716
30	Ring	6	5.72418	0.1	0.12868
Ring	40	6	5.75833	0.1	0.12439
40	50	6	5.75833	0.1	0.12439
50	Ring	6	5.75833	0.1	0.12439
Ring	60	6	5.14039	0.1	0.23752
60	70	4.8	4.69848	0.1	0.11232

Minimum 0.112

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	2225	9649.79	No Calc	No Calc
30	Ring	2225	2844.52	No Calc	No Calc
Ring	40	2300	2844.83	14.6246	25.8886
40	50	2300	2844.83	No Calc	No Calc
50	Ring	2300	2844.83	No Calc	No Calc
Ring	60	1225	2844.94	11.4279	25.8886
60	70	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 85 °C

Lower Head

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
1.800	2109.60	1172.00	0.0001185	11.85

EMAP = B/(K0*D/t) = 11.8479/(0.9 *1172.0) = 0.1123 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.698	2109.60	1242.05	0.0001118	11.18

EMAP = B/(K0*D/t) = 11.1797/(0.9 *1242.05) = 0.1 bars

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

Appendix 1-4(f) was also used in determining the required thickness of this head. The required thickness for this geometry is shown below. The required thickness is determined by iteration.

Required thickness per Appendix 1-4(f) : 0.487 mm.
The value of ts/L : 0.000951

Appendix 1-4(f) does not govern the design of this head.

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (0.167*2106.0*0.996)/(2*137.9*1.0-0.2*0.167)
= 0.1270 + 3.0000 = 3.1270 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*137.9*1.0*1.8)/(0.996*2106.0+0.2*1.8))/1.67
= 0.966 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(0.11, 0.9657)
= 0.112 bars

Thickness requirements per UG-33(a)(1) do not govern the required thickness of this head.

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 85 °C

Shell #1

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.000	2116.00	2225.00	423.20	1.0515	0.0001451	14.51

EMAP = (4*B)/(3*(D/t)) = (4*14.5112)/(3*423.2) = 0.4572 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.727	2116.00	2225.00	775.83	1.0515	0.0000582	5.82

EMAP = (4*B)/(3*(D/t)) = (4*5.8192)/(3*775.8268) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.000	2116.00	9649.79	423.20	4.5604	0.0000318	3.18

EMAP = (4*B)/(3*(D/t)) = (4*3.1756)/(3*423.2) = 0.1 bars

Cylindrical Shell From 30 to Ring #1 Ext. Chart: CS-2 at 85 °C

Shell #2

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2225.00	704.00	1.0535	0.0000680	6.79

EMAP = (4*B)/(3*(D/t)) = (4*6.7946)/(3*704.0) = 0.1287 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.724	2112.00	2225.00	775.28	1.0535	0.0000582	5.82

EMAP = (4*B)/(3*(D/t)) = (4*5.8151)/(3*775.2779) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2844.52	704.00	1.3468	0.0000529	5.28

EMAP = (4*B)/(3*(D/t)) = (4*5.2846)/(3*704.0) = 0.1001 bars

Cylindrical Shell From Ring #1 to 40 Ext. Chart: CS-2 at 85 °C

Shell #2

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2300.00	704.00	1.0890	0.0000657	6.57

EMAP = (4*B)/(3*(D/t)) = (4*6.568)/(3*704.0) = 0.1244 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.758	2112.00	2300.00	765.68	1.0890	0.0000574	5.74

EMAP = (4*B)/(3*(D/t)) = (4*5.7431)/(3*765.6818) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2844.83	704.00	1.3470	0.0000529	5.28

EMAP = (4*B)/(3*(D/t)) = (4*5.284)/(3*704.0) = 0.1001 bars

Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 85 °C

Shell #3

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2300.00	704.00	1.0890	0.0000657	6.57

EMAP = (4*B)/(3*(D/t)) = (4*6.568)/(3*704.0) = 0.1244 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.758	2112.00	2300.00	765.68	1.0890	0.0000574	5.74

EMAP = (4*B)/(3*(D/t)) = (4*5.7431)/(3*765.6818) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2844.83	704.00	1.3470	0.0000529	5.28

EMAP = (4*B)/(3*(D/t)) = (4*5.284)/(3*704.0) = 0.1001 bars

Cylindrical Shell From 50 to Ring #2 Ext. Chart: CS-2 at 85 °C

Shell #4

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2300.00	704.00	1.0890	0.0000657	6.57

EMAP = (4*B)/(3*(D/t)) = (4*6.568)/(3*704.0) = 0.1244 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.758	2112.00	2300.00	765.68	1.0890	0.0000574	5.74

EMAP = (4*B)/(3*(D/t)) = (4*5.7431)/(3*765.6818) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	2844.83	704.00	1.3470	0.0000529	5.28

EMAP = (4*B)/(3*(D/t)) = (4*5.284)/(3*704.0) = 0.1001 bars

Cylindrical Shell From Ring #2 to 60 Ext. Chart: CS-2 at 85 °C

Shell #4

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	2112.00	1225.00	704.00	0.5800	0.0001254	12.54

EMAP = (4*B)/(3*(D/t)) = (4*12.5416)/(3*704.0) = 0.2375 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.140	2112.00	1225.00	986.74	0.5800	0.0000740	7.40

EMAP = (4*B)/(3*(D/t)) = (4*7.4012)/(3*986.735) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B

```
  3.000    2112.00     2844.94    704.00    1.3470  0.0000529     5.28
EMAP = (4*B)/(3*(D/t)) = (4*5.2838)/(3*704.0) = 0.1001 bars
```

Elliptical Head From 60 to 70 Ext. Chart: CS-2 at 85 °C

Upper Head

Elastic Modulus from Chart: CS-2 at 85 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

```
    Tca         OD          D/t     Factor A           B
  1.800    2109.60     1172.00   0.0001185       11.85
EMAP = B/(K0*D/t) = 11.8479/( 0.9 *1172.0 ) = 0.1123 bars
```

Results for Required Thickness (Tca):

```
    Tca         OD          D/t     Factor A           B
  1.698    2109.60     1242.05   0.0001118       11.18
EMAP = B/(K0*D/t) = 11.1797/( 0.9 *1242.05 ) = 0.1 bars
```

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

Appendix 1-4(f) was also used in determining the required thickness of this head. The required thickness for this geometry is shown below. The required thickness is determined by iteration.

```
Required thickness per Appendix 1-4(f) :  0.487 mm.
The value of ts/L                      :  0.000951
```

Appendix 1-4(f) does not govern the design of this head.

Required Thickness due to Internal Pressure [tr]:

```
 = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
 = (0.167*2106.0*0.996)/(2*137.9*1.0-0.2*0.167)
 = 0.1270 + 3.0000 = 3.1270 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
 = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
 = ((2*137.9*1.0*1.8)/(0.996*2106.0+0.2*1.8))/1.67
 = 0.966 bars
```

Maximum Allowable External Pressure [MAEP]:

```
 = min( MAEP, MAWP )
 = min( 0.11, 0.9657 )
 = 0.112 bars
```

Thickness requirements per UG-33(a)(1) do not govern the required thickness of this head.

Stiffening Ring Calcs for : Ring #1 , SA-516 70 , Bar Ring: 60 x 6 mm.

```
Effective Length of Shell:                                    88 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
```

Shell:	2.627	1.5000	3.940
Ring :	3.600	33.0000	118.800
Total:	6.227		122.740

Centroid of Ring plus Shell: 20 mm.

	Inertia	Distance	A*Dist²
Shell:	0.020	18.2117	871.210
Ring :	10.800	-13.2883	635.685
Total:	10.820		1506.895

Available Moment of Inertia, Ring plus Shell: 26 cm**4

Required Stress in Ring plus Shell Breq 5.01 N./mm²
Required Strain in Ring plus Shell Areq 0.0000500

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (2112.0002²*2262.4998(3.0+3.6/2262.4998)0.00005)/10.9
= 15 cm**4

Results for Stiffening Ring Weld Calculations per UG-30:

Given Stiffening Ring Fillet Weld Size	Wleg	5.000	mm.
Stiffening Ring Attachment Style		INTERMITTENT	
Location of Stiffening Ring		EXTERNAL	
Radial Pressure Load	Pext*Slen	2.31	Kgf/mm.
The Radial Shear Load	V	48.73	Kgf
The First Moment of the Area (Ring + Shell)	Q	4783.79	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.90	Kgf/mm.
The Weld Allowable Stress	0.55*S	75.85	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
Maximum Space between Welds 8*TCA		50.80	mm.
The Weld Allowable Load	WLeg*0.55*S	38.67	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	2.48	Kgf/mm.

Stiffening Ring Calcs for : Ring #2 , SA-516 70 , Bar Ring: 60 x 6 mm.

Effective Length of Shell: 88 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.627	1.5000	3.940
Ring :	3.600	33.0000	118.800
Total:	6.227		122.740

Centroid of Ring plus Shell: 20 mm.

	Inertia	Distance	A*Dist²
Shell:	0.020	18.2117	871.210
Ring :	10.800	-13.2883	635.685
Total:	10.820		1506.895

Available Moment of Inertia, Ring plus Shell: 26 cm**4

```
Required Stress in Ring plus Shell      Breq        4.94 N./mm²
Required Strain in Ring plus Shell      Areq   0.0000494
```

Required Moment of Inertia, Ring plus Shell:

```
 = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
 = (2112.0002²*1762.5(3.0+3.6/1762.5)0.000049)/10.9
 = 11 cm**4
```

Results for Stiffening Ring Weld Calculations per UG-30:

```
Given Stiffening Ring Fillet Weld Size         Wleg     5.000  mm.
Stiffening Ring Attachment Style                 INTERMITTENT
Location of Stiffening Ring                          EXTERNAL
Radial Pressure Load                      Pext*Slen      1.80  Kgf/mm.
The Radial Shear Load                             V     37.96  Kgf
The First Moment of the Area ( Ring + Shell )     Q   4783.79  mm.³
Weld Shear Flow due to Rad. Shear Load         VQ/I      0.70  Kgf/mm.
The Weld Allowable Stress                    0.55*S     75.85  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
Maximum Space between Welds  8*TCA                      50.80  mm.
The Weld Allowable Load                 WLeg*0.55*S     38.67  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      1.93  Kgf/mm.
```

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	262.237	1385690	131.118	1397104	26.2237
20	30	492.741	4157072	308.401	4180861	49.2741
30	40	461.511	5196340	231.083	5226076	46.1511
40	50	338.441	3810649	169.46	3832456	33.8441
50	60	461.511	5196340	231.083	5226076	46.1511
60	70	262.237	1385690	131.118	1397104	26.2237
Total		2278	21131784.00	1202	21259678.00	227

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	1.8003	...	-262.5	Liquid: 10
10	Nozl	10.7663	...	-650.006	Drain - 3"
10	Forc	...	...	-525	Drain - 3"
10	Forc	...	...	50	Gas Inlet - 6"
10	Forc	...	...	50	Utility - 2" T
20	Pack	1246.8	...	800	Carbon Active
20	Liqd	5.40089	...	600	Liquid: 20
20	Nozl	359.779	1354.8	800	MH1 - 24"
20	Nozl	111.158	1134.14	200	Gas Inlet - 6"
20	Nozl	6.56314	1080.16	200	Utility - 2"
20	Legs	710.026	...	-275	LEGS
30	Pack	2337.75	...	750	Carbon Active
30	Liqd	6.75111	...	750	Liquid: 30
30	Ring	20.9428	...	800	Ring #1
40	Pack	1714.35	...	550	Carbon Active
40	Liqd	1713.75	...	550	Liquid: 40
50	Pack	1714.35	...	550	Carbon Active
50	Liqd	6.75111	...	750	Liquid: 50
50	Ring	20.9428	...	500	Ring #2
50	Nozl	28.7971	1134.14	1300	Gas Outlet - 6"
50	Forc	...	...	1300	Gas Outlet - 6"
60	Plat	938.986	...	750	TOP PLATFORM
60	Plat	268.95	...	1700	TOP LADDER
60	Liqd	1.80029	...	312.5	Liquid: 60
60	Nozl	381.965	...	700.006	MH2 - 24"
60	Nozl	9.09828	-750	617.423	PSV - 2"
60	Forc	...	...	400	PSV - 2"

Total Weight of Each Detail Type:

Platforms	1207.9
Packing	7013.2
Liquid	1736.3
Stiffeners	41.9

Nozzles	908.1
Legs	710.0
Sum of the Detail Weights	11617.5 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating	
Main Elements	2506.5	2506.5	2506.5	2506.5	2506.5	2506.5	
Stif. Rings	41.9	41.9	41.9	41.9	41.9	41.9	
Nozzles	908.1	908.1	908.1	908.1	908.1	908.1	
Legs	710.0	710.0	710.0	710.0	710.0	710.0	
Platforms	...	...	...	...	1207.9	1207.9	*
Packing	...	...	...	...	7013.2	7013.2	*
Ope. Liquid	...	...	...	...	...	1736.3	
Test Liquid	...	21118.9	...	...	...	...	
Totals	4166.6	25285.5	4166.6	4166.6	12387.8	14124.0	

Field Installation Options:
* Platforms installed after lifting.
* Packing installed after lifting.

Miscellaneous Weight Percent: 10.0 %

Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	4166.6 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	25285.5 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	4166.6 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	4166.6 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	12387.8 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	14124.0 kg.
Field Test Wt.	- Empty Weight + Water (Full)	25437.2 kg.
Mass of the Upper 1/3 of the Vertical Vessel		4591.5 kg.

Note: The Field Test weight as computed in the corroded condition.

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	51669.2
20	30	79771.3
30	40	99525.7
40	50	72985.5
50	60	99525.7
60	70	51669.2

Total 455146.469 cm^2

Element and Detail Weights:

From	To To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. Kg-m.	Oper. Wgt. No Liquid kg.
10	20	299.227	301.027	1551.25	...	299.227
20	Legs	509.758	1135.86	2497.53	310.3	1133.16
Legs	30	509.758	1135.86	2497.53	310.3	1133.16
30	40	528.605	2873.11	5498.02	...	2866.35
40	50	372.285	3800.38	4016.52	...	2086.63
50	60	557.402	2278.5	5526.82	32.6605	2271.75
60	70	679.524	1889.26	3139.48	6.82384	1887.46

```
Empty Support Force + the Sum of the Y forces          4010.91  Kgf
Operating Support Force + the Sum of the Y forces     13968.35  Kgf
Hydro Support Force + the Sum of the Y forces         25281.50  Kgf
```

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	...	...	...
20	Legs	-299.227	-301.027	-1551.25
Legs	30	10245.4	11977.1	20678.4
30	40	9112.2	10841.3	18180.8
40	50	6245.85	7968.15	12682.8
50	60	4159.21	4167.76	8666.3
60	70	1887.46	1889.26	3139.48

Note: The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. Kg-m.	Cumulative Oper. Mom. Kg-m.	Cumulative Hydro. Mom. Kg-m.
10	20	...	...	...
20	Legs	310.3	310.3	310.3
Legs	30	349.784	349.784	349.784
30	40	39.4844	39.4844	39.4844
40	50	39.4844	39.4844	39.4844
50	60	39.4844	39.4844	39.4844
60	70	6.82384	6.82384	6.82384

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Flange Rating Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV bars
Drain - 3"	18.15	19.60	85	150	GR 1.1	...	...	...	...
MH1 - 24"	18.15	19.60	85	150	GR 1.1	...	...	...	...
Gas Inlet - 6"	18.15	19.60	85	150	GR 1.1	...	...	...	...
Utility - 2"	18.15	19.60	85	150	GR 1.1	...	...	...	...
Gas Outlet - 6	18.15	19.60	85	150	GR 1.1	...	...	...	...
MH2 - 24"	18.15	19.60	85	150	GR 1.1	...	...	...	...
PSV - 2"	18.15	19.60	85	150	GR 1.1	...	...	...	...
Min Rating	18.150	19.600 bars [for Core Elements]					0.000	0.000	0.000

Selected Method for Derating ANSI B16.5 Flange MAWP: None Selected

ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

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The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/ eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 11.5661 Hz.

The Natural Frequency for the Vessel (Ope...) is 10.8749 Hz.

Forces/Moments Applied to Vessel (Combined w/Wind Loads)

From	To	X and Z Dir Force Res. Kgf	X,Z Moment and For Res Kg-m.
10	20	412.467	381.255
20	30	...	...
30	40	...	...
40	50	...	...
50	60	204.214	458.139
60	70	91.7234	56.3017

Forces/Moments Applied to Vessel (Combined w/Seismic Loads)

From	To	X and Z Dir Force Res. Kgf	X,Z Moment and For Res Kg-m.
10	20	412.467	381.255
20	30	...	...
30	40	...	...
40	50	...	...
50	60	204.214	458.139
60	70	91.7234	56.3017

User Input Forces and Moments:

From Node	Distance From	Forces Fx	Fy	Fz	Moments Mx	My	Mz
10	-525.00	95.	-76.	95.	30.		30.
10	50.00	144.	-181.	144.	163.		163.
10	50.00	52.	-65.	52.	21.		21.
50	1300.00	144.	-181.	144.	136.		136.
60	400.00	65.	-52.	65.	14.		14.

Wind Analysis Results per UBC 1994 or UBC 1997

```
Importance Factor as Entered by the User is          1.150
Wind Stagnation Pressure (qs) from Table 16-F       75.6      Kgs/m²
Pressure Coefficient from Table 16-H             Cq 0.800
User Entered Basic Wind Speed                        125.0       Km/hr
```

P(height) = Ce(height,Exp) * Cq * qs * Imp Fact. [18-1](1994) or [20-1](1997)

The values of Ce are shown as the in the table below:

Element	Ce
Lower Head	1.0600
Shell #1	1.0600
Shell #2	1.0600
Shell #3	1.0600
Shell #4	1.0853
Upper Head	1.1288

Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

Nomenclature

```
Cf  - Correction factor for natural frequency
 D  - Average internal diameter of vessel mm.
Df  - Damping Factor < 0.75 Unstable,  > 0.95 Stable
Dr  - Average internal diameter of top half of vessel mm.
 f  - Natural frequency of vibration (Hertz)
f1  - Natural frequency of bare vessel based on a unit value of (D/L²)(10^(4))
 L  - Total height of structure mm.
Lc  - Total length of conical section(s) of vessel mm.
tb  - Uncorroded plate thickness at bottom of vessel mm.
V30 - Design Wind Speed provided by user Km/hr
Vc  - Critical wind velocity Km/hr
Vw  - Maximum wind speed at top of structure Km/hr
W   - Total corroded weight of structure Kgf
Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. Kgf
 Z  - Maximum amplitude of vibration at top of vessel mm.
Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
Vp  - Vib. Chance, <= 0.320E-06 (High); 0.320E-06 < 0.400E-06 (Probable)
P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:

```
#1 - Total Cone Length / Total Length < 0.5
     0.0/5400.0 = 0.0

#2 - ( D / L² ) * 10^(4) < 8.0 (English Units)
   - ( 6.93/17.72² ) * 10^(4) = 220.849 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 0.400E-06 no chance. [Vp]:

```
 = W / ( L * Dr²)
 = 12940/( 5400.0 * 2106.0² )
```

= 0.54028E-06

Since Vp is > 0.400E-06 no further vibration analysis is required !

Platform Load Calculations

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force Kgf	Cf
TOP PLATFORM	35750.00	6100.00	78.41	280.32	1.30
TOP LADDER	0.00	7050.00	78.06	0.00	1.30

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force Kgf

The Natural Frequency for the Vessel (Ope...) is 10.8749 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load Kgf
10	20	331.748	3375.36	15732.7	73.6976	115.946
20	30	1175	3385.6	40627.2	73.6976	299.413
30	40	2525	3379.2	50688	73.6976	373.559
40	50	3825	3379.2	37171.2	73.6976	273.943
50	60	5125	3379.2	50688	75.4595	382.49
60	70	6123.05	3375.36	15732.7	78.48	402.732

Earthquake Load Calculation:

Input Values:

```
Seismic Design Code                                      ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                              0.714
Importance Factor                                                1.250
Table Value Fa                                                   1.050
Table Value Fv                                                   1.100
Max. Mapped Res. Acceleration       [Ss]                         1.310
Max. Eff. Ground Acceleration        [S]                         0.460
Force Modification Factor R                                      2.000
Site Class                                                           C
Component Elevation Ratio            z/h                         0.000
Amplification Factor                  Ap                         0.000
Force Factor                                                     0.000
Consider Vertical Acceleration                                      No
Minimum Acceleration Multiplier                                  0.000
User Value of Sds (used if > 0 )                                 0.920
User Value of Sd1 (used if > 0 )                                 0.340
Moment Reduction Factor Tau                                      1.000
```

Seismic Analysis Results:

```
 Sms = Fa * Ss = 1.05 * 1.31 = 1.375
 Sm1 = Fv * S1 = 1.1 * 0.46 = 0.506
 Sds = 2/3 * Sms = 2/3 * 1.375 = 0.917

 Sds = Max( 0.8*Sds, SdsUser )
     = Max( 0.734, 0.92 )
     = 0.920

 Sd1 = 2/3 * Sm1 = 2/3 * 0.506 = 0.337

 Sd1 = Max( 0.8*Sd1, Sd1User )
     = Max( 0.27, 0.34 )
     = 0.340
```

Check Approximate Fundamental Period from 12.8-7 [Ta]:

```
 = Ct * hn^(x) where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
 = 0.020 * ( 23.0479^(0.75))
 = 0.210 seconds
```

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

```
 = ( 1/Natural Frequency ) = ( 1/10.875 )
 = 0.092
```

Check the Value of T which is the smaller of Cu*Ta and T:

```
 = Minimum Value of (1.4 * 0.21, 0.092 ) per 12.8.2
 = 0.092
```

Compute the Seismic Response Coefficient per equation 12.8-2 [Cs]:

```
 = Sds / ( R / I )
 = 0.92/( 2.0/1.25 )
```

= 0.575

Check the Maximum value of Cs per equation 12.8-3 [Cs]:
= Sd1 / (T * (R / Ie))
= 0.34/(0.092 * (2.0/1.25))
= 2.311

Check the Minimum value of Cs per equation 15.4-1 [Cs]:
= max((0.044 * SDS * Ie), 0.030)
= max((0.044 * 0.92 * 1.25), 0.030)
= 0.051

Total Base Shear [V]:
= Cs * W (Equation 12.8-1):
= 0.575 * 13414.0
= 7713.048 Kgf

Final Base Shear, V = 5507.12 Kgf

Distribute the Base shear force to each element according to the equations
Fx = Cvx * V (eqn. 12.8-11) and the vertical distribution factor
Cvx = Wx*hx^(k)/(Sum of Wi*hi^(k)) and k is an exponent which is related
to the period of Vibration.

In this case, the value of k was 1.0

The Natural Frequency for the Vessel (Ope...) is 10.8749 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight Kgf	Element Ope Load Kgf	Element Emp Load Kgf
10	20	25	301.027	1.01709	1.13838
20	Legs	650	1135.86	99.7821	50.4223
Legs	30	950	1135.86	145.835	73.6942
30	40	2000	2873.11	776.599	160.882
40	50	3300	3800.38	1694.95	186.954
50	60	4600	2278.5	1416.52	390.187
60	70	5375	1889.26	1372.41	555.813

Note:
The Earthquake Loads calculated and printed in the Earthquake
Load calculation report have been factored by the input
scalar/load reduction factor of: 0.714.

Bending Moments due to user defined forces and moments.

User Force / Moment Shear and Bending

From	To	Distance to Support mm.	Cumulative Shr Wind Cas Kgf	Cumulative Shr Eqk Cas Kgf	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	848.052	...	...	...	...
20	Legs	300	412.467	412.467	381.255	381.255
Legs	30	300	708.404	708.404	2227.79	2227.79
30	40	1350	295.937	295.937	1421.48	1421.48
40	50	2650	295.937	295.937	977.565	977.565
50	60	3950	295.937	295.937	652.028	652.028
60	70	4948.05	91.7234	91.7234	56.3017	56.3017

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 1.000; Earthquake: 0.714.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear Kgf	Earthquake Shear Kgf	Wind Bending Kg-m.	Earthquake Bending Kg-m.
10	20	848.052	...	...	...	...
20	Legs	300	115.946	1.01709	28.7613	0.2523
Legs	30	300	1698.38	5407.33	4635.59	17939.4
30	40	1350	1432.72	5260.48	3874.27	14770.1
40	50	2650	1059.17	4483.88	2005.32	7461.64
50	60	3950	785.222	2788.93	990.884	3461.51
60	70	4948.05	402.732	1372.41	99.9004	340.437

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 1.000; Earthquake: 0.714.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

Wind Deflection Calculations:

The following table is for the Applied Forces Case.

Wind Deflection:

From	To	Cumulative Wind Shear Kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	0.90118	0.90118	0.00076963
20	Legs	412.467	0.90148	0.90235	0.00077344
Legs	30	708.404	0.90368	0.90539	0.00077589
30	40	295.937	0.91175	0.92107	0.0007838
40	50	295.937	0.92948	0.93897	0.00078774
50	60	295.937	0.9529	0.96725	0.00078891
60	70	91.7234	0.96773	0.96821	0.00078891

Allowable deflection at the Tower Top (For)(6.000"/100ft. Criteria)
Allowable deflection : 27.000 Actual deflection : 0.968 mm.

The following table is for the Operating Case.

Wind Deflection:

From	To	Cumulative Wind Shear Kgf	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	2.16091	2.16091	0.0018463
20	Legs	115.946	2.16153	2.16335	0.0018543
Legs	30	1698.38	2.1663	2.17029	0.0018612
30	40	1432.72	2.1859	2.20873	0.0018806
40	50	1059.17	2.22879	2.25084	0.0018878
50	60	785.222	2.28296	2.3163	0.0018911
60	70	402.732	2.31742	2.31854	0.0018911

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	658.941	4118.38
20	30	660.94	4130.88
30	40	659.691	4123.07
40	50	659.691	4123.07
50	60	659.691	4123.07
60	70	658.941	4118.38

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)

Allowable deflection : 27.000 Actual deflection : 2.319 mm.

Total Deflection in the Operating Condition + Applied Forces :
Allowable deflection : 27.000 Actual deflection : 3.287 mm.

Longitudinal Stress Constants:

From	To	Metal Area New cm^2	Metal Area Corroded cm^2	Section Modulus New $mm.^3$	Section Modulus Corroded $mm.^3$
10	20	317.395	119.193	16663505	6275487
20	30	529.796	331.594	27815242	17458646
30	40	396.971	198.769	20841426	10465215
40	50	396.971	198.769	20841426	10465215
50	60	396.971	198.769	20841426	10465215
60	70	317.395	119.193	16663505	6275487

Longitudinal Allowable Stresses:

From	To	Tensile N./mm²	Hydrotest Tensile N./mm²	Compressive N./mm²	Hydrotest Compressive N./mm²
10	20	140.658	240.516	-25.5915	-25.5915
20	Legs	140.658	240.516	-70.8725	-70.8725
Legs	30	140.658	240.516	-70.8725	-70.8725
30	40	140.658	240.516	-42.6041	-42.6041
40	50	140.658	240.516	-42.6041	-42.6041
50	60	140.658	240.516	-42.6041	-42.6041
60	70	140.658	240.516	-25.5915	-25.5915

Longitudinal Stress Report

Note: Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have also been computed in the corroded condition.

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm²	Longitudinal Stress External Pressure N./mm²	Longitudinal Stress Hydrotest Pressure N./mm²
10	20	5.84634	-2.93269	72.1438
20	30	2.10212	-1.06057	25.9402
30	40	3.5062	-1.7626	43.2665
40	50	3.5062	-1.7626	43.2665
50	60	3.5062	-1.7626	43.2665
60	70	5.84634	-2.93269	72.1438

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm²	Wght. Str. Operating N./mm²	Wght. Str. Hydrotest N./mm²	Wght. Str. Emp. Mom. N./mm²	Wght. Str. Opr. Mom. N./mm²
10	20	...	...	...	...	...
20	Legs	0.088496	0.089028	...	0.1743	0.1743
Legs	30	-3.03005	-3.02925	...	0.19648	0.19648
30	40	-4.49576	-4.49577	...	0.037	0.037
40	50	-3.08157	-3.08157	...	0.037	0.037
50	60	-2.05207	-2.05207	...	0.037	0.037
60	70	-1.55295	-1.55295	...	0.010664	0.010664

Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

From	To	Wght. Str. Hyd. Mom. N./mm²	Bend. Str. Oper. Wind N./mm²	Bend. Str. Oper. Equ. N./mm²	Bend. Str. Hyd. Wind N./mm²	Bend. Str. Hyd. Equ. N./mm²
10	20	...	...	...	...	...
20	Legs	...	0.016155	0.00014172	...	...
Legs	30	...	2.60384	10.0767	...	...
30	40	...	3.63046	13.8406	...	...
40	50	...	1.87912	6.99208	...	...
50	60	...	0.92853	3.24368	...	...
60	70	...	0.15611	0.532	...	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm²	Vortex Shedding Empty Case N./mm²	Vortex Shedding Test Case N./mm²	Earthquake Empty Case N./mm²

10	20	...	...	...	...
20	Legs	...	...	...	0.00015862
Legs	30	...	...	...	2.81424
30	40	...	...	...	3.96177
40	50	...	...	...	2.25618
50	60	...	...	...	1.18469
60	70	...	...	...	0.21545

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm²	Longitudinal Stress Y Forces Seismic N./mm²
10	20	0.2648	0.2648
20	Legs	0.16395	0.16395
Legs	30	-0.068765	-0.068765
30	40	-0.11472	-0.11472
40	50	-0.11472	-0.11472
50	60	-0.11472	-0.11472
60	70	-0.042624	-0.042624

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded N./mm²	Earthquake For/Mom Corroded N./mm²	Wind For/Mom No Corrosion N./mm²	Earthquake For/Mom No Corrosion N./mm²
10	20	...	...	...	...
20	Legs	0.21415	0.21415	0.13442	0.13442
Legs	30	1.25136	1.25136	0.78544	0.78544
30	40	1.33203	1.33203	0.66886	0.66886
40	50	0.91605	0.91605	0.45998	0.45998
50	60	0.611	0.611	0.3068	0.3068
60	70	0.087982	0.087982	0.033134	0.033134

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

IP = Longitudinal Stress due to Internal Pressure
EP = Longitudinal Stress due to External Pressure
HP = Longitudinal Stress due to Hydrotest Pressure
NP = No Pressure
EW = Longitudinal Stress due to Weight (No Liquid)
OW = Longitudinal Stress due to Weight (Operating)
HW = Longitudinal Stress due to Weight (Hydrotest)
WI = Bending Stress due to Wind Moment (Operating)
EQ = Bending Stress due to Earthquake Moment (Operating)
EE = Bending Stress due to Earthquake Moment (Empty)
HI = Bending Stress due to Wind Moment (Hydrotest)
HE = Bending Stress due to Earthquake Moment (Hydrotest)
WE = Bending Stress due to Wind Moment (Empty) (no CA)
WF = Bending Stress due to Wind Moment (Filled) (no CA)
CW = Longitudinal Stress due to Weight (Empty) (no CA)
VO = Bending Stress due to Vortex Shedding Loads (Ope)
VE = Bending Stress due to Vortex Shedding Loads (Emp)
VF = Bending Stress due to Vortex Shedding Loads (Test No CA.)
FW = Axial Stress due to Vertical Forces for the Wind Case
FS = Axial Stress due to Vertical Forces for the Seismic Case
BW = Bending Stress due to Lat. Forces for the Wind Case, Corroded
BS = Bending Stress due to Lat. Forces for the Seismic Case, Corroded
BN = Bending Stress due to Lat. Forces for the Wind Case, UnCorroded
BU = Bending Stress due to Lat. Forces for the Seismic Case, UnCorroded

General Notes:

Case types HI and HE are in the Corroded condition.

Case types WE, WF, and CW are in the Un-Corroded condition.

A blank stress and stress ratio indicates that the corresponding stress comprising those components that did not contribute to that type of stress.

An asterisk (*) in the final column denotes overstress.

Analysis of Load Case 1 : NP+EW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.26	140.66		25.59	0.0019	
20	0.66	140.66	-0.15	70.87	0.0047	0.0021
20	0.95	140.66	-7.15	70.87	0.0068	0.1009
30	0.39	140.66	-9.61	42.60	0.0028	0.2256
40		140.66	-6.03	42.60		0.1415
50		140.66	-3.74	42.60		0.0879
60		140.66	-1.85	25.59		0.0723

Analysis of Load Case 2 : NP+EW+EE+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.26	140.66		25.59	0.0019	

20	0.64	140.66	-0.14	70.87	0.0046	0.0019
20	1.16	140.66	-7.36	70.87	0.0083	0.1039
30	0.72	140.66	-9.94	42.60	0.0051	0.2333
40	0.01	140.66	-6.41	42.60	0.0001	0.1503
50		140.66	-4.00	42.60		0.0939
60		140.66	-1.91	25.59		0.0746

Analysis of Load Case 3 : NP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.26	140.66		25.59	0.0019	
20	0.66	140.66	-0.15	70.87	0.0047	0.0021
20	0.95	140.66	-7.15	70.87	0.0068	0.1009
30	0.39	140.66	-9.61	42.60	0.0028	0.2256
40		140.66	-6.03	42.60		0.1415
50		140.66	-3.74	42.60		0.0879
60		140.66	-1.85	25.59		0.0723

Analysis of Load Case 4 : NP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.26	140.66		25.59	0.0019	
20	0.64	140.66	-0.14	70.87	0.0046	0.0019
20	8.43	140.66	-14.62	70.87	0.0599	0.2063
30	10.60	140.66	-19.82	42.60	0.0754	0.4652
40	4.75	140.66	-11.14	42.60	0.0338	0.2615
50	1.72	140.66	-6.06	42.60	0.0123	0.1422
60		140.66	-2.23	25.59		0.0870

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	0.00	25.59	0.0000	0.0000
20	0.00	240.52	0.00	70.87	0.0000	0.0000
20	0.00	240.52	0.00	70.87	0.0000	0.0000
30	0.00	240.52	0.00	42.60	0.0000	0.0000
40	0.00	240.52	0.00	42.60	0.0000	0.0000
50	0.00	240.52	0.00	42.60	0.0000	0.0000
60	0.00	240.52	0.00	25.59	0.0000	0.0000

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	0.00	25.59	0.0000	0.0000
20	0.00	240.52	0.00	70.87	0.0000	0.0000
20	0.00	240.52	0.00	70.87	0.0000	0.0000
30	0.00	240.52	0.00	42.60	0.0000	0.0000
40	0.00	240.52	0.00	42.60	0.0000	0.0000
50	0.00	240.52	0.00	42.60	0.0000	0.0000
60	0.00	240.52	0.00	25.59	0.0000	0.0000

Analysis of Load Case 7 : IP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	6.11	140.66		25.59	0.0434	
20	2.76	140.66		70.87	0.0196	
20	3.06	140.66	-5.05	70.87	0.0217	0.0712

30	3.90	140.66	-6.10	42.60	0.0277	0.1433
40	3.14	140.66	-2.52	42.60	0.0223	0.0592
50	2.92	140.66	-0.24	42.60	0.0207	0.0056
60	4.51	140.66		25.59	0.0320	

Analysis of Load Case 8 : IP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	6.11	140.66		25.59	0.0434	
20	2.74	140.66		70.87	0.0195	
20	10.53	140.66	-12.52	70.87	0.0749	0.1767
30	14.11	140.66	-16.31	42.60	0.1003	0.3829
40	8.26	140.66	-7.64	42.60	0.0587	0.1792
50	5.23	140.66	-2.55	42.60	0.0372	0.0599
60	4.88	140.66		25.59	0.0347	

Analysis of Load Case 9 : EP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-2.67	25.59		0.1042
20		140.66	-1.21	70.87		0.0171
20		140.66	-8.21	70.87		0.1158
30		140.66	-11.37	42.60		0.2669
40		140.66	-7.79	42.60		0.1829
50		140.66	-5.51	42.60		0.1292
60		140.66	-4.78	25.59		0.1869

Analysis of Load Case 10 : EP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-2.67	25.59		0.1042
20		140.66	-1.20	70.87		0.0169
20	7.37	140.66	-15.68	70.87	0.0524	0.2213
30	8.84	140.66	-21.58	42.60	0.0628	0.5066
40	2.99	140.66	-12.90	42.60	0.0212	0.3029
50		140.66	-7.82	42.60		0.1836
60		140.66	-5.16	25.59		0.2016

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	72.14	240.52		25.59	0.3000	
20	25.94	240.52		70.87	0.1079	
20	25.94	240.52		70.87	0.1079	
30	43.27	240.52		42.60	0.1799	
40	43.27	240.52		42.60	0.1799	
50	43.27	240.52		42.60	0.1799	
60	72.14	240.52		25.59	0.3000	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	72.14	240.52		25.59	0.3000	
20	25.94	240.52		70.87	0.1079	
20	25.94	240.52		70.87	0.1079	
30	43.27	240.52		42.60	0.1799	
40	43.27	240.52		42.60	0.1799	

50	43.27	240.52		42.60	0.1799	
60	72.14	240.52		25.59	0.3000	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	5.85	140.66		25.59	0.0416	
20	2.36	140.66		70.87	0.0168	
20		140.66	-1.12	70.87		0.0159
30		140.66	-1.03	42.60		0.0241
40	0.46	140.66		42.60	0.0033	
50	1.49	140.66		42.60	0.0106	
60	4.30	140.66		25.59	0.0306	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	5.85	140.66		25.59	0.0416	
20	2.16	140.66		70.87	0.0153	
20	0.21	140.66		70.87	0.0015	
30	1.26	140.66		42.60	0.0089	
40	1.96	140.66		42.60	0.0140	
50	2.48	140.66		42.60	0.0176	
60	5.26	140.66		25.59	0.0374	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	5.85	140.66		25.59	0.0416	
20	2.37	140.66		70.87	0.0168	
20		140.66	-1.12	70.87		0.0159
30		140.66	-1.03	42.60		0.0241
40	0.46	140.66		42.60	0.0033	
50	1.49	140.66		42.60	0.0106	
60	4.30	140.66		25.59	0.0306	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	5.85	140.66		25.59	0.0416	
20	2.36	140.66		70.87	0.0168	
20		140.66	-1.12	70.87		0.0159
30		140.66	-1.03	42.60		0.0241
40	0.46	140.66		42.60	0.0033	
50	1.49	140.66		42.60	0.0106	
60	4.30	140.66		25.59	0.0306	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	0.00	25.59	0.0000	0.0000
20	0.26	140.66	-0.09	70.87	0.0019	0.0012
20		140.66	-3.23	70.87		0.0455
30		140.66	-4.53	42.60		0.1064
40		140.66	-3.12	42.60		0.0732
50		140.66	-2.09	42.60		0.0490
60		140.66	-1.56	25.59		0.0611

Analysis of Load Case 18 : FS+BS+IP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	6.11	140.66		25.59	0.0434	
20	2.74	140.66		70.87	0.0195	
20	0.45	140.66	-2.44	70.87	0.0032	0.0345
30	0.26	140.66	-2.47	42.60	0.0019	0.0581
40	1.26	140.66	-0.64	42.60	0.0090	0.0151
50	1.99	140.66		42.60	0.0141	
60	4.35	140.66		25.59	0.0309	

Analysis of Load Case 19 : FS+BS+EP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-2.67	25.59		0.1042
20		140.66	-1.20	70.87		0.0169
20		140.66	-5.61	70.87		0.0791
30		140.66	-7.74	42.60		0.1817
40		140.66	-5.91	42.60		0.1388
50		140.66	-4.58	42.60		0.1074
60		140.66	-4.63	25.59		0.1808

Absolute Maximum of the all of the Stress Ratio's 0.5066

Governing Element: Shell #2
Governing Load Case 10 : EP+OW+EQ+FS+BS

Shop/Field Installation Options :

Platform(s) installed in the Field after being lifted.
Packing is installed in the Field after being lifted.

Note : The CG is computed from the first Element From Node

Center of Gravity of Platforms	6311.520 mm.
Center of Gravity of Packing	2700.000 mm.
Center of Gravity of Liquid	3290.513 mm.
Center of Gravity of Stiffening Rings	3200.000 mm.
Center of Gravity of Nozzles	3129.224 mm.
Center of Gravity of Legs	-225.000 mm.
Center of Gravity of Bare Shell New and Cold	2588.865 mm.
Center of Gravity of Bare Shell Corroded	2489.359 mm.
Vessel CG in the Operating Condition	2966.083 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	2233.273 mm.
Vessel CG in the Test Condition	2623.092 mm.

Rigging Analysis Results:

Lifting Weight based the calculated Erected Weight.

Total Effective Length of Vessel for this analysis		5400.00 mm.
Total vessel weight (No Liquid)	Twt	4812.06 Kgf
Impact weight multiplication factor	Imp	2.00
Design lifting weight, DWT = Imp * Twt		9624.12 Kgf
Elevation of the Tailing Lug (bottom)		0.00 mm.
Elevation of the Lifting Lug (top)		5400.00 mm.
Design Reaction force at the tailing lug		5643.89 Kgf
Design Reaction force at the lifting lug		3980.24 Kgf
CG Distance from Tailing Lug		2233.27 mm.
CG Distance from the Nearer Lifting Lug		2233.27 mm.

Critical Values:

	Max Stress N./mm²	Elevation mm.	Allowables N./mm²	
Bending	1.90	2750.00	71.01	(UG-23)
Shear	1.12	0.00	96.53	(0.7*S)

Forces and Moments at selected elevations (not all analysis points shown):

Distance mm.	Bending Moment Kg-m.	Bending Stress N./mm²	Shear Force Kgf	Shear Stress N./mm²
0.00	0.0	0.0	3614.1	1.1
50.00	32.6	0.0	3476.7	0.6
1250.00	3149.5	1.5	726.9	0.2
2750.00	4033.7	1.9	648.0	0.2
3850.00	3169.6	1.5	2022.8	0.5

5350.00	70.9	0.0	3397.7	1.0

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0267 at elevation 2750.0 mm. - Must be <=1

Note: The rigging analysis is performed using a uniformly distributed load.

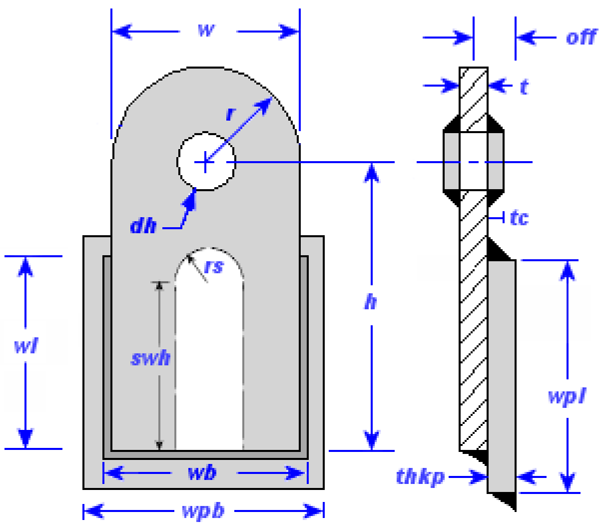
--- Plot data successfully generated ...----

Lifting Lug Calculations:

Input Values:

Lifting Lug Material		SA-283 C
Lifting Lug Yield Stress	Yield	206.85 N./mm²
Width of Lifting Lug	w	250.0000 mm.
Thickness of Lifting Lug	t	10.0000 mm.
Diameter of Hole in Lifting Lug	dh	50.0000 mm.
Radius of Semi-Circular Arc of Lifting Lug	r	125.0000 mm.
Height of Lug from bottom to Center of Hole	h	650.0000 mm.
Offset from Vessel OD to Center of Hole	off	11.0000 mm.
Lug Fillet Weld Size	tw	6.0000 mm.
Length of weld along side of Lifting Lug	wl	200.0000 mm.
Length of Weld along Bottom of Lifting Lug	wb	250.0000 mm.
Thickness of Collar (if any)	tc	0.0000 mm.
Diameter of Collar (if any)	dc	0.0000 mm.
Impact Factor	Impfac	2.00
Slot Radius		50.0000 mm.
Slot Height		100.0000 mm.
Number of Lugs in Group		2

Lifting Lug Orientation to Vessel: Flat
Lift Orientation : From Horizontal to Vertical



PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Lifting Lug and Weld Stresses at various Angles: N./mm²

Angle	Weld Stresses Primary	Weld Stresses Secondary	Weld Stresses Allowable	Lug Stresses Combined	Lug Stresses Allowable	Maximum Ratio
0	9.1	47.2	110.0	84.3	155.1	0.543
5	9.5	48.3	110.0	86.9	155.1	0.560

10	9.9	48.9	110.0	88.7	155.1	0.572
15	10.3	49.1	110.0	89.9	155.1	0.579
20	10.7	48.9	110.0	90.3	155.1	0.582
25	11.1	48.3	110.0	89.9	155.1	0.580
30	11.5	47.3	110.0	88.9	155.1	0.573
35	11.9	45.8	110.0	87.1	155.1	0.561
40	12.4	44.0	110.0	84.6	155.1	0.545
45	12.8	41.7	110.0	81.4	155.1	0.525
50	13.3	39.1	110.0	77.5	155.1	0.499
55	13.8	36.1	110.0	72.9	155.1	0.470
60	14.4	32.7	110.0	67.6	155.1	0.436
65	15.1	28.9	110.0	61.7	155.1	0.398
70	15.9	24.6	110.0	55.1	155.1	0.355
75	16.9	19.9	110.0	47.8	155.1	0.308
80	18.4	14.6	110.0	39.7	155.1	0.256
85	20.7	8.3	110.0	30.3	155.1	0.196
90	24.8	1.9	110.0	18.9	155.1	0.226

Computed Results:

```
Total vessel weight (No Liquid)                              4812.06 Kgf
Design Reaction force at the tailing lug                     5643.89 Kgf
Design Reaction force at the lifting lug                     3980.24 Kgf

Worst Case Lift Angle for Primary Weld Stresses                   90 deg
Tangential Force at this Angle                                   0.0 Kgf
Axial Force at this Angle                                     4812.1 Kgf

Worst Case Lift Angle for Secondary Weld Stresses                 15 deg
Tangential Force at this Angle                                2069.6 Kgf
Axial Force at this Angle                                      554.6 Kgf

Worst Case Lift Angle for Lug Stresses                            20 deg
Tangential Force at this Angle                                2061.1 Kgf
Axial Force at this Angle                                      750.2 Kgf
```

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

```
Weld Group Inertia about the Circumferential Axis     Ilc     1382.694 cm**4
Weld Group Centroid distance in the Long. Direction  Yll       123.028 mm.
Dist. of Weld Group Centroid from Lug bottom       Yll_b       76.972 mm.
Weld Group Inertia about the Longitudinal Axis        Ill     3661.526 cm**4
Weld Group Centroid Distance in the Circ. Direction  Ylc       129.242 mm.
```

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

```
 = sqrt( Fax^(2) + Ft^(2) + Fn^(2) )/(( 2 * wl + wb ) * tw )
 = sqrt(4812^(2)+0^(2)+0^(2))/((2*200.0+150.0)*4.242)
 = 20.23 N./mm²
```

Shear Stress in the Welds due to Bending Loads [Sblf]:

```
 = (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
 = (0(650.0-76.972))123.028/1382.694 +
```

```
    (4812 * 11.0 * 123.028/1382.694) +
    (0 * 11.0 * 129.242/3661.526)
  = 4.62 N./mm²
```

Total Shear Stress for Combined Loads [St]:

```
  = Ssll + Sblf
  = 20.227 + 4.619
  = 24.85 N./mm²
```

Allowable Shear Stress for Combined Loads [Sta]:

```
  = 0.4 * Yield * Occfac (AISC Shear Allowable)
  = 0.4 * 207 * 1.33
  = 110.04 N./mm²
```

Secondary Shear Stress in the Welds due to Shear Loads:

Unit Weld Polar Section Modulus [Uwsm]:

```
  = (2*wl+w)^3/12-wl^2(wl+w)^2/(2*wl+w)
  = 10423878.00 mm.^3
```

Loads on Welds due to Torsional Moment:

Shear Stress in Normal Direction [Fth]:

```
  = Ft * ( h-(wl-Cent) ) * (wb/2) / Uwsm
  = 8.76 Kgf/mm.
```

Shear Stress in Circumferential Direction [Ftv]:

```
  = Ft * ( h-(wl-Cent) ) * Cent / Uwsm
  = 16.18 Kgf/mm.
```

Primary Shear Stress [Fsv]:

```
  = Ft / ( 2 * wl + w )
  = 3.18 Kgf/mm.
```

Resultant Load on Weld Group [Fr]:

```
  = sqrt( Fth^2 + ( Ftv+Fsv )^2 )
  = sqrt( 8.8(^2) + ( 16.2 + 3.2 )(^2) )
  = 21.25 Kgf/mm.
```

Resultant Secondary Weld Stress [Fws]:

```
  = Fr / Tweld
  = 21.252/4.242
  = 49.13 N./mm²
```

Allowable Resultant Secondary Weld Stress [Psa]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 206.9 * 1.33
  = 110.04 N./mm²
```

Shear Stress in Lug above Hole [Shs]:

```
  = sqrt( Pl^(2) + Fn^(2) ) / Sha
  = sqrt( 4812^(2) + 0^(2) )/20.0
  = 23.60 N./mm²
```

Allowable Shear Stress in Lug above Hole [Sas]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 207 * 1.33
```

```
 = 110.04 N./mm²
```

Pin Hole Bearing Stress [Pbs]:

```
 = sqrt( Fax^(2) + Fn^(2) ) / ( t * dh )
 = sqrt( 750^(2) + 4812^(2) )/( 10.0 * 50.0 )
 = 94.38 N./mm²
```

Allowable Bearing Stress [Pba]:

```
 = min( 0.75 * Yield * Occfac, 0.9 * Yield ) AISC Bearing All.
 = min( 0.75 * 207 * 1.33, 186.2 )
 = 186.17 N./mm²
```

Bending Stress at the Base of the Lug [Fbs]:

```
 = Fn*(h-wl)/(w*t^2 / 6) + Ft*(h-wl) / (w^2*t / 6)
 = 0 *(650.0 - 200.0)/(250.0 *10.0(^2)/6) +
   2061 *(650.0 - 200.0)/(250.0(^2) *10.0/6)
 = 87.32 N./mm²
```

Tensile Stress at the Base of the Lug [Fa]:

```
 = Fax / (w * t)
 = 750/(250.0 * 10.0)
 = 2.94 N./mm²
```

Total Combined Stress at the Base of the Lug:

```
 = Fbs + Fa
 = 87.3 + 2.9
 = 90.26 N./mm²
```

Lug Allowable Stress for Bending and Tension:

```
 = min( 0.66 * Yield * Occfac, 0.75*Yield )
 = min( 0.66 * 207 * 1.33, 155.1 )
 = 155.14 N./mm²
```

Required Shackle Pin Diameter [Spd]:

```
 = sqrt[(2 * sqrt(Pl^(2) + Fn^(2))/( Pi * Sta))]
 = sqrt[2 * sqrt(4812^(2) + 0^(2))/( Pi * 110)]
 = 16.5229 mm.
```

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note: The full lug load is applied in both the circumferential and longitudinal directions simultaneously.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.0000	mm.
Vessel Diameter	Dv	2100.000	mm.
Vessel Thickness	Tv	6.000	mm.

Note: Lifting lug calculations are performed at ambient temperature conditions.

Attachment Type	Type	Rectangular	
Parameter C11	C11	262.00	mm.
Parameter C22	C22	206.00	mm.

Thickness of Reinforcing Pad	Tpad	6.000	mm.
Pad Parameter C11P	C11p	362.000	mm.
Pad Parameter C22P	C22p	256.000	mm.

Design Internal Pressure	Dp	0.000	bars
Include Pressure Thrust		No	

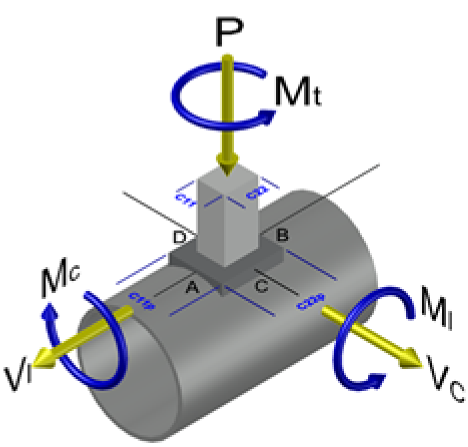
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	0.0	Kgf
Longitudinal Shear	(SUS)	Vl	4812.1	Kgf
Circumferential Shear	(SUS)	Vc	4812.1	Kgf
Circumferential Moment	(SUS)	Mc	0.0	Kg-m.
Longitudinal Moment	(SUS)	Ml	52.9	Kg-m.
Torsional Moment	(SUS)	Mt	2646.7	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	Kgf
Circumferential Shear	VC	4812.1	Kgf
Longitudinal Shear	VL	4812.1	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	52.9	Kg-m.
Torsional Moment	MT	2646.7	Kg-m.

Dimensionless Parameters used : Gamma = 88.00

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.109	4C	13.463	(A,B)
N(PHI) / (P/Rm)	0.109	3C	10.037	(C,D)
M(PHI) / (P)	0.118	2C1	0.046	(A,B)
M(PHI) / (P)	0.118	1C	0.080	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.114	3A	3.391	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.124	1A	0.078	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.106	3B	9.995	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.110	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.117	3C	9.434	(A,B)
N(x) / (P/Rm)	0.117	4C	13.181	(C,D)
M(x) / (P)	0.112	1C1	0.086	(A,B)
M(x) / (P)	0.112	2C	0.050	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.114	4A	5.936	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.127	2A	0.038	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.106	4B	3.348	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.109	2B	0.044	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	-3.4	-3.4	3.4	3.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-5.9	5.9	5.9	-5.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-9.4	2.5	9.4	-2.5	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	-1.0	-1.0	1.0	1.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-8.3	8.3	8.3	-8.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	-9.2	7.3	9.2	-7.3	0.0	0.0	0.0	0.0
Shear VC	7.5	7.5	-7.5	-7.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-9.5	-9.5	9.5	9.5
Shear MT	160.3	160.3	160.3	160.3	160.3	160.3	160.3	160.3
Tot. Shear	167.8	167.8	152.8	152.8	150.8	150.8	169.8	169.8
Str. Int.	335.6	335.6	305.6	305.6	301.5	301.5	339.7	339.7

Dimensionless Parameters used : Gamma = 175.50

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.143	4C	20.215	(A,B)
N(PHI) / (P/Rm)	0.143	3C	9.611	(C,D)
M(PHI) / (P)	0.160	2C1	0.017	(A,B)
M(PHI) / (P)	0.160	1C !	0.069	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.153	3A	5.975	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.160	1A	0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.136	3B	14.323	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.141	1B	0.014	(A,B,C,D)
N(x) / (P/Rm)	0.158	3C	8.200	(A,B)
N(x) / (P/Rm)	0.158	4C	18.963	(C,D)
M(x) / (P)	0.149	1C1	0.044	(A,B)
M(x) / (P)	0.149	2C !	0.038	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.153	4A	14.675	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.159	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.136	4B	6.580	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.139	2B	0.018	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	-8.1	-8.1	8.1	8.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	-8.1	8.1	8.1	-8.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-16.2	0.0	16.2	-0.0	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	-2.8	-2.8	2.8	2.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-13.4	7.9	13.4	-7.9	0.0	0.0	0.0	0.0
Shear VC	10.9	10.9	-10.9	-10.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Shear MT	186.7	186.7	186.7	186.7	186.7	186.7	186.7	186.7
Tot. Shear	197.6	197.6	175.9	175.9	171.4	171.4	202.1	202.1

Str. Int.	395.2	395.2	351.7	351.8	342.7	342.7	404.2	404.2

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	-3.4	-3.4	3.4	3.4	0.0	0.0	0.0	0.0
Circ. Q (SUS)	-5.9	5.9	5.9	-5.9	0.0	0.0	0.0	0.0
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	-1.0	-1.0	1.0	1.0	0.0	0.0	0.0	0.0
Long. Q (SUS)	-8.3	8.3	8.3	-8.3	0.0	0.0	0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	7.5	7.5	-7.5	-7.5	-9.5	-9.5	9.5	9.5
Shear Q (SUS)	160.3	160.3	160.3	160.3	160.3	160.3	160.3	160.3
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	15.2	15.2	15.2	15.2	19.1	19.1	19.1	19.1
Pm+Pl+Q (Total)	335.6	335.6	305.6	305.6	301.5	301.5	339.7	339.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	137.90	Passed
Pm+Pl (SUS)	19.09	206.85	Passed
Pm+Pl+Q (TOTAL)	339.69	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	-8.1	-8.1	8.1	8.1	0.0	0.0	0.0	0.0
Circ. Q (SUS)	-8.1	8.1	8.1	-8.1	0.0	0.0	0.0	0.0
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Long. Pl (SUS)	-2.8	-2.8	2.8	2.8	0.0	0.0	0.0	0.0
Long. Q (SUS)	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	10.9	10.9	-10.9	-10.9	-15.4	-15.4	15.4	15.4
Shear Q (SUS)	186.7	186.7	186.7	186.7	186.7	186.7	186.7	186.7
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	22.4	22.4	22.4	22.4	30.7	30.7	30.7	30.7
Pm+Pl+Q (Total)	395.2	395.2	351.7	351.8	342.7	342.7	404.2	404.2

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0.00	137.90	Passed
Pm+Pl (SUS)	30.72	206.85	Passed
Pm+Pl+Q (TOTAL)	404.16	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: Shell #1

Section Properties : I Beam HE160B

European Structural Steel Data

```
Overall Leg Length                                        1750.000  mm.
Effective Leg Length                             Leglen   1200.000  mm.
Distance Leg Up Side of Vessel                             600.000  mm.
Number of Legs                                     Nleg      4
Cross Sectional Area for HE160B                    Aleg     54.000  cm²
Section Inertia     ( strong axis )                       2491.988  cm**4
Section Inertia     ( weak   axis )                        888.996  cm**4
Section Modulus     ( strong axis )                     312001.281  mm.³
Section Modulus     ( weak   axis )                     111000.453  mm.³
Radius of Gyration ( strong axis )                          67.800  mm.
Radius of Gyration ( weak   axis )                          40.500  mm.
```

Leg Orientation - Strong Axis

```
Overturning Moment at top of Legs                          20167.1  Kg-m.
Total Weight Load at top of Legs                      W    14032.9  Kgf
Total Shear force at top of Legs                            6215.5  Kgf
Additional force in Leg due to Bracing             Fadd        0.0  Kgf
Occasional Load Factor                           Occfac      1.000
Effective Leg End Condition Factor                    k      0.650
```

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

```
Pad Width along Circumference                      C11P    400.000  mm.
Pad Length along Vessel Axis                       C22P    600.000  mm.
Pad Thickness                                      Tpad      8.000  mm.
```

Maximum Shear at top of one Leg [Vleg]:

```
 = ( max( Wind, Seismic ) + applied forces )( Imax / Itot )
 = ( 6215.5 )( 2482.3/6736.01 )
 = 2290.47 Kgf
```

Axial Compression, Leg furthest from the Neutral Axis [Sma]:

```
 = W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
 = 137614/4 + (.19776E+09/( 2 * 1146.004 ))/5399.989
 = 22.35 N./mm²
```

Axial Compression, Leg closest to the Neutral Axis [Sva]:

```
 = ( W / Nleg ) / Aleg
 = ( 14033/4 )/54.0
 = 6.37 N./mm²
```

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:

```
 = Occfac * ( 1-(kl/r)²/(2*Cc²))*Fy /
  ( 5/3+3*(Kl/r)/(8*Cc)-(Kl/r³)/(8*Cc³)
 = 1.0 * ( 1-( 19.26 )²/(2 * 127.18² )) * 248/
   ( 5/3+3*( 19.26 )/(8* 127.18 )-( 19.26³)/(8* 127.18³)
```

= 142.41 N./mm²

Bending at the Bottom of the Leg closest to the N.A. [S]:
= (Vleg * Leglen / Smdsa)
= (2290.47 * 1200.0/312001.28)
= 86.39 N./mm²

Allowable Bending Stress[Sb]:
= (0.6 * Fy * Occfac)
= (0.6 * 248 * 1.0)
= 148.93 N./mm²

AISC Unity Check [Sc](must be < or = to 1.00) :
= (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
= (22/142)+(0.85 *86.393)/((1 -22/2824) *149)
= 0.6540

WRC 107 Stress Analysis for Leg to Shell Junction, Ope Condition

Rectangular Attachment Parameter	C11	160.000	mm.
Rectangular Attachment Parameter	C22	580.950	mm.

Input Echo, WRC107/537 Item 1, Description: LEGS

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	2100.000	mm.
Vessel Thickness	Tv	8.000	mm.
Design Temperature	T1	85.0	°C
Attachment Type	Type	Rectangular	
Parameter C11	C11	160.00	mm.
Parameter C22	C22	580.95	mm.
Thickness of Reinforcing Pad	Tpad	8.000	mm.
Pad Parameter C11P	C11p	400.000	mm.
Pad Parameter C22P	C22p	600.000	mm.
Design Internal Pressure	Dp	0.200	bars
Include Pressure Thrust		No	
Vessel Centerline Direction Cosine	Vx	0.000	
Vessel Centerline Direction Cosine	Vy	1.000	
Vessel Centerline Direction Cosine	Vz	0.000	
Nozzle Centerline Direction Cosine	Nx	1.000	
Nozzle Centerline Direction Cosine	Ny	0.000	
Nozzle Centerline Direction Cosine	Nz	0.000	
Global Force (SUS)	Fx	184.6	Kgf
Global Force (SUS)	Fy	3508.2	Kgf
Global Force (SUS)	Fz	184.6	Kgf
Global Moment (SUS)	Mx	0.0	Kg-m.
Global Moment (SUS)	My	0.0	Kg-m.
Global Moment (SUS)	Mz	465.4	Kg-m.

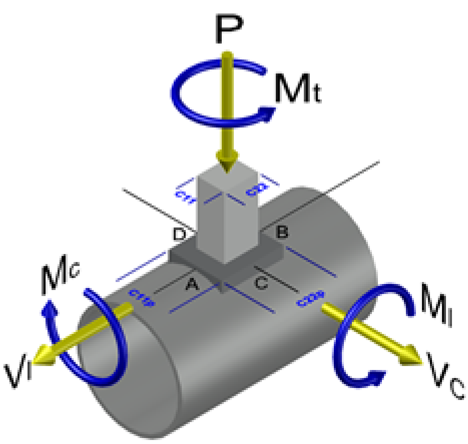
Internal Pressure (SUS)	P	0.20	bars
Include Pressure Thrust		No	

Global Force (OCC)	Fx	2290.5	Kgf
Global Force (OCC)	Fy	8798.8	Kgf
Global Force (OCC)	Fz	0.0	Kgf
Global Moment (OCC)	Mx	0.0	Kg-m.
Global Moment (OCC)	My	0.0	Kg-m.
Global Moment (OCC)	Mz	2148.6	Kg-m.
Occasional Internal Pressure (OCC)	Pvar	0.00	bars

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	184.6	Kgf
Circumferential Shear	VC	-184.6	Kgf
Longitudinal Shear	VL	3508.2	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	-465.4	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 81.50

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location

N(PHI) / (P/Rm)	0.211	4C	9.205	(A,B)
N(PHI) / (P/Rm)	0.211	3C	4.432	(C,D)
M(PHI) / (P)	0.127	2C1	0.044	(A,B)
M(PHI) / (P)	0.127	1C	0.077	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.116	3A	3.130	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.136	1A	0.076	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.178	3B	7.230	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.150	1B	0.023	(A,B,C,D)
N(x) / (P/Rm)	0.172	3C	5.893	(A,B)
N(x) / (P/Rm)	0.172	4C	10.388	(C,D)
M(x) / (P)	0.179	1C1	0.054	(A,B)
M(x) / (P)	0.179	2C !	0.036	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.116	4A	5.407	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.173	2A	0.031	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.178	4B	3.168	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.202	2B	0.019	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.2	-1.2	-1.2	-1.2	-0.6	-0.6	-0.6	-0.6
Circ. Bend. P	-2.8	2.8	-2.8	2.8	-4.9	4.9	-4.9	4.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	7.6	7.6	-7.6	-7.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	23.6	-23.6	-23.6	23.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.	27.2	-14.5	-35.2	17.6	-5.5	4.4	-5.5	4.4
Long. Memb. P	-0.8	-0.8	-0.8	-0.8	-1.4	-1.4	-1.4	-1.4
Long. Bend. P	-3.5	3.5	-3.5	3.5	-2.3	2.3	-2.3	2.3
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	6.0	6.0	-6.0	-6.0	0.0	0.0	0.0	0.0
Long. Bend. ML	14.0	-14.0	-14.0	14.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	15.8	-5.3	-24.4	10.7	-3.7	0.9	-3.7	0.9
Shear VC	-0.4	-0.4	0.4	0.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.3	-2.3	2.3	2.3
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	-0.4	-0.4	0.4	0.4	-2.3	-2.3	2.3	2.3
Str. Int.	27.2	14.5	35.2	17.7	7.1	5.7	7.1	5.7

Dimensionless Parameters used : Gamma = 211.10

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.282	4C	12.640	(A,B)
N(PHI) / (P/Rm)	0.282	3C	3.171	(C,D)
M(PHI) / (P)	0.220	2C1	0.008	(A,B)
M(PHI) / (P)	0.220	1C !	0.068	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.217	3A	4.816	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.220	1A	0.049	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.248	3B	8.439	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.226	1B	0.005	(A,B,C,D)
N(x) / (P/Rm)	0.253	3C	3.823	(A,B)
N(x) / (P/Rm)	0.253	4C	14.367	(C,D)
M(x) / (P)	0.258	1C1	0.017	(A,B)
M(x) / (P)	0.258	2C !	0.037	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.217	4A	17.172	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.251	2A	0.018	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.248	4B	3.792	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.246	2B	0.005	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-4.3	-4.3	-4.3	-4.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-3.5	3.5	-3.5	3.5	-29.5	29.5	-29.5	29.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	24.6	24.6	-24.6	-24.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	24.2	-24.2	-24.2	24.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	41.0	-0.4	-56.6	-1.2	-30.6	28.4	-30.6	28.4
Long. Memb. P	-1.3	-1.3	-1.3	-1.3	-4.9	-4.9	-4.9	-4.9
Long. Bend. P	-7.4	7.4	-7.4	7.4	-16.0	16.0	-16.0	16.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	13.9	13.9	-13.9	-13.9	0.0	0.0	0.0	0.0
Long. Bend. ML	21.3	-21.3	-21.3	21.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	26.4	-1.3	-43.9	13.5	-20.9	11.1	-20.9	11.1
Shear VC	-0.5	-0.5	0.5	0.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-5.7	-5.7	5.7	5.7
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Tot. Shear	-0.5	-0.5	0.5	0.5	-5.7	-5.7	5.7	5.7
Str. Int.	41.0	1.5	56.7	14.8	33.3	30.1	33.3	30.1

WRC 107 Stress Calculation for OCCasional loads:

Radial Load	P	2290.5	Kgf
Circumferential Shear	VC	0.0	Kgf
Longitudinal Shear	VL	8798.8	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	-2148.6	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 81.50
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-15.0	-15.0	-15.0	-15.0	-7.2	-7.2	-7.2	-7.2
Circ. Bend. P	-34.7	34.7	-34.7	34.7	-61.3	61.3	-61.3	61.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	35.0	35.0	-35.0	-35.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	109.1	-109.1	-109.1	109.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	94.4	-54.4	-193.8	93.7	-68.5	54.0	-68.5	54.0
Long. Memb. P	-9.6	-9.6	-9.6	-9.6	-16.9	-16.9	-16.9	-16.9
Long. Bend. P	-43.3	43.3	-43.3	43.3	-28.6	28.6	-28.6	28.6
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	27.9	27.9	-27.9	-27.9	0.0	0.0	0.0	0.0
Long. Bend. ML	64.8	-64.8	-64.8	64.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	39.8	-3.2	-145.7	70.6	-45.6	11.7	-45.6	11.7
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-5.7	-5.7	5.7	5.7
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-5.7	-5.7	5.7	5.7
Str. Int.	94.4	54.4	193.8	93.7	69.8	54.8	69.8	54.8

Dimensionless Parameters used : Gamma = 211.10
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-53.8	-53.8	-53.8	-53.8	-13.5	-13.5	-13.5	-13.5

Circ. Bend. P	-43.5	43.5	-43.5	43.5	-366.0	366.0	-366.0	366.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	113.6	113.6	-113.6	-113.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	111.7	-111.7	-111.7	111.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	128.1	-8.4	-322.6	-12.2	-379.5	352.5	-379.5	352.5
Long. Memb. P	-16.3	-16.3	-16.3	-16.3	-61.1	-61.1	-61.1	-61.1
Long. Bend. P	-92.1	92.1	-92.1	92.1	-198.7	198.7	-198.7	198.7
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	64.0	64.0	-64.0	-64.0	0.0	0.0	0.0	0.0
Long. Bend. ML	98.3	-98.3	-98.3	98.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	53.9	41.6	-270.7	110.1	-259.8	137.5	-259.8	137.5
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-14.4	-14.4	14.4	14.4
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-14.4	-14.4	14.4	14.4
Str. Int.	128.1	50.0	322.6	122.3	381.2	353.4	381.2	353.4

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Circ. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Circ. Pl (SUS)	6.4	6.4	-8.8	-8.8	-0.6	-0.6	-0.6	-0.6
Circ. Pl (OCC)	20.0	20.0	-50.0	-50.0	-7.2	-7.2	-7.2	-7.2
Circ. Pl(TOTAL)	26.4	26.4	-58.8	-58.8	-7.8	-7.8	-7.8	-7.8
Circ. Q (SUS)	20.8	-20.8	-26.4	26.4	-4.9	4.9	-4.9	4.9
Circ. Q (OCC)	74.4	-74.4	-143.8	143.8	-61.3	61.3	-61.3	61.3
Circ. Q (TOTAL)	95.2	-95.2	-170.2	170.2	-66.2	66.2	-66.2	66.2
Long. Pm (SUS)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Long. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Long. Pl (SUS)	5.3	5.3	-6.8	-6.8	-1.4	-1.4	-1.4	-1.4
Long. Pl (OCC)	18.3	18.3	-37.5	-37.5	-16.9	-16.9	-16.9	-16.9
Long. Pl(TOTAL)	23.6	23.6	-44.3	-44.3	-18.3	-18.3	-18.3	-18.3
Long. Q (SUS)	10.5	-10.5	-17.5	17.5	-2.3	2.3	-2.3	2.3
Long. Q (OCC)	21.5	-21.5	-108.2	108.2	-28.6	28.6	-28.6	28.6
Long. Q (TOTAL)	32.0	-32.0	-125.7	125.7	-30.9	30.9	-30.9	30.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-0.4	-0.4	0.4	0.4	-2.3	-2.3	2.3	2.3
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-5.7	-5.7	5.7	5.7
Shear Pl(TOTAL)	-0.4	-0.4	0.4	0.4	-8.0	-8.0	8.0	8.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Pm (SUS+OCC)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Pm+Pl (SUS)	8.1	8.1	7.3	7.3	4.8	4.8	4.8	4.8
Pm+Pl (SUS+OCC)	28.0	28.1	57.2	57.2	21.6	21.6	21.6	21.6
Pm+Pl+Q (Total)	123.2	67.2	227.4	113.0	74.8	61.3	74.8	61.3

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	1.63	137.90	Passed
Pm (SUS+OCC)	1.63	165.48	Passed
Pm+Pl (SUS)	8.10	206.85	Passed
Pm+Pl (SUS+OCC)	57.22	248.22	Passed
Pm+Pl+Q (TOTAL)	227.39	413.70	Passed

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.
This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Circ. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Circ. Pl (SUS)	20.3	20.3	-28.9	-28.9	-1.1	-1.1	-1.1	-1.1
Circ. Pl (OCC)	59.8	59.8	-167.4	-167.4	-13.5	-13.5	-13.5	-13.5
Circ. Pl(TOTAL)	80.1	80.1	-196.4	-196.4	-14.6	-14.6	-14.6	-14.6
Circ. Q (SUS)	20.7	-20.7	-27.7	27.7	-29.5	29.5	-29.5	29.5
Circ. Q (OCC)	68.3	-68.3	-155.2	155.2	-366.0	366.0	-366.0	366.0
Circ. Q (TOTAL)	89.0	-89.0	-182.9	182.9	-395.5	395.5	-395.5	395.5
Long. Pm (SUS)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Long. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Long. Pl (SUS)	12.6	12.6	-15.2	-15.2	-4.9	-4.9	-4.9	-4.9
Long. Pl (OCC)	47.7	47.7	-80.3	-80.3	-61.1	-61.1	-61.1	-61.1

Long. Pl(TOTAL)	60.3	60.3	-95.5	-95.5	-66.1	-66.1	-66.1	-66.1
Long. Q (SUS)	13.9	-13.9	-28.7	28.7	-16.0	16.0	-16.0	16.0
Long. Q (OCC)	6.2	-6.2	-190.4	190.4	-198.7	198.7	-198.7	198.7
Long. Q (TOTAL)	20.0	-20.0	-219.1	219.1	-214.7	214.7	-214.7	214.7
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-0.5	-0.5	0.5	0.5	-5.7	-5.7	5.7	5.7
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-14.4	-14.4	14.4	14.4
Shear Pl(TOTAL)	-0.5	-0.5	0.5	0.5	-20.1	-20.1	20.1	20.1
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS+OCC)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm+Pl (SUS)	24.5	24.5	24.8	24.7	12.9	12.9	12.9	12.9
Pm+Pl (SUS+OCC)	84.3	84.3	192.2	192.1	70.7	70.7	70.7	70.7
Pm+Pl+Q (Total)	173.2	47.0	375.1	135.0	409.0	386.8	409.0	386.8

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	4.22	137.90	Passed
Pm (SUS+OCC)	4.22	165.48	Passed
Pm+Pl (SUS)	24.76	206.85	Passed
Pm+Pl (SUS+OCC)	192.15	248.22	Passed
Pm+Pl+Q (TOTAL)	408.96	413.70	Passed

The Pm+Pl+Q allowable was based on a temperature range cycling from ambient to design temperature.
This allowable is computed per ASME VIII-2, 5.5.6.1(1) Part 5, 3((Smc + Smh)/2).

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-283 C	
Baseplate Allowable Stress	SBA	108.25	N./mm²
Baseplate Length	B	500.0000	mm.
Baseplate Width	D	500.0000	mm.
Baseplate Thickness	BTHK	45.0000	mm.
Leg Dimension Along Baseplate Length	d	159.9997	mm.
Leg Dimension Along Baseplate Width	b	159.9997	mm.
Dist. from the Leg Edge to Bolt Hole Center	z	70.0000	mm.
Bolt Material		SA-36	
Bolt Allowable Tensile Stress	STBA	114.46	N./mm²
Bolt Allowable Shear Stress	SBShear	68.67	N./mm²
Anchor Bolt Nominal Diameter	BOD	27.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	2	
Total Number of Anchors Bolt per Leg	NBT	4	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm²

Shear Stress in a Single Bolt [taub]:
= Shear Force / (2 * Bolt Area * Number of Bolts)
= 6216/(2 * 4.14 * 4)
= 18.4 N./mm². Must be less than 68.7 N./mm².

LEG BASEPLATE and BOLTING Analysis, including Moments

I-Beam Leg

Base Plate Available Area (AA):
= B * D
= 500.0 * 500.0
= 2500.00 cm²

Clearance Between The Bolt And The Leg Edge (BCL):
= z - BOD / 2
= 70.0 - 27.0/2
= 56.50 mm.

Moment at Baseplate (MOMENT):
= Vleg * Lleg
= 2290.47 * 1750.0
= 4008.40 Kg-m.

Axial Load on the baseplate (P):
= Operating Weight per leg (as Seismic + Operating case is controlling)
= 3531.01 Kgf

Eccentricity (e):
= MOMENT * Conv_Factor / P
= 4008.4 *9806.64/3531.01
= 1135.18 mm. > D/6 [Plate Uplift Condition]

a = (D - d) / 2
= (500.0 - 160.0)/2
= 170.00 mm.

Modular Ratio Of Steel/Concrete (n):
= ES / EC
= 203402.5/21526.32
= 9.45

F = 0.5 * d + z
= 0.5 * 160.0 + 70.0
= 150.00 mm.

K1 = 3.0 (e - 0.5*D)
= 3.0 (1135.18 - 0.5*500.0)
= 2655.54

K2 = 6 * n * Ast / B * (F + e)
= 6 * 9.45 * 8.28/500.0 * (150.0 + 1135.18)
= 1206.16

K3 = -K2 * (0.5 * D + F)
= -1206.16 * (0.5 * 500.0 + 150.0)

```
    = -482465.59
```

Solving For The Effective Bearing Length Using Iteration:

```
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + 104.55 * Y² + 186.96 * Y - 2944.19 = 0
Y  = 112.03  mm.

NUM = (D / 2 - Y / 3 - e)
     = (500.0/2 - 112.03/3 - 1135.18)
     = -922.52

DENOM = (D / 2 - Y / 3 + F)
       = (500.0/2 - 112.03/3 + 150.0)
       = 362.66
```

Total Bolt Tension Force (T):

```
   = - P * NUM / DENOM
   = - 3531.01 * -922.52/362.66
   = 8982.12  Kgf
```

Overturning Moment Due To Bolt In Tension (Mt):

```
   = T * (0.5 * D + F - Y)
   = 8982.12 * (0.5 * 500.0 + 150.0 - 112.03)
   = 2586.65  Kg-m.
```

Bearing Pressure (FC):

```
   = 2 * (P + T) / (Y * B)
   = 2 * (3531.01 + 8982.12)/(112.03 * 500.0)
   = 43.81 bars [ <= FCPRIME ( 206.84)]
```

Equivalent Bearing Pressure (f1):

```
   = FC * (Y - a) / Y
   = 43.81 * (112.03 - 170.0)/112.03
   = -22.67  bars
```

Overturning Moment Due To Bearing Pressure (Mc):

```
   = (a² * B / 6) * (f1 + 2 * FC)
   = (170.0² * 500.0/6) * (-22.67 + 2 * 43.81)
   = 1595.24  Kg-m.
```

The Baseplate Required Thickness (TREQ):

```
   = (6 * MAX(Mt,Mc) / (B * 1.5 * SBA))½
   = (6 * 2586.65/(500.0 * 162.38))½
   = 43.30  mm.
```

Required bolt area (ABREQM): per D. Moss

```
   = T / STBA
   = 8982.12/114.46
   = 7.6960 cm² [ < Ast ( 8.28) --> PASSED]
```

Distance from Top of Legs to Vessel CG (CD_DIST):

```
   = 2316.08 mm.
```

Total Overturning Moment at Baseplate (Mbb):

```
   = ( Mleg / max([CD_DIST], minDist) )* ( CD_DIST + Lleg )
   = ( 20167.15/max( 2316.08, 38.1 ) ) * ( 2316.08 + 1750.0 )
   = 35405.16  Kg-m.
```

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

```
= (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2) ) - W )
= (1/(4 * 114.46)) * ((4 * 35405.16/(2292.0)) - 14124.02 )
= 10.2098 cm²
```

Available Total Bolt Corr. Area per Leg (ABAVL):

```
= As * NBT
= 4.14 * 4.0
= 16.5541 cm² [ > ABREQB ( 10.21) --> PASSED]
```

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm.):	45.000	43.297	Pass
Bolt Root Area (Bednar)	(cm²):	16.55	10.21	Pass
Bolt Root Area (D. Moss)	(cm²):	8.28	7.70	Pass

Note: The required thickness calculation is performed based on:
- Strong axis orientation of the beam leg
- Even number of bolts installed only on the B dimension sides

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
Drain - 3"	1.56	OK	...	OK	4.50	OK	Passed
MH1 - 24"	3.26	OK	...	...		OK	Passed
Gas Inlet - 6"	4.07	OK	...	OK	4.50	OK	Passed
Utility - 2"	2.37	OK	...	OK	4.50	OK	Passed
Gas Outlet - 6"		...	...	OK	4.50	OK	No Calc[*]
MH2 - 24"	1.61	OK	...	...		OK	Passed
PSV - 2"	1.61	OK	...	OK	4.50	OK	Passed
PSV - 2"	1.61	OK	...	OK	4.50	OK	Passed

MAWP Summary:

```
Minimum MAWP Nozzles          :        1.564 Nozzle  : Drain - 3"
Minimum MAWP Shells/Flanges   :        1.564 Element : Lower Head
Minimum MAPnc Shells/Flanges  :        5.356 Element : Upper Head

Computed Vessel M.A.W.P.      :        1.564 bars
```

[*] - This was a small opening and the areas were not computed or
the MAWP of this connection could not be computed because
the longitudinal bending stress was greater than the hoop stress.

Note: MAWPs (Internal Case) shown above are at the High Point.

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	Drain - 3"	0.000	0.000	170.598
20	MH1 - 24"	850.000	180.000	1211.200
20	Gas Inlet - 6"	250.000	75.000	310.145
20	Utility - 2"	250.000	105.000	113.270
50	Gas Outlet - 6"	5150.000	180.000	323.658
60	MH2 - 24"	0.000	0.000	1211.200
60	PSV - 2"	0.000	180.000	113.270

The nozzle spacing is computed by the following:
= Sqrt($ll^2 + lc^2$) where
ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.
No interference violations have been detected !

Input, Nozzle Desc: Drain - 3" From: 10

Pressure for Reinforcement Calculations	P	0.249	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Elliptical Head	D	2100.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	4.8000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

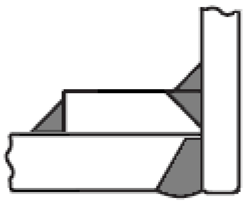
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	STD	
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	2.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	4.8000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	5.0000	mm.
Weld leg size between Pad and Shell	Wp	3.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	4.8000	mm.

```
Reinforcing Pad Width                                  50.5500  mm.

Class of attached Flange                               150
Grade of attached Flange                               GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Reinforcement CALCULATION, Description: Drain - 3"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation              3.500  in.
Actual Thickness Used in Calculation                     0.189  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]

```
 = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
 = (0.25*0.898*2106.0)/(2 *137.9*1.0-0.2*0.25)
 = 0.1708 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.25*44.45)/(118*1.0+0.4*0.25)
 = 0.0094 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1389 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl   170.5976  mm.
Parallel to Vessel Wall, opening length              d    85.2988  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     4.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
 = min( 1, Sn/Sv )
```

```
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
 = min( 1, Sp/Sv )
 = min( 1, 137.9/137.9 )
 = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
 = min( fr2, fr4 )
 = min( 0.855, 1.0 )
 = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.147	0.729	NA
Area in Shell	A1	1.381	0.086	NA
Area in Nozzle Wall	A2	0.138	0.128	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.000	0.000	NA
Area in Element	A5	2.757	2.757	NA
TOTAL AREA AVAILABLE	Atot	4.276	2.971	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	104.1561	5.0000	mm.
Based on given Pad Diameter:	190.0000	0.8403	mm.

Area Required [A]:

```
 = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
 = 0.5(85.2988*1.6985*1+2*1.8006*1.6985*1(1-0.86))
 = 0.729 cm²
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
 = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
 = 85.299( 1.0 * 1.8 - 1.0 * 1.698 ) - 2 * 1.801
   ( 1.0 * 1.8 - 1.0 * 1.6985 ) * ( 1 - 0.855 )
 = 0.086 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
 = ( 2 * Tlwp ) * ( tn - trn ) * fr2
 = ( 2 * 4.5 ) * ( 1.8 - 0.14 ) * 0.855
 = 0.128 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
 = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
 = (0.0 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
```

= 0.000 cm²

Area Available in Element, also see UG-37(h) [A5]:
```
 = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
 = ( 170.5976 - 88.9 )4.5 * 1.0 * 0.75
 = 2.757 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 3.1389 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 3.5863 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.3830 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 7.8, max( 4.5, 4.5 ) ]
 = 4.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 3.1389, 4.5 )
 = 4.5000 mm.
```

Available Nozzle Neck Thickness = 4.8006 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
Sustained  :     34.5,  Allowable :    117.9 N./mm²  Passed
Expansion  :      0.0,  Allowable :    260.2 N./mm²  Passed
Occasional :      0.3,  Allowable :    156.8 N./mm²  Passed
Shear      :     23.8,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 4.801, tr = 0.009, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.005, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 4.801, tr = 0.009, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.005, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 4.801, tr = 0.009, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.005, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 4.8, tr = 0.171, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.095, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 4.8, tr = 0.171, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.095, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Governing MDMT of the Nozzle                          :   -104 °C
Governing MDMT of the Reinforcement Pad               :   -104 °C
Governing MDMT of all the sub-joints of this Junction :   -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.25/19.60 = 0.013

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Drain - 3"

```
Intermediate Calc. for nozzle/shell Welds   Tmin       1.8006  mm.
Intermediate Calc. for pad/shell Welds   TminPad       3.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.2604 = 0.7 * tmin.	1.4140 = 0.7 * Wo mm.
Pad Weld	1.5000 = 0.5*TminPad	2.1210 = 0.7 * Wp mm.

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, ( 0.7288 - 0.0861 + 2 * 1.8006 * 0.855 *
   (1.0 * 1.8 - 1.6985 ) )138)
 = 908.23 Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.1279 + 2.7573 + 0.0 - 0.0 * 0.86 ) * 138
 = 4057.01 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.1279 + 0.0 + 0.0342 + ( 0.0554 ) ) * 138
 = 305.83 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.1279 + 0.0 + 0.0 + 2.7573 + ( 0.0554 ) ) * 138
 = 4134.94 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 88.9 * 2.0 * 0.49 * 118
 = 1645. Kgf
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 190.0 * 3.0 * 0.49 * 138
 = 6169. Kgf
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 43.5497) * ( 4.8006 - 3.0 ) * 0.7 * 118
 = 2073. Kgf
```

Tension, Pad Groove Weld [Tpgw]:
```
 = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
 =  (3.1416/2 ) * 88.9 * 4.8 * 0.74 * 138
 = 6975. Kgf
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 88.9 * ( 4.8 - 3.0 ) * 0.74 * 138
 = 2616. Kgf
```

Strength of Failure Paths:

```
 PATH11 = ( SPEW + SNW ) = ( 6169 + 2073 ) = 8242 Kgf
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 1645 + 6975 + 2616 + 0 ) = 11236 Kgf
 PATH33 = ( Spew + Tngw + Sinw )
        = ( 6169 + 2616 + 0 ) = 8785 Kgf
```

Summary of Failure Path Calculations:
```
Path 1-1 = 8242 Kgf, must exceed W = 908 Kgf or W1 = 4057 Kgf
Path 2-2 = 11235 Kgf, must exceed W = 908 Kgf or W2 = 305 Kgf
Path 3-3 = 8784 Kgf, must exceed W = 908 Kgf or W3 = 4134 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        1.613   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
Nozzle is O.K. for the External Pressure                0.100   bars
```

The Drop for this Nozzle is : 0.5217 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 155.3218 mm.

Input Echo, WRC107/537 Item 1, Description: Drain - 3" :

```
Diameter Basis for Vessel                  Vbasis      ID
Cylindrical or Spherical Vessel            Cylsph      Spherical
Internal Corrosion Allowance                  Cas      3.0000   mm.
Vessel Diameter                                Dv    3780.000   mm.
Vessel Thickness                               Tv       4.800   mm.

Design Temperature                             T1        85.0   °C
Vessel Material                                     SA-516 70
Vessel UNS Number                                      K02700
Vessel Cold S.I. Allowable                    Smc      137.90   N./mm²
Vessel Hot  S.I. Allowable                    Smh      137.90   N./mm²
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
Attachment Type                              Type      Round
WRC107 Attachment Classification           Holsol      Hollow

Diameter Basis for Nozzle                  Nbasis      OD
Corrosion Allowance for Nozzle                Can      3.0000   mm.
Nozzle Diameter                                Dn      88.900   mm.
Nozzle Thickness                               Tn       4.801   mm.
Nozzle Material                                       SA-106 B
Nozzle UNS Number                                      K03006
Nozzle Cold S.I. Allowable                   SNmc      117.90   N./mm²
Nozzle Hot  S.I. Allowable                   SNmh      117.90   N./mm²

Thickness of Reinforcing Pad                 Tpad       5.000   mm.
Diameter  of Reinforcing Pad                 Dpad     190.000   mm.

Design Internal Pressure                       Dp       0.249   bars
Include Pressure Thrust                                    No
```

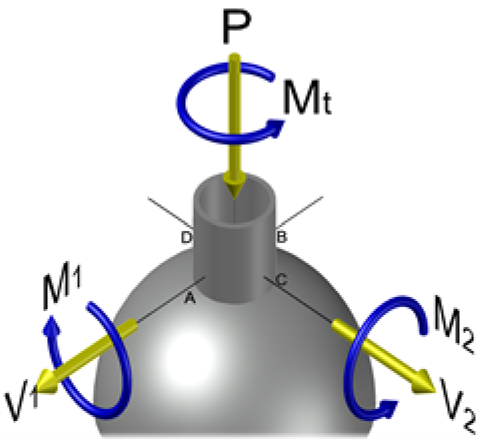
External Forces and Moments in WRC 107/537 Convention:

```
Radial Load               (SUS)                 P       -76.3   Kgf
Longitudinal Shear        (SUS)           (Vl)  V1       95.5   Kgf
Circumferential Shear     (SUS)           (Vc)  V2       95.5   Kgf
Circumferential Moment    (SUS)           (Mc)  M1      -23.7   Kg-m.
Longitudinal Moment       (SUS)           (Ml)  M2       30.2   Kg-m.
Torsional Moment          (SUS)                 Mt       38.3   Kg-m.
```

```
Use Interactive Control                          No
WRC107 Version                          Version  March  1979

Include Pressure Stress Indices per Div. 2               No
Compute Pressure Stress per WRC-368                      No
Local Loads applied at end of Nozzle/Attachment          No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
 = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
 = 88.9 + 2 * 1.65 * sqrt( 1893.9 ( 4.8 - 3.0 ) )
 = 281.577 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                P       -76.3   Kgf
Circumferential Shear               (VC)  V2        95.5   Kgf
Longitudinal Shear                  (VL)  V1        95.5   Kgf
Circumferential Moment              (MC)  M1       -23.7   Kg-m.
Longitudinal Moment                 (ML)  M2        30.2   Kg-m.
Torsional Moment                          MT        38.3   Kg-m.

Dimensionless Param: U =   0.39 TAU =  24.19 RHO =   4.00 (   3.78)
```

Dimensionless Loads for Spherical Shells at Attachment Junction:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SP 7	0.03828	(A,B,C,D)
M(x) / P	SP 7	0.02663	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SM 7	0.10400	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SM 7	0.07951	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SM 7	0.10400	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SM 7	0.07951	(A,B,C,D)
N(y) * T / P	SP 7	0.33890	(A,B,C,D)
M(y) / P	SP 7	0.10221	(A,B,C,D)

```
N(y) * T * SQRT(Rm * T ) / MC    SM 7    0.36577   (A,B,C,D)
M(y)     * SQRT(Rm * T ) / MC    SM 7    0.35444   (A,B,C,D)
N(y) * T * SQRT(Rm * T ) / ML    SM 7    0.36577   (A,B,C,D)
M(y)     * SQRT(Rm * T ) / ML    SM 7    0.35444   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Rad. Bend. P	2.6	-2.6	2.6	-2.6	2.6	-2.6	2.6	-2.6
Rad. Memb. MC	0.0	0.0	0.0	0.0	4.6	4.6	-4.6	-4.6
Rad. Memb. MC	0.0	0.0	0.0	0.0	21.1	-21.1	-21.1	21.1
Rad. Memb. ML	-5.9	-5.9	5.9	5.9	0.0	0.0	0.0	0.0
Rad. Bend. ML	-26.9	26.9	26.9	-26.9	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-29.5	19.1	36.0	-23.0	28.9	-18.4	-22.5	14.5
Tang. Memb. P	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Tang. Bend. P	9.9	-9.9	9.9	-9.9	9.9	-9.9	9.9	-9.9
Tang. Memb. MC	0.0	0.0	0.0	0.0	16.2	16.2	-16.2	-16.2
Tang. Bend. MC	0.0	0.0	0.0	0.0	94.0	-94.0	-94.0	94.0
Tang. Memb. ML	-20.6	-20.6	20.6	20.6	0.0	0.0	0.0	0.0
Tang. Bend. ML	-119.9	119.9	119.9	-119.9	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-125.1	94.8	155.9	-103.7	125.5	-82.2	-94.7	73.4
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Tot. Shear	5.4	5.4	3.5	3.5	3.5	3.5	5.4	5.4
Str. Int.	125.4	95.2	156.0	103.8	125.6	82.4	95.1	73.9

Unitless Prm: U = 1.63 TAU = 0.00 (52.26) RHO = 0.00 (1.00)

Dimensionless Loads for Spherical Shells at Pad edge:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SR 2	0.03387	(A,B,C,D)
M(x) / P	SR 2	0.01640	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SR 3	0.03260	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SR 3	0.02308	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SR 3	0.03260	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SR 3	0.02308	(A,B,C,D)
N(y) * T / P	SR 2	0.01009	(A,B,C,D)
M(y) / P	SR 2	0.00491	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SR 3	0.00976	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SR 3	0.00683	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SR 3	0.00976	(A,B,C,D)

M(y) * SQRT(Rm * T) / ML SR 3 0.00683 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Rad. Bend. P	22.7	-22.7	22.7	-22.7	22.7	-22.7	22.7	-22.7
Rad. Memb. MC	0.0	0.0	0.0	0.0	40.0	40.0	-40.0	-40.0
Rad. Memb. MC	0.0	0.0	0.0	0.0	169.9	-169.9	-169.9	169.9
Rad. Memb. ML	-51.0	-51.0	51.0	51.0	0.0	0.0	0.0	0.0
Rad. Bend. ML	-216.7	216.7	216.7	-216.7	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-237.2	150.8	298.2	-180.6	240.4	-144.8	-179.3	115.0
Tang. Memb. P	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Tang. Bend. P	6.8	-6.8	6.8	-6.8	6.8	-6.8	6.8	-6.8
Tang. Memb. MC	0.0	0.0	0.0	0.0	12.0	12.0	-12.0	-12.0
Tang. Bend. MC	0.0	0.0	0.0	0.0	50.2	-50.2	-50.2	50.2
Tang. Memb. ML	-15.3	-15.3	15.3	15.3	0.0	0.0	0.0	0.0
Tang. Bend. ML	-64.1	64.1	64.1	-64.1	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-70.2	44.4	88.5	-53.3	71.3	-42.8	-53.1	33.8
Shear VC	1.7	1.7	-1.7	-1.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.7	-1.7	1.7	1.7
Shear MT	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Tot. Shear	5.4	5.4	1.9	1.9	1.9	1.9	5.4	5.4
Str. Int.	237.4	151.1	298.3	180.6	240.4	144.8	179.5	115.3

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Rad. Pl (SUS)	-5.2	-5.2	6.5	6.5	5.2	5.2	-4.0	-4.0
Rad. Q (SUS)	-24.3	24.3	29.5	-29.5	23.7	-23.7	-18.5	18.5
Long. Pm (SUS)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Long. Pl (SUS)	-15.1	-15.1	26.1	26.1	21.6	21.6	-10.7	-10.7
Long. Q (SUS)	-110.0	110.0	129.8	-129.8	103.9	-103.9	-84.0	84.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

Pm (SUS)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Pm+Pl (SUS)	11.8	11.8	29.6	29.6	25.2	25.2	7.4	7.4
Pm+Pl+Q (Total)	121.9	98.7	159.5	100.4	129.1	79.0	91.6	77.3

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	3.47	137.90	Passed
Pm+Pl (SUS)	29.62	206.85	Passed
Pm+Pl+Q (TOTAL)	159.46	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Rad. Pl (SUS)	-43.2	-43.2	58.8	58.8	47.8	47.8	-32.2	-32.2
Rad. Q (SUS)	-194.0	194.0	239.4	-239.4	192.6	-192.6	-147.1	147.1
Long. Pm (SUS)	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Long. Pl (SUS)	-12.9	-12.9	17.6	17.6	14.3	14.3	-9.6	-9.6
Long. Q (SUS)	-57.3	57.3	70.9	-70.9	57.0	-57.0	-43.4	43.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.7	1.7	-1.7	-1.7	-1.7	-1.7	1.7	1.7
Shear Q (SUS)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Pm (SUS)	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
Pm+Pl (SUS)	30.4	30.4	72.0	72.0	61.0	61.0	22.8	22.8
Pm+Pl+Q (Total)	224.2	164.2	311.4	167.5	253.5	131.7	166.4	128.4

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	13.10	137.90	Passed
Pm+Pl (SUS)	72.00	206.85	Passed
Pm+Pl+Q (TOTAL)	311.37	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: MH1 - 24" **From: 20**

Pressure for Reinforcement Calculations	P	0.249	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	2100.00	mm.
Design Length of Section	L	2224.9998	mm.
Shell Finished (Minimum) Thickness	t	8.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		850.00	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

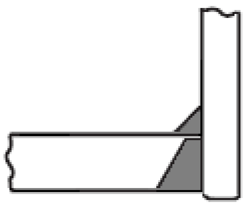
Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.0000	mm.
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	5.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	5.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

This is a Manway or Access Opening.

Class of attached Flange	150
Grade of attached Flange	GR 1.1

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: MH1 - 24"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          24.000  in.
Actual Thickness Used in Calculation                  0.197  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (0.25*1053.0)/(138*1.0-0.6*0.25)
 = 0.1902 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.25*304.8)/(138*1.0+0.4*0.25)
 = 0.0550 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4303 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)           Dl  1211.2000  mm.
Parallel to Vessel Wall, opening length             d   605.6000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     5.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 137.9/137.9 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
 = min( 1, Sn/Sv )
 = min( 1, 137.9/137.9 )
 = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
 = min( fr2, fr4 )
 = min( 1.0, 1.0 )
 = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.152	8.259	NA
Area in Shell	A1	29.128	13.763	NA
Area in Nozzle Wall	A2	0.194	0.157	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.250	0.250	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	29.573	14.170	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(605.6*2.7274*1+2*2.0*2.7274*1(1-1.0))
= 8.259 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 605.6(1.0 * 5.0 - 1.0 * 2.727) - 2 * 2.0
(1.0 * 5.0 - 1.0 * 2.7274) * (1 - 1.0)
= 13.763 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 5.0)(2.0 - 0.43)1.0
= 0.157 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo^2 - Area Lost)*fr2 + ($(Wi-can/0.707)^2$ - Area Lost)*fr2
= (5.0^2 - 0.0) * 1.0 + (0.0^2 -0.0) * 1.0
= 0.250 cm^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 5.0, tr = 0.055, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.028, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 5.0, tr = 0.055, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.028, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.25/19.60 = 0.013

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: MH1 - 24"

Intermediate Calc. for nozzle/shell Welds Tmin 2.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.4000 = 0.7 * tmin.	3.5350 = 0.7 * Wo mm.

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (8.2586 - 13.7628 + 2 * 2.0 * 1.0 *
   (1.0 * 5.0 - 2.7274 ) )138)
 = max( 0, -7611.95) Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.157 + 0.0 + 0.25 - 0.0 * 1.0 ) * 138
 = 572.26 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.157 + 0.0 + 0.25 + ( 0.2 ) ) * 138
 = 853.50 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.157 + 0.0 + 0.25 + 0.0 + ( 0.2 ) ) * 138
 = 853.50 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 609.6 * 5.0 * 0.49 * 138
 = 32989. Kgf
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 303.8) * ( 5.0 - 3.0 ) * 0.7 * 138
```

```
  = 18789. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 609.6 * ( 5.0 - 3.0 ) * 0.74 * 138
  = 19928. Kgf
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 32989 + 18789 ) = 51778 Kgf
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 32989 + 0 + 19928 + 0 ) = 52917 Kgf
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 32989 + 19928 + 0 ) = 52917 Kgf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 51777 Kgf, must exceed W = 0 Kgf or W1 = 572 Kgf
Path 2-2 = 52916 Kgf, must exceed W = 0 Kgf or W2 = 853 Kgf
Path 3-3 = 52916 Kgf, must exceed W = 0 Kgf or W3 = 853 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        3.310   bars

Nozzle is O.K. for the External Pressure                0.100   bars
```

The Drop for this Nozzle is : 45.2129 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 203.2129 mm.

Percent Elongation Calculations:

```
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  0.827 %
```

Input, Nozzle Desc: Gas Inlet - 6" From: 20

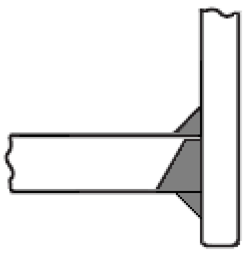
Pressure for Reinforcement Calculations	P	0.249	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	2100.00	mm.
Design Length of Section	L	2224.9998	mm.
Shell Finished (Minimum) Thickness	t	8.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		75.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	5.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.0000	mm.
Inside Projection	h	2000.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, with Inside projection

Reinforcement CALCULATION, Description: Gas Inlet - 6"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation            6.625  in.
Actual Thickness Used in Calculation                   0.378  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (0.25*1053.0)/(138*1.0-0.6*0.25)
 = 0.1902 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.25*84.1375)/(118*1.0+0.4*0.25)
 = 0.0178 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2031 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)           Dl    310.1452  mm.
Parallel to Vessel Wall, opening length             d    155.0726  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    12.5000  mm.
Normal to Vessel Wall, Inward                              9.0030  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
 = min( fr2, fr4 )
 = min( 0.855, 1.0 )
 = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.299	2.141	NA
Area in Shell	A1	7.367	3.481	NA
Area in Nozzle Wall	A2	1.407	1.368	NA
Area in Inward Nozzle	A3	0.554	0.554	NA
Area in Welds	A41+A42+A43	0.214	0.214	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	9.542	5.616	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
 = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
 = 0.5(155.0726*2.7274*1+2*6.6012*2.7274*1(1-0.86))
 = 2.141 cm²
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
 = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
 = 155.073( 1.0 * 5.0 - 1.0 * 2.727 ) - 2 * 6.601
   ( 1.0 * 5.0 - 1.0 * 2.7274 ) * ( 1 - 0.855 )
 = 3.481 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
 = ( 2 * tlnp )( tn - trn )fr2
 = ( 2 * 12.5 )( 6.6 - 0.2 ) 0.855
 = 1.368 cm²
```

Area Available in Inward Nozzle [A3]:
```
 = 2 * ti * min( h, Tl, 2.5 * ti) * fr2
 = 2 * 3.6012 * ( 9.003 ) * 0.855
 = 0.554 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
 = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
 = 5.0² * 0.855 + ( 0.0 )² * 0.855
 = 0.214 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 3.2031 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 3.1902 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 9.22, max( 4.5, 4.5 ) ]
 = 4.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 3.2031, 4.5 )
 = 4.5000 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
Sustained   :     10.0,  Allowable :    117.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    284.8 N./mm²  Passed
Occasional  :      0.1,  Allowable :    156.8 N./mm²  Passed
Shear       :      6.9,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 9.601, tr = 0.018, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 8.0, tr = 0.19, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.038, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Governing MDMT of all the sub-joints of this Junction   :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.25/19.60 = 0.013

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Gas Inlet - 6"

```
Intermediate Calc. for nozzle/shell Welds    Tmin      5.0000   mm.
```

Results Per UW-16.1:
```
                      Required Thickness    Actual Thickness
Nozzle Weld          3.5000 = 0.7 * tmin.  3.5350 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

```
Weld Load [W]:
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (2.1408 - 3.4807 + 2 * 6.6012 * 0.855 *
   (1.0 * 5.0 - 2.7274 ) )138)
 = max( 0, -1523.27) Kgf
```

Note: F is always set to 1.0 throughout the calculation.

```
Weld Load [W1]:
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.3676 + 0.0 + 0.2138 - 0.0 * 0.86 ) * 138
 = 2223.64 Kgf

Weld Load [W2]:
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 1.3676 + 0.5544 + 0.2138 + ( 0.5644 ) ) * 138
 = 3796.87 Kgf

Weld Load [W3]:
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 1.3676 + 0.5544 + 0.2138 + 0.0 + ( 0.5644 ) ) * 138
 = 3796.87 Kgf
```

Strength of Connection Elements for Failure Path Analysis

```
Shear, Outward Nozzle Weld [Sonw]:
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 168.275 * 5.0 * 0.49 * 118
 = 7786. Kgf

Shear, Nozzle Wall [Snw]:
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
 = 14109. Kgf

Tension, Shell Groove Weld [Tngw]:
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 168.275 * ( 8.0 - 3.0 ) * 0.74 * 138
 = 13752. Kgf
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 7786 + 14109 ) = 21894 Kgf
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 7786 + 0 + 13752 + 0 ) = 21538 Kgf
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 7786 + 13752 + 0 ) = 21538 Kgf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 21894 Kgf, must exceed W = 0 Kgf or W1 = 2223 Kgf
Path 2-2 = 21538 Kgf, must exceed W = 0 Kgf or W2 = 3796 Kgf
Path 3-3 = 21538 Kgf, must exceed W = 0 Kgf or W3 = 3796 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        4.120  bars
```

Nozzle is O.K. for the External Pressure 0.100 bars

The Drop for this Nozzle is : 3.3764 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 2158.0000 mm.

Input Echo, WRC107/537 Item 1, Description: Gas Inlet - 6":

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	2100.000	mm.
Vessel Thickness	Tv	8.000	mm.
Design Temperature	T1	85.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Design Internal Pressure	Dp	0.249	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

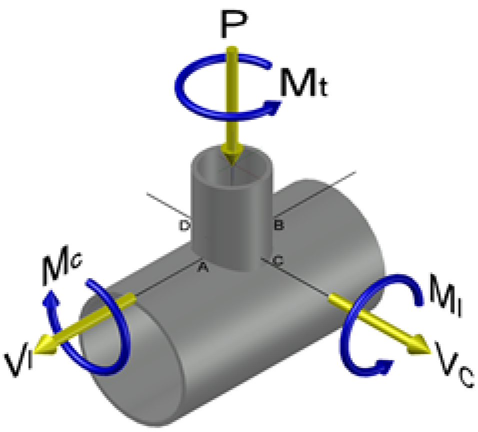
Radial Load	(SUS)	P	-144.4	Kgf
Longitudinal Shear	(SUS)	Vl	180.7	Kgf
Circumferential Shear	(SUS)	Vc	180.7	Kgf
Circumferential Moment	(SUS)	Mc	-84.4	Kg-m.
Longitudinal Moment	(SUS)	Ml	106.9	Kg-m.
Torsional Moment	(SUS)	Mt	136.2	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
 = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
 = 168.275 + 2 * 1.65 * sqrt( 1055.5 ( 8.0 - 3.0 ) )
 = 408.008 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-144.4	Kgf
Circumferential Shear	VC	180.7	Kgf
Longitudinal Shear	VL	180.7	Kgf
Circumferential Moment	MC	-84.4	Kg-m.
Longitudinal Moment	ML	106.9	Kg-m.
Torsional Moment	MT	136.2	Kg-m.

Dimensionless Parameters used : Gamma = 211.10

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.070	4C	32.151	(A,B)
N(PHI) / (P/Rm)	0.070	3C	23.152	(C,D)
M(PHI) / (P)	0.070	2C1	0.054	(A,B)
M(PHI) / (P)	0.070	1C	0.085	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.070	3A	8.190	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.070	1A	0.084	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.070	3B	23.391	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.070	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.070	3C	23.152	(A,B)
N(x) / (P/Rm)	0.070	4C	32.151	(C,D)
M(x) / (P)	0.070	1C1	0.089	(A,B)
M(x) / (P)	0.070	2C	0.054	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.070	4A	12.812	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.070	2A	0.042	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.070	4B	7.728	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.070	2B	0.048	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	8.6	8.6	8.6	8.6	6.2	6.2	6.2	6.2
Circ. Bend. P	18.2	-18.2	18.2	-18.2	29.0	-29.0	29.0	-29.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	17.5	17.5	-17.5	-17.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	225.5	-225.5	-225.5	225.5
Circ. Memb. ML	-63.1	-63.1	63.1	63.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	-107.9	107.9	107.9	-107.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-144.2	35.3	197.8	-54.4	278.1	-230.8	-207.7	185.3
Long. Memb. P	6.2	6.2	6.2	6.2	8.6	8.6	8.6	8.6
Long. Bend. P	30.3	-30.3	30.3	-30.3	18.3	-18.3	18.3	-18.3
Long. Memb. MC	0.0	0.0	0.0	0.0	27.3	27.3	-27.3	-27.3
Long. Bend. MC	0.0	0.0	0.0	0.0	113.2	-113.2	-113.2	113.2
Long. Memb. ML	-20.8	-20.8	20.8	20.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-162.4	162.4	162.4	-162.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-146.8	117.5	219.8	-165.7	167.4	-95.6	-113.7	76.3
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tot. Shear	7.3	7.3	4.7	4.7	4.7	4.7	7.3	7.3
Str. Int.	152.9	118.1	220.7	165.9	278.3	231.0	208.3	185.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5.2	5.3	5.2	5.3	5.2	5.3	5.2	5.3
Circ. Pl (SUS)	-54.5	-54.5	71.7	71.7	23.7	23.7	-11.2	-11.2
Circ. Q (SUS)	-89.7	89.7	126.1	-126.1	254.5	-254.5	-196.5	196.5
Long. Pm (SUS)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Long. Pl (SUS)	-14.6	-14.6	27.1	27.1	35.9	35.9	-18.7	-18.7
Long. Q (SUS)	-132.1	132.1	192.7	-192.7	131.5	-131.5	-95.0	95.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Pm (SUS)	5.2	5.3	5.2	5.3	5.2	5.3	5.2	5.3
Pm+Pl (SUS)	49.3	49.3	77.0	77.0	38.7	38.7	16.2	16.2
Pm+Pl+Q (Total)	149.3	120.8	223.5	163.2	283.6	225.7	203.1	191.0

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5.26	137.90	Passed
Pm+Pl (SUS)	77.01	206.85	Passed
Pm+Pl+Q (TOTAL)	283.56	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: Utility - 2" From: 20

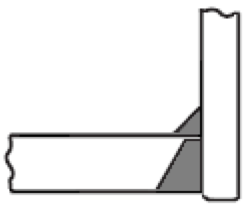
Pressure for Reinforcement Calculations	P	0.249	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	2100.00	mm.
Design Length of Section	L	2224.9998	mm.
Shell Finished (Minimum) Thickness	t	8.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		105.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	4.8000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	4.8000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: Utility - 2"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation            2.375  in.
Actual Thickness Used in Calculation                   0.191  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (0.25*1053.0)/(138*1.0-0.6*0.25)
 = 0.1902 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.25*30.1625)/(118*1.0+0.4*0.25)
 = 0.0064 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1107 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    113.2698  mm.
Parallel to Vessel Wall, opening length              d     56.6349  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      4.6126  mm.
```

Weld Strength Reduction Factor [fr1]:
```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
 = min( fr2, fr4 )
 = min( 0.855, 1.0 )
 = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc

Area Required	Ar	0.109	0.780	NA
Area in Shell	A1	2.698	1.275	NA
Area in Nozzle Wall	A2	0.145	0.137	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.197	0.197	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.040	1.608	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
 = 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
 = 0.5(56.6349*2.7274*1+2*1.845*2.7274*1(1-0.86))
 = 0.780 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
 = d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
 = 56.635(1.0 * 5.0 - 1.0 * 2.727) - 2 * 1.845
 (1.0 * 5.0 - 1.0 * 2.7274) * (1 - 0.855)
 = 1.275 cm²

Area Available in Nozzle Projecting Outward [A2]:
 = (2 * tlnp)(tn - trn)fr2
 = (2 * 4.61)(1.85 - 0.11) 0.855
 = 0.137 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
 = (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
 = (4.8² - 0.0004) * 0.855 + (0.0² -0.0) * 0.855
 = 0.197 cm²

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures       ta = 3.1107 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 3.1902 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                       tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
 = min[tb3, max(tb1,tb2)]
 = min[6.42, max(4.5, 4.5)]
 = 4.5000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
 = max(ta, tb)
 = max(3.1107, 4.5)
 = 4.5000 mm.

Available Nozzle Neck Thickness = 4.8450 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     34.8,  Allowable :    117.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    260.0 N./mm²  Passed
Occasional  :      0.2,  Allowable :    156.8 N./mm²  Passed
Shear       :     24.0,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 4.845, tr = 0.006, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 4.845, tr = 0.006, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Governing MDMT of all the sub-joints of this Junction  :   -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.25/19.60 = 0.013

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Utility - 2"

```
Intermediate Calc. for nozzle/shell Welds   Tmin      1.8450  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          1.2915 = 0.7 * tmin.  3.3936 = 0.7 * Wo mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, ( 0.7796 - 1.2749 + 2 * 1.845 * 0.855 *
   (1.0 * 5.0 - 2.7274 ) )138)
```

```
 = max( 0, -595.63) Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.1368 + 0.0 + 0.1967 - 0.0 * 0.86 ) * 138
 = 468.94 Kgf
```

Weld Load [W2]:

```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.1368 + 0.0 + 0.1967 + ( 0.1578 ) ) * 138
 = 690.77 Kgf
```

Weld Load [W3]:

```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.1368 + 0.0 + 0.1967 + 0.0 + ( 0.1578 ) ) * 138
 = 690.77 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 60.325 * 4.8 * 0.49 * 118
 = 2680. Kgf
```

Shear, Nozzle Wall [Snw]:

```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 29.24) * ( 4.845 - 3.0 ) * 0.7 * 118
 = 1426. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 60.325 * ( 4.8 - 3.0 ) * 0.74 * 138
 = 1775. Kgf
```

Strength of Failure Paths:

```
 PATH11 = ( SONW + SNW ) = ( 2680 + 1426 ) = 4106 Kgf
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 2680 + 0 + 1775 + 0 ) = 4454 Kgf
 PATH33 = ( Sonw + Tngw + Sinw )
        = ( 2680 + 1775 + 0 ) = 4454 Kgf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 4105 Kgf, must exceed W = 0 Kgf or W1 = 468 Kgf
Path 2-2 = 4454 Kgf, must exceed W = 0 Kgf or W2 = 690 Kgf
Path 3-3 = 4454 Kgf, must exceed W = 0 Kgf or W3 = 690 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        2.422  bars

Nozzle is O.K. for the External Pressure                0.100  bars
```

The Drop for this Nozzle is : 0.4333 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 158.4333 mm.

Input Echo, WRC107/537 Item 1, Description: Utility - 2" :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	2100.000	mm.
Vessel Thickness	Tv	8.000	mm.
Design Temperature	T1	85.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

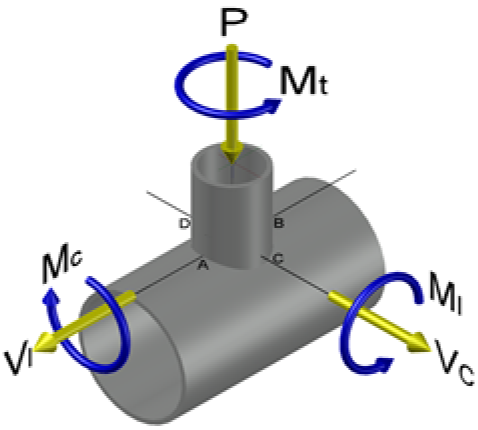
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.
Nozzle Thickness	Tn	4.845	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Design Internal Pressure	Dp	0.249	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-51.8	Kgf
Longitudinal Shear	(SUS)	Vl	64.9	Kgf
Circumferential Shear	(SUS)	Vc	64.9	Kgf
Circumferential Moment	(SUS)	Mc	-11.0	Kg-m.
Longitudinal Moment	(SUS)	Ml	13.9	Kg-m.
Torsional Moment	(SUS)	Mt	17.5	Kg-m.

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
 = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
 = 60.325 + 2 * 1.65 * sqrt( 1055.5 ( 8.0 - 3.0 ) )
 = 300.058 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-51.8	Kgf
Circumferential Shear	VC	64.9	Kgf
Longitudinal Shear	VL	64.9	Kgf
Circumferential Moment	MC	-11.0	Kg-m.
Longitudinal Moment	ML	13.9	Kg-m.
Torsional Moment	MT	17.5	Kg-m.

Dimensionless Parameters used : Gamma = 211.10

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.025	4C	39.860	(A,B)
N(PHI) / (P/Rm)	0.025	3C	37.828	(C,D)
M(PHI) / (P)	0.025	2C1 !	0.117	(A,B)
M(PHI) / (P)	0.025	1C !	0.161	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.025	3A	3.399	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.025	1A !	0.100	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.025	3B	12.435	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.025	1B !	0.055	(A,B,C,D)
N(x) / (P/Rm)	0.025	3C	37.828	(A,B)
N(x) / (P/Rm)	0.025	4C	39.860	(C,D)
M(x) / (P)	0.025	1C1	0.183	(A,B)
M(x) / (P)	0.025	2C !	0.118	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.025	4A	4.325	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.025	2A !	0.058	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.025	4B	3.345	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.025	2B !	0.086	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	3.8	3.8	3.8	3.8	3.6	3.6	3.6	3.6
Circ. Bend. P	14.3	-14.3	14.3	-14.3	19.6	-19.6	19.6	-19.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	2.6	2.6	-2.6	-2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	97.7	-97.7	-97.7	97.7
Circ. Memb. ML	-12.1	-12.1	12.1	12.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	-68.3	68.3	68.3	-68.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-62.3	45.7	98.5	-66.5	123.6	-111.1	-77.1	79.1
Long. Memb. P	3.6	3.6	3.6	3.6	3.8	3.8	3.8	3.8
Long. Bend. P	22.3	-22.3	22.3	-22.3	14.4	-14.4	14.4	-14.4
Long. Memb. MC	0.0	0.0	0.0	0.0	3.4	3.4	-3.4	-3.4
Long. Bend. MC	0.0	0.0	0.0	0.0	56.6	-56.6	-56.6	56.6
Long. Memb. ML	-3.3	-3.3	3.3	3.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-106.2	106.2	106.2	-106.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-83.6	84.3	135.4	-121.6	78.2	-63.8	-41.7	42.7
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tot. Shear	7.4	7.4	4.7	4.7	4.7	4.7	7.4	7.4
Str. Int.	85.9	85.7	136.0	122.0	124.1	111.5	78.6	80.6

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	5.2	5.3	5.2	5.3	5.2	5.3	5.2	5.3
Circ. Pl (SUS)	-8.3	-8.3	16.0	16.0	6.3	6.3	1.0	1.0
Circ. Q (SUS)	-54.0	54.0	82.5	-82.5	117.3	-117.3	-78.1	78.1
Long. Pm (SUS)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Long. Pl (SUS)	0.4	0.4	6.9	6.9	7.2	7.2	0.5	0.5
Long. Q (SUS)	-84.0	84.0	128.5	-128.5	71.0	-71.0	-42.2	42.2
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Pm (SUS)	5.2	5.3	5.2	5.3	5.2	5.3	5.2	5.3

Pm+Pl (SUS)	6.6	6.6	21.4	21.4	12.2	12.3	6.7	6.8
Pm+Pl+Q (Total)	83.1	88.4	138.6	119.4	129.3	106.3	73.5	85.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5.26	137.90	Passed
Pm+Pl (SUS)	21.39	206.85	Passed
Pm+Pl+Q (TOTAL)	138.65	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: Gas Outlet - 6" From: 50

Pressure for Reinforcement Calculations	P	0.200	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	2100.00	mm.
Design Length of Section	L	1224.9999	mm.
Shell Finished (Minimum) Thickness	t	6.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5150.00	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

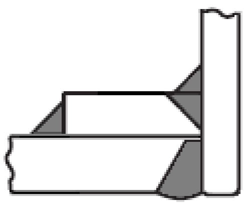
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	STD	
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	4.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	6.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	270.0000	mm.
Thickness of Pad	te	5.0000	mm.
Weld leg size between Pad and Shell	Wp	3.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	5.0000	mm.

```
Reinforcing Pad Width                                50.8625  mm.

Class of attached Flange                           150
Grade of attached Flange                           GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Reinforcement CALCULATION, Description: Gas Outlet - 6"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation             6.625  in.
Actual Thickness Used in Calculation                    0.245  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (0.2*1053.0)/(138*1.0-0.6*0.2)
 = 0.1528 mm.
```

The Longitudinal Stress Governs over the Hoop Stress on the shell course where this nozzle is located. The Maximum stress ratio times the Shell thickness will be used in the calculation of the Area required.

The Stress Ratio is 0.3029 and the shell thk. is 6.0000 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.2*84.1375)/(118*1.0+0.4*0.2)
 = 0.0143 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2031 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)             Dl   323.6580  mm.
Parallel to Vessel Wall, opening length               d   161.8290  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     7.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
```

= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.479	1.742	NA
Area in Shell	A1	3.365	1.383	NA
Area in Nozzle Wall	A2	0.412	0.387	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.208	0.208	NA
Area in Element	A5	3.815	3.815	NA
TOTAL AREA AVAILABLE	Atot	7.799	5.793	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.
The area available with the given pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(161.829*2.1404*1+2*3.223*2.1404*1(1-0.86))
= 1.742 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 161.829(1.0 * 3.0 - 1.0 * 2.14) - 2 * 3.223
(1.0 * 3.0 - 1.0 * 2.1404) * (1 - 0.855)
= 1.383 cm²

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 7.5) * (3.22 - 0.2) * 0.855
= 0.387 cm²

Area Available in Welds [A41 + A42 + A43]:
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= (0.1375) * 0.86 + (0.0) * 0.86 + 76.2² * 1.0

= 0.208 cm²

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (270.0 - 168.275)5.0 * 1.0 * 0.75
= 3.815 cm²

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 3.2031 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 3.1528 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[9.22, max(4.5, 4.5)]
= 4.5000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.2031, 4.5)
= 4.5000 mm.

Available Nozzle Neck Thickness = 6.2230 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained  :    19.1,  Allowable :    117.9 N./mm²  Passed
Expansion  :     0.0,  Allowable :    275.6 N./mm²  Passed
Occasional :     0.2,  Allowable :    156.8 N./mm²  Passed
Shear      :    13.1,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 6.223, tr = 0.014, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.004, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 5.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.051, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 5.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.051, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 5.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.051, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 6.0, tr = 0.153, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.051, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C

Governing MDMT of the Nozzle                           :  -104 °C
Governing MDMT of the Reinforcement Pad                :  -104 °C
Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.20/19.60 = 0.010

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: Gas Outlet - 6"

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.2230  mm.
Intermediate Calc. for pad/shell Welds   TminPad      3.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          2.2561 = 0.7 * tmin.  2.8280 = 0.7 * Wo mm.
Pad Weld             1.5000 = 0.5*TminPad  2.1210 = 0.7 * Wp mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (1.7419 - 1.3831 + 2 * 3.223 * 0.855 *
   (1.0 * 3.0 - 2.1404 ) )138)
```

```
 = 571.19 Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.3873 + 3.8147 + 0.2076 - 0.0 * 0.86 ) * 138
 = 6200.56 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.3873 + 0.0 + 0.1368 + ( 0.1653 ) ) * 138
 = 969.48 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.3873 + 0.0 + 0.2076 + 3.8147 + ( 0.1653 ) ) * 138
 = 6433.05 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 168.275 * 4.0 * 0.49 * 118
 = 6229. Kgf
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 270.0 * 3.0 * 0.49 * 138
 = 8767. Kgf
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 82.526) * ( 6.223 - 3.0 ) * 0.7 * 118
 = 7032. Kgf
```

Tension, Pad Groove Weld [Tpgw]:
```
 = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
 =  (3.1416/2 ) * 168.275 * 5.0 * 0.74 * 138
 = 13752. Kgf
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 168.275 * ( 6.0 - 3.0 ) * 0.74 * 138
 = 8251. Kgf
```

Strength of Failure Paths:

```
 PATH11 = ( SPEW + SNW ) = ( 8767 + 7032 ) = 15799 Kgf
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 6229 + 13752 + 8251 + 0 ) = 28232 Kgf
 PATH33 = ( Spew + Tngw + Sinw )
        = ( 8767 + 8251 + 0 ) = 17018 Kgf
```

Summary of Failure Path Calculations:
```
Path 1-1 = 15799 Kgf, must exceed W = 571 Kgf or W1 = 6200 Kgf
Path 2-2 = 28232 Kgf, must exceed W = 571 Kgf or W2 = 969 Kgf
```

Path 3-3 = 17018 Kgf, must exceed W = 571 Kgf or W3 = 6433 Kgf

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 3.333 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 3.3764 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 159.3765 mm.

Input Echo, WRC107/537 Item 1, Description: Gas Outlet - 6:

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	2100.000	mm.
Vessel Thickness	Tv	6.000	mm.
Design Temperature	T1	85.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	6.223	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Thickness of Reinforcing Pad	Tpad	5.000	mm.
Diameter of Reinforcing Pad	Dpad	270.000	mm.
Design Internal Pressure	Dp	0.200	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

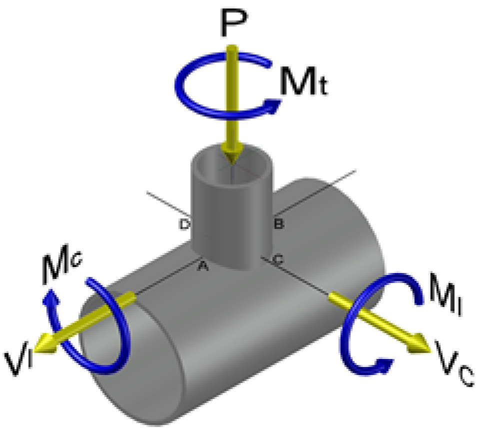
Radial Load	(SUS)	P	-144.4	Kgf
Longitudinal Shear	(SUS)	Vl	180.7	Kgf
Circumferential Shear	(SUS)	Vc	180.7	Kgf
Circumferential Moment	(SUS)	Mc	-84.4	Kg-m.
Longitudinal Moment	(SUS)	Ml	106.9	Kg-m.
Torsional Moment	(SUS)	Mt	136.2	Kg-m.

Use Interactive Control No

WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No
Compute Pressure Stress per WRC-368 No
Local Loads applied at end of Nozzle/Attachment No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 168.275 + 2 * 1.65 * sqrt(1054.5 (6.0 - 3.0))
= 353.884 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-144.4	Kgf
Circumferential Shear	VC	180.7	Kgf
Longitudinal Shear	VL	180.7	Kgf
Circumferential Moment	MC	-84.4	Kg-m.
Longitudinal Moment	ML	106.9	Kg-m.
Torsional Moment	MT	136.2	Kg-m.

Dimensionless Parameters used : Gamma = 132.12

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.070	4C	21.186	(A,B)
N(PHI) / (P/Rm)	0.070	3C	17.501	(C,D)
M(PHI) / (P)	0.070	2C1	0.071	(A,B)
M(PHI) / (P)	0.070	1C	0.105	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.070	3A	4.431	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.070	1A	0.089	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.070	3B	14.374	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.070	1B	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.070	3C	17.501	(A,B)

N(x) / (P/Rm)	0.070	4C	21.186	(C,D)
M(x) / (P)	0.070	1C1	0.109	(A,B)
M(x) / (P)	0.070	2C	0.071	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.070	4A	6.744	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.070	2A	0.049	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.070	4B	4.419	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.070	2B	0.061	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	3.5	3.5	3.5	3.5	2.9	2.9	2.9	2.9
Circ. Bend. P	9.4	-9.4	9.4	-9.4	14.0	-14.0	14.0	-14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	5.9	5.9	-5.9	-5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	94.1	-94.1	-94.1	94.1
Circ. Memb. ML	-24.2	-24.2	24.2	24.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	-52.4	52.4	52.4	-52.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-63.7	22.4	89.5	-34.0	116.9	-99.3	-83.1	77.2
Long. Memb. P	2.9	2.9	2.9	2.9	3.5	3.5	3.5	3.5
Long. Bend. P	14.5	-14.5	14.5	-14.5	9.4	-9.4	9.4	-9.4
Long. Memb. MC	0.0	0.0	0.0	0.0	9.0	9.0	-9.0	-9.0
Long. Bend. MC	0.0	0.0	0.0	0.0	51.2	-51.2	-51.2	51.2
Long. Memb. ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-81.0	81.0	81.0	-81.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.0	62.0	105.9	-85.1	73.1	-48.1	-47.3	36.4
Shear VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Tot. Shear	4.6	4.6	2.9	2.9	2.9	2.9	4.6	4.6
Str. Int.	73.3	62.6	106.4	85.3	117.1	99.4	83.7	77.7

Dimensionless Parameters used : Gamma = 300.00 (351.50)

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.112	4C	!	34.958	(A,B)
N(PHI) / (P/Rm)	0.112	3C	!	17.425	(C,D)
M(PHI) / (P)	0.112	2C1	!	0.020	(A,B)
M(PHI) / (P)	0.112	1C	!	0.070	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.112	3A	!	12.205	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.112	1A	!	0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.112	3B	!	25.572	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.112	1B	!	0.012	(A,B,C,D)

```
N(x)   / ( P/Rm )                  0.112   3C  !   17.425   (A,B)
N(x)   / ( P/Rm )                  0.112   4C  !   34.958   (C,D)
M(x)   / ( P )                     0.112   1C1 !    0.046   (A,B)
M(x)   / ( P )                     0.112   2C  !    0.036   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )     0.112   4A  !   26.375   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )     0.112   2A  !    0.025   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )     0.112   4B  !   11.012   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )     0.112   2B  !    0.016   (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	15.6	15.6	15.6	15.6	7.8	7.8	7.8	7.8
Circ. Bend. P	19.1	-19.1	19.1	-19.1	65.9	-65.9	65.9	-65.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	27.0	27.0	-27.0	-27.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	276.1	-276.1	-276.1	276.1
Circ. Memb. ML	-71.7	-71.7	71.7	71.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-72.3	72.3	72.3	-72.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-109.3	-2.8	178.7	-4.0	376.9	-307.2	-229.5	191.0
Long. Memb. P	7.8	7.8	7.8	7.8	15.6	15.6	15.6	15.6
Long. Bend. P	43.6	-43.6	43.6	-43.6	34.2	-34.2	34.2	-34.2
Long. Memb. MC	0.0	0.0	0.0	0.0	58.4	58.4	-58.4	-58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	114.6	-114.6	-114.6	114.6
Long. Memb. ML	-30.9	-30.9	30.9	30.9	0.0	0.0	0.0	0.0
Long. Bend. ML	-93.2	93.2	93.2	-93.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-72.7	26.6	175.5	-98.1	222.9	-74.7	-123.1	37.6
Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Tot. Shear	5.3	5.3	2.5	2.5	2.5	2.5	5.3	5.3
Str. Int.	110.1	31.2	180.1	98.2	376.9	307.2	229.8	191.2

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl

Circ. Pm (SUS)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Circ. Pl (SUS)	-20.6	-20.6	27.7	27.7	8.8	8.8	-3.0	-3.0
Circ. Q (SUS)	-43.1	43.1	61.8	-61.8	108.1	-108.1	-80.2	80.2
Long. Pm (SUS)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Long. Pl (SUS)	-4.5	-4.5	10.4	10.4	12.5	12.5	-5.4	-5.4
Long. Q (SUS)	-66.5	66.5	95.5	-95.5	60.6	-60.6	-41.8	41.8
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Pm (SUS)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Pm+Pl (SUS)	18.1	18.1	30.4	30.4	14.1	14.1	4.3	4.3
Pm+Pl+Q (Total)	71.7	63.9	107.7	84.0	119.7	96.8	81.1	80.3

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	2.64	137.90	Passed
Pm+Pl (SUS)	30.43	206.85	Passed
Pm+Pl+Q (TOTAL)	119.73	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107 / 537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Circ. Pl (SUS)	-56.1	-56.1	87.4	87.4	34.8	34.8	-19.2	-19.2
Circ. Q (SUS)	-53.3	53.3	91.4	-91.4	342.0	-342.0	-210.2	210.2
Long. Pm (SUS)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Long. Pl (SUS)	-23.1	-23.1	38.7	38.7	74.1	74.1	-42.8	-42.8
Long. Q (SUS)	-49.6	49.6	136.8	-136.8	148.8	-148.8	-80.3	80.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Pm (SUS)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Pm+Pl (SUS)	49.1	49.1	94.4	94.4	77.6	77.6	39.4	39.4
Pm+Pl+Q (Total)	103.1	31.1	186.6	97.7	383.9	300.2	222.7	198.2

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	7.03	137.90	Passed
Pm+Pl (SUS)	94.43	206.85	Passed
Pm+Pl+Q (TOTAL)	383.92	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: MH2 - 24" **From: 60**

Pressure for Reinforcement Calculations	P	0.200	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Elliptical Head	D	2100.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	4.8000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

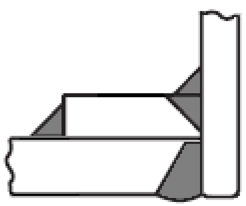
Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		24.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.0000	mm.
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	3.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	4.8000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	900.0000	mm.
Thickness of Pad	te	4.8000	mm.
Weld leg size between Pad and Shell	Wp	4.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	4.8000	mm.

```
Reinforcing Pad Width                               145.2000  mm.
This is a Manway or Access Opening.

Class of attached Flange                            150
Grade of attached Flange                            GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Reinforcement CALCULATION, Description: MH2 - 24"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation           24.000  in.
Actual Thickness Used in Calculation                   0.197  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]

```
 = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
 = (0.2*0.898*2106.0)/(2 *137.9*1.0-0.2*0.2)
 = 0.1371 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.2*304.8)/(138*1.0+0.4*0.2)
 = 0.0442 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5333 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl  1211.2000  mm.
Parallel to Vessel Wall, opening length              d   605.6000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     4.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 137.9/137.9 )
 = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
 = min( 1, Sn/Sv )
 = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.830	5.143	NA
Area in Shell	A1	10.071	0.615	NA
Area in Nozzle Wall	A2	0.176	0.132	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.160	0.160	NA
Area in Element	A5	9.801	9.801	NA
TOTAL AREA AVAILABLE	Atot	20.208	10.708	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	735.1172	4.8000	mm.
Based on given Pad Diameter:	900.0000	1.9450	mm.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(605.6*1.6985*1+2*2.0*1.6985*1(1-1.0))
= 5.143 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 605.6(1.0 * 1.8 - 1.0 * 1.698) - 2 * 2.0
(1.0 * 1.8 - 1.0 * 1.6985) * (1 - 1.0)
= 0.615 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 4.5) * (2.0 - 0.53) * 1.0
= 0.132 cm^2

Area Available in Welds [A41 + A42 + A43]:
= $(Wo^2$ - Ar Lost)*Fr3+((Wi-can/0.707)^2 - Ar Lost)*fr2 + Wp^2*fr4
= (0.0) * 1.0 + (0.0) * 1.0 + 101.6^2 * 1.0
= 0.160 cm^2

Area Available in Element, also see UG-37(h) [A5]:
```
 = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
 = ( 900.0 - 609.6 )4.5 * 1.0 * 0.75
 = 9.801 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 5.0, tr = 0.044, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.022, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 4.8, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 4.8, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 4.8, tr = 0.137, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 4.8, tr = 0.137, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C

Governing MDMT of the Nozzle                        :  -104 °C
Governing MDMT of the Reinforcement Pad             :  -104 °C
Governing MDMT of all the sub-joints of this Junction :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
```

```
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.20/19.60 = 0.010

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: MH2 - 24"

```
Intermediate Calc. for nozzle/shell Welds   Tmin      2.0000  mm.
Intermediate Calc. for pad/shell Welds   TminPad      3.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.4000 = 0.7 * tmin.	2.1210 = 0.7 * Wo mm.
Pad Weld	1.5000 = 0.5*TminPad	2.8280 = 0.7 * Wp mm.

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (5.143 - 0.6148 + 2 * 2.0 * 1.0 *
   (1.0 * 1.8 - 1.6985 ) )138)
 = 6373.11 Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.132 + 9.801 + 0.16 - 0.0 * 1.0 ) * 138
 = 14192.41 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.132 + 0.0 + 0.09 + ( 0.072 ) ) * 138
 = 413.42 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.132 + 0.0 + 0.16 + 9.801 + ( 0.072 ) ) * 138
 = 14293.65 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 609.6 * 3.0 * 0.49 * 138
 = 19793. Kgf
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 900.0 * 4.0 * 0.49 * 138
 = 38963. Kgf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 303.8) * ( 5.0 - 3.0 ) * 0.7 * 138
  = 18789. Kgf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 609.6 * 4.8 * 0.74 * 138
  = 47827. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 609.6 * ( 4.8 - 3.0 ) * 0.74 * 138
  = 17935. Kgf
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 38963 + 18789 ) = 57752 Kgf
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 19793 + 47827 + 17935 + 0 ) = 85555 Kgf
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 38963 + 17935 + 0 ) = 56898 Kgf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 57752 Kgf, must exceed W = 6373 Kgf or W1 = 14192 Kgf
Path 2-2 = 85555 Kgf, must exceed W = 6373 Kgf or W2 = 413 Kgf
Path 3-3 = 56898 Kgf, must exceed W = 6373 Kgf or W3 = 14293 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        1.613   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
Nozzle is O.K. for the External Pressure                0.100   bars
```

The Drop for this Nozzle is : 24.6886 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 279.4887 mm.

Percent Elongation Calculations:

```
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  0.827 %
```

Input, Nozzle Desc: PSV - 2" From: 60

Pressure for Reinforcement Calculations	P	0.200	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	0.10	bars
Temperature for External Pressure	Tempex	85	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Elliptical Head	D	2100.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	4.8000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	750.0000	mm.
User Entered Minimum Design Metal Temperature		-5.00	°C

Type of Element Connected to the Shell : Nozzle

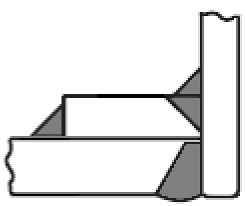
Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-105	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	400.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	3.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	4.8000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	160.0000	mm.
Thickness of Pad	te	5.0000	mm.
Weld leg size between Pad and Shell	Wp	3.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	4.8000	mm.

```
Reinforcing Pad Width                                  49.8375  mm.

Class of attached Flange                              150
Grade of attached Flange                              GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle With Pad, no Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: PSV - 2"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation             2.375  in.
Actual Thickness Used in Calculation                    0.191  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]

```
 = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
 = (0.2*0.898*2106.0)/(2 *137.9*1.0-0.2*0.2)
 = 0.1371 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (0.2*30.1625)/(118*1.0+0.4*0.2)
 = 0.0051 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1665 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl   127.0938  mm.
Parallel to Vessel Wall, opening length              d    63.5469  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     4.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:

```
 = min( 1, Sn/Sv )
 = min( 1, 117.9/137.9 )
 = 0.855
```

Weld Strength Reduction Factor [fr2]:
 = min(1, Sn/Sv)
 = min(1, 117.9/137.9)
 = 0.855

Weld Strength Reduction Factor [fr4]:
 = min(1, Sp/Sv)
 = min(1, 137.9/137.9)
 = 1.000

Weld Strength Reduction Factor [fr3]:
 = min(fr2, fr4)
 = min(0.855, 1.0)
 = 0.855

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.088	0.544	NA
Area in Shell	A1	1.048	0.064	NA
Area in Nozzle Wall	A2	0.156	0.143	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.000	0.000	NA
Area in Element	A5	2.005	2.005	NA
TOTAL AREA AVAILABLE	Atot	3.209	2.212	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 63.03 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	70.3271	5.0000	mm.
Based on given Pad Diameter:	160.0000	0.7577	mm.

Area Required [A]:
 = 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
 = 0.5(63.5469*1.6985*1+2*1.845*1.6985*1(1-0.86))
 = 0.544 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
 = d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
 = 63.547(1.0 * 1.8 - 1.0 * 1.698) - 2 * 1.845
 (1.0 * 1.8 - 1.0 * 1.6985) * (1 - 0.855)
 = 0.064 cm²

Area Available in Nozzle Wall Projecting Outward [A2]:
 = (2 * Tlwp) * (tn - trn) * fr2/sin(alpha3)
 = (2 * 4.5) * (1.85 - 0.17) * 0.855/sin(64.9)
 = 0.143 cm²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:
 = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
 = (0.0) * 0.86 + (0.0) * 0.86 + 0.0² * 1.0
 = 0.000 cm²

Area Available in Element, also see UG-37(h) [A5]:
 = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
 = (127.0938 - 67.6874)4.5 * 1.0 * 0.75
 = 2.005 cm²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 4.845, tr = 0.005, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 4.845, tr = 0.005, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 4.845, tr = 0.005, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.003, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Shell to Pad Weld Junction at Pad OD, Curve: B

Govrn. thk, tg = 4.8, tr = 0.137, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 4.8, tr = 0.137, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.076, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -104 °C
Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -104 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 0.20/19.60 = 0.010

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: PSV - 2"

```
Intermediate Calc. for nozzle/shell Welds   Tmin      1.8450  mm.
Intermediate Calc. for pad/shell Welds   TminPad      3.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.2915 = 0.7 * tmin.	2.1210 = 0.7 * Wo mm.
Pad Weld	1.5000 = 0.5*TminPad	2.1210 = 0.7 * Wp mm.

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, ( 0.5442 - 0.064 + 2 * 1.845 * 0.855 *
   (1.0 * 1.8 - 1.6985 ) )138)
 = 679.80 Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 0.1427 + 2.005 + 0.0 - 0.0 * 0.86 ) * 138
 = 3019.93 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.1427 + 0.0 + 0.077 + ( 0.0568 ) ) * 138
 = 388.68 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.1427 + 0.0 + 0.0 + 2.005 + ( 0.0568 ) ) * 138
 = 3099.79 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 67.6874 * 3.0 * 0.49 * 118
 = 1879. Kgf
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 160.0 * 3.0 * 0.49 * 138
```

```
  = 5195. Kgf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 32.8086) * ( 4.845 - 3.0 ) * 0.7 * 118
  = 1600. Kgf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 67.6874 * 4.8 * 0.74 * 138
  = 5311. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 67.6874 * ( 4.8 - 3.0 ) * 0.74 * 138
  = 1991. Kgf
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 5195 + 1600 ) = 6796 Kgf
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 1879 + 5311 + 1991 + 0 ) = 9181 Kgf
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 5195 + 1991 + 0 ) = 7187 Kgf
```

Summary of Failure Path Calculations:

```
Path 1-1 = 6795 Kgf, must exceed W = 679 Kgf or W1 = 3019 Kgf
Path 2-2 = 9181 Kgf, must exceed W = 679 Kgf or W2 = 388 Kgf
Path 3-3 = 7186 Kgf, must exceed W = 679 Kgf or W3 = 3099 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case        1.613  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
Nozzle is O.K. for the External Pressure                0.100  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: PSV - 2"

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation            2.375  in.
Actual Thickness Used in Calculation                   0.191  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]

```
  = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
  = (0.2*0.898*2106.0)/(2 *137.9*1.0-0.2*0.2)
  = 0.1371 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (0.2*30.1625)/(118*1.0+0.4*0.2)
  = 0.0051 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1665 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl   113.2698  mm.
Parallel to Vessel Wall, opening length              d    56.6349  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     4.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.078	0.486	NA
Area in Shell	A1	0.933	0.057	NA
Area in Nozzle Wall	A2	0.142	0.129	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.000	0.000	NA
Area in Element	A5	1.787	1.787	NA
TOTAL AREA AVAILABLE	Atot	2.861	1.973	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                        90.00  Degs.
```

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

```
SELECTION OF POSSIBLE REINFORCING PADS:   Diameter  Thickness
Based on given Pad Thickness:              69.1959     5.0000  mm.
Based on given Pad Diameter:              160.0000     0.7540  mm.
```

Area Required [A]:

```
 = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
 = 0.5(56.6349*1.6985*1+2*1.845*1.6985*1(1-0.86))
 = 0.486 cm²
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
 = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
 = 56.635( 1.0 * 1.8 - 1.0 * 1.698 ) - 2 * 1.845
   ( 1.0 * 1.8 - 1.0 * 1.6985 ) * ( 1 - 0.855 )
 = 0.057 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
 = ( 2 * Tlwp ) * ( tn - trn ) * fr2
 = ( 2 * 4.5 ) * ( 1.85 - 0.17 ) * 0.855
 = 0.129 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
 = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
 = (0.0 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
 = 0.000 cm²
```

Area Available in Element, also see UG-37(h) [A5]:

```
 = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
 = ( 113.2698 - 60.325 )4.5 * 1.0 * 0.75
 = 1.787 cm²
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
Wall Thickness for Internal/External pressures      ta = 3.1665 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 3.5293 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.3830 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 6.42, max( 4.5, 4.5 ) ]
 = 4.5000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
 = max( ta, tb )
 = max( 3.1665, 4.5 )
 = 4.5000 mm.
```

Available Nozzle Neck Thickness = 4.8450 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     34.8,  Allowable :    117.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    260.0 N./mm²  Passed
Occasional  :      0.1,  Allowable :    156.8 N./mm²  Passed
Shear       :     24.0,  Allowable :     82.5 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Weld Size Calculations, Description: PSV - 2"

```
Intermediate Calc. for nozzle/shell Welds   Tmin        1.8450  mm.
Intermediate Calc. for pad/shell Welds    TminPad       3.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          1.2915 = 0.7 * tmin.  2.1210 = 0.7 * Wo mm.
Pad Weld             1.5000 = 0.5*TminPad  2.1210 = 0.7 * Wp mm.
```

Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

Weld Load [W]:

```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, ( 0.4855 - 0.057 + 2 * 1.845 * 0.855 *
   (1.0 * 1.8 - 1.6985 ) )138)
 = 607.13 Kgf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
 = ( 0.1292 + 1.7869 + 0.0 - 0.0 * 0.86 ) * 138
 = 2694.28 Kgf
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 0.1292 + 0.0 + 0.077 + ( 0.0568 ) ) * 138
 = 369.69 Kgf
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = (  0.1292 + 0.0 + 0.0 + 1.7869 + ( 0.0568 ) ) * 138
 = 2774.14 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
 = (pi/2) * Dlo * Wo * 0.49 * Snw
 = ( 3.1416/2.0 ) * 60.325 * 3.0 * 0.49 * 118
 = 1675. Kgf
```

Shear, Pad Element Weld [Spew]:
```
 = (pi/2) * DP * WP * 0.49 * SEW
 = ( 3.1416/2.0 ) * 160.0 * 3.0 * 0.49 * 138
 = 5195. Kgf
```

Shear, Nozzle Wall [Snw]:
```
 = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
 = (3.1416 * 29.24) * ( 4.845 - 3.0 ) * 0.7 * 118
 = 1426. Kgf
```

Tension, Pad Groove Weld [Tpgw]:
```
 = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
 =  (3.1416/2 ) * 60.325 * 4.8 * 0.74 * 138
 = 4733. Kgf
```

Tension, Shell Groove Weld [Tngw]:
```
 = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
 = ( 3.1416/2.0 ) * 60.325 * ( 4.8 - 3.0 ) * 0.74 * 138
 = 1775. Kgf
```

Strength of Failure Paths:

```
 PATH11 = ( SPEW + SNW ) = ( 5195 + 1426 ) = 6621 Kgf
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
        = ( 1675 + 4733 + 1775 + 0 ) = 8182 Kgf
 PATH33 = ( Spew + Tngw + Sinw )
        = ( 5195 + 1775 + 0 ) = 6970 Kgf
```

Summary of Failure Path Calculations:
```
Path 1-1 = 6621 Kgf, must exceed W = 607 Kgf or W1 = 2694 Kgf
Path 2-2 = 8182 Kgf, must exceed W = 607 Kgf or W2 = 369 Kgf
Path 3-3 = 6969 Kgf, must exceed W = 607 Kgf or W3 = 2774 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case        1.613  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 0.100 bars

The Drop for this Nozzle is : 13.3211 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 418.5473 mm.

Warning:
The equations for nozzle local stress analysis pertain to radial nozzles only and this nozzle is not specified as radial. Please check the specific analysis code for all assumptions and limitations.

Input Echo, WRC107/537 Item 1, Description: PSV - 2" :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Spherical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	3780.000	mm.
Vessel Thickness	Tv	4.800	mm.
Design Temperature	T1	85.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm²

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
WRC107 Attachment Classification	Holsol	Hollow	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.
Nozzle Thickness	Tn	4.845	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Thickness of Reinforcing Pad	Tpad	5.000	mm.
Diameter of Reinforcing Pad	Dpad	160.000	mm.
Design Internal Pressure	Dp	0.200	bars
Include Pressure Thrust		No	

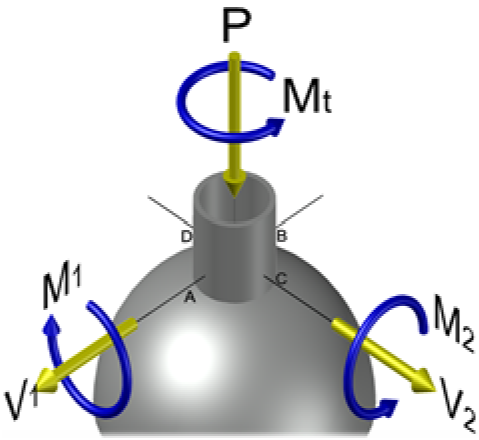
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)		P	-51.8	Kgf
Longitudinal Shear	(SUS)	(Vl)	V1	64.9	Kgf
Circumferential Shear	(SUS)	(Vc)	V2	64.9	Kgf
Circumferential Moment	(SUS)	(Mc)	M1	-11.0	Kg-m.
Longitudinal Moment	(SUS)	(Ml)	M2	13.9	Kg-m.
Torsional Moment	(SUS)		Mt	17.5	Kg-m.

```
 Use Interactive Control                              No
 WRC107 Version                             Version   March  1979

 Include Pressure Stress Indices per Div. 2                  No
 Compute Pressure Stress per WRC-368                         No
 Local Loads applied at end of Nozzle/Attachment             No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 60.325 + 2 * 1.65 * sqrt( 1893.9 ( 4.8 - 3.0 ) )
  = 253.002 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                      P         -51.8   Kgf
 Circumferential Shear                      (VC)  V2         64.9   Kgf
 Longitudinal Shear                         (VL)  V1         64.9   Kgf
 Circumferential Moment                     (MC)  M1        -11.0   Kg-m.
 Longitudinal Moment                        (ML)  M2         13.9   Kg-m.
 Torsional Moment                                 MT         17.5   Kg-m.

 Dimensionless Param: U =   0.27 TAU =  15.85 RHO =   4.00 (  3.69)
```

Dimensionless Loads for Spherical Shells at Attachment Junction:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SP 7	0.05241	(A,B,C,D)
M(x) / P	SP 7	0.03416	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SM 7	0.16450	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SM 7	0.11451	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SM 7	0.16450	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SM 7	0.11451	(A,B,C,D)
N(y) * T / P	SP 7	0.36304	(A,B,C,D)

M(y) / P	SP 7	0.15384	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SM 7	0.26384	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SM 7	0.63172	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / ML	SM 7	0.26384	(A,B,C,D)
M(y) * SQRT(Rm * T) / ML	SM 7	0.63172	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Rad. Bend. P	2.3	-2.3	2.3	-2.3	2.3	-2.3	2.3	-2.3
Rad. Memb. MC	0.0	0.0	0.0	0.0	3.4	3.4	-3.4	-3.4
Rad. Memb. MC	0.0	0.0	0.0	0.0	14.1	-14.1	-14.1	14.1
Rad. Memb. ML	-4.3	-4.3	4.3	4.3	0.0	0.0	0.0	0.0
Rad. Bend. ML	-17.8	17.8	17.8	-17.8	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-19.2	11.9	24.9	-15.2	20.3	-12.4	-14.7	9.1
Tang. Memb. P	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tang. Bend. P	10.1	-10.1	10.1	-10.1	10.1	-10.1	10.1	-10.1
Tang. Memb. MC	0.0	0.0	0.0	0.0	5.4	5.4	-5.4	-5.4
Tang. Bend. MC	0.0	0.0	0.0	0.0	78.0	-78.0	-78.0	78.0
Tang. Memb. ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Tang. Bend. ML	-98.2	98.2	98.2	-98.2	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-90.9	85.2	119.1	-97.5	97.5	-78.7	-69.3	66.4
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Tot. Shear	5.4	5.4	3.4	3.4	3.4	3.4	5.4	5.4
Str. Int.	91.3	85.6	119.3	97.6	97.7	78.9	69.8	66.9

Unitless Prm: U = 1.37 TAU = 0.00 (42.86) RHO = 0.00 (0.98)

Dimensionless Loads for Spherical Shells at Pad edge:

Curves read for 1979	Figure	Value	Location
N(x) * T / P	SR 2	0.04319	(A,B,C,D)
M(x) / P	SR 2	0.02160	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / MC	SR 3	0.04560	(A,B,C,D)
M(x) * SQRT(Rm * T) / MC	SR 3	0.03549	(A,B,C,D)
N(x) * T * SQRT(Rm * T) / ML	SR 3	0.04560	(A,B,C,D)
M(x) * SQRT(Rm * T) / ML	SR 3	0.03549	(A,B,C,D)
N(y) * T / P	SR 2	0.01298	(A,B,C,D)
M(y) / P	SR 2	0.00648	(A,B,C,D)
N(y) * T * SQRT(Rm * T) / MC	SR 3	0.01370	(A,B,C,D)
M(y) * SQRT(Rm * T) / MC	SR 3	0.01067	(A,B,C,D)

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N(y) * T * SQRT(Rm * T ) / ML     SR 3     0.01370    (A,B,C,D)
M(y)     * SQRT(Rm * T ) / ML     SR 3     0.01067    (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Memb. P	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Rad. Bend. P	20.3	-20.3	20.3	-20.3	20.3	-20.3	20.3	-20.3
Rad. Memb. MC	0.0	0.0	0.0	0.0	26.0	26.0	-26.0	-26.0
Rad. Memb. MC	0.0	0.0	0.0	0.0	121.6	-121.6	-121.6	121.6
Rad. Memb. ML	-32.8	-32.8	32.8	32.8	0.0	0.0	0.0	0.0
Rad. Bend. ML	-153.1	153.1	153.1	-153.1	0.0	0.0	0.0	0.0
Tot. Rad. Str.	-158.8	106.7	213.0	-133.8	174.7	-109.1	-120.5	82.0
Tang. Memb. P	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tang. Bend. P	6.1	-6.1	6.1	-6.1	6.1	-6.1	6.1	-6.1
Tang. Memb. MC	0.0	0.0	0.0	0.0	7.8	7.8	-7.8	-7.8
Tang. Bend. MC	0.0	0.0	0.0	0.0	36.5	-36.5	-36.5	36.5
Tang. Memb. ML	-9.8	-9.8	9.8	9.8	0.0	0.0	0.0	0.0
Tang. Bend. ML	-46.0	46.0	46.0	-46.0	0.0	0.0	0.0	0.0
Tot. Tang. Str.	-47.7	32.1	64.0	-40.2	52.5	-32.8	-36.2	24.7
Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear	3.8	3.8	1.0	1.0	1.0	1.0	3.8	3.8
Str. Int.	158.9	106.9	213.0	133.9	174.7	109.1	120.7	82.2

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Rad. Pl (SUS)	-3.7	-3.7	4.8	4.8	4.0	4.0	-2.8	-2.8
Rad. Q (SUS)	-15.5	15.5	20.0	-20.0	16.4	-16.4	-11.9	11.9
Long. Pm (SUS)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Long. Pl (SUS)	-2.8	-2.8	10.8	10.8	9.4	9.4	-1.4	-1.4
Long. Q (SUS)	-88.0	88.0	108.3	-108.3	88.1	-88.1	-67.8	67.8
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0

Shear Q (SUS)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Pm (SUS)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Pm+Pl (SUS)	2.1	2.1	13.8	13.8	12.4	12.4	2.4	2.4
Pm+Pl+Q (Total)	88.5	88.4	122.0	94.8	100.4	76.1	67.0	69.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	2.78	137.90	Passed
Pm+Pl (SUS)	13.76	206.85	Passed
Pm+Pl+Q (TOTAL)	122.04	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107 / 537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Rad. Pm (SUS)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Rad. Pl (SUS)	-26.0	-26.0	39.6	39.6	32.8	32.8	-19.3	-19.3
Rad. Q (SUS)	-132.8	132.8	173.4	-173.4	141.9	-141.9	-101.2	101.2
Long. Pm (SUS)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Long. Pl (SUS)	-7.8	-7.8	11.9	11.9	9.9	9.9	-5.8	-5.8
Long. Q (SUS)	-39.9	39.9	52.1	-52.1	42.6	-42.6	-30.4	30.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Pm+Pl (SUS)	18.4	18.4	50.1	50.1	43.4	43.4	13.8	13.8
Pm+Pl+Q (Total)	148.4	117.5	223.5	123.3	185.2	98.6	110.2	92.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	10.52	137.90	Passed
Pm+Pl (SUS)	50.14	206.85	Passed
Pm+Pl+Q (TOTAL)	223.48	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm.	Reinforcing Pad Diameter mm.	Pad Thk mm.	Cut Length mm.	Flg Class
Utility - 2"	2.000 in	80	SlipOn	2.375	5.537	...	...	158.43	150
PSV - 2"	2.000 in	80	SlipOn	2.375	5.537	160.00	5.00	418.55	150
Drain - 3"	3.000 in	STD	SlipOn	3.500	5.486	190.00	5.00	155.32	150
Gas Inlet - 6"	6.000 in	80	SlipOn	6.625	10.973	...	...	2158.00	150
Gas Outlet - 6"	6.000 in	STD	SlipOn	6.625	7.112	270.00	5.00	159.38	150
MH1 - 24"	24.000 in	Actual	SlipOn	24.000	5.000	...	...	203.21	150
MH2 - 24"	24.000 in	Actual	SlipOn	24.000	5.000	900.00	4.80	279.49	150

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
Utility - 2	SA-106 B	4.800	4.800	...	...	...
PSV - 2"	SA-106 B	4.800	3.000	3.000	4.800	...
Drain - 3"	SA-106 B	4.800	2.000	3.000	4.800	...
Gas Inlet -	SA-106 B	8.000	5.000	...	...	...
Gas Outlet	SA-106 B	6.000	4.000	3.000	5.000	...
MH1 - 24"	SA-516 70	5.000	5.000	...	...	...
MH2 - 24"	SA-516 70	4.800	3.000	4.000	4.800	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
Utility - 2"	250.000	105.0	150.00	0.00	Shell #1
PSV - 2"	...	180.0	400.00	0.00	Upper Head
Drain - 3"	...	0.0	150.00	0.00	Lower Head
Gas Inlet - 6"	250.000	75.0	150.00	2000.00	Shell #1
Gas Outlet - 6"	5150.000	180.0	150.00	0.00	Shell #4
MH1 - 24"	850.000	180.0	150.00	0.00	Shell #1
MH2 - 24"	...	0.0	250.00	0.00	Upper Head

Weld Sizes for Slip On / Socket Weld Nozzle Flanges per UW-21:

Nozzle to Flange Fillet Weld Leg dimension [xmin]:
= min(1.4 * tn, Hub Thickness)

The Nozzle Wall thicknesses shown below are in the corroded condition. Hubs are considered to be straight.

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Noz. O/Dia in	Wall Thk mm.	Hub Thk mm.	Throat Thk mm.	xmin Thk mm.
Utility - 2"	2.000 in	80	SlipOn	2.375	2.537	7.874	2.486	3.552
PSV - 2"	2.000 in	80	SlipOn	2.375	2.537	7.874	2.486	3.552
Drain - 3"	3.000 in	STD	SlipOn	3.500	2.486	8.636	2.437	3.481
Gas Inlet - 6"	6.000 in	80	SlipOn	6.625	7.973	10.287	7.201	10.287
Gas Outlet - 6"	6.000 in	STD	SlipOn	6.625	4.112	10.287	4.030	5.757
MH1 - 24"	24.000 in	Actua	SlipOn	24.000	2.000	23.749	1.960	2.800
MH2 - 24"	24.000 in	Actua	SlipOn	24.000	2.000	23.749	1.960	2.800

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
Lower Head	[10]	B	-29	-45	-29	0.708	4.800	0.85	No
Lower Head	[7]	B	-29	-48	-29	0.411	6.000	0.85	No
Shell #1	[8]	B	-29	-104	-29	0.255	8.000	0.85	No
Shell #2	[8]	B	-29	-48	-29	0.425	6.000	0.85	No
Shell #3	[8]	B	-29	-48	-29	0.425	6.000	0.85	No
Shell #4	[8]	B	-29	-48	-29	0.425	6.000	0.85	No
Upper Head	[10]	B	-29	-45	-29	0.708	4.800	0.85	No
Upper Head	[7]	B	-29	-48	-29	0.398	6.000	0.85	No
Drain - 3"	[1]	B	-29	-104		0.005	4.801	1.00	No
Nozzle Flg	[4]	B	-29	-104					
MH1 - 24"	[1]	B	-29	-104		0.028	5.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Gas Inlet - 6"	[1]	B	-29	-104		0.003	9.601	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Utility - 2"	[1]	B	-29	-104		0.003	4.845	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Gas Outlet - 6	[1]	B	-29	-104		0.004	6.223	1.00	No
Nozzle Flg	[4]	B	-29	-104					
MH2 - 24"	[1]	B	-29	-104		0.022	5.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
PSV - 2"	[1]	B	-29	-104		0.003	4.845	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Warmest MDMT:			-29	-45					

Required Minimum Design Metal Temperature -5.0 °C
Warmest Computed Minimum Design Metal Temperature -45.0 °C

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.

UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 2100.000 mm. ID
Vessel Design Length, Tangent to Tangent 5400.00 mm.

Distance of Bottom Tangent above Grade 0.00 mm.
Specified Datum Line Distance 0.00 mm.

Internal Design Temperature 85 °C
Internal Design Pressure 0.200 bars

External Design Temperature 85 °C
External Design Pressure 0.100 bars

Maximum Allowable Working Pressure 1.564 bars
External Max. Allowable Working Pressure 0.112 bars
Hydrostatic Test Pressure 2.468 bars

Required Minimum Design Metal Temperature -5.0 °C
Warmest Computed Minimum Design Metal Temperature -45.0 °C

Wind Design Code UBC
Earthquake Design Code ASCE/SEI 7-16

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	No
Head	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-516 70	...	...	K02700	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Rings	SA-516 70	...	...	K02700	No	No
Leg Baseplate	SA-283 C	...	...	K02401	No	No
Leg Bolting	SA-36	...	...	K02600	No	No

- Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
- Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Lower Head	0.249	0.10	1.564	3.0000	No	No
Shell #1	0.249	0.10	5.501	3.0000	N/A	No
Shell #2	0.249	0.10	3.285	3.0000	N/A	No
Shell #3	0.249	0.10	3.285	3.0000	N/A	No
Shell #4	0.200	0.10	3.333	3.0000	N/A	No
Upper Head	0.200	0.10	1.613	3.0000	No	No

Liquid Level: 6450.00 mm. Dens.: 0.000 kg./cm³ Sp. Gr.: 0.001

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
2050.00	Bar 60.0 x 6.	Ring #1
4350.00	Bar 60.0 x 6.	Ring #2

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	50.0	50.0	6.0	4.8	4.5	...	0.85	0.85
Cylinder	1250.0	1200.0	8.0	8.0	4.5	...	0.85	0.85
Cylinder	2750.0	1500.0	6.0	6.0	4.5	...	0.85	0.85
Cylinder	3850.0	1100.0	6.0	6.0	4.5	...	0.85	0.85
Cylinder	5350.0	1500.0	6.0	6.0	4.5	...	0.85	0.85
Ellipse	5400.0	50.0	6.0	4.8	4.5	...	0.85	0.85

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	4.8	4.69848	0.1	0.11232
20	30	8	5.72741	0.1	0.45716
30	Ring	6	5.72418	0.1	0.12868
Ring	40	6	5.75833	0.1	0.12439
40	50	6	5.75833	0.1	0.12439
50	Ring	6	5.75833	0.1	0.12439
Ring	60	6	5.14039	0.1	0.23752
60	70	4.8	4.69848	0.1	0.11232

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	2225	9649.79	No Calc	No Calc
30	Ring	2225	2844.52	No Calc	No Calc
Ring	40	2300	2844.83	14.6246	25.8886
40	50	2300	2844.83	No Calc	No Calc
50	Ring	2300	2844.83	No Calc	No Calc
Ring	60	1225	2844.94	11.4279	25.8886
60	70	No Calc	No Calc	No Calc	No Calc

Loads for Foundation/Support Design:

Factored Loads:

Total Wind Shear on top of all Legs	2556.	Kgf
Total Earthquake Shear on top of all Legs	6216.	Kgf
Total Wind Moment at top of all Legs	6863.	Kg-m.

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Total Earthquake Moment at top of all Legs              20167.  Kg-m.

Max. Wind Shear on one Leg (top & bottom)                 942.  Kgf
Max. Earthq. Shear on one Leg (top & bottom)             2290.  Kgf
Max. Wind Moment at base of one Leg                      1649.  Kg-m.
Max. Earthquake Moment at base of one Leg                4008.  Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg               6503.  Kgf
Max. Vertical Load (Wt. + Eq.) on one Leg               12307.  Kgf
```

Un-Factored Loads:

```
Total Earthquake Shear on top of all Legs                8705.  Kgf
Total Wind Moment at top of all Legs                     6863.  Kg-m.
Total Earthquake Moment at top of all Legs              28245.  Kg-m.

Max. Wind Shear on one Leg (top & bottom)                 942.  Kgf
Max. Earthq. Shear on one Leg (top & bottom)             3208.  Kgf
Max. Wind Moment at base of one Leg                      1649.  Kg-m.
Max. Earthquake Moment at base of one Leg                5614.  Kg-m.
Max. Vertical Load (Wt. + Wind) on one Leg               6503.  Kgf
Max. Vertical Load (Wt. + Eq.) on one Leg               17237.  Kgf
```

Note:
Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	Pass Fail
Lift Lug	WRC-107/537	0.977	Passed
LEGS	WRC-107/537	0.989	Passed
Drain - 3"	WRC-107/537	0.753	Passed
Gas Inlet - 6"	WRC-107/537	0.685	Passed
Utility - 2"	WRC-107/537	0.335	Passed
Gas Outlet - 6	WRC-107/537	0.928	Passed
PSV - 2"	WRC-107/537	0.540	Passed

Weights:

```
Fabricated - Bare  W/O Removable Internals               4166.6   kg.
Shop Test  - Fabricated + Water ( Full )                25285.5   kg.
Shipping   - Fab. + Rem. Intls.+ Shipping App.           4166.6   kg.
Erected    - Fab. + Rem. Intls.+ Insul. (etc)            4166.6   kg.
Empty      - Fab. + Intls. + Details + Wghts.           12387.8   kg.
Operating  - Empty + Operating Liquid (No CA)           14124.0   kg.
Field Test - Empty Weight + Water (Full)                25437.2   kg.
```