30 Sawkins Rd
Rondebosch
Cape Town
7442
Tel: 065 144 9562

Air Receiver 10m3 16 BAR

Analysis as per PD5500 2021

XGM Consulting Engineers South Africa

DOCUMENT No: DC_10M3-16-01

GA DRAWING No. 10M3-16-01

19 AUGUST 2022

CONTAINED IN THIS DOCUMENT

1. Drawings

GA	10M3-16-01 Rev 0
SADDLE	10M3-16-02 Rev 0
MANHOLE	10M3-16-03 Rev 0
DAVIT	10M3-16-04 Rev 0
LUG	10M3-16-05 Rev 0
NOZZLE 80NB	10M3-16-06 Rev 0

2. Calculations PD5500 2021

DOCUMENT No.: DC_10m3 Air Receiver

DESIGN PRESSURE: 1600 kPa

FIELD TEST PRESSURE: 2000 kPa

SHOP TEST PRESSURE: 2352 kPa

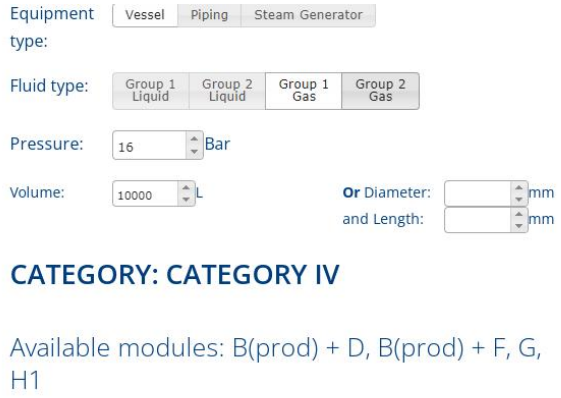
DESIGN TEMPERATURE: 50 Deg C

OPERATING MEDIUM: Air

CAPACITY: 10m3

SANS 347 Hazard Category: IV

CONFORMITY ASSESMENT MODULE: G



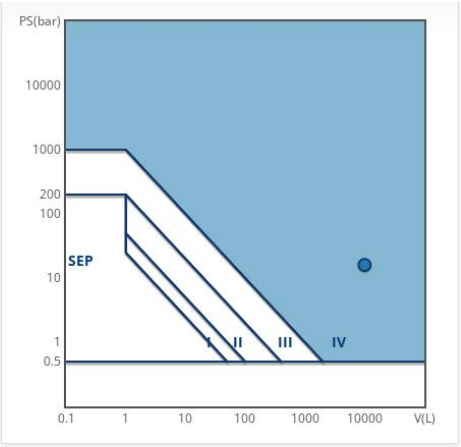
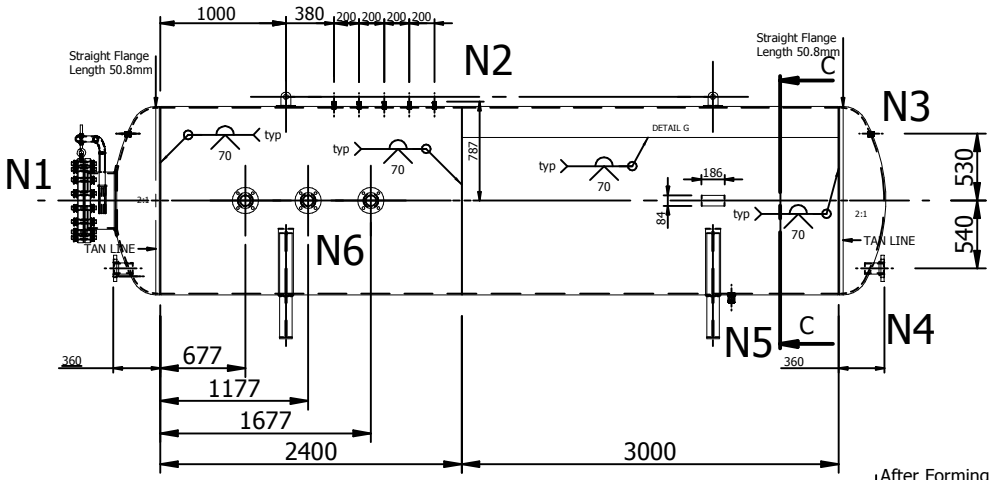
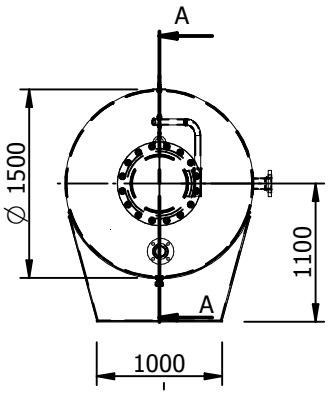


Chart 1 - Vessels for Group 1 gases

REPORT PREPARED FOR: CLAWS FABRICATION AND ENGINEERING

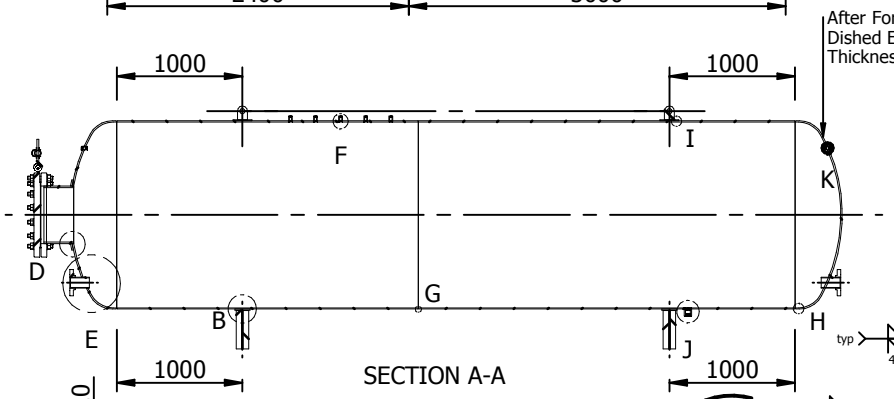
COMPILED BY: LE GREEN (PrTechEng)

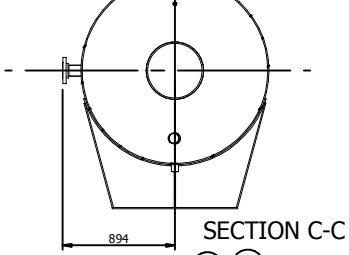




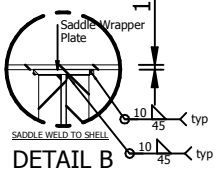
Item Number	Title	Quantity
1	Elliptical Dished End MHS_OD 1500mm_BS1501-151 Gr430A	1
2	Shell_D1500 x 2400mm x 10mm_BS1501-151 Gr430A	1
3	Manhole Assembly 450NB_Pipe A106B_Flanges A105	1
4	Saddle Assembly_BS1501-151 Gr430A	2
5	Lug Assembly_BS1501-151 Gr430A	2
6	Forged Coupling_1/2" NPT Female 3000#	7
7*	Forged Coupling_1 1/4" NPT Female_3000#	1
8	Shell_D1500 x 3000mm x 10mm_BS1501-151 Gr430A	1
9	Elliptical Dished End_OD 1500mm_BS1501-151 Gr430A	1
10	80NB Nozzle_Pipe A106B_Flange A105	5
11	Nameplate Bracket_Stainles Steel 314	1
12*	Repad_12mm THK_OD698_W120mm _BS1501-151 Gr430A	1

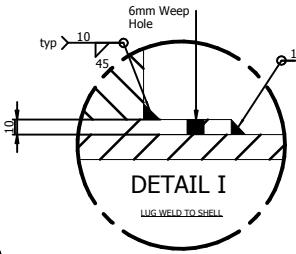
MARK	QTY	SIZE	RATING (NB)	SERVICE
N1	1	450NB	SCH80	MANWAY
N2	5	1/2" NPT	3000 lbs	INLET / OUTLET
N3	2	1/2" NPT	3000 lbs	SAFETY VALVE
N4	2	3"	SCH80	
N5	1	1 1/4"	3000 lbs	DRAIN
N6	3	3"	SCH40	

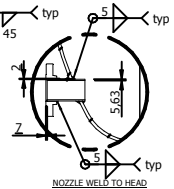


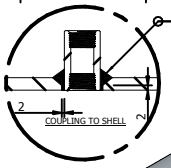


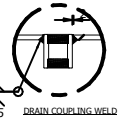
DESIGN DATA	
DESIGN CODE	PD5500 cat 2 (2021)
DESIGN PRESSURE (kPa)	1600
DESIGN TEMPERATURE (Deg C)	50
SHOP TEST PRESSURE	2352
FIELD TEST PRESSURE	2000
NDE	RADIOGRAPHY 10%
PWHT	NO
INSPECTION AUTHORITY	TUV RHEINLAND PER 057
DATE OF TEST	2022
CORROSION ALLOWANCE (mm)	1.5mm
WORKING PRESSURE (kPa)	1600
MIN/MAX DESIGN TEMP	5/50
OPERATING TEMP	21
VOLUME (m3)	10

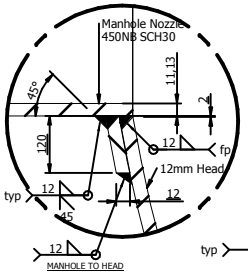


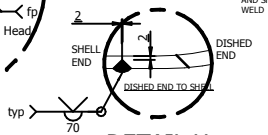


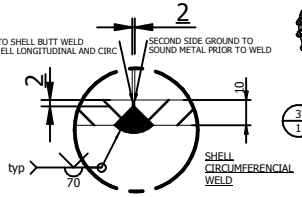












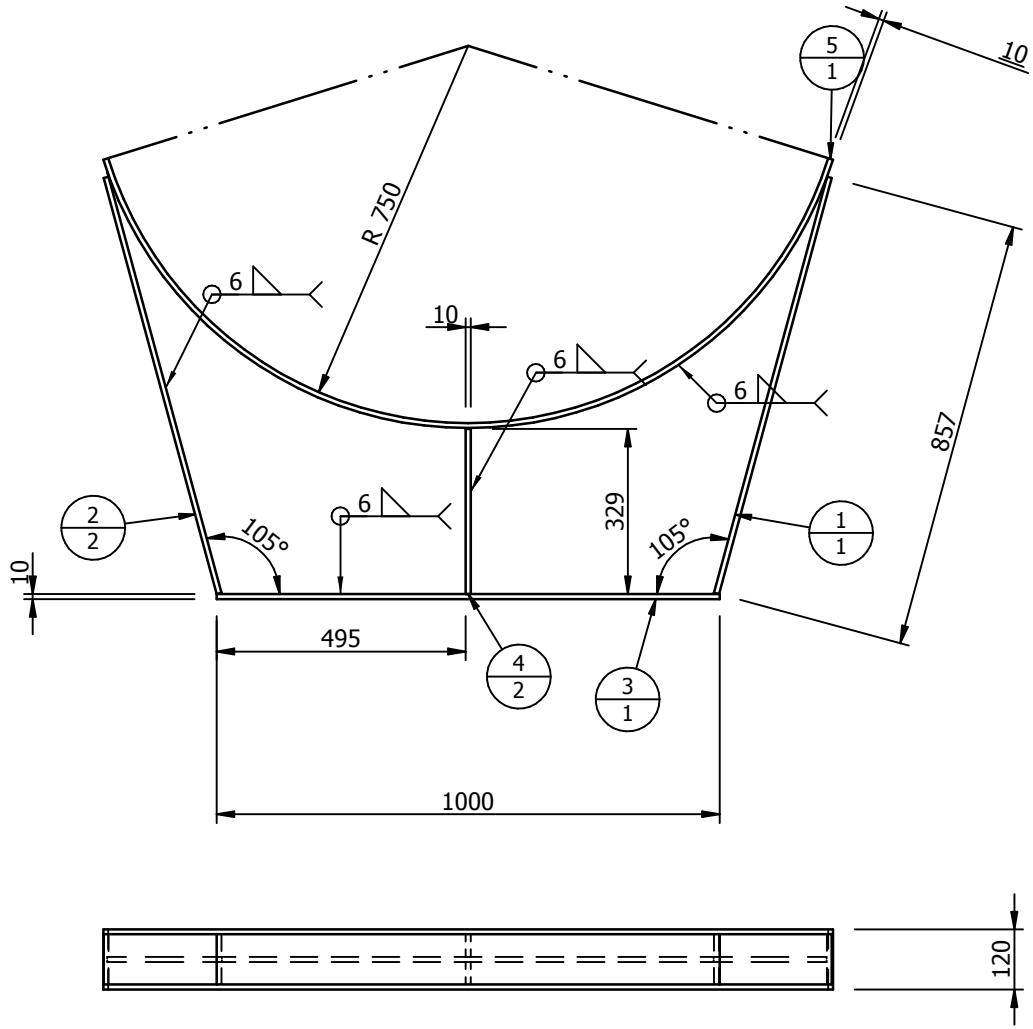
VESSEL DESIGNED ACCRODING TO:
PD5500 2021
SANS 347 CONFORMITY ASSESMENT: G
HAZARD CATEGORY: IV
LESLIE GREEN (PrTechEng) 201470150

REV	BY	CHKD	REVISION DESCRIPTION

XGM Consulting Engineers
UNIT ED CENTURY SQUARE
CENCURY CITY

	NAME	DATE
CHECKED	LG	04-08-22
DRAWN	LG	
ENG APPR	LG	

TITLE: 10 m3 AIR RECEIVER TANK
SIZE A1 | DRAWING NO. 10M3-16-01 | REV 0
FOR APPROVAL
SCALE: | WEIGHT:



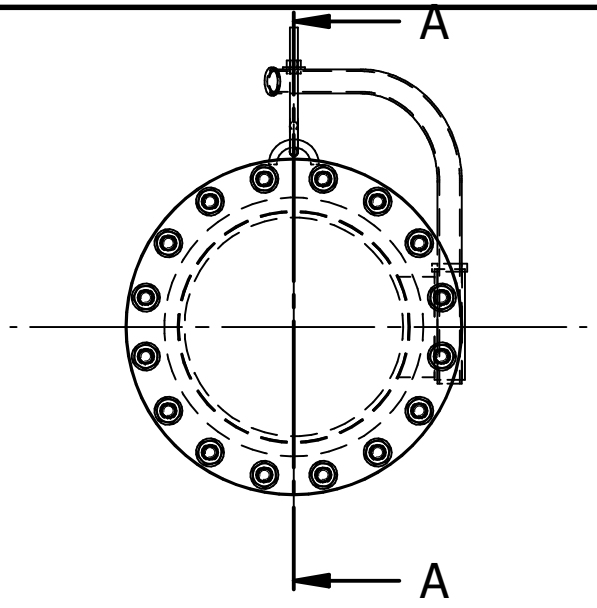
Item Number	Title	Quantity
1	Plate_1436 x 840 x10mm_BS1501-151 Gr430A	1
2	Plates_857 x 100 x 10mm_BS1501-151 Gr430A	2
3	Plate_1000 x 100 x 10mm_BS1501-151 Gr430A	1
4	Plate_328 x 45 x 10mm_BS1501-151 Gr430A	2
5	Wrapper plate_10mm THK_BS1501-151 Gr430A	1

APPROVED	DESCRIPTION	DATE	REV
REVISION HISTORY			

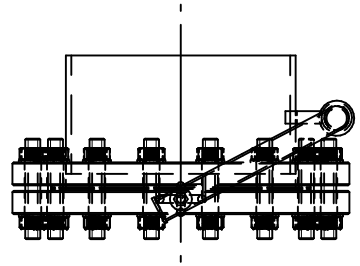
XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

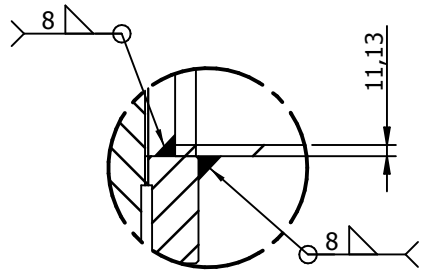
TITLE: SADDLE ASSEMBLY
A3

Client:	Order No.	Scale:
Drawn:	Date:	Client Dwg No.
Drawing No. 10M3-16-02		Revision 0

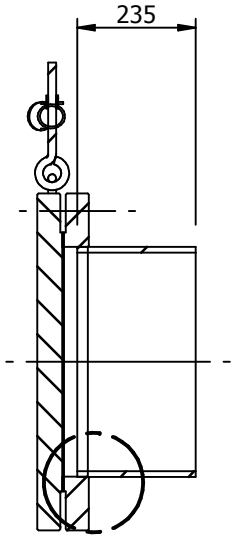


Item Number	Title	Quantity
1	Flange Blank_150#_450NB_ANSI B16.5_A105_RF	1
2	Flange_150#_SORF 450NB_ANSI B16.5_A105	1
3	Pipe_450NB SCH30_260mm_ASTM A 106B	1
4*	Gasket_KLINERT_450NB	1
5*	M30 HT STUD_200mm_A193 GrB7	16
6*	M30 Washer_A194 Gr 2H ASME SF844	32
7*	M30 Nut_A194 Gr 2H	32
8	Davit Arm Assembly	1

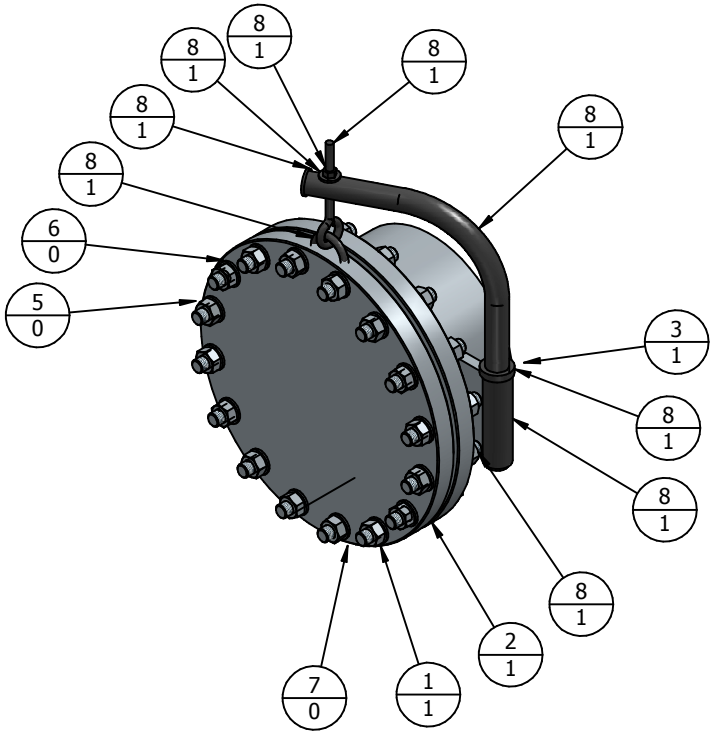




DETAIL B



B
SECTION A-A

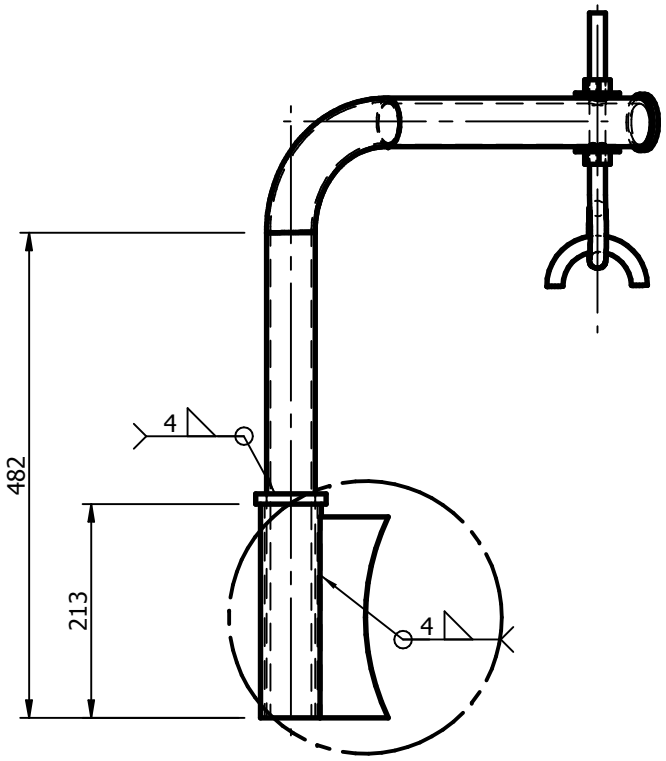


APPROVED	DESCRIPTION	DATE	REV
REVISION HISTORY			

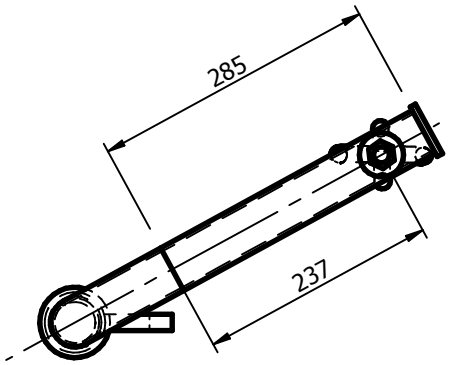
XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

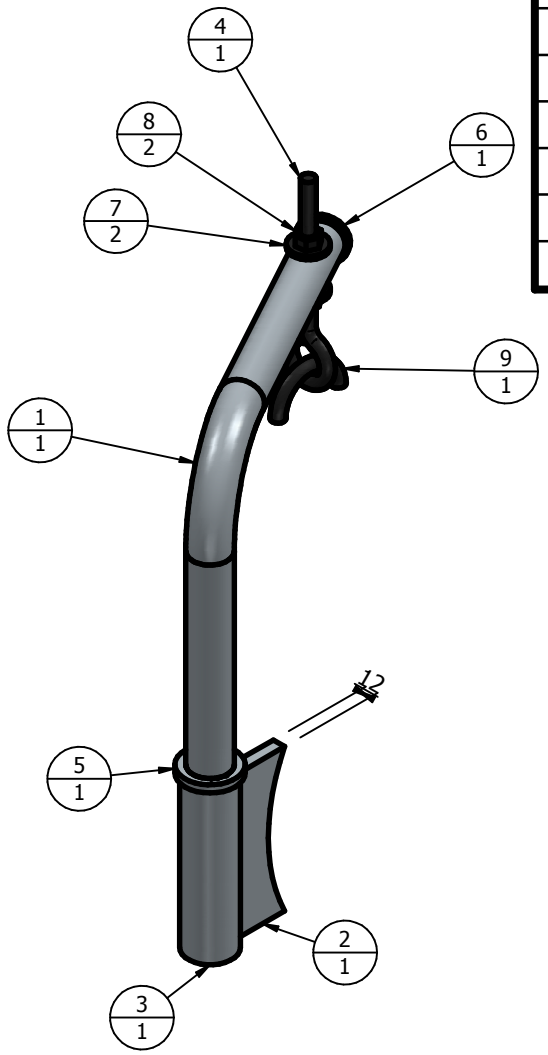
TITLE: A3 MANHOLE AND DAVIT ASSEMBLY		
Client:	Order No.	Scale:
Drawn:	Date:	Client Dwg No.
Drawing No. 10M3-16-03		Revision 0

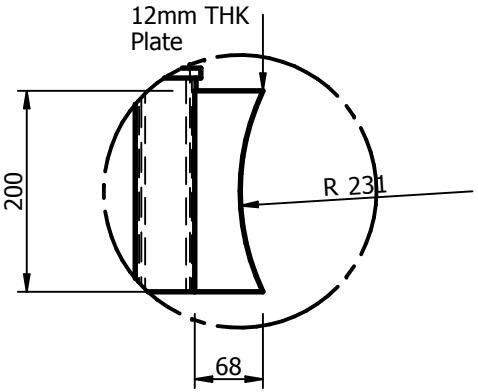
Item Number	Title	Quantity
1	Pipe_40NB_SCH40_650mm_A106B	1
2	Support Bracket 12mm thk_BS1501-151 Gr430A	1
3	Pipe 50NB_ SCH40_212mm_A106 B	1
4	M16 Eyebolt	1
5	Plate Disc_Steel	1
6	Plate disc d56x3mm thk_Steel	1
7	M16 Washer	2
8	M16 hex bolt	2
9	Eye_D93 x d16mm	1



A





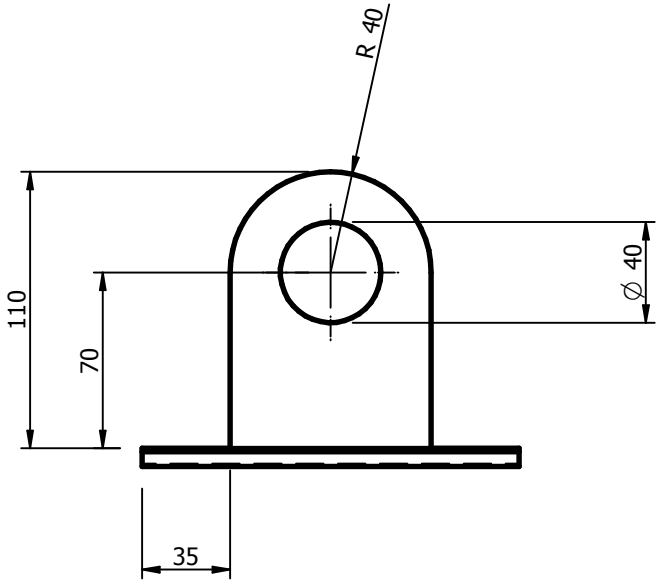


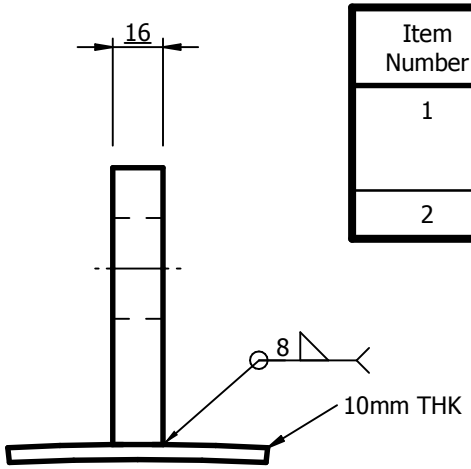
DETAIL A

APPROVED	DESCRIPTION	DATE	REV
REVISION HISTORY			

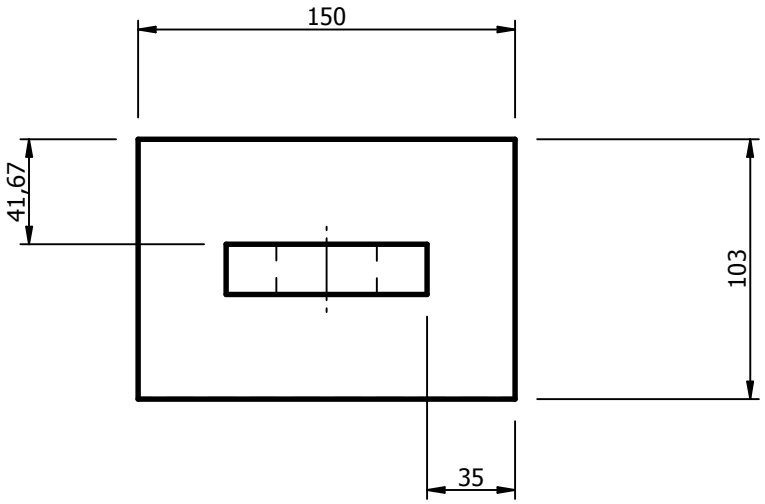
XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

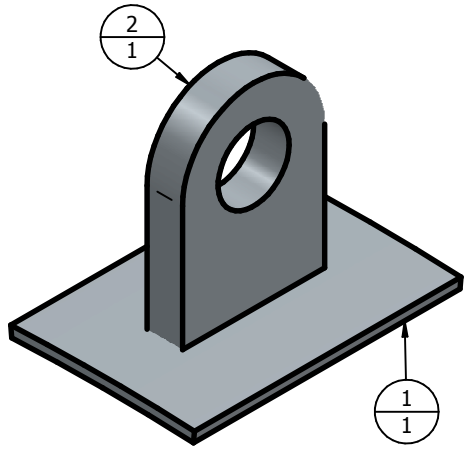
TITLE: DAVIT ARM		
A3		
Client:	Order No.	Scale:
Drawn:	Date:	Client Dwg No.
Drawing No. 10M3-16-04		Revision 0





Item Number	Title	Quantity
1	Lug Reinforcing Pad_10mm_BS1501-151 Gr430A	1
2	Lug_Commercial Steel	1



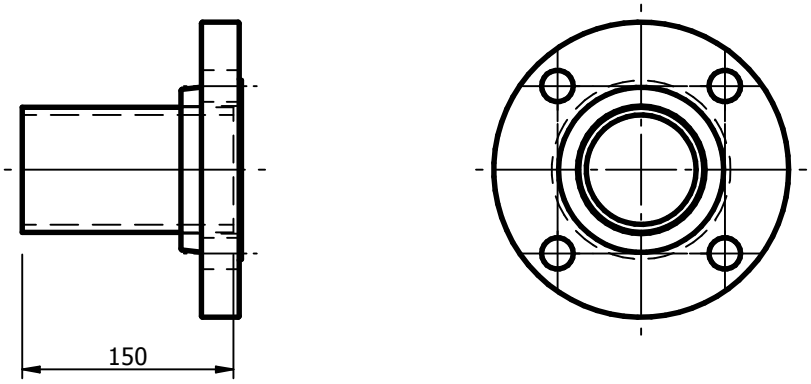


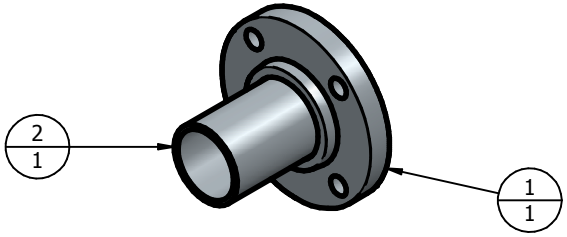
APPROVED	DESCRIPTION	DATE	REV
REVISION HISTORY			

XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

TITLE: A3	LUG ASSEMBLY	
Client:	Order No.	Scale:
Drawn:	Date:	Client Dwg No.
Drawing No. 10M3_16_05		Revision 0

Item Number	Title	Quantity
1	Flange_ANSI B16.5_80NB_150#_A105	1
2	Pipe_80NB_SCH40_150mm_A106 B	1





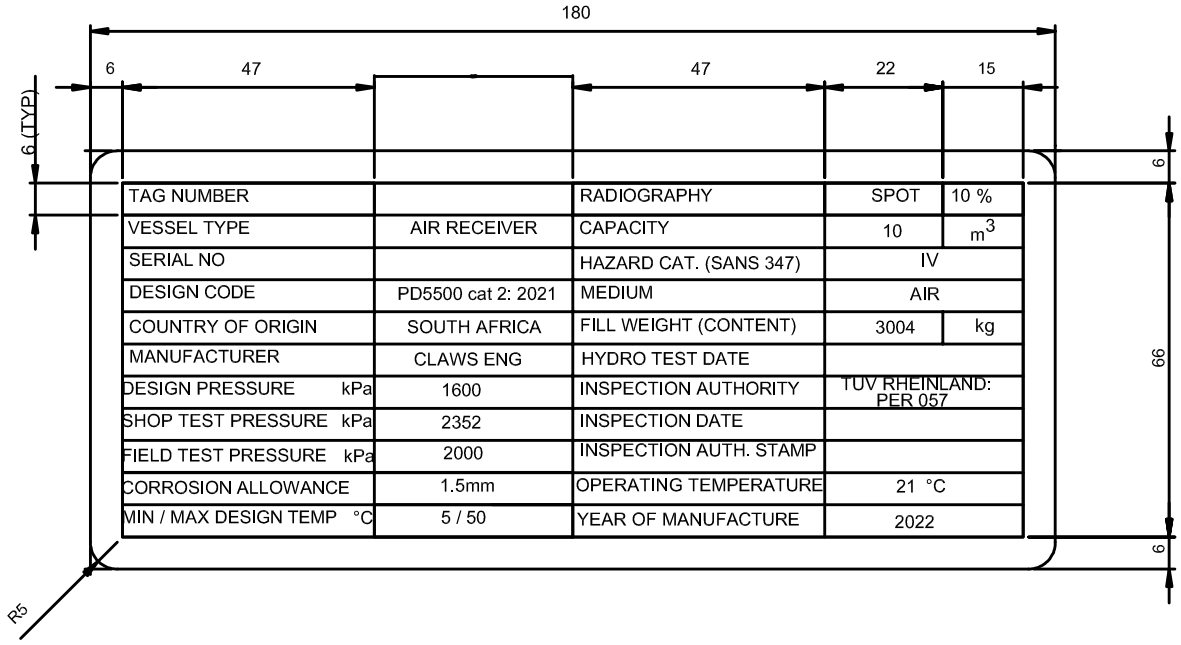
N6 3 OFF SCH40 (MOUNTED ON SHELL)

N4 2 OFF SCH80 (MOUNTED ON HEAD)

APPROVED	DESCRIPTION	DATE	REV
REVISION HISTORY			

XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

TITLE: A3	NOZZLE 80NB		
Client:	Order No.	Scale:	
Drawn:	Date:	Client Dwg No.	
Drawing No.	10M3-16-06	Revision	0



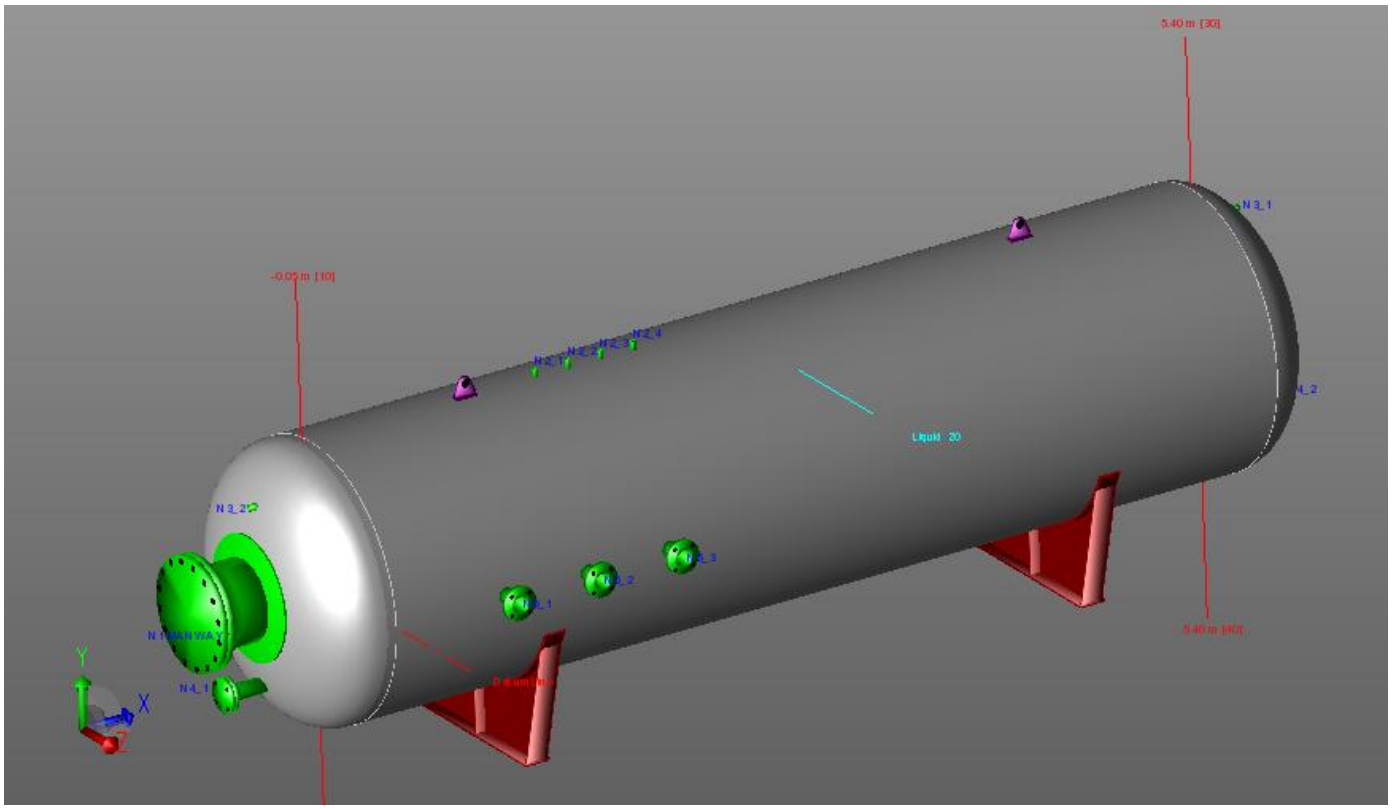
TAG NUMBER		RADIOGRAPHY	SPOT	10 %
VESSEL TYPE	AIR RECEIVER	CAPACITY	10	m^3
SERIAL NO		HAZARD CAT. (SANS 347)	IV	
DESIGN CODE	PD5500 cat 2: 2021	MEDIUM	AIR	
COUNTRY OF ORIGIN	SOUTH AFRICA	FILL WEIGHT (CONTENT)	3004	kg
MANUFACTURER	CLAWS ENG	HYDRO TEST DATE		
DESIGN PRESSURE kPa	1600	INSPECTION AUTHORITY	TUV RHEINLAND: PER 057	
SHOP TEST PRESSURE kPa	2352	INSPECTION DATE		
FIELD TEST PRESSURE kPa	2000	INSPECTION AUTH. STAMP		
CORROSION ALLOWANCE	1.5mm	OPERATING TEMPERATURE	21 °C	
MIN / MAX DESIGN TEMP °C	5 / 50	YEAR OF MANUFACTURE	2022	

VESSEL DESIGNED ACCORDING TO PD5500: 2021
LESLIE GREEN (PrTechEng)
201470150

CONFORMITY ASSESMENT MODULE: G

NOTES:
1. HEIGHT OF ALL LETTERS TO BE 3 MM
2. FOR ALL LETTERS USE "ARIAL NARROW" FONT
3. FINAL ENGRAVING DETAIL FOR THE SPECIFIC VESSEL WILL BE SUPPLIED WITH REQUEST OF QUOTATION
4. TO BE STAMPED ON COMPLETION OF HYDRO TEST

TITLE: Name Plate_10m3 AIR RECEIVER				DOCUMENT TYPE: Detail part drawing	REVISION: 1.00
	NAME	SIGNATURE	DATE	DWG NO. 10M3-16-07	
DRAWN	R.H	L.G	2021-08-08		
CHK'D	L.G	L.G			
APPV'D	L.G	L.G		MATERIAL: STAINLESS STEEL	
	Project				
	SCALE:1:1			Page size: A3	SHEET 1 OF 1


5.40 m [30]
N 3_1
-0.05 m [10]
N 3_2
Liquid : 20
N 4_1
Y
X

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	1.6	N/mm²
Design Internal Temperature	50.0	°C
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm
Projection of Nozzle from Vessel Bottom	0	mm
Minimum Design Metal Temperature	-28.9	°C
Construction Category	Category 2	
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	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	

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		SANS 10160-3:2010	
Basic Wind Speed	[V]	28	m/sec
Terrain Category		A	
Base Elevation		0	m
Topography Factor		1.0	
Site Elevation		0	m.
Force Coefficient [Cf]		0.69999999	
Seismic Design Code		SANS 10160-4:2010	
Ref. horizontal peak ground accel.	[ag]	0.1000	
Ground type		1	
Behavior factor	[q]	1.0000	
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	

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	0.0508	m
Element Outside Diameter	1550	mm
Element Thickness	12	mm

Internal Corrosion Allowance	1.5	mm
Nominal Thickness	11.48	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1.6	N/mm²
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm²
Design Temperature External Pressure	35	°C
Effective Diameter Multiplier	1.2	
Material Name	BS1501-151,430A	
Allowable Stress, Ambient	166996	kPa
Allowable Stress, Operating	166996	kPa
Material Density	7810	kg/m³
Elliptical Head Factor	2.0	
Weld is pre-Heated	N/A	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N1 MANWAY	
Dist. from "FROM" Node / Offset dist	0	mm
Nozzle Diameter	450	mm
Nozzle Schedule	30	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	1994.8	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N4_1	
Dist. from "FROM" Node / Offset dist	500	mm
Nozzle Diameter	80	mm
Nozzle Schedule	80	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N3_2	
Dist. from "FROM" Node / Offset dist	500	mm
Nozzle Diameter	38.1	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	5.4	m
Element Outside Diameter	1550	mm
Element Thickness	10	mm
Internal Corrosion Allowance	1.5	mm
Nominal Thickness	10	mm

External Corrosion Allowance	0	mm
Design Internal Pressure	1.6	N/mm²
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm²
Design Temperature External Pressure	35	°C
Effective Diameter Multiplier	1.2	
Material Name	BS1501-151,430A	
Weld is pre-Heated	N/A	

Element From Node	20	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	1	m
Width of Saddle	120	mm
Height of Saddle at Bottom	1100	mm
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm
Width of Wear Plate	100	mm
Thickness of Wear Plate	10	mm
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.0	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	m

Element From Node	20	
Detail Type	Saddle	
Detail ID	Sdl 2 Fr20	
Dist. from "FROM" Node / Offset dist	4.4	m
Width of Saddle	120	mm
Height of Saddle at Bottom	1100	mm
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm
Width of Wear Plate	100	mm
Thickness of Wear Plate	10	mm
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.0	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	m

Element From Node	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	m
Height/Length of Liquid	1.4	m
Liquid Density	500	kg/m³

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N2_2	
Dist. from "FROM" Node / Offset dist	1.58	m
Nozzle Diameter	28.58	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N2_1	
Dist. from "FROM" Node / Offset dist	1.38	m
Nozzle Diameter	28.58	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N2_3	
Dist. from "FROM" Node / Offset dist	1.78	m
Nozzle Diameter	28.58	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N2_4	
Dist. from "FROM" Node / Offset dist	1.98	m
Nozzle Diameter	28.58	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N6_1	
Dist. from "FROM" Node / Offset dist	0.677	m
Nozzle Diameter	80	mm
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	76.35	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N6_2	
Dist. from "FROM" Node / Offset dist	1.177	m
Nozzle Diameter	80	mm
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	20

Detail Type	Nozzle	
Detail ID	N6_3	
Dist. from "FROM" Node / Offset dist	1.677	m
Nozzle Diameter	80	mm
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N5	
Dist. from "FROM" Node / Offset dist	4.6	m
Nozzle Diameter	57.15	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	30	
Element To Node	40	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	0	m
Element Outside Diameter	1550	mm
Element Thickness	10	mm
Internal Corrosion Allowance	1.5	mm
Nominal Thickness	10	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1.6	N/mm^2
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm^2
Design Temperature External Pressure	35	°C
Effective Diameter Multiplier	1.2	
Material Name	BS1501-151,430A	
Elliptical Head Factor	2.0	
Weld is pre-Heated	N/A	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N4_2	
Dist. from "FROM" Node / Offset dist	500	mm
Nozzle Diameter	80	mm
Nozzle Schedule	80	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N3_1	
Dist. from "FROM" Node / Offset dist	600	mm
Nozzle Diameter	38.1	mm
Nozzle Schedule	None	

Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

XY Coordinate Calculations:

From	To	X (Horiz.) m	Y (Vert.) m	DX (Horiz.) m	DY (Vert.) m
10	20	0.0508	...	0.0508	...
20	30	5.4508	...	5.4	...
30	40	5.4508	...	...	...

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd N/mm²	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) kPa
10	20	1.6	11.48	1.5	1550	166996
20	30	1.6069	10	1.5	1550	166996
30	40	1.6	10	1.5	1550	166996

Element Required Thickness and MAWP :

From	To	Design Pressure N/mm²	M.A.W.P. Corroded N/mm²	M.A.P. New & Cold N/mm²	Minimum Thickness mm	Required Thickness mm
10	20	1.6	2.18721	2.55105	12	9.51124
20	30	1.6	1.83484	2.16883	10	8.92134
30	40	1.6	1.7501	2.10616	10	9.37688
Minimum			1.750	1.960		

MAWP: 1.750 N/mm², limited by: Elliptical Head.

Internal Pressure Calculation Results :

British Standard PD 5500:2021

Elliptical Head From 10 To 20 BS1501-151.430A at 50 °C

Thickness Due to Internal Pressure (er):
= Values_Used_Min(HT, HE1, HE2), P/f, he/D, D Per 3.5.2 Domed Ends
= Values_Used_Min(393.5,2539975,2539975),0.00958,0.2539,1550.0
= 8.0112 + 1.5000 = 9.5112 mm

Max. All. Working Pressure at Given Thickness (MAWP):
= 2.19 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= 2.55 N/mm²

Actual Stress at Given Thickness:
= (P * Rica) / ecor
= (1.6*764.5)/10.5
= 116492.55 kPa

Required Thickness of Straight Flange = 8.975 mm

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 12.000 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-38.9 - (-49.83 + 0.4408*12.0 + 0.1792*12.0^2 - 0.006218*12.0^3 + 5.992E-5*12.0^4))/
(1.868 - 0.1324*12.0 + 0.00512*12.0^2 - 0.000101*12.0^3 + 7.939E-7*12.0^4)
= -12.4 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
166996.2	116492.5	2	As Welded	0	-10	0

Design Reference Temperature ThetaR: -39°C, per Paragraph D.6.1.

Caution: Please review the above results to ensure compliance with the specific project requirements.

Cylindrical Shell From 20 To 30 BS1501-151,430A at 50 °C

Thickness Due to Internal Pressure (er):
= (P * Do) / (2 * f + p) per 3.5.1.2 Eqn. 3.5.1-2
= (1.61*1550.0)/(2*166996.17+1.61)
= 7.4213 + 1.5000 = 8.9213 mm

Max. All. Working Pressure at Given Thickness (MAWP):
Less Operating Hydrostatic Head Pressure of 0.01 N/mm²
= (2 * f * ecor) / (Doca - ecor)
= (2*166996.17*8.5)/(1550.0-8.5)
= 1.84 - 0.01 = 1.83 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= (2 * fa * e) / (D - e)
= (2*166996.17*10.0)/(1550.0-10.0)
= 2.17 N/mm²

Actual Stress at Given Thickness:
= (P * Ri) / ecor
= (1.61*766.5)/8.5
= 144898.70 kPa

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 10.000 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-15.0 - (-49.83 + 0.4408*10.0 + 0.1792*10.0^2 - 0.006218*10.0^3 + 5.992E-5*10.0^4))/
(1.868 - 0.1324*10.0 + 0.00512*10.0^2 - 0.000101*10.0^3 + 7.939E-7*10.0^4)
= 18.8 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
166996.2	144898.7	2	As Welded	0	-10	0

Design Reference Temperature ThetaR: -39°C, (Modified Below)

Because Thickness <= 10 mm Table D.3 is Applied, thus:
Table D.3 give limiting ThetaR = -15 °C for 10.0 mm
ThetaR = -39 °C, but from Table D.3 Exempt Temp. = -15.0 °C

Because Actual ThetaR < Table D.3 ThetaR - IMPACT TESTING IS MANDATORY

Caution: Please review the above results to ensure compliance with the specific project requirements.

Elliptical Head From 30 To 40 BS1501-151,430A at 50 °C

Thickness Due to Internal Pressure (er):
= Values_Used_Min(HT, HE1, HE2), P/f, he/D, D Per 3.5.2 Domed Ends
= Values_Used_Min(397.5,2539975,2539975),0.00958,0.2565,1550.0
= 7.8769 + 1.5000 = 9.3769 mm

Max. All. Working Pressure at Given Thickness (MAWP):
= 1.75 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= 2.11 N/mm²

Actual Stress at Given Thickness:
= (P * Rica) / ecor
= (1.6*766.5)/8.5
= 144279.03 kPa

Required Thickness of Straight Flange = 8.975 mm

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 10.000 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-15.0 - (-49.83 + 0.4408*10.0 + 0.1792*10.0^2 - 0.006218*10.0^3 + 5.992E-5*10.0^4))/
(1.868 - 0.1324*10.0 + 0.00512*10.0^2 - 0.000101*10.0^3 + 7.939E-7*10.0^4)
= 18.8 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
166996.2	144279.0	2	As Welded	0	-10	0

Design Reference Temperature ThetaR: -39°C, (Modified Below)

Because Thickness <= 10 mm Table D.3 is Applied, thus:
Table D.3 give limiting ThetaR = -15 °C for 10.0 mm
ThetaR = -39 °C, but from Table D.3 Exempt Temp. = -15.0 °C

Because Actual ThetaR < Table D.3 ThetaR - IMPACT TESTING IS MANDATORY

Caution: Please review the above results to ensure compliance with the
specific project requirements.

Hydrostatic Test Pressure Results:

PD:5500 5.8.5-1, Standard Test Pressure
= 1.25 * P * fa/ft * (t / (t - c)) (per 5.8.5-1)
= 1.25 * 1.6 * 1.0 * (12.0/(12.0 - 1.5))
= 2.2857 N/mm²

PD:5500 5.8.5-1, Field Test Pressure
= 1.25 * P * fa/ft (per 5.8.5-1)
= 1.25 * 1.6069 * 166996.172/166996.172
= 2.0086 N/mm²

Lower Bound Test Pressure	ptL	2.286	N/mm²
Upper Bound Test Pressure	ptH	2.363	N/mm²
1.35 times the Specified Design P	1.35*Dsgprs	2.160	N/mm²

Standard Test Pressure, 2.2857 N/mm², used in table below.

Stresses on Elements due to Test Pressure (kPa):

From	To	Pressure	Stress	Allowable	Ratio
10	20	2.301	150621.4	224991.5	0.669
20	30	2.301	176015.4	224991.5	0.782
30	40	2.301	182437.5	224991.5	0.811

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length m	Outside Diameter mm	Corroded Thickness mm	Factor A	Factor B kPa
10	20	No Calc	1550	10.5	No Calc	No Calc
20	30	5.7564	1550	8.5	No Calc	No Calc
30	40	No Calc	1550	8.5	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm	External Required T. mm	External Design Pressure N/mm²	External M.A.W.P. N/mm²
10	20	12	No Calc	...	1.05407
20	30	10	No Calc	...	0.10524
30	40	10	No Calc	...	0.75206
Minimum					0.105

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners m	Allowable Length Bet. Stiffeners m	Ring Inertia Required mm**4	Ring Inertia Available mm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	5.7564	No Calc	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

British Standard PD 5500:2018+A1:2018

Elliptical Head From 10 to 20

Determine the Stress Yield point [Py]:
= 2 * Sfact * f * ea / R
= 2 * 1.4 * 166996.172 * 10.5/1526.37
= 3216.586 kPa

Determine the Elastic Instability Pressure [Pm]:
= 1.21 * E * ea^2 / R^2
= 1.21 * 208242.8 * $10.5^2/1526.37^2$
= 11.924 kPa

External Allowable Pressure [Pmax]:
= delta * Py
= 0.328 * 3.217
= 1.054 N/mm^2

Cylindrical Shell From 20 to 30

Determine the Stress Yield point [Py]:
= Sfact * f * ea / R
= 1.4 * 166996.172 * 8.5/770.75
= 2578.339 kPa

Strain Factor [Z]:
= pi * R / L
= 3.141 * 770.75/5756.4
= 0.421

Determine the ratio Pm/Py:
= Pm / Py
= 316.98/2578.339
= 0.123

Determine delta from Figure 3.6-4:
= 0.041

Determine the critical Strain [strain]:
$= 1/(n^2-1+Z^2/2)[1/(n^2/Z^2+1)^2+ea^2/(12R^2(.91))*(n^2-1+Z^2)^2]$
$= 1/(3^2-1+0.421^2/2)$
$[1/(3^2/0.421^2+1)^2+8.5^2/(12*770.8^2(1-0.3^2)$
$(3^2-1+0.421^2)^2]$
$= 0.0001380$

Where n is the expected number of lobes [n]:
= 3

Determine the Elastic Instability Pressure [Pm]:
= E * ea * strain / R
= 208242.8 * 8.5 * 0.000138/770.75
$= 0.317\ N/mm^2$

External Allowable Pressure [Pmax]:
= delta * Py
= 0.041 * 2.578
$= 0.105\ N/mm^2$

Elliptical Head From 30 to 40

Determine the Stress Yield point [Py]:
= 2 * Sfact * f * ea / R
= 2 * 1.4 * 166996.172 * 8.5/1530.25
= 2597.285 kPa

Determine the Elastic Instability Pressure [Pm]:
$= 1.21 * E * ea^2 / R^2$
$= 1.21 * 208242.8 * 8.5^2/1530.25^2$
= 7.774 kPa

External Allowable Pressure [Pmax]:
= delta * Py
= 0.29 * 2.597
$= 0.752\ N/mm^2$

Element and Detail Weights:

From	To	Element Metal Wgt. kgm	Element ID Volume m³	Corroded Metal Wgt. kgm	Corroded ID Volume m³	Extra due Misc % kgm
10	20	288.338	0.55817	252.296	0.56129	...
20	30	2040.44	9.92989	1736.05	9.96887	...
30	40	221.687	0.46891	188.434	0.47168	...
Total		2550	10.96	2176	11.00	0

Weight of Details:

From	Type	Weight of Detail kgm	X Offset, Dtl. Cent. m	Y Offset, Dtl. Cent. m	Description
10	Nozl	203.428	-0.3815	...	N1 MANWAY
10	Nozl	13.4284	-0.28817	...	N4_1
10	Nozl	0.21613	-0.28817	...	N3_2
20	Sadl	103.216	1	0.9225	Lft Sdl
20	Sadl	103.216	4.4	0.9225	Sdl 2 Fr20
20	Liqd	4760.87	2.7	0.065	Liquid: 20
20	Nozl	0.10555	1.58	0.77929	N2_2
20	Nozl	0.10555	1.38	0.77929	N2_1
20	Nozl	0.10555	1.78	0.77929	N2_3
20	Nozl	0.10555	1.98	0.77929	N2_4
20	Nozl	7.78602	0.677	0.80945	N6_1
20	Nozl	6.60929	1.177	0.80945	N6_2
20	Nozl	6.60929	1.677	0.80945	N6_3
20	Nozl	0.60871	4.6	0.79358	N5
30	Nozl	8.15429	0.28949	...	N4_2
30	Nozl	0.22815	0.23729	...	N3_1

Total Weight of Each Detail Type:

Saddles	206.4
Liquid	4760.9
Nozzles	247.5
Sum of the Detail Weights	5214.8 kgm

Weight Summation Results: (kgm)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	2550.5	2550.5	2550.5	2550.5	2550.5	2550.5
Saddles	206.4	206.4	206.4	206.4	206.4	206.4
Nozzles	247.5	247.5	247.5	247.5	247.5	247.5
Ope. Liquid	...	...	...	...	...	4760.9
Test Liquid	...	10950.3	...	...	...	...
Totals	3004.4	13954.7	3004.4	3004.4	3004.4	7765.3

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	3004.4 kgm
Shop Test Wt.	- Fabricated Weight + Water (Full)	13954.7 kgm
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	3004.4 kgm
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	3004.4 kgm
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	3004.4 kgm
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	7765.3 kgm

```
 Oper. Wt. + CA  - Corr Wt. + Operating Liquid                    7391.6 kgm
 Field Test Wt.  - Empty Weight + Water (Full)                   13954.7 kgm
```

Note:
The Corroded Weight and thickness are used in the Horizontal
Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Outside Surface Areas of Elements:

From	To	Surface Area m²
10	20	2.85094
20	30	26.2886
30	40	2.60363
Total		31.743 m²

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. N/mm²	Flange Rating Ambient N/mm²	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV N/mm²
N1 MANWAY	1.92	1.96	50	150	GR 1.1	...	...	...	...
N4_1	1.92	1.96	50	150	GR 1.1	...	...	...	...
N4_2	1.92	1.96	50	150	GR 1.1	...	...	...	...
Min Rating	1.920	1.960 N/mm² [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

Input Values:

Wind Design Code		SANS 10160-3:2010	
Basic Wind Speed	[V]	28	m/sec
Terrain Category		A	
Base Elevation		0	m
Topography Factor		1.0	
Site Elevation		0	m.
Force Coefficient [Cf]		0.69999999	

Calculated Values:

Probability factor (cprob)	1.000
Table lookup value air density from Table 4	0.120E+01 kg/m³

Sample Calculation for the First Element:

Probability factor [cprob] per 7.2.3:
= [(1 - K * ln(-ln(1- p))/(1 - K * ln(-ln(0.98)))]^n
= [(1 - 0.2 * ln(-ln(1- 0.02))/(1 - 0.2 * ln(-ln(0.98)))]^ 0.5
= 1.000

Basic wind speed [vb] per 7.2.2:
= Probability factor * Fundemental value of basic wind speed
= 1.0 * 12.517
= 28.001 m/sec

Peak basic wind speed [vbpeak] per 7.3.1.1:
= 1.4 * vb
= 1.4 * 28.001
= 39.201 m/sec

Height of interest for first element [z]:
= Centroid Height + Base Height
= 1.1 + 0.0
= 1.100 m. [1.100 m]

Roughness factor at height of the first element [Cr(z)]:
= Interpolated value from the table 3 at 1.1 m.
= 0.948

Peak wind speed at height of the first element [vp(z)] per 7.3.1.1:
= Cr(z) * Co(z) * vbpeak
= 0.948 * 1.0 * 39.201
= 37.143 m/sec

Peak wind speed pressure at height of the first element [qp(z)] per 7.4:
= 1/2 * RO * vb(z)^2
= 1/2 * 0.120E+01 * 37.143^2
= 0.8278E+03 N./m² [0.8277E+00 kPa]

Wind force on the first element [Fw] per 7.5.3.2:
= Cs * Cd * Cf * qp(z) * Aref
= 1.0 * 1.0 * 0.7 * 827.75 * 0.574
= 332.3 N.

Element	z m	Area m²	Pressure kPa	Force N
Node 10 to 20	1.100	0.573	0.828	332.300
Node 20 to 30	1.100	10.042	0.828	5819.524
Node 30 to 40	1.100	0.478	0.828	276.881

Wind Load Calculation:

PV Elite Licensee: XGM
FileName : Air Receiver Aspen ----------
Wind Load Calculation: Step: 7 12:23pm Aug 23,2022

From	To	Wind Height m	Wind Diameter m	Wind Area m^2	Wind Pressure kPa	Element Wind Load N
10	20	1.1	1.86	0.57338	0.82773	332.3
20	30	1.1	1.86	10.0415	0.82773	5819.52
30	40	1.1	1.86	0.47775	0.82773	276.881

Input Values:

```
Seismic Design Code                        SANS 10160-4:2010
Ref. horizontal peak ground accel.  [ag]              0.1000
Ground type                                              1
Behavior factor                      [q]              1.0000
```

Calculated Values:

```
Soil factor based on ground type from Table 2       1.000
Value of TB based on ground type from Table 2      0.150
Value of TC based on ground type from Table 2      0.400
Value of TD based on ground type from Table 2       2.000
```

Sample Calculation for the Force on the First Element [F1n]:

Fundamental period of vibration [T]:
```
  = 1 / Natural Frequency
  = 1/33.0
  = 0.030 sec
```

Design spectrum for elastic analysis [Sd(T)] per 5.3:
```
  = ag * S[ 2/3 + T/TB ( 2.5/q - 2/3 ) ]
  = 0.1 * 1.0[ 2/3 + 0.03/0.15 ( 2.5/1.0 - 2/3 ) ]
  = 0.104
```

Sustained vertical load [Wn] per 8.3:
```
  = Summation of self weight loads of all elements
  = 72.485 KN  [72481.4 N]
```

Design Base Shear Load per 8.5.1 [Vn] :
```
  = Sd(T) * Wn
  = 0.104 * 72.485
  = 7.517 KN  [7516.6 N]
```

Factor to determine lateral seismic force on element 1 [Cv1] per 8.5.3:
```
  = W1 * h1 / SUM[ Wi * hi ]
  = 14496.352 * 0.763/55419.555
  = 0.19958
```

Vertical distribution of seismic forces for element 1 [F1n] per 8.5.3:
```
  = Cv1 * Vn
  = 0.19958 * 7.517
  = 1.500 KN  [1500.2 N]
```

Earthquake Load Calculation:

From	To	Earthquake Height m	Earthquake Weight N	Element Ope Load N
10	20	0.763	14496.4	1500.17
20	Sadl	0.765	14496.4	1504.1
Sadl	30	0.765	14496.4	1504.1
20	30	0.765	14496.4	1504.1
30	40	0.765	14496.4	1504.1

Shop/Field Installation Options :

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

```
Center of Gravity of Saddles                                  2.751 m
Center of Gravity of Liquid                                   2.751 m
Center of Gravity of Nozzles                                 -0.019 m

Center of Gravity of Bare Shell New and Cold                  2.673 m
Center of Gravity of Bare Shell Corroded                      2.663 m

Vessel CG in the Operating Condition                          2.632 m
Vessel CG in the Fabricated (Shop/Empty) Condition            2.456 m
Vessel CG in the Test Condition                               2.668 m
```

Rigging Analysis Results:

Lifting Weight based the calculated Empty Weight.

```
Total Effective Length of Vessel for this analysis            5.45 m
Total vessel weight (No Liquid)                 Twt       29460.98 N
Impact weight multiplication factor             Imp           1.50
Design lifting weight,  DWT = Imp * Twt                   44191.47 N
Distance to the Lug on the Left End                           1.00 m
Distance to the Lug on the Right End                          4.40 m
Design Reaction force at the Left End Lug                 25261.31 N
Design Reaction force at the Right End Lug                18930.16 N

CG Distance from the Left End Lug                             1.46 m
CG Distance from the Nearer Lifting Lug                       1.46 m
```

Critical Values:

	Max Stress kPa	Elevation m	Allowables kPa	
Bending	770.90	1.13	115149.50	
Shear	341.02	0.05	116897.32	(0.7*S)

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

Distance m	Bending Moment N-m	Bending Stress kPa	Shear Force N	Shear Stress kPa
0.00	0.0	0.0	15319.7	264.2
1.13	14272.5	770.9	4558.9	94.2
3.29	5694.4	307.6	6047.0	125.0
5.45	1289.7	69.7	1178.4	24.4

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0067 at elevation 1.1308 m - Must be <=1

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

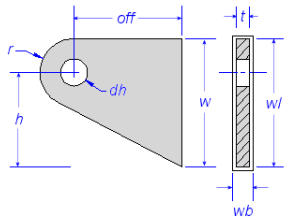
--- Plot data successfully generated ...----

Lifting Lug Calculations: Lug(s) on Left End of Vessel

Input Values:

Lifting Lug Material		BS1501-151,430A	
Lifting Lug Yield Stress	Yield	249994.28	kPa
Total Height of Lifting Lug	w	120.0000	mm
Thickness of Lifting Lug	t	14.0000	mm
Diameter of Hole in Lifting Lug	dh	40.0000	mm
Radius of Semi-Circular Arc of Lifting Lug	r	40.0000	mm
Height of Lug from bottom to Center of Hole	h	70.0000	mm
Offset from Vessel OD to Center of Hole	off	8.0000	mm
Lug Fillet Weld Size	tw	8.0000	mm
Length of weld along side of Lifting Lug	wl	128.0000	mm
Length of Weld along Bottom of Lifting Lug	wb	14.0000	mm
Thickness of Collar (if any)	tc	0.0000	mm
Diameter of Collar (if any)	dc	0.0000	mm
Impact Factor	Impfac	1.50	
Sling Angle from Horizontal		90.0000	deg
Number of Lugs in Group		1	

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : Horizontal Lift



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

Computed Results:

Total vessel weight (No Liquid)		29460.98	N
Design Reaction force at the Left end lug		25261.31	N
Design Reaction force at the Right end lug		18930.16	N
Force Along Vessel Axis	Fax	0.00	N
Force Normal to Vessel	Fn	25261.31	N
Force Tangential to Vessel	Ft	0.00	N

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

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	Ilc	2684603.750	mm**4
Weld Group Centroid distance in the Long. Direction	Yll	69.656	mm
Dist. of Weld Group Centroid from Lug bottom	Yll_b	64.000	mm
Weld Group Inertia about the Longitudinal Axis	Ill	31648.822	mm**4
Weld Group Centroid Distance in the Circ. Direction	Ylc	7.000	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(0^2+0^2+25261^2)/((2*(128.0+14.0))*5.656)
= 15726.78 kPa

Shear Stress in the Welds due to Bending Loads [Sblf]:
= (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
= (25261(70.0-64.0))69.656/2684604 +
(0 * 8.0 * 69.656/2684604) +
(0 * 8.0 * 7.0/31648.822)
= 3932.76 kPa

Total Shear Stress for Combined Loads [St]:
= Ssll + Sblf
= 15726.779 + 3932.76
= 19659.54 kPa

Allowable Shear Stress for Combined Loads [Sta]:
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 249994 * 1.0
= 99997.72 kPa

Shear Stress in Lug above Hole [Shs]:
= sqrt(Pl^2 + Fax^2) / Sha
= sqrt(25261^2 + 0^2)/0.001
= 45110.70 kPa

Allowable Shear Stress in Lug above Hole [Sas]:
= 0.4 * Yield * Occfac
= 0.4 * 249994 * 1.0
= 99997.72 kPa

Pin Hole Bearing Stress [Pbs]:
= sqrt(Fax^2 + Fn^2) / (t * dh)
= sqrt(0^2 + 25261^2)/(14.0 * 40.0)
= 45110.70 kPa

Allowable Bearing Stress [Pba]:
= min(0.75 * Yield * Occfac, 0.9 * Yield) AISC Bearing All.
= min(0.75 * 249994 * 1.0, 224994.9)
= 187495.70 kPa

Bending Stress at the Base of the Lug [Fbs]:
= Ft * off/(w * t^2/6) + Fax * off/(w^2 * t/6)
= 0 * 8.0/(120.0 * 14.0^2/6) +
0 * 8.0/(120.0^2 * 14.0/6)
= 0.00 kPa

Tensile Stress at the Base of the Lug [Fa]:
= Fn / (w * t)
= 25261/(120.0 * 14.0)
= 15036.90 kPa

Total Combined Stress at the Base of the Lug:
= Fbs + Fa
= 0.0 + 15036.9
= 15036.90 kPa

Lug Allowable Stress for Bending and Tension:
= min(0.66 * Yield * Occfac, 0.75 * Yield)
= min(0.66 * 249994 * 1.0, 187495.7)
= 164996.23 kPa

Required Shackle Pin Diameter [Spd]:
= sqrt[(2 * sqrt(Fn^2 + Fax^2)/(Pi * Sta))]
= sqrt[2 * sqrt(25261^2 + 0^2)/(Pi * 99998)]
= 12.6817 mm

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

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6 in paragraph 4.3 of WRC Bulletin 107.

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	1530.000	mm
Vessel Thickness	Tv	10.000	mm

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

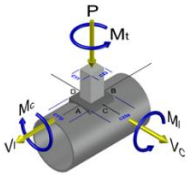
Attachment Type	Type	Rectangular	
Parameter C11	C11	14.00	mm
Parameter C22	C22	56.00	mm
Thickness of Reinforcing Pad	Tpad	10.000	mm
Pad Parameter C11P	C11p	62.000	mm
Pad Parameter C22P	C22p	136.000	mm
Design Internal Pressure	Dp	0.000	N/mm^2
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-25261.3	N
Longitudinal Shear	(SUS)	Vl	0.0	N
Circumferential Shear	(SUS)	Vc	0.0	N
Circumferential Moment	(SUS)	Mc	0.0	N-m
Longitudinal Moment	(SUS)	Ml	0.0	N-m
Torsional Moment	(SUS)	Mt	0.0	N-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	-25261.3	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	0.0	N
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	0.0	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 38.75

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.027	4C		7.475	(A,B)
N(PHI) / (P/Rm)	0.027	3C		7.667	(C,D)
M(PHI) / (P)	0.016	2C1		0.239	(A,B)
M(PHI) / (P)	0.016	1C	!	0.274	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.014	3A		0.084	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.018	1A	!	0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.023	3B		0.720	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.020	1B	!	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.022	3C		7.753	(A,B)
N(x) / (P/Rm)	0.022	4C		7.514	(C,D)
M(x) / (P)	0.023	1C1		0.272	(A,B)
M(x) / (P)	0.023	2C		0.219	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.014	4A		0.099	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.024	2A	!	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.023	4B		0.175	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.027	2B	!	0.106	(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 (kPa)

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		12182	12182	12182	12182	12495	12495	12495	12495
Circ. Bend. P		90499	-90499	90499	-90499	103892	-103892	103892	-103892
Circ. Memb. MC		0	0	0	0	0	0	0	0
Circ. Bend. MC		0	0	0	0	0	0	0	0
Circ. Memb. ML		0	0	0	0	0	0	0	0
Circ. Bend. ML		0	0	0	0	0	0	0	0
Tot. Circ. Str.		102682	-78317	102682	-78317	116388	-91396	116388	-91396
Long. Memb. P		12635	12635	12635	12635	12246	12246	12246	12246
Long. Bend. P		103020	-103020	103020	-103020	83008	-83008	83008	-83008
Long. Memb. MC		0	0	0	0	0	0	0	0
Long. Bend. MC		0	0	0	0	0	0	0	0
Long. Memb. ML		0	0	0	0	0	0	0	0
Long. Bend. ML		0	0	0	0	0	0	0	0
Tot. Long. Str.		115656	-90384	115656	-90384	95254	-70762	95254	-70762
Shear VC		0	0	0	0	0	0	0	0
Shear VL		0	0	0	0	0	0	0	0
Shear MT		0	0	0	0	0	0	0	0
Tot. Shear		0	0	0	0	0	0	0	0
Str. Int.		115656	90384	115656	90384	116388	91396	116388	91396

Dimensionless Parameters used : Gamma = 77.00

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.080	4C	13.057	(A,B)
N(PHI) / (P/Rm)	0.080	3C	11.245	(C,D)

M(PHI) / (P)	0.054	2C1	0.113	(A,B)
M(PHI) / (P)	0.054	1C	0.154	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.052	3A	1.588	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.057	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.068	3B	7.477	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.061	1B	0.050	(A,B,C,D)
N(x) / (P/Rm)	0.068	3C	12.228	(A,B)
N(x) / (P/Rm)	0.068	4C	13.327	(C,D)
M(x) / (P)	0.070	1C1	0.132	(A,B)
M(x) / (P)	0.070	2C	0.091	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.052	4A	2.095	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.069	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.068	4B	2.085	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.074	2B	0.070	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (kPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	42837	42837	42837	42837	36892	36892	36892	36892
Circ. Bend. P	171860	-171860	171860	-171860	233537	-233537	233537	-233537
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	214697	-129023	214697	-129023	270430	-196644	270430	-196644
Long. Memb. P	40116	40116	40116	40116	43721	43721	43721	43721
Long. Bend. P	199875	-199875	199875	-199875	137202	-137202	137202	-137202
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	239991	-159758	239991	-159758	180923	-93480	180923	-93480
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	239991	159758	239991	159758	270430	196644	270430	196644

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (kPa)

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
Circ. Pl (SUS)	12182	12182	12182	12182	12495	12495	12495	12495
Circ. Q (SUS)	90499	-90499	90499	-90499	103892	-103892	103892	-103892
Long. Pm (SUS)	0	0	0	0	0	0	0	0

Long. Pl (SUS)	12635	12635	12635	12635	12246	12246	12246	12246
Long. Q (SUS)	103020	-103020	103020	-103020	83008	-83008	83008	-83008
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	12635	12635	12635	12635	12495	12495	12495	12495
Pm+Pl+Q (Total)	115656	90384	115656	90384	116388	91396	116388	91396

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	12635	250494	Passed
Pm+Pl+Q (TOTAL)	116388	500988	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 (kPa)

	Stress Intensity Values at							
Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	42837	42837	42837	42837	36892	36892	36892	36892
Circ. Q (SUS)	171860	-171860	171860	-171860	233537	-233537	233537	-233537
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	40116	40116	40116	40116	43721	43721	43721	43721
Long. Q (SUS)	199875	-199875	199875	-199875	137202	-137202	137202	-137202
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	42837	42837	42837	42837	43721	43721	43721	43721
Pm+Pl+Q (Total)	239991	159758	239991	159758	270430	196644	270430	196644

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	43721	250494	Passed
Pm+Pl+Q (TOTAL)	270430	500988	Passed

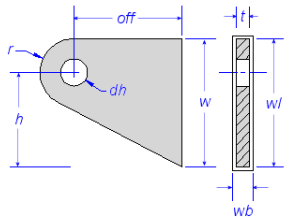
*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Lifting Lug Calculations: Lug(s) on Right End of Vessel

Input Values:

Lifting Lug Material		BS1501-151,430A	
Lifting Lug Yield Stress	Yield	249994.28	kPa
Total Height of Lifting Lug	w	120.0000	mm
Thickness of Lifting Lug	t	14.0000	mm
Diameter of Hole in Lifting Lug	dh	40.0000	mm
Radius of Semi-Circular Arc of Lifting Lug	r	40.0000	mm
Height of Lug from bottom to Center of Hole	h	70.0000	mm
Offset from Vessel OD to Center of Hole	off	8.0000	mm
Lug Fillet Weld Size	tw	8.0000	mm
Length of weld along side of Lifting Lug	wl	128.0000	mm
Length of Weld along Bottom of Lifting Lug	wb	14.0000	mm
Thickness of Collar (if any)	tc	0.0000	mm
Diameter of Collar (if any)	dc	0.0000	mm
Impact Factor	Impfac	1.50	
Sling Angle from Horizontal		90.0000	deg
Number of Lugs in Group		1	

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : Horizontal Lift



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

Computed Results:

Total vessel weight (No Liquid)		29460.98	N
Design Reaction force at the Left end lug		25261.31	N
Design Reaction force at the Right end lug		18930.16	N
Force Along Vessel Axis	Fax	0.00	N
Force Normal to Vessel	Fn	18930.16	N
Force Tangential to Vessel	Ft	0.00	N

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

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	Ilc	2684603.750	mm**4
Weld Group Centroid distance in the Long. Direction	Yll	69.656	mm
Dist. of Weld Group Centroid from Lug bottom	Yll_b	64.000	mm
Weld Group Inertia about the Longitudinal Axis	Ill	31648.822	mm**4
Weld Group Centroid Distance in the Circ. Direction	Ylc	7.000	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(0^2+0^2+18930^2)/((2*(128.0+14.0))*5.656)
= 11785.24 kPa

Shear Stress in the Welds due to Bending Loads [Sblf]:
= (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
= (18930(70.0-64.0))69.656/2684604 +
(0 * 8.0 * 69.656/2684604) +
(0 * 8.0 * 7.0/31648.822)
= 2947.11 kPa

Total Shear Stress for Combined Loads [St]:
= Ssll + Sblf
= 11785.236 + 2947.107
= 14732.34 kPa

Allowable Shear Stress for Combined Loads [Sta]:
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 249994 * 1.0
= 99997.72 kPa

Shear Stress in Lug above Hole [Shs]:
= sqrt(Pl^2 + Fax^2) / Sha
= sqrt(18930^2 + 0^2)/0.001
= 33804.77 kPa

Allowable Shear Stress in Lug above Hole [Sas]:
= 0.4 * Yield * Occfac
= 0.4 * 249994 * 1.0
= 99997.72 kPa

Pin Hole Bearing Stress [Pbs]:
= sqrt(Fax^2 + Fn^2) / (t * dh)
= sqrt(0^2 + 18930^2)/(14.0 * 40.0)
= 33804.77 kPa

Allowable Bearing Stress [Pba]:
= min(0.75 * Yield * Occfac, 0.9 * Yield) AISC Bearing All.
= min(0.75 * 249994 * 1.0, 224994.9)
= 187495.70 kPa

Bending Stress at the Base of the Lug [Fbs]:
= Ft * off/(w * t^2/6) + Fax * off/(w^2 * t/6)
= 0 * 8.0/(120.0 * 14.0^2/6) +
0 * 8.0/(120.0^2 * 14.0/6)
= 0.00 kPa

Tensile Stress at the Base of the Lug [Fa]:
= Fn / (w * t)
= 18930/(120.0 * 14.0)
= 11268.26 kPa

Total Combined Stress at the Base of the Lug:
= Fbs + Fa
= 0.0 + 11268.3
= 11268.26 kPa

Lug Allowable Stress for Bending and Tension:
= min(0.66 * Yield * Occfac, 0.75 * Yield)
= min(0.66 * 249994 * 1.0, 187495.7)
= 164996.23 kPa

Required Shackle Pin Diameter [Spd]:
= sqrt[(2 * sqrt(Fn^2 + Fax^2)/(Pi * Sta))]
= sqrt[2 * sqrt(18930^2 + 0^2)/(Pi * 99998)]
= 10.9781 mm

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

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6 in paragraph 4.3 of WRC Bulletin 107.

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	1530.000	mm
Vessel Thickness	Tv	10.000	mm

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

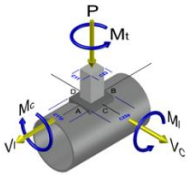
Attachment Type	Type	Rectangular	
Parameter C11	C11	14.00	mm
Parameter C22	C22	56.00	mm
Thickness of Reinforcing Pad	Tpad	10.000	mm
Pad Parameter C11P	C11p	62.000	mm
Pad Parameter C22P	C22p	136.000	mm
Design Internal Pressure	Dp	0.000	N/mm^2
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-18930.2	N
Longitudinal Shear	(SUS)	Vl	0.0	N
Circumferential Shear	(SUS)	Vc	0.0	N
Circumferential Moment	(SUS)	Mc	0.0	N-m
Longitudinal Moment	(SUS)	Ml	0.0	N-m
Torsional Moment	(SUS)	Mt	0.0	N-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	-18930.2	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	0.0	N
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	0.0	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 38.75

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.027	4C		7.475	(A,B)
N(PHI) / (P/Rm)	0.027	3C		7.667	(C,D)
M(PHI) / (P)	0.016	2C1		0.239	(A,B)
M(PHI) / (P)	0.016	1C	!	0.274	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.014	3A		0.084	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.018	1A	!	0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.023	3B		0.720	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.020	1B	!	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.022	3C		7.753	(A,B)
N(x) / (P/Rm)	0.022	4C		7.514	(C,D)
M(x) / (P)	0.023	1C1		0.272	(A,B)
M(x) / (P)	0.023	2C		0.219	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.014	4A		0.099	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.024	2A	!	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.023	4B		0.175	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.027	2B	!	0.106	(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 (kPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	9129	9129	9129	9129	9364	9364	9364	9364
Circ. Bend. P	67818	-67818	67818	-67818	77854	-77854	77854	-77854
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	76947	-58689	76947	-58689	87218	-68490	87218	-68490
Long. Memb. P	9469	9469	9469	9469	9176	9176	9176	9176
Long. Bend. P	77200	-77200	77200	-77200	62204	-62204	62204	-62204
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	86669	-67731	86669	-67731	71381	-53027	71381	-53027
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	86669	67731	86669	67731	87218	68490	87218	68490

Dimensionless Parameters used : Gamma = 77.00

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.080	4C	13.057	(A,B)
N(PHI) / (P/Rm)	0.080	3C	11.245	(C,D)

M(PHI) / (P)	0.054	2C1	0.113	(A,B)
M(PHI) / (P)	0.054	1C	0.154	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.052	3A	1.588	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.057	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.068	3B	7.477	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.061	1B	0.050	(A,B,C,D)
N(x) / (P/Rm)	0.068	3C	12.228	(A,B)
N(x) / (P/Rm)	0.068	4C	13.327	(C,D)
M(x) / (P)	0.070	1C1	0.132	(A,B)
M(x) / (P)	0.070	2C	0.091	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.052	4A	2.095	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.069	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.068	4B	2.085	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.074	2B	0.070	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (kPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	32100	32100	32100	32100	27646	27646	27646	27646
Circ. Bend. P	128787	-128787	128787	-128787	175006	-175006	175006	-175006
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	160888	-96686	160888	-96686	202653	-147360	202653	-147360
Long. Memb. P	30062	30062	30062	30062	32763	32763	32763	32763
Long. Bend. P	149781	-149781	149781	-149781	102815	-102815	102815	-102815
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	179843	-119718	179843	-119718	135579	-70052	135579	-70052
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	179843	119718	179843	119718	202653	147360	202653	147360

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (kPa)

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
Circ. Pl (SUS)	9129	9129	9129	9129	9364	9364	9364	9364
Circ. Q (SUS)	67818	-67818	67818	-67818	77854	-77854	77854	-77854
Long. Pm (SUS)	0	0	0	0	0	0	0	0

Long. Pl (SUS)	9469	9469	9469	9469	9176	9176	9176	9176
Long. Q (SUS)	77200	-77200	77200	-77200	62204	-62204	62204	-62204
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	9469	9469	9469	9469	9364	9364	9364	9364
Pm+Pl+Q (Total)	86669	67731	86669	67731	87218	68490	87218	68490

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	9469	250494	Passed
Pm+Pl+Q (TOTAL)	87218	500988	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 (kPa)

	Stress Intensity Values at							
Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	32100	32100	32100	32100	27646	27646	27646	27646
Circ. Q (SUS)	128787	-128787	128787	-128787	175006	-175006	175006	-175006
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	30062	30062	30062	30062	32763	32763	32763	32763
Long. Q (SUS)	149781	-149781	149781	-149781	102815	-102815	102815	-102815
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	32100	32100	32100	32100	32763	32763	32763	32763
Pm+Pl+Q (Total)	179843	119718	179843	119718	202653	147360	202653	147360

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	32763	250494	Passed
Pm+Pl+Q (TOTAL)	202653	500988	Passed

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

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	770.75	mm
Stiffened Vessel Length per 4.15.6	L	5.45	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	120.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	100.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	166996.17	kPa
Inside Depth of Head	h2	0.38	m
Shell Allowable Stress used in Calculation		166996.17	kPa
Head Allowable Stress used in Calculation		166996.17	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		46913.91	N

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	70369.45	166996.17
Long. Stress at Bottom of Midspan	74991.89	166996.17
Long. Stress at Top of Saddles	74005.36	166996.17
Long. Stress at Bottom of Saddles	71946.45	166996.17
Tangential Shear in Shell	6253.44	133596.95
Circ. Stress at Horn of Saddle	8437.87	208745.22
Circ. Compressive Stress in Shell	1703.92	166996.17

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (6428.7/2 + 0) * 1100.0/1359.66
= 7801.5 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(1874.18, 0.0, 0) * 1100.0/3400.0002
= 606.4 N

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
= max(Fl, Friction Force, Sum of X Forces) * B / Ls
= max(7516.59, 0.0, 0) * 1100.0/3400.0002
= 2431.8 N

Saddle Reaction Force due to Earthquake Ft [Fst]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (7517/2 + 0) * 1100.0/1359.66
= 9121.7 N

Load Combination Results for Q + Wind or Seismic [Q]:

= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 37792 + Max(606, 7801, 2432, 9122)
= 46913.9 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		47926.05	N
Transverse Shear Load Saddle	Ft	3758.29	N
Longitudinal Shear Load Saddle		7516.59	N

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0252	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0207			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R^2-$h2^2$)/(2a*L))/(1+(4h2)/3L)]
= -46914*0.5[1-(1-0.5/5.45+(0.771^2-0.383^2)/
(2*0.5*5.45))/(1+(4*0.38)/(3*5.45))]
= -2241.2 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R^2-$h2^2$)/(L^2))/(1+(4h2)/(3L))-4a/L
= 46914*5/4(1+2(0.8^2-0.4^2)/(5^2))/(1+(4*0.4)/
(3*5))-4*0.5/5
= 36677.6 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm^2t)
= 1.603 * 770.75/(2*8.5) - 36677.6/(pi*770.8^2*8.5)
= 70369.45 kPa

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm^2 * t)
= 1.603 * 770.75/(2 * 8.5) + 36677.6/(pi * 770.8^2 * 8.5)
= 74991.89 kPa

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm^2t)
= 1.603*770.75/(2*8.5)--2241.2/(0.1066*pi*770.8^2*8.5)
= 74005.36 kPa

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm^2 * t)
= 1.603*770.75/(2*8.5)+-2241.2/(0.1923*pi*770.8^2*8.5)
= 71946.45 kPa

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 46914(5.45 - 2 * 0.5)/(5.45 + (4 * 0.38/3))
= 34994.2 N

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 34994.2/(770.7501 * 8.5)
= 6253.44 kPa

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(770.75 * 8.5)
= 63.134 mm

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.7603 * 46914 * 0.1/(8.5 * (120.0 + 63.13 + 63.13))
= -1703.92 kPa

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(120.0 + 1.56 * sqrt(770.75 * 8.5), 2 * 0.502)
= 246.27 mm

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= min(Sr/S, 1)
= min(166996.172/166996.172, 1)
= 1.0000

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.7603 * 46914 * 0.1/(246.267(8.5 + 1.0 * 10.0))
= -782.88 kPa

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)^2)
= -46914/(4(8.5+ 1.0* 10.0)246.267) -
12*0.025*46914*770.75/(5.45(8.5+1.0*10.0)^2)
= -8437.87 kPa

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1000.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	100.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm
Web Thickness	Webtk	10.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239932.0	kPa
Height of Web at Center	Hw,c	306.0	mm
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	225.9	8.5	4.2	0.0	8161.3	0.280E+08
Wearplate	100.0	10.0	13.5	0.0	13500.0	0.125E+08
Web	10.0	305.0	171.0	0.0	521550.2	0.301E+08
BasePlate	100.0	10.0	328.5	0.0	328500.1	0.414E+08
Totals	...	...	...	...	871711.6	0.112E+09

Distance to Centroid [C1]:
= AY / A
= 0.034/0.007
= 125.061 mm

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 46913.91
= 9547.9980 N

Tension Stress, St = (Fh/As) = 1890.7434 kPa
Allowed Stress, Sa = 0.6 * Yield Str = 143959.2031 kPa

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 1100.0 - 766.5 * sin(1.0472)/1.0472
= 466.110 mm

Bending Moment, M = Fh * d = 4452.2178 N-m

Bending Stress, Sb = (M * C1 / I) = 4970.8750 kPa
Allowed Stress, Sa = 2/3 * Yield Str = 159954.6719 kPa

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(46914 + 1012)100.0/(4 * 1000.0 * 159954.672))½
= 4.740 mm

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
= 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
= 2 * cos(90 - 120.0/2)(765.0 + 10.0 + 10.0)
= 1359.660 mm

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 1359.6599/(3 - 1)
= 679.830 mm

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 679.83 * 100.0/2
= 0.034 m^2

Axial Load [P]:
= Ap * Bp
= 0.0 * 469255.53
= 15946.742 N

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 0.001 + 0.003
= 0.004 m^2

Compressive Stress [Sc]:
= P/Ar
= 15946.7/0.0045
= 3544.486 kPa

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	120.0	...	...	...	0.144E+07

Rib dimension [D]:
= Saddle Width - Web Thickness
= 120.0 - 10.0
= 110.000 mm

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.004
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1439999/0.004)
= 17.890 mm

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 199948/239932.0)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 368.347/17.89
= 20.589

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 7516.6/(2 * 1000.0) * 679.83 * 368.35/2
= 470.754 N-m

Compressive Allowable, KL/r < Cc (20.5893 < 128.255) per AISC E2-1 [Sca]:
= (1-$(Klr)^2/(2*Cc^2)$)Fy/(5/3+3*(Klr)/(8*Cc)-$(Klr^3)/(8*Cc^3)$)
= (1-(20.59)^2/(2 * 128.25^2))239932/
(5/3+3*(20.59)/(8* 128.25)-(20.59^3)/(8*128.25^3)
= 137191 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 3544.49/137191.41 + (470.75 * 60.0/1440000)/159954.67
= 0.148

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	110.0	0.0	0.0	0.0	0.144E+07
Web	679.8	10.0	0.0	0.0	0.0	0.567E+05
Totals	...	...	...	...	...	0.150E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.008
= 0.000 mm

Distance to Centroid [C1]:

= Saddle Width / 2
= 120.0/2
= 60.000 mm

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 1100.0 - cos(785.0/2)(10.0 + 0.0 + 0.0) - 0.0
= 305.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1495818/0.008)
= 13.762 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 305.0/13.762
= 22.163

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 7516.589/(2 * 1000.0)
= 3.758 N/mm

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 3.758 * 679.83 * 305.0
= 779.591 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 779.591/24930.316
= 31258.979 kPa

Compressive Allowable, KL/r < Cc (22.1629 < 128.255) per AISC E2-1 [Sca]:
$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
$= (1-(22.16)^2/(2 * 128.25^2))239932/$
$(5/3+3*(22.16)/(8* 128.25)-(22.16^3)/(8*128.25^3)$
= 136553 kPa

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 4284.4/136553.36 + (779.59 * 60.0/1495818)/159954.67
= 0.227

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	770.75	mm
Stiffened Vessel Length per 4.15.6	L	5.45	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	120.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	100.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	166996.17	kPa
Inside Depth of Head	h2	0.38	m
Shell Allowable Stress used in Calculation		166996.17	kPa

```
 Head Allowable Stress used in Calculation          166996.17  kPa
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Saddle Force Q, Operating Case                       41786.90  N
```

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	70622.95	166996.17
Long. Stress at Bottom of Midspan	74738.38	166996.17
Long. Stress at Top of Saddles	73864.68	166996.17
Long. Stress at Bottom of Saddles	72024.41	166996.17
Tangential Shear in Shell	5568.78	133596.95
Circ. Stress at Horn of Saddle	7515.73	208745.22
Circ. Compressive Stress in Shell	1517.70	166996.17

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 6428.7/2 + 0 ) * 1100.0/1359.66
  = 7801.5 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 1874.18, 0.0, 0 ) * 1100.0/3400.0002
  = 606.4 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 7516.59, 0.0, 0 ) * 1100.0/3400.0002
  = 2431.8 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 7517/2 + 0 ) * 1100.0/1359.66
  = 9121.7 N
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 32665 + Max( 606, 7801, 2432, 9122 )
  = 41786.9 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)             42799.04  N
 Transverse Shear Load Saddle          Ft             3758.29  N
 Longitudinal Shear Load Saddle                       7516.59  N
```

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0252     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0207
```

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R^2-$h2^2$)/(2a*L))/(1+(4h2)/3L)]
= -41787*0.5[1-(1-0.5/5.45+(0.771^2-0.384^2)/
(2*0.5*5.45))/(1+(4*0.38)/(3*5.45))]
= -2003.2 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R^2-$h2^2$)/(L^2))/(1+(4h2)/(3L))-4a/L
= 41787*5/4(1+2(0.8^2-0.4^2)/(5^2))/(1+(4*0.4)/
(3*5))-4*0.5/5
= 32654.6 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm^2t)
= 1.603 * 770.75/(2*8.5) - 32654.6/(pi*770.8^2*8.5)
= 70622.95 kPa

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm^2 * t)
= 1.603 * 770.75/(2 * 8.5) + 32654.6/(pi * 770.8^2 * 8.5)
= 74738.38 kPa

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm^2t)
= 1.603*770.75/(2*8.5)--2003.2/(0.1066*pi*770.8^2*8.5)
= 73864.68 kPa

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm^2 * t)
= 1.603*770.75/(2*8.5)+-2003.2/(0.1923*pi*770.8^2*8.5)
= 72024.41 kPa

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 41787(5.45 - 2 * 0.5)/(5.45 + (4 * 0.38/3))
= 31162.9 N

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 31162.87/(770.7501 * 8.5)
= 5568.78 kPa

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(770.75 * 8.5)
= 63.134 mm

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.7603 * 41787 * 0.1/(8.5 * (120.0 + 63.13 + 63.13))
= -1517.70 kPa

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(120.0 + 1.56 * sqrt(770.75 * 8.5), 2 * 0.502)
= 246.27 mm

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= min(Sr/S, 1)
= min(166996.172/166996.172, 1)
= 1.0000

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))

= - 0.7603 * 41787 * 0.1/(246.267(8.5 + 1.0 * 10.0))
= -697.32 kPa

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)^2)
= -41787/(4(8.5+ 1.0* 10.0)246.267) -
12*0.025*41787*770.75/(5.45(8.5+1.0*10.0)^2)
= -7515.73 kPa

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1000.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	100.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm
Web Thickness	Webtk	10.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239932.0	kPa
Height of Web at Center	Hw,c	306.0	mm
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	225.9	8.5	4.2	0.0	8161.3	0.280E+08
Wearplate	100.0	10.0	13.5	0.0	13500.0	0.125E+08
Web	10.0	305.0	171.0	0.0	521550.2	0.301E+08
BasePlate	100.0	10.0	328.5	0.0	328500.1	0.414E+08
Totals	...	...	...	...	871711.6	0.112E+09

Distance to Centroid [C1]:
= AY / A
= 0.034/0.007
= 125.061 mm

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 41786.902
= 8504.5410 N

Tension Stress, St = (Fh/As) = 1684.1127 kPa
Allowed Stress, Sa = 0.6 * Yield Str = 143959.2031 kPa

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 1100.0 - 766.5 * sin(1.0472)/1.0472
= 466.110 mm

Bending Moment, M = Fh * d = 3965.6545 N-m

Bending Stress, Sb = (M * C1 / I) = 4427.6299 kPa

Allowed Stress, Sa = 2/3 * Yield Str = 159954.6719 kPa

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(41787 + 1012)100.0/(4 * 1000.0 * 159954.672))½
= 4.480 mm

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
= 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
= 2 * cos(90 - 120.0/2)(765.0 + 10.0 + 10.0)
= 1359.660 mm

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 1359.6599/(3 - 1)
= 679.830 mm

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 679.83 * 100.0/2
= 0.034 m²

Axial Load [P]:
= Ap * Bp
= 0.0 * 417972.66
= 14203.994 N

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 0.001 + 0.003
= 0.004 m²

Compressive Stress [Sc]:
= P/Ar
= 14204.0/0.0045
= 3157.125 kPa

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	120.0	...	...	...	0.144E+07

Rib dimension [D]:
= Saddle Width - Web Thickness
= 120.0 - 10.0
= 110.000 mm

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.004
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1439999/0.004)

= 17.890 mm

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 199948/239932.0)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 368.347/17.89
= 20.589

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 7516.6/(2 * 1000.0) * 679.83 * 368.35/2
= 470.754 N-m

Compressive Allowable, KL/r < Cc (20.5893 < 128.255) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(20.59)²/(2 * 128.25²))239932/
(5/3+3*(20.59)/(8* 128.25)-(20.59³)/(8*128.25³)
= 137191 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 3157.12/137191.41 + (470.75 * 60.0/1440000)/159954.67
= 0.146

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	110.0	0.0	0.0	0.0	0.144E+07
Web	679.8	10.0	0.0	0.0	0.0	0.567E+05
Totals	...	...	...	...	...	0.150E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.008
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 1100.0 - cos(785.0/2)(10.0 + 0.0 + 0.0) - 0.0
= 305.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1495818/0.008)
= 13.762 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 305.0/13.762
= 22.163

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 7516.589/(2 * 1000.0)

= 3.758 N/mm

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 3.758 * 679.83 * 305.0
= 779.591 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 779.591/24930.316
= 31258.979 kPa

Compressive Allowable, KL/r < Cc (22.1629 < 128.255) per AISC E2-1 [Sca]:
= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
= (1-(22.16)^2/(2 * 128.25^2))239932/
(5/3+3*(22.16)/(8* 128.25)-(22.16^3)/(8*128.25^3)
= 136553 kPa

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 3816.18/136553.36 + (779.59 * 60.0/1495818)/159954.67
= 0.223

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

Input and Calculated Values:

Vessel Mean Radius	Rm	770.00	mm
Stiffened Vessel Length per 4.15.6	L	5.45	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	120.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	100.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	166996.17	kPa
Inside Depth of Head	h2	0.38	m
Shell Allowable Stress used in Calculation		237494.56	kPa
Head Allowable Stress used in Calculation		237494.56	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		73423.72	N

Horizontal Vessel Analysis Results:	Actual | kPa	Allowable | kPa
Long. Stress at Top of Midspan	85206.22	237494.56
Long. Stress at Bottom of Midspan	91370.88	237494.56
Long. Stress at Top of Saddles	90048.62	237494.56
Long. Stress at Bottom of Saddles	87313.01	237494.56
Tangential Shear in Shell	8329.93	189995.66
Circ. Stress at Horn of Saddle	11432.71	356241.84
Circ. Compressive Stress in Shell	2173.02	237494.56

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (2121.5/2 + 0) * 1100.0/1359.66
= 2574.5 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(618.48, 0.0, 0) * 1100.0/3400.0002
= 200.1 N

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 70849 + Max(200, 2574, 0, 0)
= 73423.7 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		74435.85	N
Transverse Shear Load Saddle	Ft	1060.74	N
Longitudinal Shear Load Saddle		618.48	N

Hydrostatic Test Pressure at center of Vessel: 2.293 N/mm²

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

```
K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
K5  = 0.7603     K6  = 0.0529     K7  = 0.0253     K8  = 0.3405
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
K7p = 0.0208
```

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -73424*0.5[1-(1-0.5/5.45+(0.77²-0.382²)/
  (2*0.5*5.45))/(1+(4*0.38)/(3*5.45))]
= -3496.5 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 73424*5/4(1+2(0.8²-0.4²)/(5²))/(1+(4*0.4)/
  (3*5))-4*0.5/5
= 57434.8 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 2.293 * 770.0/(2*10.0) - 57434.8/(pi*770.0²*10.0)
= 85206.22 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 2.293 * 770.0/(2 * 10.0) + 57434.8/(pi * 770.0² * 10.0 )
= 91370.88 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 2.293*770.0/(2*10.0)--3496.5/(0.1066*pi*770.0²*10.0)
= 90048.62 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 2.293*770.0/(2*10.0)+-3496.5/(0.1923*pi*770.0²*10.0)
= 87313.01 kPa
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 73424( 5.45 - 2 * 0.5)/(5.45 + ( 4 * 0.38/3))
= 54786.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 54786.88/( 770.0 * 10.0 )
= 8329.93 kPa
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 770.0 * 10.0 )
= 68.445 mm
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
```

= - 0.7603 * 73424 * 0.1/(10.0 * (120.0 + 68.44 + 68.44))
= -2173.02 kPa

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(120.0 + 1.56 * sqrt(770.0 * 10.0), 2 * 0.502)
= 256.89 mm

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
= 1.0000 Materials are the same, test case

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
= -K5 * Q * k / (B1(t + eta * tr))
= - 0.7603 * 73424 * 0.1/(256.889(10.0 + 1.0 * 10.0))
= -1086.51 kPa

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)^2)
= -73424/(4(10.0+ 1.0* 10.0)256.889) -
12*0.025*73424*770.0/(5.45(10.0+1.0*10.0)^2)
= -11432.71 kPa

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1000.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	100.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm
Web Thickness	Webtk	10.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239932.0	kPa
Height of Web at Center	Hw,c	306.0	mm
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	236.4	10.0	5.0	0.0	11822.2	0.308E+08
Wearplate	100.0	10.0	15.0	0.0	15000.0	0.108E+08
Web	10.0	305.0	172.5	0.0	526125.1	0.323E+08
BasePlate	100.0	10.0	330.0	0.0	330000.0	0.445E+08
Totals	...	...	...	...	882947.4	0.118E+09

Distance to Centroid [C1]:
= AY / A
= 0.035/0.007
= 119.085 mm

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 73423.719
= 14943.3184 N

```
 Tension Stress, St = ( Fh/As )       =       2959.1526  kPa
 Allowed Stress, Sa = 0.6 * Yield Str =     143959.2031  kPa
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 1100.0 - 765.0 * sin( 1.0472 )/1.0472
  = 467.350 mm
```

```
 Bending Moment, M  = Fh * d          =       6986.5928  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =       7019.8740  kPa
 Allowed Stress, Sa = 2/3 * Yield Str =     159954.6719  kPa
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(73424 + 1012)100.0/( 4 * 1000.0 * 159954.672 ))½
  = 5.908 mm
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 765.0 + 10.0 + 10.0 )
  = 1359.660 mm
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1359.6599/( 3 - 1 )
  = 679.830 mm
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 679.83 * 100.0/2
  = 0.034 m²
```

Axial Load [P]:
```
  = Ap * Bp
  = 0.0 * 734419
  = 24957.820 N
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 0.001 + 0.003
  = 0.004 m²
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 24957.8/0.0045
  = 5547.381 kPa
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	120.0	...	...	...	0.144E+07

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 120.0 - 10.0
  = 110.000 mm
```

Distance to Centroid from Datum [ytot]:

= AY / A
= 0.0/0.004
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1439999/0.004)
= 17.890 mm

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 199948/239932.0)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 367.62/17.89
= 20.549

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 618.5/(2 * 1000.0) * 679.83 * 367.62/2
= 38.658 N-m

Compressive Allowable, KL/r < Cc (20.5486 < 128.255) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(20.55)²/(2 * 128.25²))239932/
(5/3+3*(20.55)/(8* 128.25)-(20.55³)/(8*128.25³)
= 137208 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 5547.38/137207.67 + (38.66 * 60.0/1440000)/159954.67
= 0.050

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	110.0	0.0	0.0	0.0	0.144E+07
Web	679.8	10.0	0.0	0.0	0.0	0.567E+05
Totals	...	...	...	...	...	0.150E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.008
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 1100.0 - cos(785.0/2)(10.0 + 0.0 + 0.0) - 0.0
= 305.000 mm

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(1495818/0.008)
= 13.762 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 305.0/13.762
= 22.163

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 618.48/(2 * 1000.0)
= 0.309 N/mm

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0.309 * 679.83 * 305.0
= 64.146 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 64.146/24930.316
= 2572.051 kPa

Compressive Allowable, KL/r < Cc (22.1629 < 128.255) per AISC E2-1 [Sca]:
$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
$= (1-(22.16)^2/(2 * 128.25^2))239932/$
$(5/3+3*(22.16)/(8* 128.25)-(22.16^3)/(8*128.25^3)$
= 136553 kPa

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 6705.4/136553.36 + (64.15 * 60.0/1495818)/159954.67
= 0.065

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle
(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	770.00	mm
Stiffened Vessel Length per 4.15.6	L	5.45	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	120.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	100.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	166996.17	kPa
Inside Depth of Head	h2	0.38	m
Shell Allowable Stress used in Calculation		237494.56	kPa
Head Allowable Stress used in Calculation		237494.56	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		66540.38	N

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	85496.43	237494.56

Long. Stress at Bottom of Midspan	91080.66	237494.56
Long. Stress at Top of Saddles	89889.16	237494.56
Long. Stress at Bottom of Saddles	87401.39	237494.56
Tangential Shear in Shell	7547.32	189995.66
Circ. Stress at Horn of Saddle	10360.92	356241.84
Circ. Compressive Stress in Shell	1969.30	237494.56

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (2121.5/2 + 0) * 1100.0/1359.66
= 2574.5 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(618.48, 0.0, 0) * 1100.0/3400.0002
= 200.1 N

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 63966 + Max(200, 2574, 0, 0)
= 66540.4 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		67552.52 N
Transverse Shear Load Saddle	Ft	1060.74 N
Longitudinal Shear Load Saddle		618.48 N

Hydrostatic Test Pressure at center of Vessel: 2.293 N/mm²

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0253	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0208			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -66540*0.5[1-(1-0.5/5.45+(0.77²-0.383²)/
(2*0.5*5.45))/(1+(4*0.38)/(3*5.45))]
= -3179.7 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 66540*5/4(1+2(0.8²-0.4²)/(5²))/(1+(4*0.4)/
(3*5))-4*0.5/5
= 52027.0 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 2.293 * 770.0/(2*10.0) - 52027.0/(pi*770.0²*10.0)
= 85496.43 kPa

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 2.293 * 770.0/(2 * 10.0) + 52027.0/(pi * 770.0² * 10.0 )
  = 91080.66 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 2.293*770.0/(2*10.0)--3179.7/(0.1066*pi*770.0²*10.0)
  = 89889.16 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 2.293*770.0/(2*10.0)+-3179.7/(0.1923*pi*770.0²*10.0)
  = 87401.39 kPa
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 66540( 5.45 - 2 * 0.5)/(5.45 + ( 4 * 0.38/3))
  = 49639.6 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 49639.6/( 770.0 * 10.0 )
  = 7547.32 kPa
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 770.0 * 10.0 )
  = 68.445 mm
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 66540 * 0.1/( 10.0 * ( 120.0 + 68.44 + 68.44 ) )
  = -1969.30 kPa
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 120.0 + 1.56 * sqrt( 770.0 * 10.0 ), 2 * 0.502 )
  = 256.89 mm
```

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
```
  = 1.0000 Materials are the same, test case
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 66540 * 0.1/( 256.889( 10.0 + 1.0 * 10.0 ) )
  = -984.65 kPa
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -66540/(4(10.0+ 1.0* 10.0)256.889) -
     12*0.025*66540*770.0/(5.45(10.0+1.0*10.0)²)
  = -10360.92 kPa
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1000.0000	mm
Baseplate Thickness	Bpthk	10.0000	mm
Baseplate Width	Bpwid	100.0000	mm
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm
Web Thickness	Webtk	10.0000	mm
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239932.0	kPa
Height of Web at Center	Hw,c	306.0	mm
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	236.4	10.0	5.0	0.0	11822.2	0.308E+08
Wearplate	100.0	10.0	15.0	0.0	15000.0	0.108E+08
Web	10.0	305.0	172.5	0.0	526125.1	0.323E+08
BasePlate	100.0	10.0	330.0	0.0	330000.0	0.445E+08
Totals	...	...	...	...	882947.4	0.118E+09

Distance to Centroid [C1]:
= AY / A
= 0.035/0.007
= 119.085 mm

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)^2)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 66540.375
= 13542.4082 N

Tension Stress, St = (Fh/As) = 2681.7373 kPa
Allowed Stress, Sa = 0.6 * Yield Str = 143959.2031 kPa

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 1100.0 - 765.0 * sin(1.0472)/1.0472
= 467.350 mm

Bending Moment, M = Fh * d = 6331.6118 N-m

Bending Stress, Sb = (M * C1 / I) = 6361.7734 kPa
Allowed Stress, Sa = 2/3 * Yield Str = 159954.6719 kPa

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(66540 + 1012)100.0/(4 * 1000.0 * 159954.672))½
= 5.628 mm

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
= 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
= 2 * cos(90 - 120.0/2)(765.0 + 10.0 + 10.0)
= 1359.660 mm

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 1359.6599/(3 - 1)
= 679.830 mm

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2

= 679.83 * 100.0/2
= 0.034 m²

Axial Load [P]:
= Ap * Bp
= 0.0 * 665569
= 22618.070 N

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 0.001 + 0.003
= 0.004 m²

Compressive Stress [Sc]:
= P/Ar
= 22618.1/0.0045
= 5027.324 kPa

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	120.0	...	...	...	0.144E+07

Rib dimension [D]:
= Saddle Width - Web Thickness
= 120.0 - 10.0
= 110.000 mm

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.004
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1439999/0.004)
= 17.890 mm

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 199948/239932.0)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 367.62/17.89
= 20.549

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 618.5/(2 * 1000.0) * 679.83 * 367.62/2
= 38.658 N-m

Compressive Allowable, KL/r < Cc (20.5486 < 128.255) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(20.55)²/(2 * 128.25²))239932/
(5/3+3*(20.55)/(8* 128.25)-(20.55³)/(8*128.25³)

= 137208 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 5027.32/137207.67 + (38.66 * 60.0/1440000)/159954.67
= 0.047

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	110.0	0.0	0.0	0.0	0.144E+07
Web	679.8	10.0	0.0	0.0	0.0	0.567E+05
Totals	...	...	...	...	...	0.150E+07

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.008
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 120.0/2
= 60.000 mm

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 1100.0 - cos(785.0/2)(10.0 + 0.0 + 0.0) - 0.0
= 305.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(1495818/0.008)
= 13.762 mm

Slenderness ratio [KL/r]:
= KL/r
= 1 * 305.0/13.762
= 22.163

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 618.48/(2 * 1000.0)
= 0.309 N/mm

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0.309 * 679.83 * 305.0
= 64.146 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 64.146/24930.316
= 2572.051 kPa

Compressive Allowable, KL/r < Cc (22.1629 < 128.255) per AISC E2-1 [Sca]:
= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
= (1-(22.16)^2/(2 * 128.25^2))239932/
(5/3+3*(22.16)/(8* 128.25)-(22.16^3)/(8*128.25^3)
= 136553 kPa

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 6076.78/136553.36 + (64.15 * 60.0/1495818)/159954.67

= 0.061

Nozzle Calculation Summary:

Per Section 3.5.4 Based on Graphs 3.5-9 to 3.5-11:

Description	Act Thk mm	Calc Thk mm	Table 3.5-4	Rho Result	Pr. Area Result
N1 MANWAY	11.13	...	10.3	Passed	N/A
N4_1	7.62	...	6.2	Passed	N/A
N3_2	8.38	...	4.6	Passed	N/A
N2_2	3.62	...	...	Passed	N/A
N2_1	3.62	...	...	Passed	N/A
N2_3	3.62	...	...	Passed	N/A
N2_4	3.62	...	...	Passed	N/A
N6_1	5.49	5.08	...	Passed	N/A
N6_2	5.49	5.08	...	Passed	N/A
N6_3	5.49	5.08	...	Passed	N/A
N5	7.49	1.73	...	Passed	N/A
N4_2	7.62	3.83	6.2	Passed	N/A
N3_1	8.38	...	4.6	Passed	N/A

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm	Layout Angle deg	Mean Radius mm
10	N1 MANWAY	0.000	0.000	223.787
10	N4_1	0.000	270.000	41.390
10	N3_2	0.000	90.000	15.609
20	N2_2	1630.800	90.000	12.478
20	N2_1	1430.800	90.000	12.478
20	N2_3	1830.800	90.000	12.478
20	N2_4	2030.800	90.000	12.478
20	N6_1	727.800	0.000	42.457
20	N6_2	1227.800	0.000	42.457
20	N6_3	1727.800	0.000	42.457
20	N5	4650.799	270.000	24.828
30	N4_2	0.000	270.000	41.390
30	N3_1	0.000	90.000	15.609

If any interferences/violations are found, they will be noted below.
Note: One or more Nozzles are closely spaced. Check the Code paragraph 3.5.4.4 including paragraph 3.5.4.4.1 and sub paragraphs (a) through (e) for each ligament.

Nozzles : N4_1 and N1 MANWAY are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0039 + 0.001 - 0.0002 >= 1.0 * 1.0 * 512.083 * 6.5635
0.0048 should be greater than or equal to 0.0034 [Passed]

Dim P is: 512.08 mm Dim S is: 246.91 mm Dim Smin is: 401.04 mm

---

Nozzles : N3_2 and N1 MANWAY are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0042 + 0.001 - 0.0001 >= 0.9588 * 1.0 * 512.083 * 6.5635
0.005 should be greater than or equal to 0.0032 [Passed]

Dim P is: 512.08 mm Dim S is: 272.69 mm Dim Smin is: 401.04 mm

---

Nozzles : N2_1 and N2_2 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0015 + 0.0002 - 0. >= 1.0 * 1.0 * 200.000 * 7.4213
0.0017 should be greater than or equal to 0.0015 [Passed]

Dim P is: 200.00 mm Dim S is: 175.04 mm Dim Smin is: 320.87 mm

---

Nozzles : N2_3 and N2_2 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0015 + 0.0002 - 0. >= 1.0 * 1.0 * 200. * 7.4213
0.0017 should be greater than or equal to 0.0015 [Passed]

Dim P is: 200.00 mm Dim S is: 175.04 mm Dim Smin is: 320.87 mm

---

Nozzles : N2_4 and N2_3 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0015 + 0.0002 - 0. >= 1.0 * 1.0 * 200. * 7.4213
0.0017 should be greater than or equal to 0.0015 [Passed]

Dim P is: 200.00 mm Dim S is: 175.04 mm Dim Smin is: 320.87 mm

---

No interference violations have been detected !

Input, Nozzle Desc: N1 MANWAY From: 10

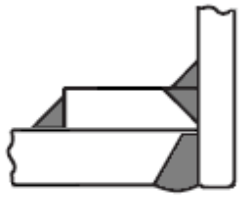
Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Elliptical Head	Di	1526.00	mm
Aspect Ratio of Elliptical Head	Ar	1.97	
Head Finished (Minimum) Thickness	ea	12.0000	mm
Head Internal Corrosion Allowance	c	1.5000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	0.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		450.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	30	
Flange Material		A-105	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
Pad Material		BS1501-151,430A	
Pad Allowable Stress at Temperature	f2	166996.17	kPa
Pad Allowable Stress At Ambient	f2a	166996.17	kPa
Diameter of Pad along vessel surface	d2	697.2000	mm
Thickness of Pad	e2	12.0000	mm
Weld leg size between Pad and Shell	Wp	10.0000	mm
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm
Reinforcing Pad Width		120.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.
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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N1 MANWAY

```
Actual Outside Diameter Used in Calculation          457.200  mm.
Actual Thickness Used in Calculation                  11.125  mm

Outside Diameter of Ellipsoidal Head                 :  1550.00 mm
Spherical Mean Diameter of Ellipsoidal Head          :  2750.94 mm

Mean Diameter of Head Skirt / 10                     :   153.80 mm
Distance from edge of head to edge of Nozzle or pad L :   426.40 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 1.6 * 2738.936/( 4 * 0.2E+06 - 0.2 * 1.6 ) + 1.5 + 0.0
  = 8.0635 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*437.9496)/(2*160996.33-1.6)
  = 2.1870 + 1.5000 = 3.6870 mm
```

Mean noz dia / Mean Shl Dia d/D: 447.575 / 2750.936 = 0.1627

Note: Mean Diameter of the Shell Includes the Pad Thickness
per PD:5500 Figure 3.5-26.

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 447.57/2750.94 * (2750.94/( 2*( 12.0 - 1.5 + 12.0 )))½
  = 1.2721
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 12.0 - 1.5 + 12.0 )/6.56, 1 )
  = Min( 3.4281, 4.0 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the
calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 457.2000.  Min. thickness for this size: 10.3000   mm
```

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    904.7748  mm
 Effective material Thickness limit              Lb    31.2866  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls   223.7874  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    65.6353  mm
```

PV Elite Licensee: XGM
FileName : Air Receiver Aspen ----------
Nozzle Calcs.: N1 MANWAY Nozl: 14 12:23pm Aug 23,2022

The Drop for this Nozzle is : 19.3109 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 181.3110 mm

Input, Nozzle Desc: N4_1 From: 10

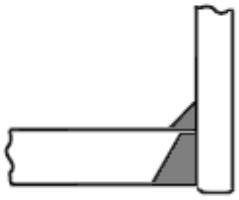
Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Elliptical Head	Di	1526.00	mm
Aspect Ratio of Elliptical Head	Ar	1.97	
Head Finished (Minimum) Thickness	ea	12.0000	mm
Head Internal Corrosion Allowance	c	1.5000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	500.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		80.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	80	
Flange Material		A-105	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N4_1

```
 Actual Outside Diameter Used in Calculation          88.900  mm.
 Actual Thickness Used in Calculation                  7.620  mm

 Outside Diameter of Ellipsoidal Head                :  1550.00 mm
 Spherical Mean Diameter of Ellipsoidal Head         :  2738.94 mm

 Mean Diameter of Head Skirt / 10                    :   153.80 mm
 Distance from edge of head to edge of Nozzle or pad L :   230.55 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 1.6 * 2738.936/( 4 * 0.2E+06 - 0.2 * 1.6 ) + 1.5 + 0.0
  = 8.0635 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*76.66)/(2*160996.33-1.6)
  = 0.3828 + 1.5000 = 1.8828 mm
```

Mean noz dia / Mean Shl Dia d/D: 90.501 / 2738.936 = 0.0330

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 90.5/2738.94 * (2738.94/( 2*( 12.0 - 1.5 + 0.0 )))½
  =  0.3774
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 12.0 - 1.5 + 0.0 )/6.56, 1 )
  = Min( 1.5998, 4.0 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 88.9000.  Min. thickness for this size: 6.2000   mm
```

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                  179.4008  mm
 Effective material Thickness limit          Lb       5.6294  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls   45.2504  mm
 Thickness Limit for Nozzle Group Calculation   Tlc   22.5081  mm
```

The Drop for this Nozzle is : 18.4456 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 181.3365 mm

Input, Nozzle Desc: N3_2 From: 10

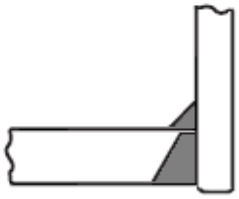
Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Elliptical Head	Di	1526.00	mm
Aspect Ratio of Elliptical Head	Ar	1.97	
Head Finished (Minimum) Thickness	ea	12.0000	mm
Head Internal Corrosion Allowance	c	1.5000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	500.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		38.1000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	8.3820	mm
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	35.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N3_2

Actual Outside Diameter Used in Calculation	38.100	mm.
Actual Thickness Used in Calculation	8.382	mm

```
 Outside Diameter of Ellipsoidal Head                 :  1550.00 mm
 Spherical Mean Diameter of Ellipsoidal Head          :  2738.94 mm

 Mean Diameter of Head Skirt / 10                     :   153.80 mm
 Distance from edge of head to edge of Nozzle or pad L :   255.95 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 1.6 * 2738.936/( 4 * 0.2E+06 - 0.2 * 1.6 ) + 1.5 + 0.0
  = 8.0635 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*24.336)/(2*160996.33-1.6)
  = 0.1215 + 1.5000 = 1.6215 mm
```

Mean noz dia / Mean Shl Dia d/D: 34.102 / 2738.936 = 0.0125

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 34.1/2738.94 * (2738.94/( 2*( 12.0 - 1.5 + 0.0 )))½
  =  0.1422
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 12.0 - 1.5 + 0.0 )/6.56, 1 )
  = Min( 1.5998, 4.0 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 38.1000.  Min. thickness for this size: 4.6000   mm
```

Note: The minimum neck thickness chosen was to the closest table value.

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    72.2020  mm
 Effective material Thickness limit             Lb     1.9478  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls    17.0510  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    14.6575  mm
```

The Drop for this Nozzle is : 7.6802 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 56.1961 mm

Input, Nozzle Desc: N2_2 From: 20

Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1.63	m

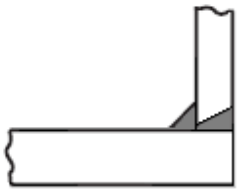
Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		28.5750	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	3.6195	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	47.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	3.6195	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N2_2

Actual Outside Diameter Used in Calculation	28.575	mm.
Actual Thickness Used in Calculation	3.619	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6 * 1533.0/( 2 * 0.2E+06 - 1.6 ) + 1.5 + 0.0
  = 8.8791 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*21.336)/(2*164996.23-1.6)
  = 0.1040 + 0.0000 = 0.1040 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1580.000 mm

Mean noz dia / Mean Shl Dia d/D: 24.955 / 1541.500 = 0.0162

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 24.96/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1542
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.38, 1 )
  = Min( 1.1519, 3.1 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		53.5305	mm
Effective material Thickness limit	Lb	1.6106	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	12.4777	mm
Thickness Limit for Nozzle Group Calculation	Tlc	9.5040	mm

The Drop for this Nozzle is : 0.1334 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 57.7584 mm

Input, Nozzle Desc: N2_1 From: 20

Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1.43	m

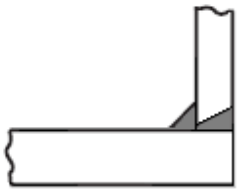
Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		28.5750	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	3.6195	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	47.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N2_1

Actual Outside Diameter Used in Calculation	28.575	mm.
Actual Thickness Used in Calculation	3.619	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6 * 1533.0/( 2 * 0.2E+06 - 1.6 ) + 1.5 + 0.0
  = 8.8791 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*21.336)/(2*164996.23-1.6)
  = 0.1040 + 0.0000 = 0.1040 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1380.000 mm

Mean noz dia / Mean Shl Dia d/D: 24.955 / 1541.500 = 0.0162

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 24.96/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1542
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.38, 1 )
  = Min( 1.1519, 3.1 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		53.5305	mm
Effective material Thickness limit	Lb	1.6106	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	12.4777	mm
Thickness Limit for Nozzle Group Calculation	Tlc	9.5040	mm

The Drop for this Nozzle is : 0.1334 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 57.7584 mm

Input, Nozzle Desc: N2_3 From: 20

Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1.83	m

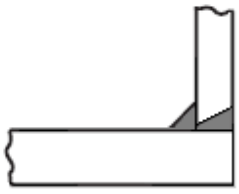
Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		28.5750	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	3.6195	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	47.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	3.6195	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N2_3

Actual Outside Diameter Used in Calculation		28.575	mm.
Actual Thickness Used in Calculation		3.619	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6 * 1533.0/( 2 * 0.2E+06 - 1.6 ) + 1.5 + 0.0
  = 8.8791 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*21.336)/(2*164996.23-1.6)
  = 0.1040 + 0.0000 = 0.1040 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1780.000 mm

Mean noz dia / Mean Shl Dia d/D: 24.955 / 1541.500 = 0.0162

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 24.96/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1542
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.38, 1 )
  = Min( 1.1519, 3.1 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		53.5305	mm
Effective material Thickness limit	Lb	1.6106	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	12.4777	mm
Thickness Limit for Nozzle Group Calculation	Tlc	9.5040	mm

The Drop for this Nozzle is : 0.1334 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 57.7584 mm

Input, Nozzle Desc: N2_4 From: 20

Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		2.03	m

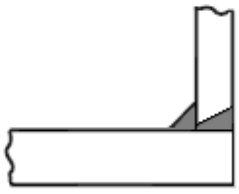
Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		28.5750	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	3.6195	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	47.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	3.6195	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N2_4

Actual Outside Diameter Used in Calculation		28.575	mm.
Actual Thickness Used in Calculation		3.619	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6 * 1533.0/( 2 * 0.2E+06 - 1.6 ) + 1.5 + 0.0
  = 8.8791 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*21.336)/(2*164996.23-1.6)
  = 0.1040 + 0.0000 = 0.1040 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1980.000 mm

Mean noz dia / Mean Shl Dia d/D: 24.955 / 1541.500 = 0.0162

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 24.96/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1542
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.38, 1 )
  = Min( 1.1519, 3.1 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		53.5305	mm
Effective material Thickness limit	Lb	1.6106	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	12.4777	mm
Thickness Limit for Nozzle Group Calculation	Tlc	9.5040	mm

The Drop for this Nozzle is : 0.1334 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 57.7584 mm

Input, Nozzle Desc: N6_1 From: 20

Pressure for Reinforcement Calculations	P	1.6031	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		0.73	m

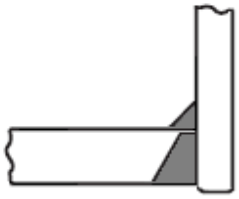
Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		80.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	40	
Flange Material		A-105	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	66.6750	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N6_1

```
 Actual Outside Diameter Used in Calculation          88.900  mm.
 Actual Thickness Used in Calculation                  5.486  mm
```

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6031 * 1533.0/( 2 * 0.2E+06 - 1.6031 ) + 1.5 + 0.0
  = 8.8935 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*80.9272)/(2*160996.33-1.6)
  = 0.4049 + 1.5000 = 1.9049 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 677.000 mm

Mean noz dia / Mean Shl Dia d/D: 84.914 / 1541.500 = 0.0551

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 84.91/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.5245
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.39, 1 )
  = Min( 1.1497, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.5 (Curve1), 0.525 (Computed rho), 0.6 (Curve2)

Values of erb/ers for values of rho: 0.34, 0.43, 0.42, 0.52

The final interpolated value of erb/ers was 0.4062 from Figure 3.5-11

Compute the Required Neck thickness [erb]

```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.4062) * ( 10.0 - 1.5 + 0.0 ) + 1.5
  = 4.952 mm
```

Note : Increasing the Nozzle thickness by the ratio [1.037]
of the shell allowable to the Nozzle allowable stress.
See paragraph 3.5.4.3.7 for more information.

```
  erb = (erb/ers) * ( eas - Cas ) * ( Fs / Fn ) + Can
      = ( 0.4062) * ( 10.0 - 1.5 ) * ( 166996.2/160996.3 ) + 1.5
      = 5.081 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 5.0812 mm

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                   173.8136  mm
 Effective material Thickness limit             Lb    17.4381  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls    42.4568  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    18.3984  mm
```

The Drop for this Nozzle is : 1.2925 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.9675 mm

Input, Nozzle Desc: N6_2 From: 20

Pressure for Reinforcement Calculations	P	1.6031	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1.23	m

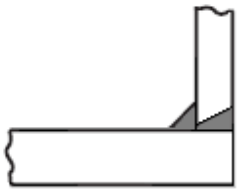
Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		80.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	40	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	66.6750	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N6_2

Actual Outside Diameter Used in Calculation	88.900	mm.
Actual Thickness Used in Calculation	5.486	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
= P * D / (2 * fs - P) + Cas + Caext [Cylindrical Shell]
= 1.6031 * 1533.0/(2 * 0.2E+06 - 1.6031) + 1.5 + 0.0
= 8.8935 mm

Nozzle required thickness due to Internal Pressure (epb)
= (P * Di) / (2 * f - p) per 3.5.1.2 Eqn. 3.5.1-1
= (1.6*80.9272)/(2*160996.33-1.6)
= 0.4049 + 1.5000 = 1.9049 mm

Dist from Center of Nozzle to Nearest Circ. Seam: 1177.000 mm

Mean noz dia / Mean Shl Dia d/D: 84.914 / 1541.500 = 0.0551

Compute the value of Rho (use eas in place of ers) [rho]:
= d/D * sqrt(D / (2 * (eas - Cas + Tp)))
= 84.91/1541.5 * (1541.5/(2*(10.0 - 1.5 + 0.0)))½
= 0.5245

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
= Max(C * (eas - Cas + Tp) / eps, 1)
= Max(1.0 * (10.0 - 1.5 + 0.0)/7.39, 1)
= Min(1.1497, 3.1)

The following are the curves of rho selected for the analysis:
Values of Rho: 0.5 (Curve1), 0.525 (Computed rho), 0.6 (Curve2)

Values of erb/ers for values of rho: 0.34, 0.43, 0.42, 0.52

The final interpolated value of erb/ers was 0.4062 from Figure 3.5-11

Compute the Required Neck thickness [erb]
= (erb/eas) * (eas - Cas + tp) + Can
= (0.4062) * (10.0 - 1.5 + 0.0) + 1.5
= 4.952 mm

Note : Increasing the Nozzle thickness by the ratio [1.037]
of the shell allowable to the Nozzle allowable stress.
See paragraph 3.5.4.3.7 for more information.

erb = (erb/ers) * (eas - Cas) * (Fs / Fn) + Can
= (0.4062) * (10.0 - 1.5) * (166996.2/160996.3) + 1.5
= 5.081 mm

Required Nozzle thickness based on Figure 3.5-11 : 5.0812 mm

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		173.8136	mm
Effective material Thickness limit	Lb	17.4381	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	42.4568	mm
Thickness Limit for Nozzle Group Calculation	Tlc	18.3984	mm

The Drop for this Nozzle is : 1.2925 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.9675 mm

Input, Nozzle Desc: N6_3 From: 20

Pressure for Reinforcement Calculations	P	1.6031	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1.73	m

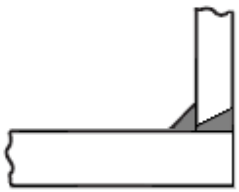
Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		80.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	40	
Flange Material		A-105	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	66.6750	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N6_3

Actual Outside Diameter Used in Calculation		88.900	mm.

```
 Actual Thickness Used in Calculation                  5.486  mm
```

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.6031 * 1533.0/( 2 * 0.2E+06 - 1.6031 ) + 1.5 + 0.0
  = 8.8935 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*80.9272)/(2*160996.33-1.6)
  = 0.4049 + 1.5000 = 1.9049 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1677.000 mm

Mean noz dia / Mean Shl Dia d/D: 84.914 / 1541.500 = 0.0551

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 84.91/1541.5 * (1541.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.5245
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/7.39, 1 )
  = Min( 1.1497, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.5 (Curve1), 0.525 (Computed rho), 0.6 (Curve2)

Values of erb/ers for values of rho: 0.34, 0.43, 0.42, 0.52

The final interpolated value of erb/ers was 0.4062 from Figure 3.5-11

Compute the Required Neck thickness [erb]

```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.4062) * ( 10.0 - 1.5 + 0.0 ) + 1.5
  = 4.952 mm
```

Note : Increasing the Nozzle thickness by the ratio [1.037]
of the shell allowable to the Nozzle allowable stress.
See paragraph 3.5.4.3.7 for more information.

```
  erb = (erb/ers) * ( eas - Cas ) * ( Fs / Fn ) + Can
      = ( 0.4062) * ( 10.0 - 1.5 ) * ( 166996.2/160996.3 ) + 1.5
      = 5.081 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 5.0812 mm

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    173.8136  mm
 Effective material Thickness limit             Lb     17.4381  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls     42.4568  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    18.3984  mm
```

The Drop for this Nozzle is : 1.2925 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.9675 mm

Input, Nozzle Desc: N5 From: 20

Pressure for Reinforcement Calculations	P	1.6069	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1530.00	mm
Shell Finished (Minimum) Thickness	ea	10.0000	mm
Shell Internal Corrosion Allowance	c	1.5000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		4.65	m

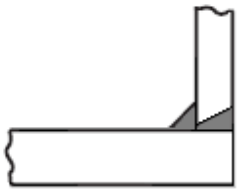
Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		57.1500	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.4930	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	66.6750	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	4.1275	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

This is a Manway or Access Opening.

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N5

Actual Outside Diameter Used in Calculation	57.150	mm.
Actual Thickness Used in Calculation	7.493	mm

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
= P * D / (2 * fs - P) + Cas + Caext [Cylindrical Shell]
= 1.6069 * 1533.0/(2 * 0.2E+06 - 1.6069) + 1.5 + 0.0
= 8.9109 mm

Nozzle required thickness due to Internal Pressure (epb)
= (P * Di) / (2 * f - p) per 3.5.1.2 Eqn. 3.5.1-1
= (1.61*42.164)/(2*164996.23-1.61)
= 0.2063 + 0.0000 = 0.2063 mm

Dist from Center of Nozzle to Nearest Circ. Seam: 800.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1541.500 = 0.0322

Compute the value of Rho (use eas in place of ers) [rho]:
= d/D * sqrt(D / (2 * (eas - Cas + Tp)))
= 49.66/1541.5 * (1541.5/(2*(10.0 - 1.5 + 0.0)))½
= 0.3067

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
= Max(C * (eas - Cas + Tp) / eps, 1)
= Max(1.0 * (10.0 - 1.5 + 0.0)/7.41, 1)
= Min(1.147, 3.1)

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.307 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.13, 0.25, 0.26, 0.35

The final interpolated value of erb/ers was 0.2013 from Figure 3.5-11

Compute the Required Neck thickness [erb]
= (erb/eas) * (eas - Cas + tp) + Can
= (0.2013) * (10.0 - 1.5 + 0.0) + 0.0
= 1.711 mm

Note : Increasing the Nozzle thickness by the ratio [1.012]
of the shell allowable to the Nozzle allowable stress.
See paragraph 3.5.4.3.7 for more information.

erb = (erb/ers) * (eas - Cas) * (Fs / Fn) + Can
= (0.2013) * (10.0 - 1.5) * (166996.2/164996.2) + 0.0
= 1.732 mm

Required Nozzle thickness based on Figure 3.5-11 : 1.7322 mm

Note: No nozzle loads - Thickness per Table 3.5-4 is not applicable.
Please refer to note 2 of the table which refers to paragraph 3.5.4.7(b)

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

Effective material Diameter limit		106.8070	mm
Effective material Thickness limit	Lb	9.2744	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	24.8285	mm
Thickness Limit for Nozzle Group Calculation	Tlc	19.2894	mm

The Drop for this Nozzle is : 0.5339 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2089 mm

Input, Nozzle Desc: N4_2 From: 30

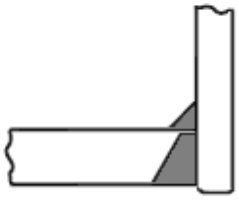
Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Elliptical Head	Di	1530.00	mm
Aspect Ratio of Elliptical Head	Ar	1.95	
Head Finished (Minimum) Thickness	ea	10.0000	mm
Head Internal Corrosion Allowance	c	1.5000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	500.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		80.0000	mm
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	80	
Flange Material		A-105	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N4_2

```
Actual Inside Diameter Used in Calculation            73.660  mm.
Actual Thickness Used in Calculation                   7.620  mm

Outside Diameter of Ellipsoidal Head                :  1550.00 mm
Spherical Mean Diameter of Ellipsoidal Head         :  2714.67 mm

Mean Diameter of Head Skirt / 10                    :   154.00 mm
Distance from edge of head to edge of Nozzle or pad L :   230.55 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)
```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 1.6 * 2714.6663/( 4 * 0.2E+06 - 0.2 * 1.6 ) + 1.5 + 0.0
  = 8.0053 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*76.66)/(2*160996.33-1.6)
  = 0.3828 + 1.5000 = 1.8828 mm
```

Mean noz dia / Mean Shl Dia d/D: 90.582 / 2714.666 = 0.0334

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 90.58/2714.67 * (2714.67/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.4217
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:
```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/6.51, 1 )
  = Min( 1.3066, 4.0 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.4 (Curve1), 0.422 (Computed rho), 0.5 (Curve2)

Values of erb/ers for values of rho: 0.17, 0.25, 0.27, 0.34

The final interpolated value of erb/ers was 0.2643 from Figure 3.5-10

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2643) * ( 10.0 - 1.5 + 0.0 ) + 1.5
  = 3.747 mm
```

Note : Increasing the Nozzle thickness by the ratio [1.037]
of the shell allowable to the Nozzle allowable stress.
See paragraph 3.5.4.3.7 for more information.

```
  erb = (erb/ers) * ( eas - Cas ) * ( Fs / Fn ) + Can
      = ( 0.2643) * ( 10.0 - 1.5 ) * ( 166996.2/160996.3 ) + 1.5
      = 3.831 mm
```

Required Nozzle thickness based on Figure 3.5-10 : 3.8306 mm

Minimum Nozzle Neck thickness per Table 3.5-4, mm
```
 Branch Nominal Size: 88.9000.  Min. thickness for this size: 6.2000   mm
```

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1
```
 Effective material Diameter limit                    179.4822  mm
 Effective material Thickness limit             Lb     13.8898  mm
```

Minimum Reqd Effective width adjacent to Nozzle	Ls	45.2911	mm
Thickness Limit for Nozzle Group Calculation	Tlc	22.5081	mm

The Drop for this Nozzle is : 18.6242 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 179.3814 mm

Input, Nozzle Desc: N3_1 From: 30

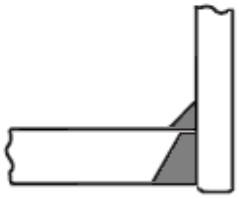
Pressure for Reinforcement Calculations	P	1.6000	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Elliptical Head	Di	1530.00	mm
Aspect Ratio of Elliptical Head	Ar	1.95	
Head Finished (Minimum) Thickness	ea	10.0000	mm
Head Internal Corrosion Allowance	c	1.5000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	600.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		38.1000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	8.3820	mm
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	37.6250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N3_1

Actual Outside Diameter Used in Calculation	38.100	mm.
Actual Thickness Used in Calculation	8.382	mm

```
 Outside Diameter of Ellipsoidal Head                 :  1550.00 mm
 Spherical Mean Diameter of Ellipsoidal Head          :  2714.67 mm

 Mean Diameter of Head Skirt / 10                     :   154.00 mm
 Distance from edge of head to edge of Nozzle or pad L :   155.95 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 1.6 * 2714.6663/( 4 * 0.2E+06 - 0.2 * 1.6 ) + 1.5 + 0.0
  = 8.0053 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.6*24.336)/(2*160996.33-1.6)
  = 0.1215 + 1.5000 = 1.6215 mm
```

Mean noz dia / Mean Shl Dia d/D: 37.170 / 2714.666 = 0.0137

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 37.17/2714.67 * (2714.67/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.173
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 10.0 - 1.5 + 0.0 )/6.51, 1 )
  = Min( 1.3066, 4.0 )
```

Note: Since the graph line for rho cuts the erb/ers = 0 line below the
calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 38.1000.  Min. thickness for this size: 4.6000   mm
```

Note: The minimum neck thickness chosen was to the closest table value.

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    75.2696  mm
 Effective material Thickness limit             Lb     1.9478  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls    18.5848  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    14.6575  mm
```

The Drop for this Nozzle is : 9.6258 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 58.4005 mm

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia mm	Wall Thk mm	Reinforcing Pad Diameter mm	Reinforcing Pad Thk mm	Cut Length mm	Flg Class
N2_2	28 mm	Actual	None	28.6	3.6	...	...	57	...
N2_1	28 mm	Actual	None	28.6	3.6	...	...	57	...
N2_3	28 mm	Actual	None	28.6	3.6	...	...	57	...
N2_4	28 mm	Actual	None	28.6	3.6	...	...	57	...
N3_2	38 mm	Actual	None	38.1	8.4	...	...	56	...
N3_1	38 mm	Actual	None	38.1	8.4	...	...	58	...
N5	57 mm	Actual	None	57.1	7.5	...	...	77	...
N4_1	80 mm	80	SlipOn	88.9	7.6	...	...	181	150
N6_1	80 mm	40	SlipOn	88.9	5.5	...	...	77	...
N6_2	80 mm	40	SlipOn	88.9	5.5	...	...	77	...
N6_3	80 mm	40	SlipOn	88.9	5.5	...	...	77	...
N4_2	80 mm	80	SlipOn	88.9	7.6	...	...	179	150
N1 MANWAY	450 mm	30	SlipOn	457.2	11.1	697.20	12.00	181	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
N2_2	A-105	3.619	10.000	...	...	...
N2_1	A-105	...	10.000	...	...	...
N2_3	A-105	3.619	10.000	...	...	...
N2_4	A-105	3.619	10.000	...	...	...
N3_2	A-106 B	12.000	10.000	...	...	...
N3_1	A-106 B	10.000	10.000	...	...	...
N5	A-105	4.128	10.000	...	...	...
N4_1	A-106 B	12.000	10.000	...	...	...
N6_1	A-106 B	10.000	10.000	...	...	...

N6_2	A-106 B	...	10.000	...	...	...
N6_3	A-106 B	...	10.000	...	...	...
N4_2	A-106 B	10.000	10.000	...	...	...
N1 MANWAY	A-106 B	12.000	10.000	10.000	12.000	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum m	Layout Angle deg	Proj Outside mm	Proj Inside mm	Installed in Component
N2_2	1.580	90.0	47.62	0.00	Node: 20
N2_1	1.380	90.0	47.62	0.00	Node: 20
N2_3	1.780	90.0	47.62	0.00	Node: 20
N2_4	1.980	90.0	47.62	0.00	Node: 20
N3_2	...	90.0	35.62	0.00	Node: 10
N3_1	...	90.0	37.62	0.00	Node: 30
N5	4.600	270.0	66.68	0.00	Node: 20
N4_1	...	270.0	150.00	0.00	Node: 10
N6_1	0.677	0.0	66.68	0.00	Node: 20
N6_2	1.177	0.0	66.68	0.00	Node: 20
N6_3	1.677	0.0	66.68	0.00	Node: 20
N4_2	...	270.0	150.00	0.00	Node: 30
N1 MANWAY	...	0.0	150.00	0.00	Node: 10

British Standard PD 5500:2021

Diameter Spec : 1550.000 mm OD	
Vessel Design Length, Tangent to Tangent	5.45 m
Specified Datum Line Distance	0.05 m
Shell Material	BS1501-151,430A
Nozzle Material	A-106 B
Nozzle Material	A-105
Re-Pad Material	BS1501-151,430A
Internal Design Temperature	50 °C
Internal Design Pressure	1.600 N/mm²
External Design Temperature	35 °C
Maximum Allowable Working Pressure	1.750 N/mm²
Hydrostatic Test Pressure	2.286 N/mm²
Wind Design Code	SANS 10160-3:2010
Earthquake Design Code	SANS 10160-4:2010

Element Pressures and MAWP (N/mm² & mm):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Ellipse	1.600	0.00	2.187	1.5000	No	...
Cylinder	1.607	0.00	1.835	1.5000	N/A	...
Ellipse	1.600	0.00	1.750	1.5000	No	...

Liquid Level: 1.40 m Dens.: 500.000 kg/m³ Sp. Gr.: 0.500

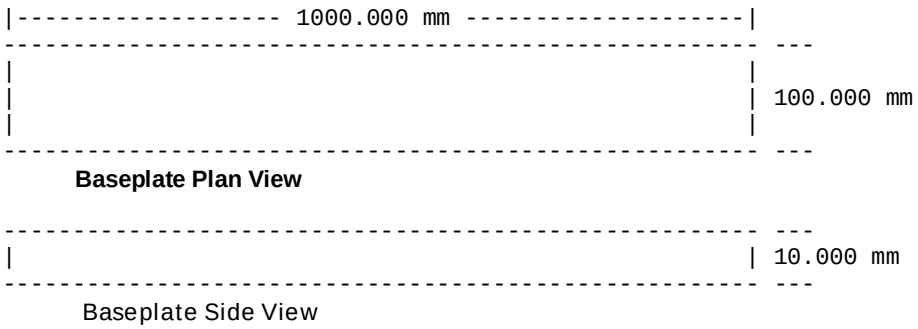
Element Types and Properties:

Element Type	"To" Elev m	Element Length m	Nominal Thickness mm	Finished Thickness mm	Reqd Thk Internal mm	Reqd Thk External mm	Long Eff	Circ Eff
Ellipse	0.0	0.1	11.5	12.0	9.5	...	0.85	0.85
Cylinder	5.4	5.4	10.0	10.0	8.9	...	0.85	0.85
Ellipse	5.4	0.0	10.0	10.0	9.4	...	0.85	0.85

Saddle Parameters:

Saddle Width	120.000	mm
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	1100.000	mm
Wear Pad Width	100.000	mm
Wear Pad Thickness	10.000	mm
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	502.000	mm
Baseplate Length	1000.000	mm
Baseplate Thickness	10.000	mm
Baseplate Width	100.000	mm
Number of Ribs (including outside ribs)	3	
Rib Thickness	10.000	mm
Web Thickness	10.000	mm
Height of Center Web	306.000	mm

Baseplate Sketch



Baseplate Plan View

Baseplate Side View

Note: The Wind and Seismic loads were not load factored in this analysis.

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	74435.85	N
Maximum Transverse Saddle Shear Load	1060.74	N
Maximum Longitudinal Saddle Shear Load	618.48	N

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	Pass Fail
Lift Lug	WRC-107/537	0.540	Passed
Lift Lug	WRC-107/537	0.405	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	3004.4	kgm
Shop Test	- Fabricated + Water (Full)	13954.7	kgm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	3004.4	kgm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	3004.4	kgm
Empty	- Fab. + Intls. + Details + Wghts.	3004.4	kgm
Operating	- Empty + Operating Liquid (No CA)	7765.3	kgm
Field Test	- Empty Weight + Water (Full)	13954.7	kgm