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

REPORT No. DCPV9000LLPG REV3

Pressure Vessel Design Calculations

PV Analysis as per PD 5500 (2018) CAT 2

XGM Consulting Engineers South Africa
9 Cubic m LPG Vessel

SimuMech
DESIGN • ANALYSE • VERIFY
APPROVED
M.A. BUYS
Pr.Eng. 20140281

DWG: PV9000LLPG
26 May, 2021

REVISION TABLE		
ITEM	DESCRIPTION	REVISION No.
1	SADDLE CORRECTIONS	1
2	NOZZLE N8 THICKENESS	1

This document comprises the following:

Sections

1. Drawing, Analysis and Results – 9 cubic meter LPG Vessel

DOCUMENT No. DCPV9000LLPG

DESIGN PRESSURE: 1750 KPa

DESIGN TEMPERATURE: 0-50 Deg C

OPERATING MEDIUM: LPG

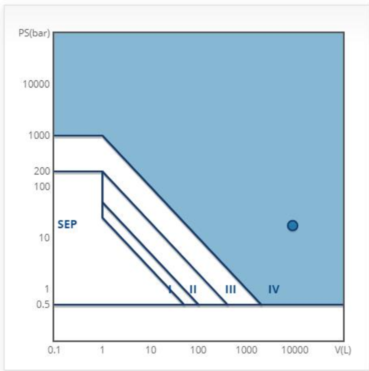
CAPACITY: 9000 Litre

SANS 347 Hazard Category: IV

PWHT (Post Weld Heat Treatment): NO

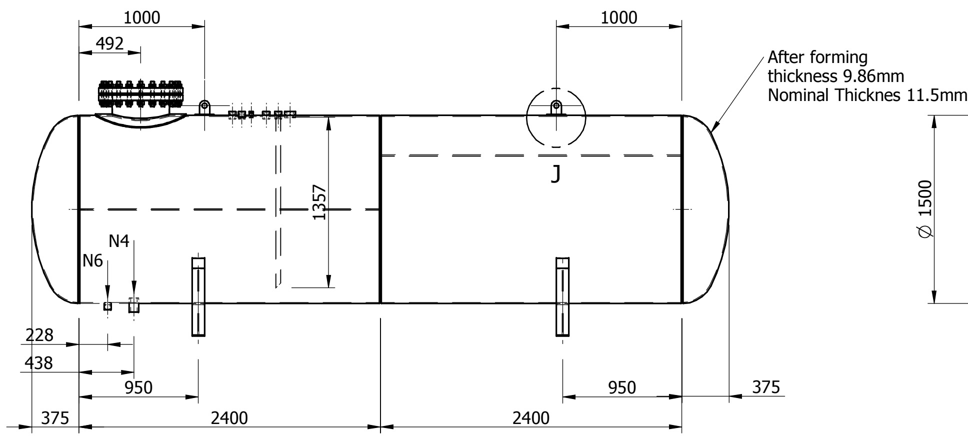
RADIOGRAPHY: YES, MPI and RT

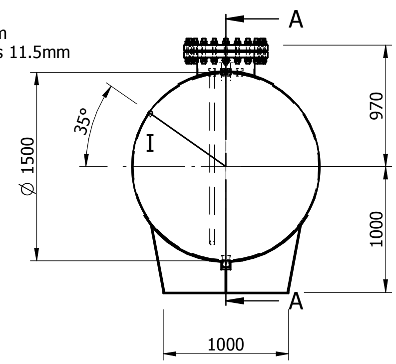
CONFORMITY ASSESMENT MODULE: G



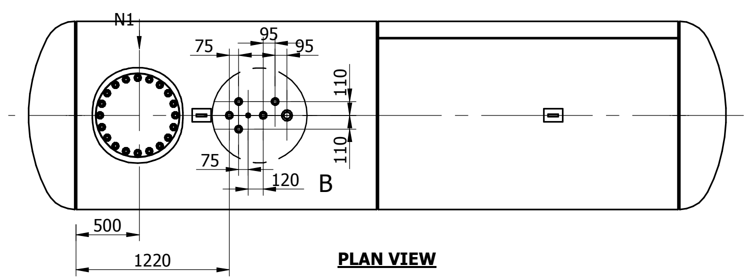
REPORT PREPARED FOR: CAPE BOILER COMPANY

COMPILED BY: LE GREEN (PrTechEng)

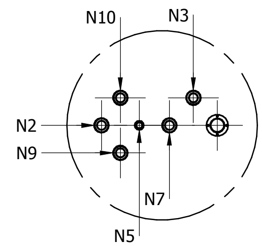




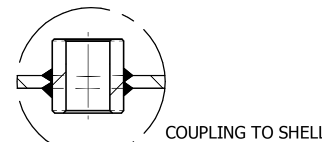
ELEVATION VIEW



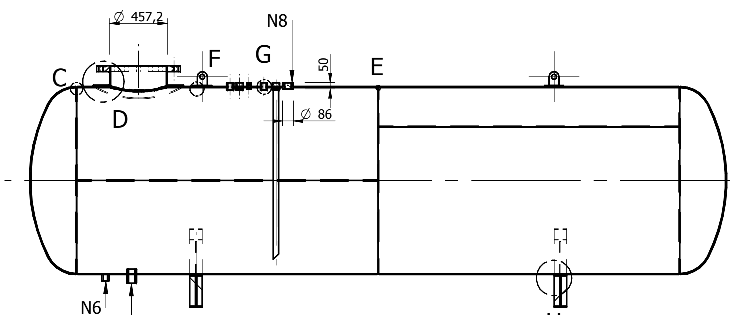
PLAN VIEW



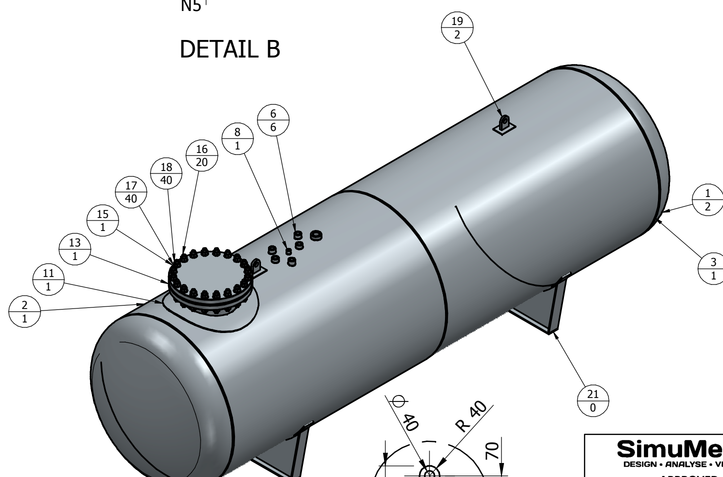
DETAIL B

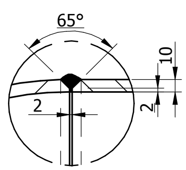


DETAIL G



SECTION A-A





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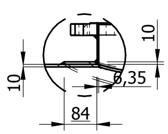

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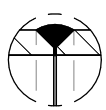
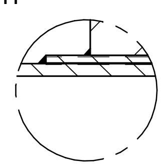
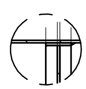


DETAIL E

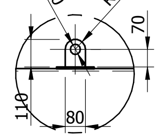


DETAIL F



DETAIL H

DETAIL I



DETAIL J

Item Number	Title	Quantity
1	Elliptical Dished End_OD 1500mm_12mm_BS1501/151 Gr430A	2
2	Shell_ D1500 x 2400mm x 10mm_BS1501-151 Gr 430A	1
3	Shell_ D1500 x 2400mm x 10mm_BS1501-151 Gr 430A	1
6	Forged Half Coupling_1 1-4 NPTF_3000#_ASTM A 105	6
7*	Forged Half Coupling_2 NPTF_3000#_ASTM A105	1
8	Forged Half Coupling_3-4 NPTF_3000#_ASTM A105	1
9*	Dip Pipe_32NB_SCH40_1350mm_ASTM A106 B	1
11	Reinforcing Pad_D634 xW88.4_10mm_BS1501-151 430A	1
12*	Pipe_450NB SCH30_200mm_ASTM A 106	1
13	Flange 150#_450NB_BS4504_BS1501-151 Gr 430A	1
14*	Gasket_KLINERT_450NB	1
15	Flange Blank150#_450NB_BS4504_BS1501-151 Gr.430A	1
16	M30 HT STUD_200mm_A193 GrB7	20
17	M30 Washer_A194 Gr 2H	40
18	M30 Nut_A194 Gr 2H	40
19	Lug_BS1501-151 Gr430A	2
20*	Lug Reinforcing Pad_10mm_BS1501-151 Gr430A	2
21*	Plate_1000 x 100 x 10mm_BS1501-151 Gr430A	2
22*	Plates_427 x 100 x 10mm_BS1501-151 430A	4
23*	Saddle Wear Plate_ID1500 x 100 x 10mm_BS1501 -151 Gr430A	2
25*	Plate_240 x 45 x 10mm_BS1501-151 430A	4
26*	Plate_1172 x 516 x 10mm_BS1501-151 Gr430A	2
27*	Magnetic Level Connection Pad_Commerical Steel	1

DESIGN DATA	
DESIGN CODE	PD5500 (2018)
DESIGN PRESSURE (kPa)	1750
DESIGN TEMPERATURE (Deg C)	50
HYDRAULIC TEST PRESSURE	2500
NDE	YES
PWHT	NO
INSPECTION AUTHORITY	RITC
DATE OF TEST	2021
CORROSION ALLOWANCE (mm)	1.5mm
WORKING PRESSURE (kPa)	1750
WORKING TEMPERATURE (Deg C)	0 - 50
VOLUME (m3)	9
SANS 347 HAZARD CATEGORY	IV

NOZZLE SCHEDULE

MARK	QTY	SIZE	RATING (NB)	SERVICE
N1	1	457.2 OD	SCH30	MANWAY
N2	1	1-1/4" NPTF	3000 lbs	FILLING
N3	1	1-1/4" NPTF	3000 lbs	LIQUID PHASE 1 WITH DIP PIPE
N4	1	2" NPTF	3000 lbs	LIQUID PHASE 2
N5	1	3/4" NPTF	3000 lbs	HIGH LEVEL AND MANOMETER
N6	1	1-1/4" NPTF	3000 lbs	DRAIN
N7	1	1-1/4" NPTF	3000 lbs	GAS PHASE
N8	1	86 OD	50mm	MAGNETIC LEVEL
N9	1	1-1/4" NPTF	3000 lbs	PRESSURE RELIEF 1
N10	1	1-1/4" NPTF	3000 lbs	PRESSURE RELIEF 2

VESSEL DESIGN CODE:
PD5500 2018

CONFORMITY ASSESMENT
MODULE: G

LESLIE GREEN (PrTechEng)
201470145

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Pr.Eng. 20140281

REV	BY	CHKD	REVISION DESCRIPTION

XGM Consulting Engineers
UNIT E9 CENTURY SQUARE
CENCURY CITY

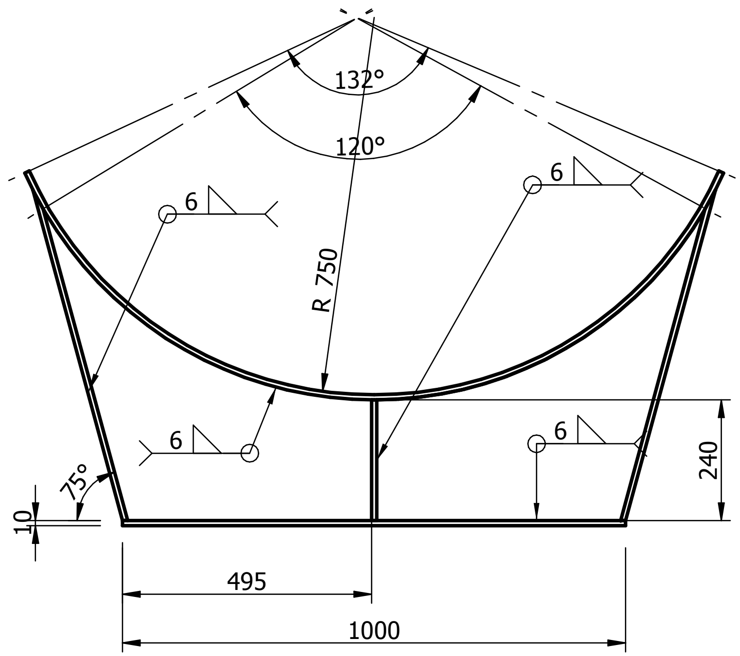
	NAME	DATE
CHECKED	LG	24-03-21
DRAWN	LG	
ENG APPR	LG	

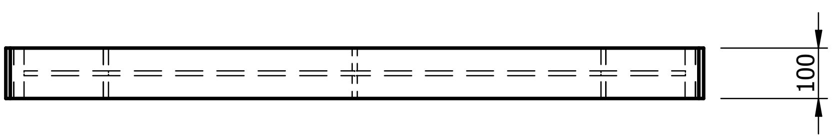
TITLE: 9 m3 LPG TANK

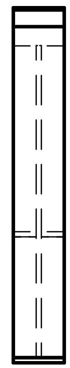
SIZE	DWG No.	REV
A1	PV9000LLPG	0

SCALE: WEIGHT:

Item Number	Title	Quantity
3	Plate_240 x 45 x 10mm_BS1501-151 430A	2
4	Plate_1000 x 100 x 10mm_BS1501-151 Gr430A	1
5	Saddle Wear Plate_ID1500 x 100 x 10mm_BS1501 -151 Gr430A	1
6*	Plate_1172 x 516 x 10mm_BS1501-151 Gr430A	1
7*	Plate_542 x 100 x 10mm_BS1501-151 Gr430A	2







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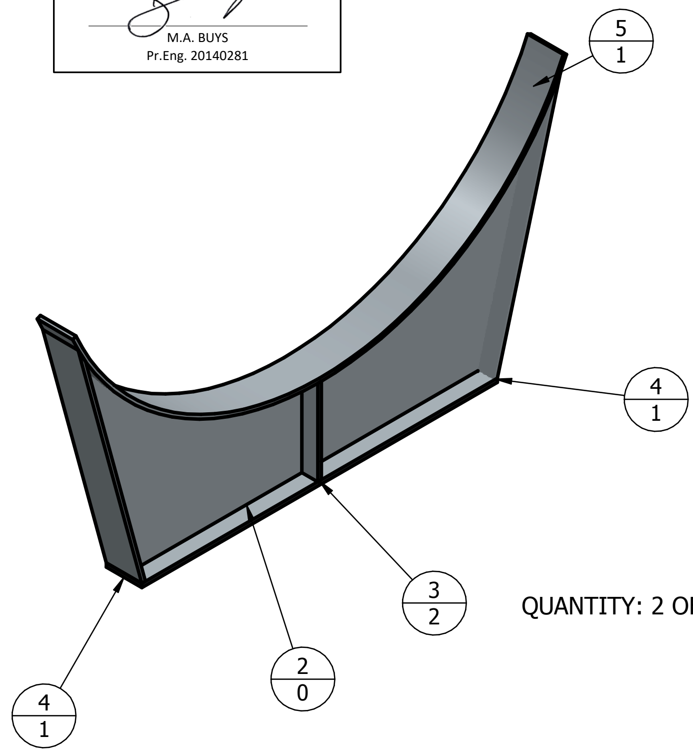

QUANTITY: 2 OFF

	SADDLE WEAR PLATE ANGLE CORRECTION		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	9m3 LPG TANK SADDLE	
Client: CBC	Order No.	Scale:
Drawn: LG	Date: 29-03-21	Client Dwg No.
Drawing No.		Revision

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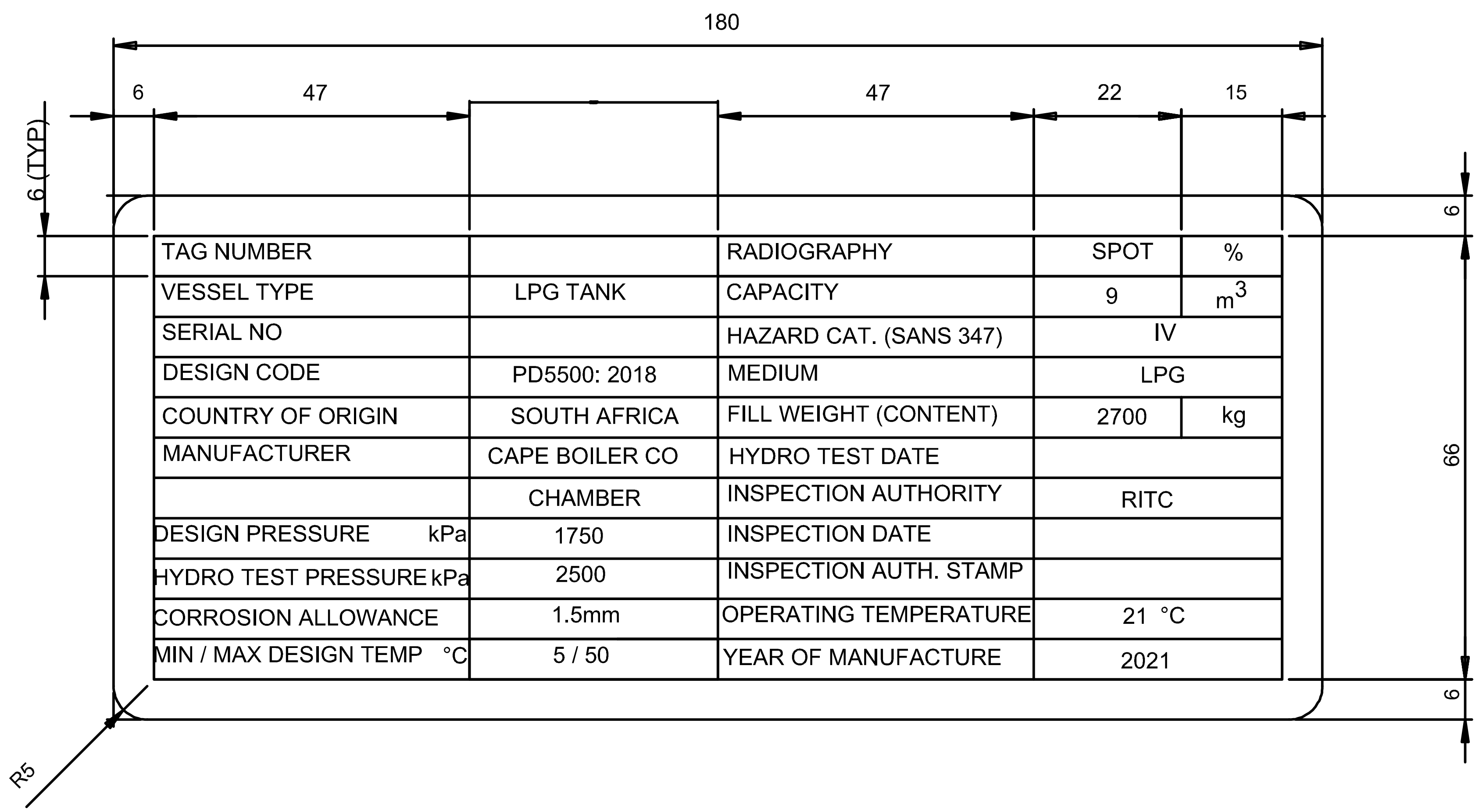
M.A. BUYS
Pr.Eng. 20140281



TAG NUMBER		RADIOGRAPHY	SPOT	%
VESSEL TYPE	LPG TANK	CAPACITY	9	m^3
SERIAL NO		HAZARD CAT. (SANS 347)	IV	
DESIGN CODE	PD5500: 2018	MEDIUM	LPG	
COUNTRY OF ORIGIN	SOUTH AFRICA	FILL WEIGHT (CONTENT)	2700	kg
MANUFACTURER	CAPE BOILER CO	HYDRO TEST DATE		
	CHAMBER	INSPECTION AUTHORITY	RITC	
DESIGN PRESSURE kPa	1750	INSPECTION DATE		
HYDRO TEST PRESSURE kPa	2500	INSPECTION AUTH. STAMP		
CORROSION ALLOWANCE	1.5mm	OPERATING TEMPERATURE	21 °C	
MIN / MAX DESIGN TEMP °C	5 / 50	YEAR OF MANUFACTURE	2021	

VESSEL DESIGNED ACCORDING
TO PD5500: 2018
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_9m3 LPG TANK			DOCUMENT TYPE: Detail part drawing REVISION: 1.00
	NAME	SIGNATURE	DATE
DRAWN	R.H	L.G	2021-03-25
CHK'D	L.G	L.G	
APPV'D	L.G	L.G	

DWG NO. PV9000LLPG

MATERIAL: BS1501-151 Gr430A

Project

SCALE:1:1

Page size: A3

SHEET 1 OF 1

Table of Contents

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	1.75	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	1500	mm
Element Thickness	12	mm
Internal Corrosion Allowance	1.5	mm
Nominal Thickness	11.48	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1.75	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	20	
Element To Node	30	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	4.8	m
Element Outside Diameter	1500	mm
Element Thickness	10	mm
Internal Corrosion Allowance	1.5	mm
Nominal Thickness	10	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1.75	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	0.95	m
Width of Saddle	100	mm
Height of Saddle at Bottom	900	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	New Sdl	
Dist. from "FROM" Node / Offset dist	3.852	m
Width of Saddle	100	mm

Height of Saddle at Bottom	900	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/m^3

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N1	
Dist. from "FROM" Node / Offset dist	0.492	m
Nozzle Diameter	457.2	mm
Nozzle Schedule	30	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	3846.3	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N2	
Dist. from "FROM" Node / Offset dist	1.22	m
Nozzle Diameter	57.15	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	N5	
Dist. from "FROM" Node / Offset dist	1.47	m
Nozzle Diameter	34.92	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	N7	

Dist. from "FROM" Node / Offset dist	1.6	m
Nozzle Diameter	57.15	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	N9	
Dist. from "FROM" Node / Offset dist	1.4	m
Nozzle Diameter	57.15	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	80.0	
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	N3	
Dist. from "FROM" Node / Offset dist	1.7	m
Nozzle Diameter	57.15	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	100.0	
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	N10	
Dist. from "FROM" Node / Offset dist	1.4	m
Nozzle Diameter	57.15	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	100.0	
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	
Dist. from "FROM" Node / Offset dist	0.228	m
Nozzle Diameter	34.92	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	

PV Elite 2019   Licensee: XGM
FileName : 9m3 LPG Tank   ---------------------------------
Input Echo: Step: 1   9:36am May 19,2021

Element From Node	20	
Detail Type	Nozzle	
Detail ID	N4	
Dist. from "FROM" Node / Offset dist	0.438	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"	0.0508	m
Element Outside Diameter	1500	mm
Element Thickness	12	mm
Internal Corrosion Allowance	1.5	mm
Nominal Thickness	11.48	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1.75	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	

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	4.8508	...	4.8	...
30	40	4.9016	...	0.0508	...

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	1.75	11.48	1.5	1500	166996
20	30	1.7569	10	1.5	1500	166996
30	40	1.75	11.48	1.5	1500	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	1.75	2.27351	2.64162	12	9.86634
20	30	1.75	1.89658	2.24161	10	9.34886
30	40	1.75	2.27351	2.64162	12	9.86634
Minimum			1.897	1.960		

MAWP: 1.897 N/mm², limited by: Cylinder.

Internal Pressure Calculation Results :

British Standard PD 5500:2018+A1:2018

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(381.0,2539975,2539975),0.01048,0.254,1500.0
  = 8.3663 + 1.5000 = 9.8663 mm
```

Max. All. Working Pressure at Given Thickness (MAWP):
```
  = 2.27 N/mm²
```

Maximum Allowable Pressure, New and Cold (MAPNC):
```
  = 2.64 N/mm²
```

Actual Stress at Given Thickness:
```
  = ( P * Rica ) / ecor
  = (1.75*739.5)/10.5
  = 123247.14 kPa
```

Required Thickness of Straight Flange = 9.416 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	123247.1	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
  = (1.76*1500.0)/(2*166996.17+1.76)
  = 7.8489 + 1.5000 = 9.3489 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)/(1500.0-8.5)
  = 1.90 - 0.01 = 1.90 N/mm²
```

Maximum Allowable Pressure, New and Cold (MAPNC):

```
  = ( 2 * fa * e ) / ( D - e )
  = (2*166996.17*10.0)/(1500.0-10.0)
  = 2.24 N/mm²
```

Actual Stress at Given Thickness:

```
  = ( P * Ri ) / ecor
  = (1.76*741.5)/8.5
  = 153257.69 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	153257.7	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(381.0,2539975,2539975),0.01048,0.254,1500.0
  = 8.3663 + 1.5000 = 9.8663 mm
```

Max. All. Working Pressure at Given Thickness (MAWP):
```
  = 2.27 N/mm²
```

Maximum Allowable Pressure, New and Cold (MAPNC):
```
  = 2.64 N/mm²
```

Actual Stress at Given Thickness:
```
  = ( P * Rica ) / ecor
  = (1.75*739.5)/10.5
  = 123247.14 kPa
```

Required Thickness of Straight Flange = 9.416 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	123247.1	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.

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 * 1.75 * 1.0 * ( 12.0/( 12.0 - 1.5 ) )
  = 2.5 N/mm²
```

PD:5500 5.8.5-1, Field Test Pressure

```
  = 1.25 * P * fa/ft (per 5.8.5-1)
  = 1.25 * 1.7569 * 166996.172/166996.172
  = 2.1961 N/mm²
```

Lower Bound Test Pressure	ptL	2.500	N/mm²
Upper Bound Test Pressure	ptH	2.584	N/mm²
1.35 times the Specified Design P	1.35*Dsgprs	2.363	N/mm²

Standard Test Pressure, 2.5000 N/mm², used in table below.

Stresses on Elements due to Test Pressure (kPa):

From	To	Pressure	Stress	Allowable	Ratio
10	20	2.515	158973.0	224991.5	0.707
20	30	2.515	186083.7	224991.5	0.827
30	40	2.515	158973.0	224991.5	0.707

Elements Suitable for Internal Pressure.

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	270.619	0.50793	236.792	0.51086	...
20	30	1754.84	8.25909	1493.11	8.29261	...
30	40	270.619	0.50793	236.792	0.51086	...
Total		2296	9.27	1966	9.31	0

Weight of Details:

From	Type	Weight of Detail kgm	X Offset, Dtl. Cent. m	Y Offset, Dtl. Cent. m	Description
20	Sadl	74.7265	0.95	0.81	Lft Sdl
20	Sadl	74.7265	3.852	0.81	New Sdl
20	Liqd	4042.27	2.4	0.04	Liquid: 20
20	Nozl	392.244	0.492	0.9686	N1
20	Nozl	0.60871	1.22	0.76857	N2
20	Nozl	0.15844	1.47	0.75746	N5
20	Nozl	0.60871	1.6	0.76857	N7
20	Nozl	0.60871	1.4	0.76857	N9
20	Nozl	0.60871	1.7	0.76857	N3
20	Nozl	0.60871	1.4	0.76857	N10
20	Nozl	0.15844	0.228	0.75746	N6
20	Nozl	0.60871	0.438	0.76857	N4

Total Weight of Each Detail Type:

Saddles	149.5
Liquid	4042.3
Nozzles	396.2
Sum of the Detail Weights	4587.9 kgm

Weight Summation Results: (kgm)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	2296.1	2296.1	2296.1	2296.1	2296.1	2296.1
Saddles	149.5	149.5	149.5	149.5	149.5	149.5
Nozzles	396.2	396.2	396.2	396.2	396.2	396.2
Ope. Liquid	...	...	...	...	...	4042.3
Test Liquid	...	9269.3	...	...	...	...
Totals	2841.7	12111.0	2841.7	2841.7	2841.7	6884.0

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	2841.7 kgm
Shop Test Wt.	- Fabricated Weight + Water (Full)	12111.0 kgm
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	2841.7 kgm
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	2841.7 kgm
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	2841.7 kgm
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	6884.0 kgm
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	6554.6 kgm

Field Test Wt. - Empty Weight + Water (Full)   12111.0 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 m^2
10	20	2.67769
20	30	22.6139
30	40	2.67769
Total		27.969 m^2

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	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

PV Elite 2019   Licensee: XGM
FileName : 9m3 LPG Tank   ---------------------------------
Wind Load Calculation: Step: 7   9:36am May 19,2021

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/m^3

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
  = 0.9 + 0.0
  = 0.900 m.  [.900 m]
```

Roughness factor at height of the first element [Cr(z)]:

```
  = Interpolated value from the table 3 at 0.9 m.
  = 0.943
```

Peak wind speed at height of the first element [vp(z)] per 7.3.1.1:

```
  = Cr(z) * Co(z) * vbpeak
  = 0.943 * 1.0 * 39.201
  = 36.947 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 * 36.947^2
  =  0.8190E+03 N./m²  [ 0.8190E+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 * 819.037 * 0.54
  = 309.8 N.
```

Element	z m	Area m^2	Pressure kPa	Force N
Node 10 to 20	0.900	0.540	0.819	309.753
Node 20 to 30	0.900	8.638	0.819	4953.348
Node 30 to 40	0.900	0.540	0.819	309.753

Wind Load Calculation:

From	To	Wind Height m	Wind Diameter m	Wind Area m^2	Wind Pressure kPa	Element Wind Load N
10	20	0.9	1.8	0.54016	0.81901	309.753
20	30	0.9	1.8	8.63786	0.81901	4953.35
30	40	0.9	1.8	0.54016	0.81901	309.753

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
  = 64.278 KN  [64274.4 N]
```

Design Base Shear Load per 8.5.1 [Vn] :
```
  = Sd(T) * Wn
  = 0.104 * 64.278
  = 6.666 KN  [6665.5 N]
```

Factor to determine lateral seismic force on element 1 [Cv1] per 8.5.3:
```
  = W1 * h1 / SUM[ Wi * hi ]
  = 12854.938 * 0.738/47511.848
  = 0.19968
```

Vertical distribution of seismic forces for element 1 [F1n] per 8.5.3:
```
  = Cv1 * Vn
  = 0.19968 * 6.666
  = 1.331 KN  [1330.9 N]
```

Earthquake Load Calculation:

From	To	Earthquake Height m	Earthquake Weight N	Element Ope Load N
10	20	0.738	12854.9	1330.93
20	Sadl	0.74	12854.9	1334.54
Sadl	30	0.74	12854.9	1334.54
20	30	0.74	12854.9	1334.54
30	40	0.738	12854.9	1330.93

Shop/Field Installation Options :

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

Center of Gravity of Saddles	2.452 m
Center of Gravity of Liquid	2.451 m
Center of Gravity of Nozzles	0.550 m
Center of Gravity of Bare Shell New and Cold	2.451 m
Center of Gravity of Bare Shell Corroded	2.451 m
Vessel CG in the Operating Condition	2.336 m
Vessel CG in the Fabricated (Shop/Empty) Condition	2.186 m
Vessel CG in the Test Condition	2.389 m

Rigging Analysis Results:

Lifting Weight based the calculated Empty Weight.

Total Effective Length of Vessel for this analysis		4.90 m
Total vessel weight (No Liquid)	Twt	27866.10 N
Impact weight multiplication factor	Imp	1.50
Design lifting weight, DWT = Imp * Twt		41799.15 N
Distance to the Lug on the Left End		1.00 m
Distance to the Lug on the Right End		3.80 m
Design Reaction force at the Left End Lug		24095.77 N
Design Reaction force at the Right End Lug		17703.38 N
CG Distance from the Left End Lug		1.19 m
CG Distance from the Nearer Lifting Lug		1.19 m

Critical Values:

	Max Stress kPa	Elevation m	Allowables kPa	
Bending	854.84	1.01	115890.12	
Shear	333.38	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	14490.4	258.3
1.01	14812.4	854.8	4459.1	95.3
2.93	7317.9	422.3	5572.7	119.1
4.85	1516.7	73.2	1114.6	19.9

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0074 at elevation 1.0108 m - Must be <=1

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

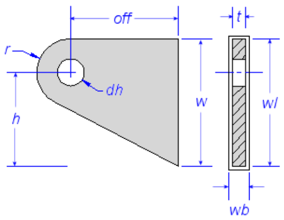
--- Plot data successfully generated ...----

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)		27866.10 N
Design Reaction force at the Left end lug		24095.77 N
Design Reaction force at the Right end lug		17703.38 N
Force Along Vessel Axis	Fax	0.00 N
Force Normal to Vessel	Fn	24095.77 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( Fax² + Ft² + Fn² )/(( 2 * (wl + wb) ) * tw )
  = sqrt(0²+0²+24096²)/((2*(128.0+14.0))*5.656)
  = 15001.15 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)
  = (24096(70.0-64.0))69.656/2684604 +
    (0 * 8.0 * 69.656/2684604) +
    (0 * 8.0 * 7.0/31648.822)
  = 3751.30 kPa
```

Total Shear Stress for Combined Loads [St]:

```
  = Ssll + Sblf
  = 15001.154 + 3751.305
  = 18752.46 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( Pl² + Fax² ) / Sha
  = sqrt( 24096² + 0² )/0.001
  = 43029.32 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( Fax² + Fn² ) / ( t * dh )
  = sqrt( 0² + 24096² )/( 14.0 * 40.0 )
  = 43029.32 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 * t²/6) + Fax * off/(w² * t/6)
  = 0 * 8.0/(120.0 * 14.0²/6) +
    0 * 8.0/(120.0² * 14.0/6)
  = 0.00 kPa
```

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

```
  = Fn / (w * t)
  = 24096/(120.0 * 14.0)
  = 14343.11 kPa
```

Total Combined Stress at the Base of the Lug:

```
  = Fbs + Fa
  = 0.0 + 14343.1
  = 14343.11 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
```

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Lifting Lug Calcs: Left Side Step: 10 9:36am May 19,2021

Required Shackle Pin Diameter [Spd]:
= sqrt[(2 * sqrt(Fn² + Fax²)/(Pi * Sta))]
= sqrt[2 * sqrt(24096² + 0²)/(Pi * 99998)]
= 12.3857 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	1480.000	mm
Vessel Thickness	Tv	10.000	mm

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

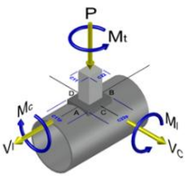
Attachment Type	Type	Rectangular	
Parameter C11	C11	14.00	mm
Parameter C22	C22	56.00	mm
Thickness of Reinforcing Pad	Tpad	10.000	mm
Pad Parameter C11P	C11p	62.000	mm
Pad Parameter C22P	C22p	136.000	mm
Design Internal Pressure	Dp	0.000	N/mm²
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-24095.8	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".



PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Lifting Lug Calcs: Left Side Step: 10 9:36am May 19,2021

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-24095.8	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 = 37.50

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.028	4C	7.222	(A,B)
N(PHI) / (P/Rm)	0.028	3C	7.414	(C,D)
M(PHI) / (P)	0.016	2C1	0.238	(A,B)
M(PHI) / (P)	0.016	1C !	0.275	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.015	3A	0.082	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.019	1A !	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.024	3B	0.703	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.021	1B !	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.022	3C	7.499	(A,B)
N(x) / (P/Rm)	0.022	4C	7.261	(C,D)
M(x) / (P)	0.023	1C1	0.270	(A,B)
M(x) / (P)	0.023	2C	0.217	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.015	4A	0.100	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.025	2A !	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.024	4B	0.171	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.028	2B !	0.107	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	11601	11601	11601	11601	11909	11909	11909	11909
Circ. Bend. P	85934	-85934	85934	-85934	99513	-99513	99513	-99513
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.	97536	-74332	97536	-74332	111422	-87603	111422	-87603
Long. Memb. P	12046	12046	12046	12046	11663	11663	11663	11663
Long. Bend. P	97722	-97722	97722	-97722	78521	-78521	78521	-78521
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.	109769	-85676	109769	-85676	90185	-66857	90185	-66857

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.	109769	85676	109769	85676	111422	87603	111422	87603

Dimensionless Parameters used : Gamma = 74.50
Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.083	4C	12.630	(A,B)
N(PHI) / (P/Rm)	0.083	3C	10.757	(C,D)
M(PHI) / (P)	0.056	2C1	0.112	(A,B)
M(PHI) / (P)	0.056	1C	0.153	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.054	3A	1.548	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.059	1A	0.099	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.070	3B	7.383	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.063	1B	0.050	(A,B,C,D)
N(x) / (P/Rm)	0.071	3C	11.704	(A,B)
N(x) / (P/Rm)	0.071	4C	12.909	(C,D)
M(x) / (P)	0.073	1C1	0.130	(A,B)
M(x) / (P)	0.073	2C	0.089	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.054	4A	2.063	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.072	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.070	4B	2.041	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.077	2B	0.068	(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	40850	40850	40850	40850	34793	34793	34793	34793
Circ. Bend. P	162229	-162229	162229	-162229	220516	-220516	220516	-220516
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.	203079	-121378	203079	-121378	255310	-185723	255310	-185723
Long. Memb. P	37856	37856	37856	37856	41752	41752	41752	41752
Long. Bend. P	188326	-188326	188326	-188326	128614	-128614	128614	-128614
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.	226183	-150470	226183	-150470	170366	-86862	170366	-86862
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.	226183	150470	226183	150470	255310	185723	255310	185723

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)	11601	11601	11601	11601	11909	11909	11909	11909
Circ. Q (SUS)	85934	-85934	85934	-85934	99513	-99513	99513	-99513
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	12046	12046	12046	12046	11663	11663	11663	11663
Long. Q (SUS)	97722	-97722	97722	-97722	78521	-78521	78521	-78521
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)	12046	12046	12046	12046	11909	11909	11909	11909
Pm+Pl+Q (Total)	109769	85676	109769	85676	111422	87603	111422	87603

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	12046	250494	Passed
Pm+Pl+Q (TOTAL)	111422	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)

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)	40850	40850	40850	40850	34793	34793	34793	34793
Circ. Q (SUS)	162229	-162229	162229	-162229	220516	-220516	220516	-220516
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	37856	37856	37856	37856	41752	41752	41752	41752
Long. Q (SUS)	188326	-188326	188326	-188326	128614	-128614	128614	-128614
Shear Pm (SUS)	0	0	0	0	0	0	0	0

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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)	40850	40850	40850	40850	41752	41752	41752	41752
Pm+Pl+Q (Total)	226183	150470	226183	150470	255310	185723	255310	185723

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	41752	250494	Passed
Pm+Pl+Q (TOTAL)	255310	500988	Passed

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

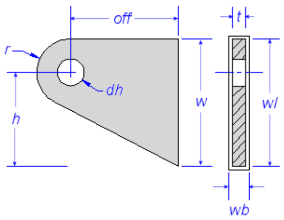
Lifting Lug Calculations: Lug(s) on Right End of Vessel

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)                                27866.10 N
 Design Reaction force at the Left end lug                      24095.77 N
 Design Reaction force at the Right end lug                     17703.38 N

 Force Along Vessel Axis                                 Fax        0.00 N
 Force Normal to Vessel                                   Fn    17703.38 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( Fax² + Ft² + Fn² )/(( 2 * (wl + wb) ) * tw )
  = sqrt(0²+0²+17703²)/((2*(128.0+14.0))*5.656)
  = 11021.49 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)
  = (17703(70.0-64.0))69.656/2684604 +
    (0 * 8.0 * 69.656/2684604) +
    (0 * 8.0 * 7.0/31648.822)
  = 2756.12 kPa
```

Total Shear Stress for Combined Loads [St]:

```
  = Ssll + Sblf
  = 11021.487 + 2756.118
  = 13777.61 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( Pl² + Fax² ) / Sha
  = sqrt( 17703² + 0² )/0.001
  = 31614.04 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( Fax² + Fn² ) / ( t * dh )
  = sqrt( 0² + 17703² )/( 14.0 * 40.0 )
  = 31614.04 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 * t²/6) + Fax * off/(w² * t/6)
  = 0 * 8.0/(120.0 * 14.0²/6) +
    0 * 8.0/(120.0² * 14.0/6)
  = 0.00 kPa
```

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

```
  = Fn / (w * t)
  = 17703/(120.0 * 14.0)
  = 10538.01 kPa
```

Total Combined Stress at the Base of the Lug:

```
  = Fbs + Fa
  = 0.0 + 10538.0
  = 10538.01 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(Fn² + Fax²)/( Pi * Sta))]
  = sqrt[2 * sqrt(17703² + 0²)/( Pi * 99998)]
  = 10.6164 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	1480.000	mm
Vessel Thickness	Tv	10.000	mm

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

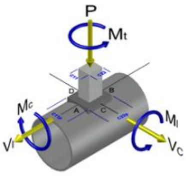
Attachment Type	Type	Rectangular	
Parameter C11	C11	14.00	mm
Parameter C22	C22	56.00	mm
Thickness of Reinforcing Pad	Tpad	10.000	mm
Pad Parameter C11P	C11p	62.000	mm
Pad Parameter C22P	C22p	136.000	mm
Design Internal Pressure	Dp	0.000	N/mm²
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-17703.4	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	-17703.4	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 = 37.50

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.028	4C	7.222	(A,B)
N(PHI) / (P/Rm)	0.028	3C	7.414	(C,D)
M(PHI) / (P)	0.016	2C1	0.238	(A,B)
M(PHI) / (P)	0.016	1C !	0.275	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.015	3A	0.082	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.019	1A !	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.024	3B	0.703	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.021	1B !	0.063	(A,B,C,D)
N(x) / (P/Rm)	0.022	3C	7.499	(A,B)
N(x) / (P/Rm)	0.022	4C	7.261	(C,D)
M(x) / (P)	0.023	1C1	0.270	(A,B)
M(x) / (P)	0.023	2C	0.217	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.015	4A	0.100	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.025	2A !	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.024	4B	0.171	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.028	2B !	0.107	(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	8524	8524	8524	8524	8749	8749	8749	8749
Circ. Bend. P	63136	-63136	63136	-63136	73113	-73113	73113	-73113
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.	71660	-54612	71660	-54612	81863	-64363	81863	-64363
Long. Memb. P	8850	8850	8850	8850	8569	8569	8569	8569
Long. Bend. P	71797	-71797	71797	-71797	57690	-57690	57690	-57690
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.	80648	-62947	80648	-62947	66259	-49120	66259	-49120

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.	80648	62947	80648	62947	81863	64363	81863	64363

Dimensionless Parameters used : Gamma = 74.50

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.083	4C	12.630	(A,B)
N(PHI) / (P/Rm)	0.083	3C	10.757	(C,D)
M(PHI) / (P)	0.056	2C1	0.112	(A,B)
M(PHI) / (P)	0.056	1C	0.153	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.054	3A	1.548	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.059	1A	0.099	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.070	3B	7.383	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.063	1B	0.050	(A,B,C,D)
N(x) / (P/Rm)	0.071	3C	11.704	(A,B)
N(x) / (P/Rm)	0.071	4C	12.909	(C,D)
M(x) / (P)	0.073	1C1	0.130	(A,B)
M(x) / (P)	0.073	2C	0.089	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.054	4A	2.063	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.072	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.070	4B	2.041	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.077	2B	0.068	(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	30012	30012	30012	30012	25562	25562	25562	25562
Circ. Bend. P	119191	-119191	119191	-119191	162015	-162015	162015	-162015
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.	149204	-89178	149204	-89178	187578	-136452	187578	-136452
Long. Memb. P	27813	27813	27813	27813	30675	30675	30675	30675
Long. Bend. P	138365	-138365	138365	-138365	94494	-94494	94494	-94494
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.	166179	-110551	166179	-110551	125169	-63818	125169	-63818
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.	166179	110551	166179	110551	187578	136452	187578	136452

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)	8524	8524	8524	8524	8749	8749	8749	8749
Circ. Q (SUS)	63136	-63136	63136	-63136	73113	-73113	73113	-73113
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	8850	8850	8850	8850	8569	8569	8569	8569
Long. Q (SUS)	71797	-71797	71797	-71797	57690	-57690	57690	-57690
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)	8850	8850	8850	8850	8749	8749	8749	8749
Pm+Pl+Q (Total)	80648	62947	80648	62947	81863	64363	81863	64363

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	8850	250494	Passed
Pm+Pl+Q (TOTAL)	81863	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)

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)	30012	30012	30012	30012	25562	25562	25562	25562
Circ. Q (SUS)	119191	-119191	119191	-119191	162015	-162015	162015	-162015
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	27813	27813	27813	27813	30675	30675	30675	30675
Long. Q (SUS)	138365	-138365	138365	-138365	94494	-94494	94494	-94494
Shear Pm (SUS)	0	0	0	0	0	0	0	0

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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)	30012	30012	30012	30012	30675	30675	30675	30675
Pm+Pl+Q (Total)	166179	110551	166179	110551	187578	136452	187578	136452

Vessel Stress Summation Comparison (kPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	166996	Passed
Pm+Pl (SUS)	30675	250494	Passed
Pm+Pl+Q (TOTAL)	187578	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	745.75	mm
Stiffened Vessel Length per 4.15.6	L	4.90	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	100.00	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	0.37	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		40806.26	N

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	75122.45	166996.17
Long. Stress at Bottom of Midspan	78694.70	166996.17
Long. Stress at Top of Saddles	78296.51	166996.17
Long. Stress at Bottom of Saddles	76139.29	166996.17
Tangential Shear in Shell	5444.12	133596.95
Circ. Stress at Horn of Saddle	8324.02	208745.22
Circ. Compressive Stress in Shell	1627.95	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 * ( 5572.9/2 + 0 ) * 900.0/1316.3586
  = 5715.3 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 1736.74, 0.0, 0 ) * 900.0/2902.0002
  = 538.6 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 6665.49, 0.0, 0 ) * 900.0/2902.0002
  = 2067.2 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 6665/2 + 0 ) * 900.0/1316.3586
```

```
  = 6835.8 N
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 33970 + Max( 539, 5715, 2067, 6836 )
  = 40806.3 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)            41539.03   N
 Transverse Shear Load Saddle          Ft            3332.75   N
 Longitudinal Shear Load Saddle                      6665.49   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  = 0.0269     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0221
```

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)]
  = -40806*0.5[1-(1-0.5/4.9+(0.746²-0.371²)/
    (2*0.5*4.9))/(1+(4*0.37)/(3*4.9))]
  = -2198.3 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 40806*5/4(1+2(0.7²-0.4²)/(5²))/(1+(4*0.4)/
    (3*5))-4*0.5/5
  = 26535.8 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 1.753 * 745.75/(2*8.5) - 26535.8/(pi*745.8²*8.5)
  = 75122.45 kPa
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 1.753 * 745.75/(2 * 8.5) + 26535.8/(pi * 745.8² * 8.5 )
  = 78694.70 kPa
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 1.753*745.75/(2*8.5)--2198.3/(0.1066*pi*745.8²*8.5)
  = 78296.51 kPa
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 1.753*745.75/(2*8.5)+-2198.3/(0.1923*pi*745.8²*8.5)
  = 76139.29 kPa
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 40806( 4.9 - 2 * 0.5)/(4.9 + ( 4 * 0.37/3))
  = 29477.1 N
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 29477.07/( 745.75 * 8.5 )
  = 5444.12 kPa
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 745.75 * 8.5 )
  = 62.101 mm
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 40806 * 0.1/( 8.5 * ( 100.0 + 62.1 + 62.1 ) )
  = -1627.95 kPa
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 100.0 + 1.56 * sqrt( 745.75 * 8.5 ), 2 * 0.502 )
  = 224.20 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 * 40806 * 0.1/( 224.203( 8.5 + 1.0 * 10.0 ) )
  = -747.97 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)
  = -40806/(4(8.5+ 1.0* 10.0)224.203) -
     12*0.027*40806*745.75/(4.9(8.5+1.0*10.0)²)
  = -8324.02 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	223.8	8.5	4.2	0.0	8086.5	0.482E+07
Wearplate	100.0	10.0	13.5	0.0	13500.0	0.169E+07
Web	10.0	130.0	83.5	0.0	108550.1	0.292E+07
BasePlate	100.0	10.0	153.5	0.0	153500.1	0.981E+07
Totals	...	...	...	...	283636.7	0.192E+08

Distance to Centroid [C1]:

```
  = AY / A
  = 0.011/0.005
  = 54.517 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 * 40806.262
  = 8304.9590 N

 Tension Stress, St = ( Fh/As )       =       2516.7217  kPa
 Allowed Stress, Sa = 0.6 * Yield Str =     143959.2031  kPa
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 900.0 - 741.5 * sin( 1.0472 )/1.0472
  = 286.784 mm

 Bending Moment, M  = Fh * d          =       2382.6985  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =       6749.3379  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(40806 + 733)100.0/( 4 * 1000.0 * 159954.672 ))½
  = 4.413 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 )( 740.0 + 10.0 + 10.0 )
  = 1316.359 mm
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1316.3586/( 3 - 1 )
  = 658.179 mm
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 658.1793 * 100.0/2
  = 0.033 m²
```

Axial Load [P]:

```
  = Ap * Bp
  = 0.0 * 408163.84
  = 13428.918 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
= 13428.9/0.0042
= 3204.393 kPa

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	100.0	...	...	...	0.833E+06

Rib dimension [D]:
= Saddle Width - Web Thickness
= 100.0 - 10.0
= 90.000 mm

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

Distance to Centroid [C1]:
= Saddle Width / 2
= 100.0/2
= 50.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(833333/0.004)
= 14.101 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 * 226.009/14.101
= 16.028

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 6665.5/(2 * 1000.0) * 658.179 * 226.01/2
= 247.981 N-m

Compressive Allowable, KL/r < Cc (16.0276 < 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-(16.03 $)^2$/(2 * 128.25^2))239932/
(5/3+3*(16.03)/(8* 128.25)-(16.03^3)/(8*128.25^3)
= 138949 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 3204.39/138948.56 + (247.98 * 50.0/833333)/159954.67
= 0.116

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	90.0	0.0	0.0	0.0	0.832E+06
Web	658.2	10.0	0.0	0.0	0.0	0.548E+05
Totals	...	...	...	...	...	0.887E+06

Distance to Centroid from Datum [ytot]:
  = AY / A
  = 0.0/0.007
  = 0.000 mm

Distance to Centroid [C1]:
  = Saddle Width / 2
  = 100.0/2
  = 50.000 mm

Length of Inner Rib [L]:
  = Saddle Height - Outside Radius - Bpthk
  = 900.0 - cos(760.0/2)(10.0 + 0.0 + 0.0) - 0.0
  = 130.000 mm

Radius of Gyration [r]:
  = sqrt(Total Inertia / Total Area)
  = sqrt(887347/0.007)
  = 10.890 mm

Slenderness ratio [KL/r]:
  = KL/r
  = 1 * 130.0/10.89
  = 11.937

Unit Force [Force,u]:
  = Fl / (2 * Baseplate Length)
  = 6665.492/(2 * 1000.0)
  = 3.333 N/mm

Moment at base of inner Rib [Mbase,c]:
  = Unit Force * e * L
  = 3.333 * 658.179 * 130.0
  = 285.276 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
  = Bending Moment / Section Modulus
  = 285.276/17746.965
  = 16068.574 kPa

Compressive Allowable, KL/r < Cc (11.9371 < 128.255) per AISC E2-1 [Sca]:
  = $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
  = $(1-(11.94)^2/(2 * 128.25^2))239932/$
    $(5/3+3*(11.94)/(8* 128.25)-(11.94^3)/(8*128.25^3)$
  = 140404 kPa

AISC Unity Check of Inside Ribs (must be <= 1)
  = Sc/Sca + (Mbase,c * C1/I)/Sba
  = 3716.01/140403.88 + (285.28 * 50.0/887347)/159954.67
  = 0.127

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

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Horizontal Vessel Analysis (Ope.): Step: 12 9:36am May 19,2021

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm      745.75  mm
 Stiffened Vessel Length per 4.15.6               L        4.90  m
 Distance from Saddle to Vessel tangent           a      502.00  mm

 Saddle Width                                     b      100.00  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        0.37  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                        35674.57  N
```

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	75347.06	166996.17
Long. Stress at Bottom of Midspan	78470.08	166996.17
Long. Stress at Top of Saddles	78121.96	166996.17
Long. Stress at Bottom of Saddles	76236.03	166996.17
Tangential Shear in Shell	4759.48	133596.95
Circ. Stress at Horn of Saddle	7277.21	208745.22
Circ. Compressive Stress in Shell	1423.22	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 * ( 5572.9/2 + 0 ) * 900.0/1316.3586
  = 5715.3 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 1736.74, 0.0, 0 ) * 900.0/2902.0002
  = 538.6 N
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 6665.49, 0.0, 0 ) * 900.0/2902.0002
  = 2067.2 N
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 6665/2 + 0 ) * 900.0/1316.3586
  = 6835.8 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 28839 + Max( 539, 5715, 2067, 6836 )
  = 35674.6 N
```

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Horizontal Vessel Analysis (Ope.): Step: 12 9:36am May 19,2021

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)            36407.33  N
 Transverse Shear Load Saddle          Ft            3332.75  N
 Longitudinal Shear Load Saddle                      6665.49  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  = 0.0269     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0221
```

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)]
  = -35675*0.5[1-(1-0.5/4.9+(0.746²-0.371²)/
    (2*0.5*4.9))/(1+(4*0.37)/(3*4.9))]
  = -1921.9 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 35675*5/4(1+2(0.7²-0.4²)/(5²))/(1+(4*0.4)/
    (3*5))-4*0.5/5
  = 23198.7 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 1.753 * 745.75/(2*8.5) - 23198.7/(pi*745.8²*8.5)
  = 75347.06 kPa
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 1.753 * 745.75/(2 * 8.5) + 23198.7/(pi * 745.8² * 8.5 )
  = 78470.08 kPa
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 1.753*745.75/(2*8.5)--1921.9/(0.1066*pi*745.8²*8.5)
  = 78121.96 kPa
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 1.753*745.75/(2*8.5)+-1921.9/(0.1923*pi*745.8²*8.5)
  = 76236.03 kPa
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 35675( 4.9 - 2 * 0.5)/(4.9 + ( 4 * 0.37/3))
  = 25770.1 N
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 25770.11/( 745.75 * 8.5 )
  = 4759.48 kPa
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 745.75 * 8.5 )
  = 62.101 mm
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 35675 * 0.1/( 8.5 * ( 100.0 + 62.1 + 62.1 ) )
  = -1423.22 kPa
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 100.0 + 1.56 * sqrt( 745.75 * 8.5 ), 2 * 0.502 )
  = 224.20 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 * 35675 * 0.1/( 224.203( 8.5 + 1.0 * 10.0 ) )
  = -653.91 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)
  = -35675/(4(8.5+ 1.0* 10.0)224.203) -
     12*0.027*35675*745.75/(4.9(8.5+1.0*10.0)²)
  = -7277.21 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	223.8	8.5	4.2	0.0	8086.5	0.482E+07
Wearplate	100.0	10.0	13.5	0.0	13500.0	0.169E+07
Web	10.0	130.0	83.5	0.0	108550.1	0.292E+07
BasePlate	100.0	10.0	153.5	0.0	153500.1	0.981E+07
Totals	...	...	...	...	283636.7	0.192E+08

Distance to Centroid [C1]:
```
  = AY / A
  = 0.011/0.005
  = 54.517 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 * 35674.566
  = 7260.5479 N

 Tension Stress, St = ( Fh/As )       =       2200.2249  kPa
 Allowed Stress, Sa = 0.6 * Yield Str =     143959.2031  kPa
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 900.0 - 741.5 * sin( 1.0472 )/1.0472
  = 286.784 mm

 Bending Moment, M  = Fh * d          =       2083.0562  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =       5900.5571  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(35675 + 733)100.0/( 4 * 1000.0 * 159954.672 ))½
  = 4.132 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 )( 740.0 + 10.0 + 10.0 )
  = 1316.359 mm
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1316.3586/( 3 - 1 )
  = 658.179 mm
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 658.1793 * 100.0/2
  = 0.033 m²
```

Axial Load [P]:
```
  = Ap * Bp
  = 0.0 * 356834.12
  = 11740.130 N
```

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

Compressive Stress [Sc]:
```
  = P/Ar
  = 11740.1/0.0042
```

= 2801.417 kPa

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	100.0	...	...	...	0.833E+06

Rib dimension [D]:
= Saddle Width - Web Thickness
= 100.0 - 10.0
= 90.000 mm

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

Distance to Centroid [C1]:
= Saddle Width / 2
= 100.0/2
= 50.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(833333/0.004)
= 14.101 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 * 226.009/14.101
= 16.028

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 6665.5/(2 * 1000.0) * 658.179 * 226.01/2
= 247.981 N-m

Compressive Allowable, KL/r < Cc (16.0276 < 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-(16.03 $)^2$/(2 * 128.25^2))239932/
(5/3+3*(16.03)/(8* 128.25)-(16.03^3)/(8*128.25^3)
= 138949 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 2801.42/138948.56 + (247.98 * 50.0/833333)/159954.67
= 0.113

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	90.0	0.0	0.0	0.0	0.832E+06

Web	658.2	10.0	0.0	0.0	0.0	0.548E+05
Totals	...	...	...	...	...	0.887E+06

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/0.007
  = 0.000 mm
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 100.0/2
  = 50.000 mm
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 900.0 - cos( 760.0/2 )( 10.0 + 0.0 + 0.0 ) - 0.0
  = 130.000 mm
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 887347/0.007 )
  = 10.890 mm
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 130.0/10.89
  = 11.937
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 6665.492/( 2 * 1000.0 )
  = 3.333 N/mm
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 3.333 * 658.179 * 130.0
  = 285.276 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 285.276/17746.965
  = 16068.574 kPa
```

Compressive Allowable, KL/r < Cc (11.9371 < 128.255) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.94 )²/(2 * 128.25² ))239932/
    ( 5/3+3*(11.94)/(8* 128.25)-( 11.94³)/(8*128.25³)
  = 140404 kPa
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 3248.7/140403.88 + ( 285.28 * 50.0/887347 )/159954.67
  = 0.124
```

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      745.00  mm
 Stiffened Vessel Length per 4.15.6               L        4.90  m
 Distance from Saddle to Vessel tangent           a      502.00  mm

 Saddle Width                                     b      100.00  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        0.37  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            63118.28  N

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             kPa |          kPa |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan      91040.23 |    237494.56 |
 Long. Stress at Bottom of Midspan      95749.45 |    237494.56 |
 Long. Stress at Top    of Saddles      95217.72 |    237494.56 |
 Long. Stress at Bottom of Saddles      92384.49 |    237494.56 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               7167.58 |    189995.66 |
 Circ. Stress at Horn of Saddle         11131.45 |    356241.84 |
 Circ. Compressive Stress in Shell       2045.08 |    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 * ( 1839.0/2 + 0 ) * 900.0/1316.3586
  = 1886.0 N
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 573.12, 0.0, 0 ) * 900.0/2902.0002
  = 177.7 N
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 61232 + Max( 178, 1886, 0, 0 )
  = 63118.3 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)              63851.05  N
 Transverse Shear Load Saddle           Ft              919.52  N
```

```
 Longitudinal Shear Load Saddle                    573.12  N
```

Hydrostatic Test Pressure at center of Vessel: 2.507 N/mm^2

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  = 0.0270     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0222
```

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)]
  = -63118*0.5[1-(1-0.5/4.9+(0.745²-0.369²)/
    (2*0.5*4.9))/(1+(4*0.37)/(3*4.9))]
  = -3389.9 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 63118*5/4(1+2(0.7²-0.4²)/(5²))/(1+(4*0.4)/
    (3*5))-4*0.5/5
  = 41071.9 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 2.507 * 745.0/(2*10.0) - 41071.9/(pi*745.0²*10.0)
  = 91040.23 kPa
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 2.507 * 745.0/(2 * 10.0) + 41071.9/(pi * 745.0² * 10.0 )
  = 95749.45 kPa
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 2.507*745.0/(2*10.0)--3389.9/(0.1066*pi*745.0²*10.0)
  = 95217.72 kPa
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 2.507*745.0/(2*10.0)+-3389.9/(0.1923*pi*745.0²*10.0)
  = 92384.49 kPa
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 63118( 4.9 - 2 * 0.5)/(4.9 + ( 4 * 0.37/3))
  = 45611.4 N
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 45611.43/( 745.0 * 10.0 )
  = 7167.58 kPa
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
```

```
  = 0.78 * sqrt( 745.0 * 10.0 )
  = 67.324 mm
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 63118 * 0.1/( 10.0 * ( 100.0 + 67.32 + 67.32 ) )
  = -2045.08 kPa
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 100.0 + 1.56 * sqrt( 745.0 * 10.0 ), 2 * 0.502 )
  = 234.65 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 * 63118 * 0.1/( 234.649( 10.0 + 1.0 * 10.0 ) )
  = -1022.54 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)
  = -63118/(4(10.0+ 1.0* 10.0)234.649) -
     12*0.027*63118*745.0/(4.9(10.0+1.0*10.0)²)
  = -11131.45 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	234.2	10.0	5.0	0.0	11709.8	0.515E+07
Wearplate	100.0	10.0	15.0	0.0	15000.0	0.136E+07
Web	10.0	130.0	85.0	0.0	110500.1	0.326E+07
BasePlate	100.0	10.0	155.0	0.0	155000.1	0.107E+08
Totals	...	...	...	...	292210.0	0.204E+08

Distance to Centroid [C1]:

```
  = AY / A
  = 0.012/0.006
  = 51.792 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 * 63118.277
  = 12845.9395 N

 Tension Stress, St = ( Fh/As )       =       3892.8130  kPa
 Allowed Stress, Sa = 0.6 * Yield Str =     143959.2031  kPa
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 900.0 - 740.0 * sin( 1.0472 )/1.0472
  = 288.025 mm

 Bending Moment, M  = Fh * d          =       3701.4509  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =       9378.2412  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(63118 + 733)100.0/( 4 * 1000.0 * 159954.672 ))½
  = 5.472 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 )( 740.0 + 10.0 + 10.0 )
  = 1316.359 mm
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1316.3586/( 3 - 1 )
  = 658.179 mm
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 658.1793 * 100.0/2
  = 0.033 m²
```

Axial Load [P]:

```
  = Ap * Bp
  = 0.0 * 631339
  = 20771.574 N
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 0.001 + 0.003
  = 0.004 m²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 20771.6/0.0042
  = 4956.489 kPa
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	100.0	...	...	...	0.833E+06

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 100.0 - 10.0
  = 90.000 mm
```

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

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 100.0/2
  = 50.000 mm
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 833333/0.004 )
  = 14.101 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 * 224.947/14.101
  = 15.952
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 573.1/( 2 * 1000.0 ) * 658.179 * 224.95/2
  = 21.222 N-m
```

Compressive Allowable, KL/r < Cc (15.9524 < 128.255) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 15.95 )²/(2 * 128.25² ))239932/
    ( 5/3+3*(15.95)/(8* 128.25)-( 15.95³)/(8*128.25³)
  = 138976 kPa
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 4956.49/138976.39 + ( 21.22 * 50.0/833333 )/159954.67
  = 0.044
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	90.0	0.0	0.0	0.0	0.832E+06
Web	658.2	10.0	0.0	0.0	0.0	0.548E+05
Totals	...	...	...	...	...	0.887E+06

Distance to Centroid from Datum [ytot]:
```
  = AY / A
```

```
  = 0.0/0.007
  = 0.000 mm
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 100.0/2
  = 50.000 mm
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 900.0 - cos( 760.0/2 )( 10.0 + 0.0 + 0.0 ) - 0.0
  = 130.000 mm
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 887347/0.007 )
  = 10.890 mm
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 130.0/10.89
  = 11.937
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 573.125/( 2 * 1000.0 )
  = 0.287 N/mm
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.287 * 658.179 * 130.0
  = 24.529 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 24.529/17746.965
  = 1381.637 kPa
```

Compressive Allowable, KL/r < Cc (11.9371 < 128.255) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.94 )²/(2 * 128.25² ))239932/
    ( 5/3+3*(11.94)/(8* 128.25)-( 11.94³)/(8*128.25³)
  = 140404 kPa
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 5747.85/140403.88 + ( 24.53 * 50.0/887347 )/159954.67
  = 0.050
```

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	745.00	mm
Stiffened Vessel Length per 4.15.6	L	4.90	m
Distance from Saddle to Vessel tangent	a	502.00	mm
Saddle Width	b	100.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	100.00	mm

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FileName : 9m3 LPG Tank ---------------------------------
Horizontal Vessel Analysis (Test): Step: 13 9:36am May 19,2021

```
 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        0.37   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          57949.02   N
```

Horizontal Vessel Analysis Results:	Actual kPa	Allowable kPa
Long. Stress at Top of Midspan	91233.08	237494.56
Long. Stress at Bottom of Midspan	95556.61	237494.56
Long. Stress at Top of Saddles	95068.43	237494.56
Long. Stress at Bottom of Saddles	92467.24	237494.56
Tangential Shear in Shell	6580.57	189995.66
Circ. Stress at Horn of Saddle	10219.81	356241.84
Circ. Compressive Stress in Shell	1877.59	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 * ( 1839.0/2 + 0 ) * 900.0/1316.3586
  = 1886.0 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 573.12, 0.0, 0 ) * 900.0/2902.0002
  = 177.7 N
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 56063 + Max( 178, 1886, 0, 0 )
  = 57949.0 N
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)            58681.79   N
 Transverse Shear Load Saddle            Ft           919.52   N
 Longitudinal Shear Load Saddle                       573.12   N
```

Hydrostatic Test Pressure at center of Vessel: 2.507 N/mm^2

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  = 0.0270     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0222
```

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)]
  = -57949*0.5[1-(1-0.5/4.9+(0.745²-0.369²)/
    (2*0.5*4.9))/(1+(4*0.37)/(3*4.9))]
  = -3112.3 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 57949*5/4(1+2(0.7²-0.4²)/(5²))/(1+(4*0.4)/
    (3*5))-4*0.5/5
  = 37708.2 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 2.507 * 745.0/(2*10.0) - 37708.2/(pi*745.0²*10.0)
  = 91233.08 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 2.507 * 745.0/(2 * 10.0) + 37708.2/(pi * 745.0² * 10.0 )
  = 95556.61 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 2.507*745.0/(2*10.0)--3112.3/(0.1066*pi*745.0²*10.0)
  = 95068.43 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 2.507*745.0/(2*10.0)+-3112.3/(0.1923*pi*745.0²*10.0)
  = 92467.24 kPa
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 57949( 4.9 - 2 * 0.5)/(4.9 + ( 4 * 0.37/3))
  = 41875.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 41875.94/( 745.0 * 10.0 )
  = 6580.57 kPa
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 745.0 * 10.0 )
  = 67.324 mm
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 57949 * 0.1/( 10.0 * ( 100.0 + 67.32 + 67.32 ) )
  = -1877.59 kPa
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 100.0 + 1.56 * sqrt( 745.0 * 10.0 ), 2 * 0.502 )
  = 234.65 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 * 57949 * 0.1/( 234.649( 10.0 + 1.0 * 10.0 ) )
  = -938.79 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)
  = -57949/(4(10.0+ 1.0* 10.0)234.649) -
     12*0.027*57949*745.0/(4.9(10.0+1.0*10.0)²)
  = -10219.81 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	234.2	10.0	5.0	0.0	11709.8	0.515E+07
Wearplate	100.0	10.0	15.0	0.0	15000.0	0.136E+07
Web	10.0	130.0	85.0	0.0	110500.1	0.326E+07
BasePlate	100.0	10.0	155.0	0.0	155000.1	0.107E+08
Totals	...	...	...	...	292210.0	0.204E+08

Distance to Centroid [C1]:

```
  = AY / A
  = 0.012/0.006
  = 51.792 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 * 57949.016
  = 11793.8818 N
```

```
 Tension Stress, St = ( Fh/As )       =       3573.9993  kPa
 Allowed Stress, Sa = 0.6 * Yield Str =     143959.2031  kPa
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 900.0 - 740.0 * sin( 1.0472 )/1.0472
```

```
  = 288.025 mm

 Bending Moment, M  = Fh * d          =       3398.3093  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =       8610.1816  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(57949 + 733)100.0/( 4 * 1000.0 * 159954.672 ))½
  = 5.246 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 )( 740.0 + 10.0 + 10.0 )
  = 1316.359 mm
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1316.3586/( 3 - 1 )
  = 658.179 mm
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 658.1793 * 100.0/2
  = 0.033 m²
```

Axial Load [P]:

```
  = Ap * Bp
  = 0.0 * 579634
  = 19070.422 N
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 0.001 + 0.003
  = 0.004 m²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 19070.4/0.0042
  = 4550.562 kPa
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	100.0	...	...	...	0.833E+06

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 100.0 - 10.0
  = 90.000 mm
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/0.004
  = 0.000 mm
```

Distance to Centroid [C1]:
= Saddle Width / 2
= 100.0/2
= 50.000 mm

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(833333/0.004)
= 14.101 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 * 224.947/14.101
= 15.952

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 573.1/(2 * 1000.0) * 658.179 * 224.95/2
= 21.222 N-m

Compressive Allowable, KL/r < Cc (15.9524 < 128.255) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(15.95)^2/(2 * 128.25^2))239932/$
$(5/3+3*(15.95)/(8* 128.25)-(15.95^3)/(8*128.25^3)$
= 138976 kPa

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 4550.56/138976.39 + (21.22 * 50.0/833333)/159954.67
= 0.041

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	90.0	0.0	0.0	0.0	0.832E+06
Web	658.2	10.0	0.0	0.0	0.0	0.548E+05
Totals	...	...	...	...	...	0.887E+06

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/0.007
= 0.000 mm

Distance to Centroid [C1]:
= Saddle Width / 2
= 100.0/2
= 50.000 mm

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 900.0 - cos(760.0/2)(10.0 + 0.0 + 0.0) - 0.0
= 130.000 mm

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

```
  = sqrt( 887347/0.007 )
  = 10.890 mm
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 130.0/10.89
  = 11.937
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 573.125/( 2 * 1000.0 )
  = 0.287 N/mm
```

Moment at base of inner Rib [Mbase,c]:

```
  = Unit Force * e * L
  = 0.287 * 658.179 * 130.0
  = 24.529 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 24.529/17746.965
  = 1381.637 kPa
```

Compressive Allowable, KL/r < Cc (11.9371 < 128.255) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.94 )²/(2 * 128.25² ))239932/
    ( 5/3+3*(11.94)/(8* 128.25)-( 11.94³)/(8*128.25³)
  = 140404 kPa
```

AISC Unity Check of Inside Ribs (must be <= 1)

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 5277.11/140403.88 + ( 24.53 * 50.0/887347 )/159954.67
  = 0.046
```

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	9.73	8.69	...	Passed	N/A
N2	7.49	2.35	...	Passed	N/A
N5	4.13	0.85	...	Passed	N/A
N7	7.49	2.35	...	Passed	N/A
N9	7.49	2.35	...	Passed	N/A
N3	7.49	2.35	...	Passed	N/A
N10	7.49	2.35	...	Passed	N/A
N6	4.13	0.90	...	Passed	N/A
N4	7.49	2.38	...	Passed	N/A

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm	Layout Angle deg	Mean Radius mm
20	N1	542.800	90.000	224.483
20	N2	1270.800	90.000	24.828
20	N5	1520.800	90.000	15.399
20	N7	1650.800	90.000	24.828
20	N9	1450.800	80.000	24.828
20	N3	1750.800	100.000	24.828
20	N10	1450.800	100.000	24.828
20	N6	278.800	270.000	15.399
20	N4	488.800	270.000	24.828

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 : N5 and N2 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0018 + 0.0003 - 0. >= 1.0 * 1.0 * 250. * 7.8489
0.0021 should be greater than or equal to 0.002 [Passed]

Dim P is: 250.00 mm Dim S is: 209.77 mm Dim Smin is: 324.59 mm

---

Nozzles : N9 and N2 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0015 + 0.0004 - 0. >= 1.0 * 0.8296 * 221.694 * 7.8489
0.0019 should be greater than or equal to 0.0014 [Passed]

Dim P is: 221.69 mm Dim S is: 172.04 mm Dim Smin is: 324.59 mm

---

Nozzles : N10 and N2 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.0015 + 0.0004 - 0. >= 1.0 * 0.8296 * 221.694 * 7.8489
 0.0019 should be greater than or equal to 0.0014 [Passed]

 Dim P is: 221.69 mm Dim S is: 172.04 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N7 and N5 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.0008 + 0.0003 - 0. >= 1.0 * 1.0 * 130. * 7.8489
 0.0011 should be greater than or equal to 0.001 [Passed]

 Dim P is: 130.00 mm Dim S is: 89.77 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N9 and N5 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.001 + 0.0003 - 0. >= 1.0 * 0.6132 * 147.134 * 7.8489
 0.0012 should be greater than or equal to 0.0007 [Passed]

 Dim P is: 147.13 mm Dim S is: 106.91 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N3 and N5 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.002 + 0.0003 - 0. >= 0.99 * 0.8798 * 263.910 * 7.8489
 0.0022 should be greater than or equal to 0.0018 [Passed]

 Dim P is: 263.91 mm Dim S is: 223.68 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N10 and N5 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.001 + 0.0003 - 0. >= 1.0 * 0.6132 * 147.134 * 7.8489
 0.0012 should be greater than or equal to 0.0007 [Passed]

 Dim P is: 147.13 mm Dim S is: 106.91 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N9 and N7 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
  0.0017 + 0.0004 - 0. >= 1.0 * 0.8524 * 238.219 * 7.8489
 0.002 should be greater than or equal to 0.0016 [Passed]

 Dim P is: 238.22 mm Dim S is: 188.56 mm Dim Smin is: 324.59 mm

 ----

Nozzles : N3 and N7 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.001 + 0.0004 - 0. >= 1.0 * 0.6869 * 163.549 * 7.8489
0.0014 should be greater than or equal to 0.0009 [Passed]

Dim P is: 163.55 mm   Dim S is: 113.89 mm   Dim Smin is: 324.59 mm

---

Nozzles : N10 and N7 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0017 + 0.0004 - 0. >= 1.0 * 0.8524 * 238.219 * 7.8489
0.002 should be greater than or equal to 0.0016 [Passed]

Dim P is: 238.22 mm   Dim S is: 188.56 mm   Dim Smin is: 324.59 mm

---

Nozzles : N10 and N9 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0018 + 0.0004 - 0. >= 1.0 * 0.5 * 258.832 * 7.8489
0.0022 should be greater than or equal to 0.001 [Passed]

Dim P is: 258.83 mm   Dim S is: 209.18 mm   Dim Smin is: 324.59 mm

---

Nozzles : N10 and N3 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0022 + 0.0004 - 0. >= 0.9445 * 1.0 * 300. * 7.8489
0.0026 should be greater than or equal to 0.0022 [Passed]

Dim P is: 300.00 mm   Dim S is: 250.34 mm   Dim Smin is: 324.59 mm

---

Nozzles : N4 and N6 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0015 + 0.0003 - 0. >= 1.0 * 1.0 * 210. * 7.8489
0.0018 should be greater than or equal to 0.0016 [Passed]

Dim P is: 210.00 mm   Dim S is: 169.77 mm   Dim Smin is: 324.59 mm

---

No interference violations have been detected !

Input, Nozzle Desc: N1   From: 20

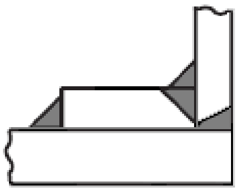
Pressure for Reinforcement Calculations	P	1.7500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1480.00	mm
Shell Finished (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		0.54	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		90.00	deg
Diameter		457.2000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	9.7350	mm
Flange Material		BS1501-151,430A	
Flange Type		Slip on	
Corrosion Allowance	can	1.5000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	100.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	5.5560	mm
Pad Material		BS1501-151,430A	
Pad Allowable Stress at Temperature	f2	159996.34	kPa
Pad Allowable Stress At Ambient	f2a	159996.34	kPa
Diameter of Pad along vessel surface	d2	634.0000	mm
Thickness of Pad	e2	10.0000	mm
Weld leg size between Pad and Shell	Wp	10.0000	mm
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm
Reinforcing Pad Width		88.4000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.
This is a Manway or Access Opening.			
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle With Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: N1

```
 Actual Outside Diameter Used in Calculation          457.200  mm.
 Actual Thickness Used in Calculation                   9.735  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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*440.73)/(2*160996.33-1.75)
  = 2.4084 + 1.5000 = 3.9084 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 492.000 mm

Mean noz dia / Mean Shl Dia d/D: 448.965 / 1501.500 = 0.2990

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

Note: Per Paragraph 3.5.4.5.1(a) if pads are to be used they must
be double sided when using the SCF method.

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 448.97/1501.5 * (1501.5/( 2*( 10.0 - 1.5 + 10.0 )))½
  = 1.9048
```

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 + 10.0 )/7.81, 1 )
  = Min( 2.3684, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 1.8 (Curve1), 1.905 (Computed rho), 2.0 (Curve2)

Values of erb/ers for values of rho: 0.3, 0.34, 0.35, 0.4

The final interpolated value of erb/ers was 0.3405 from Figure 3.5-11

Note : Computing the required nozzle thickness based on paragraph
3.5.4.3.3 subparagraph h)

```
  erb = erb1 + 10( d/D - 0.2 ) * ( erb2 - erb1 ) + Can
```

```
      = 6.299 + 10( 0.299 - 0.2 ) * ( 6.942 - 6.299 ) + 1.5
      = 8.436 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.

Required Nozzle thickness based on 3.5-11 & 3.5-12 : 8.694 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		790.5332	mm
Effective material Thickness limit	Lb	56.8318	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	166.6666	mm
Thickness Limit for Nozzle Group Calculation	Tlc	60.8048	mm

The Drop for this Nozzle is : 36.1946 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 146.1946 mm

Input, Nozzle Desc: N2   From: 20

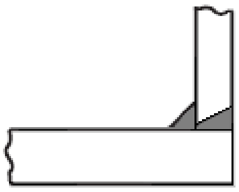
Pressure for Reinforcement Calculations	P	1.7500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1480.00	mm
Shell Finished (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		1.27	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		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	7.4930	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

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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*42.164)/(2*164996.23-1.75)
  = 0.2248 + 0.0000 = 0.2248 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1220.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2726 from Figure 3.5-11

Compute the Required Neck thickness [erb]

```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2726) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.317 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
      = ( 0.2726) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.345 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3453 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    10.7918  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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 mm

Input, Nozzle Desc: N5   From: 20

Pressure for Reinforcement Calculations	P	1.7500	N/mm^2
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	1480.00	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		1.52	m

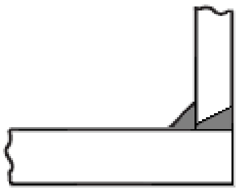
Type of Element Connected to the Shell : Nozzle

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		34.9250	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	4.1275	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	50.8000	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   34.925 mm.


```
 Actual Thickness Used in Calculation                    4.128  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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*26.67)/(2*164996.23-1.75)
  = 0.1422 + 0.0000 = 0.1422 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1470.000 mm

Mean noz dia / Mean Shl Dia d/D: 30.797 / 1491.500 = 0.0206

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 30.8/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1934
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.1 (Curve1), 0.193 (Computed rho), 0.2 (Curve2)

Values of erb/ers for values of rho: 0.0, 0.1, 0.09, 0.22

The final interpolated value of erb/ers was 0.0992 from Figure 3.5-11

Compute the Required Neck thickness [erb]

```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.0992) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  =  0.843 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
      = ( 0.0992) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 0.853 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 0.8533 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                      65.7225  mm
 Effective material Thickness limit              Lb      5.1264  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls     15.3987  mm
 Thickness Limit for Nozzle Group Calculation   Tlc     11.2746  mm
```

The Drop for this Nozzle is : 0.2060 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 61.0061 mm

Input, Nozzle Desc: N7 From: 20

Pressure for Reinforcement Calculations	P	1.7500	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	1480.00	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		1.65	m

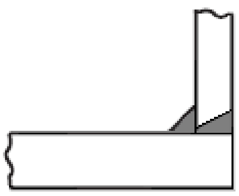
Type of Element Connected to the Shell : Nozzle

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		90.00	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: N7

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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*42.164)/(2*164996.23-1.75)
  = 0.2248 + 0.0000 = 0.2248 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1600.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2726 from Figure 3.5-11

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2726) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.317 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
      = ( 0.2726) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.345 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3453 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    10.7918  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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 mm

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Nozzle Calcs.: N9 Nozl: 14 9:36am May 19,2021

Input, Nozzle Desc: N9 From: 20

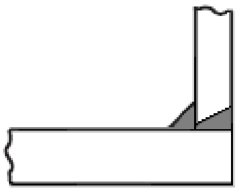
Pressure for Reinforcement Calculations	P	1.7500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		BS1501-151,430A	
Shell Allowable Stress at Temperature	f	166996.17	kPa
Shell Allowable Stress At Ambient	fa	166996.17	kPa
Inside Diameter of Cylindrical Shell	Di	1480.00	mm
Shell Finished (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		1.45	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		80.00	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: N9

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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*42.164)/(2*164996.23-1.75)
  = 0.2248 + 0.0000 = 0.2248 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1400.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2726 from Figure 3.5-11

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2726) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.317 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
      = ( 0.2726) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.345 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3453 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     10.7918  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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 mm

PV Elite 2019   Licensee: XGM
FileName : 9m3 LPG Tank   ---------------------------------
Nozzle Calcs.: N3   Nozl: 15   9:36am May 19,2021

Input, Nozzle Desc: N3   From: 20

Pressure for Reinforcement Calculations	P	1.7500	N/mm^2
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	1480.00	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		1.75	m

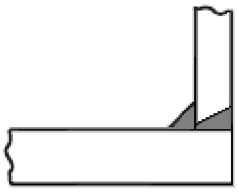
Type of Element Connected to the Shell : Nozzle

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		100.00	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: N3

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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*42.164)/(2*164996.23-1.75)
  = 0.2248 + 0.0000 = 0.2248 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1700.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2726 from Figure 3.5-11

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2726) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.317 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
      = ( 0.2726) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.345 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3453 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	10.7918	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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 mm

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Nozzle Calcs.: N10 Nozl: 16 9:36am May 19,2021

Input, Nozzle Desc: N10 From: 20

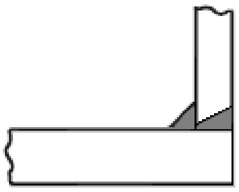
```
Pressure for Reinforcement Calculations        P      1.7500  N/mm²
Temperature for Internal Pressure           Temp          50  °C

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      1480.00  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                       1.45  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                                          100.00  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: N10

```
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]
  = 1.75 * 1483.0/( 2 * 0.2E+06 - 1.75 ) + 1.5 + 0.0
  = 9.3111 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.75*42.164)/(2*164996.23-1.75)
  = 0.2248 + 0.0000 = 0.2248 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 1400.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.81, 1 )
  = Min( 1.0882, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2726 from Figure 3.5-11

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2726) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.317 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
      = ( 0.2726) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.345 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3453 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     10.7918  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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 mm

```
PV Elite 2019      Licensee: XGM
FileName : 9m3 LPG Tank    ---------------------------------
Nozzle Calcs.: N6                   Nozl:   17   9:36am  May 19,2021
```

Input, Nozzle Desc: N6 From: 20

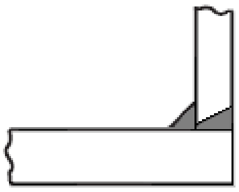
```
Pressure for Reinforcement Calculations        P      1.7569  N/mm²
Temperature for Internal Pressure           Temp          50  °C

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     1480.00  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                       0.28  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                                             34.9250   mm

Size and Thickness Basis                              Actual
Actual Thickness                              tn      4.1275  mm

Corrosion Allowance                          can      0.0000  mm
Loading Factor applied to ers/eps              C        1.00

Outside Projection                            ho     50.8000  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: N6

```
Actual Outside Diameter Used in Calculation             34.925  mm.
```

```
 Actual Thickness Used in Calculation                    4.128  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]
  = 1.7569 * 1483.0/( 2 * 0.2E+06 - 1.7569 ) + 1.5 + 0.0
  = 9.3419 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.76*26.67)/(2*164996.23-1.76)
  = 0.1427 + 0.0000 = 0.1427 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 228.000 mm

Mean noz dia / Mean Shl Dia d/D: 30.797 / 1491.500 = 0.0206

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 30.8/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.1934
```

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 )/7.84, 1 )
  = Min( 1.0839, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.1 (Curve1), 0.193 (Computed rho), 0.2 (Curve2)

Values of erb/ers for values of rho: 0.0, 0.1, 0.09, 0.22

The final interpolated value of erb/ers was 0.1047 from Figure 3.5-11

Compute the Required Neck thickness [erb]

```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.1047) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  =  0.89 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
      = ( 0.1047) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 0.9 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 0.9004 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                     65.7225  mm
 Effective material Thickness limit              Lb     5.2659  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls    15.3987  mm
 Thickness Limit for Nozzle Group Calculation   Tlc    11.2746  mm
```

The Drop for this Nozzle is : 0.2060 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 61.0061 mm

PV Elite 2019   Licensee: XGM
FileName : 9m3 LPG Tank   ----------------------------------
Nozzle Calcs.: N4   Nozl: 18   9:36am May 19,2021

Input, Nozzle Desc: N4   From: 20

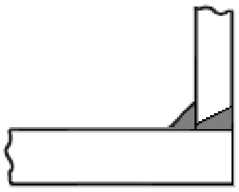
```
Pressure for Reinforcement Calculations       P       1.7569  N/mm²
Temperature for Internal Pressure          Temp          50   °C

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      1480.00  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                       0.49  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: N4

```
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]
  = 1.7569 * 1483.0/( 2 * 0.2E+06 - 1.7569 ) + 1.5 + 0.0
  = 9.3419 mm
```

Nozzle required thickness due to Internal Pressure (epb)
```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.76*42.164)/(2*164996.23-1.76)
  = 0.2257 + 0.0000 = 0.2257 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 438.000 mm

Mean noz dia / Mean Shl Dia d/D: 49.657 / 1491.500 = 0.0333

Compute the value of Rho (use eas in place of ers) [rho]:
```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.66/1491.5 * (1491.5/( 2*( 10.0 - 1.5 + 0.0 )))½
  =  0.3118
```

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 )/7.84, 1 )
  = Min( 1.0839, 3.1 )
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.3 (Curve1), 0.312 (Computed rho), 0.4 (Curve2)

Values of erb/ers for values of rho: 0.25, 0.34, 0.35, 0.45

The final interpolated value of erb/ers was 0.2765 from Figure 3.5-11

Compute the Required Neck thickness [erb]
```
  = (erb/eas) * ( eas - Cas + tp ) + Can
  = ( 0.2765) * ( 10.0 - 1.5 + 0.0 ) + 0.0
  = 2.35 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
      = ( 0.2765) * ( 10.0 - 1.5 ) * ( 166996.2/164996.2 ) + 0.0
      = 2.379 mm
```

Required Nozzle thickness based on Figure 3.5-11 : 2.3789 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	10.8686	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 : 0.5519 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.2269 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
N5	34 mm	Actual	None	34.9	4.1	...	...	61	...
N6	34 mm	Actual	None	34.9	4.1	...	...	61	...
N2	57 mm	Actual	None	57.1	7.5	...	...	77	...
N7	57 mm	Actual	None	57.1	7.5	...	...	77	...
N9	57 mm	Actual	None	57.1	7.5	...	...	77	...
N3	57 mm	Actual	None	57.1	7.5	...	...	77	...
N10	57 mm	Actual	None	57.1	7.5	...	...	77	...
N4	57 mm	Actual	None	57.1	7.5	...	...	77	...
N1	457 mm	Actual	SlipOn	457.2	9.7	634.00	10.00	146	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
N5	A-105	4.128	10.000	...	...	...
N6	A-105	4.128	10.000	...	...	...
N2	A-105	7.493	10.000	...	...	...
N7	A-105	4.128	10.000	...	...	...
N9	A-105	4.128	10.000	...	...	...
N3	A-105	4.128	10.000	...	...	...
N10	A-105	4.128	10.000	...	...	...
N4	A-105	4.128	10.000	...	...	...
N1	A-106 B	5.556	10.000	10.000	10.000	...

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
N5	1.470	90.0	50.80	0.00	Node: 20
N6	0.228	270.0	50.80	0.00	Node: 20
N2	1.220	90.0	66.68	0.00	Node: 20
N7	1.600	90.0	66.68	0.00	Node: 20
N9	1.400	80.0	66.68	0.00	Node: 20
N3	1.700	100.0	66.68	0.00	Node: 20
N10	1.400	100.0	66.68	0.00	Node: 20
N4	0.438	270.0	66.68	0.00	Node: 20
N1	0.492	90.0	100.00	0.00	Node: 20

PV Elite 2019 Licensee: XGM
FileName : 9m3 LPG Tank ---------------------------------
Vessel Design Summary: Step: 25 9:36am May 19,2021

British Standard PD 5500:2018+A1:2018

Diameter Spec : 1500.000 mm OD		
Vessel Design Length, Tangent to Tangent	4.90	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	1.750	N/mm²
External Design Temperature	35	°C
Maximum Allowable Working Pressure	1.897	N/mm²
Hydrostatic Test Pressure	2.500	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	1.750	0.00	2.274	1.5000	No	...
Cylinder	1.757	0.00	1.897	1.5000	N/A	...
Ellipse	1.750	0.00	2.274	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	9.9	...	0.85	0.85
Cylinder	4.8	4.8	10.0	10.0	9.3	...	0.85	0.85
Ellipse	4.9	0.1	11.5	12.0	9.9	...	0.85	0.85

Saddle Parameters:

Saddle Width	100.000	mm
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	900.000	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

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Baseplate Sketch

```
|------------------- 1000.000 mm --------------------|
----------------------------------------------------- ---
|                                                    |
|                                                    | 100.000 mm
|                                                    |
----------------------------------------------------- ---
```

Baseplate Plan View

```
----------------------------------------------------- ---
|                                                    | 10.000 mm
----------------------------------------------------- ---
```

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	63851.05	N
Maximum Transverse Saddle Shear Load	919.52	N
Maximum Longitudinal Saddle Shear Load	573.12	N

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	Pass Fail
Lift Lug	WRC-107/537	0.510	Passed
Lift Lug	WRC-107/537	0.374	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	2841.7	kgm
Shop Test	- Fabricated + Water (Full)	12111.0	kgm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	2841.7	kgm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	2841.7	kgm
Empty	- Fab. + Intls. + Details + Wghts.	2841.7	kgm
Operating	- Empty + Operating Liquid (No CA)	6884.0	kgm
Field Test	- Empty Weight + Water (Full)	12111.0	kgm