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	<b>DEHDASHT PETROCHEMICAL INDUSTRY COMPANY</b>  <b>DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT</b>	
	DOCUMENT TITLE: Mechanical Calculation for Liquid Receiver	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT No:DPIC9812-000-VD-1002-ME-CLN-0094	Rev. No.: D1

## Mechanical Calculation for Liquid Receiver

**(D-PK6101-2)**

There are some minor discrepancy which has been indicated in DWG and DSH, please check compatibility

<b>PURCHASER'S COMMENT/APPROVAL STATUS</b>					Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)				Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
<del>X</del>	AN: Approved With Minor Comments (Fabrication may Proceed)				
3	NF: Approved With Comments (Fabrication not Proceed)				Item No. (Tag No.):(D-PK6101-2)
4	RJ: Rejected				
5	NR: Not be Returned				
Date: 07.03.2022					Vendor Doc. No.:DPIC9812-000-VD-1002-ME-CLN-0094
Signature: A.AB					
					
D1	18.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
<b>REV</b>	<b>DATE ISSUE</b>	<b>PREPARED</b>	<b>CHECKED</b>	<b>APPROVED</b>	



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58	x	x			
59	x	x			
60	x	x			
61	x	x			
62	x	x			
63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			



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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:Liquid Receiver (D-PK6101-2)

## **DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Feb 18,2022 9:17pm

PV Elite 2018 SP2, June 2018

**Note:**

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

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Tag no:Liquid Receiver (D-PK6101-2)  
PV Elite 2018 SP2 Licensee: SPLM Licensed User  
FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
Warnings and Errors: Step: 0 9:17pm Feb 18,2022

Class From To : Basic Element Checks.  
=====

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

There were no geometry errors or warnings.

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 Tag no:Liquid Receiver (D-PK6101-2)  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Input Echo: Step: 1 9:17pm Feb 18,2022

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

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 Tag no:Liquid Receiver (D-PK6101-2)

Design Internal Pressure (for Hydrotest) 23 bar  
 Design Internal Temperature 135.0 °C  
 Type of Hydrotest UG-99(b) Note [36]  
 Hydrotest Position Horizontal  
 Projection of Nozzle from Vessel Top 0 mm.  
 Projection of Nozzle from Vessel Bottom 0 mm.  
 Minimum Design Metal Temperature -45.0 °C  
 Type of Construction Welded  
 Special Service None  
 Degree of Radiography RT-1  
 Use Higher Longitudinal Stresses (Flag) Y  
 Select t for Internal Pressure (Flag) N  
 Select t for External Pressure (Flag) N  
 Select t for Axial Stress (Flag) N  
 Select Location for Stiff. Rings (Flag) N  
 Consider Vortex Shedding N  
 Perform a Corroded Hydrotest Y  
 Is this a Heat Exchanger No  
 User Defined Hydro. Press. (Used if > 0) 0 bar  
 User defined MAWP 0 bar  
 User defined MAPnc 0 bar

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 ASCE-7 2010  
 Wind Load Reduction Scale Factor 0.600  
 Basic Wind Speed [V] 200 Km/hr  
 Surface Roughness Category C: Open Terrain  
 Importance Factor 1.0  
 Type of Surface Moderately Smooth  
 Base Elevation 300 mm.  
 Percent Wind for Hydrotest 33.0  
 Using User defined Wind Press. Vs Elev. N  
 Height of Hill or Escarpment H or Hh 0 mm.  
 Distance Upwind of Crest Lh 0 mm.  
 Distance from Crest to the Vessel x 0 mm.  
 Type of Terrain ( Hill, Escarpment ) Flat  
 Damping Factor (Beta) for Wind (Ope) 0.0100

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Input Echo: Step: 1 9:17pm Feb 18,2022

Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000
Seismic Design Code	ASCE 7-2010
Seismic Load Reduction Scale Factor	0.700
Importance Factor	1.500
Table Value Fa	1.000
Table Value Fv	1.300
Short Period Acceleration value Ss	0.900
Long Period Acceleration Value Sl	0.537
Moment Reduction Factor Tau	1.000
Force Modification Factor R	2.500
Site Class	C
Component Elevation Ratio	z/h 1.000
Amplification Factor	Ap 2.500
Force Factor	0.000
Consider Vertical Acceleration	Yes
Minimum Acceleration Multiplier	0.000
User Value of Sds (used if > 0 )	0.624
Design Pressure + Static Head	Y
Consider MAP New and Cold in Noz. Design	N
Consider External Loads for Nozzle Des.	Y
Use ASME VIII-1 Appendix 1-9	N
Material Database Year	Current w/Addenda or Code Year

#### Configuration Directives:

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

#### Complete Listing of Vessel Elements and Details:

Element From Node	10
Element To Node	20
Element Type	Elliptical
Description	head 001
Distance "FROM" to "TO"	50 mm.
Element Outside Diameter	914 mm.
Element Thickness	12 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	15 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bar
Design Temperature Internal Pressure	135 °C
Design External Pressure	1.1 bar
Design Temperature External Pressure	100 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Allowable Stress, Ambient	137.9 N./mm <sup>2</sup>
Allowable Stress, Operating	137.9 N./mm <sup>2</sup>
Allowable Stress, Hydrotest	235.81 N./mm <sup>2</sup>

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Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Input Echo: Step: 1 9:17pm Feb 18,2022

Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	30.988	mm.
Yield Stress, Operating	233.74	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	890	mm.
Liquid Density	460.79	kg/m <sup>3</sup>

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-228.5	mm.
Height/Length of Insulation	278.5	mm.
Thickness of Insulation	100	mm.
Density	0.00023	kg./cm <sup>3</sup>

Element From Node	10	
Detail Type	Nozzle	
Detail ID	M	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	20	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle ( Used if > 0 )	4.6436	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	[Normalized]

-----

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	shell 001	
Distance "FROM" to "TO"	3900	mm.
Element Outside Diameter	914	mm.
Element Thickness	12	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bar
Design Temperature Internal Pressure	135	°C
Design External Pressure	1.1	bar
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	20	
-------------------	----	--

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Input Echo: Step: 1 9:17pm Feb 18,2022

Detail Type	Saddle
Detail ID	Fixed Saddle
Dist. from "FROM" Node / Offset dist	630 mm.
Width of Saddle	172 mm.
Height of Saddle at Bottom	840 mm.
Saddle Contact Angle	120.0
Height of Composite Ring Stiffener	0 mm.
Width of Wear Plate	200 mm.
Thickness of Wear Plate	10 mm.
Contact Angle, Wear Plate (degrees)	140.0
Element From Node	20
Detail Type	Saddle
Detail ID	Sliding Saddle
Dist. from "FROM" Node / Offset dist	3270 mm.
Width of Saddle	172 mm.
Height of Saddle at Bottom	840 mm.
Saddle Contact Angle	120.0
Height of Composite Ring Stiffener	0 mm.
Width of Wear Plate	200 mm.
Thickness of Wear Plate	10 mm.
Contact Angle, Wear Plate (degrees)	140.0
Element From Node	20
Detail Type	Liquid
Detail ID	Liquid: 20
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	890 mm.
Liquid Density	460.79 kg/m <sup>3</sup>
Element From Node	20
Detail Type	Insulation
Detail ID	Ins: 20
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	3900 mm.
Thickness of Insulation	100 mm.
Density	0.00023 kg./cm <sup>3</sup>
Element From Node	20
Detail Type	Nozzle
Detail ID	A1
Dist. from "FROM" Node / Offset dist	450 mm.
Nozzle Diameter	8 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	0.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	1.1507 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	20
Detail Type	Nozzle
Detail ID	B
Dist. from "FROM" Node / Offset dist	1950 mm.
Nozzle Diameter	8 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	180.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.7092 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

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Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Input Echo: Step: 1 9:17pm Feb 18,2022

Element From Node 20  
 Detail Type Nozzle  
 Detail ID A2  
 Dist. from "FROM" Node / Offset dist 3250 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 0.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.09943 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID PT  
 Dist. from "FROM" Node / Offset dist 1700 mm.  
 Nozzle Diameter 1.5 in.  
 Nozzle Schedule XXS  
 Nozzle Class 300  
 Layout Angle 0.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.07753 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID A3  
 Dist. from "FROM" Node / Offset dist 1150 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 0.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.12 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID LT1  
 Dist. from "FROM" Node / Offset dist 3650 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 180.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1585 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID LT2  
 Dist. from "FROM" Node / Offset dist 3600 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 0.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1585 kN

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 Tag no:Liquid Receiver (D-PK6101-2)  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Input Echo: Step: 1 9:17pm Feb 18,2022

Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	20
Detail Type	Nozzle
Detail ID	D
Dist. from "FROM" Node / Offset dist	250 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	180.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1488 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

Element From Node	20
Detail Type	Nozzle
Detail ID	SV
Dist. from "FROM" Node / Offset dist	2250 mm.
Nozzle Diameter	4 in.
Nozzle Schedule	120
Nozzle Class	300
Layout Angle	0.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.413 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

-----

Element From Node	30
Element To Node	40
Element Type	Elliptical
Description	head 002
Distance "FROM" to "TO"	50 mm.
Element Outside Diameter	914 mm.
Element Thickness	12 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	15 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bar
Design Temperature Internal Pressure	135 °C
Design External Pressure	1.1 bar
Design Temperature External Pressure	100 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Elliptical Head Factor	2.0
Weld is pre-Heated	No

Element From Node	30
Detail Type	Liquid
Detail ID	Liquid: 30
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	890 mm.
Liquid Density	460.79 kg/m <sup>3</sup>

Element From Node	30
Detail Type	Insulation
Detail ID	Ins: 20
Dist. from "FROM" Node / Offset dist	0 mm.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Input Echo: Step: 1 9:17pm Feb 18,2022

Height/Length of Insulation	278.5	mm.
Thickness of Insulation	100	mm.
Density	0.00023	kg./cm <sup>3</sup>
Element From Node	30	
Detail Type	Nozzle	
Detail ID	TI	
Dist. from "FROM" Node / Offset dist	300	mm.
Nozzle Diameter	1.5	in.
Nozzle Schedule	XXS	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.0557	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

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 XY Coordinate Calculations: Step: 2 9:17pm Feb 18,2022

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
head 001		50	...	50	...
shell 001		3950	...	3900	...
head 002		4000	...	50	...

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#### Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bar	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress (SE) N./mm <sup>2</sup>
head 001		23.04	15	3	914	137.9
shell 001		23.04	12	3	914	137.9
head 002		23.04	15	3	914	137.9

#### Element Required Thickness and MAWP :

From	To	Design Pressure bar	M.A.W.P. Corroded bar	M.A.P. New & Cold bar	Minimum Thickness mm.	Required Thickness mm.
head 001		23	27.8493	37.0811	12	10.4581
shell 001		23	27.3289	36.5891	12	10.586
head 002		23	27.8493	37.0811	12	10.4581
Minimum			27.329	36.589		

MAWP: 23.089 bar, limited by: Nozzle Reinforcement.

#### Internal Pressure Calculation Results :

##### ASME Code, Section VIII Division 1, 2017

##### Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 135 °C

head 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P \cdot D_o \cdot K_{cor}) / (2 \cdot S \cdot E + 2 \cdot P \cdot (K_{cor} - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (23.04 \cdot 914 \cdot 0.991) / (2 \cdot 137.9 \cdot 1 + 2 \cdot 23.04 \cdot (0.991 - 0.1)) \\
 &= 7.4581 + 3.0000 = 10.4581 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.040 bar

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D_o - 2 \cdot t \cdot (K_{cor} - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 9) / (0.991 \cdot 914 - 2 \cdot 9 \cdot (0.991 - 0.1)) \\
 &= 27.890 - 0.040 = 27.849 \text{ bar}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 12) / (1 \cdot 914 - 2 \cdot 12 \cdot (1 - 0.1)) \\
 &= 37.081 \text{ bar}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (K_{cor} \cdot D_o - 2 \cdot t \cdot (K_{cor} - 0.1))) / (2 \cdot E \cdot t) \\
 &= (23.04 \cdot (0.991 \cdot 914 - 2 \cdot 9 \cdot (0.991 - 0.1))) / (2 \cdot 1 \cdot 9) \\
 &= 113.923 \text{ N./mm}^2
 \end{aligned}$$

Straight Flange Required Thickness:

$$\begin{aligned}
 &= (P \cdot R_o) / (S \cdot E + 0.4 \cdot P) + c_a \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.04 \cdot 457) / (137.9 \cdot 1 + 0.4 \cdot 23.04) + 3 \\
 &= 10.586 \text{ mm.}
 \end{aligned}$$

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Straight Flange Maximum Allowable Working Pressure:

**Less Operating Hydrostatic Head Pressure of 0.040 bar**

$$= (S \cdot E \cdot t) / (R_o - 0.4 \cdot t) \text{ per Appendix 1-1 (a) (1)}$$

$$= (137.9 \cdot 1 \cdot 12) / (457 - 0.4 \cdot 12)$$

$$= 36.589 - 0.040 = 36.549 \text{ bar}$$

Factor K, corroded condition [Kcor]:

$$= (2 + (\text{Inside Diameter} / (2 \cdot \text{Inside Head Depth}))^2) / 6$$

$$= (2 + (896 / (2 \cdot 225.5))^2) / 6$$

$$= 0.991160$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  7.130 %

**Note: Please Check Requirements of UCS-79 as Elongation is > 5%.**

#### MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 12, tr = 7.486, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr \cdot (E^*) / (tg - c) = 0.832$ , Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

#### MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 15, tr = 7.615, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr \cdot (E^*) / (tg - c) = 0.635$ , Temp. Reduction = 20 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C

Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

#### **Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 135 °C**

shell 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot R_o) / (S \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (23.04 \cdot 457) / (137.9 \cdot 1 + 0.4 \cdot 23.04)$$

$$= 7.5860 + 3.0000 = 10.5860 \text{ mm.}$$

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

**Less Operating Hydrostatic Head Pressure of 0.040 bar**

$$= (S \cdot E \cdot t) / (R_o - 0.4 \cdot t) \text{ per Appendix 1-1 (a) (1)}$$

$$= (137.9 \cdot 1 \cdot 9) / (457 - 0.4 \cdot 9)$$

$$= 27.369 - 0.040 = 27.329 \text{ bar}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S \cdot E \cdot t) / (R_o - 0.4 \cdot t) \text{ per Appendix 1-1 (a) (1)}$$

$$= (137.9 \cdot 1 \cdot 12) / (457 - 0.4 \cdot 12)$$

$$= 36.589 \text{ bar}$$

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

$$= (P \cdot (R_o - 0.4 \cdot t)) / (E \cdot t)$$

$$= (23.04 \cdot ((457 - 0.4 \cdot 9)) / (1 \cdot 9))$$

$$= 116.089 \text{ N./mm}^2$$

% Elongation per Table UG-79-1  $(50 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  1.330 %

#### Minimum Design Metal Temperature Results:

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Govrn. thk, tg = 12, tr = 7.615, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.846, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

### **Elliptical Head From 30 To 40 SA-516 70 , UCS-66 Crv. D at 135 °C**

head 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P \cdot Do \cdot K_{cor}) / (2 \cdot S \cdot E \cdot t + 2 \cdot P \cdot (K_{cor} - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (23.04 \cdot 914 \cdot 0.991) / (2 \cdot 137.9 \cdot 1 + 2 \cdot 23.04 \cdot (0.991 - 0.1)) \\
 &= 7.4581 + 3.0000 = 10.4581 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.040 bar

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K \cdot Do - 2 \cdot t \cdot (K - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 9) / (0.991 \cdot 914 - 2 \cdot 9 \cdot (0.991 - 0.1)) \\
 &= 27.890 - 0.040 = 27.849 \text{ bar}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K \cdot Do - 2 \cdot t \cdot (K - 0.1)) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 12) / (1 \cdot 914 - 2 \cdot 12 \cdot (1 - 0.1)) \\
 &= 37.081 \text{ bar}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (K_{cor} \cdot Do - 2 \cdot t \cdot (K_{cor} - 0.1))) / (2 \cdot E \cdot t) \\
 &= (23.04 \cdot (0.991 \cdot 914 - 2 \cdot 9 \cdot (0.991 - 0.1))) / (2 \cdot 1 \cdot 9) \\
 &= 113.923 \text{ N./mm}^2
 \end{aligned}$$

Straight Flange Required Thickness:

$$\begin{aligned}
 &= (P \cdot Ro) / (S \cdot E + 0.4 \cdot P) + ca \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.04 \cdot 457) / (137.9 \cdot 1 + 0.4 \cdot 23.04) + 3 \\
 &= 10.586 \text{ mm.}
 \end{aligned}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.040 bar

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (Ro - 0.4 \cdot t) \text{ per Appendix 1-1 (a) (1)} \\
 &= (137.9 \cdot 1 \cdot 12) / (457 - 0.4 \cdot 12) \\
 &= 36.589 - 0.040 = 36.549 \text{ bar}
 \end{aligned}$$

Factor K, corroded condition [Kcor]:

$$\begin{aligned}
 &= (2 + (\text{Inside Diameter} / (2 \cdot \text{Inside Head Depth}))^2) / 6 \\
 &= (2 + (896 / (2 \cdot 225.5))^2) / 6 \\
 &= 0.991160
 \end{aligned}$$

Percent Elong. per UCS-79, VIII-1-01-57 (75 \* tnom / Rf) \* (1 - Rf / Ro) 7.130 %

Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

**MDMT Calculations in the Knuckle Portion:**

Govrn. thk, tg = 12, tr = 7.486, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.832, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

**MDMT Calculations in the Head Straight Flange:**

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Govrn. thk, tg = 15, tr = 7.615, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.635$ , Temp. Reduction = 20 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

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

### **Hydrostatic Test Pressure Results:**

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.015 bar
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bar
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	47.476 bar
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.398 bar
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.775 bar
Pressure per App 27-4	= 1.30 * M.A.W.P. * Sa/S	30.015 bar

UG-99(b) Note 36, Test Pressure Calculation:

= Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 23 \* 1  
 = 29.900 bar

### **Horizontal Test performed per: UG-99b (Note 36)**

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

### **Stresses on Elements due to Test Pressure (N./mm<sup>2</sup> & bar):**

From To	Stress	Allowable	Ratio	Pressure
head 001	148.3	235.8	0.629	29.99
shell 001	151.1	235.8	0.641	29.99
head 002	148.3	235.8	0.629	29.99

### **Stress ratios for Nozzle and Pad Materials (N./mm<sup>2</sup>):**

Description	Pad/Nozzle	Ambient	Operating	Ratio
M	Nozzle	137.90	137.90	1.000
M	Pad	137.90	137.90	1.000
A1	Nozzle	117.90	117.90	1.000
A1	Pad	137.90	137.90	1.000
B	Nozzle	117.90	117.90	1.000
B	Pad	137.90	137.90	1.000
A2	Nozzle	117.90	117.90	1.000
A2	Pad	137.90	137.90	1.000
PT	Nozzle	117.90	117.90	1.000
A3	Nozzle	117.90	117.90	1.000
A3	Pad	137.90	137.90	1.000
LT1	Nozzle	117.90	117.90	1.000
LT1	Pad	137.90	137.90	1.000
LT2	Nozzle	117.90	117.90	1.000
LT2	Pad	137.90	137.90	1.000
D	Nozzle	117.90	117.90	1.000
D	Pad	137.90	137.90	1.000
SV	Nozzle	117.90	117.90	1.000
SV	Pad	137.90	137.90	1.000
TI	Nozzle	117.90	117.90	1.000

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-----  
 Minimum 1.000

**Stress ratios for Pressurized Vessel Elements (N./mm<sup>2</sup>):**

Description	Ambient	Operating	Ratio
head 001	137.90	137.90	1.000
shell 001	137.90	137.90	1.000
head 002	137.90	137.90	1.000
Minimum			1.000

**Hoop Stress in Nozzle Wall during Pressure Test (N./mm<sup>2</sup>):**

Description	Ambient	Operating	Ratio
M	62.29	235.80	0.264
A1	39.30	217.19	0.181
B	39.30	217.19	0.181
A2	18.28	217.19	0.084
PT	11.09	217.19	0.051
A3	18.28	217.19	0.084
LT1	18.28	217.19	0.084
LT2	18.28	217.19	0.084
D	18.28	217.19	0.084
SV	24.25	217.19	0.112
TI	11.09	217.19	0.051

Elements Suitable for Internal Pressure.

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**External Pressure Calculation Results :**

**External Pressure Calculations:**

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm <sup>2</sup>
10	20	No Calc	914	9	0.0013676	94.3429
20	30	4148.33	914	9	0.00026007	26.0008
30	40	No Calc	914	9	0.0013676	94.3429

**External Pressure Calculations:**

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bar	External M.A.W.P. bar
10	20	12	5.44078	1.1	10.3205
20	30	12	8.66323	1.1	3.41318
30	40	12	5.44078	1.1	10.3205
Minimum					3.413

**External Pressure Calculations:**

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	4148.33	86665.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

**ASME Code, Section VIII Division 1, 2017**

**Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 100 °C**

head 001

Elastic Modulus from Chart: CS-2 at 100 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
9.000	914.00	101.56	0.0013676	94.34

EMAP = B/(K0\*D/t) = 94.34/(0.9 \*101.6 ) = 10.32 bar

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
2.441	914.00	374.47	0.0003709	37.08

EMAP = B/(K0\*D/t) = 37.08/(0.9 \*374.5 ) = 1.1 bar

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P) \text{ Appendix 1-4 (c)}$$

$$= (1.837 \cdot 896 \cdot 0.991) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 1.837)$$

$$= 0.5917 + 3.0000 = 3.5917 \text{ mm.}$$

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

$$= ((2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D + 0.2 \cdot t)) / 1.67 \text{ per Appendix 1-4 (c)}$$

$$= ((2 \cdot 137.9 \cdot 1 \cdot 9) / (0.991 \cdot 896 + 0.2 \cdot 9)) / 1.67$$

$$= 16.700 \text{ bar}$$

Maximum Allowable External Pressure [MAEP]:

$$= \min(\text{MAEP}, \text{MAWP})$$

$$= \min(10.32, 16.7)$$

$$= 10.320 \text{ bar}$$

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

**Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 100 °C**

shell 001

Elastic Modulus from Chart: CS-2 at 100 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
9.000	914.00	4148.33	101.56	4.5387	0.0002601	26.00

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 26) / (3 \cdot 101.6) = 3.413 \text{ bar}$$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.663	914.00	4148.33	161.39	4.5387	0.0001332	13.32

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 13.32) / (3 \cdot 161.4) = 1.1 \text{ bar}$$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
9.000	914.00	86665.13	101.56	50.0000	0.0001071	10.71

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 10.71) / (3 \cdot 101.6) = 1.406 \text{ bar}$$

**Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 100 °C**

head 002

Elastic Modulus from Chart: CS-2 at 100 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
9.000	914.00	101.56	0.0013676	94.34

$$\text{EMAP} = B / (K_0 \cdot D/t) = 94.34 / (0.9 \cdot 101.6) = 10.32 \text{ bar}$$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
2.441	914.00	374.47	0.0003709	37.08

$$\text{EMAP} = B / (K_0 \cdot D/t) = 37.08 / (0.9 \cdot 374.5) = 1.1 \text{ bar}$$

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

Material UNS Number: K02700

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Required Thickness due to Internal Pressure [tr]:  
=  $(P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P)$  Appendix 1-4 (c)  
=  $(1.837 \cdot 896 \cdot 0.991) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 1.837)$   
=  $0.5917 + 3.0000 = 3.5917$  mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:  
=  $((2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D + 0.2 \cdot t)) / 1.67$  per Appendix 1-4 (c)  
=  $((2 \cdot 137.9 \cdot 1 \cdot 9) / (0.991 \cdot 896 + 0.2 \cdot 9)) / 1.67$   
= 16.700 bar

Maximum Allowable External Pressure [MAEP]:  
= min( MAEP, MAWP )  
= min( 10.32, 16.7 )  
= 10.320 bar

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

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**Element and Detail Weights:**

From	To	Element Metal Wgt. kg.	Element ID Volume m³	Corroded Metal Wgt. kg.	Corroded ID Volume m³	Extra due Misc % kg.
10	20	130.489	0.12047	104.391	0.12272	13.0489
20	30	1027.86	2.36894	773.455	2.40098	102.786
30	40	130.489	0.12047	104.391	0.12272	13.0489
Total		1288	2.61	982	2.65	128

**Weight of Details:**

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	56.8564	-74.1667	...	Liquid: 10
10	Insl	36.3186	-89.25	...	Ins: 20
10	Nozl	520.903	-222.5	...	M
20	Sadl	109.343	630	631.5	Fixed Saddle
20	Sadl	109.343	3270	631.5	Sliding Saddle
20	Liqd	1118.02	1950	...	Liquid: 20
20	Insl	286.081	1950	...	Ins: 20
20	Nozl	129.078	450	554.537	A1
20	Nozl	79.5605	1950	554.537	B
20	Nozl	11.1539	3250	475.163	A2
20	Nozl	8.69744	1700	469.13	PT
20	Nozl	13.4637	1150	475.163	A3
20	Nozl	17.7786	3650	475.163	LT1
20	Nozl	17.7786	3600	475.163	LT2
20	Nozl	16.6915	250	475.163	D
20	Nozl	46.3273	2250	502.15	SV
30	Liqd	56.8564	124.167	...	Liquid: 30
30	Insl	36.3186	139.25	...	Ins: 20
30	Nozl	6.24799	214.336	...	TI

**Total Weight of Each Detail Type**

Total Weight of Saddles	218.7
Total Weight of Liquid	1231.7
Total Weight of Insulation	358.7
Total Weight of Nozzles	867.7
-----	
Sum of the Detail Weights	2676.8 kg.

**Weight Summation: kg.**

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
1417.7	2504.1	1417.7	2504.1	1417.7	2862.8
218.7	2671.9	218.7	...	218.7	1231.7
867.7	...	867.7	...	...	...
...	...	...	358.7	...	...
...	...	...	...	358.7	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	867.7	...
2504.1	5175.9	2504.1	2862.8	2862.8	4094.5

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 Element and Detail Weights: Step: 5 9:17pm Feb 18,2022

**Miscellaneous Weight Percent: 10.0 %**

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

**Weight Summary**

Fabricated Wt.	- Bare Weight W/O Removable Internals	2504.1 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	5175.9 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	2504.1 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	2862.8 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	2862.8 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	4094.5 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	3757.3 kg.
Field Test Wt.	- Empty Weight + Water (Full)	5234.8 kg.

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

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

**Outside Surface Areas of Elements:**

From	To	Surface Area cm <sup>2</sup>
10	20	10620
20	30	111985
30	40	10620
Total		133225.188 cm <sup>2</sup>

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 Nozzle Flange MAWP: Step: 6 9:17pm Feb 18,2022

**Nozzle Flange MAWP Results:**

Nozzle Description	Flange Rating		Design Temp °C	Class	Grade/Group	Equiv. Press	Max Pressure		
	Ope. bar	Ambient bar					PVP	50%	DNV bar
M	45.5	51.1	135	300	GR 1.1	...	...	...	...
A1	45.5	51.1	135	300	GR 1.1	...	...	...	...
B	45.5	51.1	135	300	GR 1.1	...	...	...	...
A2	45.5	51.1	135	300	GR 1.1	...	...	...	...
PT	45.5	51.1	135	300	GR 1.1	...	...	...	...
A3	45.5	51.1	135	300	GR 1.1	...	...	...	...
LT1	45.5	51.1	135	300	GR 1.1	...	...	...	...
LT2	45.5	51.1	135	300	GR 1.1	...	...	...	...
D	45.5	51.1	135	300	GR 1.1	...	...	...	...
SV	45.5	51.1	135	300	GR 1.1	...	...	...	...
TI	45.5	51.1	135	300	GR 1.1	...	...	...	...
Min Rating	45.546	51.096 bar [for Core Elements]					0.000	0.000	0.000

**Selected Method for Derating ANSI Flange MAWP: None Selected**

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

The PVP Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the PVP method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used. Note that ANSI pipe nominal sizes up to 24 inch (600mm) are addressed.

**How the 50% Stress Method Works:**

If the computed stress/allowable stress is < 0.5 on the pipe wall, then the allowable pressure is the table rating from the ANSI/ASME standard. If the stress ratio is >= 0.5, then the full equivalent pressure is subtracted from the flange rating.

**The DNV Method:**

minimum( table rating, 1.5 \* Operating rating - equivalent pressure )

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Wind Load Calculation: Step: 7 9:17pm Feb 18,2022

### Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	[V] 200 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	300 mm.
Percent Wind for Hydrottest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.
Distance Upwind of Crest Lh	0 mm.
Distance from Crest to the Vessel x	0 mm.
Type of Terrain ( Hill, Escarpment )	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000

### Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q ) / ( 1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1+1.7*3.4*0.228*0.982) / (1+1.7*3.4*0.228))) \\
 &= \min(0.85, 0.916 ) \\
 &= 0.850
 \end{aligned}$$

Natural Frequency of Vessel (Operating)	33.000 Hz
Natural Frequency of Vessel (Empty)	33.000 Hz
Natural Frequency of Vessel (Test)	33.000 Hz

Force Coefficient	[Cf] 0.549
Structure Height to Diameter ratio	3.956

*This is classified as a rigid structure. Static analysis performed.*

### Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:

Exposure Category: C from Table 26.9.1  
 Alpha = 9.5 : Zg = 274320 mm.

Effective Height [z]:

= Centroid Height + Vessel Base Elevation  
 = 840 + 300 = 1140 mm.  
 = 3.74 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z (3.74 \text{ ft.}) < 15 \text{ ft.} \\
 &= 2.01 * ( 15 / Zg ) ^ { 2 / \text{Alpha}} \\
 &= 2.01 * ( 15/900 ) ^ {2/9.5} \\
 &= 0.849
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

= 0.95 per Table 26.6-1

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As there is No Hill Present: [Kzt]:  
 K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:  
 = ( 1 + K1 \* K2 \* K3 )<sup>2</sup>  
 = ( 1 + 0 \* 0 \* 0 )<sup>2</sup>  
 = 1

Velocity Pressure evaluated at height z, Imperial Units [qz]:  
 = max( 16, 0.00256 \* Kz \* Kzt \* Kd \* V(mph)<sup>2</sup> )  
 = max( 16, 0.00256 \* 0.849 \* 1 \* 0.95 \* 124.3<sup>2</sup> )  
 = 31.89 psf [155.7 ] Kgs/m<sup>2</sup>

Force on the first element [F]:  
 = qz \* G \* Cf \* WindArea  
 = 31.89 \* 0.85 \* 0.549 \* 3.87  
 = 57.61 lbs. [0.256 ] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
head 001	1140.0	0.000	0.000	0.000	0.849	1.000	155.683
shell 001	1140.0	0.000	0.000	0.000	0.849	1.000	155.683
head 002	1140.0	0.000	0.000	0.000	0.849	1.000	155.683

**Wind Load Calculation:**

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm <sup>2</sup>	Wind Pressure Kgs/m <sup>2</sup>	Element Wind Load kN
10	20	1140	1336.8	3595.05	155.683	0.15374
20	30	1140	1336.8	52135.2	155.683	2.22958
30	40	1140	1336.8	3595.05	155.683	0.15374

Note:  
 The Wind Loads calculated and printed in the Wind Load calculation report have been factored by the input scalar/load reduction factor of: 0.600.

*Be sure the wind speed is in accordance with the specified wind design code.*

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Earthquake Load Calculation: Step: 8 9:17pm Feb 18,2022

### Earthquake Load Calculation:

#### Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		0.900
Long Period Acceleration Value S1		0.537
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.500
Site Class		C
Component Elevation Ratio	z/h	1.000
Amplification Factor	Ap	2.500
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.624

#### Seismic Analysis Results:

$$Sms = Fa * Ss = 1 * 0.9 = 0.9$$

$$Sm1 = Fv * S1 = 1.3 * 0.537 = 0.698$$

$$Sds = 2/3 * Sms = 2/3 * 0.9 = 0.6$$

$$Sds = \text{Max}( 0.8*Sds, SdsUser )$$

$$= \text{Max}( 0.48, 0.624 )$$

$$= 0.624$$

$$Sd1 = 2/3 * Sm1 = 2/3 * 0.698 = 0.465$$

$$Sd1 = \text{Max}( 0.8*Sd1, Sd1User )$$

$$= \text{Max}( 0.372, 0.39 )$$

$$= 0.390$$

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

$$= Ct * hn^x \text{ where } Ct = 0.020, x = 0.75 \text{ and } hn = \text{Structural Height (ft.)}$$

$$= 0.020 * ( 4.216^{0.75} )$$

$$= 0.059 \text{ seconds}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

#### Fundamental Period (1/Frequency) [T]:

$$= ( 1/\text{Natural Frequency} ) = ( 1/33 )$$

$$= 0.030$$

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

$$= \text{Minimum Value of } ( 1.4 * 0.0588, 0.0303 ) \text{ per 12.8.2}$$

$$= 0.030$$

#### Compute the Seismic Force per equation 13.3-1, [Fp]:

$$= 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )$$

$$= 0.4 * 2.5 * 0.624 * 36.84 * ( 1 + 2*1 ) / ( 2.5/1.5 )$$

$$= 41.383 \text{ kN}$$

#### Check the Maximum value of Fp per equation 13.3-2:

$$= 1.6 * Sds * I * W$$

$$= 1.6 * 0.624 * 1.5 * 36.84 = 55.18 \text{ kN}$$

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Check the Minimum value of Fp per equation 13.3-3:  
 = 0.3 \* 0.624 \* 1.5 \* 36.84  
 = 10.346 kN

Compute the Total Base Shear V = Fp, [V]:  
 = 41.383 kN

Vertical load per 12.4-4, [YEq]:  
 = 0.2 \* Sds \* W  
 = 0.2 \* 0.624 \* 36.84 = 4.598 kN

Final Base Shear, V = 28.97 kN  
 Final Vertical Load, YEq = 3.22 kN

**Earthquake Load Calculation:**

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	445	7.36876	5.79362
20	Sadl	445	7.36876	5.79362
Sadl	30	445	7.36876	5.79362
20	30	445	7.36876	5.79362
30	40	445	7.36876	5.79362

Note:  
 The Earthquake Loads calculated and printed in the Earthquake Load calculation report have been factored by the input scalar/load reduction factor of: 0.700.

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 Center of Gravity Calculation: Step: 9 9:17pm Feb 18,2022

### **Shop/Field Installation Options :**

Insulation is installed in the Field.

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

Center of Gravity of Saddles	2000.000 mm.
Center of Gravity of Liquid	2000.000 mm.
Center of Gravity of Insulation	2000.000 mm.
Center of Gravity of Nozzles	511.935 mm.
Center of Gravity of Bare Shell New and Cold	2000.000 mm.
Center of Gravity of Bare Shell Corroded	2000.000 mm.
Vessel CG in the Operating Condition	1656.356 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1484.376 mm.
Vessel CG in the Test Condition	1750.545 mm.

*Warning: Lifting Lug is Higher than top of vessel !*

### **Rigging Analysis Results:**

Total Effective Length of Vessel for this analysis	4000.00 mm.
Total vessel weight (No Liquid)	Twt 28.07 kN
Impact weight multiplication factor	Imp 1.50
Design lifting weight, DWT = Imp * Twt	42.11 kN
Elevation of the Tailing Lug (bottom)	500.00 mm.
Elevation of the Lifting Lug (top )	5400.00 mm.
Design Reaction force at the tailing lug	33.65 kN
Design Reaction force at the lifting lug	8.46 kN
CG Distance from Tailing Lug	984.38 mm.
CG Distance from the Nearer Lifting Lug	984.38 mm.

### **Critical Values:**

	Max Stress N./mm <sup>2</sup>	Elevation mm.	Allowables N./mm <sup>2</sup>	
Bending	2.13	3170.00	113.45	(UG-23)
Shear	0.46	10.00	96.53	(0.7*S)

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

Distance mm.	Bending Moment N-m	Bending Stress N./mm <sup>2</sup>	Shear Force kN	Shear Stress N./mm <sup>2</sup>
0.00	0.0	0.0	14.6	0.4
830.00	1821.0	0.2	10.8	0.3
2390.00	14111.9	1.9	0.7	0.0
3950.00	14272.8	1.9	9.4	0.3

### **Unity Check (Actual Stress / Allowable Stress):**

Maximum Unity Check is 0.0188 at elevation 3170 mm. - Must be <=1

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

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

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 Horizontal Vessel Analysis (Ope.): Step: 10 9:17pm Feb 18,2022

### 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

**Note:**

Wear Pad Width (200.00) is less than  $1.56 \cdot \sqrt{r_m \cdot t}$   
 and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

$$= \min( b + 1.56 \cdot \sqrt{ R_m \cdot t }, 2a )$$

$$= \min( 172 + 1.56 \cdot \sqrt{ 452.5 \cdot 9 }, 2 \cdot 680 )$$

$$= 271.5532 \text{ mm.}$$

### Input and Calculated Values:

Vessel Mean Radius	Rm	452.50	mm.
Stiffened Vessel Length per 4.15.6	L	4000.00	mm.
Distance from Saddle to Vessel tangent	a	680.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	225.50	mm.
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		70.33	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	54.62	137.90
Long. Stress at Bottom of Midspan	61.13	137.90
Long. Stress at Top of Saddles	73.51	137.90
Long. Stress at Bottom of Saddles	49.22	137.90
-----	-----	-----
Tangential Shear in Shell	12.41	110.32
Circ. Stress at Horn of Saddle	76.03	172.38
Circ. Compressive Stress in Shell	2.19	137.90
-----	-----	-----

### Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} \cdot ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) \cdot B / E$$

$$= 3 \cdot ( 2.537/2 + 0 ) \cdot 840/783.8$$

$$= 4.1 \text{ kN}$$

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

$$= \max( F_l, \text{Friction Load, Sum of X Forces} ) \cdot B / L_s$$

$$= \max( 0.721, 0, 0 ) \cdot 840/2640$$

$$= 0.2 \text{ kN}$$

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

$$= \max( F_l, \text{Friction Force, Sum of X Forces} ) \cdot B / L_s$$

$$= \max( 28.97, 0, 0 ) \cdot 840/2640$$

$$= 9.2 \text{ kN}$$

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Saddle Reaction Force due to Earthquake Ft [Fst]:  

$$= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$$

$$= 3 * ( 28.97/2 + 0 ) * 840/783.8$$

$$= 46.6 \text{ kN}$$

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

$$= \text{Saddle Load} + \text{Max}( F_{wl}, F_{wt}, F_{sl}, F_{st} )$$

$$= 23.75 + \text{Max}( 0.229, 4.079, 9.217, 46.57 )$$

$$= 70.3 \text{ kN}$$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)	71.40 kN
Transverse Shear Load Saddle	14.48 kN
Longitudinal Shear Load Saddle	28.97 kN

**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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.3 [M1]:  

$$= -Q * a [ 1 - ( 1 - a/L + (R^2 - h^2) / (2a * L) ) / ( 1 + (4h^2) / (3L) ) ]$$

$$= -70.33 * 680 [ 1 - ( 1 - 680/4000 + (452.5^2 - 225.5^2) / (2 * 680 * 4000) ) / ( 1 + (4 * 225.5) / (3 * 4000) ) ]$$

$$= -9650.1 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:  

$$= Q * L / 4 ( 1 + 2(R^2 - h^2) / (L^2) ) / ( 1 + (4h^2) / (3L) ) - 4a/L$$

$$= 70.33 * 4000 / 4 ( 1 + 2(452.5^2 - 225.5^2) / (4000^2) ) / ( 1 + (4 * 225.5) / (3 * 4000) ) - 4 * 680 / 4000$$

$$= 18853.6 \text{ N-m}$$

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

$$= P * R_m / (2t) - M_2 / ( \pi * R_m^2 * t )$$

$$= 23.02 * 452.5 / (2 * 9) - 18854 / ( \pi * 452.5^2 * 9 )$$

$$= 54.62 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M_2 / ( \pi * R_m^2 * t )$$

$$= 23.02 * 452.5 / (2 * 9) + 18854 / ( \pi * 452.5^2 * 9 )$$

$$= 61.13 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) - M_1 / ( K_1 * \pi * R_m^2 * t )$$

$$= 23.02 * 452.5 / (2 * 9) - 9650 / ( 0.107 * \pi * 452.5^2 * 9 )$$

$$= 73.51 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M_1 / ( K_1 * \pi * R_m^2 * t )$$

$$= 23.02 * 452.5 / (2 * 9) + 9650 / ( 0.192 * \pi * 452.5^2 * 9 )$$

$$= 49.22 \text{ N./mm}^2$$

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

$$= Q(L - 2a) / ( L + (4 * h^2 / 3) )$$

$$= 70.33 ( 4000 - 2 * 680 ) / ( 4000 + ( 4 * 225.5 / 3 ) )$$

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= 43.2 kN

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

=  $K2 * T / ( Rm * t )$   
 =  $1.171 * 43.17 / ( 452.5 * 9 )$   
 = 12.41 N./mm<sup>2</sup>

Decay Length (4.15.22) [x1,x2]:

=  $0.78 * \text{sqrt}( Rm * t )$   
 =  $0.78 * \text{sqrt}( 452.5 * 9 )$   
 = 49.777 mm.

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

=  $-K5 * Q * k / ( t * ( b + X1 + X2 ) )$   
 =  $-0.76 * 70.33 * 0.1 / ( 9 * ( 172 + 49.78 + 49.78 ) )$   
 = -2.19 N./mm<sup>2</sup>

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

=  $-Q / ( 4 * t * ( b + X1 + X2 ) ) - 3 * K7 * Q / ( 2 * t^2 )$   
 =  $-70.33 / ( 4 * 9 * ( 172 + 49.78 + 49.78 ) ) -$   
 $3 * 0.0529 * 70.33 / ( 2 * 9^2 )$   
 = -76.03 N./mm<sup>2</sup>

Effective reinforcing plate width (4.15.1) [B1]:

=  $\text{min}( b + 1.56 * \text{sqrt}( Rm * t ) , 2a )$   
 =  $\text{min}( 172 + 1.56 * \text{sqrt}( 452.5 * 9 ) , 2 * 680 )$   
 = 271.55 mm.

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:

=  $\text{Alpha} * Ls * ( \text{Design Temperature} - \text{Ambient Temperature} )$   
 =  $0.00000233 * 2640 * ( 135 - 21.11 )$   
 = 3.707 mm.

**Results for Vessel Ribs, Web and Base:**

Baseplate Length	Bplen	890.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	200.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

**Moment of Inertia of Saddle - Lateral Direction**

	B	D	Y	A	AY	Io
Shell	299.	9.	4.	27.	12112.	7.27
Wearplate	200.	10.	14.	20.	28000.	40.9
Web	12.	357.	197.	43.	846090.	0.213E+05
BasePlate	200.	16.	384.	32.	1228800.	0.472E+05
Totals	...	...	...	122.	2115001.	0.685E+05

Value C1 = Sumof (Ay) / Sumof (A) = 174. mm.  
 Value I = Sumof (Io) - C1\*Sumof (Ay) = 0.318E+05 cm\*\*4  
 Value As = Sumof (A) - Ashell = 94.8 cm<sup>2</sup>

$K1 = ( 1 + \cos(\text{beta}) - 0.5 * \sin(\text{beta})^2 ) / ( \pi - \text{beta} + \sin(\text{beta}) * \cos(\text{beta}) ) = 0.2035$

Fh = K1 \* Q = 0.204 \* 70.33 = 14.31 kN

Tension Stress, St = ( Fh/As ) = 1.5093 N./mm<sup>2</sup>  
 Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm<sup>2</sup>

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**Saddle Splitting Dimension [d]:**

$$= B - R * \sin(\theta) / \theta$$

$$= 840 - 448 * \sin(1.047) / 1.047$$

$$= 469.507 \text{ mm.}$$

$$\text{Bending Moment, } M = F_h * d = 6722.6606 \text{ N-m}$$

$$\text{Bending Stress, } S_b = (M * C_1 / I) = 3.6756 \text{ N./mm}^2$$

$$\text{Allowed Stress, } S_a = 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

**Minimum Thickness of Baseplate per Moss:**

$$= (3(Q + \text{Saddle Wt}) \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2}$$

$$= (3(70.33 + 1.072)200 / (4 * 890 * 137.9))^{1/2}$$

$$= 9.342 \text{ mm.}$$

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

**Distance between Ribs [e]:**

$$= \text{Web Length} / (\text{Nr ribs} - 1)$$

$$= 814.1 / (2 - 1)$$

$$= 814.064 \text{ mm.}$$

**Baseplate Pressure Area [Ap]:**

$$= e * \text{Bpwid} / 2$$

$$= 814.1 * 200 / 2$$

$$= 814.064 \text{ cm}^2$$

**Axial Load [P]:**

$$= A_p * B_p$$

$$= 814.1 * 0.0395$$

$$= 32.163 \text{ kN}$$

**Area of the Rib and Web [Ar]:**

$$= \text{Rib Area} + \text{Web Area}$$

$$= 19.2 + 48.84$$

$$= 68.044 \text{ cm}^2$$

**Compressive Stress [Sc]:**

$$= P / A_r$$

$$= 32.16 / 68.04$$

$$= 4.727 \text{ N./mm}^2$$

**Check of Outside Ribs:**

**Inertia of Saddle, Outer Ribs - Longitudinal Direction**

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

**Bending Moment [Rm]:**

$$= F_l / (2 * \text{Bplen}) * e * r_l / 2$$

$$= 28.97 / (2 * 890) * 814.1 * 589 / 2$$

$$= 3903.189 \text{ N-m}$$

**Compressive Allowable, KL/R < Cc ( 21.54 < 138.1 ) per AISC E2-1 [Sca]:**

$$= (1 - (Kl/r)^2 / (2 * Cc^2)) * F_y / (5/3 + 3 * (Kl/r) / (8 * Cc) - (Kl/r)^3 / (8 * Cc^3))$$

$$= (1 - (21.54)^2 / (2 * 138.1^2)) * 206.9 / (5/3 + 3 * (21.54) / (8 * 138.1) - (21.54^3) / (8 * 138.1^3))$$

$$= 118.478 \text{ N./mm}^2$$

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

$$= S_c / S_{ca} + (R_m * \text{Distance Side} / I) / S_{ba}$$

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$$= 4.727/118.5 + ( 3903 * 86/5088448 )/137.9$$

$$= 0.518$$

### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	105.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	24.8	kN
Saddle Load QL (Wind/Seismic contribution)	QL	9.2	kN
Maximum Transverse Force	Ft	14.5	kN
Maximum Longitudinal Force	F1	29.0	kN
Saddle Bolted to Steel Foundation		No	

### Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarear1]:  
 = 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:  
 = F1 / (Stba \* Nbolts)  
 = 28.97/(172.4 \* 4 )  
 = 0.4202 cm<sup>2</sup>

### **Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 840 \* 14.48 + 0  
 = 12171.53 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 12172/24.83  
 = 490.05 mm. > Bplen/6 --> Uplift in Transverse direction

$$f = Bplen / 2 - Edgedis$$

$$= 890/2 - 105$$

$$= 340.00 \text{ mm.}$$

Modular Ratio Of Steel/Concrete (n1):  
 = ES / EC  
 = 203402/21526  
 = 9.45

$$K1 = 3 (e - 0.5 * Bplen)$$

$$= 3 (490.1 - 0.5*890 )$$

$$= 135.16 \text{ mm.}$$

$$K2 = 6 * n1 * At / Bpwid * (f + e)$$

$$= 6 * 9.449 * 4.341/200 * (340 + 490.1 )$$

$$= 102142.13 \text{ mm.}^2$$

$$K3 = -K2 * (0.5 * Bplen + f)$$

$$= -102142 * (0.5 * 890 + 340 )$$

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$$= -80181564.59 \text{ mm.}^3$$

Iteratively Solving for the Effective Bearing Length:

$$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$$

$$Y^3 + 135.2 * Y^2 + 102142 * Y + -80181560 = 0$$

$$Y = 321.78 \text{ mm.}$$

$$\text{Num} = (\text{Bplen} / 2 - Y / 3 - e)$$

$$= (890/2 - 321.8/3 - 490.1)$$

$$= -152.31$$

$$\text{Denom} = (\text{Bplen} / 2 - Y / 3 + f)$$

$$= (890/2 - 321.8/3 + 340)$$

$$= 677.74$$

Total Bolt Tension Force [Tforce]:

$$= -QO * \text{Num} / \text{Denom}$$

$$= -24.83 * -152.3/677.7$$

$$= 5.58 \text{ kN}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$= \text{Tforce} / (\text{Stba} * \text{Nbt})$$

$$= 5.58 / (172.4 * 2)$$

$$= 0.1619 \text{ cm}^2$$

Required Area of a Single Bolt [Bltarear]:

$$= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}]$$

$$= \max[0, 0.42, 0.162]$$

$$= 0.4202 \text{ cm}^2$$

### **Baseplate Thickness Calculation per D. Moss:**

Bearing Pressure (fc)

$$= 2(QO + \text{Tforce}) / (Y * \text{Bpwid})$$

$$= 2(24.83 + 5.58) / (321.8 * 200)$$

$$= 9.45 \text{ bar}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$= (\text{Bplen} - \text{Weblngth}) / 2$$

$$= (890 - 839.2) / 2$$

$$= 25.4000 \text{ mm.}$$

Overturning Moment due To Bolt Tension [Mt]:

$$= \text{Tforce} * \text{Adist}$$

$$= 5.58 * 25.4$$

$$= 141.78 \text{ N-m}$$

Equivalent Bearing Pressure (f1):

$$= fc * (Y - \text{Adist}) / Y$$

$$= 9.449 * (321.8 - 25.4) / 321.8$$

$$= 8.70 \text{ bar}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$= (\text{Adist}^2 * \text{Bpwid} / 6) * (f1 + 2 * fc)$$

$$= (25.4^2 * 200/6) * (8.703 + 2 * 9.449)$$

$$= 59.38 \text{ N-m}$$

Baseplate Required Thickness [Treq]:

$$= (6 * \max(\text{Mt}, \text{Mc}) / (\text{Bpwid} * \text{Sba}))^{1/2}$$

$$= (6 * \max(141.8, 59.38) / (200 * 162.4))^{1/2}$$

$$= 5.1172 \text{ mm.}$$

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

**Note:**

Wear Pad Width (200.00) is less than  $1.56 \cdot \sqrt{rm \cdot t}$   
 and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

$$= \min( b + 1.56 \cdot \sqrt{ Rm \cdot t }, 2a )$$

$$= \min( 172 + 1.56 \cdot \sqrt{ 452.5 \cdot 9 }, 2 \cdot 680 )$$

$$= 271.5532 \text{ mm.}$$

**Input and Calculated Values:**

Vessel Mean Radius	Rm	452.50	mm.
Stiffened Vessel Length per 4.15.6	L	4000.00	mm.
Distance from Saddle to Vessel tangent	a	680.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	225.50	mm.
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		60.73	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----	-----	-----	
Long. Stress at Top of Midspan	55.07	137.90	
Long. Stress at Bottom of Midspan	60.69	137.90	
Long. Stress at Top of Saddles	71.38	137.90	
Long. Stress at Bottom of Saddles	50.40	137.90	
-----	-----	-----	
Tangential Shear in Shell	10.72	110.32	
Circ. Stress at Horn of Saddle	65.66	172.38	
Circ. Compressive Stress in Shell	1.89	137.90	
-----	-----	-----	

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} \cdot ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) \cdot B / E$$

$$= 3 \cdot ( 2.537/2 + 0 ) \cdot 840/783.8$$

$$= 4.1 \text{ kN}$$

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

$$= \max( F_l, \text{Friction Load, Sum of X Forces} ) \cdot B / L_s$$

$$= \max( 0.721, 0, 0 ) \cdot 840/2640$$

$$= 0.2 \text{ kN}$$

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

$$= \max( F_l, \text{Friction Force, Sum of X Forces} ) \cdot B / L_s$$

$$= \max( 28.97, 0, 0 ) \cdot 840/2640$$

$$= 9.2 \text{ kN}$$

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Saddle Reaction Force due to Earthquake Ft [Fst]:  
 $= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$   
 $= 3 * ( 28.97/2 + 0 ) * 840/783.8$   
 $= 46.6 \text{ kN}$

Load Combination Results for Q + Wind or Seismic [Q]:  
 $= \text{Saddle Load} + \text{Max}( F_{wl}, F_{wt}, F_{sl}, F_{st} )$   
 $= 14.16 + \text{Max}( 0.229, 4.079, 9.217, 46.57 )$   
 $= 60.7 \text{ kN}$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)	61.81 kN
Transverse Shear Load Saddle	14.48 kN
Longitudinal Shear Load Saddle	28.97 kN

**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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.3 [M1]:  
 $= -Q * a [ 1 - ( 1 - a/L + (R^2 - h^2) / (2a * L) ) / ( 1 + (4h^2) / (3L) ) ]$   
 $= -60.73 * 680 [ 1 - ( 1 - 680/4000 + (452.5^2 - 225.5^2) / (2 * 680 * 4000) ) / ( 1 + (4 * 225.5) / (3 * 4000) ) ]$   
 $= -8333.9 \text{ N-m}$

Moment per Equation 4.15.4 [M2]:  
 $= Q * L / 4 ( 1 + 2 ( R^2 - h^2 ) / ( L^2 ) ) / ( 1 + ( 4h^2 ) / ( 3L ) ) - 4a/L$   
 $= 60.73 * 4000 / 4 ( 1 + 2 ( 452.5^2 - 225.5^2 ) / ( 4000^2 ) ) / ( 1 + ( 4 * 225.5 ) / ( 3 * 4000 ) ) - 4 * 680 / 4000$   
 $= 16282.1 \text{ N-m}$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:  
 $= P * R_m / ( 2t ) - M_2 / ( \pi * R_m^2 * t )$   
 $= 23.02 * 452.5 / ( 2 * 9 ) - 16282 / ( \pi * 452.5^2 * 9 )$   
 $= 55.07 \text{ N./mm}^2$

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:  
 $= P * R_m / ( 2t ) + M_2 / ( \pi * R_m^2 * t )$   
 $= 23.02 * 452.5 / ( 2 * 9 ) + 16282 / ( \pi * 452.5^2 * 9 )$   
 $= 60.69 \text{ N./mm}^2$

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:  
 $= P * R_m / ( 2t ) - M_1 / ( K_1 * \pi * R_m^2 * t )$   
 $= 23.02 * 452.5 / ( 2 * 9 ) - 8334 / ( 0.107 * \pi * 452.5^2 * 9 )$   
 $= 71.38 \text{ N./mm}^2$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:  
 $= P * R_m / ( 2t ) + M_1 / ( K_1 * \pi * R_m^2 * t )$   
 $= 23.02 * 452.5 / ( 2 * 9 ) + 8334 / ( 0.192 * \pi * 452.5^2 * 9 )$   
 $= 50.40 \text{ N./mm}^2$

Maximum Shear Force in the Saddle (4.15.5) [T]:  
 $= Q ( L - 2a ) / ( L + ( 4 * h^2 / 3 ) )$   
 $= 60.73 ( 4000 - 2 * 680 ) / ( 4000 + ( 4 * 225.5 / 3 ) )$   
 $= 37.3 \text{ kN}$

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Shear Stress in the shell no rings, not stiffened (4.15.14) [ $\tau_2$ ]:

$$= K_2 * T / ( R_m * t )$$

$$= 1.171 * 37.28 / ( 452.5 * 9 )$$

$$= 10.72 \text{ N./mm}^2$$

Decay Length (4.15.22) [ $x_1, x_2$ ]:

$$= 0.78 * \text{sqrt}( R_m * t )$$

$$= 0.78 * \text{sqrt}( 452.5 * 9 )$$

$$= 49.777 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [ $\sigma_6$ ]:

$$= -K_5 * Q * k / ( t * ( b + X_1 + X_2 ) )$$

$$= -0.76 * 60.73 * 0.1 / ( 9 * ( 172 + 49.78 + 49.78 ) )$$

$$= -1.89 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle,  $L \geq 8R_m$  (4.15.24) [ $\sigma_7$ ]:

$$= -Q / ( 4 * t * ( b + X_1 + X_2 ) ) - 3 * K_7 * Q / ( 2 * t^2 )$$

$$= -60.73 / ( 4 * 9 * ( 172 + 49.78 + 49.78 ) ) -$$

$$3 * 0.0529 * 60.73 / ( 2 * 9^2 )$$

$$= -65.66 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [ $B_1$ ]:

$$= \min( b + 1.56 * \text{sqrt}( R_m * t ), 2a )$$

$$= \min( 172 + 1.56 * \text{sqrt}( 452.5 * 9 ), 2 * 680 )$$

$$= 271.55 \text{ mm.}$$

### Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	890.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	200.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	299.	9.	4.	27.	12112.	7.27
Wearplate	200.	10.	14.	20.	28000.	40.9
Web	12.	357.	197.	43.	846090.	0.213E+05
BasePlate	200.	16.	384.	32.	1228800.	0.472E+05
Totals	...	...	...	122.	2115001.	0.685E+05

$$\text{Value } C_1 = \text{Sumof}(Ay) / \text{Sumof}(A) = 174. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C_1 * \text{Sumof}(Ay) = 0.318E+05 \text{ cm}^4$$

$$\text{Value } A_s = \text{Sumof}(A) - A_{\text{shell}} = 94.8 \text{ cm}^2$$

$$K_1 = ( 1 + \cos(\beta) - 0.5 * \sin(\beta)^2 ) / ( \pi - \beta + \sin(\beta) * \cos(\beta) ) = 0.2035$$

$$F_h = K_1 * Q = 0.204 * 60.73 = 12.36 \text{ kN}$$

$$\text{Tension Stress, } S_t = ( F_h / A_s ) = 1.3034 \text{ N./mm}^2$$

$$\text{Allowed Stress, } S_a = 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta) / \theta$$

$$= 840 - 448 * \sin( 1.047 ) / 1.047$$

$$= 469.507 \text{ mm.}$$

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$$\text{Bending Moment, } M = F_h * d = 5805.7461 \text{ N-m}$$

$$\begin{aligned} \text{Bending Stress, } S_b &= ( M * C_1 / I ) = 3.1743 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

**Minimum Thickness of Baseplate per Moss:**

$$\begin{aligned} &= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2} \\ &= ( 3(60.73 + 1.072) 200 / ( 4 * 890 * 137.9 ) )^{1/2} \\ &= 8.692 \text{ mm.} \end{aligned}$$

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

**Distance between Ribs [e]:**

$$\begin{aligned} &= \text{Web Length} / ( \text{Nr ribs} - 1 ) \\ &= 814.1 / ( 2 - 1 ) \\ &= 814.064 \text{ mm.} \end{aligned}$$

**Baseplate Pressure Area [Ap]:**

$$\begin{aligned} &= e * \text{Bpwid} / 2 \\ &= 814.1 * 200 / 2 \\ &= 814.064 \text{ cm}^2 \end{aligned}$$

**Axial Load [P]:**

$$\begin{aligned} &= A_p * B_p \\ &= 814.1 * 0.0341 \\ &= 27.776 \text{ kN} \end{aligned}$$

**Area of the Rib and Web [Ar]:**

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 19.2 + 48.84 \\ &= 68.044 \text{ cm}^2 \end{aligned}$$

**Compressive Stress [Sc]:**

$$\begin{aligned} &= P / A_r \\ &= 27.78 / 68.04 \\ &= 4.082 \text{ N./mm}^2 \end{aligned}$$

**Check of Outside Ribs:**

**Inertia of Saddle, Outer Ribs - Longitudinal Direction**

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	12.0	172.0	...	20.6	...	509.

**Bending Moment [Rm]:**

$$\begin{aligned} &= F_1 / ( 2 * B_{plen} ) * e * r_1 / 2 \\ &= 28.97 / ( 2 * 890 ) * 814.1 * 589 / 2 \\ &= 3903.189 \text{ N-m} \end{aligned}$$

**Compressive Allowable, KL/R < Cc ( 21.54 < 138.1 ) per AISC E2-1 [Sca]:**

$$\begin{aligned} &= ( 1 - ( K L r )^2 / ( 2 * C c^2 ) ) * F_y / ( 5 / 3 + 3 * ( K L r ) / ( 8 * C c ) - ( K L r^3 ) / ( 8 * C c^3 ) ) \\ &= ( 1 - ( 21.54 )^2 / ( 2 * 138.1^2 ) ) * 206.9 / \\ &\quad ( 5 / 3 + 3 * ( 21.54 ) / ( 8 * 138.1 ) - ( 21.54^3 ) / ( 8 * 138.1^3 ) ) \\ &= 118.478 \text{ N./mm}^2 \end{aligned}$$

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

$$\begin{aligned} &= S_c / S_{ca} + ( R_m * \text{Distance Side} / I ) / S_{ba} \\ &= 4.082 / 118.5 + ( 3903 * 86 / 5088448 ) / 137.9 \\ &= 0.513 \end{aligned}$$

**Input Data for Base Plate Bolting Calculations:**

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Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	105.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	15.2	kN
Saddle Load QL (Wind/Seismic contribution)	QL	9.2	kN
Maximum Transverse Force	Ft	14.5	kN
Maximum Longitudinal Force	F1	29.0	kN
Saddle Bolted to Steel Foundation		No	

### **Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:  
 = 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:  
 = F1 / (Stba \* Nbolts)  
 = 28.97 / (172.4 \* 4 )  
 = 0.4202 cm<sup>2</sup>

### **Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 840 \* 14.48 + 0  
 = 12171.53 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 12172 / 15.24  
 = 798.58 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis  
 = 890 / 2 - 105  
 = 340.00 mm.

Modular Ratio Of Steel/Concrete (n1):  
 = ES / EC  
 = 203402 / 21526  
 = 9.45

K1 = 3 (e - 0.5 \* Bplen)  
 = 3 (798.6 - 0.5 \* 890 )  
 = 1060.73 mm.

K2 = 6 \* n1 \* At / Bpwid \* (f + e)  
 = 6 \* 9.449 \* 4.341 / 200 \* (340 + 798.6 )  
 = 140107.64 mm.<sup>2</sup>

K3 = -K2 \* (0.5 \* Bplen + f)  
 = -140108 \* (0.5 \* 890 + 340 )  
 = -109984490.42 mm.<sup>3</sup>

Iteratively Solving for the Effective Bearing Length:  
 $Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$   
 $Y^3 + 1061 * Y^2 + 140108 * Y + -109984488 = 0$

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$$Y = 241.74 \text{ mm.}$$

$$\begin{aligned} \text{Num} &= (\text{Bplen} / 2 - Y / 3 - e) \\ &= (890/2 - 241.7/3 - 798.6) \\ &= -434.16 \end{aligned}$$

$$\begin{aligned} \text{Denom} &= (\text{Bplen} / 2 - Y / 3 + f) \\ &= (890/2 - 241.7/3 + 340) \\ &= 704.42 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned} &= -QO * \text{Num} / \text{Denom} \\ &= -15.24 * -434.2/704.4 \\ &= 9.39 \text{ kN} \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned} &= \text{Tforce} / (\text{Stba} * \text{Nbt}) \\ &= 9.39 / (172.4 * 2) \\ &= 0.2724 \text{ cm}^2 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\ &= \max[0, 0.42, 0.272] \\ &= 0.4202 \text{ cm}^2 \end{aligned}$$

### **Baseplate Thickness Calculation per D. Moss:**

Bearing Pressure (fc)

$$\begin{aligned} &= 2(QO + \text{Tforce}) / (Y * \text{Bpwid}) \\ &= 2(15.24 + 9.39) / (241.7 * 200) \\ &= 10.19 \text{ bar} \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned} &= (\text{Bplen} - \text{Weblngth}) / 2 \\ &= (890 - 839.2) / 2 \\ &= 25.4000 \text{ mm.} \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned} &= \text{Tforce} * \text{Adist} \\ &= 9.39 * 25.4 \\ &= 238.60 \text{ N-m} \end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned} &= fc * (Y - \text{Adist}) / Y \\ &= 10.19 * (241.7 - 25.4) / 241.7 \\ &= 9.12 \text{ bar} \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned} &= (\text{Adist}^2 * \text{Bpwid} / 6) * (f1 + 2 * fc) \\ &= (25.4^2 * 200/6) * (9.116 + 2 * 10.19) \\ &= 63.44 \text{ N-m} \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned} &= (6 * \max(\text{Mt}, \text{Mc}) / (\text{Bpwid} * \text{Sba}))^{1/2} \\ &= (6 * \max(238.6, 63.44) / (200 * 162.4))^{1/2} \\ &= 6.6384 \text{ mm.} \end{aligned}$$

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### 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

**Note:**

Wear Pad Width (200.00) is less than  $1.56 \cdot \sqrt{r_m \cdot t}$   
 and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:

$$\begin{aligned}
 &= \min( b + 1.56 \cdot \sqrt{ R_m \cdot t }, 2a ) \\
 &= \min( 172 + 1.56 \cdot \sqrt{ 452.5 \cdot 9 }, 2 \cdot 680 ) \\
 &= 271.5532 \text{ mm.}
 \end{aligned}$$

### Input and Calculated Values:

Vessel Mean Radius	Rm	452.50	mm.
Stiffened Vessel Length per 4.15.6	L	4000.00	mm.
Distance from Saddle to Vessel tangent	a	680.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	225.50	mm.
Shell Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		32.21	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	73.80	235.81
Long. Stress at Bottom of Midspan	76.78	235.81
Long. Stress at Top of Saddles	82.45	235.81
Long. Stress at Bottom of Saddles	71.32	235.81
-----	-----	-----
Tangential Shear in Shell	5.68	188.65
Circ. Stress at Horn of Saddle	34.82	353.71
Circ. Compressive Stress in Shell	1.00	235.81
-----	-----	-----

### Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
 &= F_{tr} \cdot ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) \cdot B / E \\
 &= 3 \cdot ( 0.837/2 + 0 ) \cdot 840/783.8 \\
 &= 1.3 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( F_l, \text{Friction Load, Sum of X Forces} ) \cdot B / L_s \\
 &= \max( 0.238, 0, 0 ) \cdot 840/2640 \\
 &= 0.1 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \text{Saddle Load} + \max( F_{wl}, F_{wt}, F_{sl}, F_{st} ) \\
 &= 30.86 + \max( 0.0757, 1.346, 0, 0 ) \\
 &= 32.2 \text{ kN}
 \end{aligned}$$

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**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)	33.28	kN
Transverse Shear Load Saddle	0.42	kN
Longitudinal Shear Load Saddle	0.24	kN

Hydrostatic Test Pressure at center of Vessel: 29.944 bar

**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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

**Moment per Equation 4.15.3 [M1]:**

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left( 1 + \frac{4h^2}{3L} \right) \right] \\
 &= -32.21 \cdot 680 \left[ 1 - \left( 1 - \frac{680}{4000} + \frac{452.5^2 - 225.5^2}{2 \cdot 680 \cdot 4000} \right) / \left( 1 + \frac{4 \cdot 225.5}{3 \cdot 4000} \right) \right] \\
 &= -4419.3 \text{ N-m}
 \end{aligned}$$

**Moment per Equation 4.15.4 [M2]:**

$$\begin{aligned}
 &= Q \cdot L / 4 \left( 1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left( 1 + \frac{4h^2}{3L} \right) - 4a / L \\
 &= 32.21 \cdot 4000 / 4 \left( 1 + 2 \frac{452.5^2 - 225.5^2}{4000^2} \right) / \left( 1 + \frac{4 \cdot 225.5}{3 \cdot 4000} \right) - 4 \cdot 680 / 4000 \\
 &= 8634.1 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) - 8634 / (\pi \cdot 452.5^2 \cdot 9) \\
 &= 73.80 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) + 8634 / (\pi \cdot 452.5^2 \cdot 9) \\
 &= 76.78 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) - 4419 / (0.107 \cdot \pi \cdot 452.5^2 \cdot 9) \\
 &= 82.45 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) + 4419 / (0.192 \cdot \pi \cdot 452.5^2 \cdot 9) \\
 &= 71.32 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4 \cdot h^2 / 3)) \\
 &= 32.21 \cdot (4000 - 2 \cdot 680) / (4000 + (4 \cdot 225.5 / 3)) \\
 &= 19.8 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.171 \cdot 19.77 / (452.5 \cdot 9) \\
 &= 5.68 \text{ N./mm}^2
 \end{aligned}$$

**Decay Length (4.15.22) [x1,x2]:**

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$$= 0.78 * \text{sqrt}( Rm * t )$$

$$= 0.78 * \text{sqrt}( 452.5 * 9 )$$

$$= 49.777 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [ $\sigma_6$ ]:

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

$$= -0.76 * 32.21 * 0.1 / ( 9 * ( 172 + 49.78 + 49.78 ) )$$

$$= -1.00 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle,  $L \geq 8Rm$  (4.15.24) [ $\sigma_7$ ]:

$$= -Q / ( 4 * t * ( b + X1 + X2 ) ) - 3 * K7 * Q / ( 2 * t^2 )$$

$$= -32.21 / ( 4 * 9 * ( 172 + 49.78 + 49.78 ) ) -$$

$$3 * 0.0529 * 32.21 / ( 2 * 9^2 )$$

$$= -34.82 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

$$= \text{min}( b + 1.56 * \text{sqrt}( Rm * t ), 2a )$$

$$= \text{min}( 172 + 1.56 * \text{sqrt}( 452.5 * 9 ), 2 * 680 )$$

$$= 271.55 \text{ mm.}$$

**Results for Vessel Ribs, Web and Base:**

Baseplate Length	Bplen	890.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	200.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

## Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	299.	9.	4.	27.	12112.	7.27
Wearplate	200.	10.	14.	20.	28000.	40.9
Web	12.	357.	197.	43.	846090.	0.213E+05
BasePlate	200.	16.	384.	32.	1228800.	0.472E+05
Totals	...	...	...	122.	2115001.	0.685E+05

$$\text{Value } C1 = \text{Sumof}(AY) / \text{Sumof}(A) = 174. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C1 * \text{Sumof}(AY) = 0.318E+05 \text{ cm}^{*4}$$

$$\text{Value } As = \text{Sumof}(A) - A_{\text{shell}} = 94.8 \text{ cm}^2$$

$$K1 = ( 1 + \cos(\text{beta}) - 0.5 * \sin(\text{beta})^2 ) / ( \pi - \text{beta} + \sin(\text{beta}) * \cos(\text{beta}) ) = 0.2035$$

$$Fh = K1 * Q = 0.204 * 32.21 = 6.555 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 0.6912 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\text{theta}) / \text{theta}$$

$$= 840 - 448 * \sin( 1.047 ) / 1.047$$

$$= 469.507 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 3078.6970 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M * C1 / I ) = 1.6833 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

Minimum Thickness of Baseplate per Moss:

$$= ( 3 ( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2}$$

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$$= ( 3(32.21 + 1.072 )200/( 4 * 890 * 137.9 ))^{1/2}$$

$$= 6.378 \text{ mm.}$$

#### Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nr ribs} - 1 )$$

$$= 814.1 / ( 2 - 1 )$$

$$= 814.064 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 814.1 * 200 / 2$$

$$= 814.064 \text{ cm}^2$$

Axial Load [P]:

$$= \text{Ap} * \text{Bp}$$

$$= 814.1 * 0.0181$$

$$= 14.729 \text{ kN}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 19.2 + 48.84$$

$$= 68.044 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P / \text{Ar}$$

$$= 14.73 / 68.04$$

$$= 2.165 \text{ N./mm}^2$$

#### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	12.0	172.0	...	20.6	...	509.

Bending Moment [Rm]:

$$= \text{Fl} / ( 2 * \text{Bplen} ) * e * \text{rl} / 2$$

$$= 0.238 / ( 2 * 890 ) * 814.1 * 589 / 2$$

$$= 32.067 \text{ N-m}$$

Compressive Allowable,  $\text{KL/R} < \text{Cc} ( 21.54 < 138.1 )$  per AISC E2-1 [Sca]:

$$= ( 1 - (\text{Kl/r})^2 / ( 2 * \text{Cc}^2 ) ) * \text{Fy} / ( 5/3 + 3 * (\text{Kl/r}) / ( 8 * \text{Cc} ) - (\text{Kl/r}^3) / ( 8 * \text{Cc}^3 ) )$$

$$= ( 1 - ( 21.54 )^2 / ( 2 * 138.1^2 ) ) * 206.9 /$$

$$( 5/3 + 3 * ( 21.54 ) / ( 8 * 138.1 ) - ( 21.54^3 ) / ( 8 * 138.1^3 ) )$$

$$= 118.478 \text{ N./mm}^2$$

**AISC Unity Check of Outside Ribs ( must be  $\leq 1$  )**

$$= \text{Sc} / \text{Sca} + ( \text{Rm} * \text{Distance Side/I} ) / \text{Sba}$$

$$= 2.165 / 118.5 + ( 32.07 * 86 / 5088448 ) / 137.9$$

$$= 0.022$$

#### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification	SA-193 B7	
Bolt Allowable Stress	Stba	172.38 N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0 mm.
Distance from Bolts to Edge	Edgedis	105.0 mm.
Nominal Bolt Diameter	Bnd	20.0000 mm.
Thread Series	Series	TEMA Metric

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BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	31.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.1	kN
Maximum Transverse Force	Ft	0.4	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		No	

### **Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:  
 = 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:  
 = Fl / (Stba \* Nbolts)  
 = 0.238/(172.4 \* 4 )  
 = 0.0035 cm<sup>2</sup>

### **Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 840 \* 0.419 + 0  
 = 351.78 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 351.8/31.93  
 = 11.01 mm. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:  
 = 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:  
 = max[Bltarearl, Bltarears, Bltareart]  
 = max[0, 0.00345, 0 ]  
 = 0.0035 cm<sup>2</sup>

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

Note:  
 Wear Pad Width (200.00) is less than  $1.56 \cdot \sqrt{rm \cdot t}$   
 and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:  
 = min( b +  $1.56 \cdot \sqrt{Rm \cdot t}$  , 2a )  
 = min( 172 +  $1.56 \cdot \sqrt{452.5 \cdot 9}$  , 2 \* 680 )  
 = 271.5532 mm.

### **Input and Calculated Values:**

Vessel Mean Radius	Rm	452.50	mm.
Stiffened Vessel Length per 4.15.6	L	4000.00	mm.
Distance from Saddle to Vessel tangent	a	680.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	225.50	mm.

**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY****DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT****Tag no:Liquid Receiver (D-PK6101-2)****PV Elite 2018 SP2 Licensee: SPLM Licensed User****FileName : Calculation Book for LIQID RECEIVER D-PK6101-2****Horizontal Vessel Analysis (Test): Step: 11 9:17pm Feb 18,2022**

Shell Allowable Stress used in Calculation	235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation	235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle	1.00	
Circumferential Efficiency at Mid-Span	1.00	

Saddle Force Q, Test Case, no Ext. Forces	22.61	kN
---	-------	----

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	74.24	235.81
Long. Stress at Bottom of Midspan	76.33	235.81
Long. Stress at Top of Saddles	80.31	235.81
Long. Stress at Bottom of Saddles	72.50	235.81
-----	-----	-----
Tangential Shear in Shell	3.99	188.65
Circ. Stress at Horn of Saddle	24.45	353.71
Circ. Compressive Stress in Shell	0.70	235.81
-----	-----	-----

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$$

$$= 3 * ( 0.837/2 + 0 ) * 840/783.8$$

$$= 1.3 \text{ kN}$$

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

$$= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s$$

$$= \max( 0.238, 0, 0 ) * 840/2640$$

$$= 0.1 \text{ kN}$$

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

$$= \text{Saddle Load} + \max( F_{wl}, F_{wt}, F_{sl}, F_{st} )$$

$$= 21.27 + \max( 0.0757, 1.346, 0, 0 )$$

$$= 22.6 \text{ kN}$$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)	23.69	kN
Transverse Shear Load Saddle	0.42	kN
Longitudinal Shear Load Saddle	0.24	kN

Hydrostatic Test Pressure at center of Vessel: 29.944 bar

**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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.3 [M1]:

$$= -Q * a [ 1 - ( 1 - a/L + (R^2 - h^2) / (2a * L) ) / ( 1 + (4h^2) / (3L) ) ]$$

$$= -22.61 * 680 [ 1 - ( 1 - 680/4000 + (452.5^2 - 225.5^2) / ( 2 * 680 * 4000 ) ) / ( 1 + ( 4 * 225.5 ) / ( 3 * 4000 ) ) ]$$

$$= -3103.1 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

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$$\begin{aligned}
 &= Q \cdot L / 4 (1 + 2(R^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a / L \\
 &= 22.61 \cdot 4000 / 4 (1 + 2(452.5^2 - 225.5^2) / (4000^2)) / (1 + (4 \cdot 225.5) / (3 \cdot 4000)) - 4 \cdot 680 / 4000 \\
 &= 6062.7 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) - 6063 / (\pi \cdot 452.5^2 \cdot 9) \\
 &= 74.24 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) + 6063 / (\pi \cdot 452.5^2 \cdot 9) \\
 &= 76.33 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) - 3103 / (0.107 \cdot \pi \cdot 452.5^2 \cdot 9) \\
 &= 80.31 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.94 \cdot 452.5 / (2 \cdot 9) + 3103 / (0.192 \cdot \pi \cdot 452.5^2 \cdot 9) \\
 &= 72.50 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4 \cdot h^2 / 3)) \\
 &= 22.61 (4000 - 2 \cdot 680) / (4000 + (4 \cdot 225.5 / 3)) \\
 &= 13.9 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K_2 \cdot T / (R_m \cdot t) \\
 &= 1.171 \cdot 13.88 / (452.5 \cdot 9) \\
 &= 3.99 \text{ N./mm}^2
 \end{aligned}$$

Decay Length (4.15.22) [x1,x2]:

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{R_m \cdot t} \\
 &= 0.78 \cdot \sqrt{452.5 \cdot 9} \\
 &= 49.777 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= -K_5 \cdot Q \cdot k / (t \cdot (b + X_1 + X_2)) \\
 &= -0.76 \cdot 22.61 \cdot 0.1 / (9 \cdot (172 + 49.78 + 49.78)) \\
 &= -0.70 \text{ N./mm}^2
 \end{aligned}$$

Circ. Comp. Stress at Horn of Saddle, L >= 8Rm (4.15.24) [sigma7]:

$$\begin{aligned}
 &= -Q / (4 \cdot t \cdot (b + X_1 + X_2)) - 3 \cdot K_7 \cdot Q / (2 \cdot t^2) \\
 &= -22.61 / (4 \cdot 9 \cdot (172 + 49.78 + 49.78)) - 3 \cdot 0.0529 \cdot 22.61 / (2 \cdot 9^2) \\
 &= -24.45 \text{ N./mm}^2
 \end{aligned}$$

Effective reinforcing plate width (4.15.1) [B1]:

$$\begin{aligned}
 &= \min(b + 1.56 \cdot \sqrt{R_m \cdot t}, 2a) \\
 &= \min(172 + 1.56 \cdot \sqrt{452.5 \cdot 9}, 2 \cdot 680) \\
 &= 271.55 \text{ mm.}
 \end{aligned}$$

### **Results for Vessel Ribs, Web and Base**

Baseplate Length	Bplen	890.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	200.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	

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Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	

## Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	299.	9.	4.	27.	12112.	7.27
Wearplate	200.	10.	14.	20.	28000.	40.9
Web	12.	357.	197.	43.	846090.	0.213E+05
BasePlate	200.	16.	384.	32.	1228800.	0.472E+05
Totals	...	...	...	122.	2115001.	0.685E+05

Value C1 = Sumof (Ay) / Sumof (A) = 174. mm.  
 Value I = Sumof (Io) - C1\*Sumof (Ay) = 0.318E+05 cm\*\*4  
 Value As = Sumof (A) - Ashell = 94.8 cm<sup>2</sup>

$$K1 = (1 + \cos(\beta) - 0.5 * \sin(\beta)^2) / (\pi - \beta + \sin(\beta) * \cos(\beta)) = 0.2035$$

$$Fh = K1 * Q = 0.204 * 22.61 = 4.603 \text{ kN}$$

Tension Stress, St = ( Fh/As ) = 0.4853 N./mm<sup>2</sup>  
 Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm<sup>2</sup>

## Saddle Splitting Dimension [d]:

$$= B - R * \sin(\theta) / \theta$$

$$= 840 - 448 * \sin(1.047) / 1.047$$

$$= 469.507 \text{ mm.}$$

$$\text{Bending Moment, M} = Fh * d = 2161.7832 \text{ N-m}$$

Bending Stress, Sb = ( M \* C1 / I ) = 1.1819 N./mm<sup>2</sup>  
 Allowed Stress, Sa = 2/3 \* Yield Str = 137.9000 N./mm<sup>2</sup>

## Minimum Thickness of Baseplate per Moss:

$$= ( 3 ( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2}$$

$$= ( 3(22.61 + 1.072) 200 / ( 4 * 890 * 137.9 ) )^{1/2}$$

$$= 5.381 \text{ mm.}$$

## Calculation of Axial Load, Intermediate Values and Compressive Stress:

## Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nrifs} - 1 )$$

$$= 814.1 / ( 2 - 1 )$$

$$= 814.064 \text{ mm.}$$

## Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 814.1 * 200 / 2$$

$$= 814.064 \text{ cm}^2$$

## Axial Load [P]:

$$= Ap * Bp$$

$$= 814.1 * 0.0127$$

$$= 10.342 \text{ kN}$$

## Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 19.2 + 48.84$$

$$= 68.044 \text{ cm}^2$$

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Compressive Stress [Sc]:

$$= P/Ar$$

$$= 10.34/68.04$$

$$= 1.520 \text{ N./mm}^2$$

**Check of Outside Ribs:**

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	12.0	172.0	...	20.6	...	509.

Bending Moment [Rm]:

$$= Fl / ( 2 * Bplen ) * e * r1 / 2$$

$$= 0.238 / ( 2 * 890 ) * 814.1 * 589 / 2$$

$$= 32.067 \text{ N-m}$$

Compressive Allowable,  $KL/R < Cc$  ( 21.54 < 138.1 ) per AISC E2-1 [Sca]:

$$= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3))$$

$$= ( 1 - ( 21.54 )^2 / ( 2 * 138.1^2 ) ) * 206.9 /$$

$$( 5/3 + 3 * ( 21.54 ) / ( 8 * 138.1 ) - ( 21.54^3 ) / ( 8 * 138.1^3 ) )$$

$$= 118.478 \text{ N./mm}^2$$

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

$$= Sc/Sca + ( Rm * Distance Side/I ) / Sba$$

$$= 1.52/118.5 + ( 32.07 * 86/5088448 ) / 137.9$$

$$= 0.017$$

**Input Data for Base Plate Bolting Calculations:**

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	105.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	22.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.1	kN
Maximum Transverse Force	Ft	0.4	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		No	

**Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (QO > QL --> No Uplift in Longitudinal direction)}$$

Bolt Area due to Shear Load [Bltarears]:

$$= Fl / (Stba * Nbolts)$$

$$= 0.238 / (172.4 * 4)$$

$$= 0.0035 \text{ cm}^2$$

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 840 * 0.419 + 0$$

$$= 351.78 \text{ N-m}$$

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Eccentricity (e):

=  $R_{mom} / QO$   
=  $351.8 / 22.34$   
= 15.74 mm. <  $B_{plen} / 6$  --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:

= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:

=  $\max[Bltarearl, Bltarears, Bltareart]$   
=  $\max[0, 0.00345, 0]$   
= 0.0035 cm<sup>2</sup>

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**Nozzle Calculation Summary:**

Description	MAWP bar	Ext	MAPNC bar	UG-45	[tr] mm.	Weld Path	Areas or Stresses
M	23.87	OK	...	...		OK	Passed
A1	27.33	OK	...	OK	10.16	OK	Passed
B	27.33	OK	...	OK	10.16	OK	Passed
A2	27.33	OK	...	OK	6.42	OK	Passed
PT	23.09	OK	...	OK	6.22	OK	Passed
A3	27.33	OK	...	OK	6.42	OK	Passed
LT1	27.33	OK	...	OK	6.42	OK	Passed
LT2	27.33	OK	...	OK	6.42	OK	Passed
D	27.33	OK	...	OK	6.42	OK	Passed
SV	27.33	OK	...	OK	8.26	OK	Passed
TI	24.68	OK	...	OK	6.22	OK	Passed
TI	25.10	OK	...	OK	6.22	OK	Passed

**MAWP Summary:**

Minimum MAWP Nozzles : 23.089 Nozzle : PT  
 Minimum MAWP Shells/Flanges : 27.329 Element : shell 001  
 Minimum MAPnc Shells/Flanges : 36.589 Element : shell 001  
 -----  
 Computed Vessel M.A.W.P. : 23.089 bar

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

Warning: A Nozzle Reinforcement is governing the MAWP of this Vessel.

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	M	0.000	0.000	968.000
20	A1	500.000	0.000	405.700
20	B	2000.000	180.000	405.700
20	A2	3300.000	0.000	102.068
20	PT	1750.000	0.000	72.960
20	A3	1200.000	0.000	102.068
20	LT1	3700.000	180.000	102.068
20	LT2	3650.000	0.000	102.068
20	D	300.000	180.000	102.068
20	SV	2300.000	0.000	201.662
30	TI	0.000	180.000	72.960

**The nozzle spacing is computed by the following:**

= Sqrt( ll<sup>2</sup> + lc<sup>2</sup> ) where  
 ll - Arc length along the inside vessel surface in the long. direction.  
 lc - Arc length along the inside vessel surface in the circ. direction

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

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**INPUT VALUES, Nozzle Description: M From : 10**

Pressure for Reinforcement Calculations	P	23.020	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Elliptical Head	D	890.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	12.0000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

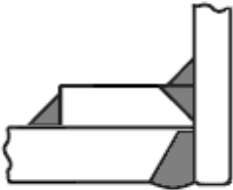
**Type of Element Connected to the Shell : Nozzle**

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	15.0000	mm.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	738.0000	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	9.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		115.0000	mm.
This is a Manway or Access Opening.			
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: M**

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

Actual Outside Diameter Used in Calculation	20.000 in.
Actual Thickness Used in Calculation	0.591 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]  
 $= (P \cdot D \cdot K) / (2 \cdot S_v \cdot E - 0.2 \cdot P)$  Appendix 1-4 (c)  
 $= (23.02 \cdot 896 \cdot 0.991) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23.02)$   
 $= 7.4260 \text{ mm.}$

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a) (1)  
 $= (23.02 \cdot 254) / (137.9 \cdot 1 + 0.4 \cdot 23.02)$   
 $= 4.2126 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 1.1318 mm.

Note: The diameter limit is greater than the head diameter.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	968.0000	mm.
Parallel to Vessel Wall, opening length	d	484.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	22.5000	mm.

Weld Strength Reduction Factor [fr1]:

$= \min(1, S_n / S_v)$   
 $= \min(1, 137.9 / 137.9)$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:

$= \min(1, S_n / S_v)$   
 $= \min(1, 137.9 / 137.9)$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:

$= \min(1, S_p / S_v)$   
 $= \min(1, 137.9 / 137.9)$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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= min( fr2, fr4 )  
 = min( 1, 1 )  
 = 1.000

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	35.942	5.907	NA
Area in Shell	A1	7.618	31.747	NA
Area in Nozzle Wall	A2	3.504	4.891	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.747	1.747	NA
Area in Element	A5	25.875	25.875	NA
TOTAL AREA AVAILABLE	Atot	38.745	64.260	NA

#### The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 713.0812 15.0000 mm.  
 Based on given Pad Diameter: 738.0000 13.3749 mm.  
 Based on Shell or Nozzle Thickness: 764.3515 12.0000 mm.

#### Area Required [A]:

= ( d \* tr \* F + 2 \* tn \* tr \* F \* (1-fr1) ) UG-37(c)  
 = (484\*7.426\*1+2\*12\*7.426\*1\*(1-1))  
 = 35.942 cm<sup>2</sup>

#### Reinforcement Areas per Figure UG-37.1

##### Area Available in Shell [A1]:

= d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 484 ( 1 \* 9 - 1 \* 7.426 ) - 2 \* 12  
 ( 1 \* 9 - 1 \* 7.426 ) \* ( 1 - 1 )  
 = 7.618 cm<sup>2</sup>

##### Area Available in Nozzle Wall Projecting Outward [A2]:

= ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 22.5 ) \* ( 12 - 4.213 ) \* 1  
 = 3.504 cm<sup>2</sup>

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

= (Wo<sup>2</sup> - Ar Lost)\*Fr3+((Wi-can/0.707)<sup>2</sup> - Ar Lost)\*fr2 + Wp<sup>2</sup>\*fr4  
 = (0.938 ) \* 1 + (0 ) \* 1 + 228.6<sup>2</sup> \* 1  
 = 1.747 cm<sup>2</sup>

##### Area Available in Element, also see UG-37(h) [A5]:

= (min(Dp,DL) - (Nozzle OD)) (min(tp,Tlwp,te)) \* fr4 \* 0.75  
 = ( 738 - 508 ) 15 \* 1 \* 0.75  
 = 25.875 cm<sup>2</sup>

#### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

##### Nozzle Neck to Flange Weld, Curve: D

Govrn. thk, tg = 15, tr = 4.213, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.351, Temp. Reduction = 77 °C

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Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

**Nozzle Neck to Pad Weld for the Nozzle, Curve: D**

Govrn. thk, tg = 15, tr = 4.213, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.351$ , Temp. Reduction = 77 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 15, tr = 4.213, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.351$ , Temp. Reduction = 77 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.426, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.825$ , Temp. Reduction = 10 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

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

Govrn. thk, tg = 12, tr = 7.426, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.825$ , Temp. Reduction = 10 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

Governing MDMT of the Nozzle : -48 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -48 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.02 / 51.10 = 0.451$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

**Weld Size Calculations, Description: M**

Intermediate Calc. for nozzle/shell Welds Tmin 12.0000 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 12.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	6.3630 = 0.7 * Wp mm.

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

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Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (35.94 - 7.618 + 2 * 12 * 1 * \\
 &\quad (1 * 9 - 7.426) ) 137.9 ) \\
 &= 395.76 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.504 + 25.88 + 1.747 - 0 * 1 ) * 137.9 \\
 &= 429.20 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.504 + 0 + 1 + ( 2.16 ) ) * 137.9 \\
 &= 91.89 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.504 + 0 + 1.747 + 25.88 + ( 2.16 ) ) * 137.9 \\
 &= 458.99 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 508 * 10 * 0.49 * 137.9 \\
 &= 539. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

$$\begin{aligned}
 &= (\pi/2) * DP * WP * 0.49 * SEW \\
 &= ( 3.142/2.0 ) * 738 * 9 * 0.49 * 137.9 \\
 &= 705. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 248 ) * ( 15 - 3 ) * 0.7 * 137.9 \\
 &= 902. \text{ kN}
 \end{aligned}$$

Tension, Pad Groove Weld [Tpgw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wgp * 0.74 * Seg \\
 &= ( 3.142/2 ) * 508 * 15 * 0.74 * 137.9 \\
 &= 1221. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 508 * ( 12 - 3 ) * 0.74 * 137.9 \\
 &= 733. \text{ kN}
 \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SPEW} + \text{SNW} ) = ( 704.9 + 902.4 ) = 1607 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 539.1 + 1221 + 732.8 + 0 ) = 2493 \text{ kN} \\
 \text{PATH33} &= ( \text{Spew} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 704.9 + 732.8 + 0 ) = 1438 \text{ kN}
 \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 1607 kN , must exceed W = 395 kN or W1 = 429 kN  
 Path 2-2 = 2493 kN , must exceed W = 395 kN or W2 = 91 kN  
 Path 3-3 = 1437 kN , must exceed W = 395 kN or W3 = 458 kN

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**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 23.893 bar

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 40.8232 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 252.8232 mm.

**Percent Elongation Calculations:**

% Elongation per Table UG-79-1 ( $50 \cdot t_{nom} / R_f \cdot (1 - R_f / R_o)$ ) 3.043 %

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**INPUT VALUES, Nozzle Description: A1 From : 20**

Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		500.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

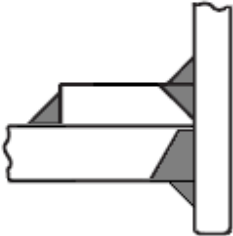
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	800.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



**Insert/Set-in Nozzle With Pad, with Inside projection**

**Reinforcement CALCULATION, Description: A1**

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

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

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

$$= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)}$$

$$= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23)$$

$$= 7.5487 \text{ mm.}$$

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

$$= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (23 \cdot 109.5) / (117.9 \cdot 1 + 0.4 \cdot 23)$$

$$= 2.1205 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.6930 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	22.5000	mm.
Normal to Vessel Wall, Inward		12.7812	mm.

Weld Strength Reduction Factor [fr1]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr4]:

$$= \min(1, S_p / S_v)$$

$$= \min(1, 137.9 / 137.9)$$

$$= 1.000$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(0.855, 1)$$

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= 0.855

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	15.490	5.811	NA
Area in Shell	A1	2.910	6.690	NA
Area in Nozzle Wall	A2	2.305	2.855	NA
Area in Inward Nozzle	A3	1.117	1.117	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	14.400	14.400	NA
TOTAL AREA AVAILABLE	Atot	22.588	26.917	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	300.2150	12.0000 mm.
Based on given Pad Diameter:	379.0750	6.0855 mm.
Based on Shell or Nozzle Thickness:	306.6952	11.1125 mm.

#### Area Required [A]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 202.8 * 7.549 * 1 + 2 * 8.113 * 7.549 * 1 * (1 - 0.855) )$$

$$= 15.490 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

##### Area Available in Shell [A1]:

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

$$= 202.8 ( 1 * 9 - 1 * 7.549 ) - 2 * 8.113$$

$$( 1 * 9 - 1 * 7.549 ) * ( 1 - 0.855 )$$

$$= 2.910 \text{ cm}^2$$

##### Area Available in Nozzle Wall Projecting Outward [A2]:

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 22.5 ) * ( 8.113 - 2.121 ) * 0.855$$

$$= 2.305 \text{ cm}^2$$

##### Area Available in Inward Nozzle [A3]:

$$= 2 * ti * \min( h, Tl, 2.5 * ti ) * fr2$$

$$= 2 * 5.112 * ( 12.78 ) * 0.855$$

$$= 1.117 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + ( 0 )^2 * 0.855 + 10^2 * 1$$

$$= 1.855 \text{ cm}^2$$

##### Area Available in Element, also see UG-37(h) [A5]:

$$= ( \min(Dp, DL) - (\text{Nozzle OD}) ) ( \min(tp, Tlwp, te) ) * fr4 * 0.75$$

$$= ( 379.1 - 219.1 ) * 12 * 1 * 0.75$$

$$= 14.400 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 5.1205 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$

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Nozzle Calcs.: A1 Nozl: 13 9:17pm Feb 18,2022

Wall Thickness, shell/head, internal pressure trb1 = 10.5487 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 10.5487 mm.  
 Wall Thickness, shell/head, external pressure trb2 = 3.3576 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 10.55, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 5.121, 10.16 )  
 = 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --&gt; OK

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

Sustained	: 50.5,	Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 244.3 N./mm <sup>2</sup>	Passed
Occasional	: 13.8,	Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4,	Allowable	: 82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:****Nozzle Neck to Flange Weld (Impact tested) :***Note:**This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :***Note:**This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 11.11, tr = 2.121, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.261, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.549, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.839, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 11.11, tr = 2.121, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.261$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -48 °C
Governing MDMT of all the sub-joints of this Junction	: -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i) (2)	-48 °C
Flange MDMT with Temp reduction per UCS-66(i) (3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: A1

Intermediate Calc. for nozzle/shell Welds	Tmin	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$5.6788 = 0.7 * t_{min}$	$7.0700 = 0.7 * W_o$ mm.
Pad Weld	$4.5000 = 0.5 * T_{minPad}$	$7.0700 = 0.7 * W_p$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (15.49 - 2.91 + 2 * 8.113 * 0.855 * \\
 &\quad (1 * 9 - 7.549) ) ) 137.9 ) \\
 &= 176.24 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 2.305 + 14.4 + 1.855 - 0 * 0.855 ) * 137.9 \\
 &= 255.93 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.305 + 1.117 + 0.855 + ( 1.249 ) ) * 137.9 \\
 &= 76.20 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.305 + 1.117 + 1.855 + 14.4 + ( 1.249 ) ) * 137.9 \\
 &= 288.55 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Nozzle Calcs.: A1 Nozl: 13 9:17pm Feb 18,2022

**Shear, Outward Nozzle Weld [Sonw]:**

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= ( 3.142/2.0 ) * 219.1 * 10 * 0.49 * 117.9$$

$$= 199. \text{ kN}$$

**Shear, Pad Element Weld [Spew]:**

$$= (\pi/2) * D_P * W_P * 0.49 * S_{EW}$$

$$= ( 3.142/2.0 ) * 379.1 * 10 * 0.49 * 137.9$$

$$= 402. \text{ kN}$$

**Shear, Nozzle Wall [Snw]:**

$$= (\pi * ( D_{lr} + D_{lo} ) / 4 ) * ( Thk - Can ) * 0.7 * S_n$$

$$= ( 3.142 * 105.5 ) * ( 11.11 - 3 ) * 0.7 * 117.9$$

$$= 222. \text{ kN}$$

**Tension, Pad Groove Weld [Tpgw]:**

$$= ( \pi/2 ) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= ( 3.142/2 ) * 219.1 * 12 * 0.74 * 137.9$$

$$= 421. \text{ kN}$$

**Tension, Shell Groove Weld [Tngw]:**

$$= (\pi/2) * D_{lo} * ( W_{gnvi-Cas} ) * 0.74 * S_{ng}$$

$$= ( 3.142/2.0 ) * 219.1 * ( 12 - 3 ) * 0.74 * 137.9$$

$$= 316. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 402.3 + 221.9 ) = 624.2 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 198.8 + 421.4 + 316 + 0 ) = 936.2 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 402.3 + 316 + 0 ) = 718.3 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 624 kN , must exceed W = 176 kN or W1 = 255 kN  
 Path 2-2 = 936 kN , must exceed W = 176 kN or W2 = 76 kN  
 Path 3-3 = 718 kN , must exceed W = 176 kN or W3 = 288 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.329 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 13.6920 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 1012.0001 mm.

**Input Echo, WRC107/537 Item 1, Description: A1 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.000	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	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".

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

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}( 452.5 ( 12.0 - 3.0 ) )$$

$$= 429.668 \text{ mm.}$$

## WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.209	4C	3.315	(A,B)
N(PHI) / ( P/Rm )	0.209	3C	2.402	(C,D)
M(PHI) / ( P )	0.209	2C1	0.050	(A,B)
M(PHI) / ( P )	0.209	1C	0.080	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.209	3A	0.874	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.209	1A	0.087	(A,B,C,D)

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N(PHI) / ( ML/(Rm**2 * Beta) )	0.209	3B	2.431	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.209	1B	0.033	(A,B,C,D)
N(x) / ( P/Rm )	0.209	3C	2.402	(A,B)
N(x) / ( P/Rm )	0.209	4C	3.315	(C,D)
M(x) / ( P )	0.209	1C1	0.084	(A,B)
M(x) / ( P )	0.209	2C	0.050	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.209	4A	1.433	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.209	2A	0.044	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.209	4B	0.826	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.209	2B	0.054	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.8	-2.8	-2.8	-2.8	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-5.4	5.4	-5.4	5.4	-8.7	8.7	-8.7	8.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-6.4	-6.4	6.4	6.4
Circ. Memb.	ML	-17.9	-17.9	17.9	17.9	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-32.1	32.1	32.1	-32.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-58.2	16.9	41.8	-11.5	-100.8	83.9	79.3	-70.5
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-2.8	-2.8	-2.8	-2.8
Long. Bend.	P	-9.1	9.1	-9.1	9.1	-5.5	5.5	-5.5	5.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend.	MC	0.0	0.0	0.0	0.0	-42.7	42.7	42.7	-42.7
Long. Memb.	ML	-6.1	-6.1	6.1	6.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-52.0	52.0	52.0	-52.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-69.2	53.0	47.0	-38.8	-61.5	34.9	45.0	-29.4
Shear	VC	1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear	MT	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Tot. Shear		6.4	6.4	4.2	4.2	4.2	4.2	6.4	6.4
Str. Int.		72.1	54.1	49.3	39.4	101.2	84.2	80.5	71.4

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.367	4C	4.320	(A,B)
N(PHI) / ( P/Rm )	0.367	3C	1.750	(C,D)
M(PHI) / ( P )	0.367	2C1	0.009	(A,B)
M(PHI) / ( P )	0.367	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.367	3A	1.360	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.367	1A	0.059	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.367	3B	2.531	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.367	1B	0.007	(A,B,C,D)
N(x) / ( P/Rm )	0.367	3C	1.750	(A,B)
N(x) / ( P/Rm )	0.367	4C	4.320	(C,D)

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M(x) / ( P )	0.367	1C1	0.022	(A,B)
M(x) / ( P )	0.367	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.367	4A	4.848	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.367	2A	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.367	4B	1.484	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.367	2B	0.010	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-8.5	-8.5	-8.5	-8.5	-3.4	-3.4	-3.4	-3.4
Circ. Bend. P		-5.2	5.2	-5.2	5.2	-38.6	38.6	-38.6	38.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-13.7	-13.7	13.7	13.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-177.9	177.9	177.9	-177.9
Circ. Memb. ML		-25.5	-25.5	25.5	25.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-59.3	-8.7	32.0	2.0	-233.7	199.4	149.5	-129.0
Long. Memb. P		-3.4	-3.4	-3.4	-3.4	-8.5	-8.5	-8.5	-8.5
Long. Bend. P		-13.2	13.2	-13.2	13.2	-19.8	19.8	-19.8	19.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-48.8	-48.8	48.8	48.8
Long. Bend. MC		0.0	0.0	0.0	0.0	-70.3	70.3	70.3	-70.3
Long. Memb. ML		-14.9	-14.9	14.9	14.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-62.5	25.8	29.3	-6.3	-147.3	32.8	90.7	-10.1
Shear VC		1.5	1.5	-1.5	-1.5	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Shear MT		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear		5.6	5.6	2.6	2.6	2.6	2.6	5.6	5.6
Str. Int.		66.8	36.2	33.6	9.8	233.7	199.4	150.0	129.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-20.7	-20.7	15.1	15.1	-8.4	-8.4	4.4	4.4
Circ. Q (SUS)		-37.5	37.5	26.6	-26.6	-92.3	92.3	74.9	-74.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-8.1	-8.1	4.1	4.1	-13.3	-13.3	7.8	7.8
Long. Q (SUS)		-61.1	61.1	42.9	-42.9	-48.2	48.2	37.2	-37.2

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.1	1.1	-1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Pm (SUS)	48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3	50.3
-----									
Pm+Pl (SUS)	27.4	29.7	63.1	65.4	39.6	41.9	52.4	54.7	
-----									
Pm+Pl+Q (Total)	46.3	80.2	90.6	54.3	53.9	134.4	128.0	22.6	

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
-----			
Pm (SUS)	50.25	137.90	Passed
Pm+Pl (SUS)	65.43	206.85	Passed
Pm+Pl+Q (TOTAL)	134.37	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
-----									
Circ. Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Circ. Pl (SUS)		-34.0	-34.0	17.0	17.0	-17.1	-17.1	10.3	10.3
Circ. Q (SUS)		-25.3	25.3	15.0	-15.0	-216.5	216.5	139.3	-139.3
-----									
Long. Pm (SUS)		56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7
Long. Pl (SUS)		-18.4	-18.4	11.5	11.5	-57.3	-57.3	40.3	40.3
Long. Q (SUS)		-44.2	44.2	17.8	-17.8	-90.1	90.1	50.4	-50.4
-----									
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.5	1.5	-1.5	-1.5	-1.5	-1.5	1.5	1.5
Shear Q (SUS)		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
-----									
Pm+Pl (SUS)		79.5	81.8	130.4	132.7	96.9	99.2	123.7	126.0
-----									
Pm+Pl+Q (Total)		61.0	108.2	145.4	117.8	120.5	315.1	263.1	60.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
-----			
Pm (SUS)	115.67	137.90	Passed
Pm+Pl (SUS)	132.69	206.85	Passed
Pm+Pl+Q (TOTAL)	315.10	413.70	Passed

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**INPUT VALUES, Nozzle Description: B From : 20**

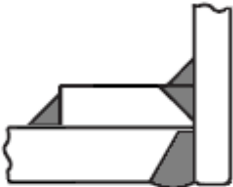
Pressure for Reinforcement Calculations	P	23.040	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2000.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: B**

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

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.04 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23.04) \\
 &= 7.5621 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.04 \cdot 109.5) / (117.9 \cdot 1 + 0.4 \cdot 23.04) \\
 &= 2.1242 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.6930 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000	mm.

**Weld Strength Reduction Factor [fr1]:**

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

**Weld Strength Reduction Factor [fr2]:**

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

**Weld Strength Reduction Factor [fr4]:**

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

**Weld Strength Reduction Factor [fr3]:**

$$\begin{aligned}
 &= \min( fr2, fr4 ) \\
 &= \min( 0.855, 1 ) \\
 &= 0.855
 \end{aligned}$$

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	15.518	5.811	NA
Area in Shell	A1	2.883	6.690	NA
Area in Nozzle Wall	A2	2.304	2.855	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	19.200	19.200	NA
TOTAL AREA AVAILABLE	Atot	26.242	30.600	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	289.7040	12.0000 mm.
Based on given Pad Diameter:	379.0750	5.2972 mm.
Based on Shell or Nozzle Thickness:	295.3448	11.1125 mm.

Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (202.8 * 7.562 * 1 + 2 * 8.113 * 7.562 * 1 * (1 - 0.855))$$

$$= 15.518 \text{ cm}^2$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 202.8 (1 * 9 - 1 * 7.562) - 2 * 8.113 (1 * 9 - 1 * 7.562) * (1 - 0.855)$$

$$= 2.883 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 22.5) * (8.113 - 2.124) * 0.855$$

$$= 2.304 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + (0)^2 * 0.855 + 10^2 * 1$$

$$= 1.855 \text{ cm}^2$$

Area Available in Element [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) * (\min(tp, Tlwp, te)) * fr4$$

$$= (379.1 - 219.1) * 12 * 1$$

$$= 19.200 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1242 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5621 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5621 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 10.1600 mm.

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Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 10.16, \max( 10.56, 4.5 ) ]$   
 $= 10.1600 \text{ mm.}$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( ta, tb )$   
 $= \max( 5.124, 10.16 )$   
 $= 10.1600 \text{ mm.}$

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

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

Sustained	: 50.5, Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0, Allowable	: 244.3 N./mm <sup>2</sup>	Passed
Occasional	: 13.9, Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4, Allowable	: 82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 11.11, tr = 2.124, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.262$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.562, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.84$ , Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 11.11, tr = 2.124, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.262$ , Temp. Reduction = 78 °C

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Nozzle Calcs.: B Nozl: 14 9:17pm Feb 18,2022

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.04/51.10 = 0.451

*Note:**Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.***Weld Size Calculations, Description: B**

Intermediate Calc. for nozzle/shell Welds Tmin 8.1125 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	4.5000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (15.52 - 2.883 + 2 * 8.113 * 0.855 * \\
 &\quad (1 * 9 - 7.562) ) 137.9 ) \\
 &= 176.97 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 2.304 + 19.2 + 1.855 - 0 * 0.855 ) * 137.9 \\
 &= 322.09 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.304 + 0 + 0.855 + ( 1.249 ) ) * 137.9 \\
 &= 60.77 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.304 + 0 + 1.855 + 19.2 + ( 1.249 ) ) * 137.9 \\
 &= 339.31 \text{ kN}
 \end{aligned}$$

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 219.1 * 10 * 0.49 * 117.9 \\
 &= 199. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

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Nozzle Calcs.: B Noz1: 14 9:17pm Feb 18,2022

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.142/2.0 ) * 379.1 * 10 * 0.49 * 137.9$$

$$= 402. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.142 * 105.5 ) * ( 11.11 - 3 ) * 0.7 * 117.9$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.142/2 ) * 219.1 * 12 * 0.74 * 137.9$$

$$= 421. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 219.1 * ( 12 - 3 ) * 0.74 * 137.9$$

$$= 316. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 402.3 + 221.9 ) = 624.2 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 198.8 + 421.4 + 316 + 0 ) = 936.2 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 402.3 + 316 + 0 ) = 718.3 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 624 kN , must exceed W = 176 kN or W1 = 322 kN  
 Path 2-2 = 936 kN , must exceed W = 176 kN or W2 = 60 kN  
 Path 3-3 = 718 kN , must exceed W = 176 kN or W3 = 339 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 27.369 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 13.6920 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.6920 mm.

#### Input Echo, WRC107/537 Item 1, Description: B :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	

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## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Nozzle Calcs.: B Nozl: 14 9:17pm Feb 18,2022

Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.040	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	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".

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

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}( 452.5 ( 12.0 - 3.0 ) )$$

$$= 429.668 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.209	4C	3.315	(A,B)
N(PHI) / ( P/Rm )	0.209	3C	2.402	(C,D)
M(PHI) / ( P )	0.209	2C1	0.050	(A,B)
M(PHI) / ( P )	0.209	1C	0.080	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.209	3A	0.874	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.209	1A	0.087	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.209	3B	2.431	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.209	1B	0.033	(A,B,C,D)
N(x) / ( P/Rm )	0.209	3C	2.402	(A,B)
N(x) / ( P/Rm )	0.209	4C	3.315	(C,D)
M(x) / ( P )	0.209	1C1	0.084	(A,B)

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M(x)	/ ( P )	0.209	2C	0.050	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.209	4A	1.433	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.209	2A	0.044	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.209	4B	0.826	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.209	2B	0.054	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-2.8	-2.8	-2.8	-2.8	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P		-5.4	5.4	-5.4	5.4	-8.7	8.7	-8.7	8.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-6.4	-6.4	6.4	6.4
Circ. Memb. ML		-17.9	-17.9	17.9	17.9	0.0	0.0	0.0	0.0
Circ. Bend. ML		-32.1	32.1	32.1	-32.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-58.2	16.9	41.8	-11.5	-100.8	83.9	79.3	-70.5
Long. Memb. P		-2.0	-2.0	-2.0	-2.0	-2.8	-2.8	-2.8	-2.8
Long. Bend. P		-9.1	9.1	-9.1	9.1	-5.5	5.5	-5.5	5.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-42.7	42.7	42.7	-42.7
Long. Memb. ML		-6.1	-6.1	6.1	6.1	0.0	0.0	0.0	0.0
Long. Bend. ML		-52.0	52.0	52.0	-52.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-69.2	53.0	47.0	-38.8	-61.5	34.9	45.0	-29.4
Shear VC		1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear MT		5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Tot. Shear		6.4	6.4	4.2	4.2	4.2	4.2	6.4	6.4
Str. Int.		72.1	54.1	49.3	39.4	101.2	84.2	80.5	71.4

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.367	4C	4.320	(A,B)
N(PHI) / ( P/Rm )	0.367	3C	1.750	(C,D)
M(PHI) / ( P )	0.367	2C1	0.009	(A,B)
M(PHI) / ( P )	0.367	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.367	3A	1.360	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.367	1A	0.059	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.367	3B	2.531	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.367	1B	0.007	(A,B,C,D)
N(x) / ( P/Rm )	0.367	3C	1.750	(A,B)
N(x) / ( P/Rm )	0.367	4C	4.320	(C,D)
M(x) / ( P )	0.367	1C1	0.022	(A,B)
M(x) / ( P )	0.367	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.367	4A	4.848	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.367	2A	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.367	4B	1.484	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.367	2B	0.010	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-8.5	-8.5	-8.5	-8.5	-3.4	-3.4	-3.4	-3.4
Circ. Bend. P		-5.2	5.2	-5.2	5.2	-38.6	38.6	-38.6	38.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-13.7	-13.7	13.7	13.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-177.9	177.9	177.9	-177.9
Circ. Memb. ML		-25.5	-25.5	25.5	25.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-59.3	-8.7	32.0	2.0	-233.7	199.4	149.5	-129.0
Long. Memb. P		-3.4	-3.4	-3.4	-3.4	-8.5	-8.5	-8.5	-8.5
Long. Bend. P		-13.2	13.2	-13.2	13.2	-19.8	19.8	-19.8	19.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-48.8	-48.8	48.8	48.8
Long. Bend. MC		0.0	0.0	0.0	0.0	-70.3	70.3	70.3	-70.3
Long. Memb. ML		-14.9	-14.9	14.9	14.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-62.5	25.8	29.3	-6.3	-147.3	32.8	90.7	-10.1
Shear VC		1.5	1.5	-1.5	-1.5	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Shear MT		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear		5.6	5.6	2.6	2.6	2.6	2.6	5.6	5.6
Str. Int.		66.8	36.2	33.6	9.8	233.7	199.4	150.0	129.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-20.7	-20.7	15.1	15.1	-8.4	-8.4	4.4	4.4
Circ. Q (SUS)		-37.5	37.5	26.6	-26.6	-92.3	92.3	74.9	-74.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-8.1	-8.1	4.1	4.1	-13.3	-13.3	7.8	7.8
Long. Q (SUS)		-61.1	61.1	42.9	-42.9	-48.2	48.2	37.2	-37.2
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)		5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Pm+Pl (SUS)		27.5	29.8	63.2	65.5	39.6	41.9	52.5	54.8

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Pm+Pl+Q (Total)	46.3	80.2	90.7	54.3	53.8	134.5	128.1	22.5
-----------------	------	------	------	------	------	-------	-------	------

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.34	137.90	Passed
Pm+Pl (SUS)	65.52	206.85	Passed
Pm+Pl+Q (TOTAL)	134.46	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.6	115.9	113.6	115.9	113.6	115.9	113.6	115.9
Circ. Pl (SUS)		-34.0	-34.0	17.0	17.0	-17.1	-17.1	10.3	10.3
Circ. Q (SUS)		-25.3	25.3	15.0	-15.0	-216.5	216.5	139.3	-139.3
Long. Pm (SUS)		56.8	56.8	56.8	56.8	56.8	56.8	56.8	56.8
Long. Pl (SUS)		-18.4	-18.4	11.5	11.5	-57.3	-57.3	40.3	40.3
Long. Q (SUS)		-44.2	44.2	17.8	-17.8	-90.1	90.1	50.4	-50.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.5	1.5	-1.5	-1.5	-1.5	-1.5	1.5	1.5
Shear Q (SUS)		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)		113.6	115.9	113.6	115.9	113.6	115.9	113.6	115.9
Pm+Pl (SUS)		79.7	82.0	130.6	132.9	97.0	99.3	123.9	126.2
Pm+Pl+Q (Total)		61.1	108.4	145.6	118.0	120.3	315.3	263.3	60.8

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.87	137.90	Passed
Pm+Pl (SUS)	132.89	206.85	Passed
Pm+Pl+Q (TOTAL)	315.30	413.70	Passed

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**INPUT VALUES, Nozzle Description: A2 From : 20**

Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3300.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

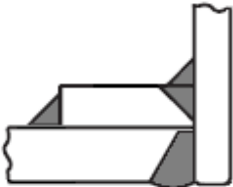
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: A2**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

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

$$= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)}$$

$$= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23)$$

$$= 7.5487 \text{ mm.}$$

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

$$= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (23 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23)$$

$$= 0.5839 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3261 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr4]:

$$= \min(1, S_p / S_v)$$

$$= \min(1, 137.9 / 137.9)$$

$$= 1.000$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

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$$= \min(0.855, 1)$$

$$= 0.855$$

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.954	1.483	NA
Area in Shell	A1	0.721	1.658	NA
Area in Nozzle Wall	A2	1.563	1.662	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	5.009	5.009	NA
TOTAL AREA AVAILABLE	Atot	8.148	9.184	NA

#### The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 67.1197 12.0000 mm.  
 Based on given Pad Diameter: 160.3250 1.9533 mm.  
 Based on Shell or Nozzle Thickness: 70.9898 7.6454 mm.

#### Area Required [A]:

$$= (d \cdot tr \cdot F + 2 \cdot tn \cdot tr \cdot F \cdot (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 \cdot 7.549 \cdot 1 + 2 \cdot 4.645 \cdot 7.549 \cdot 1 \cdot (1 - 0.855))$$

$$= 3.954 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

##### Area Available in Shell [A1]:

$$= d (E1 \cdot t - F \cdot tr) - 2 \cdot tn (E1 \cdot t - F \cdot tr) \cdot (1 - fr1)$$

$$= 51.03 (1 \cdot 9 - 1 \cdot 7.549) - 2 \cdot 4.645 (1 \cdot 9 - 1 \cdot 7.549) \cdot (1 - 0.855)$$

$$= 0.721 \text{ cm}^2$$

##### Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 \cdot Tlwp) \cdot (tn - trn) \cdot fr2$$

$$= (2 \cdot 22.5) \cdot (4.645 - 0.584) \cdot 0.855$$

$$= 1.563 \text{ cm}^2$$

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

$$= Wo^2 \cdot fr3 + (Wi - can/0.707)^2 \cdot fr2 + Wp^2 \cdot fr4$$

$$= 10^2 \cdot 0.855 + (0)^2 \cdot 0.855 + 0^2 \cdot 1$$

$$= 0.855 \text{ cm}^2$$

##### Area Available in Element [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) \cdot (\min(tp, Tlwp, te)) \cdot fr4$$

$$= (102.1 - 60.33) \cdot 12 \cdot 1$$

$$= 5.009 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 3.5839 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 10.5487 \text{ mm.}$   
 Wall Thickness  $tb1 = \max(trb1, tr16b) = 10.5487 \text{ mm.}$   
 Wall Thickness, shell/head, external pressure  $trb2 = 3.3576 \text{ mm.}$   
 Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

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Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 6.42, max( 10.55, 4.5 ) ]  
 = 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.584, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

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

Sustained	:	62.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.549, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.839, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1

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Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -48 °C
Governing MDMT of all the sub-joints of this Junction	: -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: A2

Intermediate Calc. for nozzle/shell Welds	Tmin	4.6454 mm.
Intermediate Calc. for pad/shell Welds	TminPad	9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$3.2518 = 0.7 * t_{min}$	$7.0700 = 0.7 * W_o$ mm.
Pad Weld	$4.5000 = 0.5 * T_{minPad}$	$7.0700 = 0.7 * W_p$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (3.954 - 0.721 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 9 - 7.549) ) 137.9 ) \\
 &= 46.17 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= ( 1.563 + 5.009 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 102.41 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.563 + 0 + 0.855 + ( 0.715 ) ) * 137.9 \\
 &= 43.19 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.563 + 0 + 0.855 + 5.009 + ( 0.715 ) ) * 137.9 \\
 &= 112.27 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 60.33 * 10 * 0.49 * 117.9 \\
 &= 55. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.142/2.0 ) * 160.3 * 10 * 0.49 * 137.9$$

$$= 170. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9$$

$$= 34. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.142/2 ) * 60.33 * 12 * 0.74 * 137.9$$

$$= 116. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 60.33 * ( 12 - 3 ) * 0.74 * 137.9$$

$$= 87. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 170.2 + 33.53 ) = 203.7 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 54.74 + 116 + 87.02 + 0 ) = 257.8 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 170.2 + 87.02 + 0 ) = 257.2 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 203 kN , must exceed W = 46 kN or W1 = 102 kN  
 Path 2-2 = 257 kN , must exceed W = 46 kN or W2 = 43 kN  
 Path 3-3 = 257 kN , must exceed W = 46 kN or W3 = 112 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.329 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 1.0234 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0234 mm.

**Input Echo, WRC107/537 Item 1, Description: A2 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.

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Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	160.325	mm.
Design Internal Pressure	Dp	23.000	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	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".

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

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 60.325 + 2 * 1.65 * \text{sqrt}(452.5 (12.0 - 3.0))$$

$$= 270.918 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.058	4C	4.229	(A,B)
N(PHI) / ( P/Rm )	0.058	3C	4.165	(C,D)
M(PHI) / ( P )	0.058	2C1	0.168	(A,B)
M(PHI) / ( P )	0.058	1C	0.202	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.058	3A	0.246	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.058	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.058	3B	0.967	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.058	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.058	3C	4.165	(A,B)

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N(x) / ( P/Rm )	0.058	4C	4.229	(C,D)
M(x) / ( P )	0.058	1C1	0.207	(A,B)
M(x) / ( P )	0.058	2C	0.166	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.058	4A	0.309	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.058	2A	0.063	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.058	4B	0.238	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.058	2B	0.099	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P		-4.6	4.6	-4.6	4.6	-5.5	5.5	-5.5	5.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-21.4	21.4	21.4	-21.4
Circ. Memb. ML		-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.3	12.3	12.3	-12.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-19.3	14.5	8.4	-7.1	-28.2	25.7	15.4	-16.4
Long. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Long. Bend. P		-5.6	5.6	-5.6	5.6	-4.5	4.5	-4.5	4.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-12.9	12.9	12.9	-12.9
Long. Memb. ML		-0.4	-0.4	0.4	0.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-20.5	20.5	20.5	-20.5	0.0	0.0	0.0	0.0
Tot. Long. Str.		-27.4	24.9	14.3	-15.3	-18.8	16.1	8.0	-8.8
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.2	5.2	3.2	3.2	3.2	3.2	5.2	5.2
Str. Int.		29.9	27.0	15.7	16.4	29.1	26.6	18.1	19.0

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.155	4C	7.575	(A,B)
N(PHI) / ( P/Rm )	0.155	3C	5.538	(C,D)
M(PHI) / ( P )	0.155	2C1	0.044	(A,B)
M(PHI) / ( P )	0.155	1C !	0.077	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.155	3A	2.036	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.155	1A	0.079	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.155	3B	5.450	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.155	1B	0.030	(A,B,C,D)
N(x) / ( P/Rm )	0.155	3C	5.538	(A,B)
N(x) / ( P/Rm )	0.155	4C	7.575	(C,D)
M(x) / ( P )	0.155	1C1	0.080	(A,B)
M(x) / ( P )	0.155	2C !	0.044	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.155	4A	3.512	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.155	2A	0.040	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.155 4B 1.955 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.155 2B 0.042 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.7	-3.7	-3.7	-3.7	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P		-6.5	6.5	-6.5	6.5	-11.5	11.5	-11.5	11.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-33.4	33.4	33.4	-33.4
Circ. Memb. ML		-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.6	12.6	12.6	-12.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.5	7.8	10.0	-2.2	-50.5	39.3	22.1	-21.8
Long. Memb. P		-2.7	-2.7	-2.7	-2.7	-3.7	-3.7	-3.7	-3.7
Long. Bend. P		-11.9	11.9	-11.9	11.9	-6.5	6.5	-6.5	6.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.9	-4.9	4.9	4.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-16.7	16.7	16.7	-16.7
Long. Memb. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-17.7	17.7	17.7	-17.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-35.1	24.2	5.8	-5.8	-31.8	14.6	11.5	-9.1
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Tot. Shear		2.3	2.3	0.5	0.5	0.5	0.5	2.3	2.3
Str. Int.		36.0	24.5	10.1	5.9	50.5	39.3	22.6	22.2

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-2.4	-2.4	0.6	0.6	-1.3	-1.3	-0.5	-0.5
Circ. Q (SUS)		-16.9	16.9	7.7	-7.7	-26.9	26.9	15.9	-15.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-1.2	-1.2	-0.5	-0.5	-1.4	-1.4	-0.4	-0.4
Long. Q (SUS)		-26.1	26.1	14.8	-14.8	-17.4	17.4	8.4	-8.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3

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Pm+Pl (SUS)	45.6	47.9	48.6	50.9	46.7	49.0	47.5	49.8
Pm+Pl+Q (Total)	33.7	66.2	56.9	43.4	20.4	76.2	64.2	35.2

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.25	137.90	Passed
Pm+Pl (SUS)	50.93	206.85	Passed
Pm+Pl+Q (TOTAL)	76.20	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Circ. Pl (SUS)		-11.3	-11.3	3.9	3.9	-5.6	-5.6	0.1	0.1
Circ. Q (SUS)		-19.1	19.1	6.1	-6.1	-44.9	44.9	22.0	-22.0
Long. Pm (SUS)		56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7
Long. Pl (SUS)		-5.5	-5.5	0.0	0.0	-8.6	-8.6	1.2	1.2
Long. Q (SUS)		-29.7	29.7	5.8	-5.8	-23.2	23.2	10.3	-10.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Pm+Pl (SUS)		102.0	104.3	117.3	119.6	107.8	110.1	113.5	115.8
Pm+Pl+Q (Total)		83.0	123.6	123.4	113.4	62.9	155.0	135.5	93.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.67	137.90	Passed
Pm+Pl (SUS)	119.59	206.85	Passed
Pm+Pl+Q (TOTAL)	155.00	413.70	Passed

**INPUT VALUES, Nozzle Description: PT From : 20**

Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1750.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

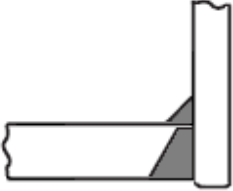
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		1.5000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	XXS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	11.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
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)**

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

**Reinforcement CALCULATION, Description: PT**

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

Actual Outside Diameter Used in Calculation 1.900 in.  
 Actual Thickness Used in Calculation 0.350 in.

Nozzle input data check completed without errors.

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

$$= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)}$$

$$= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23)$$

$$= 7.5487 \text{ mm.}$$

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

$$= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (23 \cdot 24.13) / (117.9 \cdot 1 + 0.4 \cdot 23)$$

$$= 0.4671 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2542 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	72.9600	mm.
Parallel to Vessel Wall, opening length	d	36.4800	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	14.7250	mm.

Weld Strength Reduction Factor [fr1]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

$$= \min(1, S_n / S_v)$$

$$= \min(1, 117.9 / 137.9)$$

$$= 0.855$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(0.855, 1)$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.883	1.081	NA
Area in Shell	A1	0.505	1.160	NA
Area in Nozzle Wall	A2	1.365	1.419	NA

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Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.035	1.035	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.905	3.614	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 36.48 * 7.549 * 1 + 2 * 5.89 * 7.549 * 1 * (1 - 0.855) ) \\
 &= 2.883 \text{ cm}^2
 \end{aligned}$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 36.48 ( 1 * 9 - 1 * 7.549 ) - 2 * 5.89 \\
 &\quad ( 1 * 9 - 1 * 7.549 ) * ( 1 - 0.855 ) \\
 &= 0.505 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 14.72 ) ( 5.89 - 0.467 ) 0.855 \\
 &= 1.365 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 11^2 * 0.855 + ( 0 )^2 * 0.855 \\
 &= 1.035 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.4671 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5487 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5487 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.2200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.22, \max( 10.55, 4.5 ) ] \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.467, 6.22 ) \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 8.8900 mm. --> OK

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

Note:

This Material was specified as being an Impact Tested (Low Temperature) Material.

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Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 8.89, tr = 0.467, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.0793$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :  
 Design Pressure/Ambient Rating =  $23.00/51.10 = 0.450$

Note:  
 Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: PT

Intermediate Calc. for nozzle/shell Welds Tmin 5.8900 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$4.1230 = 0.7 * t_{min}$	$7.7770 = 0.7 * W_o$ mm.

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

Weld Load [W]:  
 $= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$   
 $= \max( 0, (2.883 - 0.505 + 2 * 5.89 * 0.855 * (1 * 9 - 7.549) ) 137.9 )$   
 $= 34.81$  kN

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

Weld Load [W1]:  
 $= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv$   
 $= ( 1.365 + 0 + 1.035 - 0 * 0.855 ) * 137.9$   
 $= 33.09$  kN

Weld Load [W2]:  
 $= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$   
 $= ( 1.365 + 0 + 1.035 + ( 0.906 ) ) * 137.9$   
 $= 45.59$  kN

Weld Load [W3]:  
 $= (A2+A3+A4+A5+(2*tn*t*fr1)) * S$   
 $= ( 1.365 + 0 + 1.035 + 0 + ( 0.906 ) ) * 137.9$   
 $= 45.59$  kN

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

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$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 48.26 * 11 * 0.49 * 117.9 \\
 &= 48. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 21.18 ) * ( 8.89 - 3 ) * 0.7 * 117.9 \\
 &= 32. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 48.26 * ( 12 - 3 ) * 0.74 * 137.9 \\
 &= 70. \text{ kN}
 \end{aligned}$$

#### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 48.17 + 32.35 ) = 80.52 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 48.17 + 0 + 69.62 + 0 ) = 117.8 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 48.17 + 69.62 + 0 ) = 117.8 \text{ kN}
 \end{aligned}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 80 kN , must exceed W = 34 kN or W1 = 33 kN  
 Path 2-2 = 117 kN , must exceed W = 34 kN or W2 = 45 kN  
 Path 3-3 = 117 kN , must exceed W = 34 kN or W3 = 45 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 23.089 bar  
 Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 0.6547 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.6547 mm.

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 Nozzle Calcs.: A3 Nozl: 17 9:17pm Feb 18,2022

**INPUT VALUES, Nozzle Description: A3 From : 20**

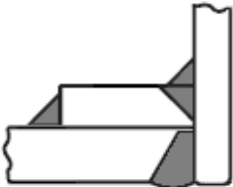
Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1200.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: A3**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 7.5487 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 0.5839 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2901 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min(0.855, 1)$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.954	1.483	NA
Area in Shell	A1	0.721	1.658	NA
Area in Nozzle Wall	A2	1.563	1.676	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.547	0.547	NA
Area in Element	A5	5.009	5.009	NA
TOTAL AREA AVAILABLE	Atot	7.840	8.890	NA

**The Internal Pressure Case Governs the Analysis.**

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	69.6847	12.0000 mm.
Based on given Pad Diameter:	160.3250	2.6906 mm.
Based on Shell or Nozzle Thickness:	75.0158	7.6454 mm.

**Area Required [A]:**

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 * 7.549 * 1 + 2 * 4.645 * 7.549 * 1 * (1 - 0.855))$$

$$= 3.954 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

**Area Available in Shell [A1]:**

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

$$= 51.03 * (1 * 9 - 1 * 7.549) - 2 * 4.645 * (1 * 9 - 1 * 7.549) * (1 - 0.855)$$

$$= 0.721 \text{ cm}^2$$

**Area Available in Nozzle Wall Projecting Outward [A2]:**

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 22.5) * (4.645 - 0.584) * 0.855$$

$$= 1.563 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 8^2 * 0.855 + (0)^2 * 0.855 + 0^2 * 1$$

$$= 0.547 \text{ cm}^2$$

**Area Available in Element [A5]:**

$$= (\min(Dp, DL) - \text{Nozzle OD}) * (\min(tp, Tlwp, te)) * fr4$$

$$= (102.1 - 60.33) * 12 * 1$$

$$= 5.009 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.5839 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5487 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5487 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 6.42, max( 10.55, 4.5 ) ]  
 = 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.584, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

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

Sustained	:	62.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.549, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.839, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1

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Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: A3

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$3.2518 = 0.7 * tmin.$	$5.6560 = 0.7 * Wo$ mm.
Pad Weld	$4.5000 = 0.5 * TminPad$	$7.0700 = 0.7 * Wp$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (3.954 - 0.721 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 9 - 7.549) ) 137.9 ) \\
 &= 46.17 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= ( 1.563 + 5.009 + 0.547 - 0 * 0.855 ) * 137.9 \\
 &= 98.16 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.563 + 0 + 0.547 + ( 0.715 ) ) * 137.9 \\
 &= 38.95 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.563 + 0 + 0.547 + 5.009 + ( 0.715 ) ) * 137.9 \\
 &= 108.02 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 60.33 * 8 * 0.49 * 117.9 \\
 &= 44. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.142/2.0 ) * 160.3 * 10 * 0.49 * 137.9$$

$$= 170. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9$$

$$= 34. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.142/2 ) * 60.33 * 12 * 0.74 * 137.9$$

$$= 116. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 60.33 * ( 12 - 3 ) * 0.74 * 137.9$$

$$= 87. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 170.2 + 33.53 ) = 203.7 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 43.79 + 116 + 87.02 + 0 ) = 246.8 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 170.2 + 87.02 + 0 ) = 257.2 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 203 kN , must exceed W = 46 kN or W1 = 98 kN  
 Path 2-2 = 246 kN , must exceed W = 46 kN or W2 = 38 kN  
 Path 3-3 = 257 kN , must exceed W = 46 kN or W3 = 108 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.329 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 1.0234 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0234 mm.

**Input Echo, WRC107/537 Item 1, Description: A3 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.

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Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	160.325	mm.
Design Internal Pressure	Dp	23.000	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	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".

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

= NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 60.325 + 2 \* 1.65 \* sqrt( 452.5 ( 12.0 - 3.0 ) )  
 = 270.918 mm.

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.058	4C	4.229	(A,B)
N(PHI) / ( P/Rm )	0.058	3C	4.165	(C,D)
M(PHI) / ( P )	0.058	2C1	0.168	(A,B)
M(PHI) / ( P )	0.058	1C	0.202	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.058	3A	0.246	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.058	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.058	3B	0.967	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.058	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.058	3C	4.165	(A,B)

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N(x)	/ ( P/Rm )	0.058	4C	4.229	(C,D)
M(x)	/ ( P )	0.058	1C1	0.207	(A,B)
M(x)	/ ( P )	0.058	2C	0.166	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.058	4A	0.309	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.058	2A	0.063	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.058	4B	0.238	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.058	2B	0.099	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P		-4.6	4.6	-4.6	4.6	-5.5	5.5	-5.5	5.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-21.4	21.4	21.4	-21.4
Circ. Memb. ML		-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.3	12.3	12.3	-12.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-19.3	14.5	8.4	-7.1	-28.2	25.7	15.4	-16.4
Long. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Long. Bend. P		-5.6	5.6	-5.6	5.6	-4.5	4.5	-4.5	4.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-12.9	12.9	12.9	-12.9
Long. Memb. ML		-0.4	-0.4	0.4	0.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-20.5	20.5	20.5	-20.5	0.0	0.0	0.0	0.0
Tot. Long. Str.		-27.4	24.9	14.3	-15.3	-18.8	16.1	8.0	-8.8
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.2	5.2	3.2	3.2	3.2	3.2	5.2	5.2
Str. Int.		29.9	27.0	15.7	16.4	29.1	26.6	18.1	19.0

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.155	4C	7.575	(A,B)
N(PHI) / ( P/Rm )	0.155	3C	5.538	(C,D)
M(PHI) / ( P )	0.155	2C1	0.044	(A,B)
M(PHI) / ( P )	0.155	1C !	0.077	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.155	3A	2.036	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.155	1A	0.079	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.155	3B	5.450	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.155	1B	0.030	(A,B,C,D)
N(x) / ( P/Rm )	0.155	3C	5.538	(A,B)
N(x) / ( P/Rm )	0.155	4C	7.575	(C,D)
M(x) / ( P )	0.155	1C1	0.080	(A,B)
M(x) / ( P )	0.155	2C !	0.044	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.155	4A	3.512	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.155	2A	0.040	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.155 4B 1.955 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.155 2B 0.042 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.7	-3.7	-3.7	-3.7	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P		-6.5	6.5	-6.5	6.5	-11.5	11.5	-11.5	11.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-33.4	33.4	33.4	-33.4
Circ. Memb. ML		-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.6	12.6	12.6	-12.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.5	7.8	10.0	-2.2	-50.5	39.3	22.1	-21.8
Long. Memb. P		-2.7	-2.7	-2.7	-2.7	-3.7	-3.7	-3.7	-3.7
Long. Bend. P		-11.9	11.9	-11.9	11.9	-6.5	6.5	-6.5	6.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.9	-4.9	4.9	4.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-16.7	16.7	16.7	-16.7
Long. Memb. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-17.7	17.7	17.7	-17.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-35.1	24.2	5.8	-5.8	-31.8	14.6	11.5	-9.1
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Tot. Shear		2.3	2.3	0.5	0.5	0.5	0.5	2.3	2.3
Str. Int.		36.0	24.5	10.1	5.9	50.5	39.3	22.6	22.2

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-2.4	-2.4	0.6	0.6	-1.3	-1.3	-0.5	-0.5
Circ. Q (SUS)		-16.9	16.9	7.7	-7.7	-26.9	26.9	15.9	-15.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-1.2	-1.2	-0.5	-0.5	-1.4	-1.4	-0.4	-0.4
Long. Q (SUS)		-26.1	26.1	14.8	-14.8	-17.4	17.4	8.4	-8.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3

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Pm+Pl (SUS)	45.6	47.9	48.6	50.9	46.7	49.0	47.5	49.8
Pm+Pl+Q (Total)	33.7	66.2	56.9	43.4	20.4	76.2	64.2	35.2

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.25	137.90	Passed
Pm+Pl (SUS)	50.93	206.85	Passed
Pm+Pl+Q (TOTAL)	76.20	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Circ. Pl (SUS)		-11.3	-11.3	3.9	3.9	-5.6	-5.6	0.1	0.1
Circ. Q (SUS)		-19.1	19.1	6.1	-6.1	-44.9	44.9	22.0	-22.0
Long. Pm (SUS)		56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7
Long. Pl (SUS)		-5.5	-5.5	0.0	0.0	-8.6	-8.6	1.2	1.2
Long. Q (SUS)		-29.7	29.7	5.8	-5.8	-23.2	23.2	10.3	-10.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Pm+Pl (SUS)		102.0	104.3	117.3	119.6	107.8	110.1	113.5	115.8
Pm+Pl+Q (Total)		83.0	123.6	123.4	113.4	62.9	155.0	135.5	93.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.67	137.90	Passed
Pm+Pl (SUS)	119.59	206.85	Passed
Pm+Pl+Q (TOTAL)	155.00	413.70	Passed

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Nozzle Calcs.: LT1 Nozl: 18 9:17pm Feb 18,2022

**INPUT VALUES, Nozzle Description: LT1 From : 20**

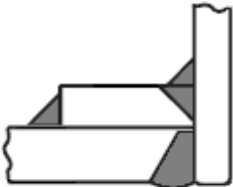
Pressure for Reinforcement Calculations	P	23.040	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3700.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: LT1**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.04 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23.04) \\
 &= 7.5621 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.04 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23.04) \\
 &= 0.5849 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2901 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min(0.855, 1)$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.961	1.483	NA
Area in Shell	A1	0.714	1.658	NA
Area in Nozzle Wall	A2	1.562	1.676	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	5.009	5.009	NA
TOTAL AREA AVAILABLE	Atot	8.141	9.198	NA

**The Internal Pressure Case Governs the Analysis.**

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	67.2364	12.0000 mm.
Based on given Pad Diameter:	160.3250	1.9868 mm.
Based on Shell or Nozzle Thickness:	71.1729	7.6454 mm.

Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 * 7.562 * 1 + 2 * 4.645 * 7.562 * 1 * (1 - 0.855))$$

$$= 3.961 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 51.03 * (1 * 9 - 1 * 7.562) - 2 * 4.645 * (1 * 9 - 1 * 7.562) * (1 - 0.855)$$

$$= 0.714 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 22.5) * (4.645 - 0.585) * 0.855$$

$$= 1.562 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + (0)^2 * 0.855 + 0^2 * 1$$

$$= 0.855 \text{ cm}^2$$

Area Available in Element [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) * (\min(tp, Tlwp, te)) * fr4$$

$$= (102.1 - 60.33) * 12 * 1$$

$$= 5.009 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.5849 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5621 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5621 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2 ) ]  
 = min[ 6.42, max( 10.56, 4.5 ) ]  
 = 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.585, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle Neck to Flange Weld (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

#### Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 7.645, tr = 0.585, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

#### Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 12, tr = 7.562, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.84$ , Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 7.645, tr = 0.585, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -48 °C
Governing MDMT of all the sub-joints of this Junction	: -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :  
 Design Pressure/Ambient Rating = 23.04/51.10 = 0.451

*Note:*  
 Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: LT1

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.0000 mm.

#### **Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	3.2518 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	4.5000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:  
 $= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$   
 $= \max( 0, (3.961 - 0.714 + 2 * 4.645 * 0.855 * (1 * 9 - 7.562) ) 137.9 )$   
 $= 46.34 \text{ kN}$

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

Weld Load [W1]:  
 $= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv$   
 $= ( 1.562 + 5.009 + 0.855 - 0 * 0.855 ) * 137.9$   
 $= 102.40 \text{ kN}$

Weld Load [W2]:  
 $= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$   
 $= ( 1.562 + 0 + 0.855 + ( 0.715 ) ) * 137.9$   
 $= 43.19 \text{ kN}$

Weld Load [W3]:  
 $= (A2+A3+A4+A5+(2*tn*t*fr1))*S$   
 $= ( 1.562 + 0 + 0.855 + 5.009 + ( 0.715 ) ) * 137.9$   
 $= 112.26 \text{ kN}$

#### **Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Snw]:  
 $= (\pi/2) * Dlo * Wo * 0.49 * Snw$   
 $= ( 3.142/2.0 ) * 60.33 * 10 * 0.49 * 117.9$   
 $= 55. \text{ kN}$

Shear, Pad Element Weld [Spew]:  
 $= (\pi/2) * DP * WP * 0.49 * SEW$   
 $= ( 3.142/2.0 ) * 160.3 * 10 * 0.49 * 137.9$   
 $= 170. \text{ kN}$

Shear, Nozzle Wall [Snw]:  
 $= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$   
 $= ( 3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9$   
 $= 34. \text{ kN}$

Tension, Pad Groove Weld [Tpgw]:

$$\begin{aligned} &= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg} \\ &= (3.142/2) * 60.33 * 12 * 0.74 * 137.9 \\ &= 116. \text{ kN} \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned} &= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng} \\ &= (3.142/2.0) * 60.33 * (12 - 3) * 0.74 * 137.9 \\ &= 87. \text{ kN} \end{aligned}$$

#### Strength of Failure Paths:

$$\begin{aligned} \text{PATH11} &= (\text{SPEW} + \text{SNW}) = (170.2 + 33.53) = 203.7 \text{ kN} \\ \text{PATH22} &= (\text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw}) \\ &= (54.74 + 116 + 87.02 + 0) = 257.8 \text{ kN} \\ \text{PATH33} &= (\text{Spew} + \text{Tngw} + \text{Sinw}) \\ &= (170.2 + 87.02 + 0) = 257.2 \text{ kN} \end{aligned}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 203 kN , must exceed W = 46 kN or W1 = 102 kN  
Path 2-2 = 257 kN , must exceed W = 46 kN or W2 = 43 kN  
Path 3-3 = 257 kN , must exceed W = 46 kN or W3 = 112 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 27.369 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 1.0234 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0234 mm.

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**INPUT VALUES, Nozzle Description: LT2 From : 20**

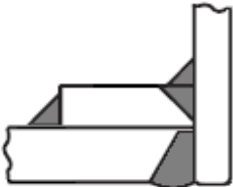
Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3650.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: LT2**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 7.5487 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 0.5839 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2901 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

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$$= \min(0.855, 1)$$

$$= 0.855$$

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.954	1.483	NA
Area in Shell	A1	0.721	1.658	NA
Area in Nozzle Wall	A2	1.563	1.676	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	5.009	5.009	NA
TOTAL AREA AVAILABLE	Atot	8.148	9.198	NA

#### The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 67.1197 12.0000 mm.  
 Based on given Pad Diameter: 160.3250 1.9533 mm.  
 Based on Shell or Nozzle Thickness: 70.9898 7.6454 mm.

#### Area Required [A]:

$$= (d \cdot tr \cdot F + 2 \cdot tn \cdot tr \cdot F \cdot (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 \cdot 7.549 \cdot 1 + 2 \cdot 4.645 \cdot 7.549 \cdot 1 \cdot (1 - 0.855))$$

$$= 3.954 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

##### Area Available in Shell [A1]:

$$= d \cdot (E1 \cdot t - F \cdot tr) - 2 \cdot tn \cdot (E1 \cdot t - F \cdot tr) \cdot (1 - fr1)$$

$$= 51.03 \cdot (1 \cdot 9 - 1 \cdot 7.549) - 2 \cdot 4.645 \cdot (1 \cdot 9 - 1 \cdot 7.549) \cdot (1 - 0.855)$$

$$= 0.721 \text{ cm}^2$$

##### Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 \cdot Tlwp) \cdot (tn - trn) \cdot fr2$$

$$= (2 \cdot 22.5) \cdot (4.645 - 0.584) \cdot 0.855$$

$$= 1.563 \text{ cm}^2$$

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

$$= Wo^2 \cdot fr3 + (Wi - can/0.707)^2 \cdot fr2 + Wp^2 \cdot fr4$$

$$= 10^2 \cdot 0.855 + (0)^2 \cdot 0.855 + 0^2 \cdot 1$$

$$= 0.855 \text{ cm}^2$$

##### Area Available in Element [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) \cdot (\min(tp, Tlwp, te)) \cdot fr4$$

$$= (102.1 - 60.33) \cdot 12 \cdot 1$$

$$= 5.009 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 3.5839 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 10.5487 \text{ mm.}$   
 Wall Thickness  $tb1 = \max(trb1, tr16b) = 10.5487 \text{ mm.}$   
 Wall Thickness, shell/head, external pressure  $trb2 = 3.3576 \text{ mm.}$   
 Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

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Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 6.42, max( 10.55, 4.5 ) ]  
 = 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.584, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

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

Sustained	:	62.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.549, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.839, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E\* = 1

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Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: LT2

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$3.2518 = 0.7 * t_{min}$	$7.0700 = 0.7 * W_o$ mm.
Pad Weld	$4.5000 = 0.5 * T_{minPad}$	$7.0700 = 0.7 * W_p$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (3.954 - 0.721 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 9 - 7.549) ) 137.9 ) \\
 &= 46.17 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= ( 1.563 + 5.009 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 102.41 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.563 + 0 + 0.855 + ( 0.715 ) ) * 137.9 \\
 &= 43.19 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.563 + 0 + 0.855 + 5.009 + ( 0.715 ) ) * 137.9 \\
 &= 112.27 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 60.33 * 10 * 0.49 * 117.9 \\
 &= 55. \text{ kN}
 \end{aligned}$$

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**Shear, Pad Element Weld [Spew]:**

$$\begin{aligned}
 &= (\pi/2) * DP * WP * 0.49 * SEW \\
 &= ( 3.142/2.0 ) * 160.3 * 10 * 0.49 * 137.9 \\
 &= 170. \text{ kN}
 \end{aligned}$$

**Shear, Nozzle Wall [Snw]:**

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9 \\
 &= 34. \text{ kN}
 \end{aligned}$$

**Tension, Pad Groove Weld [Tpgw]:**

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wgpn * 0.74 * Seg \\
 &= ( 3.142/2 ) * 60.33 * 12 * 0.74 * 137.9 \\
 &= 116. \text{ kN}
 \end{aligned}$$

**Tension, Shell Groove Weld [Tngw]:**

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 60.33 * ( 12 - 3 ) * 0.74 * 137.9 \\
 &= 87. \text{ kN}
 \end{aligned}$$

**Strength of Failure Paths:**

$$\begin{aligned}
 \text{PATH11} &= ( \text{SPEW} + \text{SNW} ) = ( 170.2 + 33.53 ) = 203.7 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 54.74 + 116 + 87.02 + 0 ) = 257.8 \text{ kN} \\
 \text{PATH33} &= ( \text{Spew} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 170.2 + 87.02 + 0 ) = 257.2 \text{ kN}
 \end{aligned}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 203 kN , must exceed W = 46 kN or W1 = 102 kN  
 Path 2-2 = 257 kN , must exceed W = 46 kN or W2 = 43 kN  
 Path 3-3 = 257 kN , must exceed W = 46 kN or W3 = 112 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.329 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 1.0234 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0234 mm.

**Input Echo, WRC107/537 Item 1, Description: LT2 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.

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Nozzle Calcs.: LT2

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Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	160.325	mm.
Design Internal Pressure	Dp	23.000	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	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".

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

= NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 60.325 + 2 \* 1.65 \* sqrt( 452.5 ( 12.0 - 3.0 ) )  
 = 270.918 mm.

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.058	4C	4.229	(A,B)
N(PHI) / ( P/Rm )	0.058	3C	4.165	(C,D)
M(PHI) / ( P )	0.058	2C1	0.168	(A,B)
M(PHI) / ( P )	0.058	1C	0.202	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.058	3A	0.246	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.058	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.058	3B	0.967	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.058	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.058	3C	4.165	(A,B)

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Nozzle Calcs.: LT2 Nozl: 19 9:17pm Feb 18,2022

N(x) / ( P/Rm )	0.058	4C	4.229	(C,D)
M(x) / ( P )	0.058	1C1	0.207	(A,B)
M(x) / ( P )	0.058	2C	0.166	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.058	4A	0.309	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.058	2A	0.063	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.058	4B	0.238	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.058	2B	0.099	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P		-4.6	4.6	-4.6	4.6	-5.5	5.5	-5.5	5.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-21.4	21.4	21.4	-21.4
Circ. Memb. ML		-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.3	12.3	12.3	-12.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-19.3	14.5	8.4	-7.1	-28.2	25.7	15.4	-16.4
Long. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Long. Bend. P		-5.6	5.6	-5.6	5.6	-4.5	4.5	-4.5	4.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-12.9	12.9	12.9	-12.9
Long. Memb. ML		-0.4	-0.4	0.4	0.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-20.5	20.5	20.5	-20.5	0.0	0.0	0.0	0.0
Tot. Long. Str.		-27.4	24.9	14.3	-15.3	-18.8	16.1	8.0	-8.8
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.2	5.2	3.2	3.2	3.2	3.2	5.2	5.2
Str. Int.		29.9	27.0	15.7	16.4	29.1	26.6	18.1	19.0

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.155	4C	7.575	(A,B)
N(PHI) / ( P/Rm )	0.155	3C	5.538	(C,D)
M(PHI) / ( P )	0.155	2C1	0.044	(A,B)
M(PHI) / ( P )	0.155	1C !	0.077	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.155	3A	2.036	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.155	1A	0.079	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.155	3B	5.450	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.155	1B	0.030	(A,B,C,D)
N(x) / ( P/Rm )	0.155	3C	5.538	(A,B)
N(x) / ( P/Rm )	0.155	4C	7.575	(C,D)
M(x) / ( P )	0.155	1C1	0.080	(A,B)
M(x) / ( P )	0.155	2C !	0.044	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.155	4A	3.512	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.155	2A	0.040	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.155 4B 1.955 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.155 2B 0.042 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.7	-3.7	-3.7	-3.7	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P		-6.5	6.5	-6.5	6.5	-11.5	11.5	-11.5	11.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-33.4	33.4	33.4	-33.4
Circ. Memb. ML		-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.6	12.6	12.6	-12.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.5	7.8	10.0	-2.2	-50.5	39.3	22.1	-21.8
Long. Memb. P		-2.7	-2.7	-2.7	-2.7	-3.7	-3.7	-3.7	-3.7
Long. Bend. P		-11.9	11.9	-11.9	11.9	-6.5	6.5	-6.5	6.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.9	-4.9	4.9	4.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-16.7	16.7	16.7	-16.7
Long. Memb. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-17.7	17.7	17.7	-17.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-35.1	24.2	5.8	-5.8	-31.8	14.6	11.5	-9.1
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Tot. Shear		2.3	2.3	0.5	0.5	0.5	0.5	2.3	2.3
Str. Int.		36.0	24.5	10.1	5.9	50.5	39.3	22.6	22.2

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-2.4	-2.4	0.6	0.6	-1.3	-1.3	-0.5	-0.5
Circ. Q (SUS)		-16.9	16.9	7.7	-7.7	-26.9	26.9	15.9	-15.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-1.2	-1.2	-0.5	-0.5	-1.4	-1.4	-0.4	-0.4
Long. Q (SUS)		-26.1	26.1	14.8	-14.8	-17.4	17.4	8.4	-8.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3

Tag no:Liquid Receiver (D-PK6101-2)

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Nozzle Calcs.: LT2

Noz1: 19 9:17pm Feb 18,2022

Pm+Pl (SUS)	45.6	47.9	48.6	50.9	46.7	49.0	47.5	49.8
Pm+Pl+Q (Total)	33.7	66.2	56.9	43.4	20.4	76.2	64.2	35.2

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.25	137.90	Passed
Pm+Pl (SUS)	50.93	206.85	Passed
Pm+Pl+Q (TOTAL)	76.20	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Circ. Pl (SUS)		-11.3	-11.3	3.9	3.9	-5.6	-5.6	0.1	0.1
Circ. Q (SUS)		-19.1	19.1	6.1	-6.1	-44.9	44.9	22.0	-22.0
Long. Pm (SUS)		56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7
Long. Pl (SUS)		-5.5	-5.5	0.0	0.0	-8.6	-8.6	1.2	1.2
Long. Q (SUS)		-29.7	29.7	5.8	-5.8	-23.2	23.2	10.3	-10.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Pm+Pl (SUS)		102.0	104.3	117.3	119.6	107.8	110.1	113.5	115.8
Pm+Pl+Q (Total)		83.0	123.6	123.4	113.4	62.9	155.0	135.5	93.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.67	137.90	Passed
Pm+Pl (SUS)	119.59	206.85	Passed
Pm+Pl+Q (TOTAL)	155.00	413.70	Passed

Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Nozzle Calcs.: D Nozl: 20 9:17pm Feb 18,2022

**INPUT VALUES, Nozzle Description: D From : 20**

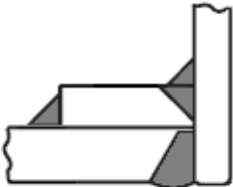
Pressure for Reinforcement Calculations	P	23.040	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		300.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.0000	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		49.8375	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: D**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.04 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23.04) \\
 &= 7.5621 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.04 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23.04) \\
 &= 0.5849 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2901 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684 mm.
Parallel to Vessel Wall, opening length	d	51.0342 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min(0.855, 1)$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.961	1.483	NA
Area in Shell	A1	0.714	1.658	NA
Area in Nozzle Wall	A2	1.562	1.676	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	5.009	5.009	NA
TOTAL AREA AVAILABLE	Atot	8.141	9.198	NA

**The Internal Pressure Case Governs the Analysis.**

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	67.2364	12.0000 mm.
Based on given Pad Diameter:	160.0000	1.9868 mm.
Based on Shell or Nozzle Thickness:	71.1729	7.6454 mm.

Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 * 7.562 * 1 + 2 * 4.645 * 7.562 * 1 * (1 - 0.855))$$

$$= 3.961 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 51.03 (1 * 9 - 1 * 7.562) - 2 * 4.645 (1 * 9 - 1 * 7.562) * (1 - 0.855)$$

$$= 0.714 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 22.5) * (4.645 - 0.585) * 0.855$$

$$= 1.562 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + (0)^2 * 0.855 + 0^2 * 1$$

$$= 0.855 \text{ cm}^2$$

Area Available in Element [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) * (\min(tp, Tlwp, te)) * fr4$$

$$= (102.1 - 60.33) * 12 * 1$$

$$= 5.009 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.5849 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5621 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5621 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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 Nozzle Calcs.: D Noz1: 20 9:17pm Feb 18,2022

Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 6.42, max( 10.56, 4.5 ) ]  
 = 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.585, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

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

Sustained	: 62.1,	Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 232.7 N./mm <sup>2</sup>	Passed
Occasional	: 5.8,	Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 33.9,	Allowable	: 82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 7.645, tr = 0.585, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.562, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.84, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 7.645, tr = 0.585, c = 3 mm., E\* = 1

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Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.126$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.04 / 51.10 = 0.451$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: D

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$3.2518 = 0.7 * t_{min}$	$7.0700 = 0.7 * W_o$ mm.
Pad Weld	$4.5000 = 0.5 * T_{minPad}$	$7.0700 = 0.7 * W_p$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (3.961 - 0.714 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 9 - 7.562) ) 137.9 ) \\
 &= 46.34 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= ( 1.562 + 5.009 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 102.40 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.562 + 0 + 0.855 + ( 0.715 ) ) * 137.9 \\
 &= 43.19 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.562 + 0 + 0.855 + 5.009 + ( 0.715 ) ) * 137.9 \\
 &= 112.26 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 60.33 * 10 * 0.49 * 117.9 \\
 &= 55. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:  
 = (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.142/2.0 ) \* 160 \* 10 \* 0.49 \* 137.9  
 = 170. kN

Shear, Nozzle Wall [Snw]:  
 = (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.142 \* 27.84 ) \* ( 7.645 - 3 ) \* 0.7 \* 117.9  
 = 34. kN

Tension, Pad Groove Weld [Tpgw]:  
 = ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.142/2 ) \* 60.33 \* 12 \* 0.74 \* 137.9  
 = 116. kN

Tension, Shell Groove Weld [Tngw]:  
 = (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.142/2.0 ) \* 60.33 \* ( 12 - 3 ) \* 0.74 \* 137.9  
 = 87. kN

**Strength of Failure Paths:**

PATH11 = ( SPEW + SNW ) = ( 169.8 + 33.53 ) = 203.3 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 54.74 + 116 + 87.02 + 0 ) = 257.8 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 169.8 + 87.02 + 0 ) = 256.8 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 203 kN , must exceed W = 46 kN or W1 = 102 kN  
 Path 2-2 = 257 kN , must exceed W = 46 kN or W2 = 43 kN  
 Path 3-3 = 256 kN , must exceed W = 46 kN or W3 = 112 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.369 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 1.0234 mm.  
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0234 mm.

**Input Echo, WRC107/537 Item 1, Description: D :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.

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Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	160.000	mm.
Design Internal Pressure	Dp	23.040	bar
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	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".

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

= NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 60.325 + 2 \* 1.65 \* sqrt( 452.5 ( 12.0 - 3.0 ) )  
 = 270.918 mm.

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 21.83

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.058	4C	4.229	(A,B)
N(PHI) / ( P/Rm )	0.058	3C	4.165	(C,D)
M(PHI) / ( P )	0.058	2C1	0.168	(A,B)
M(PHI) / ( P )	0.058	1C	0.202	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.058	3A	0.246	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.058	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.058	3B	0.967	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.058	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.058	3C	4.165	(A,B)

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N(x) / ( P/Rm )	0.058	4C	4.229	(C,D)
M(x) / ( P )	0.058	1C1	0.207	(A,B)
M(x) / ( P )	0.058	2C	0.166	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.058	4A	0.309	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.058	2A	0.063	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.058	4B	0.238	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.058	2B	0.099	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P		-4.6	4.6	-4.6	4.6	-5.5	5.5	-5.5	5.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-21.4	21.4	21.4	-21.4
Circ. Memb. ML		-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.3	12.3	12.3	-12.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-19.3	14.5	8.4	-7.1	-28.2	25.7	15.4	-16.4
Long. Memb. P		-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Long. Bend. P		-5.6	5.6	-5.6	5.6	-4.5	4.5	-4.5	4.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-12.9	12.9	12.9	-12.9
Long. Memb. ML		-0.4	-0.4	0.4	0.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-20.5	20.5	20.5	-20.5	0.0	0.0	0.0	0.0
Tot. Long. Str.		-27.4	24.9	14.3	-15.3	-18.8	16.1	8.0	-8.8
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.2	5.2	3.2	3.2	3.2	3.2	5.2	5.2
Str. Int.		29.9	27.0	15.7	16.4	29.1	26.6	18.1	19.0

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.155	4C	7.581	(A,B)
N(PHI) / ( P/Rm )	0.155	3C	5.549	(C,D)
M(PHI) / ( P )	0.155	2C1	0.044	(A,B)
M(PHI) / ( P )	0.155	1C !	0.078	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.155	3A	2.036	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.155	1A	0.079	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.155	3B	5.454	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.155	1B	0.030	(A,B,C,D)
N(x) / ( P/Rm )	0.155	3C	5.549	(A,B)
N(x) / ( P/Rm )	0.155	4C	7.581	(C,D)
M(x) / ( P )	0.155	1C1	0.081	(A,B)
M(x) / ( P )	0.155	2C !	0.044	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.155	4A	3.507	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.155	2A	0.040	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.155 4B 1.954 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.155 2B 0.042 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.7	-3.7	-3.7	-3.7	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P		-6.5	6.5	-6.5	6.5	-11.5	11.5	-11.5	11.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.9	-2.9	2.9	2.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-33.5	33.5	33.5	-33.5
Circ. Memb. ML		-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Circ. Bend. ML		-12.7	12.7	12.7	-12.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.6	7.8	10.1	-2.2	-50.6	39.4	22.2	-21.9
Long. Memb. P		-2.7	-2.7	-2.7	-2.7	-3.7	-3.7	-3.7	-3.7
Long. Bend. P		-11.9	11.9	-11.9	11.9	-6.5	6.5	-6.5	6.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.9	-4.9	4.9	4.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-16.8	16.8	16.8	-16.8
Long. Memb. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-17.8	17.8	17.8	-17.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-35.2	24.3	5.9	-5.9	-31.9	14.6	11.5	-9.1
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Tot. Shear		2.3	2.3	0.5	0.5	0.5	0.5	2.3	2.3
Str. Int.		36.1	24.6	10.1	5.9	50.6	39.4	22.6	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-2.4	-2.4	0.6	0.6	-1.3	-1.3	-0.5	-0.5
Circ. Q (SUS)		-16.9	16.9	7.7	-7.7	-26.9	26.9	15.9	-15.9
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-1.2	-1.2	-0.5	-0.5	-1.4	-1.4	-0.4	-0.4
Long. Q (SUS)		-26.1	26.1	14.8	-14.8	-17.4	17.4	8.4	-8.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3

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Pm+Pl (SUS)	45.7	48.0	48.7	51.0	46.8	49.1	47.6	49.9
Pm+Pl+Q (Total)	33.7	66.3	57.0	43.5	20.5	76.3	64.3	35.3

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.34	137.90	Passed
Pm+Pl (SUS)	51.02	206.85	Passed
Pm+Pl+Q (TOTAL)	76.29	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.6	115.9	113.6	115.9	113.6	115.9	113.6	115.9
Circ. Pl (SUS)		-11.4	-11.4	3.9	3.9	-5.6	-5.6	0.1	0.1
Circ. Q (SUS)		-19.2	19.2	6.2	-6.2	-45.0	45.0	22.0	-22.0
Long. Pm (SUS)		56.8	56.8	56.8	56.8	56.8	56.8	56.8	56.8
Long. Pl (SUS)		-5.5	-5.5	0.0	0.0	-8.6	-8.6	1.2	1.2
Long. Q (SUS)		-29.8	29.8	5.9	-5.9	-23.3	23.3	10.3	-10.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Pm (SUS)		113.6	115.9	113.6	115.9	113.6	115.9	113.6	115.9
Pm+Pl (SUS)		102.2	104.5	117.5	119.8	108.0	110.3	113.7	116.0
Pm+Pl+Q (Total)		83.1	123.8	123.7	113.6	63.0	155.3	135.8	94.1

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.87	137.90	Passed
Pm+Pl (SUS)	119.81	206.85	Passed
Pm+Pl+Q (TOTAL)	155.31	413.70	Passed

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Nozzle Calcs.: SV Nozl: 21 9:17pm Feb 18,2022

**INPUT VALUES, Nozzle Description: SV From : 20**

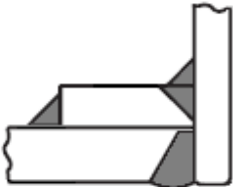
Pressure for Reinforcement Calculations	P	23.000	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	890.00	mm.
Design Length of Section	L	4148.3335	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2300.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		4.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	120	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	250.0000	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		67.8500	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: SV**

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

Actual Outside Diameter Used in Calculation	4.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 448) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 7.5487 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 57.15) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 1.1064 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.4205 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	201.6618 mm.
Parallel to Vessel Wall, opening length	d	100.8309 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		22.5000 mm.

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

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min( 1, S_n / S_v ) \\
 &= \min( 1, 117.9 / 137.9 ) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min( 1, S_p / S_v ) \\
 &= \min( 1, 137.9 / 137.9 ) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

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$$= \min( 0.855, 1 )$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.759	2.910	NA
Area in Shell	A1	1.435	3.299	NA
Area in Nozzle Wall	A2	2.165	2.429	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	10.483	10.483	NA
TOTAL AREA AVAILABLE	Atot	14.939	17.067	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	141.8286	12.0000 mm.
Based on given Pad Diameter:	250.0000	3.7813 mm.
Based on Shell or Nozzle Thickness:	148.2351	9.7345 mm.

Area Required [A]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 100.8 * 7.549 * 1 + 2 * 6.735 * 7.549 * 1 * (1 - 0.855) )$$

$$= 7.759 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 100.8 ( 1 * 9 - 1 * 7.549 ) - 2 * 6.735 ( 1 * 9 - 1 * 7.549 ) * ( 1 - 0.855 )$$

$$= 1.435 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 22.5 ) * ( 6.735 - 1.106 ) * 0.855$$

$$= 2.165 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + (Wi - can / 0.707)^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + ( 0 )^2 * 0.855 + 0^2 * 1$$

$$= 0.855 \text{ cm}^2$$

Area Available in Element [A5]:

$$= ( \min(Dp, DL) - (Nozzle OD) ) * ( \min(tp, Tlwp, te) ) * fr4$$

$$= ( 201.7 - 114.3 ) * 12 * 1$$

$$= 10.483 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 4.1064 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.5487 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.5487 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3576 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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Wall Thickness per table UG-45 tb3 = 8.2578 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 8.258, max( 10.55, 4.5 ) ]  
 = 8.2578 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 4.106, 8.258 )  
 = 8.2578 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

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

Sustained	:	51.4,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	243.4 N./mm <sup>2</sup>	Passed
Occasional	:	8.1,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	24.8,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 9.735, tr = 1.106, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.164, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 12, tr = 7.549, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.839, Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
--	--------

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

Govrn. thk, tg = 9.735, tr = 1.106, c = 3 mm., E\* = 1

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Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.164$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -48 °C
Governing MDMT of all the sub-joints of this Junction	: -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

Note:

Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: SV

Intermediate Calc. for nozzle/shell Welds	Tmin	6.7345 mm.
Intermediate Calc. for pad/shell Welds	TminPad	9.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$4.7142 = 0.7 * t_{min}$	$7.0700 = 0.7 * W_o$ mm.
Pad Weld	$4.5000 = 0.5 * T_{minPad}$	$7.0700 = 0.7 * W_p$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.759 - 1.435 + 2 * 6.735 * 0.855 * \\
 &\quad (1 * 9 - 7.549) ) ) 137.9 ) \\
 &= 89.50 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= ( 2.165 + 10.48 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 186.20 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.165 + 0 + 0.855 + ( 1.036 ) ) * 137.9 \\
 &= 55.94 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.165 + 0 + 0.855 + 10.48 + ( 1.036 ) ) * 137.9 \\
 &= 200.49 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 114.3 * 10 * 0.49 * 117.9 \\
 &= 104. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:

$$\begin{aligned}
 &= (\pi/2) * DP * WP * 0.49 * SEW \\
 &= ( 3.142/2.0 ) * 250 * 10 * 0.49 * 137.9 \\
 &= 265. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 53.78 ) * ( 9.735 - 3 ) * 0.7 * 117.9 \\
 &= 94. \text{ kN}
 \end{aligned}$$

Tension, Pad Groove Weld [Tpgw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wgpn * 0.74 * Seg \\
 &= ( 3.142/2 ) * 114.3 * 12 * 0.74 * 137.9 \\
 &= 220. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 114.3 * ( 12 - 3 ) * 0.74 * 137.9 \\
 &= 165. \text{ kN}
 \end{aligned}$$

**Strength of Failure Paths:**

$$\begin{aligned}
 \text{PATH11} &= ( \text{SPEW} + \text{SNW} ) = ( 265.3 + 93.91 ) = 359.2 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 103.7 + 219.8 + 164.9 + 0 ) = 488.4 \text{ kN} \\
 \text{PATH33} &= ( \text{Spew} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 265.3 + 164.9 + 0 ) = 430.2 \text{ kN}
 \end{aligned}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 359 kN , must exceed W = 89 kN or W1 = 186 kN  
 Path 2-2 = 488 kN , must exceed W = 89 kN or W2 = 55 kN  
 Path 3-3 = 430 kN , must exceed W = 89 kN or W3 = 200 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 27.329 bar

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

Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 3.6850 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 165.6850 mm.

**Input Echo, WRC107/537 Item 1, Description: SV :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	890.000	mm.
Vessel Thickness	Tv	12.000	mm.
Design Temperature		135.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	114.300	mm.

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Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	250.000	mm.
Design Internal Pressure	Dp	23.000	bar
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	4.0	kN
Longitudinal Shear	(SUS)	Vl	4.0	kN
Circumferential Shear	(SUS)	Vc	4.0	kN
Circumferential Moment	(SUS)	Mc	1700.0	N-m
Longitudinal Moment	(SUS)	Ml	1700.0	N-m
Torsional Moment	(SUS)	Mt	2100.0	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".

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

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 114.3 + 2 * 1.65 * \text{sqrt}( 452.5 ( 12.0 - 3.0 ) )$$

$$= 324.893 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	4.0	kN
Circumferential Shear	VC	4.0	kN
Longitudinal Shear	VL	4.0	kN
Circumferential Moment	MC	1700.0	N-m
Longitudinal Moment	ML	1700.0	N-m
Torsional Moment	MT	2100.0	N-m

Dimensionless Parameters used : Gamma = 21.83

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.109	4C	3.985	(A,B)
N(PHI) / ( P/Rm )	0.109	3C	3.570	(C,D)
M(PHI) / ( P )	0.109	2C1	0.108	(A,B)
M(PHI) / ( P )	0.109	1C	0.144	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.109	3A	0.560	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.109	1A	0.100	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.109	3B	1.958	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.109	1B	0.050	(A,B,C,D)
N(x) / ( P/Rm )	0.109	3C	3.570	(A,B)

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N(x) / ( P/Rm )	0.109	4C	3.985	(C,D)
M(x) / ( P )	0.109	1C1	0.146	(A,B)
M(x) / ( P )	0.109	2C	0.107	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.109	4A	0.781	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.109	2A	0.056	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.109	4B	0.533	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.109	2B	0.083	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-5.9	5.9	-5.9	5.9	-7.8	7.8	-7.8	7.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-46.2	46.2	46.2	-46.2
Circ. Memb. ML		-6.9	-6.9	6.9	6.9	0.0	0.0	0.0	0.0
Circ. Bend. ML		-23.2	23.2	23.2	-23.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-37.6	20.5	22.6	-12.1	-57.5	50.5	38.9	-37.9
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-8.0	8.0	-8.0	8.0	-5.8	5.8	-5.8	5.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.8	-2.8	2.8	2.8
Long. Bend. MC		0.0	0.0	0.0	0.0	-26.0	26.0	26.0	-26.0
Long. Memb. ML		-1.9	-1.9	1.9	1.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.2	38.2	38.2	-38.2	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.6	42.9	30.7	-29.9	-36.3	27.5	21.3	-19.1
Shear VC		1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear MT		4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Tot. Shear		5.9	5.9	3.8	3.8	3.8	3.8	5.9	5.9
Str. Int.		52.0	44.3	32.2	30.7	58.1	51.2	40.7	39.6

Dimensionless Parameters used : Gamma = 50.28

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.242	4C	6.159	(A,B)
N(PHI) / ( P/Rm )	0.242	3C	3.233	(C,D)
M(PHI) / ( P )	0.242	2C1	0.020	(A,B)
M(PHI) / ( P )	0.242	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.242	3A	1.879	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.242	1A	0.064	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.242	3B	4.235	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.242	1B	0.015	(A,B,C,D)
N(x) / ( P/Rm )	0.242	3C	3.233	(A,B)
N(x) / ( P/Rm )	0.242	4C	6.159	(C,D)
M(x) / ( P )	0.242	1C1	0.046	(A,B)
M(x) / ( P )	0.242	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.242	4A	4.449	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.242	2A	0.028	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.242 4B 1.966 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.242 2B 0.022 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-6.0	-6.0	-6.0	-6.0	-3.2	-3.2	-3.2	-3.2
Circ. Bend. P		-6.0	6.0	-6.0	6.0	-19.3	19.3	-19.3	19.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.2	-7.2	7.2	7.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-73.5	73.5	73.5	-73.5
Circ. Memb. ML		-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Circ. Bend. ML		-17.2	17.2	17.2	-17.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-45.4	1.0	21.3	-1.1	-103.1	82.4	58.1	-50.1
Long. Memb. P		-3.2	-3.2	-3.2	-3.2	-6.0	-6.0	-6.0	-6.0
Long. Bend. P		-13.7	13.7	-13.7	13.7	-9.9	9.9	-9.9	9.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-17.0	-17.0	17.0	17.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-31.7	31.7	31.7	-31.7
Long. Memb. ML		-7.5	-7.5	7.5	7.5	0.0	0.0	0.0	0.0
Long. Bend. ML		-25.3	25.3	25.3	-25.3	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.8	28.4	15.9	-7.3	-64.6	18.6	32.7	-10.9
Shear VC		1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear MT		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear		3.5	3.5	1.2	1.2	1.2	1.2	3.5	3.5
Str. Int.		51.7	28.9	21.5	7.5	103.2	82.5	58.6	50.5

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3
Circ. Pl (SUS)		-8.6	-8.6	5.3	5.3	-3.5	-3.5	0.5	0.5
Circ. Q (SUS)		-29.0	29.0	17.3	-17.3	-54.0	54.0	38.4	-38.4
Long. Pm (SUS)		24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Long. Pl (SUS)		-3.4	-3.4	0.4	0.4	-4.4	-4.4	1.1	1.1
Long. Q (SUS)		-46.2	46.2	30.3	-30.3	-31.9	31.9	20.2	-20.2
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)		4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Pm (SUS)		48.0	50.3	48.0	50.3	48.0	50.3	48.0	50.3

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Pm+Pl (SUS)	39.4	41.7	53.2	55.5	44.5	46.8	48.5	50.8
Pm+Pl+Q (Total)	37.9	75.0	71.4	44.7	15.0	101.1	87.6	15.7

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	50.25	137.90	Passed
Pm+Pl (SUS)	55.54	206.85	Passed
Pm+Pl+Q (TOTAL)	101.08	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Circ. Pl (SUS)		-22.2	-22.2	10.1	10.1	-10.3	-10.3	4.0	4.0
Circ. Q (SUS)		-23.2	23.2	11.2	-11.2	-92.8	92.8	54.1	-54.1
Long. Pm (SUS)		56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7
Long. Pl (SUS)		-10.7	-10.7	4.3	4.3	-23.0	-23.0	10.9	10.9
Long. Q (SUS)		-39.1	39.1	11.6	-11.6	-41.6	41.6	21.8	-21.8
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)		113.4	115.7	113.4	115.7	113.4	115.7	113.4	115.7
Pm+Pl (SUS)		91.2	93.5	123.5	125.8	103.0	105.3	117.4	119.7
Pm+Pl+Q (Total)		68.1	117.1	134.7	114.6	18.4	198.1	171.6	66.1

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.67	137.90	Passed
Pm+Pl (SUS)	125.80	206.85	Passed
Pm+Pl+Q (TOTAL)	198.11	413.70	Passed

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**INPUT VALUES, Nozzle Description: TI From : 30**

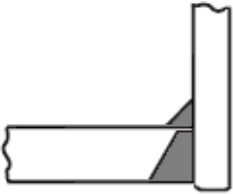
Pressure for Reinforcement Calculations	P	23.034	bar
Temperature for Internal Pressure	Temp	135	°C
Design External Pressure	Pext	1.10	bar
Temperature for External Pressure	Tempex	100	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Elliptical Head	D	890.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	12.0000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	300.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld.	pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		1.5000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	XXS	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle in the Meridional direction.

**Reinforcement CALCULATION, Description: TI**

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

Actual Outside Diameter Used in Calculation 1.900 in.  
 Actual Thickness Used in Calculation 0.350 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]  
 $= (P \cdot K_1 \cdot D) / (2 \cdot S_v \cdot E - 0.2 \cdot P)$  per UG-37(a) (3)  
 $= (23.03 \cdot 0.894 \cdot 896) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23.03)$   
 $= 6.7041 \text{ mm.}$

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a) (1)  
 $= (23.03 \cdot 24.13) / (117.9 \cdot 1 + 0.4 \cdot 23.03)$   
 $= 0.4678 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.2542 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	80.0925	mm.
Parallel to Vessel Wall, opening length	d	40.0462	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	14.7250	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr2]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr3]:  
 $= \min(fr_2, fr_4)$   
 $= \min(0.855, 1)$   
 $= 0.855$

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required Ar	2.799	0.510	NA

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Area in Shell	A1	0.880	2.515	NA
Area in Nozzle Wall	A2	1.466	1.524	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.201	4.894	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 65.64 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)} \\
 &= (40.05 * 6.704 * 1 + 2 * 5.89 * 6.704 * 1 * (1 - 0.855)) \\
 &= 2.799 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1) \\
 &= 40.05 (1 * 9 - 1 * 6.704) - 2 * 5.89 \\
 &\quad (1 * 9 - 1 * 6.704) * (1 - 0.855) \\
 &= 0.880 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= (2 * tlnp) (tn - trn) fr2 / \sin(\alpha3) \\
 &= (2 * 14.72) (5.89 - 0.468) 0.855 / \sin(68.62) \\
 &= 1.466 \text{ cm}^2
 \end{aligned}$$

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + (Wi - can / 0.707)^2 * fr2 \\
 &= 10^2 * 0.855 + (0)^2 * 0.855 \\
 &= 0.855 \text{ cm}^2
 \end{aligned}$$

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 8.89, tr = 0.468, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*) / (tg - c) = 0.0794, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C

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Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :  
 Design Pressure/Ambient Rating = 23.03/51.10 = 0.451

Note:  
 Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: TI

Intermediate Calc. for nozzle/shell Welds Tmin 5.8900 mm.

#### **Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	4.1230 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:  
 $= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$   
 $= \max( 0, (2.799 - 0.88 + 2 * 5.89 * 0.855 * (1 * 9 - 6.704) ) 137.9 )$   
 $= 29.65 \text{ kN}$

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

Weld Load [W1]:  
 $= (A2+A5+A4 - (Wi-Can/.707)^2*fr2)*Sv$   
 $= ( 1.466 + 0 + 0.855 - 0 * 0.855 ) * 137.9$   
 $= 32.01 \text{ kN}$

Weld Load [W2]:  
 $= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$   
 $= ( 1.466 + 0 + 0.855 + ( 0.906 ) ) * 137.9$   
 $= 44.51 \text{ kN}$

Weld Load [W3]:  
 $= (A2+A3+A4+A5+(2*tn*t*fr1))*S$   
 $= ( 1.466 + 0 + 0.855 + 0 + ( 0.906 ) ) * 137.9$   
 $= 44.51 \text{ kN}$

#### **Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:  
 $= (\pi/2) * Dlo * Wo * 0.49 * Snw$   
 $= ( 3.142/2.0 ) * 52.98 * 10 * 0.49 * 117.9$   
 $= 48. \text{ kN}$

Shear, Nozzle Wall [Snw]:  
 $= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$   
 $= ( 3.142 * 23.26 ) * ( 8.89 - 3 ) * 0.7 * 117.9$   
 $= 36. \text{ kN}$

Tension, Shell Groove Weld [Tngw]:  
 $= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$   
 $= ( 3.142/2.0 ) * 52.98 * ( 12 - 3 ) * 0.74 * 137.9$   
 $= 76. \text{ kN}$

#### **Strength of Failure Paths:**

PATH11 = ( SONW + SNW ) = ( 48.07 + 35.51 ) = 83.59 kN

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PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 48.07 + 0 + 76.42 + 0 ) = 124.5 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 48.07 + 76.42 + 0 ) = 124.5 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 83 kN , must exceed W = 29 kN or W1 = 32 kN  
 Path 2-2 = 124 kN , must exceed W = 29 kN or W2 = 44 kN  
 Path 3-3 = 124 kN , must exceed W = 29 kN or W3 = 44 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.716 bar  
 Nozzle is O.K. for the External Pressure 1.100 bar

Note : Checking Nozzle in the Latitudinal direction.

#### Reinforcement CALCULATION, Description: TI

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

Actual Outside Diameter Used in Calculation 1.900 in.  
 Actual Thickness Used in Calculation 0.350 in.

Nozzle input data check completed without errors.

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

= (P\*K1\*D)/(2\*Sv\*E-0.2\*P) per UG-37(a) (3)  
 = (23.03\*0.894\*896)/(2 \*137.9\*1-0.2\*23.03)  
 = 6.7041 mm.

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

= (P\*Ro)/(Sn\*E+0.4\*P) per Appendix 1-1 (a) (1)  
 = (23.03\*24.13)/(117.9\*1+0.4\*23.03)  
 = 0.4678 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2542 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	72.9600	mm.
Parallel to Vessel Wall, opening length	d	36.4800	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	14.7250	mm.

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.560	0.466	NA
Area in Shell	A1	0.798	2.281	NA
Area in Nozzle Wall	A2	1.365	1.419	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.019	4.555	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

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$$\begin{aligned}
 &= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) \text{ UG-37(c)} \\
 &= (36.48*6.704*1+2*5.89*6.704*1*(1-0.855)) \\
 &= 2.560 \text{ cm}^2
 \end{aligned}$$

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 ) \\
 &= 36.48 ( 1 * 9 - 1 * 6.704 ) - 2 * 5.89 \\
 &\quad ( 1 * 9 - 1 * 6.704 ) * ( 1 - 0.855 ) \\
 &= 0.798 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 14.72 ) ( 5.89 - 0.468 ) 0.855 \\
 &= 1.365 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi-can/0.707 )^2 * fr2 \\
 &= 10^2 * 0.855 + ( 0 )^2 * 0.855 \\
 &= 0.855 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.4678 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 10.4304 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 10.4304 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.3543 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.2200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.22, \max( 10.43, 4.5 ) ] \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.468, 6.22 ) \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 8.8900 mm. --> OK

#### Weld Size Calculations, Description: TI

Intermediate Calc. for nozzle/shell Welds Tmin 5.8900 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.1230 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (2.56 - 0.798 + 2 * 5.89 * 0.855 * \\
 &\quad (1 * 9 - 6.704) ) 137.9 ) \\
 &= 27.48 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

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Nozzle Calcs.: TI Nozl: 22 9:17pm Feb 18,2022

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2 * fr2) * Sv \\
 &= ( 1.365 + 0 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 30.62 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.365 + 0 + 0.855 + ( 0.906 ) ) * 137.9 \\
 &= 43.11 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.365 + 0 + 0.855 + 0 + ( 0.906 ) ) * 137.9 \\
 &= 43.11 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 48.26 * 10 * 0.49 * 117.9 \\
 &= 44. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 21.18 ) * ( 8.89 - 3 ) * 0.7 * 117.9 \\
 &= 32. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 48.26 * ( 12 - 3 ) * 0.74 * 137.9 \\
 &= 70. \text{ kN}
 \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 43.79 + 32.35 ) = 76.14 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 43.79 + 0 + 69.62 + 0 ) = 113.4 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 43.79 + 69.62 + 0 ) = 113.4 \text{ kN}
 \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 76 kN , must exceed W = 27 kN or W1 = 30 kN  
 Path 2-2 = 113 kN , must exceed W = 27 kN or W2 = 43 kN  
 Path 3-3 = 113 kN , must exceed W = 27 kN or W3 = 43 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 25.138 bar  
 Nozzle is O.K. for the External Pressure 1.100 bar

The Drop for this Nozzle is : 10.0669 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.9691 mm.

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Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

Nozzle Schedule: Step: 23 9:17pm Feb 18,2022

**Nozzle Schedule:**

Flg	Nominal or	Schd	Flg	Nozzle	Wall	Reinforcing Pad	Cut
Class	Actual	or FVC	Type	O/Dia	Thk	Diameter	Thk
Description	Size	Type		in	mm.	mm.	mm.
PT	1.500 in	XXS	WNF	1.900	10.160	...	162.65
300							
TI	1.500 in	XXS	WNF	1.900	10.160	...	172.97
300							
A2	2.000 in	160	WNF	2.375	8.738	160.32	12.00
300							
A3	2.000 in	160	WNF	2.375	8.738	160.32	12.00
300							
LT1	2.000 in	160	WNF	2.375	8.738	160.32	12.00
300							
LT2	2.000 in	160	WNF	2.375	8.738	160.32	12.00
300							
D	2.000 in	160	WNF	2.375	8.738	160.00	12.00
300							
SV	4.000 in	120	WNF	4.500	11.125	250.00	12.00
300							
A1	8.000 in	80	WNF	8.625	12.700	379.08	12.00
300							
B	8.000 in	80	WNF	8.625	12.700	379.08	12.00
300							
M	20.000 in	Actual	WNF	20.000	15.000	738.00	15.00
							252.82
							300

*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	Noz Shl/Pad	Pad OD	Pad Grve	Inside
		Weld	Weld	Weld	Weld	Weld
PT	SA-333 6	12.000	11.000	...	...	...
TI	SA-333 6	12.000	10.000	...	...	...
A2	SA-333 6	12.000	10.000	10.000	12.000	...
A3	SA-333 6	12.000	8.000	10.000	12.000	...
LT1	SA-333 6	12.000	10.000	10.000	12.000	...
LT2	SA-333 6	12.000	10.000	10.000	12.000	...
D	SA-333 6	12.000	10.000	10.000	12.000	...
SV	SA-333 6	12.000	10.000	10.000	12.000	...
A1	SA-333 6	12.000	10.000	10.000	12.000	...
B	SA-333 6	12.000	10.000	10.000	12.000	...

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Nozzle Schedule: Step: 23 9:17pm Feb 18,2022

M | SA-516 70 | 12.000 | 10.000 | 9.000 | 15.000 | ... |

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

**Nozzle Miscellaneous Data:**

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
PT	1750.000	0.0	150.00	0.00	shell 001
TI	...	180.0	150.00	0.00	head 002
A2	3300.000	0.0	200.00	0.00	shell 001
A3	1200.000	0.0	150.00	0.00	shell 001
LT1	3700.000	180.0	150.00	0.00	shell 001
LT2	3650.000	0.0	150.00	0.00	shell 001
D	300.000	180.0	150.00	0.00	shell 001
SV	2300.000	0.0	150.00	0.00	shell 001
A1	500.000	0.0	200.00	800.00	shell 001
B	2000.000	180.0	200.00	0.00	shell 001
M	...	0.0	200.00	0.00	head 001

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## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:Liquid Receiver (D-PK6101-2)

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FileName : Calculation Book for LIQID RECEIVER D-PK6101-2

MDMT Summary: Step: 25 9:17pm Feb 18,2022

**Minimum Design Metal Temperature Results Summary :**

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20 (f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
head 001	[10]	D	-48	-48	-29	0.832	12.000	1.00	No
head 001	[7]	D	-47	-48	-29	0.635	15.000	1.00	No
shell 001	[8]	D	-48	-48	-29	0.846	12.000	1.00	No
head 002	[10]	D	-48	-48	-29	0.832	12.000	1.00	No
head 002	[7]	D	-47	-48	-29	0.635	15.000	1.00	No
M	[1]	D	-47	-48		0.351	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-48					
A1	[1]	D	-48	-48	-29	0.839	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
B	[1]	D	-48	-48	-29	0.840	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
A2	[1]	D	-48	-48	-29	0.839	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
PT	[1]	!	-46	-104		0.079	8.890	1.00	No
Nozzle Flg	[4]	!	-46	-104					
A3	[1]	D	-48	-48	-29	0.839	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT1	[1]	D	-48	-48	-29	0.840	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT2	[1]	D	-48	-48	-29	0.839	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
D	[1]	D	-48	-48	-29	0.840	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
SV	[1]	D	-48	-48	-29	0.839	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
TI	[1]	!	-46	-104		0.079	8.890	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Warmest MDMT:			-46	-48					
Required Minimum Design Metal Temperature						-45	°C		
Warmest Computed Minimum Design Metal Temperature						-48	°C		

**Notes:**

- [ ! ] - This was an impact tested material.
- [ 1 ] - Governing Nozzle Weld.
- [ 4 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
- [ 5 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
- [ 6 ] - MDMT Calculations at the Shell/Head Joint.
- [ 7 ] - MDMT Calculations for the Straight Flange.
- [ 8 ] - Cylinder/Cone/Flange Junction MDMT.
- [ 9 ] - Calculations in the Spherical Portion of the Head.
- [10] - Calculations in the Knuckle Portion of the Head.
- [11] - Calculated (Body Flange) Flange MDMT.
- [12] - Calculated Flat Head MDMT per UCS-66.3
- [13] - Tubesheet MDMT, shell side, if applicable
- [14] - Tubesheet MDMT, tube side, if applicable
- [15] - Nozzle Material
- [16] - Shell or Head Material
- [17] - Impact Testing required
- [18] - Impact Testing not required, see UCS-66(b)(3)

UG-84(b)(2) was not considered.

UCS-66(g) was not considered.

UCS-66(i) was not considered.

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MDMT Summary: Step: 25 9:17pm Feb 18,2022

Notes:

Impact test temps were not entered in and not considered in the analysis.  
UCS-66(i) applies to impact tested materials not by specification and  
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).  
The Basic MDMT includes the (30F) PWHT credit if applicable.

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 FileName : Calculation Book for LIQID RECEIVER D-PK6101-2  
 Vessel Design Summary: Step: 26 9:17pm Feb 18,2022

**ASME Code, Section VIII Division 1, 2017**

Diameter Spec : 914.000 mm. OD  
 Vessel Design Length, Tangent to Tangent 4000.00 mm.  
 Specified Datum Line Distance 0.00 mm.  
 Shell Material SA-516 70 [Normalized]  
 Nozzle Material SA-333 6 [Impact Tested]  
 Re-Pad Material SA-516 70 [Normalized]  
 Internal Design Temperature 135 °C  
 Internal Design Pressure 23.000 bar  
 External Design Temperature 100 °C  
 External Design Pressure 1.100 bar  
 Maximum Allowable Working Pressure 23.089 bar  
 External Max. Allowable Working Pressure 3.413 bar  
 Hydrostatic Test Pressure 29.900 bar  
 Required Minimum Design Metal Temperature -45 °C  
 Warmest Computed Minimum Design Metal Temperature -48 °C  
 Wind Design Code ASCE-2010  
 Earthquake Design Code ASCE 7-2010

**Element Pressures and MAWP (bar):**

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
head 001	23.040	1.100	27.849	3.0000	No
shell 001	23.040	1.100	27.329	3.0000	N/A
head 002	23.040	1.100	27.849	3.0000	No

Liquid Level: 890.00 mm. Dens.: 460.789 kg/m³ Sp. Gr.: 0.461

**Element Types and Properties:**

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	Reqd Int.	Thk Ext.	Joint Long	Eff Circ
Ellipse	50.0	50.0	15.0	10.5	5.4	1.00	1.00
Cylinder	3950.0	3900.0	12.0	10.6	8.7	1.00	1.00
Ellipse	4000.0	50.0	15.0	10.5	5.4	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

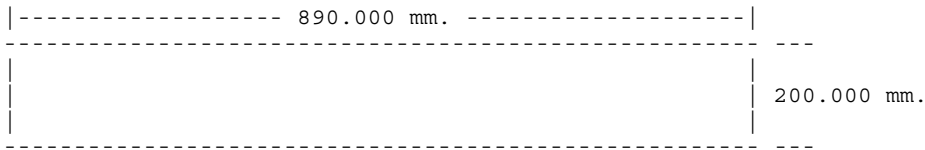
**Saddle Parameters:**

Saddle Width 172.000 mm.  
 Saddle Bearing Angle 120.000 deg.  
 Centerline Dimension 840.000 mm.  
 Wear Pad Width 200.000 mm.  
 Wear Pad Thickness 10.000 mm.  
 Wear Pad Bearing Angle 140.000 deg.  
 Distance from Saddle to Tangent 680.000 mm.  
 Baseplate Length 890.000 mm.  
 Baseplate Thickness 16.000 mm.  
 Baseplate Width 200.000 mm.

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 Vessel Design Summary: Step: 26 9:17pm Feb 18,2022

Number of Ribs (including outside ribs)	2
Rib Thickness	12.000 mm.
Web Thickness	12.000 mm.
Height of Center Web	357.000 mm.
Number of Bolts in Baseplate	4

**Baseplate Sketch**



**Baseplate Plan View**



**Baseplate Side View**

Maximum Tensile Bolt Load	5. kN
---------------------------	-------

**Summary of Maximum Saddle Loads, Operating Case :**

Maximum Vertical Saddle Load	71.40 kN
Maximum Transverse Saddle Shear Load	14.48 kN
Maximum Longitudinal Saddle Shear Load	28.97 kN

**Summary of Maximum Saddle Loads, Hydrotest Case :**

Maximum Vertical Saddle Load	33.28 kN
Maximum Transverse Saddle Shear Load	0.42 kN
Maximum Longitudinal Saddle Shear Load	0.24 kN

**Weights:**

Fabricated - Bare W/O Removable Internals	2504.1 kg.
Shop Test - Fabricated + Water ( Full )	5175.9 kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	2504.1 kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	2862.8 kg.
Empty - Fab. + Intls. + Details + Wghts.	2862.8 kg.
Operating - Empty + Operating Liquid (No CA)	4094.5 kg.
Field Test - Empty Weight + Water (Full)	5234.8 kg.