



IFA

No.: D0

- 1-Design temp shall be conformed with DSh and GA
- 2- in all parts of body JE shall be 1.
- 3-commented point on GA and DSH for nozzles shall be considered here also.

## Mechanical Calculation for K.O. Drum (D-PK6101-3)

**General comment:**

- Native files for all mechanical calculation(PVELITE files) and nozzle local stress analysis (Nozzle pro ) shall be submitted along PDFs.
- All comments on GA drawing shall be considered for revising of mechanical calculation.
- Final approval of GA drawing is pending to approval of mechanical calculation and nozzle local stress calculation.
- As per process data sheet, insulation thickness shall be 50mm; density of insulation shall be equal to 230 kg/m3. please revise GA and calculation accordingly.
- All nozzle loads shall be revised based on allowable nozzle loads specification document, attached to MR. Mechanical calculation shall be revised accordingly.

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<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	
<input checked="" type="checkbox"/>	AN: Approved With Minor Comments (Fabrication may Proceed)	Item No. (Tag No.): PK-6101	
3	NF: Approved With Comments (Fabrication not Proceed)	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0095-D0	
4	RJ: Rejected		
5	NR: Not be Returned		
Date: 15.01.2022		Signature: A.AB	

Mechanical calculation and GA drawings for all equipment shall be defined and submitted in VPIS.



D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.M
<b>REV</b>	<b>DATE ISSUE</b>	<b>PREPARED</b>	<b>CHECKED</b>	<b>APPROVED</b>



**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY**  
**DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**



DOCUMENT TITLE: Mechanical Calculation for K.O. Drum

POI: IFA

Contract No.: DPIC/98-12

DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0095

Rev. No.: D0

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67	x				
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69	x				
70	x				



**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY**  
**DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**



DOCUMENT TITLE: Mechanical Calculation for K.O. Drum

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Contract No.: DPIC/98-12

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**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY**  
**DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**



DOCUMENT TITLE: Mechanical Calculation for K.O. Drum

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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no: K.O. Drum (D-PK6101-3)

**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 : Dec 24,2021 8:44pm

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.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no: K.O. Drum (D-PK6101-3)  
PV Elite 2018 SP2 Licensee: SPLM Licensed User  
FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
Warnings and Errors: Step: 0 8:44pm Dec 24,2021

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

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

There were no geometry errors or warnings.

**PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2018**

Tag no: K.O. Drum (D-PK6101-3)

PV Elite 2018 SP2 Licensee: SPLM Licensed User

FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

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

Refer to comment  
 on process  
 Datasheet. (135)

```

DEHDASHT PETROCHEMICAL INDUSTRY COMP
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)

Design Internal Pressure (for Hydrotest)          23 bars
Design Internal Temperature                       125.0 °C
Type of Hydrotest                                UG-99(b) Note [36]
Hydrotest Position                               Vertical
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 bars
User defined MAWP                                0 bars
User defined MAPnc                               0 bars

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] 195 Km/hr
Surface Roughness Category C: Open Terrain
Importance Factor         1.0
Type of Surface           Moderately Smooth
Base Elevation            123000 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
  
```

Please revise.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
 Tag no: K.O. Drum (D-PK6101-3)  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

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		1.163
Long Period Acceleration Value Sl		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.000
Design Pressure + Static Head		Y
Consider MAP New and Cold in Noz. Design		N
Consider External Loads for Nozzle Des.		Y
Use ASME VIII-1 Appendix 1-9		N
Material Database Year	Current w/Addenda or Code Year	

Ss=0.9  
S1=0.537  
R=2.5

z/h=1  
Ap=2.5

**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.
Inside Diameter	1800 mm.
Element Thickness	18.5 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	22 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	<del>125</del> °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	<del>125</del> °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Impact Tested]
Allowable Stress, Ambient	137.9 N./mm <sup>2</sup>
Allowable Stress, Operating	137.9 N./mm <sup>2</sup>
Allowable Stress, Hydrotest	235.8 N./mm <sup>2</sup>

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	29.997	mm.
Yield Stress, Operating	235.2	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Liquid	
Detail ID	VAM + HQ	
Dist. from "FROM" Node / Offset dist	-450	mm.
Height/Length of Liquid	500	mm.
Liquid Density	0	kg./cm <sup>3</sup>

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-450	mm.
Height/Length of Insulation	500	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

based on PDS:  
 thk=50mm  
 density=230kg/m3

Element From Node	10	
Detail Type	Nozzle	
Detail ID	D	
Dist. from "FROM" Node / Offset dist	0	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 )	0.1909	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	10	
Detail Type	Nozzle	
Detail ID	LG1	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.09794	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]

Element From Node	10	
Detail Type	Nozzle	
Detail ID	LT2	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.09794	kN

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

-----

Element From Node 20  
 Element To Node 30  
 Element Type Cylinder  
 Description SHELL  
 Distance "FROM" to "TO" 2900 mm.  
 Inside Diameter 1800 mm.  
 Element Thickness 22 mm.  
 Internal Corrosion Allowance 3 mm.  
 Nominal Thickness 22 mm.  
 External Corrosion Allowance 0 mm.  
 Design Internal Pressure 23 bars  
 Design Temperature Internal Pressure 125 °C  
 Design External Pressure 1.1 bars  
 Design Temperature External Pressure 125 °C  
 Effective Diameter Multiplier 1.2  
 Material Name SA-516 70 [Impact  
 Efficiency, Longitudinal Seam 0.85  
 Efficiency, Circumferential Seam 0.85  
 Weld is pre-Heated No

Please refer to process data sheet. as defined in process data sheet, TI-TI to be 2800mm.

Based on process data sheet full radiography shall be considered.

Element From Node 20  
 Detail Type Liquid  
 Detail ID VAM + HQ  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Liquid 2900 mm.  
 Liquid Density 0 kg./cm<sup>3</sup>

Refer to comments on bottom head.

Element From Node 20  
 Detail Type Insulation  
 Detail ID Ins: 20  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Insulation 2900 mm.  
 Thickness of Insulation 100 mm.  
 Density 0.00012 kg./cm<sup>3</sup>

Element From Node 20  
 Detail Type Nozzle  
 Detail ID A1  
 Dist. from "FROM" Node / Offset dist 500 mm.  
 Nozzle Diameter 10 in.  
 Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 1.0482 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID A2  
 Dist. from "FROM" Node / Offset dist 1100 mm.  
 Nozzle Diameter 8 in.  
 Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 45.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.755 kN

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

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 2250 mm.  
 Nozzle Diameter 12 in.  
 Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 1.4197 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID LG2  
 Dist. from "FROM" Node / Offset dist 200 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 180.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.09794 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID LT2  
 Dist. from "FROM" Node / Offset dist 200 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.09794 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID SV  
 Dist. from "FROM" Node / Offset dist 1500 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 0.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.09794 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 20  
 Detail Type Nozzle  
 Detail ID M2  
 Dist. from "FROM" Node / Offset dist 2250 mm.  
 Nozzle Diameter 6 in.  
 Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 90.0

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
 Tag no: K.O. Drum (D-PK6101-3)  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.5268 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

Element From Node	20
Detail Type	Nozzle
Detail ID	T1
Dist. from "FROM" Node / Offset dist	700 mm.
Nozzle Diameter	1.5 in.
Nozzle Schedule	None
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.07803 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	20
Detail Type	Nozzle
Detail ID	M1
Dist. from "FROM" Node / Offset dist	700 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 )	5.2309 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-516 70 [Impact Tested]

Element From Node	20
Detail Type	Leg
Detail ID	LEGS
Dist. from "FROM" Node / Offset dist	300 mm.
Diameter at Leg Centerline	1844 mm.
Leg Orientation	1
Number of Legs	4

-----

Element From Node	30
Element To Node	40
Element Type	Elliptical
Description	HEAD 002
Distance "FROM" to "TO"	50 mm.
Inside Diameter	1800 mm.
Element Thickness	18.5 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	22 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Impact Tested]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	0.85
Elliptical Head Factor	2.0
Weld is pre-Heated	No

Element From Node	30
-------------------	----

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

PV Elite 2018 SP2 Licensee: SPLM Licensed User

FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Input Echo: Step: 1 8:44pm Dec 24,2021

Detail Type	Liquid
Detail ID	VAM + HQ
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	500 mm.
Liquid Density	0 kg./cm <sup>3</sup>
Element From Node	30
Detail Type	Insulation
Detail ID	Ins: 20
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	500 mm.
Thickness of Insulation	100 mm.
Density	0.00012 kg./cm <sup>3</sup>
Element From Node	30
Detail Type	Nozzle
Detail ID	V
Dist. from "FROM" Node / Offset dist	0 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 )	0.103 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

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 Tag no: K.O. Drum (D-PK6101-3)  
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 XY Coordinate Calculations: Step: 2 8:44pm Dec 24,2021

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001	...	...	50	...	50
SHELL	...	...	2950	...	2900
HEAD 002	...	...	3000	...	50

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 Internal Pressure Calculations: Step: 3 8:44pm Dec 24,2021

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

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress (SE) N./mm <sup>2</sup>
HEAD 001		23.002	22	3	1800	137.9
SHELL		23.002	22	3	1800	117.21
HEAD 002		23	22	3	1800	137.9

#### Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
HEAD 001		23	23.7308	28.2863	18.5	18.0219
SHELL		23	24.3523	28.2368	22	20.9324
HEAD 002		23	23.7328	28.2863	18.5	18.0206
Minimum			23.731	28.237		

MAWP: 23.176 bars, limited by: Nozzle Reinforcement.

#### Internal Pressure Calculation Results :

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

##### Elliptical Head From 10 To 20 SA-516 70 at 125 °C

##### HEAD 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P) \text{ Appendix 1-4 (c)} \\
 &= (23 \cdot 1806 \cdot 0.996) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23) \\
 &= 15.0219 + 3.0000 = 18.0219 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.002 bars

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D + 0.2 \cdot t) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 15.5) / (0.996 \cdot 1806 + 0.2 \cdot 15.5) \\
 &= 23.733 - 0.002 = 23.731 \text{ bars}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K \cdot D + 0.2 \cdot t) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1 \cdot 18.5) / (1 \cdot 1800 + 0.2 \cdot 18.5) \\
 &= 28.286 \text{ bars}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (K_{cor} \cdot D + 0.2 \cdot t)) / (2 \cdot E \cdot t) \\
 &= (23 \cdot (0.996 \cdot 1806 + 0.2 \cdot 15.5)) / (2 \cdot 1 \cdot 15.5) \\
 &= 133.654 \text{ N./mm}^2
 \end{aligned}$$

Straight Flange Required Thickness:

$$\begin{aligned}
 &= (P \cdot R) / (S \cdot E - 0.6 \cdot P) + c \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) + 3 \\
 &= 18.216 \text{ mm.}
 \end{aligned}$$

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Straight Flange Maximum Allowable Working Pressure:

**Less Operating Hydrostatic Head Pressure of 0.002 bars**

$$= (S*E*t)/(R+0.6*t) \text{ per UG-27 (c) (1)}$$

$$= (137.9 * 1 * 19)/(903 + 0.6 * 19)$$

$$= 28.652 - 0.002 = 28.650 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (1806/(2 * 453))^2)/6$$

$$= 0.995592$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75*t_{nom}/R_f)*(1-R_f/R_o)$  5.205 %

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

**MDMT Calculations in the Knuckle Portion:**

**Note: This Element/Detail was specified as being Impact Tested.**

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

**Note: This Element/Detail was specified as being Impact Tested.**

**Cylindrical Shell From 20 To 30 SA-516 70 at 125 °C**

SHELL

**Material UNS Number: K02700**

Required Thickness due to Internal Pressure [tr]:

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

$$= (23*903)/(137.9*0.85-0.6*23)$$

$$= 17.9324 + 3.0000 = 20.9324 \text{ mm.}$$

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

**Less Operating Hydrostatic Head Pressure of 0.002 bars**

$$= (S*E*t)/(R+0.6*t) \text{ per UG-27 (c) (1)}$$

$$= (137.9*0.85*19)/(903+0.6*19)$$

$$= 24.354 - 0.002 = 24.352 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S*E*t)/(R+0.6*t) \text{ per UG-27 (c) (1)}$$

$$= (137.9*0.85*22)/(900+0.6*22)$$

$$= 28.237 \text{ bars}$$

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

$$= (P*(R+0.6*t))/(E*t)$$

$$= (23*(903+0.6*19))/(0.85*19)$$

$$= 130.243 \text{ N./mm}^2$$

% Elongation per Table UG-79-1  $(50*t_{nom}/R_f)*(1-R_f/R_o)$  1.207 %

**Minimum Design Metal Temperature Results:**

**Note: This Element/Detail was specified as being Impact Tested.**

**Elliptical Head From 30 To 40 SA-516 70 at 125 °C**

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Internal Pressure Calculations: Step: 3 8:44pm Dec 24,2021

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:  
 =  $(P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P)$  Appendix 1-4 (c)  
 =  $(23 \cdot 1806 \cdot 0.996) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 = 15.0206 + 3.0000 = 18.0206 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:  
 Less Operating Hydrostatic Head Pressure of 0.000 bars  
 =  $(2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D + 0.2 \cdot t)$  per Appendix 1-4 (c)  
 =  $(2 \cdot 137.9 \cdot 1 \cdot 15.5) / (0.996 \cdot 1806 + 0.2 \cdot 15.5)$   
 = 23.733 - 0.000 = 23.733 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:  
 =  $(2 \cdot S \cdot E \cdot t) / (K \cdot D + 0.2 \cdot t)$  per Appendix 1-4 (c)  
 =  $(2 \cdot 137.9 \cdot 1 \cdot 18.5) / (1 \cdot 1800 + 0.2 \cdot 18.5)$   
 = 28.286 bars

Actual stress at given pressure and thickness, corroded [Sact]:  
 =  $(P \cdot (K_{cor} \cdot D + 0.2 \cdot t)) / (2 \cdot E \cdot t)$   
 =  $(23 \cdot (0.996 \cdot 1806 + 0.2 \cdot 15.5)) / (2 \cdot 1 \cdot 15.5)$   
 = 133.642 N./mm<sup>2</sup>

Straight Flange Required Thickness:  
 =  $(P \cdot R) / (S \cdot E - 0.6 \cdot P) + c$  per UG-27 (c) (1)  
 =  $(23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) + 3$   
 = 18.214 mm.

Straight Flange Maximum Allowable Working Pressure:  
 Less Operating Hydrostatic Head Pressure of 0.000 bars  
 =  $(S \cdot E \cdot t) / (R + 0.6 \cdot t)$  per UG-27 (c) (1)  
 =  $(137.9 \cdot 1 \cdot 19) / (903 + 0.6 \cdot 19)$   
 = 28.652 - 0.000 = 28.652 bars

Factor K, corroded condition [Kcor]:  
 =  $(2 + (\text{Inside Diameter} / (2 \cdot \text{Inside Head Depth}))^2) / 6$   
 =  $(2 + (1806 / (2 \cdot 453))^2) / 6$   
 = 0.995592

Percent Elong. per UCS-79, VIII-1-01-57  $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  5.205 %  
 Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

**MDMT Calculations in the Knuckle Portion:**

Note: This Element/Detail was specified as being Impact Tested.

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

Note: This Element/Detail was specified as being Impact Tested.

**Hydrostatic Test Pressure Results:**

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.129 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head (Hyd)	36.374 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.493 bars

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Internal Pressure Calculations: Step: 3 8:44pm Dec 24,2021

Pressure per PED =  $\max(1.43*DP, 1.25*DP*ratio)$  32.775 bars  
 Pressure per App 27-4 =  $1.30 * M.A.W.P. * Sa/S$  30.129 bars

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

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

**Vertical 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> & bars):**

From To	Stress	Allowable	Ratio	Pressure
HEAD 001	176.0	235.8	0.746	30.28
SHELL	171.2	235.8	0.726	30.23
HEAD 002	174.0	235.8	0.738	29.95

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
D	Nozzle	117.90	117.90	1.000
D	Pad	137.90	137.90	1.000
LG1	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
A1	Nozzle	117.90	117.90	1.000
A1	Pad	137.90	137.90	1.000
A2	Nozzle	117.90	117.90	1.000
A2	Pad	137.90	137.90	1.000
B	Nozzle	117.90	117.90	1.000
B	Pad	137.90	137.90	1.000
LG2	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
SV	Nozzle	137.90	137.90	1.000
M2	Nozzle	117.90	117.90	1.000
M2	Pad	137.90	137.90	1.000
T1	Nozzle	137.90	137.90	1.000
M1	Nozzle	137.90	137.90	1.000
M1	Pad	137.90	137.90	1.000
V	Nozzle	117.90	117.90	1.000
V	Pad	137.90	137.90	1.000
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	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>):**

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Description	Ambient	Operating	Ratio
D	18.45	217.19	0.085
LG1	8.14	223.40	0.036
LT2	8.14	223.40	0.036
A1	39.19	217.19	0.180
A2	39.47	217.19	0.182
B	38.41	217.19	0.177
LG2	8.12	223.40	0.036
LT2	8.12	223.40	0.036
SV	8.09	223.40	0.036
M2	37.06	217.19	0.171
T1	6.95	223.40	0.031
M1	39.12	235.80	0.166
V	18.25	217.19	0.084

Elements Suitable for Internal Pressure.

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 External Pressure Calculations: Step: 4 8:44pm Dec 24,2021

**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	1837	15.5	0.0011719	90.0274
20	30	3300	1844	19	0.00075914	75.8969
30	40	No Calc	1837	15.5	0.0011719	90.0274

**External Pressure Calculations:**

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	18.5	7.90534	1.1	8.43975
20	30	22	10.7157	1.1	10.4263
30	40	18.5	7.90534	1.1	8.43975
Minimum					8.440

**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	3300	75873.1	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 125 °C**

**HEAD 001**

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
15.500	1837.00	118.52	0.0011719	90.03
EMAP = B/(K0*D/t) = 90.03/(0.9 *118.5 ) = 8.44 bars				

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.905	1837.00	374.49	0.0003709	37.08
EMAP = B/(K0*D/t) = 37.08/(0.9 *374.5 ) = 1.1 bars				

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

Material UNS Number: K02700

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 External Pressure Calculations: Step: 4 8:44pm Dec 24,2021

Required Thickness due to Internal Pressure [tr]:

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

$$= (1.837 \cdot 1806 \cdot 0.996) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 1.837)$$

$$= 1.1978 + 3.0000 = 4.1978 \text{ mm.}$$

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

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

$$= ((2 \cdot 137.9 \cdot 1 \cdot 15.5) / (0.996 \cdot 1806 + 0.2 \cdot 15.5)) / 1.67$$

$$= 14.211 \text{ bars}$$

Maximum Allowable External Pressure [MAEP]:

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

$$= \min(8.44, 14.21)$$

$$= 8.440 \text{ bars}$$

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

### **Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 125 °C**

SHELL

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
19.000	1844.00	3300.00	97.05	1.7896	0.0007591	75.90

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 75.9) / (3 \cdot 97.05) = 10.43 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.716	1844.00	3300.00	238.99	1.7896	0.0001972	19.72

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 19.72) / (3 \cdot 239) = 1.1 \text{ bars}$$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
19.000	1844.00	75873.15	97.05	41.1460	0.0001180	11.79

$$\text{EMAP} = (4 \cdot B) / (3 \cdot (D/t)) = (4 \cdot 11.79) / (3 \cdot 97.05) = 1.62 \text{ bars}$$

### **Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 125 °C**

HEAD 002

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
15.500	1837.00	118.52	0.0011719	90.03

$$\text{EMAP} = B / (K_0 \cdot D/t) = 90.03 / (0.9 \cdot 118.5) = 8.44 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.905	1837.00	374.49	0.0003709	37.08

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

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

Material UNS Number: K02700

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Required Thickness due to Internal Pressure [tr]:

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

$$= (1.837 \cdot 1806 \cdot 0.996) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 1.837)$$

$$= 1.1978 + 3.0000 = 4.1978 \text{ mm.}$$

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

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

$$= ((2 \cdot 137.9 \cdot 1 \cdot 15.5) / (0.996 \cdot 1806 + 0.2 \cdot 15.5)) / 1.67$$

$$= 14.211 \text{ bars}$$

Maximum Allowable External Pressure [MAEP]:

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

$$= \min(8.44, 14.21)$$

$$= 8.440 \text{ bars}$$

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

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Element and Detail Weights: Step: 5 8:44pm Dec 24,2021

**Element and Detail Weights:**

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	726.27	890801	627.233	899312	...
20	30	2830.41	7380924	2448.47	7430211	...
30	40	726.27	890801	627.233	899312	...
Total		4282	9162526.00	3702	9228836.00	0

**Weight of Details:**

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	5.16349	...	-225	VAM + HQ
10	Insl	64.819	...	-200	Ins: 20
10	Nozl	19.4686	...	-1057.08	D
10	Nozl	9.98809	-500	-524.166	LG1
10	Nozl	9.98809	...	-524.166	LT2
20	Liqd	42.7832	...	1450	VAM + HQ
20	Insl	212.781	...	1450	Ins: 20
20	Nozl	106.891	1036.53	500	A1
20	Nozl	76.9905	1009.54	1100	A2
20	Nozl	144.778	1061.92	2250	B
20	Nozl	9.98809	925.4	200	LG2
20	Nozl	9.98809	925.4	200	LT2
20	Nozl	9.98809	925.4	1500	SV
20	Nozl	53.7219	984.138	2250	M2
20	Nozl	7.95779	919.05	700	T1
20	Nozl	533.436	1154	700	M1
20	Legs	436.745	...	-600	LEGS
30	Liqd	5.16349	...	275	VAM + HQ
30	Insl	64.819	...	250	Ins: 20
30	Nozl	10.5041	...	600	V

**Total Weight of Each Detail Type**

Total Weight of Liquid	53.1
Total Weight of Insulation	342.4
Total Weight of Nozzles	1003.7
Total Weight of Legs	436.7
-----	
Sum of the Detail Weights	1836.0 kg.

**Weight Summation: kg.**

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
4282.9	5723.4	4282.9	5723.4	4282.9	6065.8
...	9156.9	...	...	...	53.1
1003.7	...	1003.7	...	...	...
436.7	...	436.7	342.4	...	...
...	...	...	...	342.4	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	1003.7	...
...	...	...	...	436.7	...

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Element and Detail Weights: Step: 5 8:44pm Dec 24,2021

5723.4 | 14880.3 | 5723.4 | 6065.8 | 6065.8 | 6118.9 |

**Weight Summary**

Fabricated Wt.	- Bare Weight W/O Removable Internals	5723.4 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	14880.3 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	5723.4 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	6065.8 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	6065.8 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	6118.9 kg.
Field Test Wt.	- Empty Weight + Water (Full)	14709.0 kg.
Mass of the Upper 1/3 of the Vertical Vessel		1812.0 kg.

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	39755.7
20	30	168000
30	40	39755.7
Total		247511.203 cm <sup>2</sup>

**Element and Detail Weights:**

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kg.
10	20	765.715	835.697	1630.26	48.9914	830.534
20	Legs	391.463	417.901	1142.14	1061.26	413.475
Legs	30	3392.68	3621.81	9898.53	9197.62	3583.45
30	40	736.774	806.757	1601.32	...	801.593

**Cumulative Vessel Weight**

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	...	...	...
20	Legs	-830.534	-835.697	-1630.26
Legs	30	4385.04	4428.56	11499.8
30	40	801.593	806.757	1601.32

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

**Cumulative Vessel Moment**

From	To	Cumulative Empty Mom. N-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m
10	20	...	...	...
20	Legs	...	...	...
Legs	30	...	...	...
30	40	...	...	...

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Element and Detail Weights: Step: 5 8:44pm Dec 24,2021

10	20	48.9914	48.9914	48.9914
20	Legs	1110.26	1110.26	1110.26
Legs	30	9197.62	9197.62	9197.62
30	40	...	...	...

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Nozzle Flange MAWP: Step: 6 8:44pm Dec 24,2021

**Nozzle Flange MAWP Results:**

Nozzle Description	Flange Rating		Design Temp °C	Class	Grade/Group	Equiv. Press	Max Pressure		
	Ope. bars	Ambient bars					PVP	50%	DNV bars
D	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
A1	45.8	51.1	125	300	GR 1.1	...	...	...	...
A2	45.8	51.1	125	300	GR 1.1	...	...	...	...
B	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
SV	45.8	51.1	125	300	GR 1.1	...	...	...	...
M2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	45.8	51.1	125	300	GR 1.1	...	...	...	...
M1	45.8	51.1	125	300	GR 1.1	...	...	...	...
V	45.8	51.1	125	300	GR 1.1	...	...	...	...
Min Rating	45.850	51.100 bars [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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Natural Frequency Calculation: Step: 7 8:44pm Dec 24,2021

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

The Natural Frequency for the Vessel (Empty.) is 23.7922 Hz.

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

The Natural Frequency for the Vessel (Filled) is 14.9266 Hz.

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Wind Load Calculation: Step: 8 8:44pm Dec 24,2021

### Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	[V] 195 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 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
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]:

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q)/(1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1+1.7*3.4*0.228*0.962)/(1+1.7*3.4*0.228))) \\
 &= \min(0.85, 0.905) \\
 &= 0.850
 \end{aligned}$$

Natural Frequency of Vessel (Operating)	23.680 Hz
Natural Frequency of Vessel (Empty)	23.792 Hz
Natural Frequency of Vessel (Test)	14.927 Hz

Force Coefficient	[Cf] 0.513
Structure Height to Diameter ratio	1.809
Height to top of Structure	3568.500 mm.

*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]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 354 + 123000 = 123354 \text{ mm.} \\
 &= 404.7 \text{ ft. Imperial Units}
 \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z (404.7 \text{ ft.}) > 15 \text{ ft.} \\
 &= 2.01 * ( z / Zg )^{2 / \text{Alpha}} \\
 &= 2.01 * ( 404.7/900 )^{2/9.5} \\
 &= 1.699
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

$$= 0.95 \text{ per Table 26.6-1}$$

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As there is No Hill Present: [Kzt]:

$$K1 = 0, K2 = 0, K3 = 0$$

Topographical Factor [Kzt]:

$$= ( 1 + K1 * K2 * K3 )^2$$

$$= ( 1 + 0 * 0 * 0 )^2$$

$$= 1$$

Velocity Pressure evaluated at height z, Imperial Units [qz]:

$$= \max( 16, 0.00256 * Kz * Kzt * Kd * V(\text{mph})^2 )$$

$$= \max( 16, 0.00256 * 1.699 * 1 * 0.95 * 121.2^2 )$$

$$= 60.66 \text{ psf [296.2 ] Kgs/m}^2$$

Force on the first element [F]:

$$= qz * G * Cf * \text{WindArea}$$

$$= 60.66 * 0.85 * 0.513 * 13.06$$

$$= 345.8 \text{ lbs. [1.538 ] kN}$$

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
HEAD 001	*****	0.000	0.000	0.000	1.699	1.000	296.157
SHELL	*****	0.000	0.000	0.000	1.703	1.000	296.960
HEAD 002	*****	0.000	0.000	0.000	1.708	1.000	297.813

### Wind Vibration Calculations

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

#### **Nomenclature**

Cf - Correction factor for natural frequency  
 D - Average internal diameter of vessel mm.  
 Df - Damping Factor < 0.75 Unstable, > 0.95 Stable  
 Dr - Average internal diameter of top half of vessel mm.  
 f - Natural frequency of vibration (Hertz)  
 f1 - Natural frequency of bare vessel based on a unit value of (D/L<sup>2</sup>) (10<sup>4</sup>)  
 L - Total height of structure mm.  
 Lc - Total length of conical section(s) of vessel mm.  
 tb - Uncorroded plate thickness at bottom of vessel mm.  
 V30 - Design Wind Speed provided by user Km/hr  
 Vc - Critical wind velocity Km/hr  
 Vw - Maximum wind speed at top of structure Km/hr  
 W - Total corroded weight of structure kN  
 Ws - Cor. vessel weight excl. weight of parts which do not effect stiff. kN  
 Z - Maximum amplitude of vibration at top of vessel mm.  
 D1 - Logarithmic decrement ( taken as 0.03 for Welded Structures )  
 Vp - Vib. Chance, <= 0.000 (High); 0.000 < 0.000 (Probable)  
 P30 - wind pressure 30 feet above the base

Check other Conditions and Basic Assumptions:

#1 - Total Cone Length / Total Length < 0.5  
 0/3000 = 0

#2 - ( D / L<sup>2</sup> ) \* 10<sup>4</sup> < 8.0 (English Units)  
 - ( 6.705/9.843<sup>2</sup> ) \* 10<sup>4</sup> = 692.2 [Geometry Violation]

Compute the vibration possibility. If Vp > 0.000 no chance. [Vp]:

$$= W / ( L * Dr^2 )$$

$$= 54.31 / ( 3000 * 1806^2 )$$

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 Wind Load Calculation: Step: 8 8:44pm Dec 24,2021

= 0.55508E-08

Since  $V_p$  is > 0.000 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

**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	123354	2444.4	12136.4	296.157	0.92299
20	30	124950	2452.8	71131.2	296.96	5.42428
30	40	126664	2444.4	12136.4	297.813	0.92815

**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 K.O. Drum (D-PK6101-3)  
 Earthquake Load Calculation: Step: 9 8:44pm Dec 24,2021

### 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		1.163
Long Period Acceleration Value S1		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.000

#### Seismic Analysis Results:

$Sms = Fa * Ss = 1 * 1.163 = 1.163$   
 $Sm1 = Fv * S1 = 1.3 * 0.6 = 0.78$   
 $Sds = 2/3 * Sms = 2/3 * 1.163 = 0.775$   
 $Sd1 = 2/3 * Sm1 = 2/3 * 0.78 = 0.52$

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

$= Ct * hn^x$  where  $Ct = 0.020$ ,  $x = 0.75$  and  $hn =$  Structural Height (ft.)  
 $= 0.020 * (16.08^{0.75})$   
 $= 0.161$  seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

$= (1/\text{Natural Frequency}) = (1/23.68)$   
 $= 0.042$

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

$=$  Minimum Value of  $(1.4 * 0.161, 0.0422)$  per 12.8.2  
 $= 0.042$

As the time period is < 0.06 second, use section 15.4.2.

Compute the Base Shear per equation 15.4-5, [V]:

$= 0.3 * Sds * W * I$   
 $= 0.3 * 0.775 * 55.72 * 1.5$   
 $= 19.440$  kN

Final Base Shear,  $V = 13.61$  kN

Distribute the Base shear force to each element according to the equations

$Fx = Cvx * V$  (eqn. 12.8-11) and the vertical distribution factor  
 $Cvx = Wx * hx^k / (\text{Sum of } Wi * hi^k)$  and k is an exponent which is related  
 to the period of Vibration.

In this case, the value of k was 1

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

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**Earthquake Load Calculation:**

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN	Element Emp Load kN
10	20	25	8.19485	0.033279	0.030502
20	Legs	350	4.09793	0.23298	0.21831
Legs	30	1650	35.5154	9.519	8.91968
30	40	2975	7.91105	3.82306	3.49256

**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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 Wind/Earthquake Shear, Bending: Step: 10 8:44pm Dec 24,2021

The following table is for the Operating Case.

**Wind/Earthquake Shear, Bending:**

From	To	Distance to Support mm.	Cumulative Wind Shear kN	Earthquake Shear kN	Wind Bending N-m	Earthquake Bending N-m
10	20	564.463	...	...	...	...
20	Legs	150	0.92299	0.033279	244.196	8.80465
Legs	30	1300	6.71428	13.3753	8378.97	23281.4
30	40	2864.46	0.92815	3.82306	245.561	1011.47

Note:  
 The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of; Wind: 0.600; Earthquake: 0.700.

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

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 Wind Deflection: Step: 11 8:44pm Dec 24,2021

**Wind Deflection Calculations:**

The following table is for the Operating Case.

**Wind Deflection:**

From	To	Cumulative Wind Shear kN	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	0.53169	0.53169	0.00044281
20	Legs	0.92299	0.5317	0.53174	0.00044312
Legs	30	6.71428	0.53286	0.53466	0.00044427
30	40	0.92815	0.5347	0.53474	0.00044427

**Critical Wind Velocity for Tower Vibration:**

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	1039.09	6494.34
20	30	1042.67	6516.66
30	40	1039.09	6494.34

Allowable deflection at the Tower Top (Ope) ( 6.000"/100ft. Criteria)  
 Allowable deflection : 15.000 Actual Deflection : 0.535 mm.

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 Longitudinal Stress Constants:                      Step:    12    8:44pm   Dec 24,2021

**Longitudinal Stress Constants:**

From	To	Metal Area New cm <sup>2</sup>	Metal Area Corroded cm <sup>2</sup>	Section Modulus New mm. <sup>3</sup>	Section Modulus Corroded mm. <sup>3</sup>
10	20	1056.9	886.976	47570540	40052732
20	30	1259.28	1089.35	56683988	49194728
30	40	1056.9	886.976	47570540	40052732

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 Longitudinal Allowable Stresses:            Step:    13    8:44pm   Dec 24,2021

**Longitudinal Allowable Stresses:**

From	To	Tensile N./mm <sup>2</sup>	Hydrotest Tensile N./mm <sup>2</sup>	Compressive N./mm <sup>2</sup>	Hydrotest Compressive N./mm <sup>2</sup>
10	20	140.658	240.516	-125.926	-125.926
20	Legs	140.658	240.516	-130.886	-130.886
Legs	30	140.658	240.516	-130.886	-130.886
30	40	140.658	240.516	-125.926	-125.926

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 Longitudinal Stresses due to: Step: 14 8:44pm Dec 24,2021

### Longitudinal Stress Report

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

#### Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm <sup>2</sup>	Longitudinal Stress External Pressure N./mm <sup>2</sup>	Longitudinal Stress Hydrotest Pressure N./mm <sup>2</sup>
10	20	66.5406	-3.28711	86.5028
20	30	54.1984	-2.69689	70.4579
30	40	66.5406	-3.28711	86.5028

#### Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm <sup>2</sup>	Wght. Str. Operating N./mm <sup>2</sup>	Wght. Str. Hydrotest N./mm <sup>2</sup>	Wght. Str. Emp. Mom. N./mm <sup>2</sup>	Wght. Str. Opr. Mom. N./mm <sup>2</sup>
10	20	...	...	...	0.0012228	0.0012228
20	Legs	0.074769	0.075233	0.14676	0.022561	0.022561
Legs	30	-0.39476	-0.39436	-0.39476	0.1869	0.1869
30	40	-0.088628	-0.088628	-0.088628	...	...

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

From	To	Wght. Str. Hyd. Mom. N./mm <sup>2</sup>	Bend. Str. Oper. Wind N./mm <sup>2</sup>	Bend. Str. Oper. Equ. N./mm <sup>2</sup>	Bend. Str. Hyd. Wind N./mm <sup>2</sup>	Bend. Str. Hyd. Equ. N./mm <sup>2</sup>
10	20	0.0012228	...	...	...	...
20	Legs	0.022561	0.0049623	0.00017892	0.0016375	...
Legs	30	0.1869	0.17027	0.4731	0.056188	...
30	40	...	0.006129	0.025245	0.0020226	...

#### Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm <sup>2</sup>	Vortex Shedding Empty Case N./mm <sup>2</sup>	Vortex Shedding Test Case N./mm <sup>2</sup>	Earthquake Empty Case N./mm <sup>2</sup>
10	20	...	...	...	...
20	Legs	...	...	...	0.00016399
Legs	30	...	...	...	0.43809
30	40	...	...	...	0.023063

#### Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm <sup>2</sup>	Longitudinal Stress Y Forces Seismic N./mm <sup>2</sup>
10	20	...	...
20	Legs	...	...

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Longitudinal Stresses due to: Step: 14 8:44pm Dec 24,2021

Legs	30	...	...
	30	40	...

**Longitudinal Stresses due to User Forces and Moments:**

From	To	Wind For/Mom Corroded N./mm <sup>2</sup>	Earthquake For/Mom Corroded N./mm <sup>2</sup>	Wind For/Mom No Corrosion N./mm <sup>2</sup>	Earthquake For/Mom No Corrosion N./mm <sup>2</sup>
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	40	...	...	...	...

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**Stress Combination Load Cases for Vertical Vessels:**

**Load Case Definition Key**

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

**General Notes:**

Case types HI and HE are in the Corroded condition.

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

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

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

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.75	130.89		0.0057
30		140.66	-0.09	125.93		0.0008

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20	0.23	140.66	-1.02	130.89	0.0016	0.0078
30		140.66	-0.11	125.93		0.0009

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
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## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Stress due to Combined Loads: Step: 15 8:44pm Dec 24,2021

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.75	130.89		0.0057
30		140.66	-0.09	125.93		0.0008

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20	0.27	140.66	-1.05	130.89	0.0019	0.0081
30		140.66	-0.11	125.93		0.0009

## Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	-0.00	125.93	0.0000	0.0000
20	0.17	240.52		130.89	0.0007	
20		240.52	-0.64	130.89		0.0049
30		240.52	-0.09	125.93		0.0007

## Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	-0.00	125.93	0.0000	0.0000
20	0.17	240.52		130.89	0.0007	
20		240.52	-0.58	130.89		0.0044
30		240.52	-0.09	125.93		0.0007

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3861	
20	54.16	140.66		130.89	0.3851	
30	66.46	140.66		125.93	0.4725	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	54.46	140.66		130.89	0.3872	
30	66.48	140.66		125.93	0.4726	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.65	130.89		0.0202
20		140.66	-3.45	130.89		0.0263
30		140.66	-3.38	125.93		0.0269

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.64	130.89		0.0202
20		140.66	-3.75	130.89		0.0287
30		140.66	-3.40	125.93		0.0270

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Stress due to Combined Loads: Step: 15 8:44pm Dec 24,2021

## Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	86.50	240.52		125.93	0.3597	
20	70.63	240.52		130.89	0.2937	
20	70.31	240.52		130.89	0.2923	
30	86.42	240.52		125.93	0.3593	

## Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	86.50	240.52		125.93	0.3597	
20	70.63	240.52		130.89	0.2936	
20	70.25	240.52		130.89	0.2921	
30	86.41	240.52		125.93	0.3593	

## Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

## Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.26	140.66		130.89	0.3858	
20	53.86	140.66		130.89	0.3829	
30	66.47	140.66		125.93	0.4725	

## Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

## Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

## Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.58	130.89		0.0044
30		140.66	-0.09	125.93		0.0007

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	

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30 66.45 140.66 125.93 0.4724

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.64	130.89		0.0202
20		140.66	-3.28	130.89		0.0250
30		140.66	-3.38	125.93		0.0268

Absolute Maximum of the all of the Stress Ratio's 0.4731

Governing Element: HEAD 001

Governing Load Case 7 : IP+OW+WI+FW+BW

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 Center of Gravity Calculation:                    Step:    16    8:44pm   Dec 24,2021

**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 Liquid	1500.000 mm.
Center of Gravity of Insulation	1500.000 mm.
Center of Gravity of Nozzles	1032.829 mm.
Center of Gravity of Legs	-550.000 mm.
Center of Gravity of Bare Shell New and Cold	1500.000 mm.
Center of Gravity of Bare Shell Corroded	1500.000 mm.
Vessel CG in the Operating Condition	1253.702 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1261.641 mm.
Vessel CG in the Test Condition	1408.321 mm.

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 Leg Check, (Operating Case): Step: 17 8:44pm Dec 24,2021

## RESULTS FOR LEGS : Operating Case Description: LEGS

### Legs attached to: SHELL

### Section Properties : Circular Steel Pipe: PIPE

#### USA AISC 1989 Steel Table

Overall Leg Length		1800.000	mm.
Effective Leg Length	Leglen	1500.000	mm.
Distance Leg Up Side of Vessel		300.000	mm.
Number of Legs	Nleg	4	
Cross Sectional Area for PIPE	Aleg	54.190	cm <sup>2</sup>
Section Inertia ( strong axis )		3017.292	cm <sup>4</sup>
Section Inertia ( weak axis )		3017.292	cm <sup>4</sup>
Section Modulus ( strong axis )		275457.688	mm. <sup>3</sup>
Section Modulus ( weak axis )		275457.688	mm. <sup>3</sup>
Radius of Gyration ( strong axis )		74.619	mm.
Radius of Gyration ( weak axis )		74.619	mm.

#### Leg Orientation - Strong Axis

Overturning Moment at top of Legs		23281.4	N-m
Total Weight Load at top of Legs	W	55.7	kN
Total Shear force at top of Legs		13.6	kN
Additional force in leg due to Bracing	Fadd	5.5	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	
Pipe Leg Inside Diameter (Pid)		202.717	mm.
Pipe Leg Outside Diameter (Pod)		219.075	mm.

#### Note: The Legs Are Cross Braced

The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	300.000	mm.
Pad Length along Vessel Axis	C22P	400.000	mm.
Pad Thickness	Tpad	15.000	mm.

#### Maximum Shear at top of one Leg [Vleg]:

$$\begin{aligned}
 &= ( \max( \text{Wind}, \text{Seismic} ) + \text{applied forces} ) ( I_{\max} / I_{\text{tot}} ) \\
 &= ( 13.61 ) ( 3017/12069 ) \\
 &= 3.40 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= W/N_{\text{leg}} + (M_{\text{leg}} / (N_{\text{leg}} * R_n)) / A_{\text{leg}} \\
 &= 55722/4 + (23272148 / (2 * 922)) / 5419 \\
 &= 4.90 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= ( W / N_{\text{leg}} + F_{\text{add}} ) / A_{\text{leg}} \\
 &= ( 55.72/4 + 5.535 ) / 54.19 \\
 &= 3.59 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \text{Occfac} * ( 1 - (kl/r)^2 / (2 * Cc^2) ) * F_y / \\
 &\quad ( 5/3 + 3 * (kl/r) / (8 * Cc) - (kl/r^3) / (8 * Cc^3) ) \\
 &= 1.333 * ( 1 - ( 20.1 )^2 / (2 * 127.2^2) ) * 248.2 / \\
 &\quad ( 5/3 + 3 * ( 20.1 ) / (8 * 127.2) - ( 20.1^3 ) / (8 * 127.2^3) ) \\
 &= 189.37 \text{ N./mm}^2
 \end{aligned}$$

#### Bending at the Bottom of the Leg closest to the N.A. [S]:

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Leg Check, (Operating Case): Step: 17 8:44pm Dec 24,2021

$$\begin{aligned}
 &= ( Vleg * Leglen / Smdsa ) \\
 &= ( 3.402 * 1500/275458 ) \\
 &= 0 \text{ since the legs are Cross Braced}
 \end{aligned}$$

Allowable Bending Stress[Sb]:

$$\begin{aligned}
 &= ( 0.6 * Fy * Occfac ) \\
 &= ( 0.6 * 248.2 * 1.333 ) \\
 &= 198.53 \text{ N./mm}^2
 \end{aligned}$$

AISC Unity Check [Sc]( must be < or = to 1.00 ) :

$$\begin{aligned}
 &= ( Sma/Sa ) + ( 0.85 * S ) / ( ( 1 - Sma/Spex ) * Sb ) \\
 &= ( 4.9/189.4 ) + ( 0.85 * 0 ) / ( ( 1 - 4.9/3455 ) * 198.5 ) \\
 &= 0.0259
 \end{aligned}$$

### **Bolting Size Requirement for Leg Baseplates :**

Baseplate Material		SA-516	70
Baseplate Allowable Stress	SBA	137.90	N./mm <sup>2</sup>
Baseplate Length	B	350.0000	mm.
Baseplate Width	D	350.0000	mm.
Baseplate Thickness	BTHK	35.0000	mm.
Leg Dimension Along Baseplate Length	d	219.0750	mm.
Leg Dimension Along Baseplate Width	b	219.0750	mm.
Dist. from the Leg Edge to Bolt Hole Center	z	25.0000	mm.
Bolt Material		SA-193	B7
Bolt Allowable Stress	STBA	172.38	N./mm <sup>2</sup>
Anchor Bolt Nominal Diameter	BOD	30.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	2	
Total Number of Anchors Bolt per Leg	NBT	4	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm <sup>2</sup>

### **LEG BASEPLATE and BOLTING Analysis, including Moments**

Pipe Leg

Base Plate Available Area (AA):

$$\begin{aligned}
 &= B * D \\
 &= 350 * 350 \\
 &= 1225.00 \text{ cm}^2
 \end{aligned}$$

Clearance Between The Bolt And The Leg Edge (BCL):

$$\begin{aligned}
 &= z - BOD / 2 \\
 &= 25 - 30/2 \\
 &= 10.00 \text{ mm.}
 \end{aligned}$$

Moment at Baseplate (MOMENT):

$$\begin{aligned}
 &= Vleg * Lleg \\
 &= 3.402 * 1800 \\
 &= 6126.23 \text{ N-m}
 \end{aligned}$$

Axial Load on the baseplate (P):

$$\begin{aligned}
 &= \text{Operating Weight per leg (as Seismic + Operating case is controlling)} \\
 &= 13.93 \text{ kN}
 \end{aligned}$$

Eccentricity (e):

$$\begin{aligned}
 &= \text{MOMENT} * \text{Conv\_Factor} / P \\
 &= 6126 * 999.68 / 13.93 \\
 &= 439.61 \text{ mm.} > D/6 \text{ [Plate Uplift Condition]}
 \end{aligned}$$

$$a = (\text{MAX}[B,D] - 0.707 * \text{Pod}) / 2$$

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Leg Check, (Operating Case): Step: 17 8:44pm Dec 24,2021

$$= (350 - 0.707 * 219.1) / 2$$

$$= 97.56 \text{ mm.}$$

Modular Ratio Of Steel/Concrete (n):

$$= ES / EC$$

$$= 203402 / 21526$$

$$= 9.45$$

$$F = 0.5 * d + z$$

$$= 0.5 * 219.1 + 25$$

$$= 134.54 \text{ mm.}$$

$$K1 = 3.0 (e - 0.5 * D)$$

$$= 3.0 (439.6 - 0.5 * 350)$$

$$= 793.84$$

$$K2 = 6 * n * Ast / B * (F + e)$$

$$= 6 * 9.449 * 10.06 / 350 * (134.5 + 439.6)$$

$$= 935.54$$

$$K3 = -K2 * (0.5 * D + F)$$

$$= -935.5 * (0.5 * 350 + 134.5)$$

$$= -289585.77$$

Solving For The Effective Bearing Length Using Iteration:

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

$$Y^3 + 31.25 * Y^2 + 145 * Y - 1767 = 0$$

$$Y = 133.34 \text{ mm.}$$

$$NUM = (D / 2 - Y / 3 - e)$$

$$= (350 / 2 - 133.3 / 3 - 439.6)$$

$$= -309.06$$

$$DENOM = (D / 2 - Y / 3 + F)$$

$$= (350 / 2 - 133.3 / 3 + 134.5)$$

$$= 265.09$$

Total Bolt Tension Force (T):

$$= -P * NUM / DENOM$$

$$= -13.93 * -309.1 / 265.1$$

$$= 16.24 \text{ kN}$$

Overtuning Moment Due To Bolt In Tension (Mt):

$$= T * (0.5 * D + F - Y)$$

$$= 16.24 * (0.5 * 350 + 134.5 - 133.3)$$

$$= 2862.69 \text{ N-m}$$

Bearing Pressure (FC):

$$= 2 * (P + T) / (Y * B)$$

$$= 2 * (13.93 + 16.24) / (133.3 * 350)$$

$$= 12.93 \text{ bars [ } \leq \text{ FCPRIME ( } 206.84 \text{)]}$$

Equivalent Bearing Pressure (f1):

$$= FC * (Y - a) / Y$$

$$= 12.93 * (133.3 - 97.56) / 133.3$$

$$= 3.47 \text{ bars}$$

Overtuning Moment Due To Bearing Pressure (Mc):

$$= (a^2 * B / 6) * (f1 + 2 * FC)$$

$$= (97.56^2 * 350 / 6) * (3.47 + 2 * 12.93)$$

$$= 1628.94 \text{ N-m}$$

The Baseplate Required Thickness (TREQ):

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Leg Check, (Operating Case): Step: 17 8:44pm Dec 24,2021

$$= (6 * \text{MAX}(Mt, Mc) / (B * 1.5 * SBA))^{1/2}$$

$$= (6 * 2863 / (350 * 206.9))^{1/2}$$

$$= 15.40 \text{ mm.}$$

Required bolt area (ABREQM): per D. Moss

$$= T / STBA$$

$$= 16.24 / 172.4$$

$$= 0.9422 \text{ cm}^2 [ < \text{Ast} ( 10.06) \text{ --> PASSED}]$$

Distance from Top of Legs to Vessel CG (CD\_DIST):

$$= 903.7 \text{ mm.}$$

Total Overturning Moment at Baseplate (Mbb):

$$= ( M_{leg} / \max([\text{CD\_DIST}], \text{minDist}) ) * ( \text{CD\_DIST} + L_{leg} )$$

$$= ( 23281 / \max( 903.7, 38.1 ) ) * ( 903.7 + 1800 )$$

$$= 69653.50 \text{ N-m}$$

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

$$= (1 / (N_{leg} * STBA)) * ((4 * M_{bb} / (R_n * 2)) - W)$$

$$= (1 / (4 * 172.4)) * ((4 * 69654 / (1844)) - 55.72)$$

$$= 1.3824 \text{ cm}^2$$

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

$$= A_s * N_{BT}$$

$$= 5.03 * 4$$

$$= 20.1186 \text{ cm}^2 [ > \text{ABREQB} ( 1.38) \text{ --> PASSED}]$$

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	( mm. ):	35.000	15.400	Pass
Bolt Root Area (Bednar)	( cm <sup>2</sup> ):	20.12	1.38	Pass
Bolt Root Area (D. Moss)	( cm <sup>2</sup> ):	10.06	0.94	Pass

Note: The required thickness calculation is performed based on:

Beam leg analysis per Moss.

Even number of bolts installed only on the B dimension sides

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 Leg Check, (Filled w/Water): Step: 18 8:44pm Dec 24,2021

## RESULTS FOR LEGS : HydroTest Case Description: LEGS

### Legs attached to: SHELL

### Section Properties : Circular Steel Pipe: PIPE

#### USA AISC 1989 Steel Table

Overall Leg Length		1800.000	mm.
Effective Leg Length	Leglen	1500.000	mm.
Distance Leg Up Side of Vessel		300.000	mm.
Number of Legs	Nleg	4	
Cross Sectional Area for PIPE	Aleg	54.190	cm <sup>2</sup>
Section Inertia ( strong axis )		3017.292	cm <sup>4</sup>
Section Inertia ( weak axis )		3017.292	cm <sup>4</sup>
Section Modulus ( strong axis )		275457.688	mm. <sup>3</sup>
Section Modulus ( weak axis )		275457.688	mm. <sup>3</sup>
Radius of Gyration ( strong axis )		74.619	mm.
Radius of Gyration ( weak axis )		74.619	mm.

#### Leg Orientation - Strong Axis

Overturning Moment at top of Legs		2765.1	N-m
Total Weight Load at top of Legs	W	141.6	kN
Total Shear force at top of Legs		2.4	kN
Additional force in Leg due to Bracing	Fadd	1.0	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	
Pipe Leg Inside Diameter (Pid)		202.717	mm.
Pipe Leg Outside Diameter (Pod)		219.075	mm.

#### Note: The Legs Are Cross Braced

The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	300.000	mm.
Pad Length along Vessel Axis	C22P	400.000	mm.
Pad Thickness	Tpad	15.000	mm.

#### Maximum Shear at top of one Leg [Vleg]:

$$\begin{aligned}
 &= ( \max( \text{Wind}, \text{Seismic} ) + \text{applied forces} ) ( I_{\max} / I_{\text{tot}} ) \\
 &= ( 2.401 ) ( 3017/12069 ) \\
 &= 0.60 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= W/N_{\text{leg}} + (M_{\text{leg}} / (N_{\text{leg}} * R_n)) / A_{\text{leg}} \\
 &= 141641/4 + (2763959 / (2 * 922)) / 5419 \\
 &= 6.81 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= ( W / N_{\text{leg}} + F_{\text{add}} ) / A_{\text{leg}} \\
 &= ( 141.6/4 + 0.976 ) / 54.19 \\
 &= 6.71 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \text{Occfac} * ( 1 - (kl/r)^2 / (2 * C_c^2) ) * F_y / \\
 &\quad ( 5/3 + 3 * (kl/r) / (8 * C_c) - (kl/r)^3 / (8 * C_c^3) ) \\
 &= 1.333 * ( 1 - ( 20.1 )^2 / (2 * 127.2^2) ) * 248.2 / \\
 &\quad ( 5/3 + 3 * ( 20.1 ) / (8 * 127.2) - ( 20.1^3 ) / (8 * 127.2^3) ) \\
 &= 189.37 \text{ N./mm}^2
 \end{aligned}$$

#### Bending at the Bottom of the Leg closest to the N.A. [S]:

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$$\begin{aligned}
 &= ( Vleg * Leglen / Smdsa ) \\
 &= ( 0.6 * 1500 / 275458 ) \\
 &= 0 \text{ since the legs are Cross Braced}
 \end{aligned}$$

Allowable Bending Stress[Sb]:

$$\begin{aligned}
 &= ( 0.6 * Fy * Occfac ) \\
 &= ( 0.6 * 248.2 * 1.333 ) \\
 &= 198.53 \text{ N./mm}^2
 \end{aligned}$$

AISC Unity Check [Sc]( must be < or = to 1.00 ) :

$$\begin{aligned}
 &= ( Sma / Sa ) + ( 0.85 * S ) / ( ( 1 - Sma / Spex ) * Sb ) \\
 &= ( 6.811 / 189.4 ) + ( 0.85 * 0 ) / ( ( 1 - 6.811 / 3455 ) * 198.5 ) \\
 &= 0.0360
 \end{aligned}$$

### **Bolting Size Requirement for Leg Baseplates :**

Baseplate Material		SA-516	70
Baseplate Allowable Stress	SBA	137.90	N./mm <sup>2</sup>
Baseplate Length	B	350.0000	mm.
Baseplate Width	D	350.0000	mm.
Baseplate Thickness	BTHK	35.0000	mm.
Leg Dimension Along Baseplate Length	d	219.0750	mm.
Leg Dimension Along Baseplate Width	b	219.0750	mm.
Dist. from the Leg Edge to Bolt Hole Center	z	25.0000	mm.
Bolt Material		SA-193	B7
Bolt Allowable Stress	STBA	172.38	N./mm <sup>2</sup>
Anchor Bolt Nominal Diameter	BOD	30.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	2	
Total Number of Anchors Bolt per Leg	NBT	4	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm <sup>2</sup>

### **LEG BASEPLATE and BOLTING Analysis, including Moments**

Pipe Leg

Base Plate Available Area (AA):

$$\begin{aligned}
 &= B * D \\
 &= 350 * 350 \\
 &= 1225.00 \text{ cm}^2
 \end{aligned}$$

Clearance Between The Bolt And The Leg Edge (BCL):

$$\begin{aligned}
 &= z - BOD / 2 \\
 &= 25 - 30 / 2 \\
 &= 10.00 \text{ mm.}
 \end{aligned}$$

Moment at Baseplate (MOMENT):

$$\begin{aligned}
 &= Vleg * Lleg \\
 &= 0.6 * 1800 \\
 &= 1080.84 \text{ N-m}
 \end{aligned}$$

Axial Load on the baseplate (P):

$$\begin{aligned}
 &= \text{Operating Weight per leg (as Seismic + Operating case is controlling)} \\
 &= 13.93 \text{ kN}
 \end{aligned}$$

Eccentricity (e):

$$\begin{aligned}
 &= \text{MOMENT} * \text{Conv\_Factor} / P \\
 &= 1081 * 999.68 / 13.93 \\
 &= 77.56 \text{ mm.} > D/6 \text{ [Plate Uplift Condition]}
 \end{aligned}$$

$$a = (\text{MAX}[B,D] - 0.707 * Pod) / 2$$

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$$= (350 - 0.707 * 219.1) / 2$$

$$= 97.56 \text{ mm.}$$

Modular Ratio Of Steel/Concrete (n):

$$= ES / EC$$

$$= 203402 / 21526$$

$$= 9.45$$

$$F = 0.5 * d + z$$

$$= 0.5 * 219.1 + 25$$

$$= 134.54 \text{ mm.}$$

$$K1 = 3.0 (e - 0.5 * D)$$

$$= 3.0 (77.56 - 0.5 * 350)$$

$$= -292.32$$

$$K2 = 6 * n * Ast / B * (F + e)$$

$$= 6 * 9.449 * 10.06 / 350 * (134.5 + 77.56)$$

$$= 345.60$$

$$K3 = -K2 * (0.5 * D + F)$$

$$= -345.6 * (0.5 * 350 + 134.5)$$

$$= -106976.09$$

Solving For The Effective Bearing Length Using Iteration:

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

$$Y^3 + -11.51 * Y^2 + 53.57 * Y - 652.8 = 0$$

$$Y = 297.16 \text{ mm.}$$

$$NUM = (D / 2 - Y / 3 - e)$$

$$= (350 / 2 - 297.2 / 3 - 77.56)$$

$$= -1.61$$

$$DENOM = (D / 2 - Y / 3 + F)$$

$$= (350 / 2 - 297.2 / 3 + 134.5)$$

$$= 210.48$$

Total Bolt Tension Force (T):

$$= -P * NUM / DENOM$$

$$= -13.93 * -1.614 / 210.5$$

$$= 0.11 \text{ kN}$$

Overturning Moment Due To Bolt In Tension (Mt):

$$= T * (0.5 * D + F - Y)$$

$$= 0.107 * (0.5 * 350 + 134.5 - 297.2)$$

$$= 1.32 \text{ N-m}$$

Bearing Pressure (FC):

$$= 2 * (P + T) / (Y * B)$$

$$= 2 * (13.93 + 0.107) / (297.2 * 350)$$

$$= 2.70 \text{ bars [ } \leq \text{ FCPRIME ( } 206.84 \text{)]}$$

Equivalent Bearing Pressure (f1):

$$= FC * (Y - a) / Y$$

$$= 2.699 * (297.2 - 97.56) / 297.2$$

$$= 1.81 \text{ bars}$$

Overturning Moment Due To Bearing Pressure (Mc):

$$= (a^2 * B / 6) * (f1 + 2 * FC)$$

$$= (97.56^2 * 350 / 6) * (1.813 + 2 * 2.699)$$

$$= 400.53 \text{ N-m}$$

The Baseplate Required Thickness (TREQ):

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$$= (6 * \text{MAX}(M_t, M_c) / (B * 1.5 * \text{SBA}))^{1/2}$$

$$= (6 * 400.5 / (350 * 206.9))^{1/2}$$

$$= 5.76 \text{ mm.}$$

Required bolt area (ABREQM): per D. Moss

$$= T / \text{STBA}$$

$$= 0.107 / 172.4$$

$$= 0.0062 \text{ cm}^2 [ < A_{st} ( 10.06) \text{ --> PASSED}]$$

Distance from Top of Legs to Vessel CG (CD\_DIST):

$$= 1058 \text{ mm.}$$

Total Overturning Moment at Baseplate (Mbb):

$$= ( M_{leg} / \max([CD\_DIST], \text{minDist}) ) * ( CD\_DIST + L_{leg} )$$

$$= ( 2765 / \max( 1058, 38.1 ) ) * ( 1058 + 1800 )$$

$$= 7467.90 \text{ N-m}$$

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

$$= (1 / (N_{leg} * \text{STBA})) * ((4 * M_{bb} / (R_n * 2)) - W)$$

$$= (1 / (4 * 172.4)) * ((4 * 7468 / (1844)) - 55.72)$$

$$= -0.5733 \text{ cm}^2 \text{ --> (No tension in bolts)}$$

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	( mm. ):	35.000	5.760	Pass
Bolt Root Area (D. Moss)	( cm <sup>2</sup> ):	10.06	0.01	Pass

Note: The required thickness calculation is performed based on:

Beam leg analysis per Moss.

Even number of bolts installed only on the B dimension sides

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#### Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
D	23.18	OK	...	OK	6.42	OK	Passed
LG1	23.73	OK	...	OK	7.80	OK	Passed
LG1	23.73	OK	...	OK	7.80	OK	Passed
LT2	23.73	OK	...	OK	7.80	OK	Passed
LT2	23.73	OK	...	OK	7.80	OK	Passed
A1	23.32	OK	...	OK	11.10	OK	Passed
A2	23.66	OK	...	OK	10.16	OK	Passed
B	23.50	OK	...	OK	11.33	OK	Passed
LG2	24.35	OK	...	OK	7.80	OK	Passed
LT2	24.35	OK	...	OK	7.80	OK	Passed
SV	24.35	OK	...	OK	7.80	OK	Passed
M2	24.35	OK	...	OK	9.22	OK	Passed
T1	24.35	OK	...	OK	7.52	OK	Passed
M1	24.35	OK	...	...	...	OK	Passed
V	23.18	OK	...	OK	6.42	OK	Passed

#### MAWP Summary:

Minimum MAWP Nozzles : 23.176 Nozzle : D  
 Minimum MAWP Shells/Flanges : 23.731 Element : HEAD 001  
 Minimum MAPnc Shells/Flanges : 28.237 Element : SHELL  
 -----  
 Computed Vessel M.A.W.P. : 23.176 bars

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	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	D	0.000	0.000	102.068
10	LG1	0.000	180.000	115.000
10	LT2	0.000	270.000	115.000
20	A1	550.000	90.000	505.293
20	A2	1150.000	45.000	405.700
20	B	2300.000	270.000	598.626
20	LG2	250.000	180.000	122.000
20	LT2	250.000	270.000	122.000
20	SV	1550.000	0.000	122.000
20	M2	2300.000	90.000	310.145
20	T1	750.000	270.000	108.000
20	M1	750.000	0.000	940.000
30	V	0.000	0.000	102.068

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

= Sqrt(  $l_l^2 + l_c^2$  ) where

$l_l$  - Arc length along the inside vessel surface in the long. direction.

$l_c$  - 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: D From : 10**

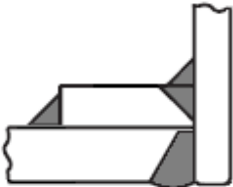
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	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 [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		200.0000	mm.
Weld leg size between Nozzle and Vessel	Wnw	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	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	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		64.8375	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 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)  
 =  $(23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 = 13.5366 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)  
 =  $(23 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23)$   
 = 0.5839 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		21.6135	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	7.091	1.285	NA
Area in Shell A1	0.976	5.264	NA
Area in Nozzle Wall A2	1.501	1.596	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	4.174	4.174	NA
TOTAL AREA AVAILABLE Atot	7.198	11.582	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:	100.9934	10.0000 mm.
Based on given Pad Diameter:	190.0000	9.7425 mm.
Based on the Estimated Diameter Limit:	100.4809	10.1276 mm.

#### Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 * 13.54 * 1 + 2 * 4.645 * 13.54 * 1 * (1 - 0.855))$$

$$= 7.091 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

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

$$= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1)$$

$$= 51.03 (1 * 15.5 - 1 * 13.54) - 2 * 4.645$$

$$(1 * 15.5 - 1 * 13.54) * (1 - 0.855)$$

$$= 0.976 \text{ cm}^2$$

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

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 21.61) * (4.645 - 0.584) * 0.855$$

$$= 1.501 \text{ cm}^2$$

##### 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]:

$$= (\min(Dp, DL) - \text{Nozzle OD}) * (\min(tp, Tlwp, te)) * fr4$$

$$= (102.1 - 60.33) * 10 * 1$$

$$= 4.174 \text{ cm}^2$$

#### 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 = 18.0219 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.0219 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7172 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( 18.02, 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

### 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 = 10, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.873$ , Temp. Reduction = 7 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

#### Nozzle-Shell/Head 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

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

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

MDMT of ANSI B16.5/47 flange per Matl. Specification -18 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -96 °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: D

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 10.0000 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	5.0000 = 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.091 - 0.976 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 15.5 - 13.54) ) 137.9 ) \\
 &= 86.47 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 1.501 + 4.174 + 0.547 - 0 * 0.855 ) * 137.9 \\
 &= 85.80 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.501 + 0 + 0.547 + ( 1.231 ) ) * 137.9 \\
 &= 45.22 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.501 + 0 + 0.547 + 4.174 + ( 1.231 ) ) * 137.9 \\
 &= 102.78 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 60.33 * 8 * 0.49 * 117.9 \\
 &= 44. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

$$\begin{aligned}
 &= (\pi/2) * DP * WP * 0.49 * SEW \\
 &= ( 3.142/2.0 ) * 190 * 10 * 0.49 * 137.9 \\
 &= 202. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

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$$= (3.142 * 27.84) * (7.645 - 3) * 0.7 * 117.9$$

$$= 34. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= (3.142/2) * 60.33 * 10 * 0.74 * 137.9$$

$$= 97. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng}$$

$$= (3.142/2) * 60.33 * (18.5 - 3) * 0.74 * 137.9$$

$$= 150. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = (S_{PEW} + S_{NW}) = (201.6 + 33.53) = 235.2 \text{ kN}$$

$$\text{PATH22} = (S_{onw} + T_{pgw} + T_{ngw} + S_{inw})$$

$$= (43.79 + 96.69 + 149.9 + 0) = 290.3 \text{ kN}$$

$$\text{PATH33} = (S_{pew} + T_{ngw} + S_{inw})$$

$$= (201.6 + 149.9 + 0) = 351.5 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 235 kN , must exceed W = 86 kN or W1 = 85 kN  
 Path 2-2 = 290 kN , must exceed W = 86 kN or W2 = 45 kN  
 Path 3-3 = 351 kN , must exceed W = 86 kN or W3 = 102 kN

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

Converged Max. Allow. Pressure in Operating case 23.178 bars  
 Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 0.2783 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 218.7783 mm.

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 Nozzle Calcs.: LG1 Nozl: 15 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: LG1 From : 10**

Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		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	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	500.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

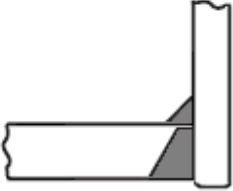
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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

Note : Checking Nozzle in the Meridional direction.

### Reinforcement CALCULATION, Description: LG1

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 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)  
 $= (23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 $= 13.5366 \text{ mm.}$

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 $= (23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 $= 0.4785 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	119.7360	mm.
Parallel to Vessel Wall, opening length	d	59.8680	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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 [fr3]:

$= \min(fr_2, fr_4)$   
 $= \min(1, 1)$   
 $= 1.000$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.104	1.468	NA

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Nozzle Calcs.: LG1 Nozl: 15 8:44pm Dec 24,2021

Area in Shell	A1	1.175	6.343	NA
Area in Nozzle Wall	A2	9.313	9.372	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.489	16.715	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 71.58 Degs.

The area available without a pad is Sufficient.

## Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (59.87 * 13.54 * 1 + 2 * 13.6 * 13.54 * 1 * (1 - 1))$$

$$= 8.104 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1)$$

$$= 59.87 (1 * 15.5 - 1 * 13.54) - 2 * 13.6$$

$$(1 * 15.5 - 1 * 13.54) * (1 - 1)$$

$$= 1.175 \text{ cm}^2$$

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

$$= (2 * t * ln * p) (tn - trn) fr2 / \sin(\alpha3)$$

$$= (2 * 34) (13.6 - 0.479) / \sin(73.34)$$

$$= 9.313 \text{ cm}^2$$

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]:

$$= W_o^2 * fr2 + (W_i - can / 0.707)^2 * fr2$$

$$= 10^2 * 1 + (0)^2 * 1$$

$$= 1.000 \text{ cm}^2$$

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

## Nozzle-Shell/Head 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
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	-18 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-48 °C

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

$$\text{Design Pressure/Ambient Rating} = 23.00/51.10 = 0.450$$

## Weld Size Calculations, Description: LG1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

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#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

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

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (8.104 - 1.175 + 2 * 13.6 * 1 * \\
 &\quad (1 * 15.5 - 13.54) ) 137.9 ) \\
 &= 102.90 \text{ kN}
 \end{aligned}$$

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

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 9.313 + 0 + 1 - 0 * 1 ) * 137.9 \\
 &= 142.21 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 9.313 + 0 + 1 + ( 4.216 ) ) * 137.9 \\
 &= 200.34 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 9.313 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9 \\
 &= 200.34 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 88.54 * 10 * 0.49 * 137.9 \\
 &= 94. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 37.1 ) * ( 16.6 - 3 ) * 0.7 * 137.9 \\
 &= 153. \text{ kN}
 \end{aligned}$$

##### Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 88.54 * ( 18.5 - 3 ) * 0.74 * 137.9 \\
 &= 220. \text{ kN}
 \end{aligned}$$

#### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 93.97 + 153 ) = 247 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 93.97 + 0 + 220 + 0 ) = 313.9 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 93.97 + 220 + 0 ) = 313.9 \text{ kN}
 \end{aligned}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 246 kN , must exceed W = 102 kN or W1 = 142 kN  
 Path 2-2 = 313 kN , must exceed W = 102 kN or W2 = 200 kN  
 Path 3-3 = 313 kN , must exceed W = 102 kN or W3 = 200 kN

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

Converged Max. Allow. Pressure in Operating case 23.733 bars

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

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

Note : Checking Nozzle in the Latitudinal direction.

### Reinforcement CALCULATION, Description: LG1

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 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)  
 $= (23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 $= 13.5366$  mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 $= (23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 $= 0.4785$  mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.689	1.393	NA
Area in Shell	A1	1.143	6.166	NA
Area in Nozzle Wall	A2	8.923	8.979	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.065	16.145	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]:  
 $= (d \cdot tr \cdot F + 2 \cdot tn \cdot tr \cdot F \cdot (1 - fr_1))$  UG-37(c)  
 $= (56.8 \cdot 13.54 \cdot 1 + 2 \cdot 13.6 \cdot 13.54 \cdot 1 \cdot (1 - 1))$   
 $= 7.689$  cm<sup>2</sup>

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:  
 $= d (E_1 \cdot t - F \cdot tr) - 2 \cdot tn (E_1 \cdot t - F \cdot tr) \cdot (1 - fr_1)$   
 $= 58.2 (1 \cdot 15.5 - 1 \cdot 13.54) - 2 \cdot 13.6$   
 $(1 \cdot 15.5 - 1 \cdot 13.54) \cdot (1 - 1)$

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Nozzle Calcs.: LG1

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$$= 1.143 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned} &= (2 * t_{lnp}) (t_n - t_{rn}) fr_2 \\ &= (2 * 34) (13.6 - 0.479) 1 \\ &= 8.923 \text{ cm}^2 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned} &= W_o^2 * fr_2 + (W_i - can / 0.707)^2 * fr_2 \\ &= 10^2 * 1 + (0)^2 * 1 \\ &= 1.000 \text{ cm}^2 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	$t_a = 3.4785 \text{ mm.}$
Wall Thickness per UG16(b),	$tr_{16b} = 4.5000 \text{ mm.}$
Wall Thickness, shell/head, internal pressure	$tr_{b1} = 18.0219 \text{ mm.}$
Wall Thickness	$tb_1 = \max(tr_{b1}, tr_{16b}) = 18.0219 \text{ mm.}$
Wall Thickness, shell/head, external pressure	$tr_{b2} = 3.7172 \text{ mm.}$
Wall Thickness	$tb_2 = \max(tr_{b2}, tr_{16b}) = 4.5000 \text{ mm.}$
Wall Thickness per table UG-45	$tb_3 = 7.8000 \text{ mm.}$

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned} &= \min[ tb_3, \max( tb_1, tb_2 ) ] \\ &= \min[ 7.8, \max( 18.02, 4.5 ) ] \\ &= 7.8000 \text{ mm.} \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned} &= \max( t_a, t_b ) \\ &= \max( 3.479, 7.8 ) \\ &= 7.8000 \text{ mm.} \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: LG1

Intermediate Calc. for nozzle/shell Welds	$T_{min}$	13.6000 mm.
---	-----------	-------------

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = $0.7 * W_o$ mm.

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

Weld Load [W]:

$$\begin{aligned} &= \max( 0, (A - A_1 + 2 * t_n * fr_1 * (E_1 * t - t_r)) Sv ) \\ &= \max( 0, (7.689 - 1.143 + 2 * 13.6 * 1 * \\ &\quad (1 * 15.5 - 13.54) ) 137.9 ) \\ &= 97.63 \text{ kN} \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned} &= (A_2 + A_5 + A_4 - (W_i - Can / .707)^2 * fr_2) * Sv \\ &= (8.923 + 0 + 1 - 0 * 1) * 137.9 \\ &= 136.82 \text{ kN} \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned} &= (A_2 + A_3 + A_4 + (2 * t_n * t * fr_1)) * Sv \\ &= (8.923 + 0 + 1 + (4.216)) * 137.9 \\ &= 194.95 \text{ kN} \end{aligned}$$

Weld Load [W3]:

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Nozzle Calcs.: LG1

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$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.923 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9 \\
 &= 194.95 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9 \\
 &= 89. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 137.9 \\
 &= 145. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 84 * ( 18.5 - 3 ) * 0.74 * 137.9 \\
 &= 209. \text{ kN}
 \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 89.15 + 145.2 ) = 234.3 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89.15 + 0 + 208.7 + 0 ) = 297.8 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89.15 + 208.7 + 0 ) = 297.8 \text{ kN}
 \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 97 kN or W1 = 136 kN  
 Path 2-2 = 297 kN , must exceed W = 97 kN or W2 = 194 kN  
 Path 3-3 = 297 kN , must exceed W = 97 kN or W3 = 194 kN

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

Converged Max. Allow. Pressure in Operating case 23.733 bars

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

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

The Drop for this Nozzle is : 14.1229 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 233.5428 mm.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: LT2

Noz1: 16 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: LT2 From : 10**

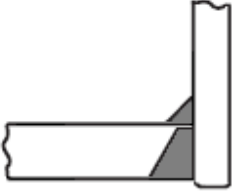
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	500.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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: LT2**

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Req'd 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)  
 $= (23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 $= 13.5366 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 $= (23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 $= 0.4785 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	119.7360	mm.
Parallel to Vessel Wall, opening length	d	59.8680	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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 [fr3]:  
 $= \min(fr2, fr4)$   
 $= \min(1, 1)$   
 $= 1.000$

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

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required <span style="float: right;">Ar</span>	8.104	1.468	NA

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: LT2

Noz1: 16 8:44pm Dec 24,2021

Area in Shell	A1	1.175	6.343	NA
Area in Nozzle Wall	A2	9.313	9.372	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.489	16.715	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 71.58 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 59.87 * 13.54 * 1 + 2 * 13.6 * 13.54 * 1 * (1 - 1) ) \\
 &= 8.104 \text{ cm}^2
 \end{aligned}$$

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 59.87 ( 1 * 15.5 - 1 * 13.54 ) - 2 * 13.6 \\
 &\quad ( 1 * 15.5 - 1 * 13.54 ) * ( 1 - 1 ) \\
 &= 1.175 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 / \sin( alpha3 ) \\
 &= ( 2 * 34 ) ( 13.6 - 0.479 ) / \sin( 73.34 ) \\
 &= 9.313 \text{ cm}^2
 \end{aligned}$$

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]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10^2 * 1 + ( 0 )^2 * 1 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

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

Nozzle-Shell/Head 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
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	-18 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-48 °C

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

$$\text{Design Pressure/Ambient Rating} = 23.00/51.10 = 0.450$$

#### Weld Size Calculations, Description: LT2

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

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 Nozzle Calcs.: LT2 Nozl: 16 8:44pm Dec 24,2021

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

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

##### Weld Load [W]:

$$= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$$

$$= \max( 0, (8.104 - 1.175 + 2 * 13.6 * 1 * (1 * 15.5 - 13.54) ) 137.9 )$$

$$= 102.90 \text{ kN}$$

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

##### Weld Load [W1]:

$$= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv$$

$$= ( 9.313 + 0 + 1 - 0 * 1 ) * 137.9$$

$$= 142.21 \text{ kN}$$

##### Weld Load [W2]:

$$= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$$

$$= ( 9.313 + 0 + 1 + ( 4.216 ) ) * 137.9$$

$$= 200.34 \text{ kN}$$

##### Weld Load [W3]:

$$= (A2+A3+A4+A5+(2*tn*t*fr1))*S$$

$$= ( 9.313 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9$$

$$= 200.34 \text{ kN}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.142/2.0 ) * 88.54 * 10 * 0.49 * 137.9$$

$$= 94. \text{ kN}$$

##### Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.142 * 37.1 ) * ( 16.6 - 3 ) * 0.7 * 137.9$$

$$= 153. \text{ kN}$$

##### Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 88.54 * ( 18.5 - 3 ) * 0.74 * 137.9$$

$$= 220. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 93.97 + 153 ) = 247 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 93.97 + 0 + 220 + 0 ) = 313.9 \text{ kN}$$

$$\text{PATH33} = ( \text{Sonw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 93.97 + 220 + 0 ) = 313.9 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 246 kN , must exceed W = 102 kN or W1 = 142 kN  
 Path 2-2 = 313 kN , must exceed W = 102 kN or W2 = 200 kN  
 Path 3-3 = 313 kN , must exceed W = 102 kN or W3 = 200 kN

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

Converged Max. Allow. Pressure in Operating case 23.733 bars

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 Nozzle Calcs.: LT2 Noz1: 16 8:44pm Dec 24,2021

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

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

Note : Checking Nozzle in the Latitudinal direction.

### Reinforcement CALCULATION, Description: LT2

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 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)  
 $= (23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 $= 13.5366$  mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 $= (23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 $= 0.4785$  mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.689	1.393	NA
Area in Shell	A1	1.143	6.166	NA
Area in Nozzle Wall	A2	8.923	8.979	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.065	16.145	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]:  
 $= (d \cdot tr \cdot F + 2 \cdot tn \cdot tr \cdot F \cdot (1 - fr_1))$  UG-37(c)  
 $= (56.8 \cdot 13.54 \cdot 1 + 2 \cdot 13.6 \cdot 13.54 \cdot 1 \cdot (1 - 1))$   
 $= 7.689$  cm<sup>2</sup>

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:  
 $= d (E_1 \cdot t - F \cdot tr) - 2 \cdot tn (E_1 \cdot t - F \cdot tr) \cdot (1 - fr_1)$   
 $= 58.2 (1 \cdot 15.5 - 1 \cdot 13.54) - 2 \cdot 13.6$   
 $(1 \cdot 15.5 - 1 \cdot 13.54) \cdot (1 - 1)$

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: LT2 Nozl: 16 8:44pm Dec 24,2021

$$= 1.143 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

$$= (2 * t_{lnp}) (t_n - t_{rn}) fr_2$$

$$= (2 * 34) (13.6 - 0.479) 1$$

$$= 8.923 \text{ cm}^2$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= W_o^2 * fr_2 + (W_i - can / 0.707)^2 * fr_2$$

$$= 10^2 * 1 + (0)^2 * 1$$

$$= 1.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	$t_a = 3.4785 \text{ mm.}$
Wall Thickness per UG16(b),	$tr_{16b} = 4.5000 \text{ mm.}$
Wall Thickness, shell/head, internal pressure	$tr_{b1} = 18.0219 \text{ mm.}$
Wall Thickness	$tb_1 = \max(tr_{b1}, tr_{16b}) = 18.0219 \text{ mm.}$
Wall Thickness, shell/head, external pressure	$tr_{b2} = 3.7172 \text{ mm.}$
Wall Thickness	$tb_2 = \max(tr_{b2}, tr_{16b}) = 4.5000 \text{ mm.}$
Wall Thickness per table UG-45	$tb_3 = 7.8000 \text{ mm.}$

Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb_3, \max( tb_1, tb_2 ) ]$$

$$= \min[ 7.8, \max( 18.02, 4.5 ) ]$$

$$= 7.8000 \text{ mm.}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( t_a, t_b )$$

$$= \max( 3.479, 7.8 )$$

$$= 7.8000 \text{ mm.}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: LT2

Intermediate Calc. for nozzle/shell Welds	$T_{min} = 13.6000 \text{ mm.}$
---	---------------------------------

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	$6.0000 = \text{Min per Code}$	$7.0700 = 0.7 * W_o \text{ mm.}$

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

Weld Load [W]:

$$= \max( 0, (A - A_1 + 2 * t_n * fr_1 * (E_1 * t - t_r)) Sv )$$

$$= \max( 0, (7.689 - 1.143 + 2 * 13.6 * 1 * (1 * 15.5 - 13.54) ) 137.9 )$$

$$= 97.63 \text{ kN}$$

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

Weld Load [W1]:

$$= (A_2 + A_5 + A_4 - (W_i - Can / .707)^2 * fr_2) * Sv$$

$$= (8.923 + 0 + 1 - 0 * 1) * 137.9$$

$$= 136.82 \text{ kN}$$

Weld Load [W2]:

$$= (A_2 + A_3 + A_4 + (2 * t_n * t * fr_1)) * Sv$$

$$= (8.923 + 0 + 1 + (4.216)) * 137.9$$

$$= 194.95 \text{ kN}$$

Weld Load [W3]:

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: LT2 Nozl: 16 8:44pm Dec 24,2021

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.923 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9 \\
 &= 194.95 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9 \\
 &= 89. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 137.9 \\
 &= 145. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 84 * ( 18.5 - 3 ) * 0.74 * 137.9 \\
 &= 209. \text{ kN}
 \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 89.15 + 145.2 ) = 234.3 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89.15 + 0 + 208.7 + 0 ) = 297.8 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89.15 + 208.7 + 0 ) = 297.8 \text{ kN}
 \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 97 kN or W1 = 136 kN  
 Path 2-2 = 297 kN , must exceed W = 97 kN or W2 = 194 kN  
 Path 3-3 = 297 kN , must exceed W = 97 kN or W3 = 194 kN

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

Converged Max. Allow. Pressure in Operating case 23.733 bars

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

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

The Drop for this Nozzle is : 14.1229 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 233.5428 mm.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: A1

Nozl: 17 8:44pm Dec 24,2021

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

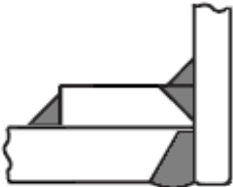
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		550.00	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		90.00	deg
Diameter		10.0000	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	22.0000	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	473.0500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	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: A1**

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

Actual Outside Diameter Used in Calculation	10.750 in.
Actual Thickness Used in Calculation	0.520 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 15.2152 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 136.5) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 2.6430 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.7856 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	505.2934	mm.
Parallel to Vessel Wall, opening length	d	252.6467	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		40.5041	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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**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	38.891	9.861	NA
Area in Shell	A1	9.450	28.176	NA
Area in Nozzle Wall	A2	5.235	6.522	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.815	2.815	NA
Area in Element	A5	22.500	22.500	NA
TOTAL AREA AVAILABLE	Atot	40.001	60.012	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:	463.1841	15.0000 mm.
Based on given Pad Diameter:	473.0500	14.2601 mm.
Based on Shell or Nozzle Thickness:	489.0845	13.2016 mm.

**Area Required [A]:**

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 252.6 * 15.22 * 1 + 2 * 10.2 * 15.22 * 1 * (1 - 0.855) )$$

$$= 38.891 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 252.6 ( 1 * 19 - 1 * 15.22 ) - 2 * 10.2$$

$$( 1 * 19 - 1 * 15.22 ) * ( 1 - 0.855 )$$

$$= 9.450 \text{ cm}^2$$

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

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 40.5 ) * ( 10.2 - 2.643 ) * 0.855$$

$$= 5.235 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + ( Wi - can / 0.707 )^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + ( 0 )^2 * 0.855 + 14^2 * 1$$

$$= 2.815 \text{ cm}^2$$

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

$$= ( \min(Dp, DL) - (\text{Nozzle OD}) ) ( \min(tp, Tlwp, te) ) * fr4 * 0.75$$

$$= ( 473 - 273 ) 15 * 1 * 0.75$$

$$= 22.500 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.6430 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2152 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2152 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 11.1026 mm.

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Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 11.1, \max( 18.22, 4.5 ) ]$   
 $= 11.1026 \text{ mm.}$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( ta, tb )$   
 $= \max( 5.643, 11.1 )$   
 $= 11.1026 \text{ mm.}$

Available Nozzle Neck Thickness = 13.2016 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	:	43.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	251.8 N./mm <sup>2</sup>	Passed
Occasional	:	13.7,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	16.3,	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 = 13.2, tr = 2.643, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.259$ , 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 = 15, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.801$ , Temp. Reduction = 11 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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-Shell/Head Weld for the Nozzle (Impact tested) :**

*Note:*

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*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  
 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 10.2016 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 15.0000 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	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (38.89 - 9.45 + 2 * 10.2 * 0.855 * \\
 &\quad (1 * 19 - 15.22) ) 137.9 ) \\
 &= 415.05 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 5.235 + 22.5 + 2.815 - 0 * 0.855 ) * 137.9 \\
 &= 421.25 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 5.235 + 0 + 0.855 + ( 3.315 ) ) * 137.9 \\
 &= 129.68 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 5.235 + 0 + 2.815 + 22.5 + ( 3.315 ) ) * 137.9 \\
 &= 466.96 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 273 * 10 * 0.49 * 117.9
 \end{aligned}$$

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= 248. kN

Shear, Pad Element Weld [Spew]:

= (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.142/2.0 ) \* 473 \* 14 \* 0.49 \* 137.9  
 = 703. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.142 \* 131.4 ) \* ( 13.2 - 3 ) \* 0.7 \* 117.9  
 = 348. kN

Tension, Pad Groove Weld [Tpgw]:

= ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.142/2 ) \* 273 \* 15 \* 0.74 \* 137.9  
 = 656. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.142/2.0 ) \* 273 \* ( 22 - 3 ) \* 0.74 \* 137.9  
 = 832. kN

#### Strength of Failure Paths:

PATH11 = ( SPEW + SNW ) = ( 702.9 + 347.6 ) = 1050 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 247.8 + 656.5 + 831.5 + 0 ) = 1736 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 702.9 + 831.5 + 0 ) = 1534 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 1050 kN , must exceed W = 415 kN or W1 = 421 kN  
 Path 2-2 = 1735 kN , must exceed W = 415 kN or W2 = 129 kN  
 Path 3-3 = 1534 kN , must exceed W = 415 kN or W3 = 466 kN

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

Converged Max. Allow. Pressure in Operating case 23.323 bars

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

The Drop for this Nozzle is : 10.4153 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 232.4153 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	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°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	273.050	mm.
Nozzle Thickness	Tn	13.202	mm.

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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	15.000	mm.
Diameter of Reinforcing Pad	Dpad	473.050	mm.
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	10.0	kN
Longitudinal Shear	(SUS)	VL	10.0	kN
Circumferential Shear	(SUS)	Vc	10.0	kN
Circumferential Moment	(SUS)	Mc	10600.0	N-m
Longitudinal Moment	(SUS)	ML	10600.0	N-m
Torsional Moment	(SUS)	Mt	13100.0	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 ) )  
 = 273.05 + 2 \* 1.65 \* sqrt( 912.5 ( 22.0 - 3.0 ) )  
 = 707.567 mm.

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	10.0	kN
Circumferential Shear	VC	10.0	kN
Longitudinal Shear	VL	10.0	kN
Circumferential Moment	MC	10600.0	N-m
Longitudinal Moment	ML	10600.0	N-m
Torsional Moment	MT	13100.0	N-m

Dimensionless Parameters used : Gamma = 27.06

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.130	4C	4.639	(A,B)
N(PHI) / ( P/Rm )	0.130	3C	3.874	(C,D)
M(PHI) / ( P )	0.130	2C1	0.082	(A,B)
M(PHI) / ( P )	0.130	1C	0.117	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.130	3A	0.857	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.130	1A	0.095	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.130	3B	2.821	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.130	1B	0.044	(A,B,C,D)
N(x) / ( P/Rm )	0.130	3C	3.874	(A,B)
N(x) / ( P/Rm )	0.130	4C	4.639	(C,D)

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M(x) / ( P )	0.130	1C1	0.120	(A,B)
M(x) / ( P )	0.130	2C	0.082	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.130	4A	1.302	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.130	2A	0.051	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.130	4B	0.829	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.130	2B	0.071	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.5	-1.5	-1.5	-1.5	-1.2	-1.2	-1.2	-1.2
Circ. Bend.	P	-4.2	4.2	-4.2	4.2	-6.1	6.1	-6.1	6.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-2.4	-2.4	2.4	2.4
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-43.6	43.6	43.6	-43.6
Circ. Memb.	ML	-8.0	-8.0	8.0	8.0	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.0	20.0	20.0	-20.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-33.8	14.8	22.3	-9.3	-53.3	46.0	38.7	-36.3
Long. Memb.	P	-1.2	-1.2	-1.2	-1.2	-1.5	-1.5	-1.5	-1.5
Long. Bend.	P	-6.2	6.2	-6.2	6.2	-4.3	4.3	-4.3	4.3
Long. Memb.	MC	0.0	0.0	0.0	0.0	-3.7	-3.7	3.7	3.7
Long. Bend.	MC	0.0	0.0	0.0	0.0	-23.6	23.6	23.6	-23.6
Long. Memb.	ML	-2.3	-2.3	2.3	2.3	0.0	0.0	0.0	0.0
Long. Bend.	ML	-32.9	32.9	32.9	-32.9	0.0	0.0	0.0	0.0
Tot. Long. Str.		-42.7	35.5	27.7	-25.5	-33.0	22.7	21.6	-17.1
Shear	VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear	MT	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Tot. Shear		4.0	4.0	2.6	2.6	2.6	2.6	4.0	4.0
Str. Int.		44.2	36.2	28.8	25.9	53.7	46.3	39.6	37.1

Dimensionless Parameters used : Gamma = 48.03

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.227	4C	6.119	(A,B)
N(PHI) / ( P/Rm )	0.227	3C	3.439	(C,D)
M(PHI) / ( P )	0.227	2C1	0.024	(A,B)
M(PHI) / ( P )	0.227	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.227	3A	1.872	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.227	1A	0.067	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.227	3B	4.299	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.227	1B	0.018	(A,B,C,D)
N(x) / ( P/Rm )	0.227	3C	3.439	(A,B)
N(x) / ( P/Rm )	0.227	4C	6.119	(C,D)
M(x) / ( P )	0.227	1C1	0.052	(A,B)
M(x) / ( P )	0.227	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.227	4A	4.122	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.227	2A	0.030	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.227	4B	1.917	(A,B,C,D)

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M(x) / ( ML/(Rm \* Beta) ) 0.227 2B 0.026 (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		-3.5	-3.5	-3.5	-3.5	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-10.7	10.7	-10.7	10.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-5.5	-5.5	5.5	5.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-56.6	56.6	56.6	-56.6
Circ. Memb. ML		-12.7	-12.7	12.7	12.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-14.9	14.9	14.9	-14.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-35.2	2.7	20.1	-1.7	-74.9	59.8	49.4	-42.3
Long. Memb. P		-2.0	-2.0	-2.0	-2.0	-3.5	-3.5	-3.5	-3.5
Long. Bend. P		-8.7	8.7	-8.7	8.7	-5.5	5.5	-5.5	5.5
Long. Memb. MC		0.0	0.0	0.0	0.0	-12.2	-12.2	12.2	12.2
Long. Bend. MC		0.0	0.0	0.0	0.0	-25.7	25.7	25.7	-25.7
Long. Memb. ML		-5.7	-5.7	5.7	5.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-22.1	22.1	22.1	-22.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-38.4	23.1	17.1	-9.7	-46.9	15.5	28.8	-11.5
Shear VC		0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tot. Shear		2.7	2.7	1.3	1.3	1.3	1.3	2.7	2.7
Str. Int.		39.9	23.4	20.5	9.9	74.9	59.9	49.7	42.5

**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)		60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)		-9.5	-9.5	6.5	6.5	-3.7	-3.7	1.2	1.2
Circ. Q (SUS)		-24.3	24.3	15.8	-15.8	-49.7	49.7	37.5	-37.5
Long. Pm (SUS)		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)		-3.6	-3.6	1.1	1.1	-5.2	-5.2	2.2	2.2
Long. Q (SUS)		-39.1	39.1	26.6	-26.6	-27.9	27.9	19.3	-19.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Pm (SUS)		60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3

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Pm+Pl (SUS)	50.5	52.8	66.5	68.8	56.3	58.6	61.2	63.5
Pm+Pl+Q (Total)	39.7	78.3	82.6	53.1	11.0	108.4	99.0	27.0

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	68.79	206.85	Passed
Pm+Pl+Q (TOTAL)	108.38	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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-16.2	-16.2	9.2	9.2	-7.5	-7.5	3.5	3.5
Circ. Q (SUS)		-18.9	18.9	10.9	-10.9	-67.3	67.3	45.9	-45.9
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-7.6	-7.6	3.7	3.7	-15.7	-15.7	8.6	8.6
Long. Q (SUS)		-30.7	30.7	13.4	-13.4	-31.2	31.2	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)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		92.0	94.3	117.4	119.7	100.7	103.0	111.7	114.0
Pm+Pl+Q (Total)		73.2	113.4	128.3	108.8	33.4	170.3	157.7	68.5

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	119.66	206.85	Passed
Pm+Pl+Q (TOTAL)	170.33	413.70	Passed

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**INPUT VALUES, Nozzle Description: A2 From : 20**

Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested] 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	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1150.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

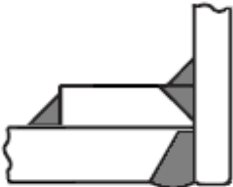
**Type of Element Connected to the Shell : Nozzle**

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		45.00	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	22.0000	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	419.0750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	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	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]

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 15.2149 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 109.5) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 2.1205 \text{ mm.}
 \end{aligned}$$

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		35.2813 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	31.221	7.916	NA
Area in Shell A1	7.589	22.625	NA
Area in Nozzle Wall A2	3.615	4.476	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	20.995	20.995	NA
TOTAL AREA AVAILABLE Atot	33.054	48.951	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:	389.4074	15.0000 mm.
Based on given Pad Diameter:	419.0750	13.6905 mm.
Based on the Estimated Diameter Limit:	404.1125	13.8079 mm.

#### Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (202.8 * 15.21 * 1 + 2 * 8.113 * 15.21 * 1 * (1 - 0.855))$$

$$= 31.221 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

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

$$= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1)$$

$$= 202.8 (1 * 19 - 1 * 15.21) - 2 * 8.113 (1 * 19 - 1 * 15.21) * (1 - 0.855)$$

$$= 7.589 \text{ cm}^2$$

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

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 35.28) * (8.113 - 2.12) * 0.855$$

$$= 3.615 \text{ cm}^2$$

##### 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, also see UG-37(h) [A5]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) (\min(tp, Tlwp, te)) * fr4 * 0.75$$

$$= (405.7 - 219.1) * 15 * 1 * 0.75$$

$$= 20.995 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1205 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2149 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2149 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 18.21, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 5.12, 10.16 )  
 = 10.1600 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	:	13.8,	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 = 2.12, 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 = 15, c = 3 mm., E\* = 1  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.801, Temp. Reduction = 11 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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-Shell/Head Weld for the Nozzle (Impact tested) :**

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-----  
**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
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	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 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	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (31.22 - 7.589 + 2 * 8.113 * 0.855 * \\
 &\quad (1 * 19 - 15.21) ) 137.9 ) \\
 &= 333.10 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.615 + 21 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 351.14 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.615 + 0 + 0.855 + ( 2.636 ) ) * 137.9 \\
 &= 97.98 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.615 + 0 + 0.855 + 21 + ( 2.636 ) ) * 137.9 \\
 &= 387.48 \text{ kN}
 \end{aligned}$$

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:

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$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.142/2.0 ) * 219.1 * 10 * 0.49 * 117.9$$

$$= 199. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.142/2.0 ) * 419.1 * 14 * 0.49 * 137.9$$

$$= 623. \text{ kN}$$

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]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.142/2 ) * 219.1 * 15 * 0.74 * 137.9$$

$$= 527. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 219.1 * ( 22 - 3 ) * 0.74 * 137.9$$

$$= 667. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 622.7 + 221.9 ) = 844.5 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 198.8 + 526.7 + 667.2 + 0 ) = 1393 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 622.7 + 667.2 + 0 ) = 1290 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 844 kN , must exceed W = 333 kN or W1 = 351 kN  
 Path 2-2 = 1392 kN , must exceed W = 333 kN or W2 = 97 kN  
 Path 3-3 = 1289 kN , must exceed W = 333 kN or W3 = 387 kN

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

Converged Max. Allow. Pressure in Operating case 23.664 bars

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

The Drop for this Nozzle is : 6.6907 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 228.6907 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	1800.000 mm.
Vessel Thickness	Tv	22.000 mm.
Design Temperature		125.00 °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.

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: A2 Nozl: 18 8:44pm Dec 24,2021

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	15.000	mm.
Diameter of Reinforcing Pad	Dpad	419.075	mm.
Design Internal Pressure	Dp	23.001	bars
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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}( 912.5 ( 22.0 - 3.0 ) )$$

$$= 653.592 \text{ mm.}$$

## 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 = 27.06

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.104	4C	4.888	(A,B)
N(PHI) / ( P/Rm )	0.104	3C	4.306	(C,D)
M(PHI) / ( P )	0.104	2C1	0.102	(A,B)
M(PHI) / ( P )	0.104	1C	0.139	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.104	3A	0.729	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.104	1A	0.099	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.104	3B	2.502	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.104	1B	0.048	(A,B,C,D)

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: A2 Nozl: 18 8:44pm Dec 24,2021

N(x) / ( P/Rm )	0.104	3C	4.306	(A,B)
N(x) / ( P/Rm )	0.104	4C	4.888	(C,D)
M(x) / ( P )	0.104	1C1	0.142	(A,B)
M(x) / ( P )	0.104	2C	0.102	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.104	4A	1.017	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.104	2A	0.055	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.104	4B	0.696	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.104	2B	0.080	(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		-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P		-4.3	4.3	-4.3	4.3	-5.8	5.8	-5.8	5.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.7	-1.7	1.7	1.7
Circ. Memb. ML		0.0	0.0	0.0	0.0	-36.4	36.4	36.4	-36.4
Circ. Bend. ML		-5.7	-5.7	5.7	5.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-17.8	17.8	17.8	-17.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.0	15.2	18.0	-9.1	-44.9	39.4	31.1	-30.0
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P		-5.9	5.9	-5.9	5.9	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.3	-2.3	2.3	2.3
Long. Bend. MC		0.0	0.0	0.0	0.0	-20.3	20.3	20.3	-20.3
Long. Memb. ML		-1.6	-1.6	1.6	1.6	0.0	0.0	0.0	0.0
Long. Bend. ML		-29.5	29.5	29.5	-29.5	0.0	0.0	0.0	0.0
Tot. Long. Str.		-38.0	32.7	24.0	-23.1	-28.1	21.0	17.1	-15.0
Shear VC		0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT		3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Tot. Shear		4.0	4.0	2.6	2.6	2.6	2.6	4.0	4.0
Str. Int.		39.5	33.5	25.0	23.6	45.3	39.7	32.2	31.0

Dimensionless Parameters used : Gamma = 48.03

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.201	4C	6.492	(A,B)
N(PHI) / ( P/Rm )	0.201	3C	4.028	(C,D)
M(PHI) / ( P )	0.201	2C1	0.030	(A,B)
M(PHI) / ( P )	0.201	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.201	3A	1.928	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.201	1A	0.071	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.201	3B	4.656	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.201	1B	0.022	(A,B,C,D)
N(x) / ( P/Rm )	0.201	3C	4.028	(A,B)
N(x) / ( P/Rm )	0.201	4C	6.492	(C,D)
M(x) / ( P )	0.201	1C1	0.061	(A,B)
M(x) / ( P )	0.201	2C !	0.034	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.201	4A	3.867	(A,B,C,D)



Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: A2 Noz1: 18 8:44pm Dec 24,2021

Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Pm+Pl (SUS)	53.1	55.4	64.4	66.7	57.2	59.5	60.5	62.8
Pm+Pl+Q (Total)	39.8	78.4	78.2	53.3	15.6	101.8	91.5	33.1

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	66.70	206.85	Passed
Pm+Pl+Q (TOTAL)	101.77	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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-13.0	-13.0	7.0	7.0	-6.0	-6.0	2.3	2.3
Circ. Q (SUS)		-17.3	17.3	9.3	-9.3	-52.6	52.6	35.1	-35.1
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-6.0	-6.0	2.3	2.3	-11.3	-11.3	5.3	5.3
Long. Q (SUS)		-27.4	27.4	11.2	-11.2	-25.1	25.1	16.1	-16.1
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.6	0.6	-0.6	-0.6	-0.6	-0.6	0.6	0.6
Shear Q (SUS)		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		95.2	97.5	115.2	117.5	102.2	104.5	110.5	112.8
Pm+Pl+Q (Total)		78.0	115.0	124.5	108.1	49.7	157.1	145.7	77.8

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	117.45	206.85	Passed
Pm+Pl+Q (TOTAL)	157.08	413.70	Passed

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

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

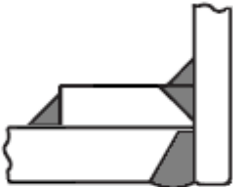
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	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		270.00	deg
Diameter		12.0000	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	22.0000	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	563.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		120.0000	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	12.750 in.
Actual Thickness Used in Calculation	0.601 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 15.2145 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 161.9) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 3.1345 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.8692 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	598.6257	mm.
Parallel to Vessel Wall, opening length	d	299.3128	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		45.6714	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]:

$$\begin{aligned}
 &= \min( fr2, fr4 ) \\
 &= \min( 0.855, 1 ) \\
 &= 0.855
 \end{aligned}$$

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	46.080	11.684	NA
Area in Shell	A1	11.196	33.374	NA
Area in Nozzle Wall	A2	7.134	8.903	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.815	2.815	NA
Area in Element	A5	27.000	27.000	NA
TOTAL AREA AVAILABLE	Atot	48.144	72.092	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:	545.5021	15.0000 mm.
Based on given Pad Diameter:	563.8500	13.8533 mm.
Based on Shell or Nozzle Thickness:	541.6033	15.2686 mm.

**Area Required [A]:**

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 299.3 * 15.21 * 1 + 2 * 12.27 * 15.21 * 1 * (1 - 0.855) )$$

$$= 46.080 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 299.3 ( 1 * 19 - 1 * 15.21 ) - 2 * 12.27$$

$$( 1 * 19 - 1 * 15.21 ) * ( 1 - 0.855 )$$

$$= 11.196 \text{ cm}^2$$

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

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 45.67 ) * ( 12.27 - 3.135 ) * 0.855$$

$$= 7.134 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + ( Wi - can / 0.707 )^2 * fr2 + Wp^2 * fr4$$

$$= 10^2 * 0.855 + ( 0 )^2 * 0.855 + 14^2 * 1$$

$$= 2.815 \text{ cm}^2$$

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

$$= ( \min(Dp, DL) - (Nozzle OD) ) ( \min(tp, Tlwp, te) ) * fr4 * 0.75$$

$$= ( 563.8 - 323.9 ) 15 * 1 * 0.75$$

$$= 27.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 6.1345 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2145 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2145 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 11.3312 mm.

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
 Tag no: K.O. Drum (D-PK6101-3)  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: B Noz1: 19 8:44pm Dec 24,2021

Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 11.33, \max( 18.21, 4.5 ) ]$   
 $= 11.3312 \text{ mm.}$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( ta, tb )$   
 $= \max( 6.135, 11.33 )$   
 $= 11.3312 \text{ mm.}$

Available Nozzle Neck Thickness = 15.2686 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	:	38.5,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	256.3 N./mm <sup>2</sup>	Passed
Occasional	:	13.5,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	13.9,	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
--	--------

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

Govrn. thk, tg = 15, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.801$ , Temp. Reduction = 11 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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 = 15, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.801$ , Temp. Reduction = 11 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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-Shell/Head Weld for the Nozzle (Impact tested) :

##### Note:

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B

Noz1: 19 8:44pm Dec 24,2021

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of the Nozzle : -46 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -46 °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: B

Intermediate Calc. for nozzle/shell Welds Tmin 12.2686 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 15.0000 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	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (46.08 - 11.2 + 2 * 12.27 * 0.855 * \\
 &\quad (1 * 19 - 15.21) )137.9 ) \\
 &= 491.97 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 7.134 + 27 + 2.815 - 0 * 0.855 ) * 137.9 \\
 &= 509.48 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 7.134 + 0 + 0.855 + ( 3.986 ) ) * 137.9 \\
 &= 165.12 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 7.134 + 0 + 2.815 + 27 + ( 3.986 ) ) * 137.9 \\
 &= 564.44 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 323.9 * 10 * 0.49 * 117.9 \\
 &= 294. \text{ kN}
 \end{aligned}$$

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

PV Elite 2018 SP2 Licensee: SPLM Licensed User

FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.142/2.0) * 563.8 * 14 * 0.49 * 137.9$$

$$= 838. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * (Dlr + Dlo) / 4) * (Thk - Can) * 0.7 * Sn$$

$$= (3.142 * 155.8) * (15.27 - 3) * 0.7 * 117.9$$

$$= 496. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.142/2) * 323.9 * 15 * 0.74 * 137.9$$

$$= 779. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi - Cas) * 0.74 * Sng$$

$$= (3.142/2.0) * 323.9 * (22 - 3) * 0.74 * 137.9$$

$$= 986. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (837.8 + 495.5) = 1333 \text{ kN}$$

$$\text{PATH22} = (\text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw})$$

$$= (293.9 + 778.6 + 986.2 + 0) = 2059 \text{ kN}$$

$$\text{PATH33} = (\text{Spew} + \text{Tngw} + \text{Sinw})$$

$$= (837.8 + 986.2 + 0) = 1824 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 1333 kN , must exceed W = 491 kN or W1 = 509 kN  
 Path 2-2 = 2058 kN , must exceed W = 491 kN or W2 = 165 kN  
 Path 3-3 = 1824 kN , must exceed W = 491 kN or W3 = 564 kN

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

Converged Max. Allow. Pressure in Operating case 23.503 bars

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

The Drop for this Nozzle is : 14.6863 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 236.6863 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	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°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	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

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	15.000	mm.
Diameter of Reinforcing Pad	Dpad	563.850	mm.
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	12.0	kN
Longitudinal Shear (SUS)	Vl	12.0	kN
Circumferential Shear (SUS)	Vc	12.0	kN
Circumferential Moment (SUS)	Mc	15300.0	N-m
Longitudinal Moment (SUS)	Ml	15300.0	N-m
Torsional Moment (SUS)	Mt	18900.0	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:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 323.85 + 2 * 1.65 * \text{sqrt}( 912.5 ( 22.0 - 3.0 ) ) \\
 &= 758.367 \text{ mm.}
 \end{aligned}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	12.0	kN
Circumferential Shear	VC	12.0	kN
Longitudinal Shear	VL	12.0	kN
Circumferential Moment	MC	15300.0	N-m
Longitudinal Moment	ML	15300.0	N-m
Torsional Moment	MT	18900.0	N-m

Dimensionless Parameters used : Gamma = 27.06

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.154	4C	4.373	(A,B)
N(PHI) / ( P/Rm )	0.154	3C	3.492	(C,D)
M(PHI) / ( P )	0.154	2C1	0.067	(A,B)
M(PHI) / ( P )	0.154	1C	0.099	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.154	3A	0.959	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.154	1A	0.091	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.154	3B	2.978	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.154	1B	0.039	(A,B,C,D)
N(x) / ( P/Rm )	0.154	3C	3.492	(A,B)
N(x) / ( P/Rm )	0.154	4C	4.373	(C,D)
M(x) / ( P )	0.154	1C1	0.104	(A,B)

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

M(x)	/ ( P )	0.154	2C	0.067	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.154	4A	1.498	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.154	2A	0.048	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.154	4B	0.933	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.154	2B	0.064	(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	-1.3	-1.3	-1.3	-1.3
Circ. Bend. P		-4.2	4.2	-4.2	4.2	-6.2	6.2	-6.2	6.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-3.3	-3.3	3.3	3.3
Circ. Memb. ML		-10.3	-10.3	10.3	10.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-21.9	21.9	21.9	-21.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-38.0	14.1	26.3	-9.1	-61.9	52.6	46.9	-42.9
Long. Memb. P		-1.3	-1.3	-1.3	-1.3	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-6.5	6.5	-6.5	6.5	-4.2	4.2	-4.2	4.2
Long. Memb. MC		0.0	0.0	0.0	0.0	-5.2	-5.2	5.2	5.2
Long. Bend. MC		0.0	0.0	0.0	0.0	-26.8	26.8	26.8	-26.8
Long. Memb. ML		-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML		-35.7	35.7	35.7	-35.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-46.7	37.6	31.0	-27.3	-37.8	24.1	26.1	-19.1
Shear VC		0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear		4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.		48.3	38.3	32.2	27.7	62.2	52.9	47.6	43.6

Dimensionless Parameters used : Gamma = 48.03

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.270	4C	5.493	(A,B)
N(PHI) / ( P/Rm )	0.270	3C	2.725	(C,D)
M(PHI) / ( P )	0.270	2C1	0.017	(A,B)
M(PHI) / ( P )	0.270	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.270	3A	1.698	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.270	1A	0.063	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.270	3B	3.658	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.270	1B	0.013	(A,B,C,D)
N(x) / ( P/Rm )	0.270	3C	2.725	(A,B)
N(x) / ( P/Rm )	0.270	4C	5.493	(C,D)
M(x) / ( P )	0.270	1C1	0.040	(A,B)
M(x) / ( P )	0.270	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.270	4A	4.431	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.270	2A	0.026	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.270	4B	1.802	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.270	2B	0.020	(A,B,C,D)

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B

Noz1: 19 8:44pm Dec 24,2021

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		-3.8	-3.8	-3.8	-3.8	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P		-3.4	3.4	-3.4	3.4	-12.9	12.9	-12.9	12.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-6.1	-6.1	6.1	6.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-64.9	64.9	64.9	-64.9
Circ. Memb. ML		-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Circ. Bend. ML		-13.1	13.1	13.1	-13.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-33.4	-0.4	19.0	-0.5	-85.8	69.9	56.2	-47.9
Long. Memb. P		-1.9	-1.9	-1.9	-1.9	-3.8	-3.8	-3.8	-3.8
Long. Bend. P		-8.1	8.1	-8.1	8.1	-6.6	6.6	-6.6	6.6
Long. Memb. MC		0.0	0.0	0.0	0.0	-15.8	-15.8	15.8	15.8
Long. Bend. MC		0.0	0.0	0.0	0.0	-27.0	27.0	27.0	-27.0
Long. Memb. ML		-6.4	-6.4	6.4	6.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-36.5	19.8	16.6	-7.5	-53.3	14.0	32.4	-8.3
Shear VC		0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tot. Shear		2.7	2.7	1.3	1.3	1.3	1.3	2.7	2.7
Str. Int.		38.1	20.9	19.6	7.7	85.8	69.9	56.5	48.0

**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)		60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)		-12.0	-12.0	8.6	8.6	-4.6	-4.6	2.0	2.0
Circ. Q (SUS)		-26.0	26.0	17.7	-17.7	-57.3	57.3	44.9	-44.9
Long. Pm (SUS)		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)		-4.6	-4.6	1.9	1.9	-6.8	-6.8	3.5	3.5
Long. Q (SUS)		-42.1	42.1	29.2	-29.2	-30.9	30.9	22.6	-22.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Pm+Pl (SUS)		48.0	50.3	68.6	70.9	55.3	57.6	61.9	64.2

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: B Nozl: 19 8:44pm Dec 24,2021

Pm+Pl+Q (Total)	39.5	77.9	86.6	53.3	8.8	115.0	107.2	21.0
-----------------	------	------	------	------	-----	-------	-------	------

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	70.87	206.85	Passed
Pm+Pl+Q (TOTAL)	115.02	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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-16.9	-16.9	9.3	9.3	-8.0	-8.0	4.2	4.2
Circ. Q (SUS)		-16.5	16.5	9.8	-9.8	-77.8	77.8	52.0	-52.0
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-8.3	-8.3	4.6	4.6	-19.6	-19.6	12.0	12.0
Long. Q (SUS)		-28.2	28.2	12.1	-12.1	-33.6	33.6	20.4	-20.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		91.3	93.6	117.5	119.8	100.2	102.5	112.4	114.7
Pm+Pl+Q (Total)		74.9	110.3	127.3	110.0	22.5	180.4	164.5	63.0

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.48	137.90	Passed
Pm+Pl (SUS)	119.77	206.85	Passed
Pm+Pl+Q (TOTAL)	180.37	413.70	Passed

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: LG2

Nozl: 20 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: LG2 From : 20**

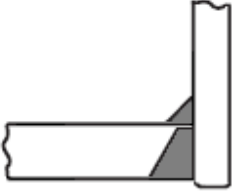
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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**

**Reinforcement CALCULATION, Description: LG2**

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 15.2153 mm.

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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 [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1, 1)$   
 = 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: LG2

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Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.390	17.336	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]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 56.8 * 15.22 * 1 + 2 * 13.6 * 15.22 * 1 * (1 - 1) )$$

$$= 8.642 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 65.2 ( 1 * 19 - 1 * 15.22 ) - 2 * 13.6$$

$$( 1 * 19 - 1 * 15.22 ) * ( 1 - 1 )$$

$$= 2.468 \text{ cm}^2$$

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

$$= ( 2 * tlnp ) ( tn - trn ) fr2$$

$$= ( 2 * 34 ) ( 13.6 - 0.479 ) 1$$

$$= 8.923 \text{ cm}^2$$

## Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2$$

$$= 10^2 * 1 + ( 0 )^2 * 1$$

$$= 1.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.4785 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2153 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2153 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

## Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 18.22, 4.5 ) ]$$

$$= 7.8000 \text{ mm.}$$

## Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

$$= \max( 3.479, 7.8 )$$

$$= 7.8000 \text{ mm.}$$

Available Nozzle Neck Thickness = 16.6000 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	: 14.9, Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0, Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9, Allowable	: 183.4 N./mm <sup>2</sup>	Passed
Shear	: 9.6, Allowable	: 96.5 N./mm <sup>2</sup>	Passed

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
 Tag no: K.O. Drum (D-PK6101-3)  
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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: LG2 Nozl: 20 8:44pm Dec 24,2021

*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-Shell/Head 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
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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

#### Weld Size Calculations, Description: LG2

Intermediate Calc. for nozzle/shell Welds T<sub>min</sub> 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * W <sub>o</sub> mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 * \\
 &\quad (1 * 19 - 15.22) )137.9 ) \\
 &= 99.34 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
 \end{aligned}$$

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Nozzle Calcs.: LG2

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.142 \* 35.2 ) \* ( 16.6 - 3 ) \* 0.7 \* 137.9  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.142/2.0 ) \* 84 \* ( 18.5 - 3 ) \* 0.74 \* 137.9  
 = 209. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89.15 + 145.2 ) = 234.3 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89.15 + 0 + 208.7 + 0 ) = 297.8 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89.15 + 208.7 + 0 ) = 297.8 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN  
 Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN  
 Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

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

Converged Max. Allow. Pressure in Operating case 24.354 bars

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

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

The Drop for this Nozzle is : 0.9806 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 mm.

### Input Echo, WRC107/537 Item 1, Description: LG2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°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	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350	LF2
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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Nozzle Calcs.: LG2

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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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(912.5 (22.0 - 3.0))$$

$$= 518.517 \text{ mm.}$$
**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 = 48.03

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.040	4C	9.159	(A,B)
N(PHI) / ( P/Rm )	0.040	3C	9.133	(C,D)
M(PHI) / ( P )	0.040	2C1	0.159	(A,B)
M(PHI) / ( P )	0.040	1C	0.201	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.040	3A	0.511	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.040	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.040	3B	2.216	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.040	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.040	3C	9.133	(A,B)
N(x) / ( P/Rm )	0.040	4C	9.159	(C,D)
M(x) / ( P )	0.040	1C1	0.208	(A,B)
M(x) / ( P )	0.040	2C	0.159	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.040	4A	0.692	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.040	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.040	4B	0.536	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.040	2B	0.100	(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>)**

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Nozzle Calcs.: LG2

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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P		-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML		-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML		-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P		-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML		-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC		0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear		3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.		27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

**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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)		-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)		-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		105.8	108.1	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)		89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result

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Nozzle Calcs.: LG2

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```
-----  
Pm (SUS) | 110.49 | 137.90 | | Passed |  
Pm+P1 (SUS) | 110.83 | 206.85 | | Passed |  
Pm+P1+Q (TOTAL) | 134.57 | 413.70 | | Passed |
```

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Nozzle Calcs.: LT2

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**INPUT VALUES, Nozzle Description: LT2 From : 20**

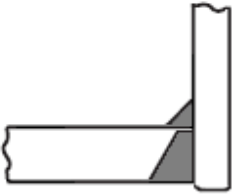
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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**

**Reinforcement CALCULATION, Description: LT2**

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 15.2153 mm.

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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 [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1, 1)$   
 = 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: LT2 Nozl: 21 8:44pm Dec 24,2021

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.390	17.336	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]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 56.8 * 15.22 * 1 + 2 * 13.6 * 15.22 * 1 * (1 - 1) )$$

$$= 8.642 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 65.2 ( 1 * 19 - 1 * 15.22 ) - 2 * 13.6$$

$$( 1 * 19 - 1 * 15.22 ) * ( 1 - 1 )$$

$$= 2.468 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

$$= ( 2 * tlnp ) ( tn - trn ) fr2$$

$$= ( 2 * 34 ) ( 13.6 - 0.479 ) 1$$

$$= 8.923 \text{ cm}^2$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2$$

$$= 10^2 * 1 + ( 0 )^2 * 1$$

$$= 1.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.4785 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2153 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2153 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 18.22, 4.5 ) ]$$

$$= 7.8000 \text{ mm.}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

$$= \max( 3.479, 7.8 )$$

$$= 7.8000 \text{ mm.}$$

Available Nozzle Neck Thickness = 16.6000 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	: 14.9, Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0, Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9, Allowable	: 183.4 N./mm <sup>2</sup>	Passed
Shear	: 9.6, Allowable	: 96.5 N./mm <sup>2</sup>	Passed

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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 Nozzle Calcs.: LT2 Nozl: 21 8:44pm Dec 24,2021

*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-Shell/Head 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
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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

#### Weld Size Calculations, Description: LT2

Intermediate Calc. for nozzle/shell Welds T<sub>min</sub> 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * W <sub>o</sub> mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 * \\
 &\quad (1 * 19 - 15.22) )137.9 ) \\
 &= 99.34 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
 \end{aligned}$$

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Nozzle Calcs.: LT2

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.142 \* 35.2 ) \* ( 16.6 - 3 ) \* 0.7 \* 137.9  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.142/2.0 ) \* 84 \* ( 18.5 - 3 ) \* 0.74 \* 137.9  
 = 209. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89.15 + 145.2 ) = 234.3 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89.15 + 0 + 208.7 + 0 ) = 297.8 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89.15 + 208.7 + 0 ) = 297.8 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN  
 Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN  
 Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

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

Converged Max. Allow. Pressure in Operating case 24.354 bars

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

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

The Drop for this Nozzle is : 0.9806 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 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	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°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	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350	LF2
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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Nozzle Calcs.: LT2

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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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(912.5 (22.0 - 3.0))$$

$$= 518.517 \text{ mm.}$$
**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 = 48.03

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.040	4C	9.159	(A,B)
N(PHI) / ( P/Rm )	0.040	3C	9.133	(C,D)
M(PHI) / ( P )	0.040	2C1	0.159	(A,B)
M(PHI) / ( P )	0.040	1C	0.201	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.040	3A	0.511	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.040	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.040	3B	2.216	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.040	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.040	3C	9.133	(A,B)
N(x) / ( P/Rm )	0.040	4C	9.159	(C,D)
M(x) / ( P )	0.040	1C1	0.208	(A,B)
M(x) / ( P )	0.040	2C	0.159	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.040	4A	0.692	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.040	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.040	4B	0.536	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.040	2B	0.100	(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>)**

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Nozzle Calcs.: LT2

Noz1: 21 8:44pm Dec 24,2021

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P		-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML		-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML		-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P		-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML		-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC		0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear		3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.		27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

**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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)		-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)		-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		105.8	108.1	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)		89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
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Pm (SUS)	110.49	137.90	Passed
Pm+P1 (SUS)	110.83	206.85	Passed
Pm+P1+Q (TOTAL)	134.57	413.70	Passed

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Nozzle Calcs.: SV Nozl: 22 8:44pm Dec 24,2021

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

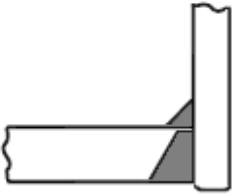
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1550.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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**

**Reinforcement CALCULATION, Description: SV**

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

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 15.2148 mm.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c) (1)  
 =  $(23 \cdot 28.4) / (137.9 \cdot 1 - 0.6 \cdot 23)$   
 = 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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 [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1, 1)$   
 = 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

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Nozzle Calcs.: SV Nozl: 22 8:44pm Dec 24,2021

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.391	17.336	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]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 56.8 * 15.21 * 1 + 2 * 13.6 * 15.21 * 1 * (1 - 1) )$$

$$= 8.642 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 65.2 ( 1 * 19 - 1 * 15.21 ) - 2 * 13.6$$

$$( 1 * 19 - 1 * 15.21 ) * ( 1 - 1 )$$

$$= 2.468 \text{ cm}^2$$

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

$$= ( 2 * tlnp ) ( tn - trn ) fr2$$

$$= ( 2 * 34 ) ( 13.6 - 0.479 ) 1$$

$$= 8.923 \text{ cm}^2$$

## Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2$$

$$= 10^2 * 1 + ( 0 )^2 * 1$$

$$= 1.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.4785 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2148 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2148 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

## Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 18.21, 4.5 ) ]$$

$$= 7.8000 \text{ mm.}$$

## Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

$$= \max( 3.479, 7.8 )$$

$$= 7.8000 \text{ mm.}$$

Available Nozzle Neck Thickness = 16.6000 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	: 14.9, Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0, Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9, Allowable	: 183.4 N./mm <sup>2</sup>	Passed
Shear	: 9.6, Allowable	: 96.5 N./mm <sup>2</sup>	Passed

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: SV Nozl: 22 8:44pm Dec 24,2021

*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-Shell/Head 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
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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

#### Weld Size Calculations, Description: SV

Intermediate Calc. for nozzle/shell Welds T<sub>min</sub> 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * W <sub>o</sub> mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 * \\
 &\quad (1 * 19 - 15.21) ) 137.9 ) \\
 &= 99.33 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9 \\
 &= 208.08 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
 \end{aligned}$$

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Nozzle Calcs.: SV

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.142 \* 35.2 ) \* ( 16.6 - 3 ) \* 0.7 \* 137.9  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.142/2.0 ) \* 84 \* ( 18.5 - 3 ) \* 0.74 \* 137.9  
 = 209. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89.15 + 145.2 ) = 234.3 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89.15 + 0 + 208.7 + 0 ) = 297.8 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89.15 + 208.7 + 0 ) = 297.8 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN  
 Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN  
 Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

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

Converged Max. Allow. Pressure in Operating case 24.353 bars

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

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

The Drop for this Nozzle is : 0.9806 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 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	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°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	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350	LF2
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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Nozzle Calcs.: SV Noz1: 22 8:44pm Dec 24,2021

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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(912.5 (22.0 - 3.0))$$

$$= 518.517 \text{ mm.}$$
**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 = 48.03

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.040	4C	9.159	(A,B)
N(PHI) / ( P/Rm )	0.040	3C	9.133	(C,D)
M(PHI) / ( P )	0.040	2C1	0.159	(A,B)
M(PHI) / ( P )	0.040	1C	0.201	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.040	3A	0.511	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.040	1A	0.104	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.040	3B	2.216	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.040	1B	0.060	(A,B,C,D)
N(x) / ( P/Rm )	0.040	3C	9.133	(A,B)
N(x) / ( P/Rm )	0.040	4C	9.159	(C,D)
M(x) / ( P )	0.040	1C1	0.208	(A,B)
M(x) / ( P )	0.040	2C	0.159	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.040	4A	0.692	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.040	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.040	4B	0.536	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.040	2B	0.100	(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>)**

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Nozzle Calcs.: SV

Noz1: 22 8:44pm Dec 24,2021

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P		-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML		-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML		-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P		-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML		-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC		0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear		3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.		27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

**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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)		-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)		-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		105.7	108.0	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)		89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
---------------------	-----------	----------------	--------

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```
-----  
Pm (SUS) | 110.48 | 137.90 | Passed |  
Pm+P1 (SUS) | 110.83 | 206.85 | Passed |  
Pm+P1+Q (TOTAL) | 134.57 | 413.70 | Passed |
```

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Nozzle Calcs.: M2

Nozl: 23 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: M2 From : 20**

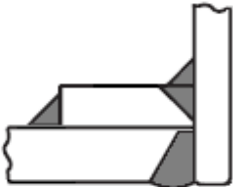
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	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		90.00	deg
Diameter		6.0000	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	22.0000	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	368.2750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	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: M2**

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

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

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23) \\
 &= 15.2145 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23 \cdot 84.14) / (117.9 \cdot 1 + 0.4 \cdot 23) \\
 &= 1.6287 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	310.1452 mm.
Parallel to Vessel Wall, opening length	d	155.0726 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		31.5030 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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Nozzle Calcs.: M2

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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	23.885	6.056	NA
Area in Shell	A1	5.798	17.283	NA
Area in Nozzle Wall	A2	2.679	3.236	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	21.281	21.281	NA
TOTAL AREA AVAILABLE	Atot	30.612	42.654	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:	265.2967	15.0000 mm.
Based on given Pad Diameter:	368.2750	10.2582 mm.
Based on the Estimated Diameter Limit:	308.5577	10.3742 mm.

#### Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (155.1 * 15.21 * 1 + 2 * 6.601 * 15.21 * 1 * (1 - 0.855))$$

$$= 23.885 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

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

$$= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1)$$

$$= 155.1 (1 * 19 - 1 * 15.21) - 2 * 6.601$$

$$(1 * 19 - 1 * 15.21) * (1 - 0.855)$$

$$= 5.798 \text{ cm}^2$$

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

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 31.5) * (6.601 - 1.629) * 0.855$$

$$= 2.679 \text{ cm}^2$$

##### 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]:

$$= (\min(Dp, DL) - (\text{Nozzle OD})) * (\min(tp, Tlwp, te)) * fr4$$

$$= (310.1 - 168.3) * 15 * 1$$

$$= 21.281 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 4.6287 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2145 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2145 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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Wall Thickness per table UG-45 tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 9.22, max( 18.21, 4.5 ) ]  
 = 9.2200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 4.629, 9.22 )  
 = 9.2200 mm.

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

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

Sustained	:	55.9,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	238.8 N./mm <sup>2</sup>	Passed
Occasional	:	13.0,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	24.1,	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 = 9.601, tr = 1.629, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.247$ , 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 = 15, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.801$ , Temp. Reduction = 11 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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-Shell/Head Weld for the Nozzle (Impact tested) :**

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-----  
**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
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: M2

Intermediate Calc. for nozzle/shell Welds	Tmin	6.6012 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

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

**Weld Load [W]:**

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (23.88 - 5.798 + 2 * 6.601 * 0.855 * \\
 &\quad (1 * 19 - 15.21) ) 137.9 ) \\
 &= 255.29 \text{ kN}
 \end{aligned}$$

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

**Weld Load [W1]:**

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 2.679 + 21.28 + 0.855 - 0 * 0.855 ) * 137.9 \\
 &= 342.16 \text{ kN}
 \end{aligned}$$

**Weld Load [W2]:**

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.679 + 0 + 0.855 + ( 2.145 ) ) * 137.9 \\
 &= 78.30 \text{ kN}
 \end{aligned}$$

**Weld Load [W3]:**

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.679 + 0 + 0.855 + 21.28 + ( 2.145 ) ) * 137.9 \\
 &= 371.73 \text{ kN}
 \end{aligned}$$

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:

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$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.142/2.0 ) * 168.3 * 10 * 0.49 * 117.9$$

$$= 153. kN$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.142/2.0 ) * 368.3 * 14 * 0.49 * 137.9$$

$$= 547. kN$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.142 * 80.84 ) * ( 9.601 - 3 ) * 0.7 * 117.9$$

$$= 138. kN$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.142/2 ) * 168.3 * 15 * 0.74 * 137.9$$

$$= 405. kN$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.142/2.0 ) * 168.3 * ( 22 - 3 ) * 0.74 * 137.9$$

$$= 512. kN$$

#### Strength of Failure Paths:

$$PATH11 = ( SPEW + SNW ) = ( 547.2 + 138.3 ) = 685.5 kN$$

$$PATH22 = ( Sonw + Tpgw + Tngw + Sinw )$$

$$= ( 152.7 + 404.6 + 512.5 + 0 ) = 1070 kN$$

$$PATH33 = ( Spew + Tngw + Sinw )$$

$$= ( 547.2 + 512.5 + 0 ) = 1060 kN$$

#### Summary of Failure Path Calculations:

Path 1-1 = 685 kN , must exceed W = 255 kN or W1 = 342 kN  
 Path 2-2 = 1069 kN , must exceed W = 255 kN or W2 = 78 kN  
 Path 3-3 = 1059 kN , must exceed W = 255 kN or W3 = 371 kN

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

Converged Max. Allow. Pressure in Operating case 24.353 bars

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

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

The Drop for this Nozzle is : 3.9414 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.9414 mm.

#### Input Echo, WRC107/537 Item 1, Description: M2 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	3.0000 mm.
Vessel Diameter	Dv	1800.000 mm.
Vessel Thickness	Tv	22.000 mm.
Design Temperature		125.00 °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

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Nozzle Calcs.: M2

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-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	15.000	mm.
Diameter of Reinforcing Pad	Dpad	368.275	mm.
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

## External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	6.0	kN
Longitudinal Shear (SUS)	Vl	6.0	kN
Circumferential Shear (SUS)	Vc	6.0	kN
Circumferential Moment (SUS)	Mc	3800.0	N-m
Longitudinal Moment (SUS)	Ml	3800.0	N-m
Torsional Moment (SUS)	Mt	4700.0	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 168.275 + 2 * 1.65 * \text{sqrt}( 912.5 ( 22.0 - 3.0 ) )$$

$$= 602.792 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTAINED loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 27.06

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.080	4C	5.021	(A,B)
N(PHI) / ( P/Rm )	0.080	3C	4.672	(C,D)
M(PHI) / ( P )	0.080	2C1	0.127	(A,B)
M(PHI) / ( P )	0.080	1C	0.164	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.080	3A	0.544	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.080	1A	0.102	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.080	3B	1.930	(A,B,C,D)

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M(PHI) / ( ML/(Rm * Beta) )	0.080	1B	0.053	(A,B,C,D)
N(x) / ( P/Rm )	0.080	3C	4.672	(A,B)
N(x) / ( P/Rm )	0.080	4C	5.021	(C,D)
M(x) / ( P )	0.080	1C1	0.166	(A,B)
M(x) / ( P )	0.080	2C	0.127	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.080	4A	0.711	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.080	2A	0.059	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.080	4B	0.526	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.080	2B	0.089	(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		-1.0	-1.0	-1.0	-1.0	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-5.1	5.1	-5.1	5.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-27.2	27.2	27.2	-27.2
Circ. Memb. ML		-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Circ. Bend. ML		-14.3	14.3	14.3	-14.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-22.4	14.1	12.5	-8.1	-34.2	30.6	22.1	-22.1
Long. Memb. P		-0.9	-0.9	-0.9	-0.9	-1.0	-1.0	-1.0	-1.0
Long. Bend. P		-5.2	5.2	-5.2	5.2	-4.0	4.0	-4.0	4.0
Long. Memb. MC		0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Long. Bend. MC		0.0	0.0	0.0	0.0	-15.8	15.8	15.8	-15.8
Long. Memb. ML		-0.9	-0.9	0.9	0.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-23.8	23.8	23.8	-23.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-30.8	27.2	18.6	-18.7	-21.9	17.6	12.1	-11.7
Shear VC		0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT		3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Tot. Shear		3.8	3.8	2.4	2.4	2.4	2.4	3.8	3.8
Str. Int.		32.2	28.2	19.5	19.2	34.6	31.0	23.4	23.4

Dimensionless Parameters used : Gamma = 48.03

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.177	4C	6.899	(A,B)
N(PHI) / ( P/Rm )	0.177	3C	4.682	(C,D)
M(PHI) / ( P )	0.177	2C1	0.037	(A,B)
M(PHI) / ( P )	0.177	1C	0.069	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.177	3A	1.950	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.177	1A	0.076	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.177	3B	5.000	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.177	1B	0.026	(A,B,C,D)
N(x) / ( P/Rm )	0.177	3C	4.682	(A,B)
N(x) / ( P/Rm )	0.177	4C	6.899	(C,D)
M(x) / ( P )	0.177	1C1	0.072	(A,B)

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M(x)	/ ( P )	0.177	2C	0.037	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.177	4A	3.601	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.177	2A	0.037	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.177	4B	1.941	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.177	2B	0.037	(A,B,C,D)

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	-2.4	-2.4	-2.4	-2.4	-1.6	-1.6	-1.6	-1.6
Circ. Bend.	P	-3.7	3.7	-3.7	3.7	-6.9	6.9	-6.9	6.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.7	29.7	29.7	-29.7
Circ. Memb.	ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.3	10.3	10.3	-10.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-23.2	4.8	11.0	-2.2	-40.9	32.4	23.8	-21.8
Long. Memb.	P	-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-7.1	7.1	-7.1	7.1	-3.7	3.7	-3.7	3.7
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	-14.4	14.4	14.4	-14.4
Long. Memb.	ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend.	ML	-14.7	14.7	14.7	-14.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-26.1	17.6	8.6	-6.5	-25.4	10.8	13.2	-8.2
Shear	VC	0.5	0.5	-0.5	-0.5	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Shear	MT	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Tot. Shear		1.7	1.7	0.6	0.6	0.6	0.6	1.7	1.7
Str. Int.		26.9	17.8	11.1	6.6	41.0	32.4	24.1	22.0

**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)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl	(SUS)	-4.1	-4.1	2.2	2.2	-1.8	-1.8	0.0	0.0
Circ. Q	(SUS)	-18.2	18.2	10.3	-10.3	-32.4	32.4	22.1	-22.1
Long. Pm	(SUS)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl	(SUS)	-1.8	-1.8	-0.0	-0.0	-2.1	-2.1	0.2	0.2
Long. Q	(SUS)	-29.0	29.0	18.7	-18.7	-19.8	19.8	11.9	-11.9
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q	(SUS)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pm	(SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3

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Pm+Pl (SUS)	55.8	58.1	62.2	64.5	58.2	60.5	60.0	62.3
Pm+Pl+Q (Total)	39.1	77.1	72.7	54.3	26.1	93.0	82.5	40.8

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	64.50	206.85	Passed
Pm+Pl+Q (TOTAL)	92.96	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)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)		-9.2	-9.2	4.4	4.4	-4.3	-4.3	1.0	1.0
Circ. Q (SUS)		-14.0	14.0	6.6	-6.6	-36.7	36.7	22.8	-22.8
Long. Pm (SUS)		54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)		-4.3	-4.3	1.0	1.0	-7.3	-7.3	2.5	2.5
Long. Q (SUS)		-21.8	21.8	7.6	-7.6	-18.1	18.1	10.7	-10.7
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.5	0.5	-0.5	-0.5	-0.5	-0.5	0.5	0.5
Shear Q (SUS)		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Pm (SUS)		108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)		99.0	101.3	112.6	114.9	103.9	106.2	109.2	111.5
Pm+Pl+Q (Total)		85.0	115.4	119.2	108.3	67.3	142.9	132.1	88.8

**Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.48	137.90	Passed
Pm+Pl (SUS)	114.90	206.85	Passed
Pm+Pl+Q (TOTAL)	142.87	413.70	Passed

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: T1

Nozl: 24 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: T1****From : 20**

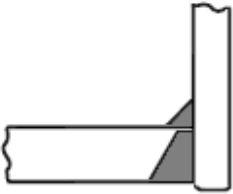
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		750.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
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)		ID	
Layout Angle		270.00	deg
Diameter		1.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	15.9500	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
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	18.5000	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**

**Reinforcement CALCULATION, Description: T1**

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

Actual Inside Diameter Used in Calculation 1.500 in.  
 Actual Thickness Used in Calculation 0.628 in.

Nozzle input data check completed without errors.

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

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

$$= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23)$$

$$= 15.2151 \text{ mm.}$$

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

$$= R \left( \exp\left(\frac{P}{S_n \cdot E}\right) - 1 \right) \text{ per Appendix 1-2 (a) (1)}$$

$$= 22.05 \left( \exp\left(\frac{23}{137.9 \cdot 1}\right) - 1 \right)$$

$$= 0.3709 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3569 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	108.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	54.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	32.3750	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 [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(1, 1)$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.710	1.701	NA
Area in Shell	A1	2.419	7.211	NA
Area in Nozzle Wall	A2	8.145	8.154	NA

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Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: T1 Nozl: 24 8:44pm Dec 24,2021

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.564	16.365	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 44.1 * 15.22 * 1 + 2 * 12.95 * 15.22 * 1 * (1 - 1) ) \\
 &= 6.710 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 63.9 ( 1 * 19 - 1 * 15.22 ) - 2 * 12.95 \\
 &\quad ( 1 * 19 - 1 * 15.22 ) * ( 1 - 1 ) \\
 &= 2.419 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 32.37 ) ( 12.95 - 0.371 ) 1 \\
 &= 8.145 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= W_o^2 * fr2 + ( W_i - can / 0.707 )^2 * fr2 \\
 &= 10^2 * 1 + ( 0 )^2 * 1 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.3709 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 18.2151 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.2151 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7207 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.5200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.52, \max( 18.22, 4.5 ) ] \\
 &= 7.5200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.371, 7.52 ) \\
 &= 7.5200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 15.9500 mm. --> OK

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

**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**

Note:

This Material was specified as being an Impact Tested (Low Temperature) Material.

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Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: T1 Noz1: 24 8:44pm Dec 24,2021

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

#### Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 12.9500 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (6.71 - 2.419 + 2 * 12.95 * 1 * \\
 &\quad (1 * 19 - 15.22) )137.9 ) \\
 &= 72.69 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.145 + 0 + 1 - 0 * 1 ) * 137.9 \\
 &= 126.10 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.145 + 0 + 1 + ( 4.921 ) ) * 137.9 \\
 &= 193.95 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.145 + 0 + 1 + 0 + ( 4.921 ) ) * 137.9 \\
 &= 193.95 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 70 * 10 * 0.49 * 137.9 \\
 &= 74. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.142 * 28.52 ) * ( 15.95 - 3 ) * 0.7 * 137.9 \\
 &= 112. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.142/2.0 ) * 70 * ( 18.5 - 3 ) * 0.74 * 137.9
 \end{aligned}$$

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Nozzle Calcs.: T1 Nozl: 24 8:44pm Dec 24,2021

= 174. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 74.29 + 112 ) = 186.3 kN

PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
= ( 74.29 + 0 + 173.9 + 0 ) = 248.2 kN

PATH33 = ( Sonw + Tngw + Sinw )  
= ( 74.29 + 173.9 + 0 ) = 248.2 kN

### Summary of Failure Path Calculations:

Path 1-1 = 186 kN , must exceed W = 72 kN or W1 = 126 kN

Path 2-2 = 248 kN , must exceed W = 72 kN or W2 = 193 kN

Path 3-3 = 248 kN , must exceed W = 72 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.354 bars

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

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

The Drop for this Nozzle is : 0.6808 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.6808 mm.

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Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: M1 Nozl: 25 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: M1 From : 20**

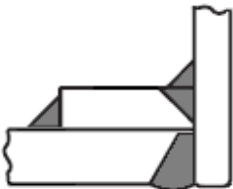
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		750.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		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	22.0000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	20.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Impact Tested]		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	808.0000	mm.
Thickness of Pad	te	22.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	22.0000	mm.
Reinforcing Pad Width		150.0000	mm.
This is a Manway or Access Opening.			
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: M1**

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	0.866 in.

Nozzle input data check completed without errors.

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

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

$$= (23 \cdot 903) / (137.9 \cdot 1 - 0.6 \cdot 23)$$

$$= 15.2151 \text{ mm.}$$

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

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

$$= (23 \cdot 254) / (137.9 \cdot 1 + 0.4 \cdot 23)$$

$$= 4.2088 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 1.2465 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	940.0001 mm.
Parallel to Vessel Wall, opening length	d	470.0000 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		47.5000 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]:

$$= \min( fr2, fr4 )$$

$$= \min( 1, 1 )$$

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Nozzle Calcs.: M1 Nozl: 25 8:44pm Dec 24,2021

= 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	71.511	18.132	NA
Area in Shell	A1	17.789	53.036	NA
Area in Nozzle Wall	A2	14.052	16.866	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		5.960	5.960	NA
Area in Element	A5	49.500	49.500	NA
TOTAL AREA AVAILABLE	Atot	87.301	125.362	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:	712.3038	22.0000 mm.
Based on given Pad Diameter:	808.0001	14.9823 mm.
Based on Shell or Nozzle Thickness:	712.3038	22.0000 mm.

**Area Required [A]:**

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 470 * 15.22 * 1 + 2 * 19 * 15.22 * 1 * (1 - 1) )$$

$$= 71.511 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

$$= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 470 ( 1 * 19 - 1 * 15.22 ) - 2 * 19$$

$$( 1 * 19 - 1 * 15.22 ) * ( 1 - 1 )$$

$$= 17.789 \text{ cm}^2$$

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

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 47.5 ) * ( 19 - 4.209 ) * 1$$

$$= 14.052 \text{ cm}^2$$

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

$$= Wo^2 * fr3 + ( Wi - can / 0.707 )^2 * fr2 + Wp^2 * fr4$$

$$= 20^2 * 1 + ( 0 )^2 * 1 + 14^2 * 1$$

$$= 5.960 \text{ cm}^2$$

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

$$= ( \min(Dp, DL) - (Nozzle OD) ) ( \min(tp, Tlwp, te) ) * fr4 * 0.75$$

$$= ( 808 - 508 ) * 22 * 1 * 0.75$$

$$= 49.500 \text{ cm}^2$$

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

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

Note: This Element/Detail was specified as being Impact Tested.

**Nozzle Neck to Pad Weld for Reinf. pad (Impact tested) :**

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 Nozzle Calcs.: M1 Noz1: 25 8:44pm Dec 24,2021

-----  
 Note: This Element/Detail was specified as being Impact Tested.

Shell to Pad Weld at Pad OD for pad (Impact tested) :

-----  
 Note: This Element/Detail was specified as being Impact Tested.

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

-----  
 Note: This Element/Detail was specified as being Impact Tested.

Governing MDMT of the Nozzle : -45 °C  
 Governing MDMT of the Reinforcement Pad : -45 °C  
 Governing MDMT of all the sub-joints of this Junction : -45 °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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Weld Size Calculations, Description: M1

Intermediate Calc. for nozzle/shell Welds Tmin 19.0000 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 19.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	14.1400 = 0.7 * Wo mm.
Pad Weld	9.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (71.51 - 17.79 + 2 * 19 * 1 * \\
 &\quad (1 * 19 - 15.22) ) 137.9 ) \\
 &= 760.59 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 14.05 + 49.5 + 5.96 - 0 * 1 ) * 137.9 \\
 &= 958.48 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 14.05 + 0 + 4 + ( 7.22 ) ) * 137.9 \\
 &= 348.47 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 14.05 + 0 + 5.96 + 49.5 + ( 7.22 ) ) * 137.9 \\
 &= 1058.04 \text{ kN}
 \end{aligned}$$

**Strength of Connection Elements for Failure Path Analysis**

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Nozzle Calcs.: M1 Nozl: 25 8:44pm Dec 24,2021

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= ( 3.142/2.0 ) * 508 * 20 * 0.49 * 137.9$$

$$= 1078. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * D_P * W_P * 0.49 * S_{EW}$$

$$= ( 3.142/2.0 ) * 808 * 14 * 0.49 * 137.9$$

$$= 1201. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( D_{lr} + D_{lo} ) / 4 ) * ( Thk - Can ) * 0.7 * S_n$$

$$= ( 3.142 * 244.5 ) * ( 22 - 3 ) * 0.7 * 137.9$$

$$= 1409. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= ( 3.142/2 ) * 508 * 22 * 0.74 * 137.9$$

$$= 1791. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * ( W_{gnvi-Cas} ) * 0.74 * S_{ng}$$

$$= ( 3.142/2.0 ) * 508 * ( 22 - 3 ) * 0.74 * 137.9$$

$$= 1547. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( S_{PEW} + S_{NW} ) = ( 1201 + 1409 ) = 2609 \text{ kN}$$

$$\text{PATH22} = ( S_{onw} + T_{pgw} + T_{ngw} + S_{inw} )$$

$$= ( 1078 + 1791 + 1547 + 0 ) = 4417 \text{ kN}$$

$$\text{PATH33} = ( S_{pew} + T_{ngw} + S_{inw} )$$

$$= ( 1201 + 1547 + 0 ) = 2748 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 2609 kN , must exceed W = 760 kN or W1 = 958 kN  
 Path 2-2 = 4416 kN , must exceed W = 760 kN or W2 = 348 kN  
 Path 3-3 = 2747 kN , must exceed W = 760 kN or W3 = 1058 kN

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

Converged Max. Allow. Pressure in Operating case 24.354 bars

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

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

The Drop for this Nozzle is : 36.5858 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 308.5858 mm.

#### Percent Elongation Calculations:

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 4.527 %

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Nozzle Calcs.: V

Noz1: 26 8:44pm Dec 24,2021

**INPUT VALUES, Nozzle Description: V****From : 30**

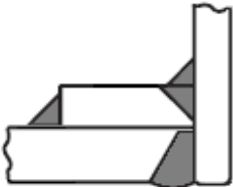
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	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 [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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	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	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		64.8375	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: V**

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.

Req'd 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)  
 =  $(23 \cdot 0.897 \cdot 1806) / (2 \cdot 137.9 \cdot 1 - 0.2 \cdot 23)$   
 = 13.5353 mm.

Req'd 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)  
 =  $(23 \cdot 30.16) / (117.9 \cdot 1 + 0.4 \cdot 23)$   
 = 0.5839 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		21.6135	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]:  
 =  $\min(fr_2, fr_4)$

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Nozzle Calcs.: V Nozl: 26 8:44pm Dec 24,2021

$$= \min(0.855, 1)$$

$$= 0.855$$

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

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required Ar	7.090	1.285	NA
Area in Shell A1	0.976	5.264	NA
Area in Nozzle Wall A2	1.501	1.596	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	4.174	4.174	NA
TOTAL AREA AVAILABLE Atot	7.199	11.582	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:	100.9798	10.0000 mm.
Based on given Pad Diameter:	190.0000	9.7392 mm.
Based on the Estimated Diameter Limit:	100.4809	10.1243 mm.

#### Area Required [A]:

$$= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)}$$

$$= (51.03 * 13.54 * 1 + 2 * 4.645 * 13.54 * 1 * (1 - 0.855))$$

$$= 7.090 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

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

$$= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1)$$

$$= 51.03 (1 * 15.5 - 1 * 13.54) - 2 * 4.645$$

$$(1 * 15.5 - 1 * 13.54) * (1 - 0.855)$$

$$= 0.976 \text{ cm}^2$$

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

$$= (2 * Tlwp) * (tn - trn) * fr2$$

$$= (2 * 21.61) * (4.645 - 0.584) * 0.855$$

$$= 1.501 \text{ cm}^2$$

##### 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]:

$$= (\min(Dp, DL) - \text{Nozzle OD}) * (\min(tp, Tlwp, te)) * fr4$$

$$= (102.1 - 60.33) * 10 * 1$$

$$= 4.174 \text{ cm}^2$$

#### 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 = 18.0205 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 18.0205 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.7172 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.

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 Nozzle Calcs.: V Nozl: 26 8:44pm Dec 24,2021

Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2 ) ]  
 = min[ 6.42, max( 18.02, 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

#### 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 = 10, c = 3 mm., E\* = 1  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.873$ , Temp. Reduction = 7 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

##### Nozzle-Shell/Head 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

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

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### 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: V

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 10.0000 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	5.0000 = 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.09 - 0.976 + 2 * 4.645 * 0.855 * \\
 &\quad (1 * 15.5 - 13.54) ) 137.9 ) \\
 &= 86.45 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 1.501 + 4.174 + 0.547 - 0 * 0.855 ) * 137.9 \\
 &= 85.80 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.501 + 0 + 0.547 + ( 1.231 ) ) * 137.9 \\
 &= 45.22 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.501 + 0 + 0.547 + 4.174 + ( 1.231 ) ) * 137.9 \\
 &= 102.78 \text{ kN}
 \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.142/2.0 ) * 60.33 * 8 * 0.49 * 117.9 \\
 &= 44. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

$$\begin{aligned}
 &= (\pi/2) * DP * WP * 0.49 * SEW \\
 &= ( 3.142/2.0 ) * 190 * 10 * 0.49 * 137.9 \\
 &= 202. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn$$

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$$= (3.142 * 27.84) * (7.645 - 3) * 0.7 * 117.9$$

$$= 34. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= (3.142/2) * 60.33 * 10 * 0.74 * 137.9$$

$$= 97. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng}$$

$$= (3.142/2) * 60.33 * (18.5 - 3) * 0.74 * 137.9$$

$$= 150. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = (S_{PEW} + S_{NW}) = (201.6 + 33.53) = 235.2 \text{ kN}$$

$$\text{PATH22} = (S_{onw} + T_{pgw} + T_{ngw} + S_{inw})$$

$$= (43.79 + 96.69 + 149.9 + 0) = 290.3 \text{ kN}$$

$$\text{PATH33} = (S_{pew} + T_{ngw} + S_{inw})$$

$$= (201.6 + 149.9 + 0) = 351.5 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 235 kN , must exceed W = 86 kN or W1 = 85 kN  
 Path 2-2 = 290 kN , must exceed W = 86 kN or W2 = 45 kN  
 Path 3-3 = 351 kN , must exceed W = 86 kN or W3 = 102 kN

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

Converged Max. Allow. Pressure in Operating case 23.178 bars

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

The Drop for this Nozzle is : 0.2783 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 218.7783 mm.

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Nozzle Schedule: Step: 32 8:44pm Dec 24,2021

**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.
T1	1.500 in	Actual	LWN	2.756	15.950	...	...
D	2.000 in	160	WNF	2.375	8.738	190.00	10.00
300							218.78
LG1	2.000 in	Actual	LWN	3.307	16.600	...	...
LT2	2.000 in	Actual	LWN	3.307	16.600	...	...
LG2	2.000 in	Actual	LWN	3.307	16.600	...	...
LT2	2.000 in	Actual	LWN	3.307	16.600	...	...
SV	2.000 in	Actual	LWN	3.307	16.600	...	...
V	2.000 in	160	WNF	2.375	8.738	190.00	10.00
300							218.78
M2	6.000 in	80	WNF	6.625	10.973	368.27	15.00
300							225.94
A2	8.000 in	80	WNF	8.625	12.700	419.07	15.00
300							228.69
A1	10.000 in	80	WNF	10.750	15.088	473.05	15.00
300							232.42
B	12.000 in	80	WNF	12.750	17.450	563.85	15.00
300							236.69
M1	20.000 in	Actual	LWN	20.000	22.000	808.00	22.00
							308.59

*General Notes for the above table:*

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:  
 Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

**Nozzle Material and Weld Fillet Leg Size Details (mm.):**

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T1	SA-350 LF2	18.500	10.000	...	...	...
D	SA-333 6	18.500	8.000	10.000	10.000	...
LG1	SA-350 LF2	18.500	10.000	...	...	...
LT2	SA-350 LF2	18.500	10.000	...	...	...
LG2	SA-350 LF2	18.500	10.000	...	...	...
LT2	SA-350 LF2	18.500	10.000	...	...	...

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SV	SA-350 LF2	18.500	10.000	...	...	...
V	SA-333 6	18.500	8.000	10.000	10.000	...
M2	SA-333 6	22.000	10.000	14.000	15.000	...
A2	SA-333 6	22.000	10.000	14.000	15.000	...
A1	SA-333 6	22.000	10.000	14.000	15.000	...
B	SA-333 6	22.000	10.000	14.000	15.000	...
M1	SA-516 70	22.000	20.000	14.000	22.000	...

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
T1	700.000	270.0	200.00	0.00	SHELL
D	...	0.0	200.00	0.00	HEAD 001
LG1	...	180.0	200.00	0.00	HEAD 001
LT2	...	270.0	200.00	0.00	HEAD 001
LG2	200.000	180.0	200.00	0.00	SHELL
LT2	200.000	270.0	200.00	0.00	SHELL
SV	1500.000	0.0	200.00	0.00	SHELL
V	...	0.0	200.00	0.00	HEAD 002
M2	2250.000	90.0	200.00	0.00	SHELL
A2	1100.000	45.0	200.00	0.00	SHELL
A1	500.000	90.0	200.00	0.00	SHELL
B	2250.000	270.0	200.00	0.00	SHELL
M1	700.000	0.0	250.00	0.00	SHELL

Note: The Description of Nozzle: LT2 is DUPLICATED

Note: For best performance, please do not duplicate nozzle descriptions.

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 FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
 MDMT Summary: Step: 34 8:44pm Dec 24,2021

**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]	!	-45			0.977	18.500	1.00	No
HEAD 001	[7]	!	-45			0.807	22.000	1.00	No
SHELL	[8]	!	-45			0.808	22.000	0.85	No
HEAD 002	[10]	!	-45			0.976	18.500	1.00	No
HEAD 002	[7]	!	-45			0.807	22.000	1.00	No
D	[1]	D	-48	-48	-29	0.873	10.000	1.00	No
Nozzle Flg	[4]	!	-18	-96					
LG1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-18	-48					
LT2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-18	-48					
A1	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
A2	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
B	[1]	!	-46	-46		0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LG2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
LT2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
SV	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
M2	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T1	[1]	!	-46	-104		0.029	15.950	1.00	No
Nozzle Flg	[5]	!	-46	-48					
M1	[1]	!	-45	-45		0.801	22.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
V	[1]	D	-48	-48	-29	0.873	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Warmest MDMT:			-18	-45					
Required Minimum Design Metal Temperature						-45	°C		
Warmest Computed Minimum Design Metal Temperature						-45	°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)

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no: K.O. Drum (D-PK6101-3)  
PV Elite 2018 SP2 Licensee: SPLM Licensed User  
FileName : Calculation Book for K.O. Drum (D-PK6101-3)  
MDMT Summary: Step: 34 8:44pm Dec 24,2021

UG-84(b)(2) was not considered.  
UCS-66(g) was not considered.  
UCS-66(i) was not considered.

**Notes:**

Impact test temps were not entered in and not considered in the analysis.  
UCS-66(i) applies to impact tested materials not by specification and  
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).  
The Basic MDMT includes the (30F) PWHT credit if applicable.

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## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no: K.O. Drum (D-PK6101-3)

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FileName : Calculation Book for K.O. Drum (D-PK6101-3)

Vessel Design Summary: Step: 35 8:44pm Dec 24,2021

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

Diameter Spec : 1800.000 mm. ID  
Vessel Design Length, Tangent to Tangent 3000.00 mm.

Distance of Bottom Tangent above Grade 123000.00 mm.  
Specified Datum Line Distance 50.00 mm.

Shell Material SA-516 70 [Impact Tested]  
Nozzle Material SA-333 6 [Impact Tested]  
Nozzle Material SA-350 LF2 [Impact Tested]  
Nozzle Material SA-516 70 [Impact Tested]  
Re-Pad Material SA-516 70 [Normalized]

Internal Design Temperature 125 °C  
Internal Design Pressure 23.000 bars

External Design Temperature 125 °C  
External Design Pressure 1.034 bars

Maximum Allowable Working Pressure 23.176 bars  
External Max. Allowable Working Pressure 8.440 bars  
Hydrostatic Test Pressure 29.900 bars

Required Minimum Design Metal Temperature -45 °C  
Warmest Computed Minimum Design Metal Temperature -45 °C

Wind Design Code ASCE-2010  
Earthquake Design Code ASCE 7-2010

**Element Pressures and MAWP (bars):**

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
HEAD 001	23.002	1.100	23.731	3.0000	No
SHELL	23.002	1.100	24.352	3.0000	N/A
HEAD 002	23.000	1.100	23.733	3.0000	No

Liquid Level: 3900.00 mm. Dens.: 0.000 kg./cm<sup>3</sup> Sp. Gr.: 0.006**Element Types and Properties:**

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	Req d Int.	Thk Ext.	Joint Eff Long	Circ
Ellipse	0.0	50.0	22.0	18.0	7.9	1.00	0.85
Cylinder	2900.0	2900.0	22.0	20.9	10.7	0.85	0.85
Ellipse	2950.0	50.0	22.0	18.0	7.9	1.00	0.85

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

**Loads for Foundation/Support Design:**

Total Wind Shear on top of all Legs 7. kN  
Total Earthquake Shear on top of all Legs 14. kN  
Total Wind Moment at top of all Legs 8379. N-m  
Total Earthquake Moment at top of all Legs 23281. N-m

Max. Wind Shear on one Leg (top & bottom) 2. kN  
Max. Earthq. Shear on one Leg (top & bottom) 3. kN  
Max. Wind Moment at base of one Leg 3275. N-m

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Max. Earthquake Moment at base of one Leg	6126.	N-m
Max. Vertical Load (Wt. + Wind) on one Leg	19.	kN
Max. Vertical Load (Wt. + Eq.) on one Leg	27.	kN

**Note:**

Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

**Weights:**

Fabricated - Bare W/O Removable Internals	5723.4	kg.
Shop Test - Fabricated + Water ( Full )	14880.3	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	5723.4	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	6065.8	kg.
Empty - Fab. + Intls. + Details + Wghts.	6065.8	kg.
Operating - Empty + Operating Liquid (No CA)	6118.9	kg.
Field Test - Empty Weight + Water (Full)	14709.0	kg.

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