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	<b>DEHDASHT PETROCHEMICAL INDUSTRY COMPANY</b>  <b>DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT</b>	
	DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT No:DPIC9812-000-VD-1002-ME-CLN-0092	Rev. No.: D1

**DOCUMENT TITLE:**

**Mechanical Calculation for Evaporator  
(E-6101)**

<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
2	AN: Approved With Minor Comments (Fabrication may Proceed)				
3	NF: Approved With Comments (Fabrication not Proceed)				Item No. (Tag No.): PK-6101
4	RJ: Rejected				
5	NR: Not be Returned				Vendor Doc. No.:DPIC9812-000-VD-1002-ME-CLN-0092-D1
Date:		Signature:			
					
D1	06.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
<b>REV</b>	<b>DATE ISSUE</b>	<b>PREPARED</b>	<b>CHECKED</b>	<b>APPROVED</b>	



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63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			



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133	x	x			
134	x	x			
135	x	x			
136	x	x			
137	x	x			
138	x	x			
139	x	x			
140	x	x			



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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:Evaporator E-PK1601

## **DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Feb 7,2022 1:34am

PV Elite 2018 SP2, June 2018

**Note:**

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

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Tag no:Evaporator E-PK1601  
PV Elite 2018 SP2 Licensee: SPLM Licensed User  
FileName : Calculation Book for Evaporator E-PK1601  
Warnings and Errors: Step: 0 1:34am Feb 7,2022

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**

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

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 Tag no:Evaporator E-PK1601

**Exchanger Design Pressures and Temperatures**

Shell Side Design Pressure	23	bars
Channel Side Design Pressure	23	bars
Shell Side Design Temperature	125.0	°C
Channel Side Design Temperature	125.0	°C

Type of Hydrotest	UG-99(b) Note [36]
Hydrotest Position	Horizontal
Projection of Nozzle from Vessel Top	0 mm.
Projection of Nozzle from Vessel Bottom	0 mm.
Type of Construction	Welded
Special Service	None
Degree of Radiography	RT-3
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	Yes
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	200 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	20.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.

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 Tag no:Evaporator E-PK1601  
 PV Elite 2018 SP2 Licensee: SPLM Licensed User  
 FileName : Calculation Book for Evaporator E-PK1601

Input Echo: Step: 1 1:34am Feb 7,2022

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	
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		0.900	
Short Period Acceleration value Ss		0.537	
Long Period Acceleration Value Sl		0.600	
Moment Reduction Factor Tau		2.500	
Force Modification Factor R		3.000	
Site Class		C	
Component Elevation Ratio	z/h	1.000	
Amplification Factor	Ap	2.500	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0 )		0.624	
Design Pressure + Static Head		Y	
Consider MAP New and Cold in Noz. Design		N	
Consider External Loads for Nozzle Des.		Y	
Use ASME VIII-1 Appendix 1-9		N	

Material Database Year Current w/Addenda or Code Year

#### Configuration Directives:

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

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

Element From Node	10
Element To Node	20
Element Type	Elliptical
Description	HEAD 001
Distance "FROM" to "TO"	50 mm.
Inside Diameter	1200 mm.
Element Thickness	15 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	18 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.0342 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2

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Tag no:Evaporator E-PK1601  
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Input Echo: Step: 1 1:34am Feb 7,2022

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, Hydrottest	235.8	N./mm <sup>2</sup>
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	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Liquid	
Detail ID	1	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000707	kg./cm <sup>3</sup>

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-300	mm.
Height/Length of Insulation	350	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	SHELL 001	
Distance "FROM" to "TO"	990	mm.
Inside Diameter	1200	mm.
Element Thickness	15	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	15	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	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	1.0	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Liquid	
Detail ID	2	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000707	kg./cm <sup>3</sup>

Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	

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Tag no:Evaporator E-PK1601

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FileName : Calculation Book for Evaporator E-PK1601

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Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	990	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T2	
Dist. from "FROM" Node / Offset dist	400	mm.
Nozzle Diameter	20	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	2.9969	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	[Normalized]

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	400	mm.
Nozzle Diameter	20	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	2.9969	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	[Normalized]

-----

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	BODY FLANGE 001	
Distance "FROM" to "TO"	155	mm.
Flange Inside Diameter	1200	mm.
Element Thickness	110	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	60	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-350 LF2	[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	223.4	N./mm <sup>2</sup>
Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	31.75	mm.
Yield Stress, Operating	222.82	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03011	
Class / Thickness / Grade	1::	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		

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Grade of ANSI B16.5/B16.47 Flange  
 Weld is pre-Heated No

Element From Node	30	
Detail Type	Liquid	
Detail ID	3	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000707	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	155	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description	body flange 02	
Distance "FROM" to "TO"	155	mm.
Flange Inside Diameter	1200	mm.
Element Thickness	110	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	60	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-350 LF2	[Impact Tested]
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	

Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000581	kg./cm <sup>3</sup>

Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	155	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description	SHELL 002	

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Distance "FROM" to "TO"	200	mm.
Inside Diameter	1200	mm.
Element Thickness	20	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	20	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	bars
Design Temperature External Pressure	125	°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>
Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	29.007	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	1.0	
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	200	mm.
Width of Saddle	172	mm.
Height of Saddle at Bottom	1374	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	350	mm.
Thickness of Wear Plate	25	mm.
Contact Angle, Wear Plate (degrees)	140.0	

Element From Node	50	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000581	kg./cm <sup>3</sup>

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	200	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	60	
Element To Node	70	
Element Type	Conical	
Description	CON	
Distance "FROM" to "TO"	830	mm.
Inside Diameter	1200	mm.
Element Thickness	20	mm.
Internal Corrosion Allowance	3	mm.

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Nominal Thickness	20	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	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	1.0	
Cone Diameter at "To" End	1656	mm.
Design Length of Cone	830	mm.
Half Apex Angle of Cone	28.784285	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	60	
Detail Type	Liquid	
Detail ID	Liquid: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000581	kg./cm <sup>3</sup>

Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	830	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

Element From Node	60	
Detail Type	Nozzle	
Detail ID	D2	
Dist. from "FROM" Node / Offset dist	380	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 )	0.1015	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]

-----

Element From Node	70	
Element To Node	80	
Element Type	Cylinder	
Description	SHELL 002	
Distance "FROM" to "TO"	4000	mm.
Inside Diameter	1656	mm.
Element Thickness	18	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	18	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Impact Tested]
Efficiency, Longitudinal Seam	1.0	

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Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	70	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	2520	mm.
Width of Saddle	172	mm.
Height of Saddle at Bottom	1600	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	352	mm.
Thickness of Wear Plate	25	mm.
Contact Angle, Wear Plate (degrees)	140.0	
Element From Node	70	
Detail Type	Liquid	
Detail ID	Liquid: 70	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000581	kg./cm <sup>3</sup>
Element From Node	70	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	4000	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>
Element From Node	70	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	8	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.8591	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	70	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	3050	mm.
Nozzle Diameter	8	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.8591	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	70	
Detail Type	Nozzle	
Detail ID	S3	
Dist. from "FROM" Node / Offset dist	700	mm.
Nozzle Diameter	8	in.
Nozzle Schedule	80	
Nozzle Class	300	

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Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.8591 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID D1  
 Dist. from "FROM" Node / Offset dist 2200 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 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID D3  
 Dist. from "FROM" Node / Offset dist 3600 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 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID TT  
 Dist. from "FROM" Node / Offset dist 3850 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 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID V  
 Dist. from "FROM" Node / Offset dist 150 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID S4  
 Dist. from "FROM" Node / Offset dist 3050 mm.  
 Nozzle Diameter 8 in.

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Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.8591 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LG1  
 Dist. from "FROM" Node / Offset dist 1800 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 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LG2  
 Dist. from "FROM" Node / Offset dist 1800 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LT1  
 Dist. from "FROM" Node / Offset dist 1200 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.2227 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LT3  
 Dist. from "FROM" Node / Offset dist 1500 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.2227 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-333 6 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LT2

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Dist. from "FROM" Node / Offset dist	1200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.2227	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	70	
Detail Type	Nozzle	
Detail ID	LT4	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.2227	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

-----

Element From Node	80	
Element To Node	90	
Element Type	Elliptical	
Description	HEAD 002	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1656	mm.
Element Thickness	17	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	20	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.0342	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	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	80	
Detail Type	Liquid	
Detail ID	Liquid: 80	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000581	kg./cm <sup>3</sup>

Element From Node	80	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	464	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm <sup>3</sup>

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XY Coordinate Calculations: Step: 2 1:34am Feb 7,2022

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001		50	...	50	...
SHELL 001		1040	...	990	...
BODY FLANGE 001		1195	...	155	...
body flange 02		1505.53	...	155	...
SHELL 002		1705.53	...	200	...
CON		2535.52	...	830	...
SHELL 002		6535.53	...	4000	...
HEAD 002		6585.52	...	50	...

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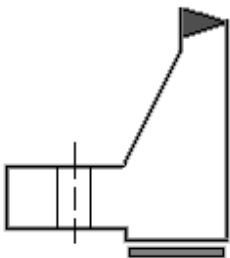
FileName : Calculation Book for Evaporator E-PK1601

Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

**Flange Input Data Values Description: New Flange :**

**BODY FLANGE 001**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.08	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	1200.000	mm.
Flange Outside Diameter	A	1360.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	gl	23.0000	mm.
Length of Hub	h	45.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm <sup>2</sup>
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm <sup>2</sup>
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm <sup>2</sup>
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm <sup>2</sup>
Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		72	
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm <sup>2</sup>
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.



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

Hub Small End Required Thickness due to Internal Pressure:  
 =  $(P*(D/2+Ca))/(S*E-0.6*P)$  per UG-27 (c) (1)  
 =  $(23.08*(1200.0/2+3.0))/(137.9*1.0-0.6*23.08)+Ca$   
 = 13.1967 mm.

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Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

Hub Small End Hub MAWP:

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

$$= (137.9 \cdot 1.0 \cdot 12.0) / (603.0 + 0.6 \cdot 12.0)$$

$$= 27.117 \text{ bars}$$

Corroded Flange Thickness, tc = T-ci	107.000	mm.
Corroded Flange ID, Bcor = B+2*Fcor	1206.000	mm.
Corroded Large Hub, g1Cor = g1-ci	20.000	mm.
Corroded Small Hub, g0Cor = go-ci	12.000	mm.
Code R Dimension, R = ((C-Bcor)/2) -g1cor	32.000	mm.
Gasket Contact Width, N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width, bo = N / 2	10.000	mm.
Effective Gasket Width, b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter, G = Go - 2 * b	1250.063	mm.

### **Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 \cdot G^2 \cdot Peq$$

$$= 0.785 \cdot 1250.0626^2 \cdot 23.083$$

$$= 2832.941 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 \cdot b \cdot Pi \cdot G \cdot m \cdot P$$

$$= 2 \cdot 7.9687 \cdot 3.1416 \cdot 1250.0626 \cdot 3.0 \cdot 23.08$$

$$= 433.415 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= Pi \cdot Bcor^2 \cdot P / 4$$

$$= 3.1416 \cdot 1206.0^2 \cdot 23.0832 / 4$$

$$= 2636.748 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - Hd$$

$$= 2833 - 2637$$

$$= 196.193 \text{ kN}$$

Operating Bolt Load [Wm1]:

$$= \max( H + Hp + H'p, 0 )$$

$$= \max( 2833 + 433 + 0, 0 )$$

$$= 3266.356 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y \cdot b \cdot Pi \cdot G + yPart \cdot bPart \cdot lp$$

$$= 68.95 \cdot 7.9687 \cdot 3.1416 \cdot 1250.063 + 0.0 \cdot 0.0 \cdot 0.0$$

$$= 2157.577 \text{ kN}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } Wm1/Sb, Wm2/Sa$$

$$= \text{Maximum of } 3266/172, 2158/172$$

$$= 189.507 \text{ cm}^2$$

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

$$= 2a + 6t / (m + 0.5)$$

$$= 2 \cdot 22.225 + 6 \cdot 107.0 / (3.0 + 0.5)$$

$$= 227.879 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

$$= C \cdot \sin( pi / n )$$

$$= 1310.0 \cdot \sin( 3.142 / 72 )$$

$$= 57.141 \text{ mm.}$$

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

$$= \max( \sqrt{ Bs / ( 2a + t ) }, 1 )$$

$$= \max( \sqrt{ 57.141 / ( 2 \cdot 22.225 + 107.0 ) }, 1 )$$

$$= 1.0000$$

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 FileName : Calculation Book for Evaporator E-PK1601  
 Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

#### Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	189.507	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	25.000	
Circumferential Spacing between the Bolt	52.400	57.141	227.879

#### Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

$$= A_b * S_a / ( y * \pi * (G_o + G_i) )$$

$$= 194.632 * 172.38 / (68.95 * 3.14 * (1266.0 + 1226.0) )$$

$$= 6.215 \text{ mm.}$$

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

$$= 32.000 \text{ mm. [Note: Exceeds actual gasket width, 20.000 ]}$$

#### Flange Design Bolt Load, Gasket Seating [W]:

$$= S_a * ( A_m + A_b ) / 2$$

$$= 172.38 * ( 189.5074 + 194.6319 ) / 2$$

$$= 3310.52 \text{ kN}$$

#### Gasket Load for the Operating Condition [HG]:

$$= W_{m1} - H$$

$$= 3266 - 2833$$

$$= 433.42 \text{ kN}$$

#### Moment Arm Calculations:

##### Distance to Gasket Load Reaction [hg]:

$$= ( C - G ) / 2$$

$$= ( 1310.0 - 1250.0626 ) / 2$$

$$= 29.9687 \text{ mm.}$$

##### Distance to Face Pressure Reaction [ht]:

$$= ( R + g_1 + h_g ) / 2$$

$$= ( 32.0 + 20.0 + 29.9687 ) / 2$$

$$= 40.9843 \text{ mm.}$$

##### Distance to End Pressure Reaction [hd]:

$$= R + ( g_1 / 2 )$$

$$= 32.0 + ( 20.0 / 2.0 )$$

$$= 42.0000 \text{ mm.}$$

#### Summary of Moments for Internal Pressure: (N-m)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2637.	42.0000	1.0000	110788.
Face Pressure, Mt	196.	40.9843	1.0000	8044.
Gasket Load, Mg	433.	29.9687	1.0000	12994.
Gasket Seating, Matm	3311.	29.9687	1.0000	99252.
Total Moment for Operation, Mop				131826. N-m
Total Moment for Gasket seating, Matm				99252. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			120.300 mm.	
Hub Ratio, h/h0 = HL / H0			0.374	
Thickness Ratio, g1/g0 = (g1Cor/goCor)			1.667	

#### Flange Factors for Integral Flange:

Factor F	0.861
Factor V	0.313
Factor f	1.178

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Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

Factors from Figure 2-7.1  
 T = 1.867  
 Y = 16.171  
 d = 0.98424E+06 mm.<sup>3</sup>  
 K = 1.128  
 U = 17.771  
 Z = 8.361  
 e = 0.0072 mm.<sup>-1</sup>  
 Stress Factors  
 BETA = 2.021  
 DELTA = 1.245  
 ALPHA = 1.766  
 GAMMA = 0.946  
 Lamda = 2.191

Longitudinal Hub Stress, Operating [SHo]:  
 = ( f \* Mop / Bcor ) / ( L \* g1<sup>2</sup> )  
 = ( 1.1782\*131826/1206.0 ) / ( 2.1905\*20.0<sup>2</sup> )  
 = 146.94 N./mm<sup>2</sup>

Longitudinal Hub Stress, Seating [SHa]:  
 = ( f \* Matm / Bcor ) / ( L \* g1<sup>2</sup> )  
 = ( 1.1782\*99252/1206.0 ) / ( 2.1905\*20.0<sup>2</sup> )  
 = 110.63 N./mm<sup>2</sup>

Radial Flange Stress, Operating [SRo]:  
 = ( Beta \* Mop / Bcor ) / ( L \* t<sup>2</sup> )  
 = ( 2.0214\*131826/1206.0 ) / ( 2.1905\*107.0<sup>2</sup> )  
 = 8.81 N./mm<sup>2</sup>

Radial Flange Stress, Seating [SRa]:  
 = ( Beta \* Matm/Bcor ) / ( L \* t<sup>2</sup> )  
 = ( 2.0214\*99252/1206.0 ) / ( 2.1905\*107.0<sup>2</sup> )  
 = 6.63 N./mm<sup>2</sup>

Tangential Flange Stress, Operating [STo]:  
 = ( Y \* Mo / ( t<sup>2</sup> \* Bcor ) ) - Z \* SRo  
 = ( 16.1715\*131826 / ( 107.0<sup>2</sup> \* 1206.0 ) ) - 8.3612\*9  
 = 80.71 N./mm<sup>2</sup>

Tangential Flange Stress, Seating [STa]:  
 = ( y \* Matm / ( t<sup>2</sup> \* Bcor ) ) - Z \* SRa  
 = ( 16.1715\*99252 / ( 107.0<sup>2</sup> \* 1206.0 ) ) - 8.3612\*7  
 = 60.76 N./mm<sup>2</sup>

Average Flange Stress, Operating [SAo]:  
 = ( SHo + max( SRo, STo ) ) / 2  
 = ( 147+max( 9, 81 ) ) / 2  
 = 113.82 N./mm<sup>2</sup>

Average Flange Stress, Seating [SAa]:  
 = ( SHa + max( SRa, STa ) ) / 2  
 = ( 111+max( 7, 61 ) ) / 2  
 = 85.70 N./mm<sup>2</sup>

Bolt Stress, Operating [BSo]:  
 = Wm1 / Ab  
 = 3266/194.6319  
 = 167.84 N./mm<sup>2</sup>

Bolt Stress, Seating [BSa]:  
 = ( Wm2 / Ab )  
 = ( 2158/194.6319 )  
 = 110.86 N./mm<sup>2</sup>

**Flange Stress Analysis Results: N./mm<sup>2</sup>**

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	147.	207.	111.	207.
Radial Flange	9.	138.	7.	138.
Tangential Flange	81.	138.	61.	138.
Maximum Average	114.	138.	86.	138.

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Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

Bolting 168. | 172. | 111. | 172. |

Minimum Required Flange Thickness [Rigidity] 107.721 mm.  
 Estimated M.A.W.P. ( Operating ) 23.707 bars  
 Estimated Finished Weight of Flange at given Thk. 299.6 kg.  
 Estimated Unfinished Weight of Forging at given Thk 386.5 kg.

**Flange Rigidity Based on Required Thickness [ASME]:**

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99252.1/1.0 * 999.68 * 0.313 / ( 2.103 * 202713 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.730 \text{ (should be } \leq 1)$$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 131826.5/1.0 * 999.68 * 0.313 / ( 2.103 * 196612 * 12.0^2 * 120.3 * 0.3 )$$

$$= 1.000 \text{ (should be } \leq 1)$$

**Flange Rigidity Based on Given Thickness [ASME]:**

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99252.1/1.0 * 999.68 * 0.313 / ( 2.191 * 202713 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.701 \text{ (should be } \leq 1)$$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 131826.5/1.0 * 999.68 * 0.313 / ( 2.191 * 196612 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.960 \text{ (should be } \leq 1)$$

**Minimum Design Metal Temperature Results:**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

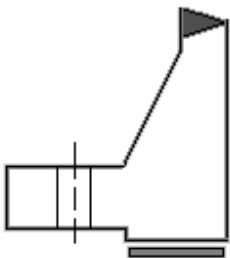
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 FileName : Calculation Book for Evaporator E-PK1601  
 Flg Calc [Int P]: New Flange Flng: 8 1:34am Feb 7,2022

**Flange Input Data Values Description: New Flange :**

body flange 02

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.07	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	1200.000	mm.
Flange Outside Diameter	A	1360.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	20.0000	mm.
Thickness of Hub at Large End	gl	23.0000	mm.
Length of Hub	h	45.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm <sup>2</sup>
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm <sup>2</sup>
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm <sup>2</sup>
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm <sup>2</sup>
Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		72	
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm <sup>2</sup>
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.



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

Hub Small End Required Thickness due to Internal Pressure:  
 $= (P*(D/2+Ca))/(S*E-0.6*P)$  per UG-27 (c) (1)  
 $= (23.07*(1200.0/2+3.0))/(137.9*1.0-0.6*23.07)+Ca$   
 $= 13.1901$  mm.

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FileName : Calculation Book for Evaporator E-PK1601

Flg Calc [Int P]: New Flange Flng: 8 1:34am Feb 7,2022

Hub Small End Hub MAWP:

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

$$= (137.9 \cdot 1.0 \cdot 17.0) / (603.0 + 0.6 \cdot 17.0)$$

$$= 38.228 \text{ bars}$$

Corroded Flange Thickness, tc = T-ci	107.000	mm.
Corroded Flange ID, Bcor = B+2*Fcor	1206.000	mm.
Corroded Large Hub, g1Cor = g1-ci	20.000	mm.
Corroded Small Hub, g0Cor = go-ci	17.000	mm.
Code R Dimension, R = ((C-Bcor)/2) -g1cor	32.000	mm.
Gasket Contact Width, N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width, bo = N / 2	10.000	mm.
Effective Gasket Width, b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter, G = Go - 2 * b	1250.063	mm.

**Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 \cdot G^2 \cdot Peq$$

$$= 0.785 \cdot 1250.0626^2 \cdot 23.068$$

$$= 2831.121 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 \cdot b \cdot Pi \cdot G \cdot m \cdot P$$

$$= 2 \cdot 7.9687 \cdot 3.1416 \cdot 1250.0626 \cdot 3.0 \cdot 23.07$$

$$= 433.137 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= Pi \cdot Bcor^2 \cdot P / 4$$

$$= 3.1416 \cdot 1206.0^2 \cdot 23.0684 / 4$$

$$= 2635.054 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - Hd$$

$$= 2831 - 2635$$

$$= 196.067 \text{ kN}$$

Operating Bolt Load [Wm1]:

$$= \max( H + Hp + H'p, 0 )$$

$$= \max( 2831 + 433 + 0, 0 )$$

$$= 3264.258 \text{ kN}$$

$$= 3266.356 \text{ kN, Mating Flange Load Governs}$$

Gasket Seating Bolt Load [Wm2]:

$$= y \cdot b \cdot Pi \cdot G + yPart \cdot bPart \cdot lp$$

$$= 68.95 \cdot 7.9687 \cdot 3.1416 \cdot 1250.063 + 0.0 \cdot 0.0 \cdot 0.0$$

$$= 2157.577 \text{ kN}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } Wm1/Sb, Wm2/Sa$$

$$= \text{Maximum of } 3266/172, 2158/172$$

$$= 189.507 \text{ cm}^2$$

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

$$= 2a + 6t / (m + 0.5)$$

$$= 2 \cdot 22.225 + 6 \cdot 107.0 / (3.0 + 0.5)$$

$$= 227.879 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

$$= C \cdot \sin( pi / n )$$

$$= 1310.0 \cdot \sin( 3.142 / 72 )$$

$$= 57.141 \text{ mm.}$$

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

$$= \max( \sqrt{ Bs / ( 2a + t ) }, 1 )$$

$$= \max( \sqrt{ 57.141 / ( 2 \cdot 22.225 + 107.0 ) }, 1 )$$

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 Flg Calc [Int P]: New Flange Flng: 8 1:34am Feb 7,2022

= 1.0000

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	189.507	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	25.000	
Circumferential Spacing between the Bolt	52.400	57.141	227.879

**Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:**

=  $A_b * S_a / ( \gamma * \pi * (G_o + G_i) )$   
 =  $194.632 * 172.38 / (68.95 * 3.14 * (1266.0 + 1226.0) )$   
 = 6.215 mm.

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

= 32.000 mm. [Note: Exceeds actual gasket width, 20.000 ]

**Flange Design Bolt Load, Gasket Seating [W]:**

=  $S_a * ( A_m + A_b ) / 2$   
 =  $172.38 * ( 189.5074 + 194.6319 ) / 2$   
 = 3310.52 kN

**Gasket Load for the Operating Condition [HG]:**

=  $W_{m1} - H$   
 = 3266 - 2831  
 = 435.24 kN

**Moment Arm Calculations:**

**Distance to Gasket Load Reaction [hg]:**

=  $( C - G ) / 2$   
 =  $( 1310.0 - 1250.0626 ) / 2$   
 = 29.9687 mm.

**Distance to Face Pressure Reaction [ht]:**

=  $( R + g_1 + h_g ) / 2$   
 =  $( 32.0 + 20.0 + 29.9687 ) / 2$   
 = 40.9843 mm.

**Distance to End Pressure Reaction [hd]:**

=  $R + ( g_1 / 2 )$   
 =  $32.0 + ( 20.0 / 2.0 )$   
 = 42.0000 mm.

**Summary of Moments for Internal Pressure: (N-m)**

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2635.	42.0000	1.0000	110717.
Face Pressure, Mt	196.	40.9843	1.0000	8039.
Gasket Load, Mg	435.	29.9687	1.0000	13049.
Gasket Seating, Matm	3311.	29.9687	1.0000	99252.
Total Moment for Operation, Mop				131805. N-m
Total Moment for Gasket seating, Matm				99252. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			143.185 mm.	
Hub Ratio, h/h0 = HL / H0			0.314	
Thickness Ratio, g1/g0 = (g1Cor/goCor)			1.176	

**Flange Factors for Integral Flange:**

Factor F 0.893  
 Factor V 0.459

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Flg Calc [Int P]: New Flange Flng: 8 1:34am Feb 7,2022

Factor f 1.000  
 Factors from Figure 2-7.1 K = 1.128  
 T = 1.867 U = 17.771  
 Y = 16.171 Z = 8.361  
 d = 0.16019E+07 mm.<sup>3</sup> e = 0.0062 mm.<sup>-1</sup>  
 Stress Factors ALPHA = 1.667  
 BETA = 1.890 GAMMA = 0.893  
 DELTA = 0.765 Lamda = 1.658

Longitudinal Hub Stress, Operating [SHo]:

$$= ( f * Mop / Bcor ) / ( L * g1^2 )$$

$$= ( 1.0 * 131805 / 1206.0 ) / ( 1.6578 * 20.0^2 )$$

$$= 164.76 \text{ N./mm}^2$$

Longitudinal Hub Stress, Seating [SHa]:

$$= ( f * Matm / Bcor ) / ( L * g1^2 )$$

$$= ( 1.0 * 99252 / 1206.0 ) / ( 1.6578 * 20.0^2 )$$

$$= 124.07 \text{ N./mm}^2$$

Radial Flange Stress, Operating [SRO]:

$$= ( Beta * Mop / Bcor ) / ( L * t^2 )$$

$$= ( 1.89 * 131805 / 1206.0 ) / ( 1.6578 * 107.0^2 )$$

$$= 10.88 \text{ N./mm}^2$$

Radial Flange Stress, Seating [SRa]:

$$= ( Beta * Matm / Bcor ) / ( L * t^2 )$$

$$= ( 1.89 * 99252 / 1206.0 ) / ( 1.6578 * 107.0^2 )$$

$$= 8.19 \text{ N./mm}^2$$

Tangential Flange Stress, Operating [STo]:

$$= ( Y * Mo / ( t^2 * Bcor ) ) - Z * SRO$$

$$= ( 16.1715 * 131805 / ( 107.0^2 * 1206.0 ) ) - 8.3612 * 11$$

$$= 63.36 \text{ N./mm}^2$$

Tangential Flange Stress, Seating [STa]:

$$= ( y * Matm / ( t^2 * Bcor ) ) - Z * SRa$$

$$= ( 16.1715 * 99252 / ( 107.0^2 * 1206.0 ) ) - 8.3612 * 8$$

$$= 47.71 \text{ N./mm}^2$$

Average Flange Stress, Operating [SAo]:

$$= ( SHo + \max( SRO, STo ) ) / 2$$

$$= ( 165 + \max( 11, 63 ) ) / 2$$

$$= 114.06 \text{ N./mm}^2$$

Average Flange Stress, Seating [SAa]:

$$= ( SHa + \max( SRa, STa ) ) / 2$$

$$= ( 124 + \max( 8, 48 ) ) / 2$$

$$= 85.89 \text{ N./mm}^2$$

Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 3266 / 194.6319$$

$$= 167.84 \text{ N./mm}^2$$

Bolt Stress, Seating [BSa]:

$$= ( Wm2 / Ab )$$

$$= ( 2158 / 194.6319 )$$

$$= 110.86 \text{ N./mm}^2$$

**Flange Stress Analysis Results: N./mm<sup>2</sup>**

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	165.	207.	124.	207.
Radial Flange	11.	138.	8.	138.
Tangential Flange	63.	138.	48.	138.

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Flg Calc [Int P]: New Flange Flng: 8 1:34am Feb 7,2022

Maximum Average	114.	138.	86.	138.
Bolting	168.	172.	111.	172.

Minimum Required Flange Thickness	94.564 mm.
Estimated M.A.W.P. ( Operating )	23.707 bars
Estimated Finished Weight of Flange at given Thk.	303.0 kg.
Estimated Unfinished Weight of Forging at given Thk	386.5 kg.

**Flange Rigidity Based on Required Thickness [ASME]:**

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99252.1/1.0 * 999.68 * 0.459/( 1.321 * 202713 * 17.0^2 * 143.185 * 0.3 )$$

$$= 0.715 \quad (\text{should be } \leq 1)$$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 131804.7/1.0 * 999.68 * 0.459/( 1.321 * 196612 * 17.0^2 * 143.185 * 0.3 )$$

$$= 0.978 \quad (\text{should be } \leq 1)$$

**Flange Rigidity Based on Given Thickness [ASME]:**

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99252.1/1.0 * 999.68 * 0.459/( 1.658 * 202713 * 17.0^2 * 143.185 * 0.3 )$$

$$= 0.569 \quad (\text{should be } \leq 1)$$

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 131804.7/1.0 * 999.68 * 0.459/( 1.658 * 196612 * 17.0^2 * 143.185 * 0.3 )$$

$$= 0.779 \quad (\text{should be } \leq 1)$$

**Minimum Design Metal Temperature Results:**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

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 Internal Pressure Calculations: Step: 6 1:34am Feb 7,2022

#### 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	23.083	18	3	1200	137.9
SHELL	001	23.083	15	3	1200	137.9
BODY FLANGE	001	23.083	60	3	1200	137.9
body flange	02	23.068	60	3	1200	137.9
SHELL	002	23.069	20	3	1200	137.9
CON		23.069	20	3	1656	137.9
SHELL	002	23.069	18	3	1656	137.9
HEAD	002	23.069	20	3	1656	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	27.4845	34.387	15	13.0447
SHELL	001	23	27.034	33.9635	15	13.1968
BODY FLANGE	001	23	23.6239	23.7071	110	107.721
body flange	02	23	23.6387	23.7071	110	94.5642
SHELL	002	23	38.1598	45.0627	20	13.1901
CON		23	24.3794	28.8256	20	19.0311
SHELL	002	23	24.555	29.5906	18	17.0431
HEAD	002	23	23.2347	28.2531	17	16.8588

#### Summary of Heat Exchanger Maximum Allowable Working Pressures :

##### Note:

For Exchanger designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

Shell Side MAWP = 23.639 bars  
 Shell Side MAPnc = 23.707 bars  
 Channel Side MAWP = 23.160 bars  
 Channel Side MAPnc = 23.707 bars

#### 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]:

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

$$= (23.083 \cdot 1206.0 \cdot 0.993) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.083)$$

$$= 10.0447 + 3.0000 = 13.0447 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.083 bars

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

$$= (2 * 137.9 * 1.0 * 12.0) / (0.993 * 1206.0 + 0.2 * 12.0)$$

$$= 27.568 - 0.083 = 27.484 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (2 * S * E * t) / (K * D + 0.2 * t) \text{ per Appendix 1-4 (c)}$$

$$= (2 * 137.9 * 1.0 * 15.0) / (1.0 * 1200.0 + 0.2 * 15.0)$$

$$= 34.387 \text{ bars}$$

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

$$= (P * (K_{cor} * D + 0.2 * t)) / (2 * E * t)$$

$$= (23.083 * (0.993 * 1206.0 + 0.2 * 12.0)) / (2 * 1.0 * 12.0)$$

$$= 115.468 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.083 * 603.0) / (137.9 * 1.0 - 0.6 * 23.083) + 3.0$$

$$= 13.197 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.083 bars

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

$$= (137.9 * 1.0 * 15.0) / (603.0 + 0.6 * 15.0)$$

$$= 33.797 - 0.083 = 33.714 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (1206.0 / (2 * 303.0))^2) / 6$$

$$= 0.993416$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 * t_{nom} / R_f) * (1 - R_f / R_o)$  6.338 %

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 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.083 * 603.0) / (137.9 * 1.0 - 0.6 * 23.083)$$

$$= 10.1968 + 3.0000 = 13.1968 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.083 bars

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

$$= (137.9 * 1.0 * 12.0) / (603.0 + 0.6 * 12.0)$$

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$$= 27.117 - 0.083 = 27.034 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

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

$$= (137.9 \cdot 1.0 \cdot 15.0) / (600.0 + 0.6 \cdot 15.0)$$

$$= 33.964 \text{ bars}$$

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

$$= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t)$$

$$= (23.083 \cdot (603.0 + 0.6 \cdot 12.0)) / (1.0 \cdot 12.0)$$

$$= 117.386 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 ( $50 \cdot t_{nom} / R_f \cdot (1 - R_f / R_o)$ ) 1.235 %

**Minimum Design Metal Temperature Results:**

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

### **Cylindrical Shell From 50 To 60 SA-516 70 at 125 °C**

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.069 \cdot 603.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.069)$$

$$= 10.1901 + 3.0000 = 13.1901 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.069 bars

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

$$= (137.9 \cdot 1.0 \cdot 17.0) / (603.0 + 0.6 \cdot 17.0)$$

$$= 38.228 - 0.069 = 38.160 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

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

$$= (137.9 \cdot 1.0 \cdot 20.0) / (600.0 + 0.6 \cdot 20.0)$$

$$= 45.063 \text{ bars}$$

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

$$= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t)$$

$$= (23.069 \cdot (603.0 + 0.6 \cdot 17.0)) / (1.0 \cdot 17.0)$$

$$= 83.214 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 ( $50 \cdot t_{nom} / R_f \cdot (1 - R_f / R_o)$ ) 1.639 %

**Minimum Design Metal Temperature Results:**

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

### **Conical Section From 60 To 70 SA-516 70 at 125 °C**

CON

Material UNS Number: K02700

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Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot D) / (2 \cdot \cos(a) \cdot (S \cdot E - 0.6 \cdot P)) \text{ per Appendix 1-4 (e)}$$

$$= (23.069 \cdot 1662.8459) / (2 \cdot 0.8764 \cdot (137.9 \cdot 1.0 - 0.6 \cdot 23.069))$$

$$= 16.0311 + 3.0000 = 19.0311 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.069 bars

$$= (2 \cdot S \cdot E \cdot t \cdot \cos(a)) / (D + 1.2 \cdot t \cdot \cos(a)) \text{ per App 1-4 (e)}$$

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 17.0 \cdot 0.876) / (1662.846 + 1.2 \cdot 17.0 \cdot 0.876)$$

$$= 24.448 - 0.069 = 24.379 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (2 \cdot S \cdot E \cdot t \cdot \cos(a)) / (D + 1.2 \cdot t \cdot \cos(a)) \text{ per App 1-4 (e)}$$

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 20.0 \cdot 0.8764) / (1656.0 + 1.2 \cdot 20.0 \cdot 0.8764)$$

$$= 28.826 \text{ bars}$$

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

$$= (P \cdot (D + 1.2 \cdot t \cdot \cos(a))) / (2 \cdot E \cdot t \cdot \cos(a))$$

$$= (23.069 \cdot (1662.8459 + 1.2 \cdot 17.0 \cdot 0.8764)) / (2 \cdot 1.0 \cdot 17.0 \cdot 0.8764)$$

$$= 130.119 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 1.636 %

**Minimum Design Metal Temperature Results:**

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

**Cylindrical Shell From 70 To 80 SA-516 70 at 125 °C**

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.069 \cdot 831.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.069)$$

$$= 14.0431 + 3.0000 = 17.0431 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.069 bars

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

$$= (137.9 \cdot 1.0 \cdot 15.0) / (831.0 + 0.6 \cdot 15.0)$$

$$= 24.624 - 0.069 = 24.555 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

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

$$= (137.9 \cdot 1.0 \cdot 18.0) / (828.0 + 0.6 \cdot 18.0)$$

$$= 29.591 \text{ bars}$$

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

$$= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t)$$

$$= (23.069 \cdot (831.0 + 0.6 \cdot 15.0)) / (1.0 \cdot 15.0)$$

$$= 129.191 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 1.075 %

**Minimum Design Metal Temperature Results:**

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

**Elliptical Head From 80 To 90 SA-516 70 at 125 °C**

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.069 \cdot 1662.0 \cdot 0.995) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.069)$$

$$= 13.8588 + 3.0000 = 16.8588 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.069 bars

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

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 14.0) / (0.995 \cdot 1662.0 + 0.2 \cdot 14.0)$$

$$= 23.303 - 0.069 = 23.235 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

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

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 17.0) / (1.0 \cdot 1656.0 + 0.2 \cdot 17.0)$$

$$= 28.253 \text{ bars}$$

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

$$= (P \cdot (K_{cor} \cdot D + 0.2 \cdot t)) / (2 \cdot E \cdot t)$$

$$= (23.069 \cdot (0.995 \cdot 1662.0 + 0.2 \cdot 14.0)) / (2 \cdot 1.0 \cdot 14.0)$$

$$= 136.511 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.069 \cdot 831.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.069) + 3.0$$

$$= 17.043 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.069 bars

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

$$= (137.9 \cdot 1.0 \cdot 17.0) / (831.0 + 0.6 \cdot 17.0)$$

$$= 27.867 - 0.069 = 27.798 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (1662.0 / (2 \cdot 417.0))^2) / 6$$

$$= 0.995212$$

Percent Elong. per UCS-79, VIII-1-01-57 (75 \cdot t\_{nom} / R\_f) \cdot (1 - R\_f / R\_o) 5.145 %

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:**

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Exchanger Shell Side Hydrostatic Test Pressures:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.730	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	30.657	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	26.003	bars
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	30.730	bars

Exchanger Channel Side Hydrostatic Test Pressures:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.108	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	30.657	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.476	bars
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	30.108	bars

## UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:

$$= \text{Test Factor} * \text{Design Pressure} * \text{Stress Ratio}$$

$$= 1.3 * 23.0 * 1.0$$

$$= 29.900 \text{ bars}$$

## UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:

$$= \text{Test Factor} * \text{Design Pressure} * \text{Stress Ratio}$$

$$= 1.3 * 23.0 * 1.0$$

$$= 29.900 \text{ bars}$$

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

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

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

From To	Stress	Allowable	Ratio	Pressure
HEAD 001	150.2	235.8	0.637	30.02
SHELL 001	152.6	235.8	0.647	30.02
SHELL 002	108.3	235.8	0.459	30.02
CON	169.6	235.8	0.719	30.06
SHELL 002	168.4	235.8	0.714	30.06
HEAD 002	177.9	235.8	0.754	30.06

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	137.90	137.90	1.000
T2	Pad	137.90	137.90	1.000
T1	Nozzle	137.90	137.90	1.000
T1	Pad	137.90	137.90	1.000
D2	Nozzle	137.90	137.90	1.000
S2	Nozzle	117.90	117.90	1.000
S2	Pad	137.90	137.90	1.000
S1	Nozzle	117.90	117.90	1.000
S1	Pad	137.90	137.90	1.000
S3	Nozzle	117.90	117.90	1.000
S3	Pad	137.90	137.90	1.000
D1	Nozzle	137.90	137.90	1.000

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D3	Nozzle	137.90	137.90	1.000
TT	Nozzle	137.90	137.90	1.000
V	Nozzle	137.90	137.90	1.000
S4	Nozzle	117.90	117.90	1.000
S4	Pad	137.90	137.90	1.000
LG1	Nozzle	137.90	137.90	1.000
LG2	Nozzle	137.90	137.90	1.000
LT1	Nozzle	117.90	117.90	1.000
LT3	Nozzle	117.90	117.90	1.000
LT2	Nozzle	117.90	117.90	1.000
LT4	Nozzle	117.90	117.90	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 001	137.90	137.90	1.000
BODY FLANGE 001	137.90	137.90	1.000
body flange 02	137.90	137.90	1.000
SHELL 002	137.90	137.90	1.000
CON	137.90	137.90	1.000
SHELL 002	137.90	137.90	1.000
HEAD 002	137.90	137.90	1.000

-----  
 Minimum 1.000

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

Description	Ambient	Operating	Ratio
Tube Material	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000

-----  
 Minimum 1.000

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

Description	Ambient	Operating	Ratio
T2	43.65	235.80	0.185
T1	43.65	235.80	0.185
D2	8.08	223.40	0.036
S2	39.39	217.19	0.181
S1	39.39	217.19	0.181
S3	39.39	217.19	0.181
D1	8.08	223.40	0.036
D3	8.08	223.40	0.036
TT	8.08	223.40	0.036
V	8.08	223.40	0.036
S4	39.39	217.19	0.181
LG1	8.08	223.40	0.036
LG2	8.08	223.40	0.036
LT1	18.32	217.19	0.084
LT3	18.32	217.19	0.084
LT2	18.32	217.19	0.084
LT4	18.32	217.19	0.084

-----  
 Elements Suitable for Internal Pressure.

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**External Pressure Calculation Results :****External Pressure Calculations:**

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm <sup>2</sup>
10	20	No Calc	1230	12	0.001355	94.0922
20	30	1140	1230	12	0.0014054	95.0759
30	40	No Calc	...	107	No Calc	No Calc
40	50	No Calc	...	107	No Calc	No Calc
50	60	5218	1240	17	0.00046617	46.6065
60	70	5218	1696	17	0.00040569	40.5597
70	80	5218	1692	15	0.00034124	34.1167
80	90	No Calc	1690	14	0.0011506	89.495

**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	15	6.18473	1.03419	10.1991
20	30	15	6.81561	1.03419	12.3669
30	40	110	79.2734	1.03419	No Calc
40	50	110	58.547	1.03419	No Calc
50	60	20	10.2323	1.03419	8.51898
60	70	20	11.6968	1.03419	5.4204
70	80	18	11.6842	1.03419	4.03247
80	90	17	7.37574	1.03419	8.23707

Minimum

4.032

**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	1140	24339.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	5218	112034	No Calc	No Calc
60	70	5218	115500	No Calc	No Calc
70	80	5218	46275.1	No Calc	No Calc
80	90	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.

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Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
12.000	1230.00	102.50	0.0013550	94.09

EMAP =  $B / (K0 * D/t) = 94.0922 / (0.9 * 102.5) = 10.1991$  bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
3.185	1230.00	386.22	0.0003596	35.95

EMAP =  $B / (K0 * D/t) = 35.9532 / (0.9 * 386.2177) = 1.0343$  bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

=  $(P * D * K_{cor}) / (2 * S * E - 0.2 * P)$  Appendix 1-4 (c)  
 =  $(1.727 * 1206.0 * 0.993) / (2 * 137.9 * 1.0 - 0.2 * 1.727)$   
 =  $0.7504 + 3.0000 = 3.7504$  mm.

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

=  $((2 * S * E * t) / (K_{cor} * D + 0.2 * t)) / 1.67$  per Appendix 1-4 (c)  
 =  $((2 * 137.9 * 1.0 * 12.0) / (0.993 * 1206.0 + 0.2 * 12.0)) / 1.67$   
 = 16.508 bars

Maximum Allowable External Pressure [MAEP]:

= min( MAEP, MAWP )  
 = min( 10.2, 16.5077 )  
 = 10.199 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 001

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
12.000	1230.00	1140.00	102.50	0.9268	0.0014054	95.08

EMAP =  $(4 * B) / (3 * (D/t)) = (4 * 95.0759) / (3 * 102.5) = 12.3669$  bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.816	1230.00	1140.00	322.36	0.9268	0.0002501	25.01

EMAP =  $(4 * B) / (3 * (D/t)) = (4 * 25.0064) / (3 * 322.3596) = 1.0342$  bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1230.00	24339.10	102.50	19.7879	0.0001069	10.69

EMAP =  $(4 * B) / (3 * (D/t)) = (4 * 10.6869) / (3 * 102.5) = 1.3901$  bars

### **Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 125 °C**

SHELL 002

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

Results for Maximum Allowable External Pressure (MAEP):

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Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1240.00	5218.00	72.94	4.2081	0.0004662	46.61
EMAP = (4*B)/(3*(D/t)) = (4*46.6065)/(3*72.9412) = 8.519 bars						

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.232	1240.00	5218.00	171.45	4.2081	0.0001330	13.30
EMAP = (4*B)/(3*(D/t)) = (4*13.3003)/(3*171.4528) = 1.0343 bars						

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1240.00	112033.63	72.94	50.0000	0.0002131	21.31
EMAP = (4*B)/(3*(D/t)) = (4*21.3074)/(3*72.9412) = 3.8947 bars						

**Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 125 °C**

## CON

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
17.000	1696.00	5218.00	99.76	3.0767	0.0004057	40.56
EMAP = (4*B)/(3*(D/t)) = (4*40.5597)/(3*99.7647) = 5.4204 bars						

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.697	1696.00	5218.00	195.01	3.0767	0.0001513	15.13
EMAP = (4*B)/(3*(D/t)) = (4*15.1274)/(3*195.0137) = 1.0342 bars						

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1696.00	115500.43	99.76	50.0000	0.0001106	11.06
EMAP = (4*B)/(3*(D/t)) = (4*11.06)/(3*99.7647) = 1.4781 bars						

**Cylindrical Shell From 70 to 80 Ext. Chart: CS-2 at 125 °C**

## SHELL 002

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
15.000	1692.00	5218.00	112.80	3.0839	0.0003412	34.12
EMAP = (4*B)/(3*(D/t)) = (4*34.1167)/(3*112.8) = 4.0325 bars						

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.684	1692.00	5218.00	194.84	3.0839	0.0001512	15.11
EMAP = (4*B)/(3*(D/t)) = (4*15.1136)/(3*194.8375) = 1.0342 bars						

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
15.000	1692.00	46275.10	112.80	27.3493	0.0000884	8.84
EMAP = (4*B)/(3*(D/t)) = (4*8.8357)/(3*112.8) = 1.0444 bars						

**Elliptical Head From 80 to 90 Ext. Chart: CS-2 at 125 °C**

## HEAD 002

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

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Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
14.000	1690.00	120.71	0.0011506	89.50

EMAP =  $B / (K0 * D / t) = 89.495 / (0.9 * 120.7143) = 8.2371$  bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.376	1690.00	386.22	0.0003596	35.95

EMAP =  $B / (K0 * D / t) = 35.9529 / (0.9 * 386.2208) = 1.0343$  bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$= (P * D * K_{cor}) / (2 * S * E - 0.2 * P)$  Appendix 1-4 (c)  
 $= (1.727 * 1662.0 * 0.995) / (2 * 137.9 * 1.0 - 0.2 * 1.727)$   
 $= 1.0360 + 3.0000 = 4.0360$  mm.

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

$= ((2 * S * E * t) / (K_{cor} * D + 0.2 * t)) / 1.67$  per Appendix 1-4 (c)  
 $= ((2 * 137.9 * 1.0 * 14.0) / (0.995 * 1662.0 + 0.2 * 14.0)) / 1.67$   
 $= 13.954$  bars

Maximum Allowable External Pressure [MAEP]:

$= \min(\text{MAEP}, \text{MAWP})$   
 $= \min(8.24, 13.954)$   
 $= 8.237$  bars

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

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**Element and Detail Weights:**

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	274.398	282794	228.665	286772	54.8796
20	30	439.322	1119864	352.324	1131091	87.8643
30	40	299.644	176580	286.023	177090	59.9288
40	50	303.042	176580	289.421	177090	60.6084
50	60	118.823	127029	101.247	129297	23.7645
60	70	669.082	1340840	570.06	1353618	133.816
70	80	2934.72	8616848	2449.98	8679401	586.944
80	90	561.942	702273	477.651	709541	112.388
Total		5600	12542809.00	4755	12643901.00	1120

For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.

**Weight of Details:**

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	199.87	-100	-0.00004	1
10	Insl	31.0015	-125	...	Ins: 20
20	Liqd	791.485	495	...	2
20	Insl	49.6345	495	...	Ins: 20
20	Nozl	366.74	400	854	T2
20	Nozl	366.74	400	854	T1
30	Liqd	124.81	77.5	...	3
30	Insl	5.87196	77.5	...	Ins: 20
40	Liqd	102.566	77.5	...	4
40	Insl	5.93855	77.5	...	Ins: 20
50	Sadl	707.36	200	964.5	Lft Sdl
50	Liqd	73.785	100	...	5
50	Insl	10.1026	100	...	Ins: 20
60	Liqd	633.315	415	114	Liquid: 60
60	Insl	55.5007	415	...	Ins: 20
60	Nozl	12.4214	380	853.4	D2
70	Sadl	908.635	2520	1192.5	Lft Sdl
70	Liqd	3884.36	2000	228	Liquid: 70
70	Insl	270.206	2000	...	Ins: 20
70	Nozl	105.134	500	937.537	S2
70	Nozl	105.134	3050	937.537	S1
70	Nozl	105.134	700	937.537	S3
70	Nozl	12.4214	2200	853.4	D1
70	Nozl	12.4214	3600	853.4	D3
70	Nozl	12.4214	3850	853.4	TT
70	Nozl	12.4214	150	853.4	V
70	Nozl	105.134	3050	937.537	S4
70	Nozl	12.4214	1800	853.4	LG1
70	Nozl	12.4214	1800	853.4	LG2
70	Nozl	27.2525	1200	858.162	LT1
70	Nozl	27.2525	1500	858.162	LT3
70	Nozl	27.2525	1200	858.162	LT2
70	Nozl	27.2525	1500	858.162	LT4
80	Liqd	332.159	188	228	Liquid: 80
80	Insl	54.7541	232	...	Ins: 20
30	FTsh	1245.75	231	...	TUBE SHEET

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30|Tube| 11050.1 | 2261 | ... |

**Total Weight of Each Detail Type**

Total Weight of Saddles	1616.0
Total Weight of Liquid	6142.3
Total Weight of Insulation	483.0
Total Weight of Nozzles	1350.0
Total Weight of Exchanger Components	12295.8
Total Weight of Liquid in Tubes	900.5
-----	
Sum of the Detail Weights	22787.6 kg.

**Weight Summation: kg.**

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
6721.2	21983.0	6721.2	21983.0	6721.2	22466.0
1616.0	12535.2	1616.0	...	1616.0	6142.3
1350.0	...	1350.0	...	...	...
...	1286.4	...	483.0	...	...
...	...	...	...	483.0	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	1350.0	900.5
12295.8	...	12295.8	...	...	...
...	...	...	...	12295.8	...
21983.0	35804.5	22466.0	22466.0	22466.0	29508.8

**Miscellaneous Weight Percent: 20.0 %**

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

**Note:**  
 The shipping total has been modified because some items have been specified as being installed in the shop.

**Weight Summary**

Fabricated Wt.	- Bare Weight W/O Removable Internals	21983.0 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	35804.5 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	22466.0 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	22466.0 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	22466.0 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	29508.8 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	28494.1 kg.
Field Test Wt.	- Empty Weight + Water (Full)	35373.8 kg.

**Exchanger Tube Data**

Volume of Exchanger tubes :	1287149.9 Cm3
Weight of Ope Liq in tubes :	900.5 kg.
Weight of Water in tubes :	1286.4 kg.

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

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

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**Outside Surface Areas of Elements:**

From	To	Surface Area cm <sup>2</sup>
10	20	18501.5
20	30	38255.2
30	40	9678.31
40	50	9678.31
50	60	7791.15
60	70	39848.9
70	80	212623
80	90	33844
Total		370220.344 cm <sup>2</sup>

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 Nozzle Flange MAWP: Step: 9 1:34am Feb 7,2022

**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
T2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	45.8	51.1	125	300	GR 1.1	...	...	...	...
D2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S1	45.8	51.1	125	300	GR 1.1	...	...	...	...
S3	45.8	51.1	125	300	GR 1.1	...	...	...	...
D1	45.8	51.1	125	300	GR 1.1	...	...	...	...
D3	45.8	51.1	125	300	GR 1.1	...	...	...	...
TT	45.8	51.1	125	300	GR 1.1	...	...	...	...
V	45.8	51.1	125	300	GR 1.1	...	...	...	...
S4	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT3	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT4	45.8	51.1	125	300	GR 1.1	...	...	...	...

**Shellside Flange Rating**

**Channelside Flange Rating**

Lowest Flange Pressure Rating was (Ope) [TubeSide ]: 45.850 bars  
 Lowest Flange Pressure Rating was (Amb) [TubeSide ]: 51.100 bars

**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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 Wind Load Calculation: Step: 10 1:34am Feb 7,2022

### Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	[V] 200 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 mm.
Percent Wind for Hydrotest	20.0
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]:

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q ) / ( 1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1+1.7*3.4*0.143*0.836) / (1+1.7*3.4*0.143))) \\
 &= \min(0.85, 0.856 ) \\
 &= 0.850
 \end{aligned}$$

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

Force Coefficient	[Cf] 0.553
Structure Height to Diameter ratio	4.205

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

### Sample Calculation for the First Element

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

Value of [Alpha] and [Zg]:

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

Effective Height [z]:

= Centroid Height + Vessel Base Elevation  
 = 1600.0 + 123000. = 124600. mm.  
 = 408.793 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z \text{ (408.793 ft.) } > 15 \text{ ft.} \\
 &= 2.01 * ( z / Zg ) ^ { 2 / \text{Alpha} } \\
 &= 2.01 * ( 408.793 / 900.0 ) ^ { 2 / 9.5 } \\
 &= 1.702
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

= 0.95 per Table 26.6-1

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

Topographical Factor [Kzt]:  
 = ( 1 + K1 \* K2 \* K3 )<sup>2</sup>  
 = ( 1 + 0.0\* 0.0\* 0.0 )<sup>2</sup>  
 = 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:  
 = max( 16, 0.00256 \* Kz \* Kzt \* Kd \* V(mph)<sup>2</sup> )  
 = max( 16, 0.00256 \* 1.702 \* 1.0 \* 0.95 \* 124.278<sup>2</sup> )  
 = 63.9 psf [312.199] Kgs/m<sup>2</sup>

Force on the first element [F]:  
 = qz \* G \* Cf \* WindArea  
 = 63.943 \* 0.85 \* 0.553 \* 5.941  
 = 178.7 lbs. [ 0.8] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
HEAD 001	*****	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 001	*****	0.000	0.000	0.000	1.702	1.000	312.199
BODY FLANGE 001	*****	0.000	0.000	0.000	1.702	1.000	312.199
body flange 02	*****	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 002	*****	0.000	0.000	0.000	1.702	1.000	312.199
CON	*****	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 002	*****	0.000	0.000	0.000	1.702	1.000	312.199
HEAD 002	*****	0.000	0.000	0.000	1.702	1.000	312.199

**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	124600	1716	5518.95	312.199	0.47687
20	30	124600	1716	16988.4	312.199	1.46791
30	40	124600	1680	2604	312.199	0.225
40	50	124600	1680	2604	312.199	0.225
50	60	124600	1728	3456	312.199	0.29862
60	70	124600	2001.6	16613.3	312.199	1.43549
70	80	124600	2270.4	90816	312.199	7.84708
80	90	124600	2268	9016.18	312.199	0.77905

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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Earthquake Load Calculation: Step: 11 1:34am Feb 7,2022

### Earthquake Load Calculation:

#### Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		0.900
Short Period Acceleration value Ss		0.537
Long Period Acceleration Value S1		0.600
Moment Reduction Factor Tau		2.500
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	1.000
Amplification Factor	Ap	2.500
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.624

#### Seismic Analysis Results:

$Sms = Fa * Ss = 1.0 * 0.537 = 0.537$   
 $Sm1 = Fv * S1 = 0.9 * 0.6 = 0.54$   
 $Sds = 2/3 * Sms = 2/3 * 0.537 = 0.358$

$Sds = \text{Max}( 0.8*Sds, SdsUser )$   
 $= \text{Max}( 0.286, 0.624 )$   
 $= 0.624$

$Sd1 = 2/3 * Sm1 = 2/3 * 0.54 = 0.36$

$Sd1 = \text{Max}( 0.8*Sd1, Sd1User )$   
 $= \text{Max}( 0.288, 0.39 )$   
 $= 0.390$

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

$= Ct * hn^x$  where  $Ct = 0.020$ ,  $x = 0.75$  and  $hn = \text{Structural Height (ft.)}$   
 $= 0.020 * ( 7.9659^{0.75} )$   
 $= 0.095 \text{ seconds}$

The Coefficient Cu from Table 12.8-1 is : 1.400

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

$= ( 1/\text{Natural Frequency} ) = ( 1/33.0 )$   
 $= 0.030$

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

$= \text{Minimum Value of } ( 1.4 * 0.095, 0.03 ) \text{ per 12.8.2}$   
 $= 0.030$

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

$= 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )$   
 $= 0.4 * 2.5 * 0.624 * 279 * ( 1 + 2*1.0 ) / ( 3.0/1.5 )$   
 $= 261.530 \text{ kN}$

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

$= 1.6 * Sds * I * W$   
 $= 1.6 * 0.624 * 1.5 * 279 = 418.45 \text{ kN}$

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Check the Minimum value of  $F_p$  per equation 13.3-3:

$$\begin{aligned}
 &= 0.3 * 0.62 * 1.5 * 279 \\
 &= 78.459 \text{ kN}
 \end{aligned}$$

Compute the Total Base Shear  $V = F_p, [V]$ :

$$= 261.530 \text{ kN}$$

Vertical load per 12.4-4, [YEq]:

$$\begin{aligned}
 &= 0.2 * S_d * W \\
 &= 0.2 * 0.624 * 279 = 34.87 \text{ kN}
 \end{aligned}$$

Final Base Shear,  $V = 183.07 \text{ kN}$

Final Vertical Load, YEq = 24.41 kN

#### Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	600	27.9413	16.4337
20	30	600	27.9413	16.4337
30	40	600	27.9413	16.4337
40	50	600	27.9413	16.4337
50	60	600	27.9413	16.4337
50	60	600	27.9413	16.4337
60	70	600	27.9413	16.4337
70	0	828	27.9413	22.6785
70	80	828	27.9413	22.6785
80	90	828	27.9413	22.6785

#### 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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 FileName : Calculation Book for Evaporator E-PK1601  
 Center of Gravity Calculation:                    Step:    12    1:34am    Feb 7,2022

**Shop/Field Installation Options :**

Insulation is installed in the Shop.

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

Center of Gravity of Saddles	3589.149 mm.
Center of Gravity of Liquid	3583.260 mm.
Center of Gravity of Insulation	3660.804 mm.
Center of Gravity of Nozzles	2199.080 mm.
Center of Gravity of Tubesheet(s)	1271.000 mm.
Center of Gravity of Tubes	3301.000 mm.
Center of Gravity of Bare Shell New and Cold	3520.615 mm.
Center of Gravity of Bare Shell Corroded	3497.506 mm.
Vessel CG in the Operating Condition	3282.684 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3216.387 mm.
Vessel CG in the Test Condition	3428.823 mm.

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 FileName : Calculation Book for Evaporator E-PK1601  
 Horizontal Vessel Analysis (Ope.): Step: 13 1:34am Feb 7,2022

### ASME Horizontal Vessel Analysis: Stresses for the Left Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

#### Input and Calculated Values:

Vessel Mean Radius	Rm	611.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	352.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	350.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		508.39	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	39.35	137.90
Long. Stress at Bottom of Midspan	54.55	137.90
Long. Stress at Top of Saddles	-0.99	-409.94
Long. Stress at Top of Saddles	0.99	137.90
Long. Stress at Bottom of Saddles	64.94	137.90
-----	-----	-----
Tangential Shear in Shell	56.29	110.32
Circ. Stress at Horn of Saddle	123.58	172.37
Circ. Compressive Stress in Shell	6.87	137.90
-----	-----	-----

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

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
 &= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E \\
 &= 3.0 * ( 12.8/2 + 0 ) * 1374.0/1059.149 \\
 &= 24.8 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s \\
 &= \max( 2.66, 0.0, 0 ) * 1374.0/3350.0 \\
 &= 1.1 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( F_l, \text{Friction Force, Sum of X Forces} ) * B / L_s \\
 &= \max( 183.07, 0.0, 0 ) * 1374.0/3350.0 \\
 &= 75.1 \text{ kN}
 \end{aligned}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

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$$= 3.0 * ( 183/2 + 0 ) * 1374.0/1059.149$$

$$= 356.2 \text{ kN}$$

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

$$= \text{Saddle Load} + \text{Max}( \text{Fwl}, \text{Fwt}, \text{Fsl}, \text{Fst} )$$

$$= 152 + \text{Max}( 1, 25, 75, 356 )$$

$$= 508.4 \text{ kN}$$

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

Vertical Load (including saddle weight)	515.32	kN
Transverse Shear Load Saddle	91.54	kN
Longitudinal Shear Load Saddle	183.07	kN

**Formulas and Substitutions for Horizontal Vessel Analysis:**

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

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0192	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0379
K7p = 0.0138			

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

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

Moment per Equation 4.15.3 [M1]:

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

$$= -508*352.0 [1 - (1 - 352.0/355.0 + (611.5^2 - 0.0^2) / (2*352.0*355.0)) / (1 + (4*0.0) / (3*355.0))]$$

$$= 90346.4 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

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

$$= 508*355/4 (1 + 2(611^2 - 0^2)/(355^2)) / (1 + (4*0) / (3*355)) - 4*352/355$$

$$= 133971.2 \text{ N-m}$$

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

$$= P * R_m / (2t) - M2 / (\pi * R_m^2 * t)$$

$$= 23.034 * 611.5 / (2 * 15.0) - 133971.2 / (\pi * 611.5^2 * 15.0)$$

$$= 39.35 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M2 / (\pi * R_m^2 * t)$$

$$= 23.034 * 611.5 / (2 * 15.0) + 133971.2 / (\pi * 611.5^2 * 15.0)$$

$$= 54.55 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) - M1 / (K1 * \pi * R_m^2 * t)$$

$$= 23.034 * 611.5 / (2 * 17.0) - 90346.4 / (0.1066 * \pi * 611.5^2 * 17.0)$$

$$= -0.99 \text{ N./mm}^2$$

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

$$= P * R_m / (2t) + M1 / (K1 * \pi * R_m^2 * t)$$

$$= 23.034 * 611.5 / (2 * 17.0) + 90346.4 / (0.1923 * \pi * 611.5^2 * 17.0)$$

$$= 64.94 \text{ N./mm}^2$$

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

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

$$= 508(355.0 - 2 * 352.0) / (355.0 + (4 * 0.0 / 3))$$

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$$= -499.8 \text{ kN}$$

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

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

$$= 1.1707 * -499.8 / ( 611.5 * 17.0 )$$

$$= -56.29 \text{ N./mm}^2$$

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

$$= 0.78 * \sqrt{ R_m * t }$$

$$= 0.78 * \sqrt{ 611.5 * 17.0 }$$

$$= 79.527 \text{ mm.}$$

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

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

$$= - 0.7603 * 508 * 0.1 / ( 17.0 * ( 172.0 + 79.53 + 79.53 ) )$$

$$= -6.87 \text{ N./mm}^2$$

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

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

$$= \min( 172.0 + 1.56 * \sqrt{ 611.5 * 17.0 }, 2 * 352.0 )$$

$$= 331.05 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [ $\eta$ ]:

$$= \min( S_r/S, 1 )$$

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

$$= 1.0000$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [ $\sigma_6, r$ ]:

$$= -K_5 * Q * k / ( B_1( t + \eta * t_r ) )$$

$$= - 0.7603 * 508 * 0.1 / ( 331.055( 17.0 + 1.0 * 25.0 ) )$$

$$= -2.78 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle,  $L < 8R_m$  (4.15.28) [ $\sigma_7, r^*$ ]:

$$= -Q / ( 4( t + \eta * t_r ) b_1 ) - 12 * K_7 * Q * R_m / ( L( t + \eta * t_r )^2 )$$

$$= -508 / ( 4( 17.0 + 1.0 * 25.0 ) 331.055 ) -$$

$$12 * 0.019 * 508 * 611.5 / ( 355.0( 17.0 + 1.0 * 25.0 )^2 )$$

$$= -123.58 \text{ N./mm}^2$$

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

$$= \alpha * L_s * ( \text{Design Temperature} - \text{Ambient Temperature} )$$

$$= 0.000012 * 3350.0 * ( 125.0 - 21.1 )$$

$$= 4.268 \text{ mm.}$$

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

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

## Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	508.	17.	8.	86.	73398.	83.2
Wearplate	350.	25.	29.	88.	258125.	807.
Web	30.	704.	394.	211.	8321278.	0.415E+06
BasePlate	220.	25.	758.	55.	4171750.	0.316E+06
Totals	...	...	...	440.	12824552.	0.732E+06

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Value C1 = Sumof (Ay) / Sumof (A) = 291. mm.  
 Value I = Sumof (Io) - C1\*Sumof (Ay) = 0.359E+06 cm\*\*4  
 Value As = Sumof (A) - Ashell = 354. cm^2

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

$$Fh = K1 * Q = 0.2035 * 508.387 = 103.4678 \text{ kN}$$

Tension Stress, St = ( Fh/As ) = 2.9255 N./mm^2  
 Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm^2

**Saddle Splitting Dimension [d]:**

= B - R \* sin( theta ) / theta  
 = 1374.0 - 603.0 \* sin( 1.0472 ) / 1.0472  
 = 875.323 mm.

$$\text{Bending Moment, } M = Fh * d = 90604.4766 \text{ N-m}$$

Bending Stress, Sb = ( M \* C1 / I ) = 7.3594 N./mm^2  
 Allowed Stress, Sa = 2/3 \* Yield Str = 137.9000 N./mm^2

**Minimum Thickness of Baseplate per Moss:**

= ( 3 ( Q + Saddle\_Wt ) BasePlateWidth / ( 4 \* BasePlateLength \* AllStress ) )<sup>1/2</sup>  
 = ( 3(508 + 7)220.0 / ( 4 \* 1450.0 \* 137.9 ) )<sup>1/2</sup>  
 = 20.622 mm.

**Calculation of Axial Load, Intermediate Values and Compressive Stress:****Distance between Ribs [e]:**

= Web Length / ( Nr ribs - 1 )  
 = 1122.3689 / ( 5 - 1 )  
 = 280.592 mm.

**Baseplate Pressure Area [Ap]:**

= e \* Bpwid / 2  
 = 280.5922 \* 220.0 / 2  
 = 308.651 cm^2

**Axial Load [P]:**

= Ap \* Bp  
 = 308.7 \* 0.16  
 = 49.189 kN

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

= Rib Area + Web Area  
 = 42.6 + 42.089  
 = 84.689 cm^2

**Compressive Stress [Sc]:**

= P/Ar  
 = 49.2/84.6888  
 = 5.809 N./mm^2

**Check of Outside Ribs:****Inertia of Saddle, Outer Ribs - Longitudinal Direction**

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

**Bending Moment [Rm]:**

= Fl / ( 2 \* Bplen ) \* e \* rl / 2  
 = 183.1 / ( 2 \* 1450.0 ) \* 280.592 \* 1025.0 / 2

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$$= 9081.711 \text{ N-m}$$

Compressive Allowable,  $KL/R < Cc$  ( 26.4469 < 138.1347 ) per AISC E2-1 [Sca]:

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

$$= (1 - (26.45)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (26.45) / (8 * 138.13) - (26.45^3) / (8 * 138.13^3))$$

$$= 116.863 \text{ N./mm}^2$$

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

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

$$= 5.81/116.86 + ( 9081.71 * 86.0/12721121 ) / 137.9$$

$$= 0.495$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	280.6	30.0	0.0	84.2	0.0	63.1
Values	...	...	...	126.8	...	0.133E+04

Compressive Allowable,  $KL/R < Cc$  ( 21.6551 < 138.1347 ) per AISC E2-1 [Sca]:

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

$$= (1 - (21.66)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (21.66) / (8 * 138.13) - (21.66^3) / (8 * 138.13^3))$$

$$= 118.441 \text{ N./mm}^2$$

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

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

$$= 7.37/118.44 + ( 12422.01 * 86.0/1328.494 ) / 137.9$$

$$= 0.645$$

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

Total Number of Bolts per BasePlate	Nbolts	4
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification		SA-193 B7
Bolt Allowable Stress	Stba	172.38 N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0 mm.
Distance from Bolts to Edge	Edgedis	75.0 mm.
Nominal Bolt Diameter	Bnd	30.0000 mm.
Thread Series	Series	TEMA Metric
BasePlate Allowable Stress	S	108.25 N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	5.0297 cm <sup>2</sup>
Saddle Load QO (Weight)	QO	159.1 kN
Saddle Load QL (Wind/Seismic contribution)	QL	75.1 kN
Maximum Transverse Force	Ft	91.5 kN
Maximum Longitudinal Force	F1	183.1 kN
Saddle Bolted to Steel Foundation		No

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

Bolt Area Requirement Due to Longitudinal Load [Bltarear]:

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

Bolt Area due to Shear Load [Bltarears]:

$$= F1 / (Stba * Nbolts)$$

$$= 183.07 / (172.38 * 4.0)$$

$$= 2.6554 \text{ cm}^2$$

**Bolt Area due to Transverse Load:**

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Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned}
 &= B * Ft + \text{Sum of X Moments} \\
 &= 1374.0 * 91.54 + 0.0 \\
 &= 125820.93 \text{ N-m}
 \end{aligned}$$

Eccentricity (e):

$$\begin{aligned}
 &= Rmom / QO \\
 &= 125820.93/159.08 \\
 &= 790.58 \text{ mm.} > Bplen/6 \text{ --> Uplift in Transverse direction}
 \end{aligned}$$

$$\begin{aligned}
 f &= Bplen / 2 - Edgedis \\
 &= 1450.0/2 - 75.0 \\
 &= 650.00 \text{ mm.}
 \end{aligned}$$

Modular Ratio Of Steel/Concrete (n1):

$$\begin{aligned}
 &= ES / EC \\
 &= 203402.5/21526.32 \\
 &= 9.45
 \end{aligned}$$

$$\begin{aligned}
 K1 &= 3 (e - 0.5 * Bplen) \\
 &= 3 (790.58 - 0.5*1450.0) \\
 &= 196.75 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n1 * At / Bpwid * (f + e) \\
 &= 6 * 9.45 * 10.06/220.0 * (650.0 + 790.58) \\
 &= 373440.44 \text{ mm.}^2
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * Bplen + f) \\
 &= -373440.44 * (0.5 * 1450.0 + 650.0) \\
 &= -513480572.95 \text{ mm.}^3
 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned}
 Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\
 Y^3 + 196.75 * Y^2 + 373440.44 * Y + -0.5E+09 &= 0 \\
 Y &= 601.53 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 \text{Num} &= (Bplen / 2 - Y / 3 - e) \\
 &= (1450.0/2 - 601.53/3 - 790.58) \\
 &= -266.09
 \end{aligned}$$

$$\begin{aligned}
 \text{Denom} &= (Bplen / 2 - Y / 3 + f) \\
 &= (1450.0/2 - 601.53/3 + 650.0) \\
 &= 1174.49
 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned}
 &= - QO * \text{Num} / \text{Denom} \\
 &= - 159.08 * -266.09/1174.49 \\
 &= 36.04 \text{ kN}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= Tforce / (Stba * Nbt) \\
 &= 36.04 / (172.38 * 2.0) \\
 &= 1.0456 \text{ cm}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\
 &= \max[0.0, 2.6554, 1.0456] \\
 &= 2.6554 \text{ cm}^2
 \end{aligned}$$

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

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**Bearing Pressure (fc)**

$$= 2(QO + Tforce) / (Y * Bpwid)$$

$$= 2(159.08 + 36.04) / (601.53 * 220.0)$$

$$= 29.49 \text{ bars}$$

**Distance from Baseplate Edge to the Web [ADIST]:**

$$= (Bplen - Weblngth) / 2$$

$$= (1450.0 - 1399.2) / 2$$

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

**Overturning Moment due To Bolt Tension [Mt]:**

$$= Tforce * Adist$$

$$= 36.04 * 25.4$$

$$= 915.85 \text{ N-m}$$

**Equivalent Bearing Pressure (f1):**

$$= fc * (Y - Adist) / Y$$

$$= 29.49 * (601.53 - 25.4) / 601.53$$

$$= 28.25 \text{ bars}$$

**Overturning Moment due to Bearing Pressure [Mc]:**

$$= (Adist^2 * Bpwid / 6) * (f1 + 2 * fc)$$

$$= (25.4^2 * 220.0 / 6) * (28.25 + 2 * 29.49)$$

$$= 206.42 \text{ N-m}$$

**Baseplate Required Thickness [Treq]:**

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

$$= (6 * \max(915.85, 206.42) / (220.0 * 162.38))^{1/2}$$

$$= 12.4006 \text{ mm.}$$

**ASME Horizontal Vessel Analysis: Stresses for the Right Saddle**

(per ASME Sec. VIII Div. 2 based on the Zick method.)

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

**Input and Calculated Values:**

Vessel Mean Radius	Rm	838.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	466.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	352.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Inside Depth of Head	h2	417.00	mm.
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		438.36	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	

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Long. Stress at Top of Midspan	66.21	137.90
Long. Stress at Bottom of Midspan	62.48	137.90
Long. Stress at Top of Saddles	93.18	137.90
Long. Stress at Bottom of Saddles	48.37	137.90
-----		
Tangential Shear in Shell	25.84	110.32
Circ. Stress at Horn of Saddle	144.84	172.37
Circ. Compressive Stress in Shell	6.40	137.90
-----		

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 12.8/2 + 0 ) * 1600.0/1452.3246$$

$$= 21.1 \text{ kN}$$

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

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

$$= \max( 4.96, 43.42, 0 ) * 1600.0/3350.0$$

$$= 20.7 \text{ kN}$$

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

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

$$= \max( 183.07, 43.42, 0 ) * 1600.0/3350.0$$

$$= 87.4 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * ( 183/2 + 0 ) * 1600.0/1452.3246$$

$$= 302.5 \text{ kN}$$

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

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

$$= 136 + \max( 21, 21, 87, 303 )$$

$$= 438.4 \text{ kN}$$

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

Vertical Load (including saddle weight)	447.27	kN
Transverse Shear Load Saddle	91.54	kN
Longitudinal Shear Load Saddle	183.07	kN

### Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0176	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0379
K7p = 0.0126			

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

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

Moment per Equation 4.15.3 [M1]:

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

$$= -438 * 466.0 [ 1 - ( 1 - 466.0 / 355.0 + ( 838.5^2 - 417.0^2 ) / ( 2 * 466.0 * 355.0 ) ) / ( 1 + ( 4 * 417.0 ) / ( 3 * 355.0 ) ) ]$$

$$= -101886.1 \text{ N-m}$$

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Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= Q \cdot L / 4 (1 + 2(R^2 - h^2) / (L^2)) / (1 + (4h^2) / (3L)) - 4a / L \\
 &= 438 \cdot 355 / 4 (1 + 2(838^2 - 417^2) / (355^2)) / (1 + (4 \cdot 417) / (3 \cdot 355)) - 4 \cdot 466 / 355 \\
 &= -61820.0 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_2 / (\pi \cdot R_m^2 t) \\
 &= 23.021 \cdot 838.5 / (2 \cdot 15.0) - (-61820.0) / (\pi \cdot 838.5^2 \cdot 15.0) \\
 &= 66.21 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 23.021 \cdot 838.5 / (2 \cdot 15.0) + (-61820.0) / (\pi \cdot 838.5^2 \cdot 15.0) \\
 &= 62.48 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_1 / (K_1 \cdot \pi \cdot R_m^2 t) \\
 &= 23.021 \cdot 838.5 / (2 \cdot 15.0) - (-101886.1) / (0.1066 \cdot \pi \cdot 838.5^2 \cdot 15.0) \\
 &= 93.18 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 23.021 \cdot 838.5 / (2 \cdot 15.0) + (-101886.1) / (0.1923 \cdot \pi \cdot 838.5^2 \cdot 15.0) \\
 &= 48.37 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4 \cdot h^2 / 3)) \\
 &= 438(355.0 - 2 \cdot 466.0) / (355.0 + (4 \cdot 417.0 / 3)) \\
 &= -277.6 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K_2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot (-277.64) / (838.4999 \cdot 15.0) \\
 &= -25.84 \text{ N./mm}^2
 \end{aligned}$$

Decay Length (4.15.22) [x1,x2]:

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{R_m \cdot t} \\
 &= 0.78 \cdot \sqrt{838.5 \cdot 15.0} \\
 &= 87.477 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= -K_5 \cdot Q \cdot k / (t \cdot (b + X_1 + X_2)) \\
 &= -0.7603 \cdot 438 \cdot 0.1 / (15.0 \cdot (172.0 + 87.48 + 87.48)) \\
 &= -6.40 \text{ N./mm}^2
 \end{aligned}$$

Effective reinforcing plate width (4.15.1) [B1]:

$$\begin{aligned}
 &= \min(b + 1.56 \cdot \sqrt{R_m \cdot t}, 2a) \\
 &= \min(172.0 + 1.56 \cdot \sqrt{838.5 \cdot 15.0}, 2 \cdot 466.0) \\
 &= 346.95 \text{ mm.}
 \end{aligned}$$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:

$$\begin{aligned}
 &= \min(S_r / S, 1) \\
 &= \min(137.9 / 137.9, 1) \\
 &= 1.0000
 \end{aligned}$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

$$\begin{aligned}
 &= -K_5 \cdot Q \cdot k / (B_1(t + \eta \cdot t_r)) \\
 &= -0.7603 \cdot 438 \cdot 0.1 / (346.953(15.0 + 1.0 \cdot 25.0)) \\
 &= -2.40 \text{ N./mm}^2
 \end{aligned}$$

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Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r\*]:

$$= -Q/(4(t+\eta*tr)b1) - 12*K7*Q*Rm/(L(t+\eta*tr)^2)$$

$$= -438/(4(15.0+ 1.0* 25.0)346.953) -$$

$$12*0.018*438*838.5/(355.0(15.0+1.0*25.0)^2)$$

$$= -144.84 \text{ N./mm}^2$$

### Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

### Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	526.	15.	8.	79.	59194.	59.2
Wearplate	352.	25.	27.	88.	242000.	711.
Web	30.	704.	392.	211.	8279038.	0.412E+06
BasePlate	220.	25.	756.	55.	4160749.	0.315E+06
Totals	...	...	...	433.	12740981.	0.727E+06

Value C1 = Sumof (Ay) /Sumof (A) = 294. mm.

Value I = Sumof (Io) - C1\*Sumof (Ay) = 0.353E+06 cm\*\*4

Value As = Sumof (A) - Ashell = 354. cm^2

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

$$Fh = K1 * Q = 0.2035 * 438.357 = 89.2151 \text{ kN}$$

Tension Stress, St = ( Fh/As ) = 2.5190 N./mm^2

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

### Saddle Splitting Dimension [d]:

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

$$= 1600.0 - 831.0 * \sin(1.0472) / 1.0472$$

$$= 912.768 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 81465.7500 \text{ N-m}$$

Bending Stress, Sb = ( M \* C1 / I ) = 6.7956 N./mm^2

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

### Minimum Thickness of Baseplate per Moss:

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

$$= ( 3(438 + 9)220.0 / ( 4 * 1450.0 * 137.9 ) )^{1/2}$$

$$= 19.212 \text{ mm.}$$

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

#### Distance between Ribs [e]:

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

$$= 1513.8124 / ( 5 - 1 )$$

$$= 378.453 \text{ mm.}$$

#### Baseplate Pressure Area [Ap]:

$$= e * Bpwid / 2$$

$$= 378.4531 * 220.0 / 2$$



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Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	5.0297	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	144.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	87.4	kN
Maximum Transverse Force	Ft	91.5	kN
Maximum Longitudinal Force	F1	183.1	kN
Saddle Bolted to Steel Foundation		No	

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

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

Bolt Area due to Shear Load [Bltarears]:  
 = F1 / (Stba \* Nbolts)  
 = 183.07 / (172.38 \* 4.0)  
 = 2.6554 cm<sup>2</sup>

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

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 1600.0 \* 91.54 + 0.0  
 = 146516.38 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 146516.38 / 144.74  
 = 1011.88 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis  
 = 1450.0 / 2 - 75.0  
 = 650.00 mm.

Modular Ratio Of Steel/Concrete (n1):  
 = ES / EC  
 = 203402.5 / 21526.32  
 = 9.45

K1 = 3 (e - 0.5 \* Bplen)  
 = 3 (1011.88 - 0.5 \* 1450.0)  
 = 860.64 mm.

K2 = 6 \* n1 \* At / Bpwid \* (f + e)  
 = 6 \* 9.45 \* 10.06 / 220.0 \* (650.0 + 1011.88)  
 = 430807.07 mm.<sup>2</sup>

K3 = -K2 \* (0.5 \* Bplen + f)  
 = -430807.06 \* (0.5 \* 1450.0 + 650.0)  
 = -592359683.58 mm.<sup>3</sup>

### **Iteratively Solving for the Effective Bearing Length:**

$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$   
 $Y^3 + 860.64 * Y^2 + 430807.06 * Y + -0.6E+09 = 0$   
 Y = 517.66 mm.

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$$\begin{aligned}
 \text{Num} &= (\text{Bplen} / 2 - Y / 3 - e) \\
 &= (1450.0/2 - 517.66/3 - 1011.88) \\
 &= -459.43
 \end{aligned}$$

$$\begin{aligned}
 \text{Denom} &= (\text{Bplen} / 2 - Y / 3 + f) \\
 &= (1450.0/2 - 517.66/3 + 650.0) \\
 &= 1202.45
 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned}
 &= - QO * \text{Num} / \text{Denom} \\
 &= - 144.74 * -459.43/1202.45 \\
 &= 55.30 \text{ kN}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= \text{Tforce} / (\text{Stba} * \text{Nbt}) \\
 &= 55.3 / (172.38 * 2.0) \\
 &= 1.6042 \text{ cm}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\
 &= \max[0.0, 2.6554, 1.6042] \\
 &= 2.6554 \text{ cm}^2
 \end{aligned}$$

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

Bearing Pressure (fc)

$$\begin{aligned}
 &= 2(QO + \text{Tforce}) / (Y * \text{Bpwid}) \\
 &= 2(144.74 + 55.3) / (517.66 * 220.0) \\
 &= 35.13 \text{ bars}
 \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned}
 &= (\text{Bplen} - \text{Weblength}) / 2 \\
 &= (1450.0 - 1399.2) / 2 \\
 &= 25.4000 \text{ mm.}
 \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned}
 &= \text{Tforce} * \text{Adist} \\
 &= 55.3 * 25.4 \\
 &= 1405.23 \text{ N-m}
 \end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned}
 &= \text{fc} * (Y - \text{Adist}) / Y \\
 &= 35.13 * (517.66 - 25.4) / 517.66 \\
 &= 33.41 \text{ bars}
 \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned}
 &= (\text{Adist}^2 * \text{Bpwid} / 6) * (\text{f1} + 2 * \text{fc}) \\
 &= (25.4^2 * 220.0 / 6) * (33.41 + 2 * 35.13) \\
 &= 245.33 \text{ N-m}
 \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned}
 &= (6 * \max(\text{Mt}, \text{Mc}) / (\text{Bpwid} * \text{Sba}))^{1/2} \\
 &= (6 * \max(1405.23, 245.33) / (220.0 * 162.38))^{1/2} \\
 &= 15.3605 \text{ mm.}
 \end{aligned}$$

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

Horizontal Vessel Stress Calculations : Test Case

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

**Input and Calculated Values:**

Vessel Mean Radius	Rm	611.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	352.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	350.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Shell Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		169.83	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	58.53	235.81	
Long. Stress at Bottom of Midspan	63.61	235.81	
Long. Stress at Top of Saddles	39.72	235.81	
Long. Stress at Bottom of Saddles	61.74	235.81	
-----			
Tangential Shear in Shell	18.80	188.65	
Circ. Stress at Horn of Saddle	41.28	353.71	
Circ. Compressive Stress in Shell	2.29	235.81	
-----			

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 2.6/2 + 0 ) * 1374.0/1059.149$$

$$= 5.0 \text{ kN}$$

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

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

$$= \max( 0.53, 0.0, 0 ) * 1374.0/3350.0$$

$$= 0.2 \text{ kN}$$

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

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

$$= 165 + \max( 0.2, 5, 0, 0 )$$

$$= 169.8 \text{ kN}$$

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

Vertical Load (including saddle weight)	176.76	kN
Transverse Shear Load Saddle	1.28	kN

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Longitudinal Shear Load Saddle 0.53 kN

Hydrostatic Test Pressure at center of Vessel: 29.960 bars

**Formulas and Substitutions for Horizontal Vessel Analysis:**

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

**The Computed K values from Table 4.15.1:**

K1 = 0.1066      K2 = 1.1707      K3 = 0.8799      K4 = 0.4011  
 K5 = 0.7603      K6 = 0.0529      K7 = 0.0192      K8 = 0.3405  
 K9 = 0.2711      K10 = 0.0581      K1\* = 0.1923      K6p = 0.0379  
 K7p = 0.0138

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

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

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

$$= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left( 1 + \frac{4h^2}{3L} \right) \right]$$

$$= -170 \cdot 352.0 \left[ 1 - \left( 1 - \frac{352.0}{355.0} + \frac{611.5^2 - 0.0^2}{2 \cdot 352.0 \cdot 355.0} \right) / \left( 1 + \frac{4 \cdot 0.0}{3 \cdot 355.0} \right) \right]$$

$$= 30180.5 \text{ N-m}$$

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

$$= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left( 1 + \frac{4h^2}{3L} \right) - 4a/L$$

$$= \frac{170 \cdot 355}{4} \left( 1 + 2 \frac{611^2 - 0^2}{355^2} \right) / \left( 1 + \frac{4 \cdot 0}{3 \cdot 355} \right) - 4 \cdot 352 / 355$$

$$= 44753.4 \text{ N-m}$$

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

$$= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 29.96 \cdot 611.5 / (2 \cdot 15.0) - 44753.4 / (\pi \cdot 611.5^2 \cdot 15.0)$$

$$= 58.53 \text{ N./mm}^2$$

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

$$= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 29.96 \cdot 611.5 / (2 \cdot 15.0) + 44753.4 / (\pi \cdot 611.5^2 \cdot 15.0)$$

$$= 63.61 \text{ N./mm}^2$$

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

$$= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t)$$

$$= 29.96 \cdot 611.5 / (2 \cdot 17.0) - 30180.5 / (0.1066 \cdot \pi \cdot 611.5^2 \cdot 17.0)$$

$$= 39.72 \text{ N./mm}^2$$

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

$$= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t)$$

$$= 29.96 \cdot 611.5 / (2 \cdot 17.0) + 30180.5 / (0.1923 \cdot \pi \cdot 611.5^2 \cdot 17.0)$$

$$= 61.74 \text{ N./mm}^2$$

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

$$= \frac{Q(L - 2a)}{L + (4 \cdot h^2 / 3)}$$

$$= \frac{170(355.0 - 2 \cdot 352.0)}{355.0 + (4 \cdot 0.0 / 3)}$$

$$= -167.0 \text{ kN}$$

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

$$= \frac{K2 \cdot T}{R_m \cdot t}$$

$$= \frac{1.1707 \cdot -166.96}{611.5 \cdot 17.0}$$

$$= -18.80 \text{ N./mm}^2$$

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

$$= 0.78 \cdot \sqrt{R_m \cdot t}$$

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$$= 0.78 * \text{sqrt}( 611.5 * 17.0 )$$

$$= 79.527 \text{ mm.}$$

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

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

$$= - 0.7603 * 170 * 0.1 / ( 17.0 * ( 172.0 + 79.53 + 79.53 ) )$$

$$= -2.29 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \text{min}( 172.0 + 1.56 * \text{sqrt}( 611.5 * 17.0 ), 2 * 352.0 )$$

$$= 331.05 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [ $\eta$ ]:

$$= 1.0000 \text{ Materials are the same, test case}$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [ $\sigma_6, r$ ]:

$$= -K5 * Q * k / ( B1( t + \eta * tr ) )$$

$$= - 0.7603 * 170 * 0.1 / ( 331.055( 17.0 + 1.0 * 25.0 ) )$$

$$= -0.93 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [ $\sigma_7, r^*$ ]:

$$= -Q / ( 4( t + \eta * tr ) b1 ) - 12 * K7 * Q * Rm / ( L( t + \eta * tr )^2 )$$

$$= -170 / ( 4( 17.0 + 1.0 * 25.0 ) 331.055 ) -$$

$$12 * 0.019 * 170 * 611.5 / ( 355.0( 17.0 + 1.0 * 25.0 )^2 )$$

$$= -41.28 \text{ N./mm}^2$$

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

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	508.	17.	8.	86.	73398.	83.2
Wearplate	350.	25.	29.	88.	258125.	807.
Web	30.	704.	394.	211.	8321278.	0.415E+06
BasePlate	220.	25.	758.	55.	4171750.	0.316E+06
Totals	...	...	...	440.	12824552.	0.732E+06

$$\text{Value } C1 = \text{Sumof}(Ay) / \text{Sumof}(A) = 291. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay) = 0.359E+06 \text{ cm}^4$$

$$\text{Value } As = \text{Sumof}(A) - A_{\text{shell}} = 354. \text{ cm}^2$$

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

$$Fh = K1 * Q = 0.2035 * 169.828 = 34.5637 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 0.9773 \text{ N./mm}^2$$

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

Saddle Splitting Dimension [d]:

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

$$= 1374.0 - 603.0 * \sin( 1.0472 ) / 1.0472$$

$$= 875.323 \text{ mm.}$$

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$$\text{Bending Moment, } M = F_h * d = 30266.6797 \text{ N-m}$$

$$\text{Bending Stress, } S_b = ( M * C_1 / I ) = 2.4584 \text{ N./mm}^2$$

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

#### Minimum Thickness of Baseplate per Moss:

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

$$= ( 3(170 + 7)220.0 / ( 4 * 1450.0 * 137.9 ) )^{1/2}$$

$$= 12.078 \text{ mm.}$$

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

##### Distance between Ribs [e]:

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

$$= 1122.3689 / ( 5 - 1 )$$

$$= 280.592 \text{ mm.}$$

##### Baseplate Pressure Area [Ap]:

$$= e * B_{\text{pwid}} / 2$$

$$= 280.5922 * 220.0 / 2$$

$$= 308.651 \text{ cm}^2$$

##### Axial Load [P]:

$$= A_p * B_p$$

$$= 308.7 * 0.05$$

$$= 16.432 \text{ kN}$$

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

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

$$= 42.6 + 42.089$$

$$= 84.689 \text{ cm}^2$$

##### Compressive Stress [Sc]:

$$= P / A_r$$

$$= 16.4 / 84.6888$$

$$= 1.940 \text{ N./mm}^2$$

#### Check of Outside Ribs:

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

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

##### Bending Moment [Rm]:

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

$$= 0.5 / ( 2 * 1450.0 ) * 280.592 * 1025.0 / 2$$

$$= 26.410 \text{ N-m}$$

##### Compressive Allowable, $KL/R < C_c$ ( 26.4469 < 138.1347 ) per AISC E2-1 [Sca]:

$$= ( 1 - ( K L r )^2 / ( 2 * C_c^2 ) ) * F_y / ( 5/3 + 3 * ( K L r ) / ( 8 * C_c ) - ( K L r^3 ) / ( 8 * C_c^3 ) )$$

$$= ( 1 - ( 26.45 )^2 / ( 2 * 138.13^2 ) ) * 207 /$$

$$( 5/3 + 3 * ( 26.45 ) / ( 8 * 138.13 ) - ( 26.45^3 ) / ( 8 * 138.13^3 ) )$$

$$= 116.863 \text{ N./mm}^2$$

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

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

$$= 1.94 / 116.86 + ( 26.41 * 86.0 / 12721121 ) / 137.9$$

$$= 0.018$$

#### Check of Inside Ribs:

##### Inertia of Saddle, Inner Ribs - Axial Direction

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	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	280.6	30.0	0.0	84.2	0.0	63.1
Values	...	...	...	126.8	...	0.133E+04

Compressive Allowable,  $KL/R < Cc$  ( 21.6551 < 138.1347 ) per AISC E2-1 [Sca]:

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

$$= (1 - (21.66)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (21.66) / (8 * 138.13) - (21.66^3) / (8 * 138.13^3))$$

$$= 118.441 \text{ N./mm}^2$$

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

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

$$= 2.46/118.44 + ( 36.12 * 86.0/1328.494 ) / 137.9$$

$$= 0.022$$

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

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	5.0297	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	171.8	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.3	kN
Maximum Longitudinal Force	F1	1.0	kN
Saddle Bolted to Steel Foundation		No	

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

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

$$= F1 / (Stba * Nbolts)$$

$$= 0.99 / (172.38 * 4.0)$$

$$= 0.0144 \text{ cm}^2$$

#### Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

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

$$= 1374.0 * 1.28 + 0.0$$

$$= 1753.25 \text{ N-m}$$

Eccentricity (e):

$$= Rmom / QO$$

$$= 1753.25 / 171.8$$

$$= 10.20 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

$$= \max[Bltarearl, Bltarears, Bltareart]$$

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$$= \max[0.0, 0.0144, 0.0]$$

$$= 0.0144 \text{ cm}^2$$

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

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

**Input and Calculated Values:**

Vessel Mean Radius	Rm	838.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	466.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	352.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Inside Depth of Head	h2	417.00	mm.
Shell Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		179.34	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	84.57	235.81	
Long. Stress at Bottom of Midspan	83.04	235.81	
Long. Stress at Top of Saddles	95.60	235.81	
Long. Stress at Bottom of Saddles	77.27	235.81	
-----			
Tangential Shear in Shell	10.57	188.65	
Circ. Stress at Horn of Saddle	59.26	353.71	
Circ. Compressive Stress in Shell	2.62	235.81	
-----			

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

**Saddle Reaction Force due to Wind Ft [Fwt]:**

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

$$= 3.0 * ( 2.6/2 + 0 ) * 1600.0/1452.3246$$

$$= 4.2 \text{ kN}$$

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

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

$$= \max( 0.99, 0.0, 0 ) * 1600.0/3350.0$$

$$= 0.5 \text{ kN}$$

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

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

$$= 175 + \max( 0.5, 4, 0, 0 )$$

$$= 179.3 \text{ kN}$$

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

Vertical Load (including saddle weight)	188.25	kN
Transverse Shear Load Saddle	1.28	kN
Longitudinal Shear Load Saddle	0.99	kN

Hydrostatic Test Pressure at center of Vessel: 29.982 bars

**Formulas and Substitutions for Horizontal Vessel Analysis:**

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

**The Computed K values from Table 4.15.1:**

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0176	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0379
K7p = 0.0126			

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

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

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

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left( 1 + \frac{4h^2}{3L} \right) \right] \\
 &= -179 \cdot 466.0 \left[ 1 - \left( 1 - \frac{466.0}{355.0} + \frac{838.5^2 - 417.0^2}{2 \cdot 466.0 \cdot 355.0} \right) / \left( 1 + \frac{4 \cdot 417.0^2}{3 \cdot 355.0} \right) \right] \\
 &= -41683.5 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left( 1 + \frac{4h^2}{3L} \right) - 4a/L \\
 &= \frac{179 \cdot 355}{4} \left( 1 + 2 \frac{838^2 - 417^2}{355^2} \right) / \left( 1 + \frac{4 \cdot 417}{3 \cdot 355} \right) - 4 \cdot 466 / 355 \\
 &= -25291.7 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.982 \cdot 838.5 / (2 \cdot 15.0) - -25291.7 / (\pi \cdot 838.5^2 \cdot 15.0) \\
 &= 84.57 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.982 \cdot 838.5 / (2 \cdot 15.0) + -25291.7 / (\pi \cdot 838.5^2 \cdot 15.0) \\
 &= 83.04 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.982 \cdot 838.5 / (2 \cdot 15.0) - -41683.5 / (0.1066 \cdot \pi \cdot 838.5^2 \cdot 15.0) \\
 &= 95.60 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.982 \cdot 838.5 / (2 \cdot 15.0) + -41683.5 / (0.1923 \cdot \pi \cdot 838.5^2 \cdot 15.0) \\
 &= 77.27 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{L + (4 \cdot h^2 / 3)} \\
 &= \frac{179(355.0 - 2 \cdot 466.0)}{355.0 + (4 \cdot 417.0 / 3)} \\
 &= -113.6 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{K2 \cdot T}{R_m \cdot t} \\
 &= \frac{1.1707 \cdot -113.59}{838.4999 \cdot 15.0} \\
 &= -10.57 \text{ N./mm}^2
 \end{aligned}$$

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Decay Length (4.15.22) [x1,x2]:

$$= 0.78 * \sqrt{Rm * t}$$

$$= 0.78 * \sqrt{838.5 * 15.0}$$

$$= 87.477 \text{ mm.}$$

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

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

$$= - 0.7603 * 179 * 0.1 / ( 15.0 * ( 172.0 + 87.48 + 87.48 ) )$$

$$= -2.62 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min( 172.0 + 1.56 * \sqrt{838.5 * 15.0} , 2 * 466.0 )$$

$$= 346.95 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:

$$= 1.0000 \text{ Materials are the same, test case}$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

$$= -K5 * Q * k / ( B1( t + eta * tr ) )$$

$$= - 0.7603 * 179 * 0.1 / ( 346.953( 15.0 + 1.0 * 25.0 ) )$$

$$= -0.98 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r\*]:

$$= -Q / ( 4( t + eta * tr ) b1 ) - 12 * K7 * Q * Rm / ( L( t + eta * tr )^2 )$$

$$= -179 / ( 4( 15.0 + 1.0 * 25.0 ) 346.953 ) -$$

$$12 * 0.018 * 179 * 838.5 / ( 355.0( 15.0 + 1.0 * 25.0 )^2 )$$

$$= -59.26 \text{ N./mm}^2$$

### Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	526.	15.	8.	79.	59194.	59.2
Wearplate	352.	25.	27.	88.	242000.	711.
Web	30.	704.	392.	211.	8279038.	0.412E+06
BasePlate	220.	25.	756.	55.	4160749.	0.315E+06
Totals	...	...	...	433.	12740981.	0.727E+06

$$\text{Value } C1 = \text{Sumof}(Ay) / \text{Sumof}(A) = 294. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay) = 0.353E+06 \text{ cm}^{*4}$$

$$\text{Value } As = \text{Sumof}(A) - \text{Ashell} = 354. \text{ cm}^2$$

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

$$Fh = K1 * Q = 0.2035 * 179.34 = 36.4996 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 1.0306 \text{ N./mm}^2$$

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

Saddle Splitting Dimension [d]:

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$$\begin{aligned}
 &= B - R * \sin(\theta) / \theta \\
 &= 1600.0 - 831.0 * \sin(1.0472) / 1.0472 \\
 &= 912.768 \text{ mm.}
 \end{aligned}$$

$$\text{Bending Moment, } M = F_h * d = 33329.1797 \text{ N-m}$$

$$\begin{aligned}
 \text{Bending Stress, } S_b &= (M * C_1 / I) = 2.7802 \text{ N./mm}^2 \\
 \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2
 \end{aligned}$$

#### Minimum Thickness of Baseplate per Moss:

$$\begin{aligned}
 &= (3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2} \\
 &= (3(179 + 9)220.0 / (4 * 1450.0 * 137.9))^{1/2} \\
 &= 12.464 \text{ mm.}
 \end{aligned}$$

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

##### Distance between Ribs [e]:

$$\begin{aligned}
 &= \text{Web Length} / (\text{Nr ribs} - 1) \\
 &= 1513.8124 / (5 - 1) \\
 &= 378.453 \text{ mm.}
 \end{aligned}$$

##### Baseplate Pressure Area [Ap]:

$$\begin{aligned}
 &= e * B_{pwid} / 2 \\
 &= 378.4531 * 220.0 / 2 \\
 &= 416.298 \text{ cm}^2
 \end{aligned}$$

##### Axial Load [P]:

$$\begin{aligned}
 &= A_p * B_p \\
 &= 416.3 * 0.06 \\
 &= 23.404 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \text{Rib Area} + \text{Web Area} \\
 &= 42.6 + 56.768 \\
 &= 99.368 \text{ cm}^2
 \end{aligned}$$

##### Compressive Stress [Sc]:

$$\begin{aligned}
 &= P / A_r \\
 &= 23.4 / 99.368 \\
 &= 2.355 \text{ N./mm}^2
 \end{aligned}$$

#### Check of Outside Ribs:

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

	B	D	Y	A	AY	I <sub>o</sub>
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

##### Bending Moment [Rm]:

$$\begin{aligned}
 &= F_l / (2 * B_{plen}) * e * r_l / 2 \\
 &= 1.0 / (2 * 1450.0) * 378.453 * 1139.44 / 2 \\
 &= 73.728 \text{ N-m}
 \end{aligned}$$

##### Compressive Allowable, KL/R < Cc ( 31.8458 < 138.1347 ) per AISC E2-1 [Sca]:

$$\begin{aligned}
 &= (1 - (Kl/r)^2 / (2 * Cc^2)) * F_y / (5/3 + 3 * (Kl/r) / (8 * Cc) - (Kl/r)^3 / (8 * Cc^3)) \\
 &= (1 - (31.85)^2 / (2 * 138.13^2)) * 207 / \\
 &\quad (5/3 + 3 * (31.85) / (8 * 138.13) - (31.85^3) / (8 * 138.13^3)) \\
 &= 114.955 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= S_c / S_{ca} + (R_m * \text{Distance Side} / I) / S_{ba} \\
 &= 2.36 / 114.95 + (73.73 * 86.0 / 12721121) / 137.9 \\
 &= 0.024
 \end{aligned}$$

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Check of Inside Ribs:

**Inertia of Saddle, Inner Ribs - Axial Direction**

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	378.5	30.0	0.0	113.5	0.0	85.2
Values	...	...	...	156.1	...	0.135E+04

Compressive Allowable,  $KL/R < Cc$  ( 23.8353 < 138.1347 ) per AISC E2-1 [Sca]:  
 $= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3))$   
 $= (1 - (23.84)^2 / (2 * 138.13^2)) * 207 /$   
 $(5/3 + 3 * (23.84) / (8 * 138.13) - (23.84^3) / (8 * 138.13^3))$   
 $= 117.737 \text{ N./mm}^2$

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

$= Sc/Sca + ( Rm * \text{Distance Center}/I ) / Sba$   
 $= 2.87/117.74 + ( 90.72 * 86.0/1350.513 ) / 137.9$   
 $= 0.029$

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

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	5.0297	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	184.0	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.5	kN
Maximum Transverse Force	Ft	1.3	kN
Maximum Longitudinal Force	F1	1.0	kN
Saddle Bolted to Steel Foundation		No	

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

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:

$= F1 / (Stba * Nbolts)$   
 $= 0.99 / (172.38 * 4.0)$   
 $= 0.0144 \text{ cm}^2$

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

$= B * Ft + \text{Sum of X Moments}$   
 $= 1600.0 * 1.28 + 0.0$   
 $= 2041.63 \text{ N-m}$

Eccentricity (e):

$= Rmom / QO$   
 $= 2041.63 / 184.03$   
 $= 11.09 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction}$

Bolt Area due to Transverse Load [Bltareart]:

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= 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:  
= max[Bltarearl, Bltarears, Bltareart]  
= max[0.0, 0.0144, 0.0]  
= 0.0144 cm<sup>2</sup>

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Conical Section: CON Cone: 4 1:34am Feb 7,2022

### Conical Reinforcement Calculations, ASME VIII Div. 1, App. 1

#### Conical Section From 60 To 70 SA-516 70

CON

Elastic Modulus Data from ASME Section II Part D at 125 °C

Elastic Modulus of Cone Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large End Reinforcement	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small End Reinforcement	0.197E+09 KPa. at 124 °C

Elastic Modulus Data from ASME Section II Part D at 125 °C

Elastic Modulus of Cone Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large End Reinforcement	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small End Reinforcement	0.197E+09 KPa. at 124 °C

Axial Force on Small End of Cone	0.00 kN
Axial Force on Large End of Cone	0.00 kN
Moment on Small End of Cone	0.00 N-m
Moment on Large End of Cone	0.00 N-m

Note: Axial forces and moments are not computed for Horizontal geometries.

Please compute them manually and input them as Miscellaneous Load on the ends of the cone.

Note: Neither end of Cone is a Line of Support

Maximum Centroid Reinforcement Distance Large End	28.1625 mm.
Maximum Centroid Reinforcement Distance Small End	25.6661 mm.

Note: No ring was found close enough to the large end to be considered.

Note: No ring was found close enough to the small end to be considered.

#### **Reinforcement Calculations for Cone / Large Cylinder:**

##### **Required Area of Reinforcement for Large End Under Internal Pressure**

Large end ratio of pressure to allowable stress	0.01673
Large end max. half apex angle w/o reinforcement	30.000 degrees
Large end actual half apex angle	28.784 degrees

##### **Required Area of Reinforcement for Large End Under External Pressure**

Large end ratio of pressure to allowable stress	0.00075
Large end max. half apex angle w/o reinforcement	1.875 degrees
Large end actual half apex angle	28.784 degrees

Intermediate Value [k]:

= max( Y / ( Srl \* Erl ), 1 )  
= max( 0.27111E+11/( 137.9 \* 0.19660E+09 ), 1 )  
= 1.0000

where [Y] is:

= Large End All. Stress \* Large End Elastic Modulus (Ext. temp.)  
= 137.9 \* 0.19660E+09  
= 27111170048.0 N./mm<sup>2</sup>

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Allowable Stress of Large End Material (Ext. Temp) 137.9 N./mm<sup>2</sup>  
 Allowable Stress of Cone Material (Ext. Temp) 137.9 N./mm<sup>2</sup>

**Required Area of Reinforcement, Large End, External [Arl]:**

$$= (k \cdot QL \cdot R1 \cdot \tan(\text{angle}) / (Ss \cdot E1)) \cdot (1 - 1/4 \cdot ((P \cdot R1 - QL) / QL) \cdot (\text{delta} / \alpha))$$

$$= (1.0 \cdot 0.0437 \cdot 846.0 \cdot 0.549 / (138 \cdot 1.0)) \cdot$$

$$(1 - 1/4 \cdot ((1.03 \cdot 846.0 - 0.044) / 0.044) \cdot (1.875 / 28.784))$$

$$= 1.451 \text{ cm}^2$$

**Force per Length, Cone Large End External Pressure [QL]:**

$$= P_{\text{ext}}(R1/2) + F_{\text{axial}} / (\pi(D1 - T1)) + \text{Moment} / (\pi(R1 - T1/2)(R1 - T1/2))$$

$$= 1.034(846.0/2) + 0.0 / (\pi(1692.0 - 18.0)) +$$

$$0.0 / (\pi(846.0 - 18.0/2)(846.0 - 18.0/2))$$

$$= 0.044 \text{ kN/mm.}$$

**Available Area of Reinforcement, Large End, External [Ael]:**

$$= 0.55 \cdot (D1 \cdot ts) \cdot \frac{1}{2} \cdot (ts + tc / \cos(\alpha))$$

$$= 0.55 \cdot (1692.0 \cdot 15.0) \cdot \frac{1}{2} \cdot (15.0 + 17.0 / 0.876)$$

$$= 30.1387 \text{ cm}^2$$

**Summary of Reinforcement Area, Large End, External Pressure:**

Area of reinforcement required per App. 1-8(1)	1.4505	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-8(2)	30.1387	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

**Reinforcement Calculations for Cone / Small Cylinder:**

**Required Area of Reinforcement for Small End under Internal Pressure**

Small end ratio of pressure to allowable stress	0.01673	
Small end max. half apex angle w/o reinforcement	11.355	degrees
Small end actual half apex angle	28.784	degrees

**Intermediate Value [k]:**

$$= \max(Y / (Sr \cdot Ers), 1)$$

$$= \max(0.27111E+11 / (137.9 \cdot 0.19660E+09), 1)$$

$$= 1.0000$$

where [Y] is:

$$= \text{Small End All. Stress} \cdot \text{Small End Elastic Modulus (Int. temp.)}$$

$$= 137.9 \cdot 0.19660E+09$$

$$= 27111170048.0 \text{ N./mm}^2$$

**Decay Length, Cone Small End:**

$$= 1.4 \cdot \sqrt{Rs(ts - ca)}$$

$$= 1.4 \cdot \sqrt{603.0(20.0 - 3.0)}$$

$$= 141.746 \text{ mm.}$$

**Required Area of Reinforcement, Small End, Internal [Ars]:**

$$= k \cdot QS \cdot Rs / (Ss \cdot E1) \cdot (1 - \text{delta} / \alpha) \cdot \tan(\alpha)$$

$$= 1.0 \cdot 0.6955 \cdot 603.0 / (138 \cdot 1.0) \cdot$$

$$(1 - 11.36 / 28.78) \cdot 0.5494$$

$$= 10.12 \text{ cm}^2$$

**Force per Length, Cone Small End [QS]:**

$$= P(Rs/2) - F_{\text{axial}} / (\pi(Ds + Ts)) + \text{Moment} / (\pi(Rs + Ts/2)(Rs + Ts/2))$$

$$= 23.069(603.0/2) - 0.0 / (\pi(1206.0 + 20.0)) +$$

$$0.0 / (\pi(603.0 + 20.0/2)(603.0 + 20.0/2))$$

$$= 0.695 \text{ kN/mm.}$$

**Area of Reinforcement Available in Small End Shell [Aes]:**

$$= 0.78(Rs \cdot Ts) \cdot \frac{1}{2} \cdot ((Ts - t) + (Tc - Tr) / \cos(\alpha))$$

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$$= 0.78 * (603.0 * 17.0) \frac{1}{2} * ((17.0 - 10.19) + (17.0 - 11.627) / 0.88)$$

$$= 10.2196 \text{ cm}^2$$

**Summary of Reinforcement Area, Small End, Internal Pressure:**

Area of reinforcement required per App. 1-5(3)	10.1179	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-5(4)	10.2196	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

**Required Area of Reinforcement for Small End Under External Pressure**

Allowable Stress of Small End Material (Ext. Temp)	137.9	N./mm <sup>2</sup>
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm <sup>2</sup>

Intermediate Value [k]:

$$= \max(Y / (Srs * Ers), 1)$$

$$= \max(0.27111E+11 / (137.9 * 0.19660E+09), 1)$$

$$= 1.0000$$

where [Y] is:

$$= \text{Small End All. Stress} * \text{Small End Elastic Modulus (Ext. temp.)}$$

$$= 137.9 * 0.19660E+09$$

$$= 27111170048.0 \text{ N./mm}^2$$

**Area of Reinforcement Required in Small End Shell [Ars]:**

$$= k * QS * Rs * \tan(\alpha) / (Ss * E1)$$

$$= (1.0 * 0.0321 * 620.0 * 0.5494) / (138 * 1.0)$$

$$= 0.792 \text{ cm}^2$$

**Force per Length, Cone Small End [QS]:**

$$= Pext(Rs/2) + Faxial / (\pi(Ds - Ts)) + Moment / (\pi(Rs - Ts/2)(Rs - Ts/2))$$

$$= 1.034(620.0/2) + 0.0 / (\pi(1240.0 - 20.0)) +$$

$$0.0 / (\pi(620.0 - 20.0/2)(620.0 - 20.0/2))$$

$$= 0.032 \text{ kN/mm.}$$

**Area of Reinforcement Available in Small End Shell [Aes]:**

$$= 0.55 * (Ds * ts) \frac{1}{2} * [(ts - t) + (tc - tr) / \cos(\alpha)]$$

$$= 0.55 * (1240.0 * 17.0) \frac{1}{2} * [(17.0 - 7.232) + (17.0 - 3.633) / 0.876]$$

$$= 19.9791 \text{ cm}^2$$

**Summary of Reinforcement Area, Small End, External Pressure:**

Area of reinforcement required per App. 1-8(3)	0.7920	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-8(4)	19.9791	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

Note: The following calculations are only required per 1-5(g)(1) and do include external loads due to wind or seismic. These discontinuity stresses are computed at the shell/cone junction and do not include effects of local stiffening from a junction ring.

**Results for Discontinuity Stresses per Bednar p. 236 2nd Edition**

Stress Type	Stress	Allowable	Location
Tensile Stress	195.82	413.70	Small Cyl. Long.
Compres. Stress	-112.83	-413.70	Small Cyl. Long.
Membrane Stress	167.93	-206.85	Small End Tang.
Tensile Stress	201.66	413.70	Cone Longitudinal
Compres. Stress	-106.98	-413.70	Cone Longitudinal
Compres. Stress	179.63	-206.85	Cone Tangential
Tensile Stress	370.71	413.70	Large Cyl. Long.
Compres. Stress	-241.75	-413.70	Large Cyl. Long.
Membrane Stress	-20.90	-206.85	Large End Tang.

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Tensile Stress	303.33	413.70	Cone Longitudinal
Compres. Stress	-173.50	-413.70	Cone Longitudinal
Compres Stress	-20.03	-206.85	Cone Tangential

Note: An asterisk (\*) denotes that this stress was not applicable  
for this combination of loads.

**Maximum Allowable Working Pressure for Cone to Shell Junction:**  
= 23.2 bars, determined by iteration

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**Nozzle Calculation Summary:**

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T2	24.91	OK	...	OK	11.33	OK	Passed
T1	24.82	OK	...	OK	11.33	OK	Passed
D2	24.38	OK	...	OK	7.80	OK	Passed
S2	24.56	OK	...	OK	10.16	OK	Passed
S1	24.56	OK	...	OK	10.16	OK	Passed
S3	24.56	OK	...	OK	10.16	OK	Passed
D1	24.56	OK	...	OK	7.80	OK	Passed
D3	24.56	OK	...	OK	7.80	OK	Passed
TT	24.56	OK	...	OK	7.80	OK	Passed
V	24.56	OK	...	OK	7.80	OK	Passed
S4	24.56	OK	...	OK	10.16	OK	Passed
LG1	24.56	OK	...	OK	7.80	OK	Passed
LG2	24.56	OK	...	OK	7.80	OK	Passed
LT1	24.56	OK	...	OK	6.42	OK	Passed
LT3	24.56	OK	...	OK	6.42	OK	Passed
LT2	24.56	OK	...	OK	6.42	OK	Passed
LT4	24.56	OK	...	OK	6.42	OK	Passed

**MAWP Summary:**

Minimum MAWP Nozzles : 24.379 Nozzle : D2

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T2	450.000	90.000	948.000
20	T1	450.000	270.000	948.000
60	D2	2085.525	270.000	118.000
70	S2	3035.526	270.000	405.700
70	S1	5585.525	270.000	405.700
70	S3	3235.525	90.000	405.700
70	D1	4735.525	270.000	114.000
70	D3	6135.525	270.000	114.000
70	TT	6385.525	270.000	114.000
70	V	2685.526	90.000	114.000
70	S4	5585.525	90.000	405.700
70	LG1	4335.525	270.000	114.000
70	LG2	4335.525	90.000	114.000
70	LT1	3735.525	90.000	115.034
70	LT3	4035.525	90.000	115.034
70	LT2	3735.525	270.000	115.034
70	LT4	4035.525	270.000	115.034

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

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

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

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Nozzle Calcs.: T2

Nozl: 18 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: T2****From : 20**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1200.00	mm.
Design Length of Section	L	1140.0000	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		450.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

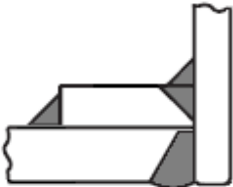
**Type of Element Connected to the Shell : Nozzle**

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	20.0000	mm.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	18.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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	748.0000	mm.
Thickness of Pad	te	20.0000	mm.
Weld leg size between Pad and Shell	Wp	12.0000	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.

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 FileName : Calculation Book for Evaporator E-PK1601  
 Nozzle Calcs.: T2 Nozl: 18 1:34am Feb 7,2022

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



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

**Reinforcement CALCULATION, Description: T2**

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	0.787 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 603.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 10.1595 \text{ mm.}$$

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

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

$$= (23.0 \cdot 254.0) / (138 \cdot 1.0 + 0.4 \cdot 23.0)$$

$$= 4.2086 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	948.0001	mm.
Parallel to Vessel Wall, opening length	d	474.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	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 [fr4]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(1.0, 1.0)$$

$$= 1.000$$

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Nozzle Calcs.: T2

Noz1: 18 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	48.156	9.043	NA
Area in Shell	A1	8.724	38.794	NA
Area in Nozzle Wall	A2	7.675	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.439	88.446	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:	692.7844	20.0000 mm.
Based on given Pad Diameter:	748.0001	15.3987 mm.
Based on Shell or Nozzle Thickness:	754.3792	15.0000 mm.

Area Required [A]:

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

$$= (474.0 * 10.1595 * 1.0 + 2 * 17.0 * 10.1595 * 1.0 * (1 - 1.0))$$

$$= 48.156 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 474.0( 1.0 * 12.0 - 1.0 * 10.16 ) - 2 * 17.0$$

$$( 1.0 * 12.0 - 1.0 * 10.1595 ) * ( 1 - 1.0 )$$

$$= 8.724 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) * ( 17.0 - 4.21 ) * 1.0$$

$$= 7.675 \text{ cm}^2$$

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

$$= (Wo^2 - Ar \text{ Lost}) * Fr3 + ((Wi - can / 0.707)^2 - Ar \text{ Lost}) * fr2 + Wp^2 * fr4$$

$$= (2.6)^2 * 1.0 + (0.0)^2 * 1.0 + 304.8^2 * 1.0$$

$$= 4.040 \text{ cm}^2$$

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

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

$$= ( 748.0 - 508.0 ) 20.0 * 1.0 * 0.75$$

$$= 36.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 7.2086 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 13.1595 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 13.1595 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4525 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 11.3312 mm.

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 11.331, max( 13.1595, 4.5 ) ]  
 = 11.3312 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 7.2086, 11.3312 )  
 = 11.3312 mm.

Available Nozzle Neck Thickness = 20.0000 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	:	32.6,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	312.2 N./mm <sup>2</sup>	Passed
Occasional	:	15.5,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	11.0,	Allowable	:	96.5 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, Curve: D**

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °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 = 15.0, tr = 10.16, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.847$ , Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.16, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.847$ , Temp. Reduction = 9 °C

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

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

Governing MDMT of the Nozzle : -48 °C

Governing MDMT of the Reinforcement Pad : -48 °C

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

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C

Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C

Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:

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

#### Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds Tmin 17.0000 mm.

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

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	11.9000 = 0.7 * tmin	12.7260 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	8.4840 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (48.1563 - 8.7237 + 2 * 17.0 * 1.0 * \\
 &\quad (1.0 * 12.0 - 10.1595) ) 138) \\
 &= 552.36 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 7.6749 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138 \\
 &= 657.93 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 7.6749 + 0.0 + 3.24 + ( 4.08 ) ) * 138 \\
 &= 206.76 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 7.6749 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138 \\
 &= 714.19 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 508.0 * 18.0 * 0.49 * 138 \\
 &= 970. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

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$$= ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138$$

$$= 953. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 245.5 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 1266. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= ( \text{pi}/2 ) * \text{Dlo} * \text{Wgnp} * 0.74 * \text{Seg}$$

$$= ( 3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138$$

$$= 1221. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 977. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 953 + 1266 ) = 2218 \text{ kN}$$

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

$$= ( 970 + 1221 + 977 + 0 ) = 3169 \text{ kN}$$

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

$$= ( 953 + 977 + 0 ) = 1930 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 2218 kN , must exceed W = 552 kN or W1 = 657 kN  
 Path 2-2 = 3168 kN , must exceed W = 552 kN or W2 = 206 kN  
 Path 3-3 = 1929 kN , must exceed W = 552 kN or W3 = 714 kN

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

Converged Max. Allow. Pressure in Operating case 24.907 bars  
 Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 56.4156 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

**Percent Elongation Calculations:**

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 4.098 %

**Input Echo, WRC107/537 Item 1, Description: T2 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1200.000	mm.
Vessel Thickness	Tv	15.000	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	508.000	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-516	70

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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>
Thickness of Reinforcing Pad	Tpad	20.000	mm.
Diameter of Reinforcing Pad	Dpad	748.000	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

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

Radial Load (SUS)	P	20.0	kN
Longitudinal Shear (SUS)	Vl	20.0	kN
Circumferential Shear (SUS)	Vc	20.0	kN
Circumferential Moment (SUS)	Mc	28000.0	N-m
Longitudinal Moment (SUS)	Ml	42500.1	N-m
Torsional Moment (SUS)	Mt	52500.1	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 508.0 + 2 * 1.65 * \text{sqrt}(609.0 (15.0 - 3.0))$$

$$= 790.107 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	20.0	kN
Circumferential Shear	VC	20.0	kN
Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.359	4C	2.373	(A,B)
N(PHI) / ( P/Rm )	0.359	3C	1.389	(C,D)
M(PHI) / ( P )	0.359	2C1	0.023	(A,B)
M(PHI) / ( P )	0.359	1C !	0.057	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.359	3A	0.798	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.359	1A	0.075	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.359	3B	1.693	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.359	1B	0.019	(A,B,C,D)
N(x) / ( P/Rm )	0.359	3C	1.389	(A,B)
N(x) / ( P/Rm )	0.359	4C	2.373	(C,D)
M(x) / ( P )	0.359	1C1	0.045	(A,B)

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M(x)	/ ( P )	0.359	2C !	0.030	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.359	4A	1.812	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.359	2A	0.034	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.359	4B	0.768	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.359	2B	0.032	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
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	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear		4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8
Str. Int.		52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.537	4C !	2.960	(A,B)
N(PHI) / ( P/Rm )	0.537	3C !	1.042	(C,D)
M(PHI) / ( P )	0.537	2C1 !	0.004	(A,B)
M(PHI) / ( P )	0.537	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.537	1B !	0.003	(A,B,C,D)
N(x) / ( P/Rm )	0.537	3C !	1.042	(A,B)
N(x) / ( P/Rm )	0.537	4C !	2.960	(C,D)
M(x) / ( P )	0.537	1C1 !	0.010	(A,B)



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Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)	42.2	44.5	42.2	44.5	42.2	44.5	42.2	44.5
Pm+Pl (SUS)	23.5	25.8	56.2	58.5	35.8	38.1	45.9	48.2
Pm+Pl+Q (Total)	30.1	56.5	75.0	44.0	27.8	100.2	95.0	13.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.52	137.90	Passed
Pm+Pl (SUS)	58.48	206.85	Passed
Pm+Pl+Q (TOTAL)	100.21	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)		114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Circ. Pl (SUS)		-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)		-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8
Long. Pm (SUS)		57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
Long. Pl (SUS)		-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9
Long. Q (SUS)		-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	-53.5
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)		114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Pm+Pl (SUS)		78.9	81.2	133.9	136.2	103.4	105.7	122.8	125.1
Pm+Pl+Q (Total)		61.0	104.7	149.1	121.3	157.3	360.4	271.8	72.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	116.74	137.90	Passed
Pm+Pl (SUS)	136.16	206.85	Passed
Pm+Pl+Q (TOTAL)	360.40	413.70	Passed

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**INPUT VALUES, Nozzle Description: T1 From : 20**

Pressure for Reinforcement Calculations	P	23.083	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1200.00	mm.
Design Length of Section	L	1140.0000	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		450.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	20.0000	mm.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	18.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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	748.0000	mm.
Thickness of Pad	te	20.0000	mm.
Weld leg size between Pad and Shell	Wp	12.0000	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.

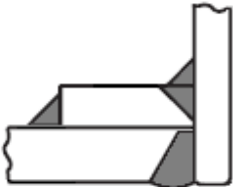
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**Nozzle Sketch (may not represent actual weld type/configuration)**



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

**Reinforcement CALCULATION, Description: T1**

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 0.787 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned} &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\ &= (23.08 \cdot 603.0) / (138 \cdot 1.0 - 0.6 \cdot 23.08) \\ &= 10.1967 \text{ mm.} \end{aligned}$$

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

$$\begin{aligned} &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\ &= (23.08 \cdot 254.0) / (138 \cdot 1.0 + 0.4 \cdot 23.08) \\ &= 4.2237 \text{ mm.} \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	948.0001	mm.
Parallel to Vessel Wall, opening length	d	474.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

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]:

$$\begin{aligned} &= \min( fr2, fr4 ) \\ &= \min( 1.0, 1.0 ) \\ &= 1.000 \end{aligned}$$

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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	48.332	9.043	NA
Area in Shell	A1	8.548	38.794	NA
Area in Nozzle Wall	A2	7.666	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.254	88.446	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:	695.1907	20.0000 mm.
Based on given Pad Diameter:	748.0001	15.5992 mm.
Based on Shell or Nozzle Thickness:	757.5876	15.0000 mm.

Area Required [A]:

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

$$= ( 474.0 * 10.1967 * 1.0 + 2 * 17.0 * 10.1967 * 1.0 * (1 - 1.0) )$$

$$= 48.332 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 474.0( 1.0 * 12.0 - 1.0 * 10.197 ) - 2 * 17.0$$

$$( 1.0 * 12.0 - 1.0 * 10.1967 ) * ( 1 - 1.0 )$$

$$= 8.548 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) * ( 17.0 - 4.22 ) * 1.0$$

$$= 7.666 \text{ cm}^2$$

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

$$= (Wo^2 - Ar \text{ Lost}) * Fr3 + ((Wi - can / 0.707)^2 - Ar \text{ Lost}) * fr2 + Wp^2 * fr4$$

$$= ( 2.6 ) * 1.0 + ( 0.0 ) * 1.0 + 304.8^2 * 1.0$$

$$= 4.040 \text{ cm}^2$$

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

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

$$= ( 748.0 - 508.0 ) 20.0 * 1.0 * 0.75$$

$$= 36.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 7.2237 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 13.1967 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 13.1967 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4525 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 11.3312 mm.

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Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1,tb2) ]  
 = min[ 11.331, max( 13.1967, 4.5 ) ]  
 = 11.3312 mm.

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

= max( ta, tb )  
 = max( 7.2237, 11.3312 )  
 = 11.3312 mm.

Available Nozzle Neck Thickness = 20.0000 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	:	32.6,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	312.1 N./mm <sup>2</sup>	Passed
Occasional	:	15.5,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	11.0,	Allowable	:	96.5 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, Curve: D

Govrn. thk, tg = 20.0, tr = 4.224, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 20.0, tr = 4.224, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 20.0, tr = 4.224, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °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 = 15.0, tr = 10.197, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.85, Temp. Reduction = 8 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.197, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.85, Temp. Reduction = 8 °C

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

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

Governing MDMT of the Nozzle : -48 °C

Governing MDMT of the Reinforcement Pad : -48 °C

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

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C

Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C

Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

Design Pressure/Ambient Rating = 23.08/51.10 = 0.452

Note:

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

#### Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 17.0000 mm.

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

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	11.9000 = 0.7 * tmin	12.7260 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	8.4840 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (48.3322 - 8.5478 + 2 * 17.0 * 1.0 * \\
 &\quad (1.0 * 12.0 - 10.1967) ) 138) \\
 &= 557.03 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 7.6658 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138 \\
 &= 657.81 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 7.6658 + 0.0 + 3.24 + ( 4.08 ) ) * 138 \\
 &= 206.64 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 7.6658 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138 \\
 &= 714.07 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 508.0 * 18.0 * 0.49 * 138 \\
 &= 970. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

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$$= ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138$$

$$= 953. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 245.5 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 1266. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= ( \text{pi}/2 ) * \text{Dlo} * \text{Wgnp} * 0.74 * \text{Seg}$$

$$= ( 3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138$$

$$= 1221. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 977. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 953 + 1266 ) = 2218 \text{ kN}$$

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

$$= ( 970 + 1221 + 977 + 0 ) = 3169 \text{ kN}$$

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

$$= ( 953 + 977 + 0 ) = 1930 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 2218 kN , must exceed W = 557 kN or W1 = 657 kN  
 Path 2-2 = 3168 kN , must exceed W = 557 kN or W2 = 206 kN  
 Path 3-3 = 1929 kN , must exceed W = 557 kN or W3 = 714 kN

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

Converged Max. Allow. Pressure in Operating case 24.907 bars  
 Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 56.4156 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

**Percent Elongation Calculations:**

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 4.098 %

**Input Echo, WRC107/537 Item 1, Description: T1 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1200.000	mm.
Vessel Thickness	Tv	15.000	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	508.000	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-516	70

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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>
Thickness of Reinforcing Pad	Tpad	20.000	mm.
Diameter of Reinforcing Pad	Dpad	748.000	mm.
Design Internal Pressure	Dp	23.083	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	20.0	kN
Longitudinal Shear (SUS)	Vl	20.0	kN
Circumferential Shear (SUS)	Vc	20.0	kN
Circumferential Moment (SUS)	Mc	28000.0	N-m
Longitudinal Moment (SUS)	Ml	42500.1	N-m
Torsional Moment (SUS)	Mt	52500.1	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 508.0 + 2 * 1.65 * \text{sqrt}(609.0 (15.0 - 3.0))$$

$$= 790.107 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTAINED loads:

Radial Load	P	20.0	kN
Circumferential Shear	VC	20.0	kN
Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.359	4C	2.373	(A,B)
N(PHI) / ( P/Rm )	0.359	3C	1.389	(C,D)
M(PHI) / ( P )	0.359	2C1	0.023	(A,B)
M(PHI) / ( P )	0.359	1C !	0.057	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.359	3A	0.798	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.359	1A	0.075	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.359	3B	1.693	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.359	1B	0.019	(A,B,C,D)
N(x) / ( P/Rm )	0.359	3C	1.389	(A,B)
N(x) / ( P/Rm )	0.359	4C	2.373	(C,D)
M(x) / ( P )	0.359	1C1	0.045	(A,B)

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M(x)	/ ( P )	0.359	2C !	0.030	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.359	4A	1.812	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.359	2A	0.034	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.359	4B	0.768	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.359	2B	0.032	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
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	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear		4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8
Str. Int.		52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.537	4C !	2.960	(A,B)
N(PHI) / ( P/Rm )	0.537	3C !	1.042	(C,D)
M(PHI) / ( P )	0.537	2C1 !	0.004	(A,B)
M(PHI) / ( P )	0.537	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.537	1B !	0.003	(A,B,C,D)
N(x) / ( P/Rm )	0.537	3C !	1.042	(A,B)
N(x) / ( P/Rm )	0.537	4C !	2.960	(C,D)
M(x) / ( P )	0.537	1C1 !	0.010	(A,B)



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Nozzle Calcs.: T1 Nozl: 19 1:34am Feb 7,2022

Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)	42.4	44.7	42.4	44.7	42.4	44.7	42.4	44.7
-----								
Pm+Pl (SUS)	23.7	26.0	56.3	58.6	35.9	38.2	46.1	48.4
-----								
Pm+Pl+Q (Total)	30.1	56.6	75.1	44.1	27.7	100.4	95.2	13.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.68	137.90	Passed
Pm+Pl (SUS)	58.64	206.85	Passed
Pm+Pl+Q (TOTAL)	100.38	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)		114.9	117.2	114.9	117.2	114.9	117.2	114.9	117.2
Circ. Pl (SUS)		-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)		-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8
-----									
Long. Pm (SUS)		57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4
Long. Pl (SUS)		-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9
Long. Q (SUS)		-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	-53.5
-----									
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)		114.9	117.2	114.9	117.2	114.9	117.2	114.9	117.2
-----									
Pm+Pl (SUS)		79.3	81.6	134.3	136.6	103.6	105.9	123.2	125.5
-----									
Pm+Pl+Q (Total)		61.2	105.2	149.5	121.7	156.9	360.8	272.2	72.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	117.17	137.90	Passed
Pm+Pl (SUS)	136.58	206.85	Passed
Pm+Pl+Q (TOTAL)	360.83	413.70	Passed

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Nozzle Calcs.: D2

Noz1: 20 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: D2 From : 60**

Pressure for Reinforcement Calculations	P	23.030	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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 Cone at Nozzle Location	D	1408.77	mm.
Equivalent Length of Conical Section	Le	5217.9990	mm.
Cone Half Apex Angle	Alpha	28.78	Degrees
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2085.52	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	20.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

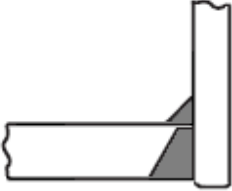
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Nozzle Calcs.: D2

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

**Reinforcement CALCULATION, Description: D2**

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 Conical Transition, Tr [Int. Press]

$$= (P \cdot D) / (2 \cdot \cos(a) \cdot (S_v \cdot E - 0.6 \cdot P)) \text{ Appendix 1-4 (e)}$$

$$= (23.03 \cdot (1415.6171 + 2 \cdot 0.0)) / (2 \cdot 0.8764 \cdot (138 \cdot 1.0 - 0.6 \cdot 23.03))$$

$$= 13.6246 \text{ mm.}$$

Reqd Cone thickness at Nozzle Location under External Pres. : 11.6968 mm.

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

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

$$= (23.03 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.03)$$

$$= 0.4791 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	118.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	59.0000	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]:

$$= \min(fr2, fr4)$$

$$= \min(1.0, 1.0)$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required Ar	7.739	2.470	NA

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Nozzle Calcs.: D2 Nozl: 20 1:34am Feb 7,2022

Area in Shell	A1	2.066	5.082	NA
Area in Nozzle Wall	A2	8.922	9.015	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	11.988	15.096	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]:

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

$$= ( 56.8 * 13.6246 * 1.0 + 2 * 13.6 * 13.6246 * 1.0 * (1 - 1.0) )$$

$$= 7.739 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

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

$$= 61.2 ( 1.0 * 17.0 - 1.0 * 13.625 ) - 2 * 13.6$$

$$( 1.0 * 17.0 - 1.0 * 13.6246 ) * ( 1 - 1.0 )$$

$$= 2.066 \text{ cm}^2$$

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

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

$$= 8.922 \text{ cm}^2$$

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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

Wall Thickness for Internal/External pressures	ta = 3.4791 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 16.6246 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 16.6246 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6060 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 16.6246, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4791, 7.8 )$$

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

Available Nozzle Neck Thickness = 16.6000 mm. --&gt; OK

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

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

-----  
Note:

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 Nozzle Calcs.: D2 Nozl: 20 1:34am Feb 7,2022

*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 = 23.03/51.10 = 0.451

Weld Size Calculations, Description: D2

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.7388 - 2.0657 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 17.0 - 13.6246) ) 138) \\
 &= 90.88 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9222 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9222 + 0.0 + 1. + ( 4.624 ) ) * 138 \\
 &= 200.57 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9222 + 0.0 + 1. + 0.0 + ( 4.624 ) ) * 138 \\
 &= 200.57 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 35.2 ) * ( 16.6 - 3.0 ) * 0.7 * 138 \\
 &= 145. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

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Nozzle Calcs.: D2 Nozl: 20 1:34am Feb 7,2022

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 84.0 * ( 20.0 - 3.0 ) * 0.74 * 138 \\
 &= 229. \text{ kN}
 \end{aligned}$$

#### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 89 + 145 ) = 234 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89 + 0 + 229 + 0 ) = 318 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 89 + 229 + 0 ) = 318 \text{ kN}
 \end{aligned}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 90 kN or W1 = 136 kN  
 Path 2-2 = 318 kN , must exceed W = 90 kN or W2 = 200 kN  
 Path 3-3 = 318 kN , must exceed W = 90 kN or W3 = 200 kN

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

Converged Max. Allow. Pressure in Operating case 24.409 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.2533 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.2533 mm.

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Nozzle Calcs.: S2

Nozl: 21 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: S2****From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3035.53	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		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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

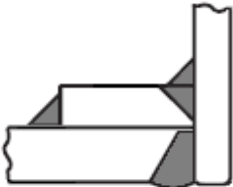
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Nozzle Calcs.: S2 Nozl: 21 1:34am Feb 7,2022

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



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

**Reinforcement CALCULATION, Description: S2**

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]

$$\begin{aligned} &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\ &= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07) \\ &= 14.0430 \text{ mm.} \end{aligned}$$

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

$$\begin{aligned} &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\ &= (23.07 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.07) \\ &= 2.1266 \text{ mm.} \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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		37.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned} &= \min( 1, S_p / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned} &= \min( fr2, fr4 ) \\ &= \min( 0.855, 1.0 ) \\ &= 0.855 \end{aligned}$$

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: S2 Noz1: 21 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.817	8.910	NA
Area in Shell	A1	1.919	12.663	NA
Area in Nozzle Wall	A2	3.838	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.367	49.092	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:	331.5703	18.0000 mm.
Based on given Pad Diameter:	379.0750	12.6557 mm.
Based on Shell or Nozzle Thickness:	401.2946	11.1125 mm.

**Area Required [A]:**

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

$$= ( 202.85 * 14.043 * 1.0 + 2 * 8.1125 * 14.043 * 1.0 * (1 - 0.86) )$$

$$= 28.817 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

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

$$= 202.85( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 8.113$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 )$$

$$= 1.919 \text{ cm}^2$$

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

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

$$= ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855$$

$$= 3.838 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Trapfr4$$

$$= ( 1. ) * 0.86 + ( 0.0 ) * 0.86 + 195.5274^2 * 1.0$$

$$= 2.810 \text{ cm}^2$$

**Area Available in Element [A5]:**

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

$$= ( 379.075 - 219.075 ) * 18.0 * 1.0$$

$$= 28.800 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1266 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 10.1600 mm.

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 17.043, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1266, 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	:	13.9,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	20.4,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

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

Govrn. thk, tg = 11.113, tr = 2.127, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.262, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 18.0, tr = 14.043, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.936, Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-43 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-46 °C

**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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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 : -46 °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 = 23.07/51.10 = 0.451

Note:

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

#### Weld Size Calculations, Description: S2

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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.8166 - 1.9187 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 372.72 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8384 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.80 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8384 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.41 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8384 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.49 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118 \\
 &= 199. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 105.4813 ) * ( 11.1125 - 3.0 ) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgnp * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 527. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 563 + 222 ) = 785 \text{ kN}$$

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

$$= ( 199 + 632 + 527 + 0 ) = 1358 \text{ kN}$$

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

$$= ( 563 + 527 + 0 ) = 1090 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 372 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 372 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 372 kN or W3 = 517 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

#### Input Echo, WRC107/537 Item 1, Description: S2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	219.075	mm.

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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	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.068	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 589.168 \text{ mm.}$$

## 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 = 25.68

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.113	4C	4.590	(A,B)
N(PHI) / ( P/Rm )	0.113	3C	3.985	(C,D)
M(PHI) / ( P )	0.113	2C1	0.097	(A,B)
M(PHI) / ( P )	0.113	1C	0.134	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.113	3A	0.723	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.113	1A	0.098	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.113	3B	2.471	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.113	1B	0.047	(A,B,C,D)
N(x) / ( P/Rm )	0.113	3C	3.985	(A,B)

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N(x) / ( P/Rm )	0.113	4C	4.590	(C,D)
M(x) / ( P )	0.113	1C1	0.136	(A,B)
M(x) / ( P )	0.113	2C	0.097	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.113	4A	1.032	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.113	2A	0.054	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.113	4B	0.691	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.113	2B	0.078	(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		-1.3	-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	-5.9	5.9	-5.9	5.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML		-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P		-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML		-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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.		41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.198	4C	7.314	(A,B)
N(PHI) / ( P/Rm )	0.198	3C	4.343	(C,D)
M(PHI) / ( P )	0.198	2C1	0.028	(A,B)
M(PHI) / ( P )	0.198	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.198	3A	2.187	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.198	1A	0.069	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.198	3B	5.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.198	1B	0.020	(A,B,C,D)
N(x) / ( P/Rm )	0.198	3C	4.343	(A,B)
N(x) / ( P/Rm )	0.198	4C	7.314	(C,D)
M(x) / ( P )	0.198	1C1	0.058	(A,B)
M(x) / ( P )	0.198	2C !	0.034	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.198	4A	4.611	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.198	2A	0.032	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.198 4B 2.241 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.198 2B 0.028 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P		-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML		-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P		-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P		-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC		0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML		-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tot. Shear		3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.		55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3

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Pm+Pl (SUS)	49.4	51.7	61.9	64.2	54.0	56.3	57.7	60.0
Pm+Pl+Q (Total)	38.6	75.7	76.4	50.2	12.0	100.6	90.4	28.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.27	137.90	Passed
Pm+Pl (SUS)	64.24	206.85	Passed
Pm+Pl+Q (TOTAL)	100.60	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)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)		105.1	107.4	139.0	141.3	116.8	119.1	131.0	133.3
Pm+Pl+Q (Total)		77.2	135.6	155.1	125.2	27.4	208.6	192.5	72.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	141.30	206.85	Passed
Pm+Pl+Q (TOTAL)	208.57	413.70	Passed

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Nozzle Calcs.: S1 Nozl: 22 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: S1 From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5585.52	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		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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

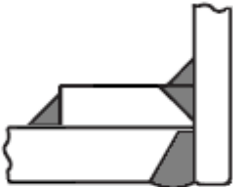
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Nozzle Calcs.: S1 Nozl: 22 1:34am Feb 7,2022

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



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

**Reinforcement CALCULATION, Description: S1**

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]

$$\begin{aligned} &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\ &= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07) \\ &= 14.0430 \text{ mm.} \end{aligned}$$

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

$$\begin{aligned} &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\ &= (23.07 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.07) \\ &= 2.1266 \text{ mm.} \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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		37.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned} &= \min( 1, S_p / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned} &= \min( fr2, fr4 ) \\ &= \min( 0.855, 1.0 ) \\ &= 0.855 \end{aligned}$$

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Nozzle Calcs.: S1 Noz1: 22 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.817	8.910	NA
Area in Shell	A1	1.919	12.663	NA
Area in Nozzle Wall	A2	3.838	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.367	49.092	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:	331.5703	18.0000 mm.
Based on given Pad Diameter:	379.0750	12.6557 mm.
Based on Shell or Nozzle Thickness:	401.2946	11.1125 mm.

**Area Required [A]:**

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

$$= ( 202.85 * 14.043 * 1.0 + 2 * 8.1125 * 14.043 * 1.0 * (1 - 0.86) )$$

$$= 28.817 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

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

$$= 202.85( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 8.113$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 )$$

$$= 1.919 \text{ cm}^2$$

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

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

$$= ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855$$

$$= 3.838 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Trapfr4$$

$$= ( 1. ) * 0.86 + ( 0.0 ) * 0.86 + 195.5274^2 * 1.0$$

$$= 2.810 \text{ cm}^2$$

**Area Available in Element [A5]:**

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

$$= ( 379.075 - 219.075 ) * 18.0 * 1.0$$

$$= 28.800 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1266 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 10.1600 mm.

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 17.043, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1266, 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	: 13.9, Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4, Allowable	: 82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

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

Govrn. thk, tg = 11.113, tr = 2.127, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.262, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 18.0, tr = 14.043, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.936, Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-43 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-46 °C

**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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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 : -46 °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 = 23.07/51.10 = 0.451

Note:

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

#### Weld Size Calculations, Description: S1

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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.8166 - 1.9187 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 372.72 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8384 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.80 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8384 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.41 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8384 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.49 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118 \\
 &= 199. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 105.4813) * (11.1125 - 3.0) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 219.075 * (18.0 - 3.0) * 0.74 * 138$$

$$= 527. \text{ kN}$$

#### Strength of Failure Paths:

$$PATH11 = (SPEW + SNW) = (563 + 222) = 785 \text{ kN}$$

$$PATH22 = (Sonw + Tpgw + Tngw + Sinw)$$

$$= (199 + 632 + 527 + 0) = 1358 \text{ kN}$$

$$PATH33 = (Spew + Tngw + Sinw)$$

$$= (563 + 527 + 0) = 1090 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 372 kN or W1 = 488 kN

Path 2-2 = 1357 kN , must exceed W = 372 kN or W2 = 93 kN

Path 3-3 = 1089 kN , must exceed W = 372 kN or W3 = 517 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

#### Input Echo, WRC107/537 Item 1, Description: S1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	219.075	mm.

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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	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.068	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 589.168 \text{ mm.}$$

## 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 = 25.68

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.113	4C	4.590	(A,B)
N(PHI) / ( P/Rm )	0.113	3C	3.985	(C,D)
M(PHI) / ( P )	0.113	2C1	0.097	(A,B)
M(PHI) / ( P )	0.113	1C	0.134	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.113	3A	0.723	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.113	1A	0.098	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.113	3B	2.471	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.113	1B	0.047	(A,B,C,D)
N(x) / ( P/Rm )	0.113	3C	3.985	(A,B)

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N(x) / ( P/Rm )	0.113	4C	4.590	(C,D)
M(x) / ( P )	0.113	1C1	0.136	(A,B)
M(x) / ( P )	0.113	2C	0.097	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.113	4A	1.032	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.113	2A	0.054	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.113	4B	0.691	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.113	2B	0.078	(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		-1.3	-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	-5.9	5.9	-5.9	5.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML		-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P		-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML		-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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.		41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.198	4C	7.314	(A,B)
N(PHI) / ( P/Rm )	0.198	3C	4.343	(C,D)
M(PHI) / ( P )	0.198	2C1	0.028	(A,B)
M(PHI) / ( P )	0.198	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.198	3A	2.187	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.198	1A	0.069	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.198	3B	5.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.198	1B	0.020	(A,B,C,D)
N(x) / ( P/Rm )	0.198	3C	4.343	(A,B)
N(x) / ( P/Rm )	0.198	4C	7.314	(C,D)
M(x) / ( P )	0.198	1C1	0.058	(A,B)
M(x) / ( P )	0.198	2C !	0.034	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.198	4A	4.611	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.198	2A	0.032	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.198 4B 2.241 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.198 2B 0.028 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P		-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML		-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P		-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P		-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC		0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML		-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tot. Shear		3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.		55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3

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Pm+Pl (SUS)	49.4	51.7	61.9	64.2	54.0	56.3	57.7	60.0
Pm+Pl+Q (Total)	38.6	75.7	76.4	50.2	12.0	100.6	90.4	28.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.27	137.90	Passed
Pm+Pl (SUS)	64.24	206.85	Passed
Pm+Pl+Q (TOTAL)	100.60	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)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)		105.1	107.4	139.0	141.3	116.8	119.1	131.0	133.3
Pm+Pl+Q (Total)		77.2	135.6	155.1	125.2	27.4	208.6	192.5	72.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	141.30	206.85	Passed
Pm+Pl+Q (TOTAL)	208.57	413.70	Passed

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Nozzle Calcs.: S3 Nozl: 23 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: S3 From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3235.53	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		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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

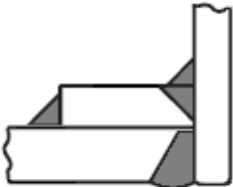
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Nozzle Calcs.: S3 Nozl: 23 1:34am Feb 7,2022

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



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

**Reinforcement CALCULATION, Description: S3**

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]

$$\begin{aligned} &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\ &= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\ &= 14.0010 \text{ mm.} \end{aligned}$$

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

$$\begin{aligned} &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\ &= (23.0 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.0) \\ &= 2.1204 \text{ mm.} \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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		37.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned} &= \min( 1, S_p / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned} &= \min( fr2, fr4 ) \\ &= \min( 0.855, 1.0 ) \\ &= 0.855 \end{aligned}$$

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Nozzle Calcs.: S3 Nozl: 23 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.730	8.910	NA
Area in Shell	A1	2.003	12.663	NA
Area in Nozzle Wall	A2	3.842	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.456	49.092	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:	330.6005	18.0000 mm.
Based on given Pad Diameter:	379.0750	12.5466 mm.
Based on Shell or Nozzle Thickness:	399.7238	11.1125 mm.

**Area Required [A]:**

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

$$= ( 202.85 * 14.001 * 1.0 + 2 * 8.1125 * 14.001 * 1.0 * (1 - 0.86) )$$

$$= 28.730 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

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

$$= 202.85( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 8.113$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )$$

$$= 2.003 \text{ cm}^2$$

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

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

$$= ( 2 * 37.5 ) * ( 8.11 - 2.12 ) * 0.855$$

$$= 3.842 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Trapfr4$$

$$= ( 1. ) * 0.86 + ( 0.0 ) * 0.86 + 195.5274^2 * 1.0$$

$$= 2.810 \text{ cm}^2$$

**Area Available in Element [A5]:**

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

$$= ( 379.075 - 219.075 ) * 18.0 * 1.0$$

$$= 28.800 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1204 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 10.1600 mm.

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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 Nozzle Calcs.: S3 Nozl: 23 1:34am Feb 7,2022

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 17.001, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1204, 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 = 11.113, tr = 2.12, c = 3.0 mm., E\* = 1.0  
 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 = 18.0, tr = 14.001, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.933$ , Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-43 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-46 °C

**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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Nozzle Calcs.: S3

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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 : -46 °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: S3

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]:

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

$$= \max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 * (1.0 * 15.0 - 14.001) ) 138 )$$

$$= 370.45 \text{ kN}$$

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

Weld Load [W1]:

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

$$= ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138$$

$$= 488.85 \text{ kN}$$

Weld Load [W2]:

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

$$= ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138$$

$$= 93.47 \text{ kN}$$

Weld Load [W3]:

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

$$= ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138$$

$$= 517.54 \text{ kN}$$

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

Shear, Outward Nozzle Weld [Sonw]:

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

$$= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118$$

$$= 199. \text{ kN}$$

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 105.4813 ) * ( 11.1125 - 3.0 ) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 527. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 563 + 222 ) = 785 \text{ kN}$$

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

$$= ( 199 + 632 + 527 + 0 ) = 1358 \text{ kN}$$

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

$$= ( 563 + 527 + 0 ) = 1090 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 370 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 370 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 370 kN or W3 = 517 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

#### Input Echo, WRC107/537 Item 1, Description: S3 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	219.075	mm.

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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	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.000	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 589.168 \text{ mm.}$$

## 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 = 25.68

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.113	4C	4.590	(A,B)
N(PHI) / ( P/Rm )	0.113	3C	3.985	(C,D)
M(PHI) / ( P )	0.113	2C1	0.097	(A,B)
M(PHI) / ( P )	0.113	1C	0.134	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.113	3A	0.723	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.113	1A	0.098	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.113	3B	2.471	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.113	1B	0.047	(A,B,C,D)
N(x) / ( P/Rm )	0.113	3C	3.985	(A,B)

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N(x) / ( P/Rm )	0.113	4C	4.590	(C,D)
M(x) / ( P )	0.113	1C1	0.136	(A,B)
M(x) / ( P )	0.113	2C	0.097	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.113	4A	1.032	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.113	2A	0.054	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.113	4B	0.691	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.113	2B	0.078	(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		-1.3	-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	-5.9	5.9	-5.9	5.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML		-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P		-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML		-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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.		41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.198	4C	7.314	(A,B)
N(PHI) / ( P/Rm )	0.198	3C	4.343	(C,D)
M(PHI) / ( P )	0.198	2C1	0.028	(A,B)
M(PHI) / ( P )	0.198	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.198	3A	2.187	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.198	1A	0.069	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.198	3B	5.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.198	1B	0.020	(A,B,C,D)
N(x) / ( P/Rm )	0.198	3C	4.343	(A,B)
N(x) / ( P/Rm )	0.198	4C	7.314	(C,D)
M(x) / ( P )	0.198	1C1	0.058	(A,B)
M(x) / ( P )	0.198	2C !	0.034	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.198	4A	4.611	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.198	2A	0.032	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.198 4B 2.241 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.198 2B 0.028 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P		-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML		-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P		-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P		-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC		0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML		-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC		0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tot. Shear		3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.		55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1

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Pm+Pl (SUS)	49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)	38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	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)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)		104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)		76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

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Nozzle Calcs.: D1

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**INPUT VALUES, Nozzle Description: D1**

**From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4735.53	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

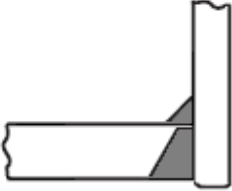
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Nozzle Calcs.: D1

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

**Reinforcement CALCULATION, Description: D1**

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]

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 0.4799 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	NA
Area in Nozzle Wall	A2	8.922	9.015	NA

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:Evaporator E-PK1601

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: D1 Nozl: 24 1:34am Feb 7,2022

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	10.469	13.627	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]:

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

$$= ( 56.8 * 14.043 * 1.0 + 2 * 13.6 * 14.043 * 1.0 * (1 - 1.0) )$$

$$= 7.976 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

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

$$= 57.2( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )$$

$$= 0.547 \text{ cm}^2$$

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

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

$$= 8.922 \text{ cm}^2$$

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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

Wall Thickness for Internal/External pressures	ta = 3.4799 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.043, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4799, 7.8 )$$

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

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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 Nozzle Calcs.: D1 Nozl: 24 1:34am Feb 7,2022

*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 = 23.07/51.10 = 0.451

#### Weld Size Calculations, Description: D1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 106.03 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.81 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
 \end{aligned}$$

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 35.2 ) \* ( 16.6 - 3.0 ) \* 0.7 \* 138  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

### Input Echo, WRC107/537 Item 1, Description: D1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	23.068	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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Nozzle Calcs.: D1 Nozl: 24 1:34am Feb 7,2022

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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 454.093 \text{ mm.}$$

**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 = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
-----				
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: D1

Noz1: 24 1:34am Feb 7,2022

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)		122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)		97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

**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.: D3 Nozl: 25 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: D3 From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6135.53	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

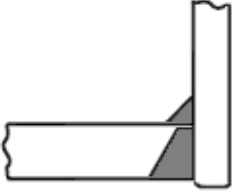
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Nozzle Calcs.: D3

Nozl: 25 1:34am Feb 7,2022



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

**Reinforcement CALCULATION, Description: D3**

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]

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 0.4799 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	NA
Area in Nozzle Wall	A2	8.922	9.015	NA

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Nozzle Calcs.: D3 Nozl: 25 1:34am Feb 7,2022

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	10.469	13.627	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]:

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

$$= ( 56.8 * 14.043 * 1.0 + 2 * 13.6 * 14.043 * 1.0 * (1 - 1.0) )$$

$$= 7.976 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 57.2( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )$$

$$= 0.547 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0$$

$$= 8.922 \text{ cm}^2$$

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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

Wall Thickness for Internal/External pressures	ta = 3.4799 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.043, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4799, 7.8 )$$

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

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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 FileName : Calculation Book for Evaporator E-PK1601  
 Nozzle Calcs.: D3 Nozl: 25 1:34am Feb 7,2022

*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 = 23.07/51.10 = 0.451

#### Weld Size Calculations, Description: D3

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 106.03 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.81 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
 \end{aligned}$$

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 35.2 ) \* ( 16.6 - 3.0 ) \* 0.7 \* 138  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

### Input Echo, WRC107/537 Item 1, Description: D3 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	23.068	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 454.093 \text{ mm.}$$
**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 = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)		122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)		97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

**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)	128.97	137.90	Passed
Pm+P1 (SUS)	130.01	206.85	Passed
Pm+P1+Q (TOTAL)	166.50	413.70	Passed

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**INPUT VALUES, Nozzle Description: TT From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6385.52	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

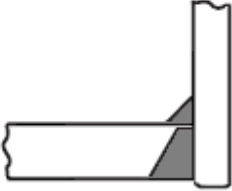
**Nozzle Sketch (may not represent actual weld type/configuration)**

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

**Reinforcement CALCULATION, Description: TT**

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]

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 0.4799 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min(fr2, fr4)$$

$$= \min(1.0, 1.0)$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	NA
Area in Nozzle Wall	A2	8.922	9.015	NA

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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	10.469	13.627	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]:

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

$$= ( 56.8 * 14.043 * 1.0 + 2 * 13.6 * 14.043 * 1.0 * (1 - 1.0) )$$

$$= 7.976 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 57.2( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )$$

$$= 0.547 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

$$= 8.922 \text{ cm}^2$$

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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

Wall Thickness for Internal/External pressures	ta = 3.4799 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.043, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4799, 7.8 )$$

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

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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 Tag no:Evaporator E-PK1601  
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 FileName : Calculation Book for Evaporator E-PK1601  
 Nozzle Calcs.: TT Noz1: 26 1:34am Feb 7,2022

*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 = 23.07/51.10 = 0.451

#### Weld Size Calculations, Description: TT

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 106.03 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.81 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
 \end{aligned}$$

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 35.2 ) \* ( 16.6 - 3.0 ) \* 0.7 \* 138  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

#### Input Echo, WRC107/537 Item 1, Description: TT :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	23.068	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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Nozzle Calcs.: TT Nozl: 26 1:34am Feb 7,2022

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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 454.093 \text{ mm.}$$
**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 = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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.: TT Nozl: 26 1:34am Feb 7,2022

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)		126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)		122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)		97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

**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.: V

Nozl: 27 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: V From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2685.53	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		90.00	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

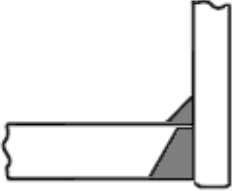
**Nozzle Sketch (may not represent actual weld type/configuration)**

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: V Nozl: 27 1:34am Feb 7,2022



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

**Reinforcement CALCULATION, Description: V**

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]

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

$$= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 14.0010 \text{ mm.}$$

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

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

$$= (23.0 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 0.4785 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min(fr2, fr4)$$

$$= \min(1.0, 1.0)$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA
Area in Nozzle Wall	A2	8.923	9.015	NA

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Nozzle Calcs.: V Nozl: 27 1:34am Feb 7,2022

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	10.494	13.627	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]:

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

$$= ( 56.8 * 14.001 * 1.0 + 2 * 13.6 * 14.001 * 1.0 * (1 - 1.0) )$$

$$= 7.953 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

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

$$= 57.2 ( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )$$

$$= 0.571 \text{ cm}^2$$

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

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

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

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

## 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 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.001, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4785, 7.8 )$$

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

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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 Tag no:Evaporator E-PK1601  
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 FileName : Calculation Book for Evaporator E-PK1601  
 Nozzle Calcs.: V Nozl: 27 1:34am Feb 7,2022

*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: V

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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.001) ) 138) \\
 &= 105.52 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
 \end{aligned}$$

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= 89. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 35.2 ) \* ( 16.6 - 3.0 ) \* 0.7 \* 138  
 = 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 105 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 105 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 105 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

### Input Echo, WRC107/537 Item 1, Description: V :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 454.093 \text{ mm.}$$
**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 = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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.: V

Noz1: 27 1:34am Feb 7,2022

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)		122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)		97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0

**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)	128.59	137.90	Passed
Pm+P1 (SUS)	129.63	206.85	Passed
Pm+P1+Q (TOTAL)	166.12	413.70	Passed

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**INPUT VALUES, Nozzle Description: S4 From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5585.52	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		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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

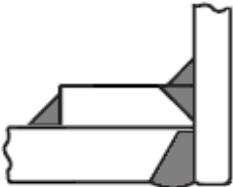
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**Nozzle Sketch (may not represent actual weld type/configuration)**



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

**Reinforcement CALCULATION, Description: S4**

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]

$$\begin{aligned} &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\ &= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\ &= 14.0010 \text{ mm.} \end{aligned}$$

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

$$\begin{aligned} &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\ &= (23.0 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.0) \\ &= 2.1204 \text{ mm.} \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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		37.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned} &= \min( 1, S_n / S_v ) \\ &= \min( 1, 117.9 / 137.9 ) \\ &= 0.855 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned} &= \min( 1, S_p / S_v ) \\ &= \min( 1, 137.9 / 137.9 ) \\ &= 1.000 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned} &= \min( fr2, fr4 ) \\ &= \min( 0.855, 1.0 ) \\ &= 0.855 \end{aligned}$$

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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	28.730	8.910	NA
Area in Shell	A1	2.003	12.663	NA
Area in Nozzle Wall	A2	3.842	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.456	49.092	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:	330.6005	18.0000 mm.
Based on given Pad Diameter:	379.0750	12.5466 mm.
Based on Shell or Nozzle Thickness:	399.7238	11.1125 mm.

**Area Required [A]:**

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

$$= ( 202.85 * 14.001 * 1.0 + 2 * 8.1125 * 14.001 * 1.0 * (1 - 0.86) )$$

$$= 28.730 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

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

$$= 202.85( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 8.113$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )$$

$$= 2.003 \text{ cm}^2$$

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

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

$$= ( 2 * 37.5 ) * ( 8.11 - 2.12 ) * 0.855$$

$$= 3.842 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Trapfr4$$

$$= ( 1. ) * 0.86 + ( 0.0 ) * 0.86 + 195.5274^2 * 1.0$$

$$= 2.810 \text{ cm}^2$$

**Area Available in Element [A5]:**

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

$$= ( 379.075 - 219.075 ) * 18.0 * 1.0$$

$$= 28.800 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1204 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 10.1600 mm.

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 17.001, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1204, 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 = 11.113, tr = 2.12, c = 3.0 mm., E\* = 1.0  
 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 = 18.0, tr = 14.001, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.933, Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-43 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-46 °C

**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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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 : -46 °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: S4

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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.001) )138) \\
 &= 370.45 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.85 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.47 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.54 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118 \\
 &= 199. \text{ kN}
 \end{aligned}$$

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 105.4813) * (11.1125 - 3.0) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 219.075 * (18.0 - 3.0) * 0.74 * 138$$

$$= 527. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (563 + 222) = 785 \text{ kN}$$

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

$$= (199 + 632 + 527 + 0) = 1358 \text{ kN}$$

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

$$= (563 + 527 + 0) = 1090 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 370 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 370 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 370 kN or W3 = 517 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

#### Input Echo, WRC107/537 Item 1, Description: S4 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	219.075	mm.

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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	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.000	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}(838.5 (18.0 - 3.0))$$

$$= 589.168 \text{ mm.}$$

## 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 = 25.68

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.113	4C	4.590	(A,B)
N(PHI) / ( P/Rm )	0.113	3C	3.985	(C,D)
M(PHI) / ( P )	0.113	2C1	0.097	(A,B)
M(PHI) / ( P )	0.113	1C	0.134	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.113	3A	0.723	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.113	1A	0.098	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.113	3B	2.471	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.113	1B	0.047	(A,B,C,D)
N(x) / ( P/Rm )	0.113	3C	3.985	(A,B)

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N(x) / ( P/Rm )	0.113	4C	4.590	(C,D)
M(x) / ( P )	0.113	1C1	0.136	(A,B)
M(x) / ( P )	0.113	2C	0.097	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.113	4A	1.032	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.113	2A	0.054	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.113	4B	0.691	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.113	2B	0.078	(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		-1.3	-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	-5.9	5.9	-5.9	5.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML		-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P		-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML		-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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.		41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.198	4C	7.314	(A,B)
N(PHI) / ( P/Rm )	0.198	3C	4.343	(C,D)
M(PHI) / ( P )	0.198	2C1	0.028	(A,B)
M(PHI) / ( P )	0.198	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.198	3A	2.187	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.198	1A	0.069	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.198	3B	5.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.198	1B	0.020	(A,B,C,D)
N(x) / ( P/Rm )	0.198	3C	4.343	(A,B)
N(x) / ( P/Rm )	0.198	4C	7.314	(C,D)
M(x) / ( P )	0.198	1C1	0.058	(A,B)
M(x) / ( P )	0.198	2C !	0.034	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.198	4A	4.611	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.198	2A	0.032	(A,B,C,D)

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N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.198 4B 2.241 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.198 2B 0.028 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend.	P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb.	ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb.	P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend.	P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb.	MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend.	MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb.	ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend.	ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear	VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear	MT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tot. Shear		3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.		55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl	(SUS)	-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q	(SUS)	-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm	(SUS)	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl	(SUS)	-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q	(SUS)	-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm	(SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1

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Pm+Pl (SUS)	49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)	38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	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)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)		104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)		76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

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Nozzle Calcs.: LG1

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**INPUT VALUES, Nozzle Description: LG1 From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4335.53	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

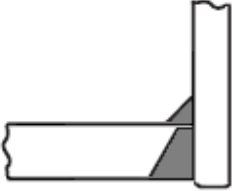
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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LG1

Nozl: 29 1:34am Feb 7,2022



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

**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 Cylindrical Shell, Tr [Int. Press]

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 0.4799 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	NA
Area in Nozzle Wall	A2	8.922	9.015	NA

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LGL Nozl: 29 1:34am Feb 7,2022

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	10.469	13.627	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]:

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

$$= ( 56.8 * 14.043 * 1.0 + 2 * 13.6 * 14.043 * 1.0 * (1 - 1.0) )$$

$$= 7.976 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

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

$$= 57.2 ( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )$$

$$= 0.547 \text{ cm}^2$$

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

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

$$= 8.922 \text{ cm}^2$$

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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

Wall Thickness for Internal/External pressures	ta = 3.4799 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0430 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.043, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4799, 7.8 )$$

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

Available Nozzle Neck Thickness = 16.6000 mm. --&gt; 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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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LG1 Noz1: 29 1:34am Feb 7,2022

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 = 23.07/51.10 = 0.451

#### Weld Size Calculations, Description: LG1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.043 ) )138) \\
 &= 106.03 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.81 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.07 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 35.2 ) * ( 16.6 - 3.0 ) * 0.7 * 138 \\
 &= 145. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
 \end{aligned}$$

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Nozzle Calcs.: LG1

Noz1: 29 1:34am Feb 7,2022

= 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN

PATH22 = ( Sonw + Tpgw + Tngw + Sinw )

= ( 89 + 0 + 202 + 0 ) = 291 kN

PATH33 = ( Sonw + Tngw + Sinw )

= ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN

Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN

Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

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Nozzle Calcs.: LG2

Nozl: 30 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: LG2 From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4335.53	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		90.00	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

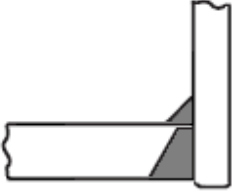
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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LG2

Noz1: 30 1:34am Feb 7,2022



**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.

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

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

$$= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 14.0010 \text{ mm.}$$

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

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

$$= (23.0 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 0.4785 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	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]:

$$= \min(fr2, fr4)$$

$$= \min(1.0, 1.0)$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA
Area in Nozzle Wall	A2	8.923	9.015	NA

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Nozzle Calcs.: LG2 Nozl: 30 1:34am Feb 7,2022

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	10.494	13.627	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]:

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

$$= ( 56.8 * 14.001 * 1.0 + 2 * 13.6 * 14.001 * 1.0 * (1 - 1.0) )$$

$$= 7.953 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 57.2 ( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )$$

$$= 0.571 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 34.0 ) ( 13.6 - 0.48 ) 1.0$$

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

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

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

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

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

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 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.001, 4.5 ) ]$$

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

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

$$= \max( ta, tb )$$

$$= \max( 3.4785, 7.8 )$$

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

Available Nozzle Neck Thickness = 16.6000 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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Nozzle Calcs.: LG2

Noz1: 30 1:34am Feb 7,2022

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 Tmin 13.6000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.001) ) 138) \\
 &= 105.52 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo ) / 4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 35.2 ) * ( 16.6 - 3.0 ) * 0.7 * 138 \\
 &= 145. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
 \end{aligned}$$

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 FileName : Calculation Book for Evaporator E-PK1601  
 Nozzle Calcs.: LG2 Nozl: 30 1:34am Feb 7,2022

= 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
           = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
           = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 105 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 105 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 105 kN or W3 = 193 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LT1

Nozl: 31 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: LT1 From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3735.53	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		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L`	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

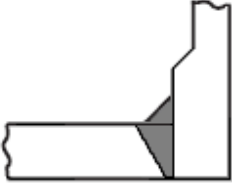
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Nozzle Calcs.: LT1

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**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT1**

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

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 14.0010 \text{ mm.}$$

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

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

$$= (23.0 \cdot 30.1625) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$$

$$= 0.5839 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):

$$= 2.5 \cdot \text{Corroded Hub Thickness}$$

$$= 2.5 \cdot 17.0 \text{ Note: less than the hub height, use (e-2)}$$

$$= 42.5000 \text{ mm.}$$

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 0.855, 1.0 )$$

$$= 0.855$$

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Nozzle Calcs.: LT1 Nozl: 31 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.836	2.430	NA
Area in Shell	A1	0.590	3.731	NA
Area in Nozzle Wall	A2	10.527	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.972	15.306	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 51.0342 * 14.001 * 1.0 + 2 * 17.0 * 14.001 * 1.0 * (1 - 0.86) ) \\
 &= 7.836 \text{ cm}^2
 \end{aligned}$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 64.0( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 ) \\
 &= 0.590 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 37.5 ) ( 17.0 - 0.58 ) 0.855 \\
 &= 10.527 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 0.855 + ( 0.0 )^2 * 0.855 \\
 &= 0.855 \text{ cm}^2
 \end{aligned}$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

**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 = 17.0010 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 17.0010 mm.  
 Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 17.001, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.5839, 6.42 ) \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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 Nozzle Calcs.: LT1 Nozl: 31 1:34am Feb 7,2022

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME**

**B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle-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
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: LT1**

Intermediate Calc. for nozzle/shell Welds Tmin 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.

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

Weld Load [W]:

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

$$= \max( 0, (7.8355 - 0.5901 + 2 * 17.0 * 0.855 * (1.0 * 15.0 - 14.001) ) 138 )$$

$$= 103.91 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

$$\begin{aligned} &= (A2+A4-(Wi-Can/.707)^2*fr2)*Sv \\ &= ( 10.5268 + 0.855 - 0.0 * 0.86 ) * 138 \\ &= 156.94 \text{ kN} \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned} &= ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 ) ) * Sv \\ &= ( 10.5268 + 0.0 + 0.855 + ( 4.3605 ) ) * 138 \\ &= 217.07 \text{ kN} \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned} &= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 ) ) * Sv \\ &= ( 10.5268 + 0.0 + 0.855 + 0.0 ) * 138 \\ &= 217.07 \text{ kN} \end{aligned}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned} &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\ &= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 118 \\ &= 55. \text{ kN} \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned} &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\ &= (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 118 \\ &= 123. \text{ kN} \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned} &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\ &= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138 \\ &= 145. \text{ kN} \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned} \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 55 + 123 ) = 177 \text{ kN} \\ \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 55 + 0 + 145 + 0 ) = 200 \text{ kN} \\ \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 55 + 145 + 0 ) = 200 \text{ kN} \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 177 kN , must exceed W = 103 kN or W1 = 156 kN  
Path 2-2 = 199 kN , must exceed W = 103 kN or W2 = 217 kN  
Path 3-3 = 199 kN , must exceed W = 103 kN or W3 = 217 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

### Input Echo, WRC107/537 Item 1, Description: LT1 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical

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Nozzle Calcs.: LTI

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Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	85.034	mm.
Nozzle Thickness	Tn	20.000	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>
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

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

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

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

**Note:**

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

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

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 455.127 \text{ mm.}
 \end{aligned}$$

## 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 = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

-----  
 Curves read for 1979                      Beta   Figure   Value   Location

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Nozzle Calcs.: LTI Nozl: 31 1:34am Feb 7,2022

N (PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N (PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M (PHI) / ( P )	0.044	2C1	0.146	(A,B)
M (PHI) / ( P )	0.044	1C	0.186	(C,D)
N (PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M (PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N (PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M (PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
N (x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N (x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M (x) / ( P )	0.044	1C1	0.192	(A,B)
M (x) / ( P )	0.044	2C	0.145	(C,D)
N (x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M (x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N (x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M (x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P		-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	0.0	-0.7	0.7	0.7
Circ. Memb. ML		0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Bend. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5
-----									
Long. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML		-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
-----									
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
-----									
Str. Int.		41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl

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Nozzle Calcs.: LT1

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Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

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Nozzle Calcs.: LT3

Noz1: 32 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: LT3 From : 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4035.53	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		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L`	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

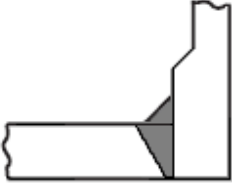
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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LT3

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**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT3**

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

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 14.0010 \text{ mm.}$$

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

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

$$= (23.0 \cdot 30.1625) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$$

$$= 0.5839 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):

$$= 2.5 \cdot \text{Corroded Hub Thickness}$$

$$= 2.5 \cdot 17.0 \text{ Note: less than the hub height, use (e-2)}$$

$$= 42.5000 \text{ mm.}$$

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 0.855, 1.0 )$$

$$= 0.855$$

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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	7.836	2.430	NA
Area in Shell	A1	0.590	3.731	NA
Area in Nozzle Wall	A2	10.527	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.972	15.306	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]:

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

$$= ( 51.0342 * 14.001 * 1.0 + 2 * 17.0 * 14.001 * 1.0 * (1 - 0.86) )$$

$$= 7.836 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 64.0( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )$$

$$= 0.590 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 37.5 ) ( 17.0 - 0.58 ) 0.855$$

$$= 10.527 \text{ cm}^2$$

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

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

$$= 10.0^2 * 0.855 + ( 0.0 )^2 * 0.855$$

$$= 0.855 \text{ cm}^2$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

**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 = 17.0010 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 17.0010 mm.  
 Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 6.42, \max( 17.001, 4.5 ) ]$$

$$= 6.4200 \text{ mm.}$$

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

$$= \max( ta, tb )$$

$$= \max( 3.5839, 6.42 )$$

$$= 6.4200 \text{ mm.}$$

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 Nozzle Calcs.: LT3 Nozl: 32 1:34am Feb 7,2022

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME**

**B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.0,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle-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
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: LT3**

Intermediate Calc. for nozzle/shell Welds T<sub>min</sub> 15.0000 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]:

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

$$= \max( 0, (7.8355 - 0.5901 + 2 * 17.0 * 0.855 * (1.0 * 15.0 - 14.001) ) 138)$$

$$= 103.91 \text{ kN}$$

For hub type nozzles, A<sub>2</sub> includes the area of the hub.

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

Weld Load [W1]:  

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

$$= ( 10.5268 + 0.855 - 0.0 * 0.86 ) * 138$$

$$= 156.94 \text{ kN}$$

Weld Load [W2]:  

$$= ( A2 + A3 + A4 + (2(\text{Hub Thickness}) * t * fr1 ) ) * Sv$$

$$= ( 10.5268 + 0.0 + 0.855 + ( 4.3605 ) ) * 138$$

$$= 217.07 \text{ kN}$$

Weld Load [W3]:  

$$= (A2+A3+A4+(2*(\text{Hub Thickness})* t * fr1 ) ) * Sv$$

$$= ( 10.5268 + 0.0 + 0.855 + 0.0 ) * 138$$

$$= 217.07 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 118$$

$$= 55. \text{ kN}$$

Shear, Nozzle Wall [Snw]:  

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

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 118$$

$$= 123. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 55 + 123 ) = 177 \text{ kN}$$

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

$$= ( 55 + 0 + 145 + 0 ) = 200 \text{ kN}$$

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

$$= ( 55 + 145 + 0 ) = 200 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 177 kN , must exceed W = 103 kN or W1 = 156 kN  
 Path 2-2 = 199 kN , must exceed W = 103 kN or W2 = 217 kN  
 Path 3-3 = 199 kN , must exceed W = 103 kN or W3 = 217 kN

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

Converged Max. Allow. Pressure in Operating case 24.555 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

### Input Echo, WRC107/537 Item 1, Description: LT3 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical

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Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	85.034	mm.
Nozzle Thickness	Tn	20.000	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>
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

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

Note:

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

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

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 455.127 \text{ mm.}
 \end{aligned}$$

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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

-----  
 Curves read for 1979 Beta Figure Value Location

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Nozzle Calcs.: LT3

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N (PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N (PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M (PHI) / ( P )	0.044	2C1	0.146	(A,B)
M (PHI) / ( P )	0.044	1C	0.186	(C,D)
N (PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M (PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N (PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M (PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
N (x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N (x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M (x) / ( P )	0.044	1C1	0.192	(A,B)
M (x) / ( P )	0.044	2C	0.145	(C,D)
N (x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M (x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N (x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M (x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P		-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. ML		0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Bend. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5
-----									
Long. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML		-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
-----									
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
-----									
Str. Int.		41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl

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Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

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Nozzle Calcs.: LT2 Nozl: 33 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: LT2 From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3735.53	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		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L`	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

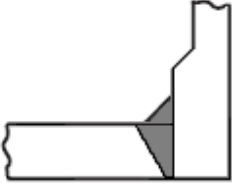
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Nozzle Calcs.: LT2

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**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT2**

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

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

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

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 30.1625) / (118 \cdot 1.0 + 0.4 \cdot 23.07)$$

$$= 0.5856 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):

$$= 2.5 \cdot \text{Corroded Hub Thickness}$$

$$= 2.5 \cdot 17.0 \text{ Note: less than the hub height, use (e-2)}$$

$$= 42.5000 \text{ mm.}$$

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 0.855, 1.0 )$$

$$= 0.855$$

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FileName : Calculation Book for Evaporator E-PK1601

Nozzle Calcs.: LT2

Noz1: 33 1:34am Feb 7,2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.859	2.430	NA
Area in Shell	A1	0.565	3.731	NA
Area in Nozzle Wall	A2	10.526	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.946	15.306	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 51.0342 * 14.043 * 1.0 + 2 * 17.0 * 14.043 * 1.0 * (1 - 0.86) ) \\
 &= 7.859 \text{ cm}^2
 \end{aligned}$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 64.0( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 17.0 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 ) \\
 &= 0.565 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 37.5 ) ( 17.0 - 0.59 ) 0.855 \\
 &= 10.526 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 0.855 + ( 0.0 )^2 * 0.855 \\
 &= 0.855 \text{ cm}^2
 \end{aligned}$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

Wall Thickness for Internal/External pressures  $ta = 3.5856 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 17.0430 \text{ mm.}$   
 Wall Thickness  $tb1 = \max(trb1, tr16b) = 17.0430 \text{ mm.}$   
 Wall Thickness, shell/head, external pressure  $trb2 = 3.6235 \text{ mm.}$   
 Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$   
 Wall Thickness per table UG-45  $tb3 = 6.4200 \text{ mm.}$

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 17.043, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.5856, 6.42 ) \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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 Nozzle Calcs.: LT2 Nozl: 33 1:34am Feb 7,2022

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME**

**B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle-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
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 = 23.07/51.10 = 0.451

*Note:*

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

**Weld Size Calculations, Description: LT2**

Intermediate Calc. for nozzle/shell Welds Tmin 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.

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

Weld Load [W]:

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

$$= \max( 0, (7.8591 - 0.5653 + 2 * 17.0 * 0.855 * (1.0 * 15.0 - 14.043) ) 138 )$$

$$= 104.41 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:  

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

$$= ( 10.5257 + 0.855 - 0.0 * 0.86 ) * 138$$

$$= 156.93 \text{ kN}$$

Weld Load [W2]:  

$$= ( A2 + A3 + A4 + (2(\text{Hub Thickness}) * t * fr1 ) ) * Sv$$

$$= ( 10.5257 + 0.0 + 0.855 + ( 4.3605 ) ) * 138$$

$$= 217.05 \text{ kN}$$

Weld Load [W3]:  

$$= (A2+A3+A4 + (2 * (\text{Hub Thickness}) * t * fr1 ) ) * Sv$$

$$= ( 10.5257 + 0.0 + 0.855 + 0.0 ) * 138$$

$$= 217.05 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 118$$

$$= 55. \text{ kN}$$

Shear, Nozzle Wall [Snw]:  

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

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 118$$

$$= 123. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 55 + 123 ) = 177 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  

$$= ( 55 + 0 + 145 + 0 ) = 200 \text{ kN}$$
  
 PATH33 = ( Sonw + Tngw + Sinw )  

$$= ( 55 + 145 + 0 ) = 200 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 177 kN , must exceed W = 104 kN or W1 = 156 kN  
 Path 2-2 = 199 kN , must exceed W = 104 kN or W2 = 217 kN  
 Path 3-3 = 199 kN , must exceed W = 104 kN or W3 = 217 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

### Input Echo, WRC107/537 Item 1, Description: LT2 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical

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Nozzle Calcs.: LT2 Nozl: 33 1:34am Feb 7,2022

Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	85.034	mm.
Nozzle Thickness	Tn	20.000	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>
Design Internal Pressure	Dp	23.068	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

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

Note:

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

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

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 455.127 \text{ mm.}
 \end{aligned}$$

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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

-----  
 Curves read for 1979 Beta Figure Value Location

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Nozzle Calcs.: LT2

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N (PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N (PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M (PHI) / ( P )	0.044	2C1	0.146	(A,B)
M (PHI) / ( P )	0.044	1C	0.186	(C,D)
N (PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M (PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N (PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M (PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
N (x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N (x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M (x) / ( P )	0.044	1C1	0.192	(A,B)
M (x) / ( P )	0.044	2C	0.145	(C,D)
N (x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M (x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N (x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M (x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P		-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. ML		0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Bend. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5
-----									
Long. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML		-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
-----									
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
-----									
Str. Int.		41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl

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Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	98.0	149.4	136.7	121.1	85.0	166.1	145.4	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.02	206.85	Passed
Pm+Pl+Q (TOTAL)	166.06	413.70	Passed

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Nozzle Calcs.: LT4 Nozl: 34 1:34am Feb 7,2022

**INPUT VALUES, Nozzle Description: LT4 From : 70**

Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4035.53	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		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L`	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

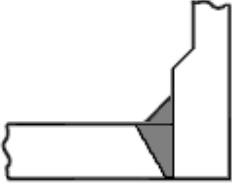
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Nozzle Calcs.: LT4

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**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT4**

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

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

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

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

$$= (23.07 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.07)$$

$$= 14.0430 \text{ mm.}$$

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

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

$$= (23.07 \cdot 30.1625) / (118 \cdot 1.0 + 0.4 \cdot 23.07)$$

$$= 0.5856 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):

$$= 2.5 \cdot \text{Corroded Hub Thickness}$$

$$= 2.5 \cdot 17.0 \text{ Note: less than the hub height, use (e-2)}$$

$$= 42.5000 \text{ mm.}$$

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

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 0.855, 1.0 )$$

$$= 0.855$$

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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	7.859	2.430	NA
Area in Shell	A1	0.565	3.731	NA
Area in Nozzle Wall	A2	10.526	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.946	15.306	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]:

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

$$= ( 51.0342 * 14.043 * 1.0 + 2 * 17.0 * 14.043 * 1.0 * (1 - 0.86) )$$

$$= 7.859 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

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

$$= 64.0 ( 1.0 * 15.0 - 1.0 * 14.043 ) - 2 * 17.0$$

$$( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 )$$

$$= 0.565 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 37.5 ) ( 17.0 - 0.59 ) 0.855$$

$$= 10.526 \text{ cm}^2$$

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

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

$$= 10.0^2 * 0.855 + ( 0.0 )^2 * 0.855$$

$$= 0.855 \text{ cm}^2$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

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

Wall Thickness for Internal/External pressures ta = 3.5856 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 17.0430 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 17.0430 mm.  
 Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 6.42, \max( 17.043, 4.5 ) ]$$

$$= 6.4200 \text{ mm.}$$

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

$$= \max( ta, tb )$$

$$= \max( 3.5856, 6.42 )$$

$$= 6.4200 \text{ mm.}$$

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Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME**

**B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

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

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

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle-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
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 = 23.07/51.10 = 0.451

*Note:*

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

**Weld Size Calculations, Description: LT4**

Intermediate Calc. for nozzle/shell Welds Tmin 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.

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

Weld Load [W]:

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

$$= \max( 0, (7.8591 - 0.5653 + 2 * 17.0 * 0.855 * (1.0 * 15.0 - 14.043) ) 138 )$$

$$= 104.41 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:  

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

$$= ( 10.5257 + 0.855 - 0.0 * 0.86 ) * 138$$

$$= 156.93 \text{ kN}$$

Weld Load [W2]:  

$$= ( A2 + A3 + A4 + (2(\text{Hub Thickness}) * t * fr1 ) ) * Sv$$

$$= ( 10.5257 + 0.0 + 0.855 + ( 4.3605 ) ) * 138$$

$$= 217.05 \text{ kN}$$

Weld Load [W3]:  

$$= (A2+A3+A4 + (2 * (\text{Hub Thickness}) * t * fr1 ) ) * Sv$$

$$= ( 10.5257 + 0.0 + 0.855 + 0.0 ) * 138$$

$$= 217.05 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 118$$

$$= 55. \text{ kN}$$

Shear, Nozzle Wall [Snw]:  

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

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 118$$

$$= 123. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:  

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

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 55 + 123 ) = 177 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  

$$= ( 55 + 0 + 145 + 0 ) = 200 \text{ kN}$$
  
 PATH33 = ( Sonw + Tngw + Sinw )  

$$= ( 55 + 145 + 0 ) = 200 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 177 kN , must exceed W = 104 kN or W1 = 156 kN  
 Path 2-2 = 199 kN , must exceed W = 104 kN or W2 = 217 kN  
 Path 3-3 = 199 kN , must exceed W = 104 kN or W3 = 217 kN

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

Converged Max. Allow. Pressure in Operating case 24.623 bars

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

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

### Input Echo, WRC107/537 Item 1, Description: LT4 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical

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Nozzle Calcs.: LT4

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Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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	85.034	mm.
Nozzle Thickness	Tn	20.000	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>
Design Internal Pressure	Dp	23.068	bars
Include Pressure Thrust		No	

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

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

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

**Note:**

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

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

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 455.127 \text{ mm.}
 \end{aligned}$$

## 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 = 55.90

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

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Curves read for 1979	Beta	Figure	Value	Location
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Nozzle Calcs.: LT4

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N (PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N (PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M (PHI) / ( P )	0.044	2C1	0.146	(A,B)
M (PHI) / ( P )	0.044	1C	0.186	(C,D)
N (PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M (PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N (PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M (PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
N (x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N (x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M (x) / ( P )	0.044	1C1	0.192	(A,B)
M (x) / ( P )	0.044	2C	0.145	(C,D)
N (x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M (x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N (x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M (x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P		-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. ML		0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Bend. ML		-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5
-----									
Long. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML		-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML		-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
-----									
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
-----									
Str. Int.		41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl

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Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	98.0	149.4	136.7	121.1	85.0	166.1	145.4	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.02	206.85	Passed
Pm+Pl+Q (TOTAL)	166.06	413.70	Passed

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**Nozzle Schedule:**

Flg	Nominal or	Schd	Flg	Nozzle	Wall	Reinforcing Pad	Cut			
Class	Actual	or FVC	Type	O/Dia	Thk	Diameter	Thk	Length		
Description	Size	Type		in	mm.	mm.	mm.	mm.		
D2	2.000 in	Actual	LWN	3.307	16.600	...	...	171.25	300	
D1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
D3	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
TT	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
V	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LG1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LG2	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LT1	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
LT3	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
LT2	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
LT4	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
S2	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
S1	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
S3	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
S4	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
T2	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	300	
T1	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	300	

*General Notes for the above table:*

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:  
 Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

**Nozzle Material and Weld Fillet Leg Size Details (mm.):**

	Shl Grve	Noz Shl/Pad	Pad OD	Pad Grve	Inside
--	----------	-------------	--------	----------	--------

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Description	Material	Weld	Weld	Weld	Weld	Weld
D2	SA-350 LF2	20.000	10.000	...	...	...
D1	SA-350 LF2	18.000	10.000	...	...	...
D3	SA-350 LF2	18.000	10.000	...	...	...
TT	SA-350 LF2	18.000	10.000	...	...	...
V	SA-350 LF2	18.000	10.000	...	...	...
LG1	SA-350 LF2	18.000	10.000	...	...	...
LG2	SA-350 LF2	18.000	10.000	...	...	...
LT1	SA-333 6	18.000	10.000	...	...	...
LT3	SA-333 6	18.000	10.000	...	...	...
LT2	SA-333 6	18.000	10.000	...	...	...
LT4	SA-333 6	18.000	10.000	...	...	...
S2	SA-333 6	18.000	10.000	14.000	18.000	...
S1	SA-333 6	18.000	10.000	14.000	18.000	...
S3	SA-333 6	18.000	10.000	14.000	18.000	...
S4	SA-333 6	18.000	10.000	14.000	18.000	...
T2	SA-516 70	15.000	18.000	12.000	15.000	...
T1	SA-516 70	15.000	18.000	12.000	15.000	...

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

**Nozzle Miscellaneous Data:**

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
D2	2035.525	270.0	150.00	0.00	CON
D1	4685.525	270.0	150.00	0.00	SHELL 002
D3	6085.525	270.0	150.00	0.00	SHELL 002
TT	6335.525	270.0	150.00	0.00	SHELL 002
V	2635.526	90.0	150.00	0.00	SHELL 002
LG1	4285.525	270.0	150.00	0.00	SHELL 002
LG2	4285.525	90.0	150.00	0.00	SHELL 002
LT1	3685.525	90.0	150.00	0.00	SHELL 002
LT3	3985.525	90.0	150.00	0.00	SHELL 002
LT2	3685.525	270.0	150.00	0.00	SHELL 002
LT4	3985.525	270.0	150.00	0.00	SHELL 002
S2	2985.525	270.0	150.00	0.00	SHELL 002
S1	5535.525	270.0	150.00	0.00	SHELL 002
S3	3185.525	90.0	150.00	0.00	SHELL 002
S4	5535.525	90.0	150.00	0.00	SHELL 002
T2	400.000	90.0	150.00	0.00	SHELL 001
T1	400.000	270.0	150.00	0.00	SHELL 001

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**Input Echo, Tubesheet Number 1, Description: TUBE SHEET**

**Shell Data:**

**Main Shell Description: SHELL 002**

Shell Maximum Design Pressure	Psd,max	23.00	bars
Shell Maximum Operating Pressure	Psox,max	23.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	20.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1200.000	mm.
Shell Temperature for Internal Pressure	Ts	125.00	°C
Shell Material		SA-516 70	

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm <sup>2</sup>
Shell Allowable Stress at Ambient		137.90	N./mm <sup>2</sup>

**Channel Description: SHELL 001**

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	23.00	bars
Channel Maximum Operating Pressure	Ptox,max	23.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	15.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	1200.000	mm.
Channel Design Temperature	TEMPC	125.00	°C
Channel Material		SA-516 70	

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm <sup>2</sup>
Channel Allowable Stress at Ambient		137.90	N./mm <sup>2</sup>

**Tube Data:**

Number of Tube Holes	Nt	1740	
Tube Wall Thickness	et	2.7700	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	4200.00	mm.
Straight Tube Length (bet. inner tubsht faces) L		4060.00	mm.
Design Temperature of the Tubes		125.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used	Smls. & wld. tube		
Tube Allowable Stress at Temperature		117.90	N./mm <sup>2</sup>
Tube Allowable Stress At Ambient		117.90	N./mm <sup>2</sup>
Tube Yield Stress At design Temperature	Syt	216.71	N./mm <sup>2</sup>
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Square	
Fillet Weld Leg	af	2.0000	mm.

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Groove Weld Leg	ag	2.0000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		f	
Radius to Outermost Tube Hole Center	ro	581.890	mm.
Largest Center-to-Center Tube Distance	Ul	57.8000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

**Tubesheet Data:**

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	125.00	°C
Tubesheet Material		SA-350 LF2	

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
Make sure that material properties at this temperature are not  
time-dependent for Material: SA-350 LF2

Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm <sup>2</sup>
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm <sup>2</sup>
Thickness of Tubesheet	h	140.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	1360.000	mm.

**Additional Data for Stepped Tubesheets:**

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	1266.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	1197.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	1266.00	mm.
Step 1 Depth on the Shellside	hs1	6.00	mm.
Step 2 Diameter on the Shellside	ds2	1197.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		1360.00	mm.

Note: Tubesheet diameter is now: 1360.000 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	1250.063	mm.
Area of the Untubed Lanes	AL	255.9	cm <sup>2</sup>
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Channel Side Min. Design Pressure	Ptd,min	1.0342	bars

**Additional Data for Gasketed Tubesheets:**

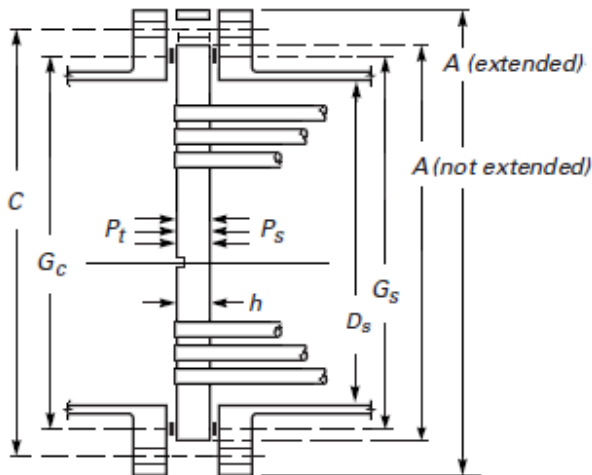
Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	1360.000	mm.
Flange Inside Diameter	B	1200.000	mm.
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.

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Small end Hub thk.	g0	20.0000	mm.
Large end Hub thk.	g1	23.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm <sup>2</sup>
Flange Facing Sketch	Code	Sketch 1a	
Column for Gasket Seating	Code	Column II	

**Tubesheet Gasketed With Shell and Channel**



**Configuration d:**

3.0000 mm.  
 Full face Gasket Flange Option

Gasket Thickness

tg

Program Selects

**Bolting Information:**

Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	TEMA	Thread Series	
Number of Bolts	n	72	
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm <sup>2</sup>
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm <sup>2</sup>
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		3266.36	kN
Alternate Flange Seating Bolt Load, Wm2		2157.58	kN
Alternate Flange Design Bolt Load, W		3310.52	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	118.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

**ASME TubeSheet Results per Part UHX, 2017**

**Elasticity/Expansion Material Properties :**

Shell - TM-1 Carbon Steels with C<= 0.3%

-----		
Elastic Mod. at Design Temperature	125.0 °C	0.19660E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

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Channel - TM-1 Carbon Steels with C<= 0.3%

-----  
 Elastic Mod. at Design Temperature 125.0 °C 0.19660E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20270E+09 KPa.

Tubes - TM-1 Carbon Steels with C<= 0.3%

-----  
 Elastic Mod. at Tubsht. Design Temp. 125.0 °C 0.19660E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20270E+09 KPa.

TubeSheet - TM-1 Carbon Steels with C> 0.3%

-----  
 Elastic Mod. at Design Temperature 125.0 °C 0.19522E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20132E+09 KPa.

**Tube Required Thickness under Internal Pressure (Tubeside pressure) :**

Thickness Due to Internal Pressure:

$$= (P*(D/2-CAE)) / (S*E+0.4*P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (23.0*(19.05/2-0.0))/(117.9*1.0+0.4*23.0)$$

$$= 0.1844 + 0.0000 = 0.1844 \text{ mm.}$$

**Tube Required Thickness under External Pressure (Shellside pressure) :**

External Pressure Chart CS-2 at 125.00 °C  
 Elastic Modulus for Material 199943392.00 KPa.

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.7700	19.05	4641.89	6.88	50.0000	0.0232575	122.73

$$\text{EMAWP} = (2.167/(D/T)-0.0833)*B = 284.4698 \text{ bars}$$

Results for Req'd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4839	19.05	4641.89	39.37	50.0000	0.0007098	70.97

$$\text{EMAWP} = (4*B)/(3*(D/T)) = (4*70.9667)/(3*39.3659) = 24.0352 \text{ bars}$$

**Summary of Tube Required Thickness Results:**

Total Required Thickness including Corrosion all.	0.4839 mm.
Allowable Internal Pressure at Corroded thickness	388.00 bars
Required Internal Design Pressure	23.00 bars
Allowable External Pressure at Corroded thickness	284.47 bars
Required External Design Pressure	24.03 bars
Required Thickness due to Shell Side pressure	0.4839 mm.

**Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)**

**Intermediate Calculations For Tubesheets Extended As Flanges:**

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

Gasket Contact Width,	$N = (Goc-Gic) / 2$	20.000 mm.
Basic Gasket Width,	$b0 = N / 2.0$	10.000 mm.
Effective Gasket Width,	$b = \text{SQRT}(b0) * 2.5$	7.966 mm.
Gasket Reaction Diameter,	$G = Go-2.0*b$	1250.068 mm.

**ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:**

$$= 2a + 6t/(m + 0.5)$$

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$$= 2 * 22.225 + 6 * 118.0 / (3.0 + 0.5)$$

$$= 246.736 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

$$= C * \sin(\pi / n)$$

$$= 1310.0 * \sin(3.142/72)$$

$$= 57.141 \text{ mm.}$$

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

$$= \max(\sqrt{Bs / (2a + t)}, 1)$$

$$= \max(\sqrt{57.141 / (2 * 22.225 + 118.0)}, 1)$$

$$= 1.0000$$

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

Distance Across Corners for Nuts 40.361 mm.  
Circular Wrench End Diameter a 60.325 mm.

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	188.817	194.632	

Flange Design Bolt Load, Seating Condition W : 3310.52 kN  
Flange Design Bolt Load, Operating Condition Wm1: 3254.46 kN

**Results for ASME U-tube Tubesheet Calculations for Configuration d,  
Per Edition 2017, Original Thickness :**

Minimum Required Thickness for Shear [HreqS]:

$$= 1 / (4 * \mu) * (Do / (0.8 * S)) * [Ps - Pt] + Cats + Catc$$

$$= 1 / (4 * 0.206) * (1182.83 / (0.8 * 137.9)) * [23.0 - 23.0] + 0.0$$

$$= 0.0000 \text{ mm.}$$

**UHX-12.5.1 Step 1:**

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

$$= 2 * ro + dt$$

$$= 2 * 581.89 + 19.05 = 1182.83 \text{ mm.}$$

Determine the Basic Ligament Efficiency for Shear [ $\mu$ ]:

$$= (p - dt) / p$$

$$= (24.0 - 19.05) / 24.0 = 0.206$$

**UHX-12.5.2 Step 2:**

Compute the Ratio [Rhos]:

$$= Gs / Do \text{ (Configurations d, e, f)}$$

$$= 1250.0685 / 1182.83 = 1.0568$$

Compute the Ratio [Rhoc]:

$$= Gc / Do \text{ (Configurations d)}$$

$$= 1250.0626 / 1182.83 = 1.0568$$

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

$$= Do^2 / 16 * [(Rhos - 1) * (Rhos^2 + 1) * Ps - (Rhoc - 1) * (Rhoc^2 + 1) * Pt]$$

$$= 1182.83^2 / 16 * [(1.057 - 1) * (1.057^2 + 1) * 23.0 -$$

$$(1.057 - 1) * (1.057^2 + 1) * 23.0]$$

$$= 22.5152 \text{ bars*mm.}^2$$

**UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :**

Compute the Ratio [ $\rho$ ]:

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$$= l_{tx}/h = 0.0/140.0 = 0.0 \text{ ( must be } 0 \leq \rho \leq 1 \text{ )}$$

Compute the Effective Tube Hole Diameter [d\*]:

$$\begin{aligned} &= \max( dt - 2tt * ( Et/E ) ( St/S ) ( \rho ), dt - 2tt ) \\ &= \max( 19.05 - 2 * 2.77 * (.19660E+09 / .19522E+09) * \\ &\quad ( 117/137 ) * (0.0 ), 19.05 - 2 * 2.77 ) \\ &= 19.0500 \text{ mm.} \end{aligned}$$

Compute the Effective Tube Pitch [p\*]:

$$\begin{aligned} &= p / \sqrt{ 1 - 4 * \min( AL * CNV\_factor, 4 * Do * p ) / ( \pi * Do^2 ) } \\ &= 24.0 / \sqrt{ 1 - 4 * \min( 255.94 * 100.0, 4 * 1182.83 * 24.0 ) \\ &\quad ( 3.141 * 1182.83^2 ) } \\ &= 24.2845 \text{ mm.} \end{aligned}$$

Compute the Effective Ligament Efficiency for Bending [mu\*]:

$$= (p^* - d^*)/p^* = (24.2845 - 19.05) / 24.2845 = 0.21555$$

E\*/E, nu\* for Square pattern from Fig. UHX-11.4.

$$\begin{aligned} h/p &= 5.833333 ; \mu^* = 0.215548 \\ E^*/E &= 0.251278 ; \nu^* = 0.335866 ; E^* = 49054772. \text{ KPa.} \end{aligned}$$

Note: As h/p (5.833) is > 2, data values for h/p = 2 were used.

**Skip Step 4 for Configuration d :**

**UHX-12.5.5 Step 5:**

Diameter ratio [K]:

$$= A/Do = 1360.0/1182.83 = 1.1498$$

Determine Coefficient [F]:

$$\begin{aligned} &= (1 - \nu^*)/E^* * ( E * \ln(K) ) \\ &= (1 - 0.34) / 49054772 * ( 0.19522E+09 * \ln(1.15) ) \\ &= 0.3689 \end{aligned}$$

**UHX-12.5.6 Step 6:**

Moment Acting on Unperforated Tubesheet Rim [M\*]

$$\begin{aligned} &= M_{ts} + W^* * (G_c - G_s) / (2 * \pi * Do) \\ &= 22.5 + 3266.4 * (1250.063 - 1250.063) / (2 * \pi * 1182.83) \\ &= 22.5152 \text{ bars*mm.}^2 \end{aligned}$$

Note: W\* is the maximum of the bolt loads between the shell and channel sides.

**UHX-12.5.7 Step 7:**

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

$$\begin{aligned} &= ((M^*) - Do^2/32 * F * (P_s - P_t)) / (1 + F) \\ &= ((22.52) - 1182.83^2/32 * 0.369 * (23.0 - 23.0)) / (1 + 0.37) \\ &= 16.4477 \text{ bars*mm.}^2 \end{aligned}$$

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

$$\begin{aligned} &= M_p + Do^2/64 * (3 + r_{\nu^*}) (P_s - P_t) \\ &= 16.45 + 1182.83^2/64 * (3 + 0.336) (23.0 - 23.0) \\ &= 16.4477 \text{ bars*mm.}^2 \end{aligned}$$

Maximum Bending Moment acting on Tubesheet [M]:

$$\begin{aligned} &= \max( \text{abs}(M_p), \text{abs}(M_o) ) \\ &= \max( \text{abs}(16.448), \text{abs}(16.448) ) \\ &= 16.4477 \text{ bars*mm.}^2 \end{aligned}$$

**UHX-12.5.8 Step 8:**

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Tubesheet Bending Stress at Original Thickness:

$$= 6 * M / ( (\mu^*) * ( h - hg' )^2 )$$

$$= 6 * 16.448 / ( ( 0.2155 ) * ( 140.0 - 5.0 )^2 )$$

$$= 0.0025 \text{ N./mm}^2$$

The Allowable Tubesheet Bending Stress [SigmaAll]:

$$= 2 * S = 2 * 137.9 = 275.8 \text{ N./mm}^2$$

Tubesheet Bending Stress at Final Thickness [Sigma]:

$$= 6 * M / ( (\mu^*) * ( h - hg' )^2 )$$

$$= 6 * 16.473 / ( ( 0.2155 ) * ( 0.508 - 5.0 )^2 )$$

$$= 2.2726 \text{ N./mm}^2$$

Required Tubesheet Thickness, for Bending Stress [HreqB]:

$$= H + CATS + CATC = 0.508 + 0.0 + 0.0 = 0.508 \text{ mm.}$$

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:

$$= \text{Max}( HreqB, HreqS ) = \text{Max}( 0.508, 0.0 ) = 0.508 \text{ mm.}$$

#### UHX-12.5.9 Step 9:

$$\text{abs}(Ps - Pt) = \text{abs}(23.0 - 23.0) = 0.0 \text{ bars}$$

Shear Stress check [Tau\_limit]:

$$= 3.2 * S * MU * h / Do$$

$$= 3.2 * 137.9 * 0.206 * 140.0 / 1182.83 = 107.72 \text{ bars}$$

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:

$$= 1 / (4 * Mu) * (Do/h) * [Ps - Pt]$$

$$= 1 / (4 * 0.206) * (1182.83 / 140.0) * [23.0 - 23.0] \text{ N./mm}^2$$

$$= 0.00 \text{ N./mm}^2$$

Note: Analysis Completed for Tubesheet Configuration d.

#### Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

$$= 3.1415 * t * ( do - t ) * Sa$$

$$= 3.1415 * 2.77 * ( 19.05 - 2.77 ) * 117.9 = 16.702 \text{ kN}$$

Fillet Weld Strength [Ff]:

$$= 0.55 * 3.1415 * af * ( do + 0.67 * af ) * Sw \text{ (but not } > Ft)$$

$$= 0.55 * 3.1415 * 2.0 * ( 19.05 + 0.67 * 2.0 ) * 117.9$$

$$= 8.3072 \text{ kN}$$

Groove Weld Strength [Fg]:

$$= 0.85 * 3.1415 * ag * ( do + 0.67 * ag ) * Sw \text{ (but not } > Ft)$$

$$= 0.85 * 3.1415 * 2.0 * ( 19.05 + 0.67 * 2.0 ) * 117.9$$

$$= 12.8384 \text{ kN}$$

Max. Allow. Tube-Tubesheet Joint load, Lmax

$$= Ft = 16.7023 \text{ kN}$$

Design Strength Ratio [fd]:

$$= 1.0000$$

Weld Strength Factor [fw]:

$$= Sot / ( \text{Min}(Sot, S) ) = 1.0000$$

Min Weld Length [ar]:

$$= 2 * ( ( (0.75 * do)^2 + 1.07 * t * (do - t) * fw * fd ) )^{1/2} - 0.75 * do$$

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= 3.1983 mm.

Minimum Required Fillet Weld Leg afr 1.5991 mm.  
 Minimum Required Groove Weld Leg agr 1.5991 mm.

Tube-Tubesheet Jt allowable, 16.7 is >= tube strength 16.7 kN  
 Note: This tube-tubesheet joint is a Full Strength joint

**Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):**

Stress Description	Actual	Allowable	Pass/Fail
Tubesheet bend. stress	0.0 <=	275.8 N./mm <sup>2</sup>	Ok
Tubesheet shear stress	0.0 <=	110.3 N./mm <sup>2</sup>	Ok

**Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):**

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	0.508	140.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.599	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.599	2.000	Ok

**U-Tube Tubesheet results per ASME UHX-12 2017**

**Results for 8 Load Cases:**

Case#	--Reqd. Thk. + CA Tbsht Extnsn	---- Tubesheet Bend Allwd	Stresses Shear Allwd	Case Type	Pass/ Fail
D1uc	131.418 33.068	242 276	24 110	Ps+Pt D1	Ok
D2uc	134.225 ...	253 276	25 110	Ps+Pt D2	Ok
D3uc	0.508 ...	... 276	... 110	Ps+Pt D3	Ok
D4uc	31.855 ...	11 276	1 110	Ps+Pt D4	Ok
D1c	134.407 33.068	253 276	25 110	Ps+Pt-c D1	Ok
D2c	137.218 ...	264 276	26 110	Ps+Pt-c D2	Ok
D3c	6.508 ...	... 276	... 110	Ps+Pt-c D3	Ok
D4c	34.828 ...	11 276	1 110	Ps+Pt-c D4	Ok
Max:	137.2176 33.068 mm.	0.958	0.233 (Str. Ratio)		

**Load Case Definitions:**

[Ps & Pt]:  
 Shell-side and Tube-side Design or Operating Pressures  
 derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the  
 Load Case Tables

[c]:  
 With or Without Corrosion Allowance

[D1, D2, D3]:  
 Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:  
 Design Load Case using the Minimum (Vacuum) Pressures (if specified)

**Summary of Thickness Comparisons for 8 Load Cases:**

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 ASME TS Calc: Case: 1 1:34a Feb 7,2022

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	137.218	140.000	Ok
Tubesheet Thickness Flanged Extension :	33.068	118.000	Ok
Tube Thickness :	0.484	2.770	Ok
Tube-Tubesheet Fillet Weld Leg :	1.599	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.599	2.000	Ok

Note: This is a full strength Tube to Tubesheet Joint.

**Tubesheet MAWP used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	25.080	1.000	25.080	1.000
Tubesheet Shear Stress	103.101	1.000	103.101	1.000
Tube Pressure Stress	387.995	1.000	284.469	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAWP	23.707		25.080	

**Tubesheet MAPnc used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	26.233	1.000	26.233	1.000
Tubesheet Shear Stress	107.717	1.000	107.717	1.000
Tube Pressure Stress	387.995	1.000	284.469	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAPnc	23.707		26.233	

**Tubesheet MDMT Calculations:**

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

**Determine the governing MDMT considering the governing condition:**

Governing thickness on the shell side per figure UCS-66.3 (c):  
 = tubesheet thickness/4  
 = 140.0/4  
 = 35.000 mm.

Note:  
 This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification -46 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:  
 = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1  
 = max( 23.0/23.71, 23.0/26.23 )  
 = 0.970

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**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
body flange 0	[11]	!	-46	-46		0.997	20.000	1.00	No
SHELL 002	[8]	!	-45			0.614	20.000	1.00	No
Tubesheet: SS	[13]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:			-45	-46					
BODY FLANGE 0	[11]	!	-46	-46		0.977	15.000	1.00	No
HEAD 001	[10]	!	-45			0.840	15.000	1.00	No
HEAD 001	[7]	!	-45			0.682	18.000	1.00	No
SHELL 001	[8]	!	-45			0.853	15.000	1.00	No
CON	[8]	!	-45			0.947	20.000	1.00	No
SHELL 002	[8]	!	-45			0.940	18.000	1.00	No
HEAD 002	[10]	!	-45			0.994	17.000	1.00	No
HEAD 002	[7]	!	-45			0.829	20.000	1.00	No
T2	[1]	D	-47	-48	-29	0.847	15.000	1.00	No
Nozzle Flg T1	[4]	D	-29	-104					
T1	[1]	D	-47	-48	-29	0.850	15.000	1.00	No
Nozzle Flg D2	[4]	D	-29	-104					
D2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg S2	[5]	!	-46	-48					
S2	[1]	D	-43	-46	-29	0.936	18.000	1.00	No
Nozzle Flg S1	[4]	!	-46	-104					
S1	[1]	D	-43	-46	-29	0.936	18.000	1.00	No
Nozzle Flg S3	[4]	!	-46	-104					
S3	[1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg D1	[4]	!	-46	-104					
D1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg D3	[5]	!	-46	-48					
D3	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg TT	[5]	!	-46	-48					
TT	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg V	[5]	!	-46	-104					
V	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg S4	[5]	!	-46	-48					
S4	[1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg LG1	[4]	!	-46	-104					
LG1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg LG2	[5]	!	-46	-48					
LG2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg LT1	[5]	!	-46	-48					
LT1	[1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg LT3	[4]	!	-46	-104					
LT3	[1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg LT2	[4]	!	-46	-104					
LT2	[1]	!	-46	-46		0.936	18.000	1.00	No
Nozzle Flg LT4	[4]	!	-46	-104					
LT4	[1]	!	-46	-46		0.936	18.000	1.00	No
Nozzle Flg Tubesheet: CS	[4]	!	-46	-104					
Tubesheet: CS	[14]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:			-29	-46					
Exchanger Side	Computed MDMT °C		Required MDMT °C		Pass/Fail				

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Shell	-45	-45	Pass
Channel/Tube	-45	-45	Pass

**Notes:**

- [ ! ] - This was an impact tested material.
- [ 1 ] - Governing Nozzle Weld.
- [ 4 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
- [ 5 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
- [ 6 ] - MDMT Calculations at the Shell/Head Joint.
- [ 7 ] - MDMT Calculations for the Straight Flange.
- [ 8 ] - Cylinder/Cone/Flange Junction MDMT.
- [ 9 ] - Calculations in the Spherical Portion of the Head.
- [10] - Calculations in the Knuckle Portion of the Head.
- [11] - Calculated (Body Flange) Flange MDMT.
- [12] - Calculated Flat Head MDMT per UCS-66.3
- [13] - Tubesheet MDMT, shell side, if applicable
- [14] - Tubesheet MDMT, tube side, if applicable
- [15] - Nozzle Material
- [16] - Shell or Head Material
- [17] - Impact Testing required
- [18] - Impact Testing not required, see UCS-66(b)(3)

UG-84(b)(2) was not considered.  
 UCS-66(g) was not considered.  
 UCS-66(i) was not considered.

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

Diameter Spec : 1200.000 x 1656.000 mm. ID  
 Vessel Design Length, Tangent to Tangent 6585.52 mm.  
 Specified Datum Line Distance 50.00 mm.  
 Shell Material SA-516 70 [Impact Tested]  
 Nozzle Material SA-350 LF2 [Impact Tested]  
 Nozzle Material SA-333 6 [Impact Tested]  
 Re-Pad Material SA-516 70 [Normalized]  
 Shell Side Design Temperature 125 °C  
 Channel Side Design Temperature 125 °C  
 Shell Side Design Pressure 23.000 bars  
 Channel Side Design Pressure 23.000 bars  
 Shell Side Hydrostatic Test Pressure 29.900 bars  
 Channel Side Hydrostatic Test Pressure 29.900 bars  
 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	23.083	1.034	27.484	3.0000	No
SHELL 001	23.083	1.034	27.034	3.0000	N/A
BODY FLANGE 001	23.083	1.034	23.624	3.0000	N/A
body flange 02	23.068	1.034	23.639	3.0000	N/A
SHELL 002	23.069	1.034	38.160	3.0000	N/A
CON	23.069	1.034	24.379	3.0000	N/A
SHELL 002	23.069	1.034	24.555	3.0000	N/A
HEAD 002	23.069	1.034	23.235	3.0000	No

Liquid Level: 1200.00 mm. Dens.: 0.001 kg./cm<sup>3</sup> Sp. Gr.: 0.581

**Element Types and Properties:**

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	Reqd Int.	Thk Ext.	Joint Eff Long	Joint Eff Circ
Ellipse	0.0	50.0	18.0	13.0	6.2	1.00	1.00
Cylinder	990.0	990.0	15.0	13.2	6.8	1.00	1.00
Body Flg	1145.0	155.0	110.0	107.7	79.3	1.00	1.00
Body Flg	1455.5	155.0	110.0	94.6	58.5	1.00	1.00
Cylinder	1655.5	200.0	20.0	13.2	10.2	1.00	1.00
Conical	2485.5	830.0	20.0	19.0	11.7	1.00	1.00
Cylinder	6485.5	4000.0	18.0	17.0	11.7	1.00	1.00
Ellipse	6535.5	50.0	20.0	16.9	7.4	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

**Saddle Parameters:**

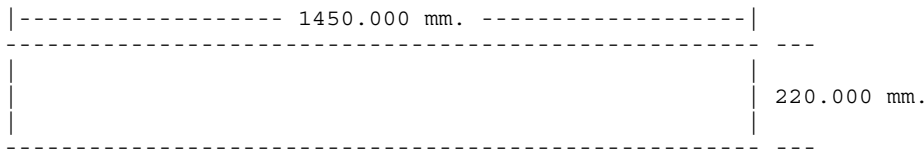
Saddle Width 172.000 mm.  
 Saddle Bearing Angle 120.000 deg.  
 Centerline Dimension 1374.000 mm.  
 Wear Pad Width 350.000 mm.

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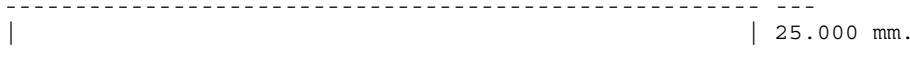
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Wear Pad Thickness	25.000	mm.
Wear Pad Bearing Angle	140.000	deg.
Distance from Saddle to Tangent	352.000	mm.
Baseplate Length	1450.000	mm.
Baseplate Thickness	25.000	mm.
Baseplate Width	220.000	mm.
Number of Ribs (including outside ribs)	5	
Rib Thickness	30.000	mm.
Web Thickness	30.000	mm.
Height of Center Web	720.000	mm.
Number of Bolts in Baseplate	4	

**Baseplate Sketch**



**Baseplate Plan View**



**Baseplate Side View**

Maximum Tensile Bolt Load 28. kN

**Summary of Maximum Saddle Loads, Operating Case :**

Maximum Vertical Saddle Load	515.32	kN
Maximum Transverse Saddle Shear Load	91.54	kN
Maximum Longitudinal Saddle Shear Load	183.07	kN

**Summary of Maximum Saddle Loads, Hydrotest Case :**

Maximum Vertical Saddle Load	188.25	kN
Maximum Transverse Saddle Shear Load	1.28	kN
Maximum Longitudinal Saddle Shear Load	0.99	kN

**Weights:**

Fabricated - Bare W/O Removable Internals	21983.0	kg.
Shop Test - Fabricated + Water ( Full )	35804.5	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	22466.0	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	22466.0	kg.
Empty - Fab. + Intls. + Details + Wghts.	22466.0	kg.
Operating - Empty + Operating Liquid (No CA)	29508.8	kg.
Field Test - Empty Weight + Water (Full)	35373.8	kg.

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#### Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Feb 07 01:05:45 2018.

- [Model Notes](#)
- [Load Case Report](#)
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- [ASME Code Stress Output Plots](#)
- [Stress Results - Notes](#)
- [ASME Overstressed Areas](#)
- [Highest Primary Stress Ratios](#)
- [Highest Secondary Stress Ratios](#)
- [Highest Fatigue Stress Ratios](#)
- [Highest Occasional Stress Ratios](#)
- [Stress Intensification Factors](#)
- [Allowable Loads](#)
- [Flexibilities](#)
- [Graphical Results](#)

---

Model Notes  
 Model Notes

Input Echo:

```

Model Type                : Cylindrical Shell

Parent Geometry
  Parent Outside Diam.    : 1230.000 mm.
  Thickness                : 12.000 mm.

Parent Properties:
  Cold Allowable          : 174.4 MPa
  Hot Allowable           : 156.5 MPa
  Material DB # 7005218.
  Ultimate Tensile (Amb)  : 482.6 MPa
  Yield Strength (Amb)    : 262.0 MPa
  Yield Strength (Hot)    : 235.1 MPa
  Elastic Modulus (Amb)   : 202720.0 MPa
  Poissons Ratio          : 0.300
  Expansion Coefficient   : 0.1227E-04 mm./mm./deg.
  Weight Density          : 0.0000E+00 N /cu.mm. (NOT USED)

Nozzle Geometry
  Nozzle Outside Diam.    : 508.000 mm.
  Thickness                : 17.000 mm.
  Length                  : 200.000 mm.
  
```

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RePad Width : 120.000 mm.  
 RePad Thickness : 20.000 mm.  
 Nozzle Tilt Angle : 0.000 deg.  
 Distance from Top : 495.000 mm.  
 Distance from Bottom : 495.000 mm.

Nozzle Properties

Cold Allowable : 174.4 MPa  
 Hot Allowable : 156.5 MPa  
 Material DB # 7005218.  
 Ultimate Tensile (Amb) : 482.6 MPa  
 Yield Strength (Amb) : 262.0 MPa  
 Yield Strength (Hot) : 235.1 MPa  
 Elastic Modulus (Amb) : 202720.0 MPa  
 Poissons Ratio : 0.300  
 Expansion Coefficient : 0.1227E-04 mm./mm./deg.  
 Weight Density : 0.0000E+00 N /cu.mm. (NOT USED)

Design Operating Cycles : 7000.  
 Ambient Temperature (Deg.) : 21.10

Uniform thermal expansion produces no stress in this geometry.  
 Any thermal loads will come through operating forces and moments applied through the nozzle.

Nozzle Inside Temperature : 125.00 deg.  
 Nozzle Outside Temperature : 125.00 deg.  
 Vessel Inside Temperature : 125.00 deg.  
 Vessel Outside Temperature : 125.00 deg.

Nozzle Pressure : 2.300 MPa  
 Vessel Pressure : 2.300 MPa

Operating Pressure : 2.3 MPa

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 1.000

User Defined Load Input Echo:

Loads are given at the End of Nozzle  
 Loads are defined in Global Coordinates

Forces( N ) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OPER:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OCC:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0

FEA Model Loads:

These are the actual loads applied to the FEA model.  
 These are the User Defined Loads translated to the end of the nozzle and reported in global coordinates.

Forces( N ) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OPER:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OCC:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle connection to the shell. This will produce conservative results for external loads and may tend to produce more realistic inside surface pressure stresses.

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No pad weld dimensions have been given for the pad connection to the shell. Few correlations have been performed to investigate the sensitivity of peak stresses to this value. Reasonable lengths have been assumed.

Vessel Centerline Vector : 0.000 1.000 0.000  
 Nozzle Orientation Vector : 1.000 0.000 0.000

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Load Case Report  
 FE/Pipe Version 10.0 Jobname: NOZZLE \$P  
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Load Case Report \$X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE 10 LOAD CASES ANALYZED ARE:

1 WEIGHT ONLY (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/----- Loads in Case 1  
 Loads due to Weight

2 SUSTAINED (Wgt+Pr)

Sustained case run to satisfy local primary membrane and bending stress limits.

/----- Loads in Case 2  
 Loads due to Weight  
 Pressure Case 1

3 OPERATING

Case run to compute the operating stresses used in secondary, peak and range calculations as needed.

/----- Loads in Case 3  
 Pressure Case 1  
 Loads from (Operating)

4 RANGE (Fatigue Calc Performed)

Case run to get the RANGE of stresses. as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

/----- Combinations in Range Case 4  
 Plus Stress Results from CASE 3  
 Minus Stress Results from CASE 1

5 OCCASIONAL

Occasional load case established per the requirements of the Code.

/----- Loads in Case 5  
 Loads due to Weight  
 Pressure Case 1  
 Loads from (Occasional)

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- 6 Program Generated -- Force Only  
Case run to compute sif's and flexibilities.  
/----- Loads in Case 6  
Loads from (Axial)
- 7 Program Generated -- Force Only  
Case run to compute sif's and flexibilities.  
/----- Loads in Case 7  
Loads from (Inplane)
- 8 Program Generated -- Force Only  
Case run to compute sif's and flexibilities.  
/----- Loads in Case 8  
Loads from (Outplane)
- 9 Program Generated -- Force Only  
Case run to compute sif's and flexibilities.  
/----- Loads in Case 9  
Loads from (Torsion)
- 10 Program Generated -- Force Only  
Case run to compute sif's and flexibilities.  
/----- Loads in Case 10  
Pressure Case 1

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Solution Data  
FE/Pipe Version 10.0 Jobname: NOZZLE \$P  
Released Nov 2017 1:05am FEB 7,2018

Solution Data

Maximum Solution Row Size = 594  
Number of Nodes = 1968  
Number of Elements = 648  
Number of Solution Cases = 9

Summation of Loads per Case

Case #	FX	FY	FZ
1	20000.	20002.	19999.
2	-9632.	2699605.	19999.
3	-9632.	2699605.	19999.
4	10368.	2719607.	39998.
5	3616029.	0.	0.
6	0.	20.	0.
7	0.	0.	-12.
8	0.	0.	0.
9	-29632.	2679603.	0.

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ASME Code Stress Output Plots  
FE/Pipe Version 10.0 Jobname: NOZZLE \$P  
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PV Elite 2018 SP2 Licensee: SPLM Licensed User

FileName : Calculation Book for Evaporator E-PK1601

Vessel Design Summary: Step: 36 1:10am Feb 7,2022

ASME Code Stress Output Plots

\$X

- 1) P1 < SPL (SUS,Membrane) Case 2
- 2) Qb < SPS (SUS,Bending) Case 2
- 3) P1+Pb+Q < SPS (SUS,Inside) Case 2
- 4) P1+Pb+Q < SPS (SUS,Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
- 6) P1+Pb+Q < SPS (OPE,Inside) Case 3
- 7) P1+Pb+Q < SPS (OPE,Outside) Case 3
- 8) Membrane < User (OPE,Membrane) Case 3
- 9) Bending < User (OPE,Bending) Case 3
- 10) S1+S2+S3 < 4S (OPE,S1+S2+S3) Case 3
- 11) P1+Pb+Q+F < Sa (SIF,Outside) Case 6
- 12) P1+Pb+Q+F < Sa (SIF,Outside) Case 7
- 13) P1+Pb+Q+F < Sa (SIF,Outside) Case 8
- 14) P1+Pb+Q+F < Sa (SIF,Outside) Case 9
- 15) P1+Pb+Q+F < Sa (SIF,Outside) Case 10
- 16) P1 < SPL (OCC,Membrane) Case 5
- 17) Qb < 3(Smh) (OCC,Bending) Case 5
- 18) P1+Pb+Q < SPS (OCC,Inside) Case 5
- 19) P1+Pb+Q < SPS (OCC,Outside) Case 5
- 20) P1+Pb+Q < SPS (EXP,Inside) Case 4
- 21) P1+Pb+Q < SPS (EXP,Outside) Case 4
- 22) P1+Pb+Q+F < Sa (EXP,Inside) Case 4
- 23) P1+Pb+Q+F < Sa (EXP,Outside) Case 4

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Stress Results - Notes  
FE/Pipe Version 10.0  
Released Nov 2017

Jobname: NOZZLE  
1:05am FEB 7,2018

\$P

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2013-2015 ASME Section VIII Division 2

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- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 1.000000  
Assume pressure increases all other stresses.
- Assume free end displacements of attached pipe  
(e.g. thermal loads) are secondary within the limits  
of nozzle reinforcement.
- Use Equivalent Stress (Von Mises).
- Include S1+S2+S3 evaluation for operating stress.  
Include S1+S2+S3 evaluation in primary case evaluation.  
Assume bending stress not local primary for S1+S2+S3.
- Use local tensor values for averaged and not  
averaged stresses.

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ASME Overstressed Areas  
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ASME Overstressed Areas \$X

\*\*\* NO OVERSTRESSED NODES IN THIS MODEL \*\*\*

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Highest Primary Stress Ratios  
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Highest Primary Stress Ratios \$X

Pad/Header at Junction

P1	SPL	Primary Membrane Load Case 2
153	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

64%

Branch at Junction

P1	SPL	Primary Membrane Load Case 2
160	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

68%

Branch Transition

P1	SPL	Primary Membrane Load Case 2
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## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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66	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

28%

## Pad Outer Edge Weld

P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
393	497	Plot Reference:
MPa	MPa	4) P1+Pb+Q < SPS (SUS,Outside) Case 2

78%

## Header Outside Pad Area

P1	SPL	Primary Membrane Load Case 2
129	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

54%

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## Highest Secondary Stress Ratios

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## Highest Secondary Stress Ratios \$X

## Pad/Header at Junction

P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
218	497	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5

43%

## Branch at Junction

P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
400	497	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5

80%

## Branch Transition

P1+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
121	497	Plot Reference:
MPa	MPa	18) P1+Pb+Q < SPS (OCC,Inside) Case 5

24%

## Pad Outer Edge Weld

P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
476	497	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5

95%

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Header Outside Pad Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
181	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

36%

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Highest Fatigue Stress Ratios

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Highest Fatigue Stress Ratios

\$X

Pad/Header at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
97	0.019 Life	Stress Concentration Factor = 1.350
MPa	0.336 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 371,369.
289.9		"B31" Fatigue Stress Allowable = 413.6
MPa		Mark1 Fatigue Stress Allowable = 287.5
33%		WRC 474 Mean Cycles to Failure = 836,769.
		WRC 474 99% Probability Cycles = 194,389.
		WRC 474 95% Probability Cycles = 269,885.
		BS5500 Allowed Cycles(Curve F) = 173,074.
		Membrane-to-Bending Ratio = 3.861
		Bending-to-PL+PB+Q Ratio = 0.206
		Plot Reference:
		22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Branch at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
96	0.017 Life	Stress Concentration Factor = 1.350
MPa	0.331 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 401,575.
289.9		"B31" Fatigue Stress Allowable = 413.6
MPa		Mark1 Fatigue Stress Allowable = 287.5
33%		WRC 474 Mean Cycles to Failure = 1,409,810.
		WRC 474 99% Probability Cycles = 327,512.
		WRC 474 95% Probability Cycles = 454,709.
		BS5500 Allowed Cycles(Curve F) = 241,319.
		Membrane-to-Bending Ratio = 1.861
		Bending-to-PL+PB+Q Ratio = 0.350
		Plot Reference:
		22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Branch Transition

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
47	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.164 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 9.7250E10
289.9		"B31" Fatigue Stress Allowable = 413.6
MPa		Mark1 Fatigue Stress Allowable = 287.5
16%		WRC 474 Mean Cycles to Failure = 5,483,744.
		WRC 474 99% Probability Cycles = 1,273,924.
		WRC 474 95% Probability Cycles = 1,768,682.
		BS5500 Allowed Cycles(Curve F) = 808,979.
		Membrane-to-Bending Ratio = 0.275

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Bending-to-PL+PB+Q Ratio = 0.785  
 Plot Reference:  
 23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Pad Outer Edge Weld

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
198	0.294 Life	Stress Concentration Factor = 1.350
MPa	0.683 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 23,811.
Allowable		"B31" Fatigue Stress Allowable = 413.6
289.9		Mark1 Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 195,969.
		WRC 474 99% Probability Cycles = 45,525.
68%		WRC 474 95% Probability Cycles = 63,206.
		BS5500 Allowed Cycles(Curve F) = 27,296.
		Membrane-to-Bending Ratio = 0.515
		Bending-to-PL+PB+Q Ratio = 0.660
		Plot Reference:
		23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
75	0.001 Life	Stress Concentration Factor = 1.000
MPa	0.258 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 10,560,117.
Allowable		"B31" Fatigue Stress Allowable = 413.6
289.9		Mark1 Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 1,502,322.
		WRC 474 99% Probability Cycles = 349,003.
25%		WRC 474 95% Probability Cycles = 484,547.
		BS5500 Allowed Cycles(Curve F) = 205,556.
		Membrane-to-Bending Ratio = 1.650
		Bending-to-PL+PB+Q Ratio = 0.377
		Plot Reference:
		22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

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Highest Occasional Stress Ratios

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Highest Occasional Stress Ratios

\$X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 5
169	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

71%

Qb	3(Smh)	Primary Bending Load Case 5
128	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

25%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
192	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

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38%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
218	497	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

43%

## Branch at Junction

Pl	SPL	Primary Membrane Load Case 5
199	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

84%

Qb	3(Smh)	Primary Bending Load Case 5
367	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

73%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
377	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

75%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
400	497	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

80%

## Branch Transition

Pl	SPL	Primary Membrane Load Case 5
84	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

35%

Qb	3(Smh)	Primary Bending Load Case 5
75	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

15%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
121	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

24%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
118	497	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

23%

## Pad Outer Edge Weld

Pl	SPL	Primary Membrane Load Case 5
162	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

69%

Qb	3(Smh)	Primary Bending Load Case 5
356	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

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71%

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 5  
 252 497 Plot Reference:  
 MPa MPa 18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

50%

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5  
 476 497 Plot Reference:  
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

95%

Header Outside Pad Area

Pl SPL Primary Membrane Load Case 5  
 144 235 Plot Reference:  
 MPa MPa 16) Pl < SPL (OCC,Membrane) Case 5

61%

Qb 3(Smh) Primary Bending Load Case 5  
 145 497 Plot Reference:  
 MPa MPa 17) Qb < 3(Smh) (OCC,Bending) Case 5

29%

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 5  
 181 497 Plot Reference:  
 MPa MPa 18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

36%

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5  
 152 497 Plot Reference:  
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

30%

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Stress Intensification Factors

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Stress Intensification Factors

\$X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	7.327	5.588	10.855	2.240
Inplane :	3.994	2.959	5.918	2.247
Outplane:	8.011	5.934	11.868	2.286
Torsion :	0.800	1.051	1.186	1.267
Pressure:	1.681	1.245	2.491	1.596

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal

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pressure stress in the PARENT or HEADER, calculated from PDo/2T. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

Pipe OD : 508.000 mm.  
 Pipe Thk: 17.000 mm.  
 Z approx: 3218855.250 cu.mm.  
 Z exact : 3114867.000 cu.mm.

(SSI = SIF^x) Axial Inpl Outpl Tors Pres  
 SIF/SSI Exponents: 0.864 0.783 0.856 -0.224 0.422

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 11.933  
 Header Pressure i-factor = 3.396

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

B31.3 (Branch)		
Peak Stress Sif ....	0.000	Axial
	5.513	Inplane
	6.879	Outplane
	1.000	Torsional
B31.1 (Branch)		
Peak Stress Sif ....	0.000	Axial
	6.879	Inplane
	6.879	Outplane
	6.879	Torsional
WRC 330 (Branch)		
Peak Stress Sif ....	0.000	Axial
	4.855	Inplane
	6.879	Outplane
	4.855	Torsional

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Allowable Loads  
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Allowable Loads \$X

SECONDARY	Maximum	Conservative	Realistic
Load Type (Range):	Individual	Simultaneous	Simultaneous
	Occuring	Occuring	Occuring
Axial Force ( N )	1037814.	175056.	262584.
Inplane Moment (mm. N )	226131072.	35770668.	75881040.
Outplane Moment (mm. N )	112755640.	13422793.	28474042.
Torsional Moment (mm. N )	1128424320.	119076232.	178614352.
Pressure (MPa )	3.37	2.30	2.30
PRIMARY	Maximum	Conservative	Realistic
Load Type:	Individual	Simultaneous	Simultaneous
	Occuring	Occuring	Occuring
Axial Force ( N )	1103191.	155554.	233331.
Inplane Moment (mm. N )	247503200.	29003524.	61525764.
Outplane Moment (mm. N )	123412416.	14462014.	30678564.
Torsional Moment (mm. N )	696742336.	110850176.	166275264.
Pressure (MPa )	3.68	2.30	2.30



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