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	<b>DEHDASHT PETROCHEMICAL INDUSTRY COMPANY</b>  <b>DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT</b>	
	DOCUMENT TITLE: Mechanical Calculation for Condenser	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0093	Rev. No.: D1

**DOCUMENT TITLE:**

**Mechanical Calculation for Condenser**

**(E-PK6101-2)**

<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.): E-PK6101-2
4	RJ: Rejected				
5	NR: Not be Returned				Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0093-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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15	x	x			
16	x	x			
17	x	x			
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59	x	x			
60	x	x			
61	x	x			
62	x	x			
63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			



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120	x	x			
121	x	x			
122	x	x			
123	x	x			
124	x	x			
125	x	x			
126	x	x			
127	x	x			
128	x	x			
129	x	x			
130	x	x			
131	x	x			
132	x	x			
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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155	x	x			
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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:CONDENSER E-PK6101-2

## **DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :  
Date of Analysis : Feb 6,2022 10:31pm

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:CONDENSER E-PK6101-2  
PV Elite 2018 SP2 Licensee: SPLM Licensed User  
FileName : Calculation Book for CONDENSER E-PK6101-2  
Warnings and Errors: Step: 0 10:31pm Feb 6,2022

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

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

There were no geometry errors or warnings.

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Tag no:CONDENSER E-PK6101-2

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FileName : Calculation Book for CONDENSER E-PK6101-2

Input Echo: Step: 1 10:31pm Feb 6,2022

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

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 Tag no:CONDENSER E-PK6101-2

**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	190.0	°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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FileName : Calculation Book for CONDENSER E-PK6101-2

Input Echo: Step: 1 10:31pm Feb 6,2022

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		1.300	
Short Period Acceleration value Ss		0.900	
Long Period Acceleration Value Sl		0.537	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		2.500	
Site Class		C	
Component Elevation Ratio	z/h	1.000	
Amplification Factor	Ap	2.500	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0 )		0.624	

Design Pressure + Static Head		Y
Consider MAP New and Cold in Noz. Design		N
Consider External Loads for Nozzle Des.		Y
Use ASME VIII-1 Appendix 1-9		N

Material Database Year Current w/Addenda or Code Year

**Configuration Directives:**

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No

Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes

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

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	HEAD 1	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1180	mm.
Element Thickness	13	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	15	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	

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FileName : Calculation Book for CONDENSER E-PK6101-2

Input Echo: Step: 1 10:31pm Feb 6,2022

Material Name	SA-516 70	[Normalized]
Allowable Stress, Ambient	137.9	N./mm <sup>2</sup>
Allowable Stress, Operating	137.9	N./mm <sup>2</sup>
Allowable Stress, 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	226.1	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
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	1180	mm.
Liquid Density	0.000994	kg./cm <sup>3</sup>

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 10	
Dist. from "FROM" Node / Offset dist	-295	mm.
Height/Length of Insulation	345	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	CHANNEL 01	
Distance "FROM" to "TO"	749	mm.
Inside Diameter	1180	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	120	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	120	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
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	1180	mm.
Liquid Density	0.000994	kg./cm <sup>3</sup>

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

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Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	749	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm <sup>3</sup>
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	375	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	1.6136	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T2	
Dist. from "FROM" Node / Offset dist	375	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	1.6136	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

-----

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	BODY FLANGE 01	
Distance "FROM" to "TO"	146	mm.
Flange Inside Diameter	1180	mm.
Element Thickness	110	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°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	214.16	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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Input Echo: Step: 1 10:31pm Feb 6,2022

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	1180	mm.
Liquid Density	0.000994	kg./cm <sup>3</sup>

Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	146	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	SHELL	
Distance "FROM" to "TO"	4844	mm.
Inside Diameter	1180	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	1.1	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	29.997	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	
Weld is pre-Heated	No	

Element From Node	40	
Detail Type	Saddle	
Detail ID	FIXED SADDLE	
Dist. from "FROM" Node / Offset dist	920	mm.
Width of Saddle	172	mm.
Height of Saddle at Bottom	950	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	305	mm.
Thickness of Wear Plate	15	mm.
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
-------------------	----	--

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 FileName : Calculation Book for CONDENSER E-PK6101-2

Input Echo: Step: 1 10:31pm Feb 6,2022

Detail Type	Saddle	
Detail ID	New Sd1	
Dist. from "FROM" Node / Offset dist	3920	mm.
Width of Saddle	172	mm.
Height of Saddle at Bottom	950	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	305	mm.
Thickness of Wear Plate	15	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1180	mm.
Liquid Density	0.000468	kg./cm <sup>3</sup>
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	4844	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm <sup>3</sup>
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	265	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 )	0.8717	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	4480	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	1.6205	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S3	
Dist. from "FROM" Node / Offset dist	265	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 )	0.1175	kN
Grade of Attached Flange	GR 1.1	

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Input Echo: Step: 1 10:31pm Feb 6,2022

Nozzle Matl	SA-350 LF2	[Impact Tested]
Element From Node	40	
Detail Type	Weight	
Detail ID	WEIGHT BAFFLE	
Dist. from "FROM" Node / Offset dist	2422	mm.
Miscellaneous Weight	2.9418	kN
Offset from Element Centerline	0	mm.

-----

Element From Node	50	
Element To Node	60	
Element Type	Flange	
Description	BODY FLANGE 002	
Distance "FROM" to "TO"	146	mm.
Flange Inside Diameter	1180	mm.
Element Thickness	110	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°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	214.16	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		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1180	mm.
Liquid Density	0.000994	kg./cm <sup>3</sup>

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	146	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm <sup>3</sup>

-----

Element From Node	60
Element To Node	70

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Input Echo: Step: 1 10:31pm Feb 6,2022

Element Type	Cylinder
Description	CHANNEL 002
Distance "FROM" to "TO"	299 mm.
Inside Diameter	1180 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	190 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	190 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Allowable Stress, Ambient	137.9 N./mm <sup>2</sup>
Allowable Stress, Operating	137.9 N./mm <sup>2</sup>
Allowable Stress, 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	226.1 N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	D
External Pressure Chart Name	CS-2
UNS Number	K02700
Product Form	Plate
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Weld is pre-Heated	No
Element From Node	60
Detail Type	Liquid
Detail ID	5
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	1180 mm.
Liquid Density	0.000994 kg./cm <sup>3</sup>
Element From Node	60
Detail Type	Insulation
Detail ID	Ins: 60
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	299 mm.
Thickness of Insulation	80 mm.
Density	0.00012 kg./cm <sup>3</sup>
Element From Node	60
Detail Type	Nozzle
Detail ID	T4
Dist. from "FROM" Node / Offset dist	150 mm.
Nozzle Diameter	0.75 in.
Nozzle Schedule	None
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.04826 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]
Element From Node	60
Detail Type	Nozzle
Detail ID	T3
Dist. from "FROM" Node / Offset dist	150 mm.
Nozzle Diameter	1 in.
Nozzle Schedule	None
Nozzle Class	300

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Input Echo: Step: 1 10:31pm Feb 6,2022

Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.05845 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	Elliptical
Description	HEAD 002
Distance "FROM" to "TO"	50 mm.
Inside Diameter	1180 mm.
Element Thickness	13 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	15 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	190 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	190 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	0.85
Elliptical Head Factor	2.0
Weld is pre-Heated	No

Element From Node	70
Detail Type	Liquid
Detail ID	6
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	1180 mm.
Liquid Density	0.000994 kg./cm <sup>3</sup>

Element From Node	70
Detail Type	Insulation
Detail ID	Ins: 70
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	345 mm.
Thickness of Insulation	80 mm.
Density	0.00012 kg./cm <sup>3</sup>

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 XY Coordinate Calculations: Step: 2 10:31pm Feb 6,2022

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		799	...	749	...
BODY FLANGE 01		945	...	146	...
SHELL		5875.17	...	4844	...
BODY FLANGE 002		6027.35	...	146	...
CHANNEL 002		6406.35	...	299	...
HEAD 002		6456.35	...	50	...

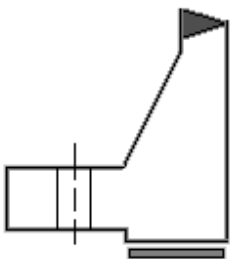
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 Flg Calc [Int P]: FLANGE Flng: 3 10:31pm Feb 6,2022

**Flange Input Data Values Description: FLANGE :**

**BODY FLANGE 01**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	bars
Design Temperature		190	°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	1180.000	mm.
Flange Outside Diameter	A	1350.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	gl	27.0000	mm.
Length of Hub	h	36.0000	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	1298.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		76	
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm <sup>2</sup>
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	1078.0000	mm.
Width of Partition Gasket	tp	10.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm <sup>2</sup>



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

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Flg Calc [Int P]: FLANGE Flng: 3 10:31pm Feb 6,2022

Hub Small End Required Thickness due to Internal Pressure:

$$= (P*(D/2+Ca))/(S*E-0.6*P) \text{ per UG-27 (c) (1)}$$

$$= (23.12*(1180.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca$$

$$= 13.0415 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0)$$

$$= 27.569 \text{ bars}$$

Corroded Flange Thickness, $t_c = T-ci$	107.000	mm.
Corroded Flange ID, $Bcor = B+2*Fcor$	1186.000	mm.
Corroded Large Hub, $g1Cor = g1-ci$	24.000	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, $b = Cb \text{ sqrt}(bo)$	7.969	mm.
Gasket Reaction Diameter, $G = Go - 2 * b$	1247.063	mm.

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

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * Peq$$

$$= 0.785 * 1247.0626^2 * 23.115$$

$$= 2823.246 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P$$

$$= 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.12$$

$$+ 2.0 * 1078.0 * 5.0 * 3.75 * 23.115$$

$$= 638.983 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= Pi * Bcor^2 * P / 4$$

$$= 3.1416 * 1186.0^2 * 23.115 / 4$$

$$= 2553.534 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - Hd$$

$$= 2823 - 2554$$

$$= 269.713 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(2823 + 639 + 0, 0)$$

$$= 3462.229 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * Pi * G + yPart * bPart * lp$$

$$= 62.05 * 7.9687 * 3.141 * 1247.063 + 62.05 * 5.0 * 1078.0$$

$$= 2271.524 \text{ kN}$$

Required Bolt Area [Am]:

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

$$= \text{Maximum of } 3462/172, 2272/172$$

$$= 200.872 \text{ cm}^2$$

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

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

$$= 2 * 22.225 + 6 * 107.0/(3.78 + 0.5)$$

$$= 194.450 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 1298.0 * \sin(3.142/76)$$

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Flg Calc [Int P]: FLANGE Flng: 3 10:31pm Feb 6,2022

= 53.640 mm.

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

= max( sqrt( Bs/( 2a + t ) ), 1 )  
 = max( sqrt( 53.64/( 2 \* 22.225 + 107.0 ) ), 1 )  
 = 1.0000

**Bolting Information for UNC Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	200.872	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	26.000	
Circumferential Spacing between the Bolt	52.400	53.640	194.450

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

= Ab \* Sa/( γ \* Pi \* (Go + Gi) )  
 = 205.445 \* 172.38/(62.05 \* 3.14 \* (1263.0 + 1223.0) )  
 = 7.307 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]:

= Sa \* ( Am + Ab ) / 2  
 = 172.38 \* ( 200.8716 + 205.4447 ) / 2  
 = 3501.64 kN

Gasket Load for the Operating Condition [HG]:

= Wm1 - H  
 = 3462 - 2823  
 = 638.98 kN

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

= ( C - G ) / 2  
 = ( 1298.0 - 1247.0626 ) / 2  
 = 25.4687 mm.

Distance to Face Pressure Reaction [ht]:

= ( R + g1 + hg ) / 2  
 = ( 32.0 + 24.0 + 25.4687 ) / 2  
 = 40.7344 mm.

Distance to End Pressure Reaction [hd]:

= R + ( g1 / 2 )  
 = 32.0 + ( 24.0 / 2.0 )  
 = 44.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2554.	44.0000	1.0000	112401.
Face Pressure, Mt	270.	40.7344	1.0000	10991.
Gasket Load, Mg	639.	25.4687	1.0000	16281.
Gasket Seating, Matm	3502.	25.4687	1.0000	89218.
Total Moment for Operation, Mop				139673. N-m
Total Moment for Gasket seating, Matm				89218. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			119.298 mm.	
Hub Ratio, h/h0 = HL / H0			0.302	

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Flg Calc [Int P]: FLANGE Flng: 3 10:31pm Feb 6,2022

Thickness Ratio,  $g1/g0 = (g1Cor/goCor)$  2.000

## Flange Factors for Integral Flange:

Factor F		0.870
Factor V		0.302
Factor f		2.068
Factors from Figure 2-7.1	K =	1.138
	T =	1.863
	U =	16.510
	Y =	15.024
	Z =	7.764
	d =	0.94014E+06 mm. <sup>3</sup>
	e =	0.0073 mm. <sup>-1</sup>
Stress Factors	ALPHA =	1.780
	BETA =	2.040
	GAMMA =	0.955
	DELTA =	1.303
	Lamda =	2.259

## Longitudinal Hub Stress, Operating [SHo]:

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

$$= (2.0679 * 139673 / 1186.0) / (2.2585 * 24.0^2)$$

$$= 187.14 \text{ N./mm}^2$$

## Longitudinal Hub Stress, Seating [SHa]:

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

$$= (2.0679 * 89218 / 1186.0) / (2.2585 * 24.0^2)$$

$$= 119.54 \text{ N./mm}^2$$

## Radial Flange Stress, Operating [SRo]:

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

$$= (2.0403 * 139673 / 1186.0) / (2.2585 * 107.0^2)$$

$$= 9.29 \text{ N./mm}^2$$

## Radial Flange Stress, Seating [SRa]:

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

$$= (2.0403 * 89218 / 1186.0) / (2.2585 * 107.0^2)$$

$$= 5.93 \text{ N./mm}^2$$

## Tangential Flange Stress, Operating [STo]:

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

$$= (15.0244 * 139673 / (107.0^2 * 1186.0)) - 7.764 * 9$$

$$= 82.37 \text{ N./mm}^2$$

## Tangential Flange Stress, Seating [STa]:

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

$$= (15.0244 * 89218 / (107.0^2 * 1186.0)) - 7.764 * 6$$

$$= 52.62 \text{ N./mm}^2$$

## Average Flange Stress, Operating [SAo]:

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

$$= (187 + \max(9, 82)) / 2$$

$$= 134.76 \text{ N./mm}^2$$

## Average Flange Stress, Seating [SAa]:

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

$$= (120 + \max(6, 53)) / 2$$

$$= 86.08 \text{ N./mm}^2$$

## Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 3462 / 205.4447$$

$$= 168.54 \text{ N./mm}^2$$

## Bolt Stress, Seating [BSa]:

$$= (Wm2 / Ab)$$

$$= (2272 / 205.4447)$$

$$= 110.58 \text{ N./mm}^2$$
Flange Stress Analysis Results: N./mm<sup>2</sup>

Operating | Gasket Seating |

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Flg Calc [Int P]: FLANGE Flng: 3 10:31pm Feb 6,2022

	Actual	Allowed	Actual	Allowed
Longitudinal Hub	187.	207.	120.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	82.	138.	53.	138.
Maximum Average	135.	138.	86.	138.
Bolting	169.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity] 108.737 mm.  
 Estimated M.A.W.P. ( Operating ) 23.641 bars  
 Estimated Finished Weight of Flange at given Thk. 310.1 kg.  
 Estimated Unfinished Weight of Forging at given Thk 382.2 kg.

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

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

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

$$= 52.14 * 89218.4/1.0 * 999.68 * 0.302 / ( 2.207 * 202713 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.608 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 139672.8/1.0 * 999.68 * 0.302 / ( 2.207 * 193088 * 12.0^2 * 119.298 * 0.3 )$$

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

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

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

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

$$= 52.14 * 89218.4/1.0 * 999.68 * 0.302 / ( 2.259 * 202713 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.595 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 139672.8/1.0 * 999.68 * 0.302 / ( 2.259 * 193088 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.977 \quad (\text{should be } \leq 1)$$

**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

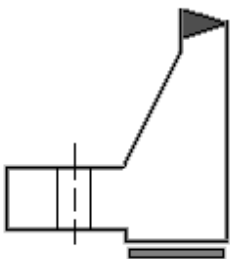
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 Flg Calc [Int P]: New Flange Flng: 4 10:31pm Feb 6,2022

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

**BODY FLANGE 002**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	bars
Design Temperature		190	°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	1180.000	mm.
Flange Outside Diameter	A	1346.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	gl	27.0000	mm.
Length of Hub	h	36.0000	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	1298.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		76	
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm <sup>2</sup>
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	1078.0000	mm.
Width of Partition Gasket	tp	10.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm <sup>2</sup>



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

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Flg Calc [Int P]: New Flange Flng: 4 10:31pm Feb 6,2022

Hub Small End Required Thickness due to Internal Pressure:

$$= (P*(D/2+Ca))/(S*E-0.6*P) \text{ per UG-27 (c) (1)}$$

$$= (23.12*(1180.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca$$

$$= 13.0415 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0)$$

$$= 27.569 \text{ bars}$$

Corroded Flange Thickness, $t_c = T-ci$	107.000	mm.
Corroded Flange ID, $Bcor = B+2*Fcor$	1186.000	mm.
Corroded Large Hub, $g1Cor = g1-ci$	24.000	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, $b = Cb \text{ sqrt}(bo)$	7.969	mm.
Gasket Reaction Diameter, $G = Go - 2 * b$	1247.063	mm.

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

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * Peq$$

$$= 0.785 * 1247.0626^2 * 23.115$$

$$= 2823.246 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P$$

$$= 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.12$$

$$+ 2.0 * 1078.0 * 5.0 * 3.75 * 23.115$$

$$= 638.983 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= Pi * Bcor^2 * P / 4$$

$$= 3.1416 * 1186.0^2 * 23.115 / 4$$

$$= 2553.534 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - Hd$$

$$= 2823 - 2554$$

$$= 269.713 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(2823 + 639 + 0, 0)$$

$$= 3462.229 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * Pi * G + yPart * bPart * lp$$

$$= 62.05 * 7.9687 * 3.141 * 1247.063 + 62.05 * 5.0 * 1078.0$$

$$= 2271.524 \text{ kN}$$

Required Bolt Area [Am]:

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

$$= \text{Maximum of } 3462/172, 2272/172$$

$$= 200.872 \text{ cm}^2$$

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

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

$$= 2 * 22.225 + 6 * 107.0/(3.78 + 0.5)$$

$$= 194.450 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 1298.0 * \sin(3.142/76)$$

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= 53.640 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:  
 = max( sqrt( Bs/( 2a + t ) ), 1 )  
 = max( sqrt( 53.64/( 2 \* 22.225 + 107.0 ) ), 1 )  
 = 1.0000

**Bolting Information for UNC Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	200.872	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	24.000	
Circumferential Spacing between the Bolt	52.400	53.640	194.450

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:  
 = Ab \* Sa/( γ \* Pi \* (Go + Gi) )  
 = 205.445 \* 172.38/(62.05 \* 3.14 \* (1263.0 + 1223.0) )  
 = 7.307 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]:  
 = Sa \* ( Am + Ab ) / 2  
 = 172.38 \* ( 200.8716 + 205.4447 ) / 2  
 = 3501.64 kN

Gasket Load for the Operating Condition [HG]:  
 = Wm1 - H  
 = 3462 - 2823  
 = 638.98 kN

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:  
 = ( C - G ) / 2  
 = ( 1298.0 - 1247.0626 ) / 2  
 = 25.4687 mm.

Distance to Face Pressure Reaction [ht]:  
 = ( R + g1 + hg ) / 2  
 = ( 32.0 + 24.0 + 25.4687 ) / 2  
 = 40.7344 mm.

Distance to End Pressure Reaction [hd]:  
 = R + ( g1 / 2 )  
 = 32.0 + ( 24.0 / 2.0 )  
 = 44.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2554.	44.0000	1.0000	112401.
Face Pressure, Mt	270.	40.7344	1.0000	10991.
Gasket Load, Mg	639.	25.4687	1.0000	16281.
Gasket Seating, Matm	3502.	25.4687	1.0000	89218.
Total Moment for Operation, Mop				139673. N-m
Total Moment for Gasket seating, Matm				89218. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)				119.298 mm.
Hub Ratio, h/h0 = HL / H0				0.302

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Flg Calc [Int P]: New Flange Flng: 4 10:31pm Feb 6,2022

Thickness Ratio,  $g1/g0 = (g1Cor/goCor)$  2.000

## Flange Factors for Integral Flange:

Factor F		0.870
Factor V		0.302
Factor f		2.068
Factors from Figure 2-7.1	K =	1.135
	T =	1.864
	U =	16.891
	Y =	15.370
	Z =	7.944
	d =	0.96179E+06 mm. <sup>3</sup>
	e =	0.0073 mm. <sup>-1</sup>
Stress Factors	ALPHA =	1.780
	BETA =	2.040
	GAMMA =	0.955
	DELTA =	1.274
	Lamda =	2.229

## Longitudinal Hub Stress, Operating [SHo]:

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

$$= (2.0679 * 139673 / 1186.0) / (2.2286 * 24.0^2)$$

$$= 189.66 \text{ N./mm}^2$$

## Longitudinal Hub Stress, Seating [SHa]:

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

$$= (2.0679 * 89218 / 1186.0) / (2.2286 * 24.0^2)$$

$$= 121.15 \text{ N./mm}^2$$

## Radial Flange Stress, Operating [SRo]:

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

$$= (2.0403 * 139673 / 1186.0) / (2.2286 * 107.0^2)$$

$$= 9.41 \text{ N./mm}^2$$

## Radial Flange Stress, Seating [SRa]:

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

$$= (2.0403 * 89218 / 1186.0) / (2.2286 * 107.0^2)$$

$$= 6.01 \text{ N./mm}^2$$

## Tangential Flange Stress, Operating [STo]:

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

$$= (15.3704 * 139673 / (107.0^2 * 1186.0)) - 7.9441 * 9$$

$$= 83.27 \text{ N./mm}^2$$

## Tangential Flange Stress, Seating [STa]:

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

$$= (15.3704 * 89218 / (107.0^2 * 1186.0)) - 7.9441 * 6$$

$$= 53.19 \text{ N./mm}^2$$

## Average Flange Stress, Operating [SAo]:

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

$$= (190 + \max(9, 83)) / 2$$

$$= 136.46 \text{ N./mm}^2$$

## Average Flange Stress, Seating [SAa]:

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

$$= (121 + \max(6, 53)) / 2$$

$$= 87.17 \text{ N./mm}^2$$

## Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 3462 / 205.4447$$

$$= 168.54 \text{ N./mm}^2$$

## Bolt Stress, Seating [BSa]:

$$= (Wm2 / Ab)$$

$$= (2272 / 205.4447)$$

$$= 110.58 \text{ N./mm}^2$$
Flange Stress Analysis Results: N./mm<sup>2</sup>

Operating | Gasket Seating |

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Flg Calc [Int P]: New Flange Flng: 4 10:31pm Feb 6,2022

	Actual	Allowed	Actual	Allowed
Longitudinal Hub	190.	207.	121.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	83.	138.	53.	138.
Maximum Average	136.	138.	87.	138.
Bolting	169.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity] 109.474 mm.  
 Estimated M.A.W.P. ( Operating ) 23.339 bars  
 Estimated Finished Weight of Flange at given Thk. 302.9 kg.  
 Estimated Unfinished Weight of Forging at given Thk 372.7 kg.

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

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

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

$$= 52.14 * 89218.4/1.0 * 999.68 * 0.302 / ( 2.207 * 202713 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.608 \text{ (should be } \leq 1 \text{)}$$

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

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

$$= 52.14 * 139672.8/1.0 * 999.68 * 0.302 / ( 2.207 * 193088 * 12.0^2 * 119.298 * 0.3 )$$

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

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

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

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

$$= 52.14 * 89218.4/1.0 * 999.68 * 0.302 / ( 2.229 * 202713 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.603 \text{ (should be } \leq 1 \text{)}$$

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

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

$$= 52.14 * 139672.8/1.0 * 999.68 * 0.302 / ( 2.229 * 193088 * 12.0^2 * 119.298 * 0.3 )$$

$$= 0.990 \text{ (should be } \leq 1 \text{)}$$

**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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#### 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 1		23.115	15	3	1180	137.9
CHANNEL 01		23.115	15	3	1180	117.21
BODY FLANGE 01		23.115	79	3	1180	137.9
SHELL		23.054	15	3	1180	137.9
BODY FLANGE 002		23.115	79	3	1180	137.9
CHANNEL 002		23.115	15	3	1180	137.9
HEAD 002		23.115	15	3	1180	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 1		23	No Calc	No Calc	13	12.8907
CHANNEL 01		23	No Calc	No Calc	15	14.8349
BODY FLANGE 01		23	No Calc	No Calc	110	108.737
SHELL		23	No Calc	No Calc	15	13.0149
BODY FLANGE 002		23	No Calc	No Calc	110	109.474
CHANNEL 002		23	No Calc	No Calc	15	13.0417
HEAD 002		23	No Calc	No Calc	13	12.8907

#### 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 = 40.431 bars  
 Shell Side MAPnc = 51.100 bars  
 Channel Side MAWP = 23.641 bars  
 Channel Side MAPnc = 23.641 bars

##### Note:

PV Elite could not compute the MAWP of one of the Flanges. Please check the reported MAWP by entering it as the design pressure and performing an extra analysis.

#### Internal Pressure Calculation Results :

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

##### Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 190 °C

##### HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

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Internal Pressure Calculations: Step: 5 10:31pm Feb 6,2022

$$= (23.115 * 1186.0 * 0.993) / (2 * 137.9 * 1.0 - 0.2 * 23.115)$$

$$= 9.8907 + 3.0000 = 12.8907 \text{ mm.}$$

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

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

$$= (23.115 * (0.993 * 1186.0 + 0.2 * 10.0)) / (2 * 1.0 * 10.0)$$

$$= 136.395 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.115 * 593.0) / (137.9 * 1.0 - 0.6 * 23.115) + 3.0$$

$$= 13.042 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.115 bars

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

$$= (137.9 * 1.0 * 12.0) / (593.0 + 0.6 * 12.0)$$

$$= 27.569 - 0.115 = 27.454 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (1186.0 / (2 * 298.0))^2) / 6$$

$$= 0.993306$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 * t_{nom} / R_f) * (1 - R_f / R_o)$  5.406 %

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

**MDMT Calculations in the Knuckle Portion:**

Govrn. thk,  $t_g = 13.0$ ,  $t_r = 9.891$ ,  $c = 3.0$  mm.,  $E^* = 1.0$

Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.989$ , Temp. Reduction = 1 °C

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

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

Govrn. thk,  $t_g = 15.0$ ,  $t_r = 10.042$ ,  $c = 3.0$  mm.,  $E^* = 1.0$

Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.837$ , 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

**Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 120 °C**

CHANNEL 01

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.115 * 593.0) / (137.9 * 0.85 - 0.6 * 23.115)$$

$$= 11.8349 + 3.0000 = 14.8349 \text{ mm.}$$

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

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

$$= (23.115 * (593.0 + 0.6 * 12.0)) / (0.85 * 12.0)$$

$$= 136.026 \text{ N./mm}^2$$

% Elongation per Table UG-79-1  $(50 * t_{nom} / R_f) * (1 - R_f / R_o)$  1.255 %

**Minimum Design Metal Temperature Results:**

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Govrn. thk, tg = 15.0, tr = 11.835, c = 3.0 mm., E\* = 0.85  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.838$ , 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

**Cylindrical Shell From 40 To 50 SA-516 70 at 125 °C**

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:  
 =  $(P * R) / (S * E - 0.6 * P)$  per UG-27 (c) (1)  
 =  $(23.054 * 593.0) / (137.9 * 1.0 - 0.6 * 23.054)$   
 =  $10.0149 + 3.0000 = 13.0149$  mm.

Actual stress at given pressure and thickness, corroded [Sact]:  
 =  $(P * (R + 0.6 * t)) / (E * t)$   
 =  $(23.054 * (593.0 + 0.6 * 12.0)) / (1.0 * 12.0)$   
 =  $115.317$  N./mm<sup>2</sup>

% Elongation per Table UG-79-1 ( $50 * t_{nom} / R_f * (1 - R_f / R_o)$ ) 1.255 %

**Minimum Design Metal Temperature Results:**

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

**Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 190 °C**

CHANNEL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:  
 =  $(P * R) / (S * E - 0.6 * P)$  per UG-27 (c) (1)  
 =  $(23.115 * 593.0) / (137.9 * 1.0 - 0.6 * 23.115)$   
 =  $10.0417 + 3.0000 = 13.0417$  mm.

Actual stress at given pressure and thickness, corroded [Sact]:  
 =  $(P * (R + 0.6 * t)) / (E * t)$   
 =  $(23.115 * (593.0 + 0.6 * 12.0)) / (1.0 * 12.0)$   
 =  $115.622$  N./mm<sup>2</sup>

% Elongation per Table UG-79-1 ( $50 * t_{nom} / R_f * (1 - R_f / R_o)$ ) 1.255 %

**Minimum Design Metal Temperature Results:**

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.837$ , 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

**Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 190 °C**

HEAD 002

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Required Thickness due to Internal Pressure [tr]:

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

$$= (23.115 \cdot 1186.0 \cdot 0.993) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.115)$$

$$= 9.8907 + 3.0000 = 12.8907 \text{ mm.}$$

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

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

$$= (23.115 \cdot (0.993 \cdot 1186.0 + 0.2 \cdot 10.0)) / (2 \cdot 1.0 \cdot 10.0)$$

$$= 136.395 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.115 \cdot 593.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.115) + 3.0$$

$$= 13.042 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.115 bars

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

$$= (137.9 \cdot 1.0 \cdot 12.0) / (593.0 + 0.6 \cdot 12.0)$$

$$= 27.569 - 0.115 = 27.454 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (1186.0 / (2 \cdot 298.0))^2) / 6$$

$$= 0.993306$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  5.406 %

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

#### MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 13.0, tr = 9.891, c = 3.0 mm., E\* = 1.0

Thickness Ratio =  $tr \cdot (E^*) / (tg - c) = 0.989$ , Temp. Reduction = 1 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E\* = 1.0

Thickness Ratio =  $tr \cdot (E^*) / (tg - c) = 0.837$ , 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

#### Hydrostatic Test Pressure Results:

##### Exchanger Shell Side Hydrostatic Test Pressures:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	52.560 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	66.430 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	44.474 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	52.560 bars

##### Exchanger Channel Side Hydrostatic Test Pressures:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.734 bars
--------------------	--------------------------	-------------

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Pressure per UG99b[36] = 1.30 \* Design Pres \* Sa/S 29.900 bars  
 Pressure per UG99c = 1.30 \* M.A.P. - Head(Hyd) 30.618 bars  
 Pressure per UG100 = 1.10 \* M.A.W.P. \* Sa/S 26.006 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 30.734 bars

UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:  
 = Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 23.0 \* 1.0  
 = 29.900 bars

UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:  
 = Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 23.0 \* 1.0  
 = 29.900 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 1	177.1	235.8	0.751	30.02
CHANNEL 01	176.6	235.8	0.749	30.02
SHELL	150.1	235.8	0.637	30.02
CHANNEL 002	150.1	235.8	0.637	30.02
HEAD 002	177.1	235.8	0.751	30.02

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1	Nozzle	117.90	117.90	1.000
T1	Pad	137.90	137.90	1.000
T2	Nozzle	117.90	117.90	1.000
T2	Pad	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	137.90	137.90	1.000
T4	Nozzle	137.90	137.90	1.000
T3	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
HEAD 1	137.90	137.90	1.000
CHANNEL 01	137.90	137.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	137.90	137.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	137.90	137.90	1.000
HEAD 002	137.90	137.90	1.000

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 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
T1	38.42	217.19	0.177
T2	38.42	217.19	0.177
S2	39.33	217.19	0.181
S1	38.42	217.19	0.177
S3	8.07	223.40	0.036
T4	5.14	223.40	0.023
T3	5.97	223.40	0.027

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	1206	10	0.0011516	82.603
20	30	897.333	1210	12	0.0018252	101.647
30	40	No Calc	...	107	No Calc	No Calc
40	50	4844	1210	12	0.00030147	30.1399
50	60	No Calc	...	107	No Calc	No Calc
60	70	447.333	1210	12	0.0039525	106.227
70	80	No Calc	1206	10	0.0011516	82.603

**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	13	6.26226	1.1	7.60993
20	30	15	6.49927	1.1	13.4402
30	40	110	69.7738	1.1	No Calc
40	50	15	10.0794	1.1	3.98521
50	60	110	70.2056	1.1	No Calc
60	70	15	5.65111	1.1	14.0457
70	80	13	6.26226	1.1	7.60993
Minimum					3.985

**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	897.333	19354.8	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	4844	102403	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	447.333	9164.93	No Calc	No Calc
70	80	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 190 °C**

**HEAD 1**

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
10.000	1206.00	120.60	0.0011516	82.60

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$$EMAP = B / (K0 * D / t) = 82.603 / (0.9 * 120.6) = 7.6099 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
3.262	1206.00	369.68	0.0003757	36.60

$$EMAP = B / (K0 * D / t) = 36.6032 / (0.9 * 369.6828) = 1.1001 \text{ bars}$$

*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]:

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

$$= (1.837 * 1186.0 * 0.993) / (2 * 137.9 * 1.0 - 0.2 * 1.837)$$

$$= 0.7848 + 3.0000 = 3.7848 \text{ mm.}$$

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

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

$$= ((2 * 137.9 * 1.0 * 10.0) / (0.993 * 1186.0 + 0.2 * 10.0)) / 1.67$$

$$= 13.994 \text{ bars}$$

Maximum Allowable External Pressure [MAEP]:

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

$$= \min(7.61, 13.9942)$$

$$= 7.610 \text{ bars}$$

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

### **Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 120 °C**

#### CHANNEL 01

Elastic Modulus from Chart: CS-2 at 120 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	897.33	100.83	0.7416	0.0018252	101.65

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 101.6474) / (3 * 100.8333) = 13.4402 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.499	1210.00	897.33	345.79	0.7416	0.0002854	28.53

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 28.5301) / (3 * 345.7867) = 1.1 \text{ bars}$$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	19354.77	100.83	15.9957	0.0001115	11.15

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 11.1462) / (3 * 100.8333) = 1.4738 \text{ bars}$$

### **Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 125 °C**

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	4844.00	100.83	4.0033	0.0003015	30.14

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 30.1399) / (3 * 100.8333) = 3.9852 \text{ bars}$$

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Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.079	1210.00	4844.00	170.92	4.0033	0.0001411	14.10

EMAP =  $(4*B)/(3*(D/t)) = (4*14.1022)/(3*170.9189) = 1.1$  bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	102403.33	100.83	50.0000	0.0001084	10.84

EMAP =  $(4*B)/(3*(D/t)) = (4*10.841)/(3*100.8333) = 1.4334$  bars

### **Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 190 °C**

#### CHANNEL 002

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	447.33	100.83	0.3697	0.0039525	106.23

EMAP =  $(4*B)/(3*(D/t)) = (4*106.2269)/(3*100.8333) = 14.0457$  bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.651	1210.00	447.33	456.41	0.3697	0.0003865	37.66

EMAP =  $(4*B)/(3*(D/t)) = (4*37.658)/(3*456.4122) = 1.1001$  bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	9164.93	100.83	7.5743	0.0001492	14.54

EMAP =  $(4*B)/(3*(D/t)) = (4*14.5391)/(3*100.8333) = 1.9224$  bars

### **Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 190 °C**

#### HEAD 002

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
10.000	1206.00	120.60	0.0011516	82.60

EMAP =  $B/(K0*D/t) = 82.603/(0.9 * 120.6) = 7.6099$  bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
3.262	1206.00	369.68	0.0003757	36.60

EMAP =  $B/(K0*D/t) = 36.6032/(0.9 * 369.6828) = 1.1001$  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]:

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

$$= (1.837*1186.0*0.993)/(2*137.9*1.0-0.2*1.837)$$

$$= 0.7848 + 3.0000 = 3.7848 \text{ mm.}$$

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

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

$$= ((2*137.9*1.0*10.0)/(0.993*1186.0+0.2*10.0))/1.67$$

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= 13.994 bars

Maximum Allowable External Pressure [MAEP]:

= min( MAEP, MAWP )  
= min( 7.61, 13.9942 )  
= 7.610 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: Step: 7 10:31pm Feb 6,2022

**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	220.523	269800	176.418	273656	11.0261
20	30	326.905	819244	262.18	827597	16.3452
30	40	310.101	160919	297.484	161321	15.505
40	50	2114.19	2809912	1695.59	2863930	105.709
50	60	302.88	160919	290.263	161321	15.144
60	70	130.5	327042	104.662	330376	6.525
70	80	220.523	269800	176.418	273656	11.0261
Total		3625	4817636.00	3003	4891856.00	181

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	268.112	-98.3333	-0.00004	1
10	Insl	22.6473	-122.5	...	Ins: 10
20	Liqd	814.119	374.5	...	2
20	Insl	29.1379	374.5	...	Ins: 20
20	Nozl	172.777	375	751.925	T1
20	Nozl	172.777	375	751.925	T2
30	Liqd	159.912	73	...	3
30	Insl	4.20609	73	...	Ins: 30
40	Sadl	203.713	920	755	FIXED SADDLE
40	Sadl	203.713	3920	755	New Sdl
40	Liqd	1314.7	2422	...	4
40	Insl	188.443	2422	...	Ins: 40
40	Nozl	93.335	265	699.537	S2
40	Nozl	173.514	4480	751.925	S1
40	Nozl	12.585	265	615.4	S3
40	Wght	300	2422	...	WEIGHT BAFFLE
50	Liqd	159.912	73	...	5
50	Insl	4.10815	73	...	Ins: 50
60	Liqd	324.995	149.5	...	5
60	Insl	11.6318	149.5	...	Ins: 60
60	Nozl	5.16718	150	599.525	T4
60	Nozl	6.25877	150	602.7	T3
70	Liqd	268.112	148.333	-0.00004	6
70	Insl	22.6473	172.5	...	Ins: 70
30	FTsh	597.512	192	...	TUBE SHEET
30	Tube	8226.77	2652	...	
30	RTsh	597.512	5112	...	

**Total Weight of Each Detail Type**

Total Weight of Saddles	407.4
Total Weight of Liquid	3309.9
Total Weight of Insulation	282.8
Total Weight of Nozzles	636.4
Total Weight of Weights	300.0

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Total Weight of Exchanger Components	9421.8
Total Weight of Liquid in Tubes	1089.5
-----	
Sum of the Detail Weights	15447.8 kg.

**Weight Summation: kg.**

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
3806.9	14572.5	3806.9	14572.5	3806.9	14855.3
407.4	4814.7	407.4	...	407.4	3309.9
636.4	...	636.4	...	...	...
...	1556.5	...	282.8	...	...
...	...	...	...	282.8	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	636.4	1089.5
9421.8	...	9421.8	...	...	...
300.0	...	300.0	...	...	...
...	...	...	...	9421.8	...
...	...	...	...	300.0	...
14572.5	20943.7	14572.5	14855.3	14855.3	19254.7

**Miscellaneous Weight Percent: 5.0 %**

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

**Weight Summary**

Fabricated Wt.	- Bare Weight W/O Removable Internals	14572.5 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	20943.7 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	14572.5 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	14855.3 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	14855.3 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	19254.7 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	18601.0 kg.
Field Test Wt.	- Empty Weight + Water (Full)	20647.0 kg.

**Exchanger Tube Data**

Volume of Exchanger tubes :	1557431.8 Cm3
Weight of Ope Liq in tubes :	1089.5 kg.
Weight of Water in tubes :	1556.5 kg.

**Note:**

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

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

**Outside Surface Areas of Elements:**

From	To	Surface Area cm^2
10	20	17771.3
20	30	28471.9
30	40	9438.89
40	50	184136

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50	60	9340.36
60	70	11366
70	80	17771.3

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Total 278296.031 cm<sup>2</sup>

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Nozzle Flange MAWP: Step: 8 10:31pm Feb 6,2022

**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
T1	46.0	51.1	120	300	GR 1.1	...	...	...	...
T2	46.0	51.1	120	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	...	...	...	...
T4	44.1	51.1	190	300	GR 1.1	...	...	...	...
T3	44.1	51.1	190	300	GR 1.1	...	...	...	...

**Shellside Flange Rating**

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

**Channelside Flange Rating**

Lowest Flange Pressure Rating was (Ope) [TubeSide ] : 44.060 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: 9 10:31pm Feb 6,2022

### 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] 0.570
Structure Height to Diameter ratio	5.196

*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  
 = 950.0 + 123000. = 123950. mm.  
 = 406.66 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z \text{ (406.66 ft.) } > 15 \text{ ft.} \\
 &= 2.01 * ( z / Zg ) ^ { 2 / \text{Alpha} } \\
 &= 2.01 * ( 406.66 / 900.0 ) ^ { 2 / 9.5 } \\
 &= 1.7
 \end{aligned}$$

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 \* 1.7 \* 1.0 \* 0.95 \* 124.278<sup>2</sup> )  
 = 63.9 psf [311.856] Kgs/m<sup>2</sup>

Force on the first element [F]:  
 = qz \* G \* Cf \* WindArea  
 = 63.872 \* 0.85 \* 0.57 \* 5.363  
 = 165.9 lbs. [ 0.7] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
HEAD 1	*****	0.000	0.000	0.000	1.700	1.000	311.856
CHANNEL 01	*****	0.000	0.000	0.000	1.700	1.000	311.856
BODY FLANGE 01	*****	0.000	0.000	0.000	1.700	1.000	311.856
SHELL	*****	0.000	0.000	0.000	1.700	1.000	311.856
BODY FLANGE 002	*****	0.000	0.000	0.000	1.700	1.000	311.856
CHANNEL 002	*****	0.000	0.000	0.000	1.700	1.000	311.856
HEAD 002	*****	0.000	0.000	0.000	1.700	1.000	311.856

**Wind Loads on Masses/Equipment/Piping**

ID	Wind Area cm <sup>2</sup>	Elevation mm.	Pressure Kgs/m <sup>2</sup>	Force kN
WEIGHT BAFFLE	0.00	125422.01	311.86	0.00

**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	123950	1639.2	4982.27	311.856	0.44286
20	30	123950	1644	12313.6	311.856	1.09451
30	40	123950	1608	2347.68	311.856	0.20868
40	50	123950	1644	79635.4	311.856	7.07852
50	60	123950	1608	2347.68	311.856	0.20868
60	70	123950	1644	4915.56	311.856	0.43693
70	80	123950	1639.2	4982.27	311.856	0.44286

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: 10 10:31pm Feb 6,2022

### Earthquake Load Calculation:

#### Input Values:

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

#### Seismic Analysis Results:

$$\begin{aligned}
 S_{ms} &= F_a * S_s = 1.0 * 0.9 = 0.9 \\
 S_{m1} &= F_v * S_1 = 1.3 * 0.537 = 0.698 \\
 S_{ds} &= 2/3 * S_{ms} = 2/3 * 0.9 = 0.6
 \end{aligned}$$

$$\begin{aligned}
 S_{ds} &= \text{Max}( 0.8 * S_{ds}, S_{dsUser} ) \\
 &= \text{Max}( 0.48, 0.624 ) \\
 &= 0.624
 \end{aligned}$$

$$S_{d1} = 2/3 * S_{m1} = 2/3 * 0.698 = 0.465$$

$$\begin{aligned}
 S_{d1} &= \text{Max}( 0.8 * S_{d1}, S_{d1User} ) \\
 &= \text{Max}( 0.372, 0.39 ) \\
 &= 0.390
 \end{aligned}$$

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

$$\begin{aligned}
 &= C_t * h_n^x \text{ where } C_t = 0.020, x = 0.75 \text{ and } h_n = \text{Structural Height (ft.)} \\
 &= 0.020 * ( 5.0525^{0.75} ) \\
 &= 0.067 \text{ seconds}
 \end{aligned}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

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

$$\begin{aligned}
 &= ( 1/\text{Natural Frequency} ) = ( 1/33.0 ) \\
 &= 0.030
 \end{aligned}$$

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

$$\begin{aligned}
 &= \text{Minimum Value of } ( 1.4 * 0.067, 0.03 ) \text{ per 12.8.2} \\
 &= 0.030
 \end{aligned}$$

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

$$\begin{aligned}
 &= 0.4 * A_p * S_{ds} * W * ( 1 + 2 * (z/h) ) / ( R / I_e ) \\
 &= 0.4 * 2.5 * 0.624 * 182 * ( 1 + 2 * 1.0 ) / ( 2.5 / 1.5 ) \\
 &= 204.873 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= 1.6 * S_{ds} * I * W \\
 &= 1.6 * 0.624 * 1.5 * 182 = 273.16 \text{ kN}
 \end{aligned}$$

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

$$= 0.3 * 0.62 * 1.5 * 182$$

$$= 51.218 \text{ kN}$$

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

$$= 204.873 \text{ kN}$$

Vertical load per 12.4-4, [YEq]:

$$= 0.2 * S_d_s * W$$

$$= 0.2 * 0.624 * 182 = 22.76 \text{ kN}$$

Final Base Shear,  $V = 143.41 \text{ kN}$

Final Vertical Load, YEq = 15.93 kN

#### Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	590	20.2668	15.9346
20	30	590	20.2668	15.9346
30	40	590	20.2668	15.9346
40	Sadl	590	20.2668	15.9346
Sadl	50	590	20.2668	15.9346
40	50	590	20.2668	15.9346
50	60	590	20.2668	15.9346
60	70	590	20.2668	15.9346
70	80	590	20.2668	15.9346

#### Note:

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

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 Center of Gravity Calculation: Step: 11 10:31pm Feb 6,2022

**Shop/Field Installation Options :**

Insulation is installed in the Field.

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

Center of Gravity of Saddles	3451.175 mm.
Center of Gravity of Liquid	2943.195 mm.
Center of Gravity of Insulation	3218.363 mm.
Center of Gravity of Nozzles	2061.410 mm.
Center of Gravity of Added Weights (Operating)	3453.175 mm.
Center of Gravity of Added Weights (Empty)	3453.175 mm.
Center of Gravity of Tubesheet(s)	3451.000 mm.
Center of Gravity of Tubes	3451.000 mm.
Center of Gravity of Bare Shell New and Cold	3241.814 mm.
Center of Gravity of Bare Shell Corroded	3246.094 mm.
Vessel CG in the Operating Condition	3274.865 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3335.716 mm.
Vessel CG in the Test Condition	3290.232 mm.

***Warning: CG of Vessel is too near or Outside the Lift Points!***

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 Horizontal Vessel Analysis (Ope.): Step: 12 10:31pm Feb 6,2022

### 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

#### Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	thetal	132.00	degrees
Wear Plate Thickness	tr	15.0	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		304.87	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	51.70	137.90
Long. Stress at Bottom of Midspan	63.25	137.90
Long. Stress at Top of Saddles	92.60	137.90
Long. Stress at Bottom of Saddles	38.01	137.90
-----	-----	-----
Tangential Shear in Shell	29.32	110.32
Circ. Stress at Horn of Saddle	42.43	172.37
Circ. Compressive Stress in Shell	6.35	137.90
-----	-----	-----

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 9.9/2 + 0 ) * 950.0/1037.4984$$

$$= 13.6 \text{ kN}$$

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

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

$$= \max( 2.53, 0.0, 0 ) * 950.0/3000.0$$

$$= 0.8 \text{ kN}$$

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

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

$$= \max( 143.41, 0.0, 0 ) * 950.0/3000.0$$

$$= 45.4 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * ( 143/2 + 0 ) * 950.0/1037.4984$$

$$= 197.0 \text{ kN}$$

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

$$\begin{aligned}
 &= \text{Saddle Load} + \text{Max}(F_{wl}, F_{wt}, F_{sl}, F_{st}) \\
 &= 108 + \text{Max}(0.8, 14, 45, 197) \\
 &= 304.9 \text{ kN}
 \end{aligned}$$

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

Vertical Load (including saddle weight)	306.86	kN
Transverse Shear Load Saddle	71.71	kN
Longitudinal Shear Load Saddle	143.41	kN

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

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

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

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

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]:

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{R^2 - h^2}{2aL} \right) / \left( 1 + \frac{4h^2}{3L} \right) \right] \\
 &= -305 \cdot 992.0 \left[ 1 - \left( 1 - \frac{992.0}{4844.0} + \frac{599.0^2 - 0.0^2}{2 \cdot 992.0 \cdot 4844.0} \right) / \left( 1 + \frac{4 \cdot 0.0}{3 \cdot 4844.0} \right) \right] \\
 &= -50663.4 \text{ N-m}
 \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left( 1 + \frac{4h^2}{3L} \right) - 4a/L \\
 &= \frac{305 \cdot 4844}{4} \left( 1 + 2 \frac{599^2 - 0^2}{4844^2} \right) / \left( 1 + \frac{4 \cdot 0}{3 \cdot 4844} \right) - 4 \cdot 992 / 4844 \\
 &= 78087.9 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 23.027 \cdot 599.0 / (2 \cdot 12.0) - 78087.9 / (\pi \cdot 599.0^2 \cdot 12.0) \\
 &= 51.70 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 23.027 \cdot 599.0 / (2 \cdot 12.0) + 78087.9 / (\pi \cdot 599.0^2 \cdot 12.0) \\
 &= 63.25 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 23.027 \cdot 599.0 / (2 \cdot 12.0) - 50663.4 / (0.1066 \cdot \pi \cdot 599.0^2 \cdot 12.0) \\
 &= 92.60 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1* \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 23.027 \cdot 599.0 / (2 \cdot 12.0) + 50663.4 / (0.1923 \cdot \pi \cdot 599.0^2 \cdot 12.0) \\
 &= 38.01 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{L + (4h^2/3)} \\
 &= \frac{305(4844.0 - 2 \cdot 992.0)}{4844.0 + (4 \cdot 0.0/3)} \\
 &= 180.0 \text{ kN}
 \end{aligned}$$

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

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$$= K2 * T / ( Rm * t )$$

$$= 1.1707 * 180.0 / ( 599.0 * 12.0 )$$

$$= 29.32 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

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

$$= 0.78 * \text{sqrt}( 599.0 * 12.0 )$$

$$= 66.130 \text{ mm.}$$

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

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

$$= - 0.7603 * 305 * 0.1 / ( 12.0 * ( 172.0 + 66.13 + 66.13 ) )$$

$$= -6.35 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \text{min}( 172.0 + 1.56 * \text{sqrt}( 599.0 * 12.0 ), 2 * 992.0 )$$

$$= 304.26 \text{ mm.}$$

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

$$= \text{min}( Sr/S, 1 )$$

$$= \text{min}( 137.9/137.9, 1 )$$

$$= 1.0000$$

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

$$= -K5 * Q * k / ( B1( t + eta * tr ) )$$

$$= - 0.7603 * 305 * 0.1 / ( 304.26( 12.0 + 1.0 * 15.0 ) )$$

$$= -2.82 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L&gt;=8Rm (4.15.27) [sigma7,r]:

$$= -Q / ( 4( t + eta * tr ) b1 ) - 3 * K7 * Q / ( 2( t + eta * tr )^2 )$$

$$= -305 / ( 4( 12.0 + 1.0 * 15.0 ) 304.26 ) -$$

$$3 * 0.053 * 305 / ( 2( 12.0 + 1.0 * 15.0 )^2 )$$

$$= -42.43 \text{ N./mm}^2$$

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

$$= \text{Alpha} * Ls * ( \text{Design Temperature} - \text{Ambient Temperature} )$$

$$= 0.000012 * 3000.0 * ( 125.0 - 21.1 )$$

$$= 3.822 \text{ mm.}$$

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

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

## Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

$$\text{Value } C1 = \text{Sumof}(Ay) / \text{Sumof}(A) = 132. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay) = 0.394E+05 \text{ cm}^4$$

$$\text{Value } As = \text{Sumof}(A) - \text{Ashell} = 136. \text{ cm}^2$$

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Horizontal Vessel Analysis (Ope.): Step: 12 10:31pm Feb 6,2022

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

$$F_h = K1 * Q = 0.2035 * 304.865 = 62.0467 \text{ kN}$$

$$\begin{aligned} \text{Tension Stress, } S_t &= (F_h / A_s) = 4.5543 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2 \end{aligned}$$

**Saddle Splitting Dimension [d]:**

$$\begin{aligned} &= B - R * \sin(\theta) / \theta \\ &= 950.0 - 593.0 * \sin(1.0472) / 1.0472 \\ &= 459.593 \text{ mm.} \end{aligned}$$

$$\text{Bending Moment, } M = F_h * d = 28527.7695 \text{ N-m}$$

$$\begin{aligned} \text{Bending Stress, } S_b &= (M * C1 / I) = 9.5776 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

**Minimum Thickness of Baseplate per Moss:**

$$\begin{aligned} &= (3(Q + \text{Saddle\_Wt}) \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2} \\ &= (3(305 + 2)220.0 / (4 * 1050.0 * 137.9))^{1/2} \\ &= 18.701 \text{ mm.} \end{aligned}$$

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

**Distance between Ribs [e]:**

$$\begin{aligned} &= \text{Web Length} / (\text{Nr ribs} - 1) \\ &= 1079.0676 / (4 - 1) \\ &= 359.689 \text{ mm.} \end{aligned}$$

**Baseplate Pressure Area [Ap]:**

$$\begin{aligned} &= e * B_{pwid} / 2 \\ &= 359.6892 * 220.0 / 2 \\ &= 395.658 \text{ cm}^2 \end{aligned}$$

**Axial Load [P]:**

$$\begin{aligned} &= A_p * B_p \\ &= 395.7 * 0.13 \\ &= 52.217 \text{ kN} \end{aligned}$$

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

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 23.55 + 26.977 \\ &= 50.527 \text{ cm}^2 \end{aligned}$$

**Compressive Stress [Sc]:**

$$\begin{aligned} &= P / A_r \\ &= 52.2 / 50.5267 \\ &= 10.336 \text{ N./mm}^2 \end{aligned}$$

**Check of Outside Ribs:**

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

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	15.0	172.0	...	25.8	...	636.

**Bending Moment [Rm]:**

$$\begin{aligned} &= F1 / (2 * B_{plen}) * e * r1 / 2 \\ &= 143.4 / (2 * 1050.0) * 359.689 * 619.79 / 2 \\ &= 7615.189 \text{ N-m} \end{aligned}$$

Compressive Allowable,  $KL/R < C_c$  ( 17.4685 < 138.1347 ) per AISC E2-1 [Sca]:

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$$\begin{aligned}
&= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3)) \\
&= (1 - (17.47)^2 / (2 * 138.13^2)) * 207 / \\
&\quad (5/3 + 3 * (17.47) / (8 * 138.13) - (17.47^3) / (8 * 138.13^3)) \\
&= 119.729 \text{ N./mm}^2
\end{aligned}$$

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

$$\begin{aligned}
&= Sc/Sca + ( Rm * Distance Side/I ) / Sba \\
&= 10.34/119.73 + ( 7615.19 * 86.0/6360561 ) / 137.9 \\
&= 0.833
\end{aligned}$$

Check of Inside Ribs:

**Inertia of Saddle, Inner Ribs - Axial Direction**

	B	D	Y	A	AY	Io
Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

Compressive Allowable, KL/R &lt; Cc ( 11.5546 &lt; 138.1347 ) per AISC E2-1 [Sca]:

$$\begin{aligned}
&= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3)) \\
&= (1 - (11.55)^2 / (2 * 138.13^2)) * 207 / \\
&\quad (5/3 + 3 * (11.55) / (8 * 138.13) - (11.55^3) / (8 * 138.13^3)) \\
&= 121.396 \text{ N./mm}^2
\end{aligned}$$

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

$$\begin{aligned}
&= Sc/Sca + ( Rm * Distance Center/I ) / Sba \\
&= 12.91/121.4 + ( 8195.84 * 86.0/645.75 ) / 137.9 \\
&= 0.898
\end{aligned}$$

**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	85.0 mm.
Nominal Bolt Diameter	Bnd	24.0000 mm.
Thread Series	Series	TEMA Metric
BasePlate Allowable Stress	S	108.25 N./mm <sup>2</sup>
Area Available in a Single Bolt	BlArea	3.1275 cm <sup>2</sup>
Saddle Load QO (Weight)	QO	109.9 kN
Saddle Load QL (Wind/Seismic contribution)	QL	45.4 kN
Maximum Transverse Force	Ft	71.7 kN
Maximum Longitudinal Force	F1	143.4 kN
Saddle Bolted to Steel Foundation		Yes

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

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

$$\begin{aligned}
&= F1 / (Stba * Nbolts) \\
&= 143.41 / (172.38 * 4.0) \\
&= 2.0801 \text{ cm}^2
\end{aligned}$$

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

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

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$$= 950.0 * 71.71 + 0.0$$

$$= 68148.02 \text{ N-m}$$

Eccentricity (e):

$$= R_{mom} / QO$$

$$= 68148.02 / 109.89$$

$$= 619.91 \text{ mm.} > B_{plen} / 6 \text{ --> Uplift in Transverse direction}$$

$$f = B_{plen} / 2 - E_{gedis}$$

$$= 1050.0 / 2 - 85.0$$

$$= 440.00 \text{ mm.}$$

$$K1 = 3 (e - 0.5 * B_{plen})$$

$$= 3 (619.91 - 0.5 * 1050.0)$$

$$= 284.73 \text{ mm.}$$

$$K2 = 6 * n1 * A_t / B_{pwid} * (f + e)$$

$$= 6 * 1.0 * 6.25 / 220.0 * (440.0 + 619.91)$$

$$= 18080.96 \text{ mm.}^2$$

$$K3 = -K2 * (0.5 * B_{plen} + f)$$

$$= -18080.96 * (0.5 * 1050.0 + 440.0)$$

$$= -17448129.25 \text{ mm.}^3$$

Iteratively Solving for the Effective Bearing Length:

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

$$Y^3 + 284.73 * Y^2 + 18080.96 * Y + -0.2E+08 = 0$$

$$Y = 175.97 \text{ mm.}$$

$$Num = (B_{plen} / 2 - Y / 3 - e)$$

$$= (1050.0 / 2 - 175.97 / 3 - 619.91)$$

$$= -153.57$$

$$Denom = (B_{plen} / 2 - Y / 3 + f)$$

$$= (1050.0 / 2 - 175.97 / 3 + 440.0)$$

$$= 906.34$$

Total Bolt Tension Force [Tforce]:

$$= -QO * Num / Denom$$

$$= -109.89 * -153.57 / 906.34$$

$$= 18.62 \text{ kN}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$= Tforce / (Stba * Nbt)$$

$$= 18.62 / (172.38 * 2.0)$$

$$= 0.5401 \text{ cm}^2$$

Required Area of a Single Bolt [Bltarear]:

$$= \max[Bltarearl, Bltarears, Bltareart]$$

$$= \max[0.0, 2.0801, 0.5401]$$

$$= 2.0801 \text{ cm}^2$$

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

Bearing Pressure (fc)

$$= 2(QO + Tforce) / (Y * B_{pwid})$$

$$= 2(109.89 + 18.62) / (175.97 * 220.0)$$

$$= 66.39 \text{ bars}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$= (B_{plen} - Weblngth) / 2$$

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$$= (1050.0 - 999.2) / 2$$

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

Overturning Moment due To Bolt Tension [Mt]:

$$= Tforce * Adist$$

$$= 18.62 * 25.4$$

$$= 473.11 \text{ N-m}$$

Equivalent Bearing Pressure (f1):

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

$$= 66.39 * (175.97 - 25.4) / 175.97$$

$$= 56.81 \text{ bars}$$

Overturning Moment due to Bearing Pressure [Mc]:

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

$$= (25.4^2 * 220.0 / 6) * (56.81 + 2 * 66.39)$$

$$= 448.65 \text{ N-m}$$

Baseplate Required Thickness [Treq]:

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

$$= (6 * \max(473.11, 448.65) / (220.0 * 162.38))^{1/2}$$

$$= 8.9128 \text{ mm.}$$

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

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

#### Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	15.0	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		283.43	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----	-----	-----
Long. Stress at Top of Midspan	38.57	137.90
Long. Stress at Bottom of Midspan	76.38	137.90
Long. Stress at Top of Saddles	55.05	137.90
Long. Stress at Bottom of Saddles	58.82	137.90
-----	-----	-----
Tangential Shear in Shell	39.57	110.32
Circ. Stress at Horn of Saddle	19.92	172.37
Circ. Compressive Stress in Shell	5.90	137.90
-----	-----	-----

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

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Saddle Reaction Force due to Wind Ft [Fwt]:  
 $= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$   
 $= 3.0 * ( 9.9/2 + 0 ) * 950.0/1037.4984$   
 $= 13.6 \text{ kN}$

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:  
 $= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s$   
 $= \max( 2.53, 0.0, 0 ) * 950.0/3000.0$   
 $= 0.8 \text{ kN}$

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:  
 $= \max( F_l, \text{Friction Force, Sum of X Forces} ) * B / L_s$   
 $= \max( 143.41, 0.0, 0 ) * 950.0/3000.0$   
 $= 45.4 \text{ kN}$

Saddle Reaction Force due to Earthquake Ft [Fst]:  
 $= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$   
 $= 3.0 * ( 143/2 + 0 ) * 950.0/1037.4984$   
 $= 197.0 \text{ kN}$

Load Combination Results for Q + Wind or Seismic [Q]:  
 $= \text{Saddle Load} + \max( F_{wl}, F_{wt}, F_{sl}, F_{st} )$   
 $= 86 + \max( 0.8, 14, 45, 197 )$   
 $= 283.4 \text{ kN}$

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

Vertical Load (including saddle weight)	285.42	kN
Transverse Shear Load Saddle	71.71	kN
Longitudinal Shear Load Saddle	143.41	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 = 0.0194	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0159			

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]:  
 $= -Q * a [ 1 - ( 1 - a/L + (R^2 - h^2) / (2a * L) ) / ( 1 + (4h^2) / (3L) ) ]$   
 $= -283 * 346.0 [ 1 - ( 1 - 346.0/4844.0 + (599.0^2 - 0.0^2) / (2 * 346.0 * 4844.0) ) / ( 1 + (4 * 0.0) / (3 * 4844.0) ) ]$   
 $= 3493.6 \text{ N-m}$

Moment per Equation 4.15.4 [M2]:  
 $= Q * L / 4 ( 1 + 2 ( R^2 - h^2 ) / ( L^2 ) ) / ( 1 + ( 4h^2 ) / ( 3L ) ) - 4a / L$   
 $= 283 * 4844 / 4 ( 1 + 2 ( 599^2 - 0^2 ) / ( 4844^2 ) ) / ( 1 + ( 4 * 0 ) / ( 3 * 4844 ) ) - 4 * 346 / 4844$   
 $= 255763.7 \text{ N-m}$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:  
 $= P * R_m / ( 2t ) - M_2 / ( \pi * R_m^2 t )$   
 $= 23.027 * 599.0 / ( 2 * 12.0 ) - 255763.7 / ( \pi * 599.0^2 * 12.0 )$   
 $= 38.57 \text{ N./mm}^2$

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

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

$$= 23.027 * 599.0 / (2 * 12.0) + 255763.7 / (\pi * 599.0^2 * 12.0)$$

$$= 76.38 \text{ N./mm}^2$$

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

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

$$= 23.027 * 599.0 / (2 * 12.0) - 3493.6 / (0.1066 * \pi * 599.0^2 * 12.0)$$

$$= 55.05 \text{ N./mm}^2$$

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

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

$$= 23.027 * 599.0 / (2 * 12.0) + 3493.6 / (0.1923 * \pi * 599.0^2 * 12.0)$$

$$= 58.82 \text{ N./mm}^2$$

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

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

$$= 283(4844.0 - 2 * 346.0) / (4844.0 + (4 * 0.0 / 3))$$

$$= 242.9 \text{ kN}$$

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

$$= K2 * T / (Rm * t)$$

$$= 1.1707 * 242.94 / (599.0 * 12.0)$$

$$= 39.57 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

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

$$= 0.78 * \sqrt{599.0 * 12.0}$$

$$= 66.130 \text{ mm.}$$

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

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

$$= -0.7603 * 283 * 0.1 / (12.0 * (172.0 + 66.13 + 66.13))$$

$$= -5.90 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min(172.0 + 1.56 * \sqrt{599.0 * 12.0}, 2 * 346.0)$$

$$= 304.26 \text{ mm.}$$

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

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

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

$$= 1.0000$$

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

$$= -K5 * Q * k / (B1(t + \eta * tr))$$

$$= -0.7603 * 283 * 0.1 / (304.26(12.0 + 1.0 * 15.0))$$

$$= -2.62 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:

$$= -Q / (4(t + \eta * tr)b1) - 3 * K7 * Q / (2(t + \eta * tr)^2)$$

$$= -283 / (4(12.0 + 1.0 * 15.0)304.26) -$$

$$3 * 0.019 * 283 / (2(12.0 + 1.0 * 15.0)^2)$$

$$= -19.92 \text{ N./mm}^2$$

### Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	

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Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

## Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

Value C1 = Sumof (Ay) / Sumof (A) = 132. mm.  
 Value I = Sumof (Io) - C1\*Sumof (Ay) = 0.394E+05 cm\*\*4  
 Value As = Sumof (A) - Ashell = 136. cm^2

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

$$Fh = K1 * Q = 0.2035 * 283.426 = 57.6833 \text{ kN}$$

Tension Stress, St = ( Fh/As ) = 4.2340 N./mm^2  
 Allowed Stress, Sa = 0.6 \* Yield Str = 124.1100 N./mm^2

## Saddle Splitting Dimension [d]:

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

$$= 950.0 - 593.0 * \sin(1.0472) / 1.0472$$

$$= 459.593 \text{ mm.}$$

$$\text{Bending Moment, M} = Fh * d = 26521.5703 \text{ N-m}$$

Bending Stress, Sb = ( M \* C1 / I ) = 8.9041 N./mm^2  
 Allowed Stress, Sa = 2/3 \* Yield Str = 137.9000 N./mm^2

## Minimum Thickness of Baseplate per Moss:

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

$$= ( 3(283 + 2)220.0 / ( 4 * 1050.0 * 137.9 ) )^{1/2}$$

$$= 18.036 \text{ mm.}$$

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

## Distance between Ribs [e]:

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

$$= 1079.0676 / ( 4 - 1 )$$

$$= 359.689 \text{ mm.}$$

## Baseplate Pressure Area [Ap]:

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

$$= 359.6892 * 220.0 / 2$$

$$= 395.658 \text{ cm}^2$$

## Axial Load [P]:

$$= Ap * Bp$$

$$= 395.7 * 0.12$$

$$= 48.545 \text{ kN}$$

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

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

$$= 23.55 + 26.977$$

$$= 50.527 \text{ cm}^2$$

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## Compressive Stress [Sc]:

$$= P/Ar$$

$$= 48.5/50.5267$$

$$= 9.609 \text{ N./mm}^2$$

Check of Outside Ribs:

## Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

## Bending Moment [Rm]:

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

$$= 143.4 / ( 2 * 1050.0 ) * 359.689 * 619.79 / 2$$

$$= 7615.189 \text{ N-m}$$

Compressive Allowable,  $KL/R < Cc$  ( 17.4685 < 138.1347 ) per AISC E2-1 [Sca]:

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

$$= ( 1 - ( 17.47 )^2 / ( 2 * 138.13^2 ) ) * 207 /$$

$$( 5/3 + 3 * (17.47) / (8 * 138.13) - ( 17.47^3 ) / (8 * 138.13^3) )$$

$$= 119.729 \text{ N./mm}^2$$

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

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

$$= 9.61/119.73 + ( 7615.19 * 86.0/6360561 ) / 137.9$$

$$= 0.827$$

## Check of Inside Ribs:

## Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

Compressive Allowable,  $KL/R < Cc$  ( 11.5546 < 138.1347 ) per AISC E2-1 [Sca]:

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

$$= ( 1 - ( 11.55 )^2 / ( 2 * 138.13^2 ) ) * 207 /$$

$$( 5/3 + 3 * (11.55) / (8 * 138.13) - ( 11.55^3 ) / (8 * 138.13^3) )$$

$$= 121.396 \text{ N./mm}^2$$

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

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

$$= 12.0/121.4 + ( 8195.84 * 86.0/645.75 ) / 137.9$$

$$= 0.890$$

**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	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	3.1275	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	88.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	45.4	kN
Maximum Transverse Force	Ft	71.7	kN

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Maximum Longitudinal Force Fl 143.4 kN  
 Saddle Bolted to Steel Foundation Yes

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

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

Bolt Area due to Shear Load [Bltarears]:  
 = Fl / (Stba \* Nbolts)  
 = 143.41 / (172.38 \* 4.0)  
 = 2.0801 cm<sup>2</sup>

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

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 950.0 \* 71.71 + 0.0  
 = 68148.02 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 68148.02 / 88.45  
 = 770.17 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis  
 = 1050.0 / 2 - 85.0  
 = 440.00 mm.

K1 = 3 (e - 0.5 \* Bplen)  
 = 3 (770.17 - 0.5 \* 1050.0)  
 = 735.52 mm.

K2 = 6 \* n1 \* At / Bpwid \* (f + e)  
 = 6 \* 1.0 \* 6.25 / 220.0 \* (440.0 + 770.17)  
 = 20644.30 mm.<sup>2</sup>

K3 = -K2 \* (0.5 \* Bplen + f)  
 = -20644.3 \* (0.5 \* 1050.0 + 440.0)  
 = -19921745.99 mm.<sup>3</sup>

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

$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$   
 $Y^3 + 735.52 * Y^2 + 20644.3 * Y + -0.2E+08 = 0$   
 Y = 139.55 mm.

Num = (Bplen / 2 - Y / 3 - e)  
 = (1050.0 / 2 - 139.55 / 3 - 770.17)  
 = -291.69

Denom = (Bplen / 2 - Y / 3 + f)  
 = (1050.0 / 2 - 139.55 / 3 + 440.0)  
 = 918.48

Total Bolt Tension Force [Tforce]:  
 = - QO \* Num / Denom  
 = - 88.45 \* -291.69 / 918.48  
 = 28.09 kN

Bolt Area Required due to Transverse Load [Bltareart]:  
 = Tforce / (Stba \* Nbt)  
 = 28.09 / ( 172.38 \* 2.0 )

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$$= 0.8148 \text{ cm}^2$$

Required Area of a Single Bolt [Bltarear]:

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

$$= \max[0.0, 2.0801, 0.8148]$$

$$= 2.0801 \text{ cm}^2$$

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

Bearing Pressure (fc)

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

$$= 2(88.45 + 28.09) / (139.55 * 220.0)$$

$$= 75.92 \text{ bars}$$

Distance from Baseplate Edge to the Web [ADIST]:

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

$$= (1050.0 - 999.2) / 2$$

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

Overturning Moment due To Bolt Tension [Mt]:

$$= Tforce * Adist$$

$$= 28.09 * 25.4$$

$$= 713.75 \text{ N-m}$$

Equivalent Bearing Pressure (f1):

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

$$= 75.92 * (139.55 - 25.4) / 139.55$$

$$= 62.10 \text{ bars}$$

Overturning Moment due to Bearing Pressure [Mc]:

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

$$= (25.4^2 * 220.0 / 6) * (62.1 + 2 * 75.92)$$

$$= 506.29 \text{ N-m}$$

Baseplate Required Thickness [Treq]:

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

$$= (6 * \max(713.75, 506.29) / (220.0 * 162.38))^{1/2}$$

$$= 10.9472 \text{ mm.}$$

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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

**Input and Calculated Values:**

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	thetal	132.00	degrees
Wear Plate Thickness	tr	15.0	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		114.43	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	72.61	235.81	
Long. Stress at Bottom of Midspan	76.94	235.81	
Long. Stress at Top of Saddles	87.96	235.81	
Long. Stress at Bottom of Saddles	67.47	235.81	
-----			
Tangential Shear in Shell	11.00	188.65	
Circ. Stress at Horn of Saddle	15.93	353.71	
Circ. Compressive Stress in Shell	2.38	235.81	
-----			

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 2.0/2 + 0 ) * 950.0/1037.4984$$

$$= 2.7 \text{ kN}$$

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

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

$$= \max( 0.51, 0.0, 0 ) * 950.0/3000.0$$

$$= 0.2 \text{ kN}$$

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

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

$$= 112 + \max( 0.2, 3, 0, 0 )$$

$$= 114.4 \text{ kN}$$

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

Vertical Load (including saddle weight)	116.43	kN
Transverse Shear Load Saddle	0.99	kN
Longitudinal Shear Load Saddle	0.51	kN

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Hydrostatic Test Pressure at center of Vessel: 29.959 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 = 0.0529      K8 = 0.3405  
 K9 = 0.2711      K10 = 0.0581      K1\* = 0.1923      K6p = 0.0434  
 K7p = 0.0434

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]:**

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

$$= -114 \cdot 992.0 \left[ 1 - \left( 1 - \frac{992.0}{4844.0} + \frac{599.0^2 - 0.0^2}{2 \cdot 992.0 \cdot 4844.0} \right) / \left( 1 + \frac{4 \cdot 0.0}{3 \cdot 4844.0} \right) \right]$$

$$= -19016.3 \text{ N-m}$$

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

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

$$= \frac{114 \cdot 4844}{4} \left( 1 + 2 \frac{599^2 - 0^2}{4844^2} \right) / \left( 1 + \frac{4 \cdot 0}{3 \cdot 4844} \right) - 4 \cdot 992 / 4844$$

$$= 29310.1 \text{ N-m}$$

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

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

$$= 29.959 \cdot 599.0 / (2 \cdot 12.0) - 29310.1 / (\pi \cdot 599.0^2 \cdot 12.0)$$

$$= 72.61 \text{ N./mm}^2$$

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

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

$$= 29.959 \cdot 599.0 / (2 \cdot 12.0) + 29310.1 / (\pi \cdot 599.0^2 \cdot 12.0)$$

$$= 76.94 \text{ N./mm}^2$$

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

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

$$= 29.959 \cdot 599.0 / (2 \cdot 12.0) - 19016.3 / (0.1066 \cdot \pi \cdot 599.0^2 \cdot 12.0)$$

$$= 87.96 \text{ N./mm}^2$$

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

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

$$= 29.959 \cdot 599.0 / (2 \cdot 12.0) + 19016.3 / (0.1923 \cdot \pi \cdot 599.0^2 \cdot 12.0)$$

$$= 67.47 \text{ N./mm}^2$$

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

$$= \frac{Q(L - 2a)}{L + \frac{4h^2}{3}}$$

$$= \frac{114(4844.0 - 2 \cdot 992.0)}{4844.0 + (4 \cdot 0.0/3)}$$

$$= 67.6 \text{ kN}$$

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

$$= \frac{K2 \cdot T}{R_m \cdot t}$$

$$= \frac{1.1707 \cdot 67.56}{599.0 \cdot 12.0}$$

$$= 11.00 \text{ N./mm}^2$$

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

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

$$= 0.78 \cdot \sqrt{599.0 \cdot 12.0}$$

$$= 66.130 \text{ mm.}$$

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Circumferential Stress in shell, no rings (4.15.23) [ $\sigma_6$ ]:  
 $= -K5 * Q * k / ( t * ( b + X1 + X2 ) )$   
 $= - 0.7603 * 114 * 0.1 / ( 12.0 * ( 172.0 + 66.13 + 66.13 ) )$   
 $= -2.38 \text{ N./mm}^2$

Effective reinforcing plate width (4.15.1) [B1]:  
 $= \min( b + 1.56 * \text{sqrt}( Rm * t ), 2a )$   
 $= \min( 172.0 + 1.56 * \text{sqrt}( 599.0 * 12.0 ), 2 * 992.0 )$   
 $= 304.26 \text{ mm.}$

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [ $\sigma_6,r$ ]:  
 $= -K5 * Q * k / ( B1( t + \eta * tr ) )$   
 $= - 0.7603 * 114 * 0.1 / ( 304.26( 12.0 + 1.0 * 15.0 ) )$   
 $= -1.06 \text{ N./mm}^2$

Circ. Comp. Stress at Horn of Saddle,  $L \geq 8Rm$  (4.15.27) [ $\sigma_7,r$ ]:  
 $= -Q / ( 4( t + \eta * tr ) b1 ) - 3 * K7 * Q / ( 2( t + \eta * tr )^2 )$   
 $= -114 / ( 4( 12.0 + 1.0 * 15.0 ) 304.26 ) -$   
 $3 * 0.053 * 114 / ( 2( 12.0 + 1.0 * 15.0 )^2 )$   
 $= -15.93 \text{ N./mm}^2$

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

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

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

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

Value  $C1 = \text{Sumof}(Ay) / \text{Sumof}(A)$  = 132. mm.  
 Value  $I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay)$  = 0.394E+05  $\text{cm}^4$   
 Value  $As = \text{Sumof}(A) - A_{shell}$  = 136.  $\text{cm}^2$

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

$Fh = K1 * Q = 0.2035 * 114.43 = 23.289 \text{ kN}$

Tension Stress,  $St = ( Fh / As ) = 1.7094 \text{ N./mm}^2$   
 Allowed Stress,  $Sa = 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2$

#### **Saddle Splitting Dimension [d]:**

$= B - R * \sin(\theta) / \theta$   
 $= 950.0 - 593.0 * \sin( 1.0472 ) / 1.0472$   
 $= 459.593 \text{ mm.}$

Bending Moment,  $M = Fh * d = 10707.8164 \text{ N-m}$

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$$\begin{aligned} \text{Bending Stress, } S_b &= ( M * C_1 / I ) = 3.5949 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

**Minimum Thickness of Baseplate per Moss:**

$$\begin{aligned} &= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2} \\ &= ( 3(114 + 2)220.0 / ( 4 * 1050.0 * 137.9 ) )^{1/2} \\ &= 11.519 \text{ mm.} \end{aligned}$$

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

**Distance between Ribs [e]:**

$$\begin{aligned} &= \text{Web Length} / ( N_{\text{ribs}} - 1 ) \\ &= 1079.0676 / ( 4 - 1 ) \\ &= 359.689 \text{ mm.} \end{aligned}$$

**Baseplate Pressure Area [Ap]:**

$$\begin{aligned} &= e * B_{\text{pwid}} / 2 \\ &= 359.6892 * 220.0 / 2 \\ &= 395.658 \text{ cm}^2 \end{aligned}$$

**Axial Load [P]:**

$$\begin{aligned} &= A_p * B_p \\ &= 395.7 * 0.05 \\ &= 19.600 \text{ kN} \end{aligned}$$

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

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 23.55 + 26.977 \\ &= 50.527 \text{ cm}^2 \end{aligned}$$

**Compressive Stress [Sc]:**

$$\begin{aligned} &= P / A_r \\ &= 19.6 / 50.5267 \\ &= 3.879 \text{ N./mm}^2 \end{aligned}$$

**Check of Outside Ribs:**

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

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

**Bending Moment [Rm]:**

$$\begin{aligned} &= F_1 / ( 2 * B_{\text{plen}} ) * e * r_1 / 2 \\ &= 0.5 / ( 2 * 1050.0 ) * 359.689 * 619.79 / 2 \\ &= 26.889 \text{ N-m} \end{aligned}$$

**Compressive Allowable, KL/R < Cc ( 17.4685 < 138.1347 ) per AISC E2-1 [Sca]:**

$$\begin{aligned} &= ( 1 - ( K L r )^2 / ( 2 * C c^2 ) ) * F_y / ( 5 / 3 + 3 * ( K L r ) / ( 8 * C c ) - ( K L r^3 ) / ( 8 * C c^3 ) ) \\ &= ( 1 - ( 17.47 )^2 / ( 2 * 138.13^2 ) ) * 207 / \\ &\quad ( 5 / 3 + 3 * ( 17.47 ) / ( 8 * 138.13 ) - ( 17.47^3 ) / ( 8 * 138.13^3 ) ) \\ &= 119.729 \text{ N./mm}^2 \end{aligned}$$

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

$$\begin{aligned} &= S_c / S_{c a} + ( R_m * \text{Distance Side} / I ) / S_{b a} \\ &= 3.88 / 119.73 + ( 26.89 * 86.0 / 6360561 ) / 137.9 \\ &= 0.035 \end{aligned}$$

**Check of Inside Ribs:**

**Inertia of Saddle, Inner Ribs - Axial Direction**

	B	D	Y	A	AY	Io

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Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

Compressive Allowable,  $KL/R < Cc$  (  $11.5546 < 138.1347$  ) per AISC E2-1 [Sca]:  
 $= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3))$   
 $= (1 - (11.55)^2 / (2 * 138.13^2)) * 207 /$   
 $(5/3 + 3 * (11.55) / (8 * 138.13) - (11.55^3) / (8 * 138.13^3))$   
 $= 121.396 \text{ N./mm}^2$

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

$= Sc/Sca + ( Rm * \text{Distance Center}/I ) / Sba$   
 $= 4.85/121.4 + ( 28.94 * 86.0/645.75 ) / 137.9$   
 $= 0.043$

**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	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	3.1275	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	113.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.5	kN
Saddle Bolted to Steel Foundation		Yes	

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

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$= 0.0$  (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:

$= Fl / (Stba * Nbolts)$   
 $= 0.51 / (172.38 * 4.0)$   
 $= 0.0073 \text{ cm}^2$

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

$= B * Ft + \text{Sum of X Moments}$   
 $= 950.0 * 0.99 + 0.0$   
 $= 942.12 \text{ N-m}$

Eccentricity (e):

$= Rmom / QO$   
 $= 942.12 / 113.7$   
 $= 8.28 \text{ mm.} < Bplen/6$  --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:

$= 0$  (No Uplift)

Required Area of a Single Bolt [Bltarear]:

$= \max[Bltarearl, Bltarears, Bltareart]$   
 $= \max[0.0, 0.0073, 0.0]$   
 $= 0.0073 \text{ cm}^2$

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

**Input and Calculated Values:**

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	thetal	132.00	degrees
Wear Plate Thickness	tr	15.0	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		92.39	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	68.61	235.81	
Long. Stress at Bottom of Midspan	80.94	235.81	
Long. Stress at Top of Saddles	73.99	235.81	
Long. Stress at Bottom of Saddles	75.21	235.81	
-----			
Tangential Shear in Shell	12.90	188.65	
Circ. Stress at Horn of Saddle	6.49	353.71	
Circ. Compressive Stress in Shell	1.92	235.81	
-----			

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 2.0/2 + 0 ) * 950.0/1037.4984$$

$$= 2.7 \text{ kN}$$

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

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

$$= \max( 0.51, 0.0, 0 ) * 950.0/3000.0$$

$$= 0.2 \text{ kN}$$

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

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

$$= 90 + \max( 0.2, 3, 0, 0 )$$

$$= 92.4 \text{ kN}$$

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

Vertical Load (including saddle weight)	94.39	kN
Transverse Shear Load Saddle	0.99	kN
Longitudinal Shear Load Saddle	0.51	kN

Hydrostatic Test Pressure at center of Vessel: 29.959 bars

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### **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 = 0.0194	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0159			

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]:

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left( 1 + \frac{4h^2}{3L} \right) \right] \\
 &= -92 \cdot 346.0 \left[ 1 - \left( 1 - \frac{346.0}{4844.0} + \frac{599.0^2 - 0.0^2}{2 \cdot 346.0 \cdot 4844.0} \right) / \left( 1 + \frac{4 \cdot 0.0}{3 \cdot 4844.0} \right) \right] \\
 &= 1138.9 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q \cdot L / 4 \left( 1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left( 1 + \frac{4h^2}{3L} \right) - 4a / L \\
 &= 92 \cdot 4844 / 4 \left( 1 + 2 \frac{599^2 - 0^2}{4844^2} \right) / \left( 1 + \frac{4 \cdot 0}{3 \cdot 4844} \right) - 4 \cdot 346 / 4844 \\
 &= 83377.1 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.959 \cdot 599.0 / (2 \cdot 12.0) - 83377.1 / (\pi \cdot 599.0^2 \cdot 12.0) \\
 &= 68.61 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.959 \cdot 599.0 / (2 \cdot 12.0) + 83377.1 / (\pi \cdot 599.0^2 \cdot 12.0) \\
 &= 80.94 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.959 \cdot 599.0 / (2 \cdot 12.0) - 1138.9 / (0.1066 \cdot \pi \cdot 599.0^2 \cdot 12.0) \\
 &= 73.99 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.959 \cdot 599.0 / (2 \cdot 12.0) + 1138.9 / (0.1923 \cdot \pi \cdot 599.0^2 \cdot 12.0) \\
 &= 75.21 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q(L - 2a) / (L + (4 \cdot h^2 / 3)) \\
 &= 92(4844.0 - 2 \cdot 346.0) / (4844.0 + (4 \cdot 0.0 / 3)) \\
 &= 79.2 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot 79.2 / (599.0 \cdot 12.0) \\
 &= 12.90 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{R_m \cdot t} \\
 &= 0.78 \cdot \sqrt{599.0 \cdot 12.0} \\
 &= 66.130 \text{ mm.}
 \end{aligned}$$

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

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

$$= - 0.7603 * 92 * 0.1 / ( 12.0 * ( 172.0 + 66.13 + 66.13 ) )$$

$$= -1.92 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min( 172.0 + 1.56 * \text{sqrt}( 599.0 * 12.0 ), 2 * 346.0 )$$

$$= 304.26 \text{ mm.}$$

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) [ $\sigma_6, r$ ]:

$$= -K5 * Q * k / ( B1( t + \eta * tr ) )$$

$$= - 0.7603 * 92 * 0.1 / ( 304.26( 12.0 + 1.0 * 15.0 ) )$$

$$= -0.86 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle,  $L \geq 8Rm$  (4.15.27) [ $\sigma_7, r$ ]:

$$= -Q / ( 4( t + \eta * tr ) b1 ) - 3 * K7 * Q / ( 2( t + \eta * tr )^2 )$$

$$= -92 / ( 4( 12.0 + 1.0 * 15.0 ) 304.26 ) -$$

$$3 * 0.019 * 92 / ( 2( 12.0 + 1.0 * 15.0 )^2 )$$

$$= -6.49 \text{ N./mm}^2$$

### Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

### Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
Baseplate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

$$\text{Value } C1 = \text{Sumof}( Ay ) / \text{Sumof}( A ) = 132. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}( Io ) - C1 * \text{Sumof}( Ay ) = 0.394E+05 \text{ cm}^4$$

$$\text{Value } As = \text{Sumof}( A ) - A_{\text{shell}} = 136. \text{ cm}^2$$

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

$$Fh = K1 * Q = 0.2035 * 92.395 = 18.8043 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 1.3803 \text{ N./mm}^2$$

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

Saddle Splitting Dimension [d]:

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

$$= 950.0 - 593.0 * \sin( 1.0472 ) / 1.0472$$

$$= 459.593 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 8645.8369 \text{ N-m}$$

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$$\begin{aligned} \text{Bending Stress, } S_b &= ( M * C1 / I ) = 2.9027 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

**Minimum Thickness of Baseplate per Moss:**

$$\begin{aligned} &= ( 3 ( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2} \\ &= ( 3(92 + 2)220.0 / ( 4 * 1050.0 * 137.9 ) )^{1/2} \\ &= 10.372 \text{ mm.} \end{aligned}$$

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

**Distance between Ribs [e]:**

$$\begin{aligned} &= \text{Web Length} / ( \text{Nr ribs} - 1 ) \\ &= 1079.0676 / ( 4 - 1 ) \\ &= 359.689 \text{ mm.} \end{aligned}$$

**Baseplate Pressure Area [Ap]:**

$$\begin{aligned} &= e * \text{Bpwid} / 2 \\ &= 359.6892 * 220.0 / 2 \\ &= 395.658 \text{ cm}^2 \end{aligned}$$

**Axial Load [P]:**

$$\begin{aligned} &= A_p * B_p \\ &= 395.7 * 0.04 \\ &= 15.825 \text{ kN} \end{aligned}$$

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

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 23.55 + 26.977 \\ &= 50.527 \text{ cm}^2 \end{aligned}$$

**Compressive Stress [Sc]:**

$$\begin{aligned} &= P / A_r \\ &= 15.8 / 50.5267 \\ &= 3.132 \text{ N./mm}^2 \end{aligned}$$

**Check of Outside Ribs:**

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

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

**Bending Moment [Rm]:**

$$\begin{aligned} &= F1 / ( 2 * \text{Bplen} ) * e * r1 / 2 \\ &= 0.5 / ( 2 * 1050.0 ) * 359.689 * 619.79 / 2 \\ &= 26.889 \text{ N-m} \end{aligned}$$

**Compressive Allowable, KL/R < Cc ( 17.4685 < 138.1347 ) per AISC E2-1 [Sca]:**

$$\begin{aligned} &= ( 1 - ( \text{Klr} )^2 / ( 2 * \text{Cc}^2 ) ) * F_y / ( 5/3 + 3 * ( \text{Klr} ) / ( 8 * \text{Cc} ) - ( \text{Klr}^3 ) / ( 8 * \text{Cc}^3 ) ) \\ &= ( 1 - ( 17.47 )^2 / ( 2 * 138.13^2 ) ) * 207 / \\ &\quad ( 5/3 + 3 * ( 17.47 ) / ( 8 * 138.13 ) - ( 17.47^3 ) / ( 8 * 138.13^3 ) ) \\ &= 119.729 \text{ N./mm}^2 \end{aligned}$$

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

$$\begin{aligned} &= S_c / S_{ca} + ( R_m * \text{Distance Side} / I ) / S_{ba} \\ &= 3.13 / 119.73 + ( 26.89 * 86.0 / 6360561 ) / 137.9 \\ &= 0.029 \end{aligned}$$

**Check of Inside Ribs:**

**Inertia of Saddle, Inner Ribs - Axial Direction**

	B	D	Y	A	AY	Io

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Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

Compressive Allowable,  $KL/R < Cc$  (  $11.5546 < 138.1347$  ) per AISC E2-1 [Sca]:  
 $= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3))$   
 $= (1 - (11.55)^2 / (2 * 138.13^2)) * 207 /$   
 $(5/3 + 3 * (11.55) / (8 * 138.13) - (11.55^3) / (8 * 138.13^3))$   
 $= 121.396 \text{ N./mm}^2$

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

$= Sc/Sca + ( Rm * \text{Distance Center}/I ) / Sba$   
 $= 3.91/121.4 + ( 28.94 * 86.0/645.75 ) / 137.9$   
 $= 0.035$

**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	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	3.1275	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	91.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.5	kN
Saddle Bolted to Steel Foundation		Yes	

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

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$= 0.0$  (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:

$= Fl / (Stba * Nbolts)$   
 $= 0.51 / (172.38 * 4.0)$   
 $= 0.0073 \text{ cm}^2$

**Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:

$= B * Ft + \text{Sum of X Moments}$   
 $= 950.0 * 0.99 + 0.0$   
 $= 942.12 \text{ N-m}$

Eccentricity (e):

$= Rmom / QO$   
 $= 942.12 / 91.67$   
 $= 10.27 \text{ mm.} < Bplen/6$  --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:

$= 0$  (No Uplift)

Required Area of a Single Bolt [Bltarear]:

$= \max[Bltarearl, Bltarears, Bltareart]$   
 $= \max[0.0, 0.0073, 0.0]$   
 $= 0.0073 \text{ cm}^2$

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Nozzle Summary: Step: 22 10:31pm Feb 6,2022

#### Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1	...	OK	...	OK	11.33	OK	Passed
T2	...	OK	...	OK	11.33	OK	Passed
S2	...	OK	...	OK	10.16	OK	Passed
S1	...	OK	...	OK	11.33	OK	Passed
S3	...	OK	...	OK	7.80	OK	Passed
T4	...	OK	...	OK	6.22	OK	Passed
T3	...	OK	...	OK	6.42	OK	Passed

#### MAWP Summary:

Minimum MAWP Nozzles : 0.000 Nozzle : T3

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	T1	425.000	270.000	598.626
20	T2	425.000	90.000	598.626
40	S2	1296.175	270.000	405.700
40	S1	5511.175	90.000	598.626
40	S3	1296.175	90.000	113.600
60	T4	6257.350	90.000	71.550
60	T3	6257.350	270.000	78.000

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

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

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

l<sub>c</sub> - 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.: T1 Nozl: 8 10:31pm Feb 6,2022

**INPUT VALUES, Nozzle Description: T1 From : 20**

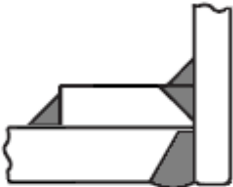
Pressure for Reinforcement Calculations	P	23.115	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	897.3333	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		425.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	14.0000	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	483.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: T1**

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

Actual Outside Diameter Used in Calculation	12.750 in.
Actual Thickness Used in Calculation	0.601 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.12 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12) \\
 &= 10.0415 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.12 \cdot 161.925) / (118 \cdot 1.0 + 0.4 \cdot 23.12) \\
 &= 3.1500 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.8692 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	598.6257	mm.
Parallel to Vessel Wall, opening length	d	299.3128	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	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.: T1 Nozl: 8 10:31pm Feb 6, 2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.413	5.299	NA
Area in Shell	A1	5.792	25.141	NA
Area in Nozzle Wall	A2	4.678	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.676	2.676	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	31.146	51.665	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: 477.3341 15.0000 mm.

Based on given Pad Diameter: 483.8500 14.3891 mm.

Based on Shell or Nozzle Thickness: 477.3341 15.0000 mm.

Area Required [A]:

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

$$= (299.3128 * 10.0415 * 1.0 + 2 * 12.2686 * 10.0415 * 1.0 * (1 - 0.86))$$

$$= 30.413 \text{ cm}^2$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 299.313( 1.0 * 12.0 - 1.0 * 10.042 ) - 2 * 12.269$$

$$( 1.0 * 12.0 - 1.0 * 10.0415 ) * ( 1 - 0.855 )$$

$$= 5.792 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) * ( 12.27 - 3.15 ) * 0.855$$

$$= 4.678 \text{ cm}^2$$

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

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

$$= 14.0^2 * 0.86 + (0.0)^2 * 0.86 + 10.0^2 * 1.0$$

$$= 2.676 \text{ cm}^2$$

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

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

$$= ( 483.85 - 323.85 ) 15.0 * 1.0 * 0.75$$

$$= 18.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 6.1500 \text{ mm.}$

Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$

Wall Thickness, shell/head, internal pressure  $trb1 = 13.0415 \text{ mm.}$

Wall Thickness  $tb1 = \max(trb1, tr16b) = 13.0415 \text{ mm.}$

Wall Thickness, shell/head, external pressure  $trb2 = 3.4733 \text{ mm.}$

Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

Wall Thickness per table UG-45  $tb3 = 11.3312 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 11.331, \max( 13.0415, 4.5 ) ]$$

$$= 11.3312 \text{ mm.}$$

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

$$= \max( ta, tb )$$

$$= \max( 6.15, 11.3312 )$$

$$= 11.3312 \text{ mm.}$$

Available Nozzle Neck Thickness = 15.2686 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	38.5,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	256.2 N./mm <sup>2</sup>	Passed
Occasional	:	13.5,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	13.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

#### Nozzle Neck to Flange Weld (Impact tested) :

*Note:*

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

*Note:*

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

Impact Test Temperature provided per Specification	-46 °C
--	--------

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

Govrn. thk, tg = 15.0, c = 3.0 mm., E\* = 1.0

Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.837$ , Temp. Reduction = 9 °C

Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E\* = 1.0

Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.837$ , 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 = 10.042, c = 3.0 mm., E\* = 1.0

Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.837$ , Temp. Reduction = 9 °C

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

Governing MDMT of the Nozzle : -46 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -46 °C

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

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

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

Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

Note:

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

#### Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 12.2686 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 12.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	9.8980 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (30.4129 - 5.7923 + 2 * 12.2686 * 0.855 * \\
 &\quad (1.0 * 12.0 - 10.0415) ) )138) \\
 &= 345.15 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 4.6778 + 18.0 + 2.6758 - 0.0 * 0.86 ) * 138 \\
 &= 349.60 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 4.6778 + 0.0 + 1.6758 + ( 2.5175 ) ) * 138 \\
 &= 122.32 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 4.6778 + 0.0 + 2.6758 + 18.0 + ( 2.5175 ) ) * 138 \\
 &= 384.31 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 323.85 * 14.0 * 0.49 * 118 \\
 &= 411. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

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$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138$$

$$= 514. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 155.7907 ) * ( 15.2686 - 3.0 ) * 0.7 * 118$$

$$= 496. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 323.85 * 15.0 * 0.74 * 138$$

$$= 779. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 623. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 514 + 496 ) = 1009 \text{ kN}$$

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

$$= ( 411 + 779 + 623 + 0 ) = 1813 \text{ kN}$$

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

$$= ( 514 + 623 + 0 ) = 1136 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 1009 kN , must exceed W = 345 kN or W1 = 349 kN  
 Path 2-2 = 1812 kN , must exceed W = 345 kN or W2 = 122 kN  
 Path 3-3 = 1136 kN , must exceed W = 345 kN or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 mm.

#### 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	1180.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature		120.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	483.850	mm.

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Nozzle Calcs.: T1 Nozl: 8 10:31pm Feb 6,2022

Design Internal Pressure	Dp	23.115	bars
Include Pressure Thrust		No	

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

Radial Load (SUS)	P	12.0	kN
Longitudinal Shear (SUS)	Vl	12.0	kN
Circumferential Shear (SUS)	Vc	12.0	kN
Circumferential Moment (SUS)	Mc	15300.0	N-m
Longitudinal Moment (SUS)	Ml	15300.0	N-m
Torsional Moment (SUS)	Mt	18900.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 323.85 + 2 * 1.65 * \text{sqrt}(599.0 (15.0 - 3.0))$$

$$= 603.631 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	12.0	kN
Circumferential Shear	VC	12.0	kN
Longitudinal Shear	VL	12.0	kN
Circumferential Moment	MC	15300.0	N-m
Longitudinal Moment	ML	15300.0	N-m
Torsional Moment	MT	18900.0	N-m

Dimensionless Parameters used : Gamma = 22.46

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.234	4C	3.260	(A,B)
N(PHI) / ( P/Rm )	0.234	3C	2.215	(C,D)
M(PHI) / ( P )	0.234	2C1	0.041	(A,B)
M(PHI) / ( P )	0.234	1C	0.070	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.234	3A	0.941	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.234	1A	0.083	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.234	3B	2.410	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.234	1B	0.029	(A,B,C,D)
N(x) / ( P/Rm )	0.234	3C	2.215	(A,B)
N(x) / ( P/Rm )	0.234	4C	3.260	(C,D)
M(x) / ( P )	0.234	1C1	0.073	(A,B)
M(x) / ( P )	0.234	2C	0.041	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.234	4A	1.607	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.234	2A	0.041	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.234	4B	0.902	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.234	2B	0.048	(A,B,C,D)

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Nozzle Calcs.: T1

Noz1: 8 10:31pm Feb 6,2022

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	-1.6	-1.6	-1.6	-1.6
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-6.9	6.9	-6.9	6.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-6.2	-6.2	6.2	6.2
Circ. Memb. ML		-15.9	-15.9	15.9	15.9	0.0	0.0	0.0	0.0
Circ. Bend. ML		-25.7	25.7	25.7	-25.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-48.0	11.5	35.1	-8.2	-88.5	72.8	71.4	-62.2
Long. Memb. P		-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend. P		-7.2	7.2	-7.2	7.2	-4.0	4.0	-4.0	4.0
Long. Memb. MC		0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML		-5.9	-5.9	5.9	5.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-42.6	42.6	42.6	-42.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-57.3	42.2	39.7	-31.1	-53.6	27.7	40.8	-24.4
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		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.1	5.1	3.4	3.4	3.4	3.4	5.1	5.1
Str. Int.		59.6	43.0	41.5	31.6	88.8	73.1	72.2	62.9

Dimensionless Parameters used : Gamma = 49.92

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.353	4C	4.461	(A,B)
N(PHI) / ( P/Rm )	0.353	3C	1.855	(C,D)
M(PHI) / ( P )	0.353	2C1	0.009	(A,B)
M(PHI) / ( P )	0.353	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.353	3A	1.401	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.353	1A	0.059	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.353	3B	2.663	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.353	1B	0.007	(A,B,C,D)
N(x) / ( P/Rm )	0.353	3C	1.855	(A,B)
N(x) / ( P/Rm )	0.353	4C	4.461	(C,D)
M(x) / ( P )	0.353	1C1	0.024	(A,B)
M(x) / ( P )	0.353	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.353	4A	4.827	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.353	2A	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.353	4B	1.536	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.353	2B	0.011	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: T1 Noz1: 8 10:31pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P		-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML		-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML		-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P		-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P		-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML		-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.		-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
Shear VC		1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear		5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.		68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Circ. Pl (SUS)		-18.3	-18.3	13.5	13.5	-7.8	-7.8	4.6	4.6
Circ. Q (SUS)		-29.7	29.7	21.7	-21.7	-80.6	80.6	66.8	-66.8
Long. Pm (SUS)		24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl (SUS)		-7.6	-7.6	4.3	4.3	-13.0	-13.0	8.2	8.2
Long. Q (SUS)		-49.8	49.8	35.4	-35.4	-40.7	40.7	32.6	-32.6
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)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Pm+Pl (SUS)		31.4	33.7	63.2	65.5	41.8	44.1	54.3	56.6
Pm+Pl+Q (Total)		35.6	70.6	85.3	50.5	39.9	124.9	121.5	14.8

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

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Nozzle Calcs.: T1 Noz1: 8 10:31pm Feb 6,2022

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.95	137.90	Passed
Pm+Pl (SUS)	65.47	206.85	Passed
Pm+Pl+Q (TOTAL)	124.92	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4
Circ. Pl (SUS)		-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q (SUS)		-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm (SUS)		56.5	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Long. Pl (SUS)		-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q (SUS)		-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm (SUS)		113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4
Pm+Pl (SUS)		78.9	81.2	132.4	134.8	95.9	98.2	124.1	126.4
Pm+Pl+Q (Total)		60.9	108.7	149.4	118.0	114.5	308.4	269.3	63.9

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.40	137.90	Passed
Pm+Pl (SUS)	134.75	206.85	Passed
Pm+Pl+Q (TOTAL)	308.39	413.70	Passed

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Nozzle Calcs.: T2

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**INPUT VALUES, Nozzle Description: T2****From : 20**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	897.3333	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		425.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

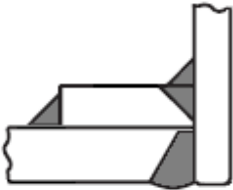
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	14.0000	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	483.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	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: T2**

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

Actual Outside Diameter Used in Calculation	12.750 in.
Actual Thickness Used in Calculation	0.601 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 9.9911 \text{ mm.}$$

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

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

$$= (23.0 \cdot 161.925) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$$

$$= 3.1344 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.8692 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	598.6257	mm.
Parallel to Vessel Wall, opening length	d	299.3128	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr4]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(0.855, 1.0)$$

$$= 0.855$$

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Nozzle Calcs.: T2

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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	30.260	5.299	NA
Area in Shell	A1	5.942	25.141	NA
Area in Nozzle Wall	A2	4.686	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.676	2.676	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	31.303	51.665	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: 474.5778 15.0000 mm.

Based on given Pad Diameter: 483.8500 14.1307 mm.

Based on Shell or Nozzle Thickness: 474.5778 15.0000 mm.

Area Required [A]:

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

$$= ( 299.3128 * 9.9911 * 1.0 + 2 * 12.2686 * 9.9911 * 1.0 * (1 - 0.86) )$$

$$= 30.260 \text{ cm}^2$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 299.313( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 12.269$$

$$( 1.0 * 12.0 - 1.0 * 9.991 ) * ( 1 - 0.855 )$$

$$= 5.942 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) * ( 12.27 - 3.13 ) * 0.855$$

$$= 4.686 \text{ cm}^2$$

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

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

$$= 14.0^2 * 0.86 + (0.0)^2 * 0.86 + 10.0^2 * 1.0$$

$$= 2.676 \text{ cm}^2$$

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

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

$$= ( 483.85 - 323.85 ) 15.0 * 1.0 * 0.75$$

$$= 18.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 6.1344 \text{ mm.}$

Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$

Wall Thickness, shell/head, internal pressure  $trb1 = 12.9911 \text{ mm.}$

Wall Thickness  $tb1 = \max(trb1, tr16b) = 12.9911 \text{ mm.}$

Wall Thickness, shell/head, external pressure  $trb2 = 3.4733 \text{ mm.}$

Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

Wall Thickness per table UG-45  $tb3 = 11.3312 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 11.331, max( 12.9911, 4.5 ) ]  
 = 11.3312 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 6.1344, 11.3312 )  
 = 11.3312 mm.

Available Nozzle Neck Thickness = 15.2686 mm. --> OK

#### Stresses on Nozzle due to External and Pressure Loads per the ASME

##### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	38.5,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	256.3 N./mm <sup>2</sup>	Passed
Occasional	:	13.5,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	13.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

##### Nozzle Neck to Flange Weld (Impact tested) :

###### Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

##### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

###### Note:

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

Impact Test Temperature provided per Specification	-46 °C
--	--------

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

Govrn. thk, tg = 15.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.833, Temp. Reduction = 9 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 15.0, tr = 9.991, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.833, 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 = 9.991, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.833, Temp. Reduction = 9 °C

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

Governing MDMT of the Nozzle : -46 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -46 °C

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

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:

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

#### Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds Tmin 12.2686 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 12.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	9.8980 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (30.26 - 5.9415 + 2 * 12.2686 * 0.855 * \\
 &\quad (1.0 * 12.0 - 9.9911) ) 138) \\
 &= 341.13 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 4.6858 + 18.0 + 2.6758 - 0.0 * 0.86 ) * 138 \\
 &= 349.71 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 4.6858 + 0.0 + 1.6758 + ( 2.5175 ) ) * 138 \\
 &= 122.43 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 4.6858 + 0.0 + 2.6758 + 18.0 + ( 2.5175 ) ) * 138 \\
 &= 384.42 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 323.85 * 14.0 * 0.49 * 118 \\
 &= 411. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

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$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138$$

$$= 514. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 155.7907 ) * ( 15.2686 - 3.0 ) * 0.7 * 118$$

$$= 496. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 323.85 * 15.0 * 0.74 * 138$$

$$= 779. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 623. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 514 + 496 ) = 1009 \text{ kN}$$

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

$$= ( 411 + 779 + 623 + 0 ) = 1813 \text{ kN}$$

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

$$= ( 514 + 623 + 0 ) = 1136 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 1009 kN , must exceed W = 341 kN or W1 = 349 kN  
 Path 2-2 = 1812 kN , must exceed W = 341 kN or W2 = 122 kN  
 Path 3-3 = 1136 kN , must exceed W = 341 kN or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 mm.

#### 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	1180.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature		120.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	483.850	mm.

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Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

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

Radial Load (SUS)	P	12.0	kN
Longitudinal Shear (SUS)	Vl	12.0	kN
Circumferential Shear (SUS)	Vc	12.0	kN
Circumferential Moment (SUS)	Mc	15300.0	N-m
Longitudinal Moment (SUS)	Ml	15300.0	N-m
Torsional Moment (SUS)	Mt	18900.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 323.85 + 2 * 1.65 * \text{sqrt}(599.0 (15.0 - 3.0))$$

$$= 603.631 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTAINED loads:

Radial Load	P	12.0	kN
Circumferential Shear	VC	12.0	kN
Longitudinal Shear	VL	12.0	kN
Circumferential Moment	MC	15300.0	N-m
Longitudinal Moment	ML	15300.0	N-m
Torsional Moment	MT	18900.0	N-m

Dimensionless Parameters used : Gamma = 22.46

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.234	4C	3.260	(A,B)
N(PHI) / ( P/Rm )	0.234	3C	2.215	(C,D)
M(PHI) / ( P )	0.234	2C1	0.041	(A,B)
M(PHI) / ( P )	0.234	1C	0.070	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.234	3A	0.941	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.234	1A	0.083	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.234	3B	2.410	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.234	1B	0.029	(A,B,C,D)
N(x) / ( P/Rm )	0.234	3C	2.215	(A,B)
N(x) / ( P/Rm )	0.234	4C	3.260	(C,D)
M(x) / ( P )	0.234	1C1	0.073	(A,B)
M(x) / ( P )	0.234	2C	0.041	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.234	4A	1.607	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.234	2A	0.041	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.234	4B	0.902	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.234	2B	0.048	(A,B,C,D)

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: T2

Noz1: 9 10:31pm Feb 6,2022

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	-1.6	-1.6	-1.6	-1.6
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-6.9	6.9	-6.9	6.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-6.2	-6.2	6.2	6.2
Circ. Memb. ML		-15.9	-15.9	15.9	15.9	0.0	0.0	0.0	0.0
Circ. Bend. ML		-25.7	25.7	25.7	-25.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-48.0	11.5	35.1	-8.2	-88.5	72.8	71.4	-62.2
Long. Memb. P		-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend. P		-7.2	7.2	-7.2	7.2	-4.0	4.0	-4.0	4.0
Long. Memb. MC		0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend. MC		0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML		-5.9	-5.9	5.9	5.9	0.0	0.0	0.0	0.0
Long. Bend. ML		-42.6	42.6	42.6	-42.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-57.3	42.2	39.7	-31.1	-53.6	27.7	40.8	-24.4
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		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.1	5.1	3.4	3.4	3.4	3.4	5.1	5.1
Str. Int.		59.6	43.0	41.5	31.6	88.8	73.1	72.2	62.9

Dimensionless Parameters used : Gamma = 49.92

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.353	4C	4.461	(A,B)
N(PHI) / ( P/Rm )	0.353	3C	1.855	(C,D)
M(PHI) / ( P )	0.353	2C1	0.009	(A,B)
M(PHI) / ( P )	0.353	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.353	3A	1.401	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.353	1A	0.059	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.353	3B	2.663	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.353	1B	0.007	(A,B,C,D)
N(x) / ( P/Rm )	0.353	3C	1.855	(A,B)
N(x) / ( P/Rm )	0.353	4C	4.461	(C,D)
M(x) / ( P )	0.353	1C1	0.024	(A,B)
M(x) / ( P )	0.353	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.353	4A	4.827	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.353	2A	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.353	4B	1.536	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.353	2B	0.011	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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Nozzle Calcs.: T2

Noz1: 9 10:31pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P		-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML		-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML		-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P		-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P		-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML		-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML		-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.		-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
Shear VC		1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear		5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.		68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		49.4	51.7	49.4	51.7	49.4	51.7	49.4	51.7
Circ. Pl (SUS)		-18.3	-18.3	13.5	13.5	-7.8	-7.8	4.6	4.6
Circ. Q (SUS)		-29.7	29.7	21.7	-21.7	-80.6	80.6	66.8	-66.8
Long. Pm (SUS)		24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
Long. Pl (SUS)		-7.6	-7.6	4.3	4.3	-13.0	-13.0	8.2	8.2
Long. Q (SUS)		-49.8	49.8	35.4	-35.4	-40.7	40.7	32.6	-32.6
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)		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		49.4	51.7	49.4	51.7	49.4	51.7	49.4	51.7
Pm+Pl (SUS)		31.2	33.5	62.9	65.2	41.6	43.9	54.0	56.3
Pm+Pl+Q (Total)		35.5	70.5	85.1	50.4	40.1	124.7	121.2	14.9

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

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Nozzle Calcs.: T2

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Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.69	137.90	Passed
Pm+Pl (SUS)	65.21	206.85	Passed
Pm+Pl+Q (TOTAL)	124.66	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)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)		-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q (SUS)		-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm (SUS)		56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)		-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q (SUS)		-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)		78.3	80.6	131.9	134.2	95.4	97.7	123.6	125.9
Pm+Pl+Q (Total)		60.6	108.1	148.8	117.5	115.1	307.8	268.8	64.1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	134.18	206.85	Passed
Pm+Pl+Q (TOTAL)	307.82	413.70	Passed

Tag no:CONDENSER E-PK6101-2

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: S2

Noz1: 10 10:31pm Feb 6,2022

**INPUT VALUES, Nozzle Description: S2 From : 40**

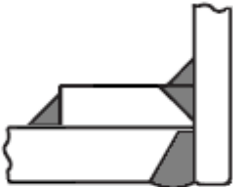
Pressure for Reinforcement Calculations	P	23.054	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	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		1296.17	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	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	379.0750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: 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]

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.05 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.05) \\
 &= 10.0148 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.05 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.05) \\
 &= 2.1253 \text{ mm.}
 \end{aligned}$$

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

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

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	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.: S2 Noz1: 10 10:31pm Feb 6, 2022

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	20.551	7.264	NA
Area in Shell	A1	3.980	9.866	NA
Area in Nozzle Wall	A2	3.071	3.806	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	26.907	33.527	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:	322.5775	15.0000 mm.
Based on given Pad Diameter:	379.0750	9.7034 mm.
Based on Shell or Nozzle Thickness:	358.7859	11.1125 mm.

**Area Required [A]:**

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

$$= ( 202.85 * 10.0148 * 1.0 + 2 * 8.1125 * 10.0148 * 1.0 * (1 - 0.86) )$$

$$= 20.551 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

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

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

$$= 202.85( 1.0 * 12.0 - 1.0 * 10.015 ) - 2 * 8.113$$

$$( 1.0 * 12.0 - 1.0 * 10.0148 ) * ( 1 - 0.855 )$$

$$= 3.980 \text{ cm}^2$$

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

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

$$= ( 2 * 30.0 ) * ( 8.11 - 2.13 ) * 0.855$$

$$= 3.071 \text{ cm}^2$$

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

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

$$= 10.0^2 * 0.86 + (0.0)^2 * 0.86 + 10.0^2 * 1.0$$

$$= 1.855 \text{ cm}^2$$

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

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

$$= ( 379.075 - 219.075 ) 15.0 * 1.0 * 0.75$$

$$= 18.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 5.1253 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 13.0148 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 13.0148 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4733 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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 FileName : Calculation Book for CONDENSER E-PK6101-2  
 Nozzle Calcs.: S2 Noz1: 10 10:31pm Feb 6,2022

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 10.16, max( 13.0148, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1253, 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 = 2.125, 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 = 15.0, tr = 10.015, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.835, 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 for the Nozzle (Impact tested) :**

*Note:*

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

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Nozzle Calcs.: S2

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

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

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

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

Design Pressure/Ambient Rating = 23.05/51.10 = 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 12.0000 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	6.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (20.5507 - 3.9802 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 12.0 - 10.0148) ) 138) \\
 &= 232.28 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.0714 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138 \\
 &= 316.13 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.0714 + 0.0 + 0.855 + ( 1.6647 ) ) * 138 \\
 &= 77.09 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.0714 + 0.0 + 1.855 + 18.0 + ( 1.6647 ) ) * 138 \\
 &= 339.08 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118 \\
 &= 199. \text{ kN}
 \end{aligned}$$

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: S2

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 379.075 * 10.0 * 0.49 * 138$$

$$= 402. \text{ kN}$$

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]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 219.075 * 15.0 * 0.74 * 138$$

$$= 527. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 219.075 * (15.0 - 3.0) * 0.74 * 138$$

$$= 421. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (402 + 222) = 624 \text{ kN}$$

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

$$= (199 + 527 + 421 + 0) = 1147 \text{ kN}$$

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

$$= (402 + 421 + 0) = 824 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 624 kN , must exceed W = 232 kN or W1 = 316 kN

Path 2-2 = 1146 kN , must exceed W = 232 kN or W2 = 77 kN

Path 3-3 = 823 kN , must exceed W = 232 kN or W3 = 339 kN

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

The Drop for this Nozzle is : 10.2574 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.2574 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	1180.000	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	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:CONDENSER E-PK6101-2

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Nozzle Calcs.: S2

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Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.054	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:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 219.075 + 2 * 1.65 * \text{sqrt}(599.0 (15.0 - 3.0))$$

$$= 498.856 \text{ mm.}$$

## 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 = 22.46

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.158	4C	3.689	(A,B)
N(PHI) / ( P/Rm )	0.158	3C	3.023	(C,D)
M(PHI) / ( P )	0.158	2C1	0.072	(A,B)
M(PHI) / ( P )	0.158	1C	0.104	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.158	3A	0.773	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.158	1A	0.093	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.158	3B	2.443	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.158	1B	0.041	(A,B,C,D)
N(x) / ( P/Rm )	0.158	3C	3.023	(A,B)
N(x) / ( P/Rm )	0.158	4C	3.689	(C,D)
M(x) / ( P )	0.158	1C1	0.109	(A,B)
M(x) / ( P )	0.158	2C	0.072	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.158	4A	1.177	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.158	2A	0.050	(A,B,C,D)

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Nozzle Calcs.: S2 Noz1: 10 10:31pm Feb 6,2022

N(x) / ( ML/(Rm\*\*2 \* Beta) ) 0.158 4B 0.745 (A,B,C,D)  
 M(x) / ( ML/(Rm \* Beta) ) 0.158 2B 0.067 (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		-1.8	-1.8	-1.8	-1.8	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-4.7	4.7	-4.7	4.7	-6.9	6.9	-6.9	6.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-3.3	-3.3	3.3	3.3
Circ. Memb. MC		0.0	0.0	0.0	0.0	-54.3	54.3	54.3	-54.3
Circ. Memb. ML		-10.6	-10.6	10.6	10.6	0.0	0.0	0.0	0.0
Circ. Bend. ML		-24.1	24.1	24.1	-24.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-41.3	16.5	28.2	-10.6	-66.0	56.4	49.4	-45.6
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.8	-1.8	-1.8	-1.8
Long. Bend. P		-7.2	7.2	-7.2	7.2	-4.7	4.7	-4.7	4.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-29.0	29.0	29.0	-29.0
Long. Memb. ML		-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML		-39.1	39.1	39.1	-39.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-51.0	41.6	33.7	-30.2	-40.6	26.8	27.5	-21.0
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		4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear		5.0	5.0	3.3	3.3	3.3	3.3	5.0	5.0
Str. Int.		53.1	42.5	35.2	30.7	66.4	56.7	50.4	46.6

Dimensionless Parameters used : Gamma = 49.92

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.277	4C	5.562	(A,B)
N(PHI) / ( P/Rm )	0.277	3C	2.690	(C,D)
M(PHI) / ( P )	0.277	2C1	0.016	(A,B)
M(PHI) / ( P )	0.277	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.277	3A	1.715	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.277	1A	0.061	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.277	3B	3.655	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.277	1B	0.012	(A,B,C,D)
N(x) / ( P/Rm )	0.277	3C	2.690	(A,B)
N(x) / ( P/Rm )	0.277	4C	5.562	(C,D)
M(x) / ( P )	0.277	1C1	0.038	(A,B)
M(x) / ( P )	0.277	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.277	4A	4.650	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.277	2A	0.025	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.277	4B	1.839	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.277	2B	0.018	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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Nozzle Calcs.: S2

Noz1: 10 10:31pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-6.2	-6.2	-6.2	-6.2	-3.0	-3.0	-3.0	-3.0
Circ. Bend.	P	-5.2	5.2	-5.2	5.2	-21.7	21.7	-21.7	21.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-9.8	-9.8	9.8	9.8
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-104.5	104.5	104.5	-104.5
Circ. Memb.	ML	-20.8	-20.8	20.8	20.8	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-19.8	19.8	19.8	-19.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-52.0	-2.0	29.3	0.0	-139.0	113.4	89.6	-76.0
Long. Memb.	P	-3.0	-3.0	-3.0	-3.0	-6.2	-6.2	-6.2	-6.2
Long. Bend.	P	-12.6	12.6	-12.6	12.6	-11.1	11.1	-11.1	11.1
Long. Memb.	MC	0.0	0.0	0.0	0.0	-26.5	-26.5	26.5	26.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-43.1	43.1	43.1	-43.1
Long. Memb.	ML	-10.5	-10.5	10.5	10.5	0.0	0.0	0.0	0.0
Long. Bend.	ML	-29.9	29.9	29.9	-29.9	0.0	0.0	0.0	0.0
Tot. Long. Str.		-56.0	29.1	24.8	-9.8	-87.0	21.5	52.3	-11.7
Shear	VC	1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear	MT	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Tot. Shear		4.2	4.2	2.0	2.0	2.0	2.0	4.2	4.2
Str. Int.		58.7	32.2	30.1	10.6	139.1	113.5	90.0	76.3

**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)	49.5	51.8	49.5	51.8	49.5	51.8	49.5	51.8
Circ. Pl	(SUS)	-12.4	-12.4	8.8	8.8	-4.8	-4.8	1.9	1.9
Circ. Q	(SUS)	-28.9	28.9	19.4	-19.4	-61.2	61.2	47.5	-47.5
Long. Pm	(SUS)	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl	(SUS)	-4.7	-4.7	1.7	1.7	-6.9	-6.9	3.3	3.3
Long. Q	(SUS)	-46.3	46.3	32.0	-32.0	-33.7	33.7	24.2	-24.2
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)	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)		49.5	51.8	49.5	51.8	49.5	51.8	49.5	51.8
Pm+Pl	(SUS)	37.2	39.5	58.3	60.6	44.7	47.0	51.4	53.7
Pm+Pl+Q	(Total)	35.9	72.4	78.2	47.1	19.5	108.4	99.4	10.3

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Nozzle Calcs.: S2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.82	137.90	Passed
Pm+Pl (SUS)	60.62	206.85	Passed
Pm+Pl+Q (TOTAL)	108.38	413.70	Passed

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		112.8	115.1	112.8	115.1	112.8	115.1	112.8	115.1
Circ. Pl (SUS)		-27.0	-27.0	14.7	14.7	-12.8	-12.8	6.8	6.8
Circ. Q (SUS)		-25.0	25.0	14.7	-14.7	-126.2	126.2	82.8	-82.8
Long. Pm (SUS)		56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4
Long. Pl (SUS)		-13.5	-13.5	7.5	7.5	-32.7	-32.7	20.3	20.3
Long. Q (SUS)		-42.6	42.6	17.3	-17.3	-54.2	54.2	32.0	-32.0
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)		3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pm (SUS)		112.8	115.1	112.8	115.1	112.8	115.1	112.8	115.1
Pm+Pl (SUS)		85.8	88.1	127.5	129.8	100.0	102.3	119.6	121.9
Pm+Pl+Q (Total)		61.1	113.7	142.2	115.2	31.3	228.6	202.6	47.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.10	137.90	Passed
Pm+Pl (SUS)	129.77	206.85	Passed
Pm+Pl+Q (TOTAL)	228.57	413.70	Passed

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:CONDENSER E-PK6101-2

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: S1

Nozl: 11 10:31pm Feb 6,2022

**INPUT VALUES, Nozzle Description: S1 From : 40**

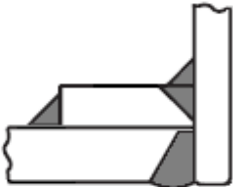
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	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		5511.17	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		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	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	523.8500	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		100.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: S1**

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

Actual Outside Diameter Used in Calculation	12.750 in.
Actual Thickness Used in Calculation	0.601 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.0 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\
 &= 9.9911 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.0 \cdot 161.925) / (118 \cdot 1.0 + 0.4 \cdot 23.0) \\
 &= 3.1344 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.8692 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	598.6257	mm.
Parallel to Vessel Wall, opening length	d	299.3128	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	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	30.260	10.721	NA
Area in Shell	A1	5.942	14.553	NA
Area in Nozzle Wall	A2	4.686	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	30.482	40.256	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: 521.3797 12.0000 mm.

Based on given Pad Diameter: 523.8500 11.8518 mm.

Based on Shell or Nozzle Thickness: 481.8738 15.0000 mm.

Area Required [A]:

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

$$= ( 299.3128 * 9.9911 * 1.0 + 2 * 12.2686 * 9.9911 * 1.0 * (1 - 0.86) )$$

$$= 30.260 \text{ cm}^2$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 299.313( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 12.269$$

$$( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 0.855 )$$

$$= 5.942 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) * ( 12.27 - 3.13 ) * 0.855$$

$$= 4.686 \text{ cm}^2$$

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

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

$$= 10.0^2 * 0.86 + (0.0)^2 * 0.86 + 10.0^2 * 1.0$$

$$= 1.855 \text{ cm}^2$$

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

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

$$= ( 523.85 - 323.85 ) 12.0 * 1.0 * 0.75$$

$$= 18.000 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 6.1344 \text{ mm.}$

Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$

Wall Thickness, shell/head, internal pressure  $trb1 = 12.9911 \text{ mm.}$

Wall Thickness  $tb1 = \max(trb1, tr16b) = 12.9911 \text{ mm.}$

Wall Thickness, shell/head, external pressure  $trb2 = 3.4733 \text{ mm.}$

Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

Wall Thickness per table UG-45  $tb3 = 11.3312 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 11.331, \max( 12.9911, 4.5 ) ]$   
 $= 11.3312 \text{ mm.}$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( ta, tb )$   
 $= \max( 6.1344, 11.3312 )$   
 $= 11.3312 \text{ mm.}$

Available Nozzle Neck Thickness = 15.2686 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	38.5,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	256.3 N./mm <sup>2</sup>	Passed
Occasional	:	13.5,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	13.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

#### Nozzle Neck to Flange Weld (Impact tested) :

##### Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

##### Note:

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

Impact Test Temperature provided per Specification	-46 °C
--	--------

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.833$ , Temp. Reduction = 9 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.833$ , Temp. Reduction = 9 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

##### Note:

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

Impact Test Temperature provided per Specification	-46 °C
--	--------

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Governing MDMT of the Nozzle : -46 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -46 °C

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

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:

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

#### Weld Size Calculations, Description: S1

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

#### Results Per UW-16.1:

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

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

Weld Load [W]:

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

$$= \max( 0, (30.26 - 5.9415 + 2 * 12.2686 * 0.855 * (1.0 * 12.0 - 9.9911) ) 138 )$$

$$= 341.13 \text{ kN}$$

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

Weld Load [W1]:

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

$$= ( 4.6858 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138$$

$$= 338.39 \text{ kN}$$

Weld Load [W2]:

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

$$= ( 4.6858 + 0.0 + 0.855 + ( 2.5175 ) ) * 138$$

$$= 111.11 \text{ kN}$$

Weld Load [W3]:

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

$$= ( 4.6858 + 0.0 + 1.855 + 18.0 + ( 2.5175 ) ) * 138$$

$$= 373.10 \text{ kN}$$

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

Shear, Outward Nozzle Weld [Sonw]:

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

$$= ( 3.1416/2.0 ) * 323.85 * 10.0 * 0.49 * 118$$

$$= 294. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 523.85 * 10.0 * 0.49 * 138$$

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= 556. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo ) / 4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 155.7907 ) \* ( 15.2686 - 3.0 ) \* 0.7 \* 118  
 = 496. kN

Tension, Pad Groove Weld [Tpgw]:

= ( pi / 2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.1416 / 2 ) \* 323.85 \* 12.0 \* 0.74 \* 138  
 = 623. kN

Tension, Shell Groove Weld [Tngw]:

= ( pi / 2 ) \* Dlo \* ( Wgnvi - Cas ) \* 0.74 \* Sng  
 = ( 3.1416 / 2.0 ) \* 323.85 \* ( 15.0 - 3.0 ) \* 0.74 \* 138  
 = 623. kN

### Strength of Failure Paths:

PATH11 = ( SPEW + SNW ) = ( 556 + 496 ) = 1052 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 294 + 623 + 623 + 0 ) = 1540 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 556 + 623 + 0 ) = 1179 kN

### Summary of Failure Path Calculations:

Path 1-1 = 1051 kN , must exceed W = 341 kN or W1 = 338 kN  
 Path 2-2 = 1539 kN , must exceed W = 341 kN or W2 = 111 kN  
 Path 3-3 = 1178 kN , must exceed W = 341 kN or W3 = 373 kN

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

The Drop for this Nozzle is : 22.6551 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 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	1180.000	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	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333	6
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	523.850	mm.
Design Internal Pressure	Dp	23.000	bars

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Include Pressure Thrust No

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

Radial Load	(SUS)	P	12.0	kN
Longitudinal Shear	(SUS)	VL	12.0	kN
Circumferential Shear	(SUS)	Vc	12.0	kN
Circumferential Moment	(SUS)	Mc	15300.0	N-m
Longitudinal Moment	(SUS)	ML	15300.0	N-m
Torsional Moment	(SUS)	Mt	18900.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 323.85 + 2 * 1.65 * \text{sqrt}(599.0 (15.0 - 3.0))$$

$$= 603.631 \text{ mm.}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	12.0	kN
Circumferential Shear	VC	12.0	kN
Longitudinal Shear	VL	12.0	kN
Circumferential Moment	MC	15300.0	N-m
Longitudinal Moment	ML	15300.0	N-m
Torsional Moment	MT	18900.0	N-m

Dimensionless Parameters used : Gamma = 25.21

## Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.234	4C	3.562	(A,B)
N(PHI) / ( P/Rm )	0.234	3C	2.326	(C,D)
M(PHI) / ( P )	0.234	2C1	0.036	(A,B)
M(PHI) / ( P )	0.234	1C !	0.066	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.234	3A	1.068	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.234	1A	0.081	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.234	3B	2.666	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.234	1B	0.026	(A,B,C,D)
N(x) / ( P/Rm )	0.234	3C	2.326	(A,B)
N(x) / ( P/Rm )	0.234	4C	3.562	(C,D)
M(x) / ( P )	0.234	1C1	0.068	(A,B)
M(x) / ( P )	0.234	2C !	0.036	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.234	4A	1.842	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.234	2A	0.039	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.234	4B	1.023	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.234	2B	0.045	(A,B,C,D)

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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		Stress Intensity Values at							
Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl	
Circ. Memb. P	-2.9	-2.9	-2.9	-2.9	-1.9	-1.9	-1.9	-1.9	
Circ. Bend. P	-4.6	4.6	-4.6	4.6	-8.2	8.2	-8.2	8.2	
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.9	-7.9	7.9	7.9	
Circ. Memb. ML	-19.8	-19.8	19.8	19.8	0.0	0.0	0.0	0.0	
Circ. Bend. ML	-29.7	29.7	29.7	-29.7	0.0	0.0	0.0	0.0	
Tot. Circ. Str.	-57.1	11.5	42.1	-8.3	-109.2	89.5	88.9	-76.9	
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-2.9	-2.9	-2.9	-2.9	
Long. Bend. P	-8.5	8.5	-8.5	8.5	-4.6	4.6	-4.6	4.6	
Long. Memb. MC	0.0	0.0	0.0	0.0	-13.7	-13.7	13.7	13.7	
Long. Bend. MC	0.0	0.0	0.0	0.0	-43.7	43.7	43.7	-43.7	
Long. Memb. ML	-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0	
Long. Bend. ML	-50.2	50.2	50.2	-50.2	0.0	0.0	0.0	0.0	
Tot. Long. Str.	-68.2	49.2	47.4	-36.0	-64.9	31.6	49.9	-28.4	
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	
Shear MT	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	
Tot. Shear	5.8	5.8	3.8	3.8	3.8	3.8	5.8	5.8	
Str. Int.	70.7	50.0	49.4	36.5	109.6	89.8	89.7	77.6	

Dimensionless Parameters used : Gamma = 49.92

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.383	4C	4.119	(A,B)
N(PHI) / ( P/Rm )	0.383	3C	1.626	(C,D)
M(PHI) / ( P )	0.383	2C1	0.008	(A,B)
M(PHI) / ( P )	0.383	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.383	3A	1.305	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.383	1A	0.058	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.383	3B	2.364	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.383	1B	0.006	(A,B,C,D)
N(x) / ( P/Rm )	0.383	3C	1.626	(A,B)
N(x) / ( P/Rm )	0.383	4C	4.119	(C,D)
M(x) / ( P )	0.383	1C1	0.020	(A,B)
M(x) / ( P )	0.383	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.383	4A	4.788	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.383	2A	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.383	4B	1.407	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.383	2B	0.010	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-6.9	-6.9	-6.9	-6.9	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-32.6	32.6	-32.6	32.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-12.1	-12.1	12.1	12.1
Circ. Memb. MC		0.0	0.0	0.0	0.0	-162.1	162.1	162.1	-162.1
Circ. Memb. ML		-21.9	-21.9	21.9	21.9	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.		-49.9	-7.8	28.1	2.0	-209.5	179.8	138.9	-120.1
Long. Memb. P		-2.7	-2.7	-2.7	-2.7	-6.9	-6.9	-6.9	-6.9
Long. Bend. P		-10.2	10.2	-10.2	10.2	-16.7	16.7	-16.7	16.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-44.5	-44.5	44.5	44.5
Long. Bend. MC		0.0	0.0	0.0	0.0	-64.2	64.2	64.2	-64.2
Long. Memb. ML		-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Long. Bend. ML		-26.4	26.4	26.4	-26.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-52.4	20.8	26.6	-5.9	-132.3	29.6	85.1	-10.0
Shear VC		1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT		3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Tot. Shear		4.9	4.9	2.4	2.4	2.4	2.4	4.9	4.9
Str. Int.		56.2	30.2	29.9	9.3	209.5	179.9	139.3	120.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Circ. Pl (SUS)		-22.8	-22.8	16.9	16.9	-9.9	-9.9	6.0	6.0
Circ. Q (SUS)		-34.3	34.3	25.2	-25.2	-99.4	99.4	82.9	-82.9
Long. Pm (SUS)		27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
Long. Pl (SUS)		-9.5	-9.5	5.7	5.7	-16.6	-16.6	10.8	10.8
Long. Q (SUS)		-58.7	58.7	41.7	-41.7	-48.2	48.2	39.1	-39.1
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)		4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Pm (SUS)		55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Pm+Pl (SUS)		33.0	35.3	72.6	74.9	45.9	48.2	61.8	64.1
Pm+Pl+Q (Total)		41.2	80.1	98.4	58.4	54.4	147.7	145.1	21.7

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Nozzle Calcs.: S1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	58.01	137.90	Passed
Pm+Pl (SUS)	74.91	206.85	Passed
Pm+Pl+Q (TOTAL)	147.69	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)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)		-28.8	-28.8	15.1	15.1	-14.8	-14.8	9.4	9.4
Circ. Q (SUS)		-21.0	21.0	13.1	-13.1	-194.6	194.6	129.5	-129.5
Long. Pm (SUS)		56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)		-15.8	-15.8	10.3	10.3	-51.3	-51.3	37.6	37.6
Long. Q (SUS)		-36.6	36.6	16.2	-16.2	-80.9	80.9	47.5	-47.5
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q (SUS)		3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)		83.7	86.0	127.6	129.9	97.7	100.0	122.0	124.3
Pm+Pl+Q (Total)		63.1	107.8	140.8	116.9	97.2	294.7	251.6	52.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	129.92	206.85	Passed
Pm+Pl+Q (TOTAL)	294.67	413.70	Passed

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Nozzle Calcs.: S3

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**INPUT VALUES, Nozzle Description: S3 From : 40**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	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		1296.17	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	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.
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)**

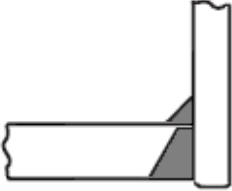
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Nozzle Calcs.: S3

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

**Reinforcement CALCULATION, Description: S3**

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]

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

$$= (23.0 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 9.9911 \text{ mm.}$$

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 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	113.6000	mm.
Parallel to Vessel Wall, opening length	d	56.8000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	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 [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	5.675	2.011	NA
Area in Shell	A1	1.141	2.795	NA
Area in Nozzle Wall	A2	7.873	7.922	NA

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Nozzle Calcs.: S3 Nozl: 12 10:31pm Feb 6,2022

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	10.014	11.717	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]:

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

$$= ( 56.8 * 9.9911 * 1.0 + 2 * 13.6 * 9.9911 * 1.0 * (1 - 1.0) )$$

$$= 5.675 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 56.8 ( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 13.6$$

$$( 1.0 * 12.0 - 1.0 * 9.991 ) * ( 1 - 1.0 )$$

$$= 1.141 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= ( 2 * 30.0 ) ( 13.6 - 0.48 ) 1.0$$

$$= 7.873 \text{ cm}^2$$

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 = 12.9911 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 12.9911 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4733 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]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 12.9911, 4.5 ) ]$$

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

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

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9, Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0, Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9, Allowable	: 183.4 N./mm <sup>2</sup>	Passed
Shear	: 9.6, Allowable	: 96.5 N./mm <sup>2</sup>	Passed

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
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*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

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

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: S3

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

#### Results Per UW-16.1:

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

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

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (5.6749 - 1.1411 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 12.0 - 9.9911 ) ) 138) \\
 &= 70.05 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 7.8729 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 122.35 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 7.8729 + 0.0 + 1. + ( 3.264 ) ) * 138 \\
 &= 167.35 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 7.8729 + 0.0 + 1. + 0.0 + ( 3.264 ) ) * 138 \\
 &= 167.35 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

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Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 35.2) * (16.6 - 3.0) * 0.7 * 138$$

$$= 145. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 84.0 * (15.0 - 3.0) * 0.74 * 138$$

$$= 162. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = (\text{SONW} + \text{SNW}) = (89 + 145) = 234 \text{ kN}$$

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

$$= (89 + 0 + 162 + 0) = 251 \text{ kN}$$

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

$$= (89 + 162 + 0) = 251 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 70 kN or W1 = 122 kN  
 Path 2-2 = 250 kN , must exceed W = 70 kN or W2 = 167 kN  
 Path 3-3 = 250 kN , must exceed W = 70 kN or W3 = 167 kN

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

The Drop for this Nozzle is : 1.4968 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.4968 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	1180.000	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	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:

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

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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:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}( 599.0 ( 15.0 - 3.0 ) )$$

$$= 363.781 \text{ mm.}$$

**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 = 49.92

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.061	4C	9.229	(A,B)
N(PHI) / ( P/Rm )	0.061	3C	8.801	(C,D)
M(PHI) / ( P )	0.061	2C1	0.121	(A,B)
M(PHI) / ( P )	0.061	1C	0.157	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.061	3A	0.985	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.061	1A	0.102	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.061	3B	3.840	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.061	1B	0.054	(A,B,C,D)
N(x) / ( P/Rm )	0.061	3C	8.801	(A,B)
N(x) / ( P/Rm )	0.061	4C	9.229	(C,D)
M(x) / ( P )	0.061	1C1	0.163	(A,B)
M(x) / ( P )	0.061	2C	0.121	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.061	4A	1.327	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.061	2A	0.059	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.061	4B	0.970	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.061	2B	0.088	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.6	-2.6	-2.6	-2.6	-2.4	-2.4	-2.4	-2.4
Circ. Bend.	P	-10.1	10.1	-10.1	10.1	-13.1	13.1	-13.1	13.1

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Nozzle Calcs.: S3 Nozl: 12 10:31pm Feb 6,2022

Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-46.3	46.3	46.3	-46.3
Circ. Memb. ML	-5.8	-5.8	5.8	5.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-42.9	26.2	17.5	-11.1	-63.4	55.5	32.3	-34.2
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-2.6	-2.6	-2.6	-2.6
Long. Bend. P	-13.6	13.6	-13.6	13.6	-10.1	10.1	-10.1	10.1
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-26.8	26.8	26.8	-26.8
Long. Memb. ML	-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Long. Bend. ML	-40.1	40.1	40.1	-40.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-57.5	49.7	25.5	-27.5	-41.5	32.4	16.2	-17.3
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Tot. Shear	5.0	5.0	2.5	2.5	2.5	2.5	5.0	5.0
Str. Int.	59.1	50.7	26.2	27.9	63.6	55.7	33.7	35.6

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)		-8.4	-8.4	3.2	3.2	-3.9	-3.9	-1.0	-1.0
Circ. Q (SUS)		-34.5	34.5	14.3	-14.3	-59.4	59.4	33.2	-33.2
Long. Pm (SUS)		56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)		-3.9	-3.9	-1.0	-1.0	-4.6	-4.6	-0.6	-0.6
Long. Q (SUS)		-53.6	53.6	26.5	-26.5	-36.9	36.9	16.7	-16.7
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)		3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)		104.2	106.5	115.8	118.1	108.6	110.9	111.6	113.9
Pm+Pl+Q (Total)		71.6	141.7	130.2	103.8	49.4	170.4	145.2	81.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	118.10	206.85	Passed
Pm+Pl+Q (TOTAL)	170.38	413.70	Passed

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FileName : Calculation Book for CONDENSER E-PK6101-2

Nozzle Calcs.: T4

Nozl: 13 10:31pm Feb 6,2022

**INPUT VALUES, Nozzle Description: T4****From : 60**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	447.3333	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		6257.35	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		0.7500	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.2500	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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)**

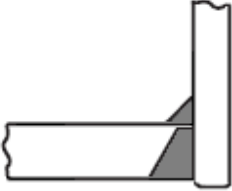
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Nozzle Calcs.: T4

Noz1: 13 10:31pm Feb 6,2022



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

**Reinforcement CALCULATION, Description: T4**

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

Actual Inside Diameter Used in Calculation 0.750 in.  
 Actual Thickness Used in Calculation 0.561 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 9.9911 \text{ mm.}$$

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

$$= R \left( \exp\left(\frac{P}{S_n \cdot E}\right) - 1 \right) \text{ per Appendix 1-2 (a) (1)}$$

$$= 12.525 \left( \exp\left(\frac{23.0}{137.9 \cdot 1.0}\right) - 1 \right)$$

$$= 0.2107 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2876 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	71.5500	mm.
Parallel to Vessel Wall	Rn+tn+t	35.7750	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	28.1250	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	2.503	0.332	NA
Area in Shell	A1	0.934	4.347	NA
Area in Nozzle Wall	A2	6.210	6.166	NA

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Nozzle Calcs.: T4 Nozl: 13 10:31pm Feb 6,2022

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	8.144	11.514	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 25.05 * 9.9911 * 1.0 + 2 * 11.25 * 9.9911 * 1.0 * (1 - 1.0) ) \\
 &= 2.503 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 46.5 ( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 11.25 \\
 &\quad ( 1.0 * 12.0 - 1.0 * 9.991 ) * ( 1 - 1.0 ) \\
 &= 0.934 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 28.13 ) ( 11.25 - 0.21 ) 1.0 \\
 &= 6.210 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.2876 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 12.9911 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 12.9911 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4733 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.2200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.22, \max( 12.9911, 4.5 ) ] \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.2876, 6.22 ) \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 14.2500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

-----  
 Govern. thk, tg = 14.25, tr = 0.211, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*) / (tg - c) = 0.019, Temp. Reduction = 78 °C

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Nozzle Calcs.: T4 Noz1: 13 10:31pm Feb 6,2022

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

Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of 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: T4

Intermediate Calc. for nozzle/shell Welds Tmin 11.2500 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (2.5028 - 0.9342 + 2 * 11.25 * 1.0 * \\
 &\quad (1.0 * 12.0 - 9.9911) )138) \\
 &= 27.86 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 6.2096 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 99.41 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 6.2096 + 0.0 + 1. + ( 2.7 ) ) * 138 \\
 &= 136.64 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 6.2096 + 0.0 + 1. + 0.0 + ( 2.7 ) ) * 138 \\
 &= 136.64 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 47.55 * 10.0 * 0.49 * 138 \\
 &= 50. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 18.15 ) * ( 14.25 - 3.0 ) * 0.7 * 138 \\
 &= 62. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 47.55 * ( 15.0 - 3.0 ) * 0.74 * 138 \\
 &= 91. \text{ kN}
 \end{aligned}$$

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Nozzle Calcs.: T4

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### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 50 + 62 ) = 112 \text{ kN}$$

$$\begin{aligned} \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 50 + 0 + 91 + 0 ) = 142 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 50 + 91 + 0 ) = 142 \text{ kN} \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 112 kN , must exceed W = 27 kN or W1 = 99 kN

Path 2-2 = 141 kN , must exceed W = 27 kN or W2 = 136 kN

Path 3-3 = 141 kN , must exceed W = 27 kN or W3 = 136 kN

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

The Drop for this Nozzle is : 0.4792 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.4792 mm.

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Nozzle Calcs.: T3

Noz1: 14 10:31pm Feb 6,2022

**INPUT VALUES, Nozzle Description: T3 From : 60**

Pressure for Reinforcement Calculations	P	23.115	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	447.3333	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		6257.35	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

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

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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)**

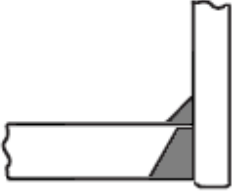
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Nozzle Calcs.: T3

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

**Reinforcement CALCULATION, Description: T3**

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

Actual Inside Diameter Used in Calculation 1.000 in.  
 Actual Thickness Used in Calculation 0.563 in.

Nozzle input data check completed without errors.

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

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

$$= (23.12 \cdot 593.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$$

$$= 10.0415 \text{ mm.}$$

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

$$= R \left( \exp\left(\frac{P}{S_n \cdot E}\right) - 1 \right) \text{ per Appendix 1-2 (a) (1)}$$

$$= 15.7 \left( \exp\left(\frac{23.12}{137.9 \cdot 1.0}\right) - 1 \right)$$

$$= 0.2654 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3088 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	78.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	39.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	28.2500	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	3.153	0.416	NA
Area in Shell	A1	0.913	4.357	NA
Area in Nozzle Wall	A2	6.235	6.210	NA

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Nozzle Calcs.: T3 Nozl: 14 10:31pm Feb 6,2022

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	8.147	11.567	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 31.4 * 10.0415 * 1.0 + 2 * 11.3 * 10.0415 * 1.0 * (1 - 1.0) ) \\
 &= 3.153 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 46.6 ( 1.0 * 12.0 - 1.0 * 10.042 ) - 2 * 11.3 \\
 &\quad ( 1.0 * 12.0 - 1.0 * 10.0415 ) * ( 1 - 1.0 ) \\
 &= 0.913 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 28.25 ) ( 11.3 - 0.27 ) 1.0 \\
 &= 6.235 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.3088 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 13.0415 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 13.0415 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.4733 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]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 13.0415, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.3088, 6.42 ) \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

-----  
 Govern. thk, tg = 14.3, tr = 0.265, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*) / (tg - c) = 0.023, Temp. Reduction = 78 °C

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Nozzle Calcs.: T3 Noz1: 14 10:31pm Feb 6,2022

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

Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of 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 = 23.12/51.10 = 0.452

#### Weld Size Calculations, Description: T3

Intermediate Calc. for nozzle/shell Welds Tmin 11.3000 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]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (3.153 - 0.9126 + 2 * 11.3 * 1.0 * \\
 &\quad (1.0 * 12.0 - 10.0415) )138) \\
 &= 37.00 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 6.2345 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 99.76 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 6.2345 + 0.0 + 1. + ( 2.712 ) ) * 138 \\
 &= 137.15 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 6.2345 + 0.0 + 1. + 0.0 + ( 2.712 ) ) * 138 \\
 &= 137.15 \text{ kN}
 \end{aligned}$$

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

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 54.0 * 10.0 * 0.49 * 138 \\
 &= 57. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 21.35 ) * ( 14.3 - 3.0 ) * 0.7 * 138 \\
 &= 73. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 54.0 * ( 15.0 - 3.0 ) * 0.74 * 138 \\
 &= 104. \text{ kN}
 \end{aligned}$$

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### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 57 + 73 ) = 130 \text{ kN}$$

$$\begin{aligned} \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 57 + 0 + 104 + 0 ) = 161 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\ &= ( 57 + 104 + 0 ) = 161 \text{ kN} \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 130 kN , must exceed W = 36 kN or W1 = 99 kN

Path 2-2 = 161 kN , must exceed W = 36 kN or W2 = 137 kN

Path 3-3 = 161 kN , must exceed W = 36 kN or W3 = 137 kN

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

The Drop for this Nozzle is : 0.6181 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6181 mm.

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Nozzle Schedule: Step: 21 10:31pm Feb 6,2022

**Nozzle Schedule:**

Flg	Nominal or	Schd	Flg	Nozzle	Wall	Reinforcing Pad	Cut
Class	Actual	or FVC	Type	O/Dia	Thk	Diameter	Thk
Description	Size	Type		in	mm.	mm.	mm.
T4	0.750 in	Actual	LWN	1.872	14.250	...	...
T3	1.000 in	Actual	LWN	2.126	14.300	...	...
S3	2.000 in	Actual	LWN	3.307	16.600	...	...
S2	8.000 in	80	WNF	8.625	12.700	379.08	15.00
T1	12.000 in	80	WNF	12.750	17.450	483.85	15.00
T2	12.000 in	80	WNF	12.750	17.450	483.85	15.00
S1	12.000 in	80	WNF	12.750	17.450	523.85	12.00

*General Notes for the above table:*

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:  
 Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

**Nozzle Material and Weld Fillet Leg Size Details (mm.):**

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T4	SA-350 LF2	15.000	10.000	...	...	...
T3	SA-350 LF2	15.000	10.000	...	...	...
S3	SA-350 LF2	15.000	10.000	...	...	...
S2	SA-333 6	15.000	10.000	10.000	15.000	...
T1	SA-333 6	15.000	14.000	10.000	15.000	...
T2	SA-333 6	15.000	14.000	10.000	15.000	...
S1	SA-333 6	15.000	10.000	10.000	12.000	...

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

**Nozzle Miscellaneous Data:**

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	6207.350	90.0	200.00	0.00	CHANNEL 002
T3	6207.350	270.0	200.00	0.00	CHANNEL 002

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S3	1246.175	90.0	200.00	0.00	SHELL
S2	1246.175	270.0	200.00	0.00	SHELL
T1	375.000	270.0	200.00	0.00	CHANNEL 01
T2	375.000	90.0	200.00	0.00	CHANNEL 01
S1	5461.175	90.0	200.00	0.00	SHELL

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**Input Echo, Tubesheet Number 1, Description: TUBE SHEET**

**Shell Data:**

**Main Shell Description: SHELL**

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	15.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1180.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°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: CHANNEL 01**

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	1180.000	mm.
Channel Design Temperature	TEMPC	190.00	°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	1802	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	5000.00	mm.
Straight Tube Length (bet. inner tubsht faces) L		4840.00	mm.
Design Temperature of the Tubes		190.00	°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	208.13	N./mm <sup>2</sup>
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Triangular	

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Fillet Weld Leg	af	1.5000	mm.
Groove Weld Leg	ag	1.5000	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	571.120	mm.
Largest Center-to-Center Tube Distance	Ul	38.1000	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: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	190.00	°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	80.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	1350.000	mm.

**Additional Data for Stepped Tubesheets:**

Is the Tubesheet Stepped?		NO	
---------------------------	--	----	--

Area of the Untubed Lanes	AL	479.0	cm <sup>2</sup>
---------------------------	----	-------	-----------------

**Additional Data for Fixed/Floating Tubesheet Exchangers:**

Unsupported Tube Span under consideration	l	1354.000	mm.
Tube End condition corresponding to Span (l)	k	0.80	

Ignore Radial Thermal Exp. effects (UHX-13.8/14.6)		YES	
--	--	-----	--

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

Tubesheet Metal Temp. at Rim	T'	21.11	°C
Shell Metal Temp. at Tubesheet	T'S	21.11	°C
Channel Metal Temp. at Tubesheet	T'C	21.11	°C
Perform Differential Pressure Design		N	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0342	bars
Channel Side Min. Design Pressure	Ptd,min	1.0314	bars

Mean Shell Metal Temp. along Shell len.	Tsm	53.80	°C
Mean Tube Metal Temp. along Tube length	Ttm	42.50	°C
Junction Stress Reduction option		Perform Plastic Calculation	

**Additional Data for Gasketed Tubesheets:**

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	1350.000	mm.
Flange Inside Diameter	B	1180.000	mm.
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Gasket Outside Diameter	Go	1263.000	mm.

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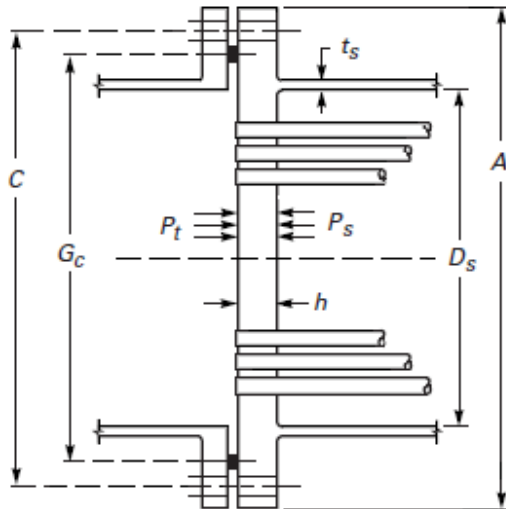
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Gasket Inside Diameter	Gi	1223.000	mm.
Small end Hub thk.	g0	15.0000	mm.
Large end Hub thk.	g1	27.0000	mm.
Gasket Factor,	m	3.78	
Gasket Design Seating Stress	y	62.05	N./mm <sup>2</sup>
Flange Facing Sketch	Code Sketch	1a	
Column for Gasket Seating	Code Column	II	
Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		
Length of Partition Gasket	lp	1078.000	mm.
Width of Partition Gasket	wp	10.0000	mm.
Partition Gasket Factor,	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm <sup>2</sup>
Partition Gasket Facing Sketch	Code Sketch	1a	
Partition Gasket Column for Gasket Seating	Code Column	II	

**Bolting Information:**

Diameter of Bolt Circle	C	1298.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	76	

**Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange**



**Configuration b:**

320 L7	Bolt Material		SA-
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.
Tubesheet Integral with	Shell		
Tubesheet Extended as Flange	Yes		
Thickness of Extended Portion of Tubesheet	Tf	64.0000	mm.
Is Bolt Load Transferred to the Tubesheet	Yes		
Is Exchanger in Creep range (skip EP, Use 3S for Sps)	NO		

**ASME TubeSheet Results per Part UHX, 2017**

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**Elasticity/Expansion Material Properties:**

Shell - TE-1 Carbon & Low Alloy Steels, Group 1  
 Shell - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. along Len	53.8 °C	0.0000118028 /°C
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09 KPa.
Th. Exp. Coeff. Metal Temp. at Tubsht	21.1 °C	0.0000115190 /°C
Elastic Mod. at Metal Temp. along Len	53.8 °C	0.20083E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

Channel - TE-1 Carbon & Low Alloy Steels, Group 1  
 Channel - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. at Tubsht	21.1 °C	0.0000115190 /°C
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

Tubes - TE-1 Carbon & Low Alloy Steels, Group 1  
 Tubes - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. along Len	42.5 °C	0.0000117296 /°C
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09 KPa.
Elastic Mod. at Metal Temp. along Len	42.5 °C	0.20148E+09 KPa.
Elastic Mod. at Tubsht. Design Temp.	190.0 °C	0.19308E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

TubeSheet - TE-1 Carbon & Low Alloy Steels, Group 1  
 TubeSheet - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. at Rim	21.1 °C	0.0000115190 /°C
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09 KPa.
Elastic Mod. at Metal Temp. at Rim	21.1 °C	0.20270E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

Note:  
 The Elasticity and Alpha values are taken from Tables in ASME II D.  
 Please insure these properties are consistent with the  
 type of Material for the tubes, shell, channel etc.

**Tube Required Thickness under Internal Pressure (Tubeside pressure) :**

Thickness Due to Internal Pressure:  
 = (P\*(D/2-CAE)) / (S\*E+0.4\*P) per Appendix 1-1 (a) (1)  
 = (24.03\*(19.05/2-0.0))/(117.9\*1.0+0.4\*24.03)  
 = 0.1926 + 0.0000 = 0.1926 mm.

**Tube Required Thickness under External Pressure (Shellside pressure) :**

External Pressure Chart CS-2 at 190.00 °C  
 Elastic Modulus for Material 194843456.00 KPa.

**Results for Max. Allowable External Pressure (Emawp):**

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.1080	19.05	4840.00	9.04	50.0000	0.0134693	118.20
EMAWP = (2.167/(D/T)-0.0833)*B = 184.9632 bars						

**Results for Reqd Thickness for Ext. Pressure (Tca):**

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4881	19.05	4840.00	39.03	50.0000	0.0007221	70.35

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$$EMAWP = (4*B)/(3*(D/T)) = ( 4 *70.3514 )/( 3 *39.0302 ) = 24.0318 \text{ bars}$$

**Summary of Tube Required Thickness Results:**

Total Required Thickness including Corrosion all.	0.4881	mm.
Allowable Internal Pressure at Corroded thickness	286.26	bars
Required Internal Design Pressure	24.03	bars
Allowable External Pressure at Corroded thickness	184.96	bars
Required External Design Pressure	24.03	bars
Required Thickness due to Shell Side pressure	0.4881	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,	$G = Go-2.0*b$	1247.068	mm.

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

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

$$= 2 * 22.225 + 6 * 64.0/(3.78 + 0.5)$$

$$= 134.170 \text{ mm.}$$

**Actual Circumferential Bolt Spacing [Bs]:**

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

$$= 1298.0 * \sin( 3.142/76 )$$

$$= 53.640 \text{ mm.}$$

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

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

$$= \max( \text{sqrt}( 53.64/( 2 * 22.225 + 64.0 ) ), 1 )$$

$$= 1.0000$$

**Bolting Information for UNC 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>	199.862	205.445	
Radial Distance between Hub and Bolts:	23.812	44.000	
Radial Distance between Bolts and the Ed	23.812	26.000	
Circumferential Spacing between the Bolt	52.400	53.640	134.170

Flange Design Bolt Load, Seating Condition	W :	3492.94	kN
Flange Design Bolt Load, Operating Condition	Wm1:	3444.83	kN

**Results for ASME Fixed Tubesheet Calculations for Configuration b.**

**Results for Tubesheet Calculations Original Thickness :**

**UHX-13.5.1 Step 1:**

Compute the Tube Expansion Depth Ratio [rho]:

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$$= l_{tx} / h \quad (\text{modified for corrosion if present})$$

$$= 0.0/80.0 = 0.0 \quad (\text{must be } 0 \leq \rho \leq 1)$$

Compute the Effective Tube Hole Diameter [d\*]:

$$= \text{Max}( dt - 2tt * ( Et/E ) ( StT/S ) ( \rho ), dt - 2tt )$$

$$= \text{Max}( 19.05 - 2 * 2.108 * (.19308E+09 / .19308E+09) * ( 117/137 ) * (0.0), 19.05 - 2 * 2.108 )$$

$$= 19.0500 \text{ mm.}$$

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

$$= 2 * r_o + dt = 2 * 571.12 + 19.05 = 1161.29 \text{ mm.}$$

Determine the Basic Ligament Efficiency for Shear [mu]:

$$= (p - dt) / p = (24.0 - 19.05) / 24.0 = 0.2063$$

Compute the Equivalent Outer Tube Limit Radius [ao]:

$$= Do / 2 = 1161.2899 / 2 = 580.645 \text{ mm.}$$

Compute the Effective Tube Pitch [p\*]:

$$= p / \sqrt{1 - 4 * \min( AL * CNV\_factor, 4 * Do * p ) / ( \pi * Do^2 )}$$

$$= 24.0 / \sqrt{1 - 4 * \min( 479.0 * 100.0, 4 * 1161.29 * 24.0 ) / ( 3.141 * 1161.29^2 )}$$

$$= 24.5618 \text{ mm.}$$

Compute the Effective Ligament Efficiency for Bending [mu\*]:

$$= (p^* - d^*) / p^* = (24.5618 - 19.05) / 24.5618 = 0.2244$$

Compute the Ratio [Rhos]:

$$= a_s / a_o = 590.0 / 580.645 = 1.016111$$

Compute the Ratio [Rhoc]:

$$= a_c / a_o = 623.5342 / 580.645 = 1.073865$$

Compute Parameter [xt]:

$$= 1 - N_t * ( ( dt - 2 * tt ) / ( 2 * a_o ) )^2$$

$$= 1 - 1802 * ( ( 19.05 - 2 * 2.108 ) / ( 2 * 580.645 ) )^2 = 0.706$$

Determine Parameter [xs]:

$$= 1 - N_t * ( dt / ( 2 * a_o ) )^2$$

$$= 1 - 1802 * ( 19.05 / ( 2 * 580.645 ) )^2 = 0.5151$$

Determine the Value [h'g]:

$$= \text{Max}( ( h_g - CATC ), 0 ) \quad (\text{For pressure only cases})$$

$$= \text{Max}( ( 5.0 - 0.0 ), 0 ) = 5.0 \text{ mm.}$$

### UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:

$$= \pi * t_s ( D_s + t_s ) E_s / L$$

$$= 3.1416 * 15.0 ( 1180.0 + 15.0 ) .19308E+09 / 4840.0$$

$$= 2246438912.0000 \text{ KPa. * mm.}$$

Determine the Axial Tube Stiffness [Kt]:

$$= \pi * tt ( D_t - tt ) E_t / L$$

$$= 3.1416 * 2.108 ( 19.05 - 2.108 ) .19308E+09 / 4840.0$$

$$= 4475801.0000 \text{ KPa. * mm.}$$

Compute the Stiffness Factor [Ks,t]:

$$= K_s / ( N_t * K_t ) = 0.22464E+1 / ( 1802 * 4475801 ) = 0.27853$$

Rigidity Ratio [J]:

$$= 1 / ( 1 + K_s / K_j )$$

$$= 1 / ( 1 + 0.22464E+1 / 0.0 ) = 1. \quad (= 1 \text{ if No Exp. } J_t.)$$

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Compute Shell Coefficient [betas]:

$$= ((12 * (1 - \text{nus}^2))^{0.25}) / ((\text{Ds} + \text{ts}) * \text{ts})^{0.5}$$

$$= ((12 * (1 - 0.3^2))^{0.25}) / ((1180.0 + 15.0) * 15.0)^{0.5}$$

$$= 0.0136 \text{ 1/mm.}$$

Determine Shell Coefficient [ks]:

$$= \text{betas} * \text{Es} * \text{ts}^3 / (6 * (1 - \text{nus}^2))$$

$$= 0.014 * 0.19308\text{E}+09 * 15.0^3 / (6 * (1 - 0.3^2))$$

$$= 16204597.0000 \text{ bars*mm.}^2$$

Determine Shell Coefficient [Lambdas]:

$$= (6 * \text{Ds} * \text{ks}) / (\text{h}^3) * (1 + \text{h} * \text{betas} + 0.5 * (\text{h} * \text{betas})^2)$$

$$= 6 * 1180.0 * 16204597 / (80.0^3) * (1 + 80.0 * 0.014 + 0.59)$$

$$= 599669.1250 \text{ bars}$$

Determine Shell Coefficient [deltaS]:

$$= \text{Ds}^2 / (4 * \text{Es} * \text{Ts}) * (1 - \text{nus} / 2)$$

$$= 1180.0^2 / (4 * 0.19308\text{E}+09 * 15.0) * (1 - 0.3 / 2)$$

$$= 0.1021587178 \text{ mm./N./mm}^2$$

Intermediate parameters for Tubesheet Gasketed on the Channel Side:  
 betac, kc, deltaC, Lambdac = 0

### UHX-13.5.3 Step 3:

E\*/E and nu\* for Triangular pattern from Fig. UHX-11.3.

$$\text{h/p} = 3.333333 ; \mu^* = 0.224406$$

$$\text{E}^*/\text{E} = 0.184708 ; \nu^* = 0.425544 ; \text{E}^* = 35662968. \text{ KPa.}$$

Note: As h/p (3.333) is > 2, data values for h/p = 2 were used.

Compute the Tube Bundle Stiffness Factor [Xa]:

$$= ((24 * (1 - \nu^*) * \text{Nt} * \text{Et} * \text{tt} * (\text{dt} - \text{tt}) * \text{ao}^2) /$$

$$(\text{E}^* * \text{L} * \text{H}^3))^{0.25}$$

$$= ((24 * (1 - 0.426^2) * 1802 * 0.19308\text{E}+09 * 2.108 *$$

$$(19.05 - 2.108) * 580.645^2) / (35662968 *$$

$$4840.0 * 80.0^3))^{0.25}$$

$$= 5.5248$$

Values from Table UHX-13.1

$$\text{Zd} = 0.008877 ; \text{Zv} = 0.032485 ; \text{Zm} = 0.257682$$

$$\text{Za} = 0.455082\text{E}+02 ; \text{Zw} = 0.032485$$

### UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:

$$= \text{A}/\text{Do} = 1350.0/1161.2899 = 1.1625$$

Compute Coefficient [F]:

$$= (1 - \nu^*) / (\text{E}^*) * (\text{Lambdas} + \text{Lambdac} + \text{E} * \ln(\text{K}))$$

$$= (1 - 0.43) / (35662968) * (599669 + 0.0 +$$

$$0.19308\text{E}+09 * \ln(1.16))$$

$$= 1.4342$$

Compute Parameter [Phi]:

$$= (1 + \nu^*) * \text{F} = (1 + 0.4255) * 1.4342 = 2.0446$$

Compute Parameter [Q1]:

$$= (\text{Rhos} - 1 - \text{Phi} * \text{Zv}) / (1 + \text{Phi} * \text{Zm})$$

$$= (1.0161 - 1 - 2.0446 * 0.0325) / (1 + 2.0446 * 0.2577)$$

$$= -0.032947633$$

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Compute Parameter [Qz1]:

$$= (Zd + Q1*Zw)/2 * Xa^4$$

$$= ( 0.00888 + -0.03295 * 0.03248 )/2 * 5.52477^4 = 3.6367$$

Compute Parameter [Qz2]:

$$= (Zv + Q1*Zm)/2 * Xa^4$$

$$= ( 0.03248 + -0.03295 * 0.25768 )/2 * 5.52477^4 = 11.1775$$

Compute Parameter [U]:

$$= (Zw + (Rhos - 1)*Zm)*Xa^4 / (1 + Phi*Zm)$$

$$= ( 0.0325 + (1.0161 - 1)* 0.2577 ) * 5.52477^4 / (1 + 2.0446 * 0.2577 )$$

$$= 22.3551$$

#### UHX-13.5.5 Step 5:

Determine factor [gamab]:

$$= ( Gc - C ) / Do \text{ (config b)}$$

$$= (1247.0685 - 1298.0 )/1161.2899 = -0.04386$$

Compute Parameter [gamma]:

$$= 0.000 \text{ mm. (For Pressure only cases)}$$

Calculate Parameter [OmegaS]:

$$= rhos * ks * Betas * deltaS( 1 + h * Betas )$$

$$= 1.0161 * 16204597 * 0.0136 * 0.102159 ( 1 + 80.0 * 0.0136 )$$

$$= 4765.0288 \text{ mm.}^2$$

Calculate Parameter [Omega\*S]:

$$= Ao^2 * ( Rhos^2 - 1 ) * ( Rhos - 1 ) / 4 - OmegaS$$

$$= 580.645^2 * ( 1.016^2 - 1 ) * ( 1.016 - 1 )/4 - 4765.029$$

$$= -4720.9180 \text{ mm.}^2$$

Calculate Parameter [OmegaC]:

$$= rhoc * kc * Betac * deltaC( 1 + h * Betac )$$

$$= 1.0739 * 0.0 * 0.0 * 0. ( 1 + 80.0 * 0.0 )$$

$$= 0.0000 \text{ mm.}^2$$

Calculate Parameter [Omega\*C]:

$$= ao^2 [ ( Rhoc^2 + 1 ) * ( Rhoc - 1 ) / 4 - (Rhos - 1) / 2 ] - OmegaC$$

$$= 580.64496^2 [ ( 1.07386^2 + 1 ) * ( 1.07386 - 1 ) / 4 - (1.01611 - 1) / 2 ] - 0.$$

$$= 10689.4580 \text{ mm.}^2$$

Compute the Pressure [P\*S]:

$$= 0 \text{ For Pressure only cases or Configurations d,e,f,A,B,C,D}$$

Compute the Pressure [P\*C]:

$$= 0 \text{ For Pressure only cases or Configurations b,c,d,B,C,D}$$

#### UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

$$= Ps * \{ xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)^2] nus -$$

$$[ (rhos^2 - 1) / (J * Kst) ] - [ (1 - J) / (2J * Kst) ] [ (Dj^2 - (Ds)^2) / Do^2 ] \}$$

$$= 23.0 * \{ 0.515 + 2( 1 - 0.515 ) 0.3 +$$

$$[2/0.279 (1180.0/1161.29)^2] 0.3 -$$

$$[ (1.016^2 - 1) / ( 1.0 * 0.279 ) ] -$$

$$[ (1 - 1.0) / (2 * 1.0 * 0.279) ] [ (0.0^2 - (1180.0)^2) / 1161.29^2 ] \}$$

$$= 67.0121 \text{ bars}$$

Compute the Pressure [P't]:

$$= [ xt + 2(1 - xt)nut + 1/(J * Kst) ] * Pt$$

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$$= [ 0.706 + 2(1 - 0.706) 0.3 + 1/(1. * 0.279) ] * 23.0$$

$$= 102.8719 \text{ bars}$$

Compute the Pressure [Pgama]:

$$= Nt * Kt * \text{gama} / ( \text{pi} * \text{ao}^2 )$$

$$= 1802 * 4475801 * 0.0 / (3.142 * 580.645^2) = 0.0 \text{ bars}$$

Compute the Pressure [Pw]:

$$= -\text{gamab} * U * W * / ( 2 * \text{pi} * \text{ao}^2 )$$

$$= --0.044 * 22.355 * 3444.83 / (2 * 3.142 * 580.645^2)$$

$$= 15.9441 \text{ bars}$$

Calculate the Pressure [Prim]:

$$= - ( U/\text{ao}^2 ) ( \text{Omega} * S * P_s - \text{Omega} * C * P_t )$$

$$= - ( 22.355/580.645^2 ) ( -7.317 * 23.0 - 16.569 * 23.0 )$$

$$= 23.5015 \text{ bars}$$

Calculate the Pressure [POmega]:

$$= U/\text{ao}^2 ( \text{Omega} * S * P_s - \text{Omega} * C * P_c )$$

$$= 22.355/580.645^2 ( 7.3858 * 0.0 - 0.0 * 0.0 )$$

$$= 0.0000 \text{ bars}$$

Determine the Effective Pressure [Pe]:

$$= J * Kst / ( 1 + J * Kst * ( Qz1 + ( Rhos - 1 ) * Qz2 ) ) * ( P's - P't + Pgama + Pw + Prim )$$

$$= 0.1000E+01 * 0.279 / ( 1 + 1.0 * 0.279 * ( 3.637 + ( 1.016 - 1 ) * 11.178 ) ) * ( 67.012 - 102.872 + 0.0 + 15.944 + 23.502 )$$

$$= 0.4841 \text{ bars}$$

**UHX-13.5.7 Step 7:**

Determine Factor [Q2]:

$$= [ ( ( \text{Omega} * S * P_s - \text{Omega} * C * P_t ) - ( \text{Omega} * S * P_s - \text{Omega} * C * P_c ) ) \text{CNV\_FAC} + W * \text{gamab} / ( 2 * \text{pi} ) ] / ( 1 + \text{Phi} * Zm )$$

$$= [ ( ( -4720.918 * 23.0 - 10689.458 * 23.0 ) - ( 4765.029 * 0.0 - 0.0 * 0.0 ) ) * 0. + 3444.8 * -0.044 / ( 2 * 3.141 ) ] / ( 1 + 2.04457 * 0.25768 )$$

$$= -38.961647034 \text{ kN}$$

Calculate Factor [Q3]:

$$= Q1 + 2 * Q2 / ( Pe * \text{ao}^2 )$$

$$= -0.033 + 2 * -38.962 / ( 0.484 * 580.645^2 )$$

$$= -4.807294$$

**Fm Value from Table UHX-13.1 = 2.403647**

The Tubesheet Bending Stress - Original Thickness [Sigma]:

$$= ( 1.5 * Fm / \mu * ) * ( 2 * \text{ao} / ( H - h'g )^2 * Pe$$

$$= ( 1.5 * 2.4036 / 0.2244 ) * ( 2 * 580.645 / ( 80.0 - 5.0 ) )^2 * 0.48$$

$$= 186.4901 \text{ N./mm}^2$$

The Allowable Tubesheet Bending Stress [Sigma allowed]:

$$= 1.5 * S = 1.5 * 137.9 = 206.85 \text{ N./mm}^2$$

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:

$$= ( 1.5 * Fm / \mu * ) * ( 2 * \text{ao} / ( h - h'g )^2 * Pe$$

$$= ( 1.5 * 1.3604 / 0.2244 ) * ( 2 * 580.645 / ( 75.699 - 5.0 ) )^2 * 0.84$$

$$= 206.8439 \text{ N./mm}^2$$

Reqd Tubesheet Thickness, for Bending Stress (Including CA ) [HReqB]:

$$= h + \text{Cats} + \text{Catc} = 75.6992 + 0.0 + 0.0 = 75.6992 \text{ mm.}$$

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**UHX-13.5.8 Step 8:**

Shear Stress check [Tau\_limit]:

$$= 1.6 * S * MU * h / a_o$$

$$= 1.6 * 137.9 * 0.206 * 80.0 / 580.64$$

$$= 6.2699 \text{ N./mm}^2$$

The Shear Stress is not required to be computed; [Pe] <= Tau\_limit

*Note: Tubesheet Shear Stress is probably low, use the following req. thk:*

Tubesheet thickness (Incl. Corr.) = 5.1216 mm.  
 Tubesheet Shear Stress = 73.8959 N./mm<sup>2</sup>

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :

$$= \text{Max}( HreqB, HreqS ) = \text{Max}( 75.6992, 5.1216 ) = 75.6992 \text{ mm.}$$

**UHX-13.5.9 Step 9:**

The Ftmin and Ftmax Coefficients from Table UHX-13.2:

$$Ftmin = -68.6108, Ftmax = 22.8356$$

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:

$$= ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )$$

$$= ( (23.0 * 0.5151 - 23.0 * 0.706) - (0.484) * -68.611 ) / (0.706 - 0.5151)$$

$$= 15.1016 \text{ N./mm}^2$$

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:

$$= ( (Ps * xs - Pt * xt) - Pe * Ftmax ) / ( Xt - Xs )$$

$$= ( (23.0 * 0.5151 - 23.0 * 0.706) - (0.484) * 22.836 ) / (0.706 - 0.5151)$$

$$= -8.0919 \text{ N./mm}^2$$

Maximum Tube Axial Stress [Sigmat,max]:

$$= \text{MAX}( \text{abs}(\text{Sigmat1}), \text{abs}(\text{Sigmat2}) ) = 15.102 \text{ N./mm}^2$$

The Allowable Tube Stress, [SigmatA]:

$$= Sot = 117.9045 \text{ N./mm}^2$$

**Check for Buckling as some of the Tubes are in Compression**

Determine the Factor of Safety [Fs]:

$$= \text{Max}( (3.25 - 0.25 * (Zd + Q3 * Zw) * Xa^4 ), 1.25 )$$

$$= \text{Max}( (3.25 - 0.25 * (0.009 + -4.807 * 0.032) * 5.525^4 ), 1.25 )$$

$$= 2.0000 \text{ (Should be } \leq 2 \text{)}$$

Determine the Factor [rt]:

$$= ( ( dt^2 + (dt - 2 * tt)^2 )^{.5} ) / 4$$

$$= ( (19.05^2 + (19.05 - 2 * 2.108)^2)^{.5} ) / 4 = 6.0361 \text{ mm.}$$

Determine the Factor [Ct]:

$$= ( 2 * PI^2 * Et / Syt )^{.5}$$

$$= ( 2 * 3.14^2 * 0.19308E+09 / 208 )^{.5} = 135.3227$$

Determine the Factor [Ft]:

$$= k * L / r = 0.8 * 1354.0 / 6.036 = 179.4539$$

The Buckling Allowable Stress [Stb]:

$$= 1 / Fs * PI^2 * Et / (Ft^2) \text{ (Ct } \leq \text{ Ft)}$$

$$= 1 / 2.0 * 3.14^2 * .19308E+09 / (179.4539^2)$$

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$$= 29.588 \text{ N./mm}^2 \quad (\text{Never greater than } S_{ot})$$

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:

$$= \text{Sigmat,max} * \text{Tube Area} = 15.1 * 1.122 = 1.69 \text{ kN}$$

#### Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

$$= 3.1415 * t * (d_o - t) * S_a$$

$$= 3.1415 * 2.108 * (19.05 - 2.108) * 117.9 = 13.228 \text{ kN}$$

Fillet Weld Strength [Ff]:

$$= 0.55 * 3.1415 * a_f * (d_o + 0.67 * a_f) * S_w \quad (\text{but not } > F_t)$$

$$= 0.55 * 3.1415 * 1.5 * (19.05 + 0.67 * 1.5) * 117.9$$

$$= 6.1280 \text{ kN}$$

Groove Weld Strength [Fg]:

$$= 0.85 * 3.1415 * a_g * (d_o + 0.67 * a_g) * S_w \quad (\text{but not } > F_t)$$

$$= 0.85 * 3.1415 * 1.5 * (19.05 + 0.67 * 1.5) * 117.9$$

$$= 9.4706 \text{ kN}$$

Max. Allow. Tube-Tubesheet Joint load, Lmax

$$= F_t = 13.2275 \text{ kN}$$

Design Strength Ratio [fd]:

$$= 1.0000$$

Weld Strength Factor [fw]:

$$= S_{ot} / (\text{Min}(S_{ot}, S)) = 1.0000$$

Min Weld Length [ar]:

$$= 2 * ( (0.75 * d_o)^2 + 1.07 * t * (d_o - t) * f_w * f_d )^{1/2} - 0.75 * d_o$$

$$= 2.5600 \text{ mm.}$$

Minimum Required Fillet Weld Leg	afr	1.2800 mm.
Minimum Required Groove Weld Leg	agr	1.2800 mm.

Tube-Tubesheet Jt allowable, 13.23 is  $\geq$  tube strength 13.23 kN

Note: This tube-tubesheet joint is a Full Strength joint

#### UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:

$$= S_s * E_{sw} = 137.9 * 1.0 = 137.9 \text{ N./mm}^2$$

Axial Membrane Stress in Shell [Sigmas,m]:

$$= a_o^2 / ((D_s + t_s) * t_s) * [P_e + (R_{hos}^2 - 1) (P_s - P_t)] + a_s^2 * P_t / ((D_s + t_s) * t_s)$$

$$= 580.645^2 / ((1180.0 + 15.0) * 15.0) * [0.48 + (1.016^2 - 1) (23.0 - 23.0)] + 590.0^2 * 23.0 / ((1180.0 + 15.0) * 15.0)$$

$$= 45.5787 \text{ N./mm}^2$$

#### UHX-13.5.11 Step 11:

Note:

For a given Shell thickness of 15.0 mm., the minimum Shell length adjacent to the tubesheet should be 239.474 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:

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$$= ao^2 / ((Ds+ts) * ts) [Pe + (Rhos^2 - 1) (Ps - Pt)] + as^2 * Pt / ((Ds+ts) * ts)$$

$$= 580.645^2 / ((1180.0 + 15.0) * 15.0) [ 0.48 + (1.016^2 - 1) (23.0 - 23.0) ] + 590.0^2 * 23.0 / ((1180.0 + 15.0) * 15.0)$$

$$= 45.5787 \text{ N./mm}^2$$

The Shell Bending Stress due to Joint Interaction [Sigmasb]:

$$= 6 * ks / ts^2 \{ betas [ \delta S * Ps + as^2 * PstarS / (Es * ts) ] + 6(1 - \nu^2) / (E * (ao/h)^3 (1 + h * betas / 2) [Pe (Zv + Zm * Q1) + 2 / ao^2 * Zm * Q2] ] \}$$

$$= 6 * 16204597 / 15.0^2 \{ 0.014 [ 0.102 * 23.0 + 590.0^2 * 0.0 / (.28962E+1) ] + 6(1 - 0.43^2) / (35662968) (580.64 / 80.0)^3 (1 + 80.0 * 0.01 / 2) [ 0.5 ( 0.032 + 0.258 * -0.033 ) + 2 / 580.64^2 * 0.258 * -38.962 ] \}$$

$$= -67.2638 \text{ N./mm}^2$$

Shell Stress Summation vs. Allowable

$$abs(\text{Sigmasm}) + abs(\text{Sigmasb}) \leq 1.5 * Ss$$

$$abs(45.6) + abs(-67.3) \leq 206.85 \text{ N./mm}^2$$

112.84 must be < or = 206.85 N./mm<sup>2</sup>

Computations Completed for ASME Tubesheet Configuration b

Stress/Force Summary for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual	Allowable	Pass/Fail
Tubesheet Bend. Stress	186.5	206.9 N./mm <sup>2</sup>	Ok
Tubesheet Shear Stress	0.9	110.3 N./mm <sup>2</sup>	Ok
Maximum Tube Stress	15.1	117.9 N./mm <sup>2</sup>	Ok
Minimum Tube Stress (Buckling)	-8.1	-29.6 N./mm <sup>2</sup>	Ok
Maximum Force on any one Tube	1.7	13.2 kN	Ok
Axial Membrane Stress in Shell	45.6	137.9 N./mm <sup>2</sup>	Ok
Shell Stress (jt. inter.)	112.8	206.9 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 :	75.699	80.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

Case#	--Reqd. Thk. + CA		---- Tubesheet Stresses				Case Type	Pass/Fail
	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd		
D1uc	70.629	31.350	171	207	18	110	Ps+Pt-Th	D1 Ok
D2uc	36.720	...	58	207	19	110	Ps+Pt-Th	D2 Ok
D3uc	75.699	...	186	207	1	110	Ps+Pt-Th	D3 Ok
D4uc	8.285	...	5	207	...	110	Ps+Pt-Th	D4 Ok
O1uc	34.589	...	173	428	29	110	Ps+Pt+Th	O1 Ok
O2uc	31.848	...	109	428	10	110	Ps+Pt+Th	O2 Ok
O3uc	40.872	...	167	428	11	110	Ps+Pt+Th	O3 Ok
O4uc	11.727	...	73	428	8	110	Ps+Pt+Th	O4 Ok
D1c	78.222	31.350	199	207	19	110	Ps+Pt-Th-c	D1 Ok

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ASME TS Calc: Case: 1 10:31p Feb 6,2022

D2c	34.078	...	48	207	20	110	Ps+Pt-Th-c	D2	Ok
D3c	79.272	...	203	207	...	110	Ps+Pt-Th-c	D3	Ok
D4c	10.429	...	5	207	...	110	Ps+Pt-Th-c	D4	Ok
O1c	48.502	...	210	428	29	110	Ps+Pt+Th-c	O1	Ok
O2c	40.611	...	125	428	12	110	Ps+Pt+Th-c	O2	Ok
O3c	51.337	...	199	428	10	110	Ps+Pt+Th-c	O3	Ok
O4c	31.835	...	90	428	6	110	Ps+Pt+Th-c	O4	Ok

-----  
 Max: 79.2725 31.350 mm. 0.982 0.261 (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

[(+)-Th]:  
 With or Without Thermal Expansion, Tt,mx & Ts,mx

[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)

[O1, O2, O3, O4]:  
 Operating Load Cases using the Maximum and Minimum Operating Pressures and  
 Operating Temperatures

**Shell Axial Membrane Stress Summary:**

Case#	Shell Stresses				:	Shell Band Stress				: Pass : Fail
	Ten	Allwd	Cmp	Allwd		Ten	Allwd	Cmp	Allwd	
D1uc	24	137	...	...	:	...	...	...	...	Ok
D2uc	19	137	...	...	:	...	...	...	...	Ok
D3uc	46	137	...	...	:	...	...	...	...	Ok
D4uc	2	137	-2	-102	:	...	...	...	...	Ok
O1uc	13	452	...	...	:	...	...	...	...	Ok
O2uc	12	452	...	...	:	...	...	...	...	Ok
O3uc	33	452	...	...	:	...	...	...	...	Ok
O4uc	9	452	-9	-102	:	...	...	...	...	Ok
D1c	30	137	...	...	:	...	...	...	...	Ok
D2c	24	137	...	...	:	...	...	...	...	Ok
D3c	57	137	...	...	:	...	...	...	...	Ok
D4c	2	137	-2	-98	:	...	...	...	...	Ok
O1c	18	452	...	...	:	...	...	...	...	Ok
O2c	17	452	...	...	:	...	...	...	...	Ok
O3c	44	452	...	...	:	...	...	...	...	Ok
O4c	8	452	-8	-98	:	...	...	...	...	Ok
Max RATIO	0.412			0.083	:	...			...	

**Tube, Shell and Channel Stress Summary:**

Case#	Tube Stresses				Tube Loads	Shell Stress	Channel Stress	Pass Fail
	Ten	Allwd	Cmp	Allwd				
				Ld	Allwd			

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D1uc	25	117	-15	-47	3	13	284	452	...	...	Ok
D2uc	10	117	-10	-34	1	13	212	452	...	...	Ok
D3uc	15	117	-8	-29	2	13	113	206	...	...	Ok
D4uc	1	117	-1	-47	...	13	2	206	...	...	Ok
O1uc	37	235	-15	-47	4	26	322	452	...	...	Ok
O2uc	7	235	...	...	1	26	72	452	...	...	Ok
O3uc	28	235	-9	-47	3	26	158	452	...	...	Ok
O4uc	16	235	-3	-47	2	26	132	452	...	...	Ok
D1c	30	117	-15	-47	3	13	324	452	...	...	Ok
D2c	12	117	-12	-39	1	13	265	452	...	...	Ok
D3c	18	117	-9	-29	2	13	108	206	...	...	Ok
D4c	1	117	-1	-47	...	13	3	206	...	...	Ok
O1c	41	235	-16	-47	5	26	358	452	...	...	Ok
O2c	7	235	...	...	1	26	117	452	...	...	Ok
O3c	30	235	-9	-47	3	26	151	452	...	...	Ok
O4c	16	235	-3	-47	2	26	140	452	...	...	Ok
-----											
Max RATIO	0.251		0.338		0.251		0.791		...		

**Summary of Thickness Comparisons for 16 Load Cases:**

Thickness (mm.)	Required	Actual	P/F
-----			
Tubesheet Thickness :	79.272	80.000	Ok
Tubesheet Thickness Flanged Extension :	31.350	64.000	Ok
Tube Thickness :	0.488	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Min Shell length of thk, (15.000) adj. to tubesheet: 239.474 mm.

Note: This is a full strength Tube to Tubesheet Joint.

**Summary of Axial Differential Expansion between Shell and Tubes :**

Due to Thermal Expansion Shell Compresses by : -0.654 mm.  
 Due to Pressure Shell Compresses by : -0.069 mm.  
 Due to Pressure + Thermal Shell Compresses by : -0.722 mm.

**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	23.939	1.000	78.953	1.000
Tubesheet Shear Stress	115.349	1.000	136.697	1.000
Tube Tensile Stress	93.185	1.000	244.176	1.000
Tube Compressive Stress	55.947	0.759	78.726	1.000
Tube-Tubesheet Joint load	93.185	1.000	244.176	1.000
Shell Stress (Axial, Junction)	23.939	1.000	40.431	1.000
Tube Pressure Stress	286.263	1.000	184.962	1.000
Tubesheet Extension Stress	23.641	...	No Calc	No Calc
-----				
Minimum MAWP	23.641		40.431	

**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	27.750	0.998	78.953	1.000
Tubesheet Shear Stress	151.232	1.000	143.924	1.000
Tube Tensile Stress	110.058	1.000	284.315	1.000

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ASME TS Calc: Case: 1 10:31p Feb 6,2022

Tube Compressive Stress	80.543	1.000	85.595	1.000
Tube-Tubesheet Joint load	110.058	1.000	284.315	1.000
Shell Stress (Axial, Junction)	27.750	0.998	58.967	1.000
Tube Pressure Stress	286.263	1.000	192.052	1.000
Tubesheet Extension Stress	23.641	...	No Calc	No Calc
-----				
Minimum MAPnc	23.641		58.967	

#### Tubesheet MDMT Calculations:

*Note: The loading conditions from this case will be used to determine the tubesheet MDMT.*

#### Shell Side MDMT calculation:

Governing thickness on the shell side per figure UCS-66.3 (e):

$$\begin{aligned}
 &= \max(\text{tubesheet thk}/4, \min(\text{tubesheet thk}, \text{shell thickness})) \\
 &= \max(80.0/4, \min(80.0, 15.0)) \\
 &= 20.000 \text{ mm.}
 \end{aligned}$$

*Note:*

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

Impact Test Temperature provided per Specification -46 °C

#### Channel Side MDMT calculation:

Governing thickness for the channel side:

$$\begin{aligned}
 &= \text{tubesheet thickness}/4 \\
 &= 80.0/4 \\
 &= 20.000 \text{ mm.}
 \end{aligned}$$

*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:

$$\begin{aligned}
 &= \max(\text{pt}/\text{Tubeside MAPnc}, \text{ps}/\text{Shellside MAPnc}), \text{ must be } \leq 1 \\
 &= \max(23.0/23.64, 23.0/58.97) \\
 &= 0.973
 \end{aligned}$$

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 FileName : Calculation Book for CONDENSER E-PK6101-2  
 MDMT Summary: Step: 23 10:31pm Feb 6,2022

**Minimum Design Metal Temperature Results Summary :**

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20 (f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
SHELL	[8]	!	-45			0.835	15.000	1.00	No
S2	[1]	D	-47	-48	-29	0.835	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	!	-46	-46		0.833	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	!	-46	-46		0.833	15.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: SS	[13]	!	-46	-46		0.973	20.000	1.00	No
Warmest MDMT:			-45	-46					
BODY FLANGE 0	[11]	!	-46	-46		0.978	15.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.990	15.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.989	13.000	1.00	No
HEAD 1	[7]	D	-47	-48	-29	0.837	15.000	1.00	No
CHANNEL 01	[8]	D	-47	-48	-29	0.838	15.000	0.85	No
CHANNEL 002	[8]	D	-47	-48	-29	0.837	15.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.989	13.000	1.00	No
HEAD 002	[7]	D	-47	-48	-29	0.837	15.000	1.00	No
T1	[1]	!	-46	-46		0.837	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	!	-46	-46		0.833	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T4	[1]	D	-48	-104		0.019	14.250	1.00	No
Nozzle Flg	[5]	!	-46	-48					
T3	[1]	D	-48	-104		0.023	14.300	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: CS	[14]	!	-46	-46		0.973	20.000	1.00	No
Warmest MDMT:			-46	-46					
Exchanger Side			Computed MDMT °C	Required MDMT °C				Pass/Fail	
	Shell		-45	-45				Pass	
	Channel/Tube		-46	-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

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[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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Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

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

Diameter Spec : 1180.000 mm. ID  
Vessel Design Length, Tangent to Tangent 6456.35 mm.  
Specified Datum Line Distance 50.00 mm.  
Shell Material SA-516 70 [Normalized]  
Nozzle Material SA-333 6 [Impact Tested]  
Nozzle Material SA-350 LF2 [Impact Tested]  
Re-Pad Material SA-516 70 [Normalized]  
Shell Side Design Temperature 125 °C  
Channel Side Design Temperature 190 °C  
Shell Side Design Pressure 23.000 bars  
Channel Side Design Pressure 23.000 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 1	23.115	1.10No Calc	70	3.0000	No
CHANNEL 01	23.115	1.10No Calc	70	3.0000	N/A
BODY FLANGE 01	23.115	1.10No Calc	70	3.0000	N/A
SHELL	23.054	1.10No Calc	70	3.0000	N/A
BODY FLANGE 002	23.115	1.10No Calc	70	3.0000	N/A
CHANNEL 002	23.115	1.10No Calc	70	3.0000	N/A
HEAD 002	23.115	1.10No Calc	70	3.0000	No

Liquid Level: 1180.00 mm. Dens.: 0.001 kg./cm<sup>3</sup> Sp. Gr.: 0.994**Element Types and Properties:**

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	R e q d Int.	T h k Ext.	Joint Eff Long	Circ
Ellipse	0.0	50.0	15.0	12.9	6.3	1.00	0.85
Cylinder	749.0	749.0	15.0	14.8	6.5	0.85	0.85
Body Flg	895.0	146.0	110.0	108.7	69.8	1.00	1.00
Cylinder	5825.2	4844.0	15.0	13.0	10.1	1.00	1.00
Body Flg	5977.4	146.0	110.0	109.5	70.2	1.00	0.85
Cylinder	6356.3	299.0	15.0	13.0	5.7	1.00	1.00
Ellipse	6406.3	50.0	15.0	12.9	6.3	1.00	0.85

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 950.000 mm.  
Wear Pad Width 305.000 mm.  
Wear Pad Thickness 15.000 mm.  
Wear Pad Bearing Angle 132.000 deg.  
Distance from Saddle to Tangent 992.000 mm.  
Baseplate Length 1050.000 mm.

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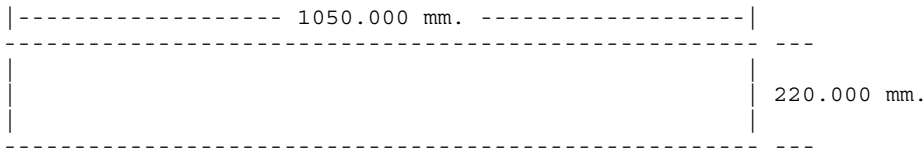
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Baseplate Thickness	20.000	mm.
Baseplate Width	220.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	15.000	mm.
Web Thickness	15.000	mm.
Height of Center Web	331.000	mm.
Number of Bolts in Baseplate	4	

**Baseplate Sketch**



**Baseplate Plan View**



**Baseplate Side View**

Maximum Tensile Bolt Load 14. kN

**Summary of Maximum Saddle Loads, Operating Case :**

Maximum Vertical Saddle Load	306.86	kN
Maximum Transverse Saddle Shear Load	71.71	kN
Maximum Longitudinal Saddle Shear Load	143.41	kN

**Summary of Maximum Saddle Loads, Hydrotest Case :**

Maximum Vertical Saddle Load	116.43	kN
Maximum Transverse Saddle Shear Load	0.99	kN
Maximum Longitudinal Saddle Shear Load	0.51	kN

**Weights:**

Fabricated - Bare W/O Removable Internals	14572.5	kg.
Shop Test - Fabricated + Water ( Full )	20943.7	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	14572.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	14855.3	kg.
Empty - Fab. + Intls. + Details + Wghts.	14855.3	kg.
Operating - Empty + Operating Liquid (No CA)	19254.7	kg.
Field Test - Empty Weight + Water (Full)	20647.0	kg.

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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: Tue Feb 06 22:21:30 2018.

- [Model Notes](#)
- [Load Case Report](#)
- [Solution Data](#)
- [ASME Code Stress Output Plots](#)
- [Stress Results - Notes](#)
- [ASME Overstressed Areas](#)
- [Highest Primary Stress Ratios](#)
- [Highest Secondary Stress Ratios](#)
- [Highest Fatigue Stress Ratios](#)
- [Stress Intensification Factors](#)
- [Allowable Loads](#)
- [Flexibilities](#)
- [Graphical Results](#)

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Model Notes  
Model Notes

Input Echo:

Model Type : Cylindrical Shell

Parent Geometry

Parent Outside Diam. : 1210.000 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. : 323.800 mm.  
Thickness : 12.290 mm.  
Length : 200.000 mm.  
RePad Width : 80.000 mm.  
RePad Thickness : 15.000 mm.  
Nozzle Tilt Angle : 0.000 deg.  
Distance from Top : 374.000 mm.

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Distance from Bottom : 375.000 mm.

Nozzle Properties

Cold Allowable : 160.7 MPa  
Hot Allowable : 144.1 MPa  
Material DB # 7002618.  
Ultimate Tensile (Amb) : 413.7 MPa  
Yield Strength (Amb) : 241.3 MPa  
Yield Strength (Hot) : 216.5 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:	12000.0	12000.0	12000.0	15300.0	15300.0	18900.0

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:	12000.0	12000.0	12000.0	15300.0	15300.0	18900.0

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.

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  
Released Nov 2017                      10:21pm FEB 6,2018

Load Case Report                      \$X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE 9 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 Program Generated -- Force Only

Case run to compute sif's and flexibilities.  
/----- Loads in Case 5  
Loads from (Axial)

6 Program Generated -- Force Only

Case run to compute sif's and flexibilities.  
/----- Loads in Case 6  
Loads from (Inplane)

7 Program Generated -- Force Only

Case run to compute sif's and flexibilities.  
/----- Loads in Case 7  
Loads from (Outplane)

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Tag no:CONDENSER E-PK6101-2

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FileName : Calculation Book for CONDENSER E-PK6101-2

Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

8 Program Generated -- Force Only  
 Case run to compute sif's and flexibilities.  
 /----- Loads in Case 8  
 Loads from (Torsion)

9 Program Generated -- Force Only  
 Case run to compute sif's and flexibilities.  
 /----- Loads in Case 9  
 Pressure Case 1

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Solution Data  
 FE/Pipe Version 10.0 Jobname: NOZZLE \$P  
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Solution Data

Maximum Solution Row Size = 594  
 Number of Nodes = 1980  
 Number of Elements = 652  
 Number of Solution Cases = 8

Summation of Loads per Case

Case #	FX	FY	FZ
1	12000.	12001.	12000.
2	-1557.	2604255.	12000.
3	-13557.	2592255.	0.
4	1658537.	0.	0.
5	0.	6.	0.
6	0.	0.	-4.
7	0.	0.	0.
8	-13557.	2592255.	0.

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ASME Code Stress Output Plots  
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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

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- 7) Pl+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) Pl+Pb+Q+F < Sa (SIF,Outside) Case 5
- 12) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6
- 13) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7
- 14) Pl+Pb+Q+F < Sa (SIF,Outside) Case 8
- 15) Pl+Pb+Q+F < Sa (SIF,Outside) Case 9
- 16) Pl+Pb+Q < SPS (EXP,Inside) Case 4
- 17) Pl+Pb+Q < SPS (EXP,Outside) Case 4
- 18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
- 19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

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Stress Results - Notes

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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2013-2015 ASME Section VIII Division 2
- 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
165	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

70%

Branch at Junction

P1	SPL	Primary Membrane Load Case 2
177	216	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

81%

Branch Transition

P1	SPL	Primary Membrane Load Case 2
65	216	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

29%

Pad Outer Edge Weld

P1	SPL	Primary Membrane Load Case 2
151	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

64%

Header Outside Pad Area

P1	SPL	Primary Membrane Load Case 2
117	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

49%

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Highest Secondary Stress Ratios  
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Released Nov 2017 10:21pm FEB 6,2018

Highest Secondary Stress Ratios \$X

Pad/Header at Junction

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
181	497	Plot Reference:
MPa	MPa	3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

36%

Branch at Junction

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
341	458	Plot Reference:
MPa	MPa	17) Pl+Pb+Q < SPS (EXP,Outside) Case 4

74%

Branch Transition

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
95	458	Plot Reference:
MPa	MPa	17) Pl+Pb+Q < SPS (EXP,Outside) Case 4

20%

Pad Outer Edge Weld

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
318	497	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

63%

Header Outside Pad Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
164	497	Plot Reference:
MPa	MPa	16) Pl+Pb+Q < SPS (EXP,Inside) Case 4

32%

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Highest Fatigue Stress Ratios  
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Highest Fatigue Stress Ratios \$X

Pad/Header at Junction

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Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4  
 120 0.046 Life Stress Concentration Factor = 1.350  
 MPa 0.415 Stress Strain Concentration Factor = 1.000  
 Cycles Allowed for this Stress = 153,187.  
 Allowable "B31" Fatigue Stress Allowable = 413.6  
 289.9 Markl Fatigue Stress Allowable = 287.5  
 MPa WRC 474 Mean Cycles to Failure = 500,446.  
 WRC 474 99% Probability Cycles = 116,258.  
 41% WRC 474 95% Probability Cycles = 161,410.  
 BS5500 Allowed Cycles(Curve F) = 104,848.  
 Membrane-to-Bending Ratio = 2.174  
 Bending-to-PL+PB+Q Ratio = 0.315  
 Plot Reference:  
 18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Branch at Junction

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4  
 230 0.465 Life Stress Concentration Factor = 1.350  
 MPa 0.794 Stress Strain Concentration Factor = 1.000  
 Cycles Allowed for this Stress = 15,042.  
 Allowable "B31" Fatigue Stress Allowable = 381.0  
 289.9 Markl Fatigue Stress Allowable = 287.5  
 MPa WRC 474 Mean Cycles to Failure = 135,017.  
 WRC 474 99% Probability Cycles = 31,366.  
 79% WRC 474 95% Probability Cycles = 43,547.  
 BS5500 Allowed Cycles(Curve F) = 17,434.  
 Membrane-to-Bending Ratio = 0.185  
 Bending-to-PL+PB+Q Ratio = 0.844  
 Plot Reference:  
 19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Branch Transition

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4  
 48 0.000 Life Stress Concentration Factor = 1.000  
 MPa 0.164 Stress Strain Concentration Factor = 1.000  
 Cycles Allowed for this Stress = 9.1563E10  
 Allowable "B31" Fatigue Stress Allowable = 381.0  
 289.9 Markl Fatigue Stress Allowable = 287.5  
 MPa WRC 474 Mean Cycles to Failure = 6,394,337.  
 WRC 474 99% Probability Cycles = 1,485,462.  
 16% WRC 474 95% Probability Cycles = 2,062,378.  
 BS5500 Allowed Cycles(Curve F) = 801,334.  
 Membrane-to-Bending Ratio = 0.680  
 Bending-to-PL+PB+Q Ratio = 0.595  
 Plot Reference:  
 19) 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  
 209 0.344 Life Stress Concentration Factor = 1.350  
 MPa 0.720 Stress Strain Concentration Factor = 1.000  
 Cycles Allowed for this Stress = 20,322.  
 Allowable "B31" Fatigue Stress Allowable = 413.6  
 289.9 Markl Fatigue Stress Allowable = 287.5  
 MPa WRC 474 Mean Cycles to Failure = 166,978.  
 WRC 474 99% Probability Cycles = 38,790.  
 71% WRC 474 95% Probability Cycles = 53,856.  
 BS5500 Allowed Cycles(Curve F) = 23,380.  
 Membrane-to-Bending Ratio = 0.602  
 Bending-to-PL+PB+Q Ratio = 0.624  
 Plot Reference:  
 19) 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  
 82 0.004 Life Stress Concentration Factor = 1.000

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Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

MPa 0.282 Stress Strain Concentration Factor = 1.000  
 Cycles Allowed for this Stress = 1,981,531.  
 Allowable "B31" Fatigue Stress Allowable = 413.6  
 289.9 MPa MarkI Fatigue Stress Allowable = 287.5  
 WRC 474 Mean Cycles to Failure = 1,150,980.  
 WRC 474 99% Probability Cycles = 267,383.  
 28% WRC 474 95% Probability Cycles = 371,228.  
 BS5500 Allowed Cycles(Curve F) = 157,115.  
 Membrane-to-Bending Ratio = 1.200  
 Bending-to-PL+PB+Q Ratio = 0.454  
 Plot Reference:  
 18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

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Stress Intensification Factors

FE/Pipe Version 10.0 Jobname: NOZZLE \$P  
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Stress Intensification Factors \$X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	7.359	5.451	10.902	1.621
Inplane :	4.217	3.123	6.247	1.654
Outplane:	7.270	5.385	10.770	1.616
Torsion :	0.658	0.914	0.975	0.831
Pressure:	1.345	1.160	1.993	1.096

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 pressure stress in the PARENT or HEADER, calculated from PD<sub>o</sub>/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 : 323.800 mm.  
 Pipe Thk: 12.290 mm.  
 Z approx: 936667.250 cu.mm.  
 Z exact : 902518.250 cu.mm.

(SSI = SIF <sup>x</sup> )	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.850	0.791	0.849	0.215	0.501

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 10.703  
 Header Pressure i-factor = 2.717

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
	4.429	Inplane
	5.564	Outplane
	1.000	Torsional

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Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

B31.1 (Branch)		
Peak Stress Sif ....	0.000	Axial
	5.564	Inplane
	5.564	Outplane
	5.564	Torsional
WRC 330 (Branch)		
Peak Stress Sif ....	0.000	Axial
	5.432	Inplane
	5.564	Outplane
	5.432	Torsional

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Allowable Loads  
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Allowable Loads \$X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force ( N )	473937.	104199.	156299.
Inplane Moment (mm. N )	62068228.	9649330.	20469320.
Outplane Moment (mm. N )	36000088.	5596692.	11872376.
Torsional Moment (mm. N )	397614656.	89136664.	133705000.
Pressure (MPa )	4.28	2.30	2.30

PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force ( N )	477691.	71398.	107097.
Inplane Moment (mm. N )	62559776.	6611798.	14025742.
Outplane Moment (mm. N )	36285192.	3834898.	8135048.
Torsional Moment (mm. N )	213750912.	32398472.	48597708.
Pressure (MPa )	4.02	2.30	2.30

NOTES:

- 1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.
- 2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.
- 3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.
- 4) Secondary allowable loads are limits for expansion and operating piping loads.
- 5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

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Flexibilities  
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Flexibilities \$X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 323.800 mm.  
Wall Thickness = 12.290 mm.

Axial Translational Stiffness = 584922. N /mm.  
Inplane Rotational Stiffness = 319725120. mm. N /deg  
Outplane Rotational Stiffness = 133334600. mm. N /deg  
Torsional Rotational Stiffness = 5327399424. mm. N /deg

Intersection Flexibility Factors for Branch/Nozzle

:

Find axial stiffness:  $K = 3EI/(kd)^3$  N /mm.  
Find bending and torsional stiffnesses:  $K = EI/(kd)$  mm. N per radian.  
The EI product is 0.29662E+14 N mm.<sup>2</sup>  
The value of (d) to use is: 311.510 mm.  
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor (k) = 1.714  
Inplane Flexibility Factor (k) = 5.198  
Outplane Flexibility Factor (k) = 12.464  
Torsional Flexibility Factor (k) = 0.312

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