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	<b>DEHDASHT PETROCHEMICAL INDUSTRY COMPANY</b> <b>DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT</b>	
	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091	Rev. No.: D0

**DOCUMENT TITLE:**

**Mechanical Calculation for Oil Cooler**

**(E-PK6101-1A/B)**

<b>PURCHASER'S COMMENT/APPROVAL STATUS</b>					Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)				Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)				
3	NF: Approved With Comments (Fabrication not Proceed)				Item No. (Tag No.): PK-6101
4	RJ: Rejected				
5	NR: Not be Returned				Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0091-D0
Date:		Signature:			
					
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
REV	DATE ISSUE	PREPARED	CHECKED	APPROVED	



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67	x				
68	x				
69	x				
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131	x				
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133	x				
134	x				
135	x				
136	x				
137	x				
138	x				
139	x				
140	x				



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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:E-PK6101-1 AB OIL COOLER

## **DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Dec 23,2021 8:06am

PV Elite 2019 SP1, March 2019

**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:E-PK6101-1 AB OIL COOLER  
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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --  
Warnings and Errors: Step: 0 8:06am Dec 23,2021

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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 FileName : Calculation Book for OIL COOLER E-PK6101-1AB --  
 Input Echo: Step: 1 8:06am Dec 23,2021

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

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 Tag no:E-PK6101-1 AB OIL COOLER

**Exchanger Design Pressures and Temperatures**

Shell Side Design Pressure	25	bars
Channel Side Design Pressure	25	bars
Shell Side Design Temperature	120.0	°C
Channel Side Design Temperature	190.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-10.0	°C
MDMT (CET), Tube Side	-10.0	°C
User defined MAWP, Shell Side	0	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

-----

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	
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	

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

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Input Echo: Step: 1 8:06am Dec 23,2021

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	195	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		123000	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain ( Hill, Escarpment )		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.500	
Table Value Fa		1.000	
Table Value Fv		1.300	
Short Period Acceleration value Ss		1.163	
Long Period Acceleration Value Sl		0.600	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		2.000	
Site Class		C	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		No	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0 )		0.000	
User Value of Sd1 (used if > 0 )		0.000	

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

Material Database Year	Current w/Addenda or Code Year
------------------------	--------------------------------

**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
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	No

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

Element From Node	10
-------------------	----

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Input Echo: Step: 1 8:06am Dec 23,2021

Element To Node	20
Element Type	Elliptical
Description	HEAD 1
Distance "FROM" to "TO"	50 mm.
Inside Diameter	381 mm.
Element Thickness	11.113 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	14 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	25 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, Hydrotest	235.81 N./mm <sup>2</sup>
Material Density	0.00775 kg./cm <sup>3</sup>
P Number Thickness	30.988 mm.
Yield Stress, Operating	226.06 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	381 mm.
Liquid Density	0.0009996 kg./cm <sup>3</sup>

-----

Element From Node	20
Element To Node	30
Element Type	Cylinder
Description	CHANNEL 01
Distance "FROM" to "TO"	321 mm.
Inside Diameter	381 mm.
Element Thickness	11.113 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	12.7 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	25 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-106 B
Allowable Stress, Ambient	117.9 N./mm <sup>2</sup>
Allowable Stress, Operating	117.9 N./mm <sup>2</sup>
Allowable Stress, Hydrotest	217.19 N./mm <sup>2</sup>
Material Density	0.00775 kg./cm <sup>3</sup>
P Number Thickness	31.75 mm.
Yield Stress, Operating	208.13 N./mm <sup>2</sup>

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UCS-66 Chart Curve Designation	B
External Pressure Chart Name	CS-2
UNS Number	K03006
Product Form	Smls. pipe
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Weld is pre-Heated	No
Element From Node	20
Detail Type	Liquid
Detail ID	2
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	381 mm.
Liquid Density	0.0009996 kg./cm <sup>3</sup>
Element From Node	20
Detail Type	Nozzle
Detail ID	T2
Dist. from "FROM" Node / Offset dist	160 mm.
Nozzle Diameter	3 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1895 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-106 B
Element From Node	20
Detail Type	Nozzle
Detail ID	T1
Dist. from "FROM" Node / Offset dist	160 mm.
Nozzle Diameter	3 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1968 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-106 B

-----

Element From Node	30
Element To Node	40
Element Type	Flange
Description	BODY FLANGE 01
Distance "FROM" to "TO"	74 mm.
Flange Inside Diameter	381 mm.
Element Thickness	48 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	79 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	25 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-266 2
Allowable Stress, Ambient	137.9 N./mm <sup>2</sup>
Allowable Stress, Operating	137.9 N./mm <sup>2</sup>

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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	B	
External Pressure Chart Name	CS-2	
UNS Number	K03506	
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	30	
Detail Type	Liquid	
Detail ID	3	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm <sup>3</sup>

-----

Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	SHELL	
Distance "FROM" to "TO"	2908	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12.7	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	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-106 B	
Allowable Stress, Ambient	117.9	N./mm <sup>2</sup>
Allowable Stress, Operating	117.9	N./mm <sup>2</sup>
Allowable Stress, Hydrotest	217.19	N./mm <sup>2</sup>
Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	31.75	mm.
Yield Stress, Operating	217.36	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
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	464	mm.
Width of Saddle	140	mm.
Height of Saddle at Bottom	500	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.

## DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Input Echo: Step: 1 8:06am Dec 23,2021

Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.0	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.

Element From Node	40	
Detail Type	Saddle	
Detail ID	Sliding Saddle	
Dist. from "FROM" Node / Offset dist	2444	mm.
Width of Saddle	140	mm.
Height of Saddle at Bottom	500	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.40000001	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.

Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0008747	kg./cm <sup>3</sup>

Element From Node	40	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	164	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.1968	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	2698	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle ( Used if > 0 )	0.1968	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

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Element From Node	40
Detail Type	Nozzle
Detail ID	S3
Dist. from "FROM" Node / Offset dist	164 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1162 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-106 B

Element From Node	40
Detail Type	Weight
Detail ID	WEIGHT BAFFLE
Dist. from "FROM" Node / Offset dist	1456 mm.
Miscellaneous Weight	0.4903 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"	74 mm.
Flange Inside Diameter	381 mm.
Element Thickness	48 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	79 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	25 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-266 2
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	B
External Pressure Chart Name	CS-2
UNS Number	K03506
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	381 mm.
Liquid Density	0.0009996 kg./cm <sup>3</sup>

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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --

Input Echo: Step: 1 8:06am Dec 23,2021

```

-----
Element From Node          60
Element To Node           70
Element Type              Cylinder
Description                CHANNEL 002
Distance "FROM" to "TO"   321 mm.
Inside Diameter           381 mm.
Element Thickness         11.113 mm.
Internal Corrosion Allowance 3 mm.
Nominal Thickness         12.7 mm.
External Corrosion Allowance 0 mm.
Design Internal Pressure   25 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-106 B
  Allowable Stress, Ambient 117.9 N./mm^2
  Allowable Stress, Operating 117.9 N./mm^2
  Allowable Stress, Hydrotest 217.19 N./mm^2
  Material Density          0.00775 kg./cm^3
  P Number Thickness       31.75 mm.
  Yield Stress, Operating   208.13 N./mm^2
  UCS-66 Chart Curve Designation B
  External Pressure Chart Name CS-2
  UNS Number                K03006
  Product Form              Smls. pipe
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  381 mm.
  Liquid Density           0.0009996 kg./cm^3

  Element From Node        60
  Detail Type              Nozzle
  Detail ID                T4
  Dist. from "FROM" Node / Offset dist 160 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 ) 0.04839 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 160 mm.
  Nozzle Diameter          1 in.
  Nozzle Schedule          None
  Nozzle Class             300
  Layout Angle             270.0
  Blind Flange (Y/N)      N

```

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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	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	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, Hydrotest	235.81	N./mm <sup>2</sup>
Material Density	0.00775	kg./cm <sup>3</sup>
P Number Thickness	30.988	mm.
Yield Stress, Operating	226.06	N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	70	
Detail Type	Liquid	
Detail ID	6	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm <sup>3</sup>

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 XY Coordinate Calculations: Step: 2 8:06am Dec 23,2021

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		371	...	321	...
BODY FLANGE 01		445	...	74	...
SHELL		3405.17	...	2908	...
BODY FLANGE 002		3485.35	...	74	...
CHANNEL 002		3852.35	...	321	...
HEAD 002		3902.35	...	50	...

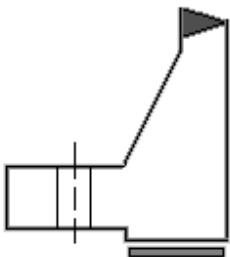
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 Flg Calc [Int P]: FLANGE Flng: 3 8:06am Dec 23,2021

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

**BODY FLANGE 01**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	25.04	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	381.000	mm.
Flange Outside Diameter	A	515.000	mm.
Flange Thickness	t	48.0000	mm.
Thickness of Hub at Small End	go	10.0000	mm.
Thickness of Hub at Large End	gl	17.0000	mm.
Length of Hub	h	26.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
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-193 B7	
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	473.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		28	
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	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	6.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm <sup>2</sup>



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 Flg Calc [Int P]: FLANGE Flng: 3 8:06am Dec 23,2021

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

Hub Small End Required Thickness due to Internal Pressure:

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

$$= (25.04*(381.0/2+3.0))/(137.9*1.0-0.6*25.04)+Ca$$

$$= 6.5521 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 * 1.0 * 7.0)/(193.5 + 0.6 * 7.0)$$

$$= 48.824 \text{ bars}$$

Corroded Flange Thickness, $t_c = T - c_i$	45.000	mm.
Corroded Flange ID, $B_{cor} = B + 2 * F_{cor}$	387.000	mm.
Corroded Large Hub, $g_{lCor} = g_l - c_i$	14.000	mm.
Corroded Small Hub, $g_{oCor} = g_o - c_i$	7.000	mm.
Code R Dimension, $R = ((C - B_{cor})/2) - g_{lCor}$	29.000	mm.
Gasket Contact Width, $N = (G_o - G_i) / 2$	20.000	mm.
Basic Gasket Width, $b_o = N / 2$	10.000	mm.
Effective Gasket Width, $b = C_b \text{ sqrt}(b_o)$	7.969	mm.
Gasket Reaction Diameter, $G = G_o - 2 * b$	428.063	mm.

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * P_{eq}$$

$$= 0.785 * 428.0626^2 * 25.037$$

$$= 360.314 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * P_i * G * m * P + 2 * l_p * b_{Part} * m_{Part} * P$$

$$= 2 * 7.9687 * 3.1416 * 428.0626 * 3.78 * 25.04$$

$$+ 2.0 * 1078.0 * 3.0 * 3.75 * 25.0373$$

$$= 263.561 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= P_i * B_{cor}^2 * P / 4$$

$$= 3.1416 * 387.0^2 * 25.0373 / 4$$

$$= 294.502 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - H_d$$

$$= 360 - 295$$

$$= 65.812 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(360 + 264 + 0, 0)$$

$$= 623.875 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * P_i * G + y_{Part} * b_{Part} * l_p$$

$$= 62.05 * 7.9687 * 3.141 * 428.063 + 62.05 * 3.0 * 1078.0$$

$$= 865.581 \text{ kN}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } W_{m1}/S_b, W_{m2}/S_a$$

$$= \text{Maximum of } 624/172, 866/172$$

$$= 50.219 \text{ cm}^2$$

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

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

$$= 2 * 19.05 + 6 * 45.0/(3.78 + 0.5)$$

$$= 101.184 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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 Flg Calc [Int P]: FLANGE Flng: 3 8:06am Dec 23,2021

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

$$= 473.0 * \sin( 3.142/28 )$$

$$= 52.959 \text{ mm.}$$

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

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

$$= \max( \text{sqrt}( 52.959 / ( 2 * 19.05 + 45.0 ) ), 1 )$$

$$= 1.0000$$

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

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	50.219	54.555	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	52.959	101.184

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

$$= Ab * Sa / ( \gamma * \pi * (Go + Gi) )$$

$$= 54.555 * 172.38 / ( 62.05 * 3.14 * ( 444.0 + 404.0 ) )$$

$$= 5.689 \text{ mm.}$$

Flange Design Bolt Load, Gasket Seating [W]:

$$= Sa * ( Am + Ab ) / 2$$

$$= 172.38 * ( 50.2192 + 54.5547 ) / 2$$

$$= 902.94 \text{ kN}$$

Gasket Load for the Operating Condition [HG]:

$$= Wm1 - H$$

$$= 624 - 360$$

$$= 263.56 \text{ kN}$$

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

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

$$= ( 473.0 - 428.0626 ) / 2$$

$$= 22.4687 \text{ mm.}$$

Distance to Face Pressure Reaction [ht]:

$$= ( R + g1 + hg ) / 2$$

$$= ( 29.0 + 14.0 + 22.4687 ) / 2$$

$$= 32.7343 \text{ mm.}$$

Distance to End Pressure Reaction [hd]:

$$= R + ( g1 / 2 )$$

$$= 29.0 + ( 14.0 / 2.0 )$$

$$= 36.0000 \text{ mm.}$$

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	295.	36.0000	1.0000	10606.
Face Pressure, Mt	66.	32.7343	1.0000	2155.
Gasket Load, Mg	264.	22.4687	1.0000	5924.
Gasket Seating, Matm	903.	22.4687	1.0000	20296.
Total Moment for Operation, Mop				18686. N-m
Total Moment for Gasket seating, Matm				20296. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			52.048 mm.	
Hub Ratio, h/h0 = HL / H0			0.500	

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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --

Flg Calc [Int P]: FLANGE Flng: 3 8:06am Dec 23,2021

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

Flange Factors for Integral Flange:

Factor F		0.826
Factor V		0.227
Factor f		1.228
Factors from Figure 2-7.1	K =	1.331
	T = 1.784	U = 7.636
	Y = 6.948	Z = 3.594
	d = 85637.820 mm. <sup>3</sup>	e = 0.0159 mm. <sup>-1</sup>
Stress Factors	ALPHA =	1.714
	BETA = 1.952	GAMMA = 0.961
	DELTA = 1.064	Lamda = 2.025

Longitudinal Hub Stress, Operating [SHo]:

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

$$= ( 1.2277 * 18686 / 387.0 ) / ( 2.0247 * 14.0^2 )$$

$$= 149.32 \text{ N./mm}^2$$

Longitudinal Hub Stress, Seating [SHa]:

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

$$= ( 1.2277 * 20296 / 387.0 ) / ( 2.0247 * 14.0^2 )$$

$$= 162.19 \text{ N./mm}^2$$

Radial Flange Stress, Operating [SRo]:

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

$$= ( 1.9519 * 18686 / 387.0 ) / ( 2.0247 * 45.0^2 )$$

$$= 22.98 \text{ N./mm}^2$$

Radial Flange Stress, Seating [SRa]:

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

$$= ( 1.9519 * 20296 / 387.0 ) / ( 2.0247 * 45.0^2 )$$

$$= 24.96 \text{ N./mm}^2$$

Tangential Flange Stress, Operating [STo]:

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

$$= ( 6.9484 * 18686 / ( 45.0^2 * 387.0 ) ) - 3.5944 * 23$$

$$= 83.03 \text{ N./mm}^2$$

Tangential Flange Stress, Seating [STa]:

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

$$= ( 6.9484 * 20296 / ( 45.0^2 * 387.0 ) ) - 3.5944 * 25$$

$$= 90.18 \text{ N./mm}^2$$

Average Flange Stress, Operating [SAo]:

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

$$= ( 149 + \max( 23, 83 ) ) / 2$$

$$= 116.17 \text{ N./mm}^2$$

Average Flange Stress, Seating [SAa]:

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

$$= ( 162 + \max( 25, 90 ) ) / 2$$

$$= 126.19 \text{ N./mm}^2$$

Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 624 / 54.5547$$

$$= 114.37 \text{ N./mm}^2$$

Bolt Stress, Seating [BSa]:

$$= ( Wm2 / Ab )$$

$$= ( 866 / 54.5547 )$$

$$= 158.68 \text{ N./mm}^2$$

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

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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --

Flg Calc [Int P]: FLANGE Flng: 3 8:06am Dec 23,2021

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	149.	207.	162.	207.
Radial Flange	23.	138.	25.	138.
Tangential Flange	83.	138.	90.	138.
Maximum Average	116.	138.	126.	138.
Bolting	114.	172.	159.	172.

Minimum Required Flange Thickness 45.136 mm.  
 Estimated M.A.W.P. ( Operating ) 29.719 bars  
 Estimated Finished Weight of Flange at given Thk. 38.5 kg.  
 Estimated Unfinished Weight of Forging at given Thk 54.1 kg.

Flange Rigidity Based on Required Thickness [ASME]:

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

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

$$= 52.14 * 20296.2/1.0 * 999.68 * 0.227/( 1.809 * 202713 * 7.0^2 * 52.048 * 0.3 )$$

$$= 0.858 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 18685.8/1.0 * 999.68 * 0.227/( 1.809 * 193088 * 7.0^2 * 52.048 * 0.3 )$$

$$= 0.829 \quad (\text{should be } \leq 1)$$

Flange Rigidity Based on Given Thickness [ASME]:

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

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

$$= 52.14 * 20296.2/1.0 * 999.68 * 0.227/( 2.025 * 202713 * 7.0^2 * 52.048 * 0.3 )$$

$$= 0.766 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 18685.8/1.0 * 999.68 * 0.227/( 2.025 * 193088 * 7.0^2 * 52.048 * 0.3 )$$

$$= 0.740 \quad (\text{should be } \leq 1)$$

**Minimum Design Metal Temperature Results:**

Thickness Ratio = 0.436, Temperature Reduction per Fig. UCS 66.1 = 43 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Note: UCS-66(b)-(c) was considered in the flange MDMT calculation.

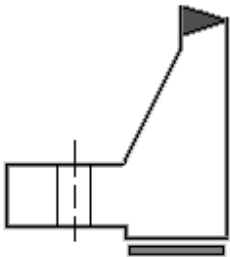
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 FileName : Calculation Book for OIL COOLER E-PK6101-1AB --  
 Flg Calc [Int P]: New Flange Flng: 4 8:06am Dec 23,2021

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

**BODY FLANGE 002**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	25.04	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	381.000	mm.
Flange Outside Diameter	A	515.000	mm.
Flange Thickness	t	48.0000	mm.
Thickness of Hub at Small End	go	11.1125	mm.
Thickness of Hub at Large End	gl	17.0000	mm.
Length of Hub	h	26.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
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-193 B7	
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	473.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		28	
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	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	6.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm <sup>2</sup>



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 Flg Calc [Int P]: New Flange Flng: 4 8:06am Dec 23,2021

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

Hub Small End Required Thickness due to Internal Pressure:

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

$$= (25.04*(381.0/2+3.0))/(137.9*1.0-0.6*25.04)+Ca$$

$$= 6.5521 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 * 1.0 * 8.1125)/(193.5 + 0.6 * 8.1125)$$

$$= 56.393 \text{ bars}$$

Corroded Flange Thickness, $t_c = T - c_i$	45.000	mm.
Corroded Flange ID, $B_{cor} = B + 2 * F_{cor}$	387.000	mm.
Corroded Large Hub, $g_{lCor} = g_l - c_i$	14.000	mm.
Corroded Small Hub, $g_{oCor} = g_o - c_i$	8.113	mm.
Code R Dimension, $R = ((C - B_{cor})/2) - g_{lCor}$	29.000	mm.
Gasket Contact Width, $N = (G_o - G_i) / 2$	20.000	mm.
Basic Gasket Width, $b_o = N / 2$	10.000	mm.
Effective Gasket Width, $b = C_b \text{ sqrt}(b_o)$	7.969	mm.
Gasket Reaction Diameter, $G = G_o - 2 * b$	428.063	mm.

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * P_{eq}$$

$$= 0.785 * 428.0626^2 * 25.037$$

$$= 360.314 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * P_i * G * m * P + 2 * l_p * b_{Part} * m_{Part} * P$$

$$= 2 * 7.9687 * 3.1416 * 428.0626 * 3.78 * 25.04$$

$$+ 2.0 * 1078.0 * 3.0 * 3.75 * 25.0373$$

$$= 263.561 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= P_i * B_{cor}^2 * P / 4$$

$$= 3.1416 * 387.0^2 * 25.0373 / 4$$

$$= 294.502 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - H_d$$

$$= 360 - 295$$

$$= 65.812 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(360 + 264 + 0, 0)$$

$$= 623.875 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * P_i * G + y_{Part} * b_{Part} * l_p$$

$$= 62.05 * 7.9687 * 3.141 * 428.063 + 62.05 * 3.0 * 1078.0$$

$$= 865.581 \text{ kN}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } W_{m1}/S_b, W_{m2}/S_a$$

$$= \text{Maximum of } 624/172, 866/172$$

$$= 50.219 \text{ cm}^2$$

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

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

$$= 2 * 19.05 + 6 * 45.0/(3.78 + 0.5)$$

$$= 101.184 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 473.0 * \sin( 3.142/28 )$$

$$= 52.959 \text{ mm.}$$

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

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

$$= \max( \text{sqrt}( 52.959 / ( 2 * 19.05 + 45.0 ) ), 1 )$$

$$= 1.0000$$

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

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	50.219	54.555	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	52.959	101.184

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

$$= Ab * Sa / ( y * \pi * (Go + Gi) )$$

$$= 54.555 * 172.38 / ( 62.05 * 3.14 * ( 444.0 + 404.0 ) )$$

$$= 5.689 \text{ mm.}$$

Flange Design Bolt Load, Gasket Seating [W]:

$$= Sa * ( Am + Ab ) / 2$$

$$= 172.38 * ( 50.2192 + 54.5547 ) / 2$$

$$= 902.94 \text{ kN}$$

Gasket Load for the Operating Condition [HG]:

$$= Wm1 - H$$

$$= 624 - 360$$

$$= 263.56 \text{ kN}$$

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

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

$$= ( 473.0 - 428.0626 ) / 2$$

$$= 22.4687 \text{ mm.}$$

Distance to Face Pressure Reaction [ht]:

$$= ( R + g1 + hg ) / 2$$

$$= ( 29.0 + 14.0 + 22.4687 ) / 2$$

$$= 32.7343 \text{ mm.}$$

Distance to End Pressure Reaction [hd]:

$$= R + ( g1 / 2 )$$

$$= 29.0 + ( 14.0 / 2.0 )$$

$$= 36.0000 \text{ mm.}$$

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	295.	36.0000	1.0000	10606.
Face Pressure, Mt	66.	32.7343	1.0000	2155.
Gasket Load, Mg	264.	22.4687	1.0000	5924.
Gasket Seating, Matm	903.	22.4687	1.0000	20296.
Total Moment for Operation, Mop				18686. N-m
Total Moment for Gasket seating, Matm				20296. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			56.032 mm.	
Hub Ratio, h/h0 = HL / H0			0.464	

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Thickness Ratio,  $g1/g0 = (g1Cor/goCor)$  1.726

Flange Factors for Integral Flange:

Factor F 0.842  
 Factor V 0.275  
 Factor f 1.000  
 Factors from Figure 2-7.1 K = 1.331  
 T = 1.784 U = 7.636  
 Y = 6.948 Z = 3.594  
 $d = 0.10241E+06 \text{ mm.}^3$  e = 0.0150 mm.<sup>-1</sup>  
 Stress Factors ALPHA = 1.676  
 BETA = 1.902 GAMMA = 0.940  
 DELTA = 0.890 Lamda = 1.829

Longitudinal Hub Stress, Operating [SHo]:

$= ( f * Mop / Bcor ) / ( L * g1^2 )$   
 $= ( 1.0 * 18686 / 387.0 ) / ( 1.8294 * 14.0^2 )$   
 $= 134.61 \text{ N./mm}^2$

Longitudinal Hub Stress, Seating [SHa]:

$= ( f * Matm / Bcor ) / ( L * g1^2 )$   
 $= ( 1.0 * 20296 / 387.0 ) / ( 1.8294 * 14.0^2 )$   
 $= 146.21 \text{ N./mm}^2$

Radial Flange Stress, Operating [SRo]:

$= ( Beta * Mop / Bcor ) / ( L * t^2 )$   
 $= ( 1.9019 * 18686 / 387.0 ) / ( 1.8294 * 45.0^2 )$   
 $= 24.78 \text{ N./mm}^2$

Radial Flange Stress, Seating [SRa]:

$= ( Beta * Matm / Bcor ) / ( L * t^2 )$   
 $= ( 1.9019 * 20296 / 387.0 ) / ( 1.8294 * 45.0^2 )$   
 $= 26.92 \text{ N./mm}^2$

Tangential Flange Stress, Operating [STo]:

$= ( Y * Mo / ( t^2 * Bcor ) ) - Z * SRO$   
 $= ( 6.9484 * 18686 / ( 45.0^2 * 387.0 ) ) - 3.5944 * 25$   
 $= 76.55 \text{ N./mm}^2$

Tangential Flange Stress, Seating [STa]:

$= ( y * Matm / ( t^2 * Bcor ) ) - Z * SRA$   
 $= ( 6.9484 * 20296 / ( 45.0^2 * 387.0 ) ) - 3.5944 * 27$   
 $= 83.15 \text{ N./mm}^2$

Average Flange Stress, Operating [SAo]:

$= ( SHO + \max( SRO, STo ) ) / 2$   
 $= ( 135 + \max( 25, 77 ) ) / 2$   
 $= 105.58 \text{ N./mm}^2$

Average Flange Stress, Seating [SAa]:

$= ( SHa + \max( SRA, STa ) ) / 2$   
 $= ( 146 + \max( 27, 83 ) ) / 2$   
 $= 114.68 \text{ N./mm}^2$

Bolt Stress, Operating [BSo]:

$= Wm1 / Ab$   
 $= 624 / 54.5547$   
 $= 114.37 \text{ N./mm}^2$

Bolt Stress, Seating [BSa]:

$= ( Wm2 / Ab )$   
 $= ( 866 / 54.5547 )$   
 $= 158.68 \text{ N./mm}^2$

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

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	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	135.	207.	146.	207.
Radial Flange	25.	138.	27.	138.
Tangential Flange	77.	138.	83.	138.
Maximum Average	106.	138.	115.	138.
Bolting	114.	172.	159.	172.

Minimum Required Flange Thickness 41.427 mm.  
 Estimated M.A.W.P. ( Operating ) 32.700 bars  
 Estimated Finished Weight of Flange at given Thk. 38.6 kg.  
 Estimated Unfinished Weight of Forging at given Thk 54.1 kg.

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

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

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

$$= 52.14 * 20296.2/1.0 * 999.68 * 0.275 / ( 1.437 * 202713 * 8.113^2 * 56.032 * 0.3 )$$

$$= 0.902 \text{ (should be } \leq 1)$$

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

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

$$= 52.14 * 18685.8/1.0 * 999.68 * 0.275 / ( 1.437 * 193088 * 8.113^2 * 56.032 * 0.3 )$$

$$= 0.872 \text{ (should be } \leq 1)$$

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

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

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

$$= 52.14 * 20296.2/1.0 * 999.68 * 0.275 / ( 1.829 * 202713 * 8.113^2 * 56.032 * 0.3 )$$

$$= 0.709 \text{ (should be } \leq 1)$$

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

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

$$= 52.14 * 18685.8/1.0 * 999.68 * 0.275 / ( 1.829 * 193088 * 8.113^2 * 56.032 * 0.3 )$$

$$= 0.685 \text{ (should be } \leq 1)$$

**Minimum Design Metal Temperature Results:**

Thickness Ratio = 0.436, Temperature Reduction per Fig. UCS 66.1 = 43 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C  
 Min Metal Temp. w/o impact per UG-20(f) -29 °C

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

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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		25.038	14	3	381	137.9
CHANNEL 01		25.038	12.7	3	381	117.9
BODY FLANGE 01		25.037	79	3	381	137.9
SHELL		25.033	12.7	3	381	117.9
BODY FLANGE 002		25.037	79	3	381	137.9
CHANNEL 002		25.038	12.7	3	381	117.9
HEAD 002		25.038	14	3	381	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		25	No Calc	No Calc	11.1125	6.44875
CHANNEL 01		25	No Calc	No Calc	11.1125	7.16235
BODY FLANGE 01		25	No Calc	No Calc	48	45.1358
SHELL		25	No Calc	No Calc	11.1125	7.16156
BODY FLANGE 002		25	No Calc	No Calc	48	41.4274
CHANNEL 002		25	No Calc	No Calc	11.1125	7.16235
HEAD 002		25	No Calc	No Calc	11.1125	6.44875

#### 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]:

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

$$= (25.038 \cdot 387.0 \cdot 0.98) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 25.038)$$

$$= 3.4487 + 3.0000 = 6.4487 \text{ mm.}$$

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

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

$$= (25.038 \cdot (0.98 \cdot 387.0 + 0.2 \cdot 8.1125)) / (2 \cdot 1.0 \cdot 8.1125)$$

$$= 58.767 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (25.038 \cdot 193.5) / (137.9 \cdot 1.0 - 0.6 \cdot 25.038) + 3.0$$

$$= 6.552 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.038 bars

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

$$= (137.9 \cdot 1.0 \cdot 11.0) / (193.5 + 0.6 \cdot 11.0)$$

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$$= 75.803 - 0.038 = 75.765 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (387.0/(2 * 98.25))^2)/6$$

$$= 0.979799$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 * t_{nom}/R_f) * (1 - R_f/R_o)$  14.630 %

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

#### MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 11.113, tr = 3.449, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.425$ , Temp. Reduction = 45 °C

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

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

Govrn. thk, tg = 14.0, tr = 3.552, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.323$ , 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

#### Cylindrical Shell From 20 To 30 SA-106 B , UCS-66 Crv. B at 190 °C

##### CHANNEL 01

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

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

$$= (25.038 * 193.5) / (117.9 * 1.0 - 0.6 * 25.038)$$

$$= 4.1623 + 3.0000 = 7.1623 \text{ mm.}$$

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

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

$$= (25.038 * (193.5 + 0.6 * 8.1125)) / (1.0 * 8.1125)$$

$$= 61.226 \text{ N./mm}^2$$

#### Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 5.046, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.622$ , Temp. Reduction = 21 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C

Min Metal Temp. at Required thickness (UCS 66.1) -47 °C

Min Metal Temp. w/o impact per UG-20(f) -29 °C

#### Cylindrical Shell From 40 To 50 SA-106 B , UCS-66 Crv. B at 120 °C

SHELL

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

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

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$$= (25.033*193.5)/(117.9*1.0-0.6*25.033)$$

$$= 4.1616 + 3.0000 = 7.1616 \text{ mm.}$$

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

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

$$= (25.033*(193.5+0.6*8.1125))/(1.0*8.1125)$$

$$= 61.214 \text{ N./mm}^2$$

#### Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-26 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

#### Cylindrical Shell From 60 To 70 SA-106 B , UCS-66 Crv. B at 190 °C

CHANNEL 002

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

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

$$= (25.038*193.5)/(117.9*1.0-0.6*25.038)$$

$$= 4.1623 + 3.0000 = 7.1623 \text{ mm.}$$

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

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

$$= (25.038*(193.5+0.6*8.1125))/(1.0*8.1125)$$

$$= 61.226 \text{ N./mm}^2$$

#### Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-26 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

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

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (25.038*387.0*0.98)/(2*137.9*1.0-0.2*25.038)$$

$$= 3.4487 + 3.0000 = 6.4487 \text{ mm.}$$

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

$$= (P*(Kcor*D+0.2*t))/(2*E*t)$$

$$= (25.038*(0.98*387.0+0.2*8.1125))/(2*1.0*8.1125)$$

$$= 58.767 \text{ N./mm}^2$$

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**Straight Flange Required Thickness:**

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

$$= (25.038 \cdot 193.5) / (137.9 \cdot 1.0 - 0.6 \cdot 25.038) + 3.0$$

$$= 6.552 \text{ mm.}$$

**Straight Flange Maximum Allowable Working Pressure:**

**Less Operating Hydrostatic Head Pressure of 0.038 bars**

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

$$= (137.9 \cdot 1.0 \cdot 11.0) / (193.5 + 0.6 \cdot 11.0)$$

$$= 75.803 - 0.038 = 75.765 \text{ bars}$$

**Factor K, corroded condition [Kcor]:**

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

$$= (2 + (387.0 / (2 \cdot 98.25))^2) / 6$$

$$= 0.979799$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  14.630 %

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

**MDMT Calculations in the Knuckle Portion:**

Govrn. thk,  $t_g = 11.113$ ,  $t_r = 3.449$ ,  $c = 3.0$  mm.,  $E^* = 1.0$   
 Thickness Ratio =  $t_r \cdot (E^*) / (t_g - c) = 0.425$ , Temp. Reduction = 45 °C

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

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

Govrn. thk,  $t_g = 14.0$ ,  $t_r = 3.552$ ,  $c = 3.0$  mm.,  $E^* = 1.0$   
 Thickness Ratio =  $t_r \cdot (E^*) / (t_g - c) = 0.323$ , 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

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

**Hydrostatic Test Pressure Results:**

**Exchanger Shell Side Hydrostatic Test Pressures:**

Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	32.500 bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	35.750 bars
Pressure per App 27-4	= M.A.W.P.	45.967 bars

**Exchanger Channel Side Hydrostatic Test Pressures:**

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	32.229 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	32.500 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	49.023 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	27.270 bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	35.750 bars
Pressure per App 27-4	= M.A.W.P.	24.791 bars

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

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

$$= 1.3 \cdot 25.0 \cdot 1.0$$

$$= 32.500 \text{ bars}$$

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

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

$$= 1.3 \cdot 25.0 \cdot 1.0$$

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= 32.500 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	76.4	235.8	0.324	32.54
CHANNEL 01	79.6	217.2	0.366	32.54
SHELL	79.6	217.2	0.366	32.54
CHANNEL 002	79.6	217.2	0.366	32.54
HEAD 002	76.4	235.8	0.324	32.54

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	117.90	117.90	1.000
T2	Pad	137.90	137.90	1.000
T1	Nozzle	117.90	117.90	1.000
T1	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	117.90	117.90	1.000
S3	Pad	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	117.90	117.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	117.90	117.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	117.90	117.90	1.000
HEAD 002	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	92.39	92.39	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
T2	20.18	217.19	0.093
T1	20.18	217.19	0.093
S2	20.18	217.19	0.093
S1	20.18	217.19	0.093
S3	19.83	217.19	0.091
T4	5.56	223.40	0.025
T3	6.47	223.40	0.029

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	403.225	8.1125	0.0027943	100.758
20	30	402.75	403.225	8.1125	0.0038853	105.978
30	40	No Calc	...	45	No Calc	No Calc
40	50	2908	403.225	8.1125	0.00050303	50.292
50	60	No Calc	...	45	No Calc	No Calc
60	70	402.75	403.225	8.1125	0.0038853	105.978
70	80	No Calc	403.225	8.1125	0.0027943	100.758

**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	11.1125	4.5	1.1	22.5225
20	30	11.1125	4.34351	1.1	28.4274
30	40	48	45.1358	1.1	No Calc
40	50	11.1125	6.07728	1.1	13.4903
50	60	48	41.4274	1.1	No Calc
60	70	11.1125	4.34351	1.1	28.4274
70	80	11.1125	4.5	1.1	22.5225

Minimum 13.490

**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	402.75	26273.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	2908	111055	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	402.75	26273.1	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

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$$8.113 \quad 403.23 \quad 49.70 \quad 0.0027943 \quad 100.76$$

$$EMAP = B/(K0*D/t) = 100.7576/(0.9 * 49.7042) = 22.5225 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.091	403.23	369.68	0.0003757	36.60

$$EMAP = B/(K0*D/t) = 36.6038/(0.9 * 369.677) = 1.1001 \text{ bars}$$

*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]:

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

$$= (1.837*387.0*0.98)/(2*137.9*1.0-0.2*1.837)$$

$$= 0.2526 + 3.0000 = 3.2526 \text{ mm.}$$

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

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

$$= ((2*137.9*1.0*8.1125)/(0.98*387.0+0.2*8.1125))/1.67$$

$$= 35.181 \text{ bars}$$

Maximum Allowable External Pressure [MAEP]:

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

$$= \min(22.52, 35.1807)$$

$$= 22.523 \text{ bars}$$

*Thickness requirements per UG-33(a)(1) govern the required thickness of this head.*

### **Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 190 °C**

#### CHANNEL 01

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
8.113	403.23	402.75	49.70	0.9988	0.0038853	105.98

$$EMAP = (4*B)/(3*(D/t)) = (4*105.978)/(3*49.7042) = 28.4274 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.344	403.23	402.75	300.13	0.9988	0.0002542	24.76

$$EMAP = (4*B)/(3*(D/t)) = (4*24.7636)/(3*300.1288) = 1.1001 \text{ bars}$$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	26273.08	49.70	50.0000	0.0004463	43.48

$$EMAP = (4*B)/(3*(D/t)) = (4*43.4818)/(3*49.7042) = 11.6635 \text{ bars}$$

### **Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 120 °C**

SHELL

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
-----	----	------	-----	-----	----------	---

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8.113 403.23 2908.00 49.70 7.2119 0.0005030 50.29  
 $EMAP = (4*B)/(3*(D/t)) = (4*50.292)/(3*49.7042) = 13.4903 \text{ bars}$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.077	403.23	2908.00	131.03	7.2119	0.0001081	10.81

$EMAP = (4*B)/(3*(D/t)) = (4*10.8112)/(3*131.0331) = 1.1 \text{ bars}$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	111054.98	49.70	50.0000	0.0004463	44.62

$EMAP = (4*B)/(3*(D/t)) = (4*44.6199)/(3*49.7042) = 11.9688 \text{ bars}$

### **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
8.113	403.23	402.75	49.70	0.9988	0.0038853	105.98

$EMAP = (4*B)/(3*(D/t)) = (4*105.978)/(3*49.7042) = 28.4274 \text{ bars}$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.344	403.23	402.75	300.13	0.9988	0.0002542	24.76

$EMAP = (4*B)/(3*(D/t)) = (4*24.7636)/(3*300.1288) = 1.1001 \text{ bars}$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	26273.08	49.70	50.0000	0.0004463	43.48

$EMAP = (4*B)/(3*(D/t)) = (4*43.4818)/(3*49.7042) = 11.6635 \text{ bars}$

### **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
8.113	403.23	49.70	0.0027943	100.76

$EMAP = B/(K0*D/t) = 100.7576/(0.9 * 49.7042) = 22.5225 \text{ bars}$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.091	403.23	369.68	0.0003757	36.60

$EMAP = B/(K0*D/t) = 36.6038/(0.9 * 369.677) = 1.1001 \text{ bars}$

*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]:

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

$$= (1.837*387.0*0.98)/(2*137.9*1.0-0.2*1.837)$$

$$= 0.2526 + 3.0000 = 3.2526 \text{ mm.}$$

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Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:  
=  $((2*S*E*t)/(Kcor*D+0.2*t))/1.67$  per Appendix 1-4 (c)  
=  $((2*137.9*1.0*8.1125)/(0.98*387.0+0.2*8.1125))/1.67$   
= 35.181 bars

Maximum Allowable External Pressure [MAEP]:  
= min( MAEP, MAWP )  
= min( 22.52, 35.1807 )  
= 22.523 bars

*Thickness requirements per UG-33(a)(1) govern the required thickness of this head.*

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 Element and Detail Weights: Step: 7 8:06am Dec 23,2021

**Element and Detail Weights:**

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	26.995	12942.4	21.2103	13470.9	1.34975
20	30	39.08	36603.5	30.0759	37765.5	1.954
30	40	61.1093	12259.1	58.1641	12353.2	3.05547
40	50	354.033	193985	272.463	204511	17.7016
50	60	61.2532	12259.1	58.3079	12353.2	3.06266
60	70	39.08	36603.5	30.0759	37765.5	1.954
70	80	26.995	12942.4	21.2103	13470.9	1.34975
Total		608	317594.72	491	331690.12	30

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	12.9345	-31.75	...	1
20	Liqd	36.5812	160.5	...	2
20	Nozl	20.2925	160	234.95	T2
20	Nozl	21.078	160	234.95	T1
30	Liqd	12.2516	37	...	3
40	Sadl	32.8035	464	334.694	Fixed Saddle
40	Sadl	32.8035	2444	334.694	Sliding Saddle
40	Liqd	169.633	1454	...	4
40	Nozl	21.078	164	234.95	S2
40	Nozl	21.078	2698	234.95	S1
40	Nozl	12.4379	164	220.662	S3
40	Wght	50	1456	...	WEIGHT BAFFLE
50	Liqd	12.2516	37	...	5
60	Liqd	36.5812	160.5	...	5
60	Nozl	5.18177	160	200.025	T4
60	Nozl	6.25877	160	203.2	T3
70	Liqd	12.9345	81.75	...	6
30	FTsh	60.2678	103	...	TUBE SHEET
30	Tube	454.709	1580	...	
30	RTsh	60.2678	3057	...	

**Total Weight of Each Detail Type:**

Saddles	65.6
Liquid	293.2
Nozzles	107.4
Weights	50.0
Exchanger Components	575.2
Liquid in Tubes	86.0
-----	
Sum of the Detail Weights	1177.5 kg.

**Weight Summation Results: (kg.)**

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	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	639.0	639.0	639.0	639.0	639.0	639.0
Saddles	65.6	65.6	65.6	65.6	65.6	65.6
Nozzles	107.4	107.4	107.4	107.4	107.4	107.4
Wld Weights	50.0	50.0	50.0	50.0	50.0	50.0
Exchanger	575.2	575.2	575.2	575.2	575.2	575.2
Ope. Liquid	...	...	...	...	...	293.2
Tube Ope Lqd	...	...	...	...	...	86.0
Test Liquid	...	317.4	...	...	...	...
Tube Tst Lqd	...	86.0	...	...	...	...
Totals	1437.2	1840.7	1437.2	1437.2	1437.2	1816.4

**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 without Removable Internals	1437.2 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	1840.7 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	1437.2 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	1437.2 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	1437.2 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	1816.4 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	1693.5 kg.
Field Test Wt.	- Empty Weight + Water (Full)	1731.9 kg.

**Exchanger Tube Data**

Volume of Exchanger tubes :	86082.2 Cm3
Weight of Ope Liq in tubes :	86.0 kg.
Weight of Water in tubes :	86.0 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	2455.76
20	30	4098.35
30	40	2560.12
40	50	37127.7
50	60	2560.12
60	70	4098.35
70	80	2455.76
Total		55356.133 cm^2

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Nozzle Flange MAWP: Step: 8 8:06am Dec 23,2021

**Nozzle Flange MAWP Results:**

Nozzle Description	Flange Rating		Design Temp °C	Class	Grade/Group	Equiv. Press	Max Pressure		
	Ope. bars	Ambient bars					PVP	50%	DNV bars
T2	44.06	51.10	190	300	GR 1.1	...	...	...	...
T1	44.06	51.10	190	300	GR 1.1	...	...	...	...
S2	46.00	51.10	120	300	GR 1.1	...	...	...	...
S1	46.00	51.10	120	300	GR 1.1	...	...	...	...
S3	46.00	51.10	120	300	GR 1.1	...	...	...	...
T4	44.06	51.10	190	300	GR 1.1	...	...	...	...
T3	44.06	51.10	190	300	GR 1.1	...	...	...	...

**Shellside Flange Rating**

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 46.000 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 B16.5 Flange MAWP: None Selected**

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

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 Wind Load Calculation: Step: 9 8:06am Dec 23,2021

### Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed [V]	195 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 mm.
Percent Wind for Hydrotest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.
Distance Upwind of Crest Lh	0 mm.
Distance from Crest to the Vessel x	0 mm.
Type of Terrain ( Hill, Escarpment )	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000

### Wind Analysis Results

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

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q) / (1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1 + 1.7 * 3.4 * 0.143 * 0.837) / (1 + 1.7 * 3.4 * 0.143))) \\
 &= \min(0.85, 0.856) \\
 &= 0.850
 \end{aligned}$$

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]	0.618
Structure Height to Diameter ratio	10.289

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

### Sample Calculation for the First Element

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

#### Value of [Alpha] and [Zg]:

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

#### Effective Height [z]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 500.0 + 123000. = 123500. \text{ mm.} \\
 &= 405.184 \text{ ft. Imperial Units}
 \end{aligned}$$

#### Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z (405.184 \text{ ft.}) > 15 \text{ ft.} \\
 &= 2.01 * ( z / Zg )^{2 / \text{Alpha}} \\
 &= 2.01 * ( 405.184 / 900.0 )^{2 / 9.5} \\
 &= 1.699
 \end{aligned}$$

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 \* 1.699 \* 1.0 \* 0.95 \* 121.171<sup>2</sup> )  
 = 60.7 psf [296.231] Kgs/m<sup>2</sup>

Force on the first element [F]:  
 = qz \* G \* Cf \* WindArea  
 = 60.672 \* 0.85 \* 0.618 \* 0.623  
 = 19.9 lbs. [ 0.1] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
HEAD 1	*****	0.000	0.000	0.000	1.699	1.000	296.231
CHANNEL 01	*****	0.000	0.000	0.000	1.699	1.000	296.231
BODY FLANGE 01	*****	0.000	0.000	0.000	1.699	1.000	296.231
SHELL	*****	0.000	0.000	0.000	1.699	1.000	296.231
BODY FLANGE 002	*****	0.000	0.000	0.000	1.699	1.000	296.231
CHANNEL 002	*****	0.000	0.000	0.000	1.699	1.000	296.231
HEAD 002	*****	0.000	0.000	0.000	1.699	1.000	296.231

**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	123500.00	296.23	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	123500	483.87	578.777	296.231	0.053013
20	30	123500	483.87	1553.22	296.231	0.14227
30	40	123500	457.2	338.328	296.231	0.030989
40	50	123500	483.87	14070.9	296.231	1.28883
50	60	123500	457.2	338.328	296.231	0.030989
60	70	123500	483.87	1553.22	296.231	0.14227
70	80	123500	483.87	578.777	296.231	0.053013

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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Wind Load Calculation: Step: 9 8:06am Dec 23,2021

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 Earthquake Load Calculation: Step: 10 8:06am Dec 23,2021

**Earthquake Load Calculation:**

**Input Values:**

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		1.163
Long Period Acceleration Value S1		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.000
User Value of Sd1 (used if > 0 )		0.000

**Seismic Analysis Results:**

Sms = Fa \* Ss = 1.0 \* 1.163 = 1.163  
 Sml = Fv \* S1 = 1.3 \* 0.6 = 0.78  
 Sds = 2/3 \* Sms = 2/3 \* 1.163 = 0.775  
 Sd1 = 2/3 \* Sml = 2/3 \* 0.78 = 0.52

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

= Ct \* hn<sup>x</sup> where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)  
 = 0.020 \* ( 2.2654<sup>0.75</sup> )  
 = 0.037 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

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

= ( 1/Natural Frequency ) = ( 1/33.0 )  
 = 0.030

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

= Minimum Value of ( 1.4 \* 0.037, 0.03 ) per 12.8.2  
 = 0.030

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

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

= 0.3 \* Sds \* W \* I  
 = 0.3 \* 0.775 \* 17 \* 1.5  
 = 5.794 kN

Final Base Shear, V = 4.06 kN

**Earthquake Load Calculation:**

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	190.5	1.8452	0.45065

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20	30	190.5	1.8452	0.45065
30	40	190.5	1.8452	0.45065
40	Sad1	190.5	1.8452	0.45065
Sad1	50	190.5	1.8452	0.45065
40	50	190.5	1.8452	0.45065
50	60	190.5	1.8452	0.45065
60	70	190.5	1.8452	0.45065
70	80	190.5	1.8452	0.45065

**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 8:06am Dec 23,2021

### Shop/Field Installation Options :

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

Center of Gravity of Saddles	1951.175 mm.
Center of Gravity of Liquid	1949.253 mm.
Center of Gravity of Nozzles	1307.450 mm.
Center of Gravity of Added Weights (Operating)	1953.175 mm.
Center of Gravity of Added Weights (Empty)	1953.175 mm.
Center of Gravity of Tubesheet(s)	1951.000 mm.
Center of Gravity of Tubes	1951.000 mm.
Center of Gravity of Bare Shell New and Cold	1946.910 mm.
Center of Gravity of Bare Shell Corroded	1946.170 mm.
Vessel CG in the Operating Condition	1908.482 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1901.172 mm.
Vessel CG in the Test Condition	1911.817 mm.

### Rigging Analysis Results:

Total Effective Length of Vessel for this analysis	3798.00 mm.
Total vessel weight (No Liquid) Twt	14.09 kN
Impact weight multiplication factor Imp	1.50
Design lifting weight, DWT = Imp * Twt	21.14 kN
Distance to the Lug on the Left End	1070.00 mm.
Distance to the Lug on the Right End	2870.00 mm.
Design Reaction force at the Left End Lug	11.38 kN
Design Reaction force at the Right End Lug	9.76 kN
CG Distance from the Left End Lug	831.17 mm.
CG Distance from the Nearer Lifting Lug	831.17 mm.

### Critical Values:

	Max Stress N./mm <sup>2</sup>	Elevation mm.	Allowables N./mm <sup>2</sup>
Bending	5.47	1026.60	117.90 (UG-23)
Shear	0.77	1026.60	82.53 (0.7*S)

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

Distance mm.	Bending Moment N-m	Bending Stress N./mm <sup>2</sup>	Shear Force kN	Shear Stress N./mm <sup>2</sup>
0.00	0.0	0.0	4.1	0.3
114.20	520.9	0.4	4.9	0.4
400.60	1863.8	1.4	7.7	0.6
2189.80	4881.8	3.7	0.2	0.0
3412.20	1120.8	0.9	3.1	0.2
3748.00	179.3	0.1	0.3	0.0

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

Maximum Unity Check is 0.0464 at elevation 1026.6001 mm. - Must be <=1

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

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

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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 : Operating Case

**Note:**

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

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

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

$$= \min( 140.0 + 1.56 \cdot \sqrt{ 197.5563 \cdot 8.1125 }, 2 \cdot 500.0 )$$

$$= 202.4521 \text{ mm.}$$

### Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	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		16.64	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	26.55	117.90	
Long. Stress at Bottom of Midspan	34.37	117.90	
Long. Stress at Top of Saddles	42.90	117.90	
Long. Stress at Bottom of Saddles	23.57	117.90	
-----			
Tangential Shear in Shell	7.98	94.32	
Circ. Stress at Horn of Saddle	22.58	147.38	
Circ. Compressive Stress in Shell	0.77	117.90	
-----			

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 \cdot ( 1.7/2 + 0 ) \cdot 500.0 / 366.5236$$

$$= 3.6 \text{ kN}$$

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

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

$$= \max( 0.27, 0.0, 0 ) \cdot 500.0 / 1980.0005$$

$$= 0.1 \text{ kN}$$

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

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

$$= \max( 4.06, 0.0, 0 ) \cdot 500.0 / 1980.0005$$

$$= 1.0 \text{ kN}$$

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Saddle Reaction Force due to Earthquake Ft [Fst]:  
 $= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$   
 $= 3.0 * ( 4/2 + 0 ) * 500.0/366.5236$   
 $= 8.3 \text{ kN}$

Load Combination Results for Q + Wind or Seismic [Q]:  
 $= \text{Saddle Load} + \text{Max}( F_{wl}, F_{wt}, F_{sl}, F_{st} )$   
 $= 8 + \text{Max}( 0.1, 4, 1, 8 )$   
 $= 16.6 \text{ kN}$

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

Vertical Load (including saddle weight)	16.96	kN
Transverse Shear Load Saddle Ft	2.03	kN
Longitudinal Shear Load Saddle	4.06	kN

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

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

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

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

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

Moment per Equation 4.15.3 [M1]:  
 $= -Q * a [ 1 - ( 1 - a/L + (R^2 - h^2) / (2a * L) ) / ( 1 + (4h^2) / (3L) ) ]$   
 $= -17 * 500.0 [ 1 - ( 1 - 500.0 / 2908.0 + (197.556^2 - 0.0^2) / (2 * 500.0 * 2908.0) ) / ( 1 + (4 * 0.0) / (3 * 2908.0) ) ]$   
 $= -1319.3 \text{ N-m}$

Moment per Equation 4.15.4 [M2]:  
 $= Q * L / 4 ( 1 + 2(R^2 - h^2) / (L^2) ) / ( 1 + (4h^2) / (3L) ) - 4a / L$   
 $= 17 * 2908 / 4 ( 1 + 2(198^2 - 0^2) / (2908^2) ) / ( 1 + (4 * 0) / (3 * 2908) ) - 4 * 500 / 2908$   
 $= 3890.3 \text{ N-m}$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:  
 $= P * R_m / (2t) - M2 / (pi * R_m^2 * t)$   
 $= 25.016 * 197.556 / (2 * 8.113) - 3890.3 / (pi * 197.6^2 * 8.113)$   
 $= 26.55 \text{ N./mm}^2$

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:  
 $= P * R_m / (2t) + M2 / (pi * R_m^2 * t)$   
 $= 25.016 * 197.556 / (2 * 8.113) + 3890.3 / (pi * 197.6^2 * 8.113)$   
 $= 34.37 \text{ N./mm}^2$

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:  
 $= P * R_m / (2t) - M1 / (K1 * pi * R_m^2 * t)$   
 $= 25.016 * 197.556 / (2 * 8.113) - 1319.3 / (0.1066 * pi * 197.6^2 * 8.113)$   
 $= 42.90 \text{ N./mm}^2$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:  
 $= P * R_m / (2t) + M1 / (K1 * pi * R_m^2 * t)$   
 $= 25.016 * 197.556 / (2 * 8.113) + 1319.3 / (0.1923 * pi * 197.6^2 * 8.113)$   
 $= 23.57 \text{ N./mm}^2$

Maximum Shear Force in the Saddle (4.15.5) [T]:  
 $= Q(L - 2a) / (L + (4 * h^2 / 3))$   
 $= 17( 2908.0 - 2 * 500.0 ) / (2908.0 + ( 4 * 0.0 / 3 ))$

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$$= 10.9 \text{ kN}$$

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

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

$$= 1.1707 * 10.92 / ( 197.5563 * 8.1125 )$$

$$= 7.98 \text{ N./mm}^2$$

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

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

$$= 0.78 * \text{sqrt}( 197.556 * 8.113 )$$

$$= 31.226 \text{ mm.}$$

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

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

$$= -0.7603 * 17 * 0.1 / ( 8.113 * ( 140.0 + 31.23 + 31.23 ) )$$

$$= -0.77 \text{ N./mm}^2$$

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

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

$$= -17 / ( 4 * 8.113 * ( 140.0 + 31.226 + 31.226 ) ) -$$

$$3 * 0.0529 * 17 / ( 2 * 8.113^2 )$$

$$= -22.58 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min( 140.0 + 1.56 * \text{sqrt}( 197.556 * 8.113 ), 2 * 500.0 )$$

$$= 202.45 \text{ mm.}$$

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

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

$$= 0.000012 * 1980.0 * ( 120.0 - 21.1 )$$

$$= 2.395 \text{ mm.}$$

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

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below  $I_o$  is  $I$  for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	$I_o$
Shell	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:

$$= AY / A$$

$$= 396.752 / 86.878$$

$$= 115.996 \text{ mm.}$$

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Angle [beta]:

$$\begin{aligned}
 &= 180 - \text{Saddle Angle}/2 \\
 &= 180 - 120.0/2 \\
 &= 120.0
 \end{aligned}$$

Saddle Splitting Coefficient [K1]:

$$\begin{aligned}
 &= ( 1 + \cos(\text{beta}) - 0.5*\sin(\text{beta})^2 ) / (\pi - \text{beta} + \sin(\text{beta})\cos(\text{beta}) ) \\
 &= ( 1 + \cos(120.0) - 0.5*\sin(120.0)^2 ) / (\pi - 2.094 + \sin(120.0)\cos(120.0) ) \\
 &= 0.2035
 \end{aligned}$$

Saddle Splitting Force [Fh]:

$$\begin{aligned}
 &= K1 * Q \\
 &= 0.204 * 16.639 \\
 &= 3.3864 \text{ kN}
 \end{aligned}$$

$$\begin{aligned}
 \text{Tension Stress, St} &= ( \text{Fh}/\text{As} ) = 0.5160 \text{ N./mm}^2 \\
 \text{Allowed Stress, Sa} &= 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2
 \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned}
 &= B - R * \sin(\text{theta}) / \text{theta} \\
 &= 500.0 - 193.5 * \sin( 1.0472 ) / 1.0472 \\
 &= 339.977 \text{ mm.}
 \end{aligned}$$

$$\text{Bending Moment, M} = \text{Fh} * d = 1151.7756 \text{ N-m}$$

$$\begin{aligned}
 \text{Bending Stress, Sb} &= ( M * C1 / I ) = 1.0180 \text{ N./mm}^2 \\
 \text{Allowed Stress, Sa} &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2
 \end{aligned}$$

**Minimum Thickness of Baseplate per Moss:**

$$\begin{aligned}
 &= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 2 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2} \\
 &= ( 3(17 + 0.3)150.0 / ( 2 * 370.0 * 137.9 ) )^{1/2} \\
 &= 8.649 \text{ mm.}
 \end{aligned}$$

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

Web Length Dimension [ Web Length ]:

$$\begin{aligned}
 &= 2 * \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} ) \\
 &= 2 * \cos( 90 - 120.0/2 ) ( 190.5 + 11.113 + 10.0 ) \\
 &= 366.524 \text{ mm.}
 \end{aligned}$$

Distance between Ribs [e]:

$$\begin{aligned}
 &= \text{Web Length} / ( \text{Nr ribs} - 1 ) \\
 &= 366.5236 / ( 2 - 1 ) \\
 &= 366.524 \text{ mm.}
 \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned}
 &= e * \text{Bpwid} / 2 \\
 &= 366.5236 * 150.0 / 2 \\
 &= 274.893 \text{ cm}^2
 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned}
 &= \text{Ap} * \text{Bp} \\
 &= 274.9 * 0.03 \\
 &= 8.241 \text{ kN}
 \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned}
 &= \text{Rib Area} + \text{Web Area} \\
 &= 13.0 + 18.326 \\
 &= 31.326 \text{ cm}^2
 \end{aligned}$$

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Compressive Stress [Sc]:

$$= P/Ar$$

$$= 8.2/31.3262$$

$$= 2.631 \text{ N./mm}^2$$

### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	I <sub>o</sub>
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

Rib dimension [D]:

$$= \text{Saddle Width} - \text{Web Thickness}$$

$$= 140.0 - 10.0$$

$$= 130.000 \text{ mm.}$$

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 106663.086/31.326$$

$$= 34.049 \text{ mm.}$$

Distance to Centroid [C1]:

$$= \max(\text{ytot}, \text{Saddle Width} - \text{ytot})$$

$$= \max(34.049, 140.0 - 34.049)$$

$$= 105.951 \text{ mm.}$$

Radius of Gyration [r]:

$$= \sqrt{\text{Total Inertia} / \text{Total Area}}$$

$$= \sqrt{557.3/31.326}$$

$$= 42.177 \text{ mm.}$$

Intermediate Term [Cc]:

$$= \sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}}$$

$$= \sqrt{2 * \pi^2 * 0.19994\text{E}+09/206.9}$$

$$= 138.135$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 58.719/42.177$$

$$= 1.392$$

Bending Moment [Rm]:

$$= F1 / (2 * B_{plen}) * e * L / 2$$

$$= 4.1 / (2 * 370.0) * 366.524 * 58.72/2$$

$$= 59.004 \text{ N-m}$$

Compressive Allowable,  $KL/r < Cc$  (  $1.3922 < 138.1347$  ) per AISC E2-1 [Sca]:

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

$$= (1 - (1.39)^2 / (2 * 138.13^2)) 207 /$$

$$(5/3 + 3 * (1.39) / (8 * 138.13) - (1.39^3) / (8 * 138.13^3))$$

$$= 123.8 \text{ N./mm}^2$$

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

$$= Sc/Sca + (Rm * C1 / I) / Sba$$

$$= 2.63/123.82 + (59.0 * 105.951/5572630) / 137.9$$

$$= 0.029$$

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### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
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	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.0	kN
Maximum Transverse Force	Ft	2.0	kN
Maximum Longitudinal Force	F1	4.1	kN
Saddle Bolted to Steel Foundation		Yes	

#### Shear Stress in a Single Bolt [taub]:

$$\begin{aligned}
 &= \text{Shear Force} / ( 2 * \text{Bolt Area} * \text{Number of Bolts} ) \\
 &= 4 / ( 2 * 2.17 * 2 ) \\
 &= 4.7 \text{ N./mm}^2. \text{ Must be less than } 103.4 \text{ N./mm}^2.
 \end{aligned}$$

### Bolt Area Calculation per Dennis R. Moss

#### Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

#### Bolt Area due to Shear Load [Bltarears]:

$$\begin{aligned}
 &= F1 / (Stba * Nbolts) \\
 &= 4.06 / (172.38 * 2.0) \\
 &= 0.1177 \text{ cm}^2
 \end{aligned}$$

#### Bolt Area due to Transverse Load:

##### Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned}
 &= B * Ft + \text{Sum of X Moments} \\
 &= 500.0 * 2.03 + 0.0 \\
 &= 1014.38 \text{ N-m}
 \end{aligned}$$

##### Eccentricity (e):

$$\begin{aligned}
 &= Rmom / QO \\
 &= 1014.38 / 8.66 \\
 &= 117.07 \text{ mm.} > Bplen/6 \text{ --> Uplift in Transverse direction}
 \end{aligned}$$

$$\begin{aligned}
 f &= Bplen / 2 - Edgedis \\
 &= 370.0 / 2 - 85.0 \\
 &= 100.00 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K1 &= 3 (e - 0.5 * Bplen) \\
 &= 3 (117.07 - 0.5 * 370.0) \\
 &= -203.80 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 K2 &= 6 * n1 * At / Bpwid * (f + e) \\
 &= 6 * 1.0 * 2.17 / 150.0 * (100.0 + 117.07) \\
 &= 1884.58 \text{ mm.}^2
 \end{aligned}$$

$$\begin{aligned}
 K3 &= -K2 * (0.5 * Bplen + f) \\
 &= -1884.58 * (0.5 * 370.0 + 100.0) \\
 &= -537105.21 \text{ mm.}^3
 \end{aligned}$$

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Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned}
 Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\
 Y^3 + -203.8 * Y^2 + 1884.58 * Y + -537105.19 &= 0 \\
 Y &= 207.21 \text{ mm.}
 \end{aligned}$$

$$\begin{aligned}
 \text{Num} &= (\text{Bplen} / 2 - Y / 3 - e) \\
 &= (370.0/2 - 207.21/3 - 117.07) \\
 &= -1.14
 \end{aligned}$$

$$\begin{aligned}
 \text{Denom} &= (\text{Bplen} / 2 - Y / 3 + f) \\
 &= (370.0/2 - 207.21/3 + 100.0) \\
 &= 215.93
 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned}
 &= - Q0 * \text{Num} / \text{Denom} \\
 &= - 8.66 * -1.14/215.93 \\
 &= 0.05 \text{ kN}
 \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned}
 &= \text{Tforce} / (\text{Stba} * \text{Nbt}) \\
 &= 0.05 / (172.38 * 1.0) \\
 &= 0.0026 \text{ cm}^2
 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned}
 &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\
 &= \max[0.0, 0.1177, 0.0026] \\
 &= 0.1177 \text{ cm}^2
 \end{aligned}$$

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

Bearing Pressure (fc)

$$\begin{aligned}
 &= 2(Q0 + \text{Tforce}) / (Y * \text{Bpwid}) \\
 &= 2(8.66 + 0.05) / (207.21 * 150.0) \\
 &= 5.60 \text{ bars}
 \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned}
 &= (\text{Bplen} - \text{Weblngth}) / 2 \\
 &= (370.0 - 319.2) / 2 \\
 &= 25.4000 \text{ mm.}
 \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned}
 &= \text{Tforce} * \text{Adist} \\
 &= 0.05 * 25.4 \\
 &= 1.16 \text{ N-m}
 \end{aligned}$$

Equivalent Bearing Pressure (f1):

$$\begin{aligned}
 &= \text{fc} * (Y - \text{Adist}) / Y \\
 &= 5.6 * (207.21 - 25.4) / 207.21 \\
 &= 4.92 \text{ bars}
 \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned}
 &= (\text{Adist}^2 * \text{Bpwid} / 6) * (\text{f1} + 2 * \text{fc}) \\
 &= (25.4^2 * 150.0 / 6) * (4.92 + 2 * 5.6) \\
 &= 26.01 \text{ N-m}
 \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned}
 &= (6 * \max(\text{Mt}, \text{Mc}) / (\text{Bpwid} * \text{Sba}))^{1/2} \\
 &= (6 * \max(1.16, 26.01) / (150.0 * 162.38))^{1/2} \\
 &= 2.5310 \text{ mm.}
 \end{aligned}$$

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

**Note:**

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

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

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

$$= \min( 140.0 + 1.56 \cdot \sqrt{ 197.5563 \cdot 8.1125 }, 2 \cdot 500.0 )$$

$$= 202.4521 \text{ mm.}$$

#### Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	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		15.92	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----	-----	-----	
Long. Stress at Top of Midspan	26.72	117.90	
Long. Stress at Bottom of Midspan	34.20	117.90	
Long. Stress at Top of Saddles	42.36	117.90	
Long. Stress at Bottom of Saddles	23.86	117.90	
-----	-----	-----	
Tangential Shear in Shell	7.63	94.32	
Circ. Stress at Horn of Saddle	21.61	147.38	
Circ. Compressive Stress in Shell	0.74	117.90	
-----	-----	-----	

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 \cdot ( 1.7/2 + 0 ) \cdot 500.0 / 366.5236$$

$$= 3.6 \text{ kN}$$

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

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

$$= \max( 0.27, 3.18, 0 ) \cdot 500.0 / 1980.0005$$

$$= 0.8 \text{ kN}$$

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

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

$$= \max( 4.06, 3.18, 0 ) \cdot 500.0 / 1980.0005$$

$$= 1.0 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

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$$= 3.0 * ( 4/2 + 0 ) * 500.0/366.5236$$

$$= 8.3 \text{ kN}$$

Load Combination Results for Q + Wind or Seismic [Q]:  
 = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )  
 = 8 + Max( 0.8, 4, 1, 8 )  
 = 15.9 kN

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

Vertical Load (including saddle weight)	16.24	kN
Transverse Shear Load Saddle	Ft	2.03 kN
Longitudinal Shear Load Saddle	4.06	kN

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

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

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

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

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

Moment per Equation 4.15.3 [M1]:

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

$$= -16*500.0 [1 - (1 - 500.0/2908.0 + (197.556^2 - 0.0^2)/(2*500.0*2908.0))/(1 + (4*0.0)/(3*2908.0))]$$

$$= -1262.6 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

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

$$= 16*2908/4(1 + 2(198^2 - 0^2)/(2908^2))/(1 + (4*0)/(3*2908)) - 4*500/2908$$

$$= 3722.9 \text{ N-m}$$

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

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

$$= 25.016 * 197.556/(2*8.113) - 3722.9/(pi*197.6^2*8.113)$$

$$= 26.72 \text{ N./mm}^2$$

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

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

$$= 25.016 * 197.556/(2 * 8.113) + 3722.9/(pi * 197.6^2 * 8.113)$$

$$= 34.20 \text{ N./mm}^2$$

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

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

$$= 25.016*197.556/(2*8.113) - 1262.6/(0.1066*pi*197.6^2*8.113)$$

$$= 42.36 \text{ N./mm}^2$$

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

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

$$= 25.016*197.556/(2*8.113) + 1262.6/(0.1923*pi*197.6^2*8.113)$$

$$= 23.86 \text{ N./mm}^2$$

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

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

$$= 16(2908.0 - 2 * 500.0)/(2908.0 + (4 * 0.0/3))$$

$$= 10.4 \text{ kN}$$

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

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

$$= 1.1707 * 10.45 / ( 197.5563 * 8.1125 )$$

$$= 7.63 \text{ N./mm}^2$$

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

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

$$= 0.78 * \text{sqrt}( 197.556 * 8.113 )$$

$$= 31.226 \text{ mm.}$$

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

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

$$= -0.7603 * 16 * 0.1 / ( 8.113 * ( 140.0 + 31.23 + 31.23 ) )$$

$$= -0.74 \text{ N./mm}^2$$

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

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

$$= -16 / ( 4 * 8.113 * ( 140.0 + 31.226 + 31.226 ) ) -$$

$$3 * 0.0529 * 16 / ( 2 * 8.113^2 )$$

$$= -21.61 \text{ N./mm}^2$$

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

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

$$= \min( 140.0 + 1.56 * \text{sqrt}( 197.556 * 8.113 ), 2 * 500.0 )$$

$$= 202.45 \text{ mm.}$$

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

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	mm.
Friction Coefficient	mu	0.400	

Note: In the tables below  $I_o$  is  $I$  for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	$I_o$
Shell	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [ $C_1$ ]:

$$= AY / A$$

$$= 396.752 / 86.878$$

$$= 115.996 \text{ mm.}$$

Angle [ $\beta$ ]:

$$= 180 - \text{Saddle Angle} / 2$$

$$= 180 - 120.0 / 2$$

$$= 120.0$$

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Saddle Splitting Coefficient [K1]:

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

$$= ( 1 + \cos(120.0) - 0.5 \cdot \sin(120.0)^2 ) / (\pi - 2.094 + \sin(120.0) \cos(120.0) )$$

$$= 0.2035$$

Saddle Splitting Force [Fh]:

$$= K1 * Q$$

$$= 0.204 * 15.923$$

$$= 3.2407 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 0.4938 \text{ N./mm}^2$$

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

Saddle Splitting Dimension [d]:

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

$$= 500.0 - 193.5 * \sin(1.0472) / 1.0472$$

$$= 339.977 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 1102.2029 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M * C1 / I ) = 0.9742 \text{ N./mm}^2$$

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

**Minimum Thickness of Baseplate per Moss:**

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

$$= ( 3(16 + 0.3)150.0 / ( 2 * 370.0 * 137.9 ) )^{1/2}$$

$$= 8.464 \text{ mm.}$$

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

Web Length Dimension [ Web Length ]:

$$= 2 * \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 * \cos( 90 - 120.0/2 ) ( 190.5 + 11.113 + 10.0 )$$

$$= 366.524 \text{ mm.}$$

Distance between Ribs [e]:

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

$$= 366.5236 / ( 2 - 1 )$$

$$= 366.524 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

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

$$= 366.5236 * 150.0 / 2$$

$$= 274.893 \text{ cm}^2$$

Axial Load [P]:

$$= Ap * Bp$$

$$= 274.9 * 0.03$$

$$= 7.887 \text{ kN}$$

Area of the Rib and Web [Ar]:

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

$$= 13.0 + 18.326$$

$$= 31.326 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P / Ar$$

$$= 7.9 / 31.3262$$

$$= 2.518 \text{ N./mm}^2$$

**Check of Outside Ribs:**

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

	B	D	Y	A	AY	I <sub>o</sub>
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

#### Rib dimension [D]:

= Saddle Width - Web Thickness  
 = 140.0 - 10.0  
 = 130.000 mm.

#### Distance to Centroid from Datum [ytot]:

= AY / A  
 = 106663.086/31.326  
 = 34.049 mm.

#### Distance to Centroid [C1]:

= max( ytot, Saddle Width - ytot )  
 = max( 34.049, 140.0 - 34.049 )  
 = 105.951 mm.

#### Radius of Gyration [r]:

= sqrt( Total Inertia / Total Area )  
 = sqrt( 557.3/31.326 )  
 = 42.177 mm.

#### Intermediate Term [Cc]:

= sqrt( 2 \* pi<sup>2</sup> \* Elastic Modulus / Yield Stress )  
 = sqrt( 2 \* pi<sup>2</sup> \* 0.19994E+09/206.9 )  
 = 138.135

#### Slenderness ratio [KL/r]:

= KL/r  
 = 1 \* 64.323/42.177  
 = 1.525

#### Bending Moment [Rm]:

= F1 / ( 2 \* Bplen ) \* e \* L / 2  
 = 4.1 / ( 2 \* 370.0 ) \* 366.524 \* 64.32 / 2  
 = 64.635 N-m

#### Compressive Allowable, KL/r < Cc ( 1.5251 < 138.1347 ) per AISC E2-1 [Sca]:

= ( 1 - (KL/r)<sup>2</sup> / (2 \* Cc<sup>2</sup>) ) Fy / ( 5/3 + 3 \* (KL/r) / (8 \* Cc) - (KL/r)<sup>3</sup> / (8 \* Cc<sup>3</sup>) )  
 = ( 1 - ( 1.53 )<sup>2</sup> / (2 \* 138.13<sup>2</sup>) ) 207 /  
 ( 5/3 + 3 \* (1.53) / (8 \* 138.13) - ( 1.53<sup>3</sup> ) / (8 \* 138.13<sup>3</sup>) )  
 = 123.8 N./mm<sup>2</sup>

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

= Sc/Sca + ( Rm \* C1 / I ) / Sba  
 = 2.52/123.79 + ( 64.64 \* 105.951/5572630 ) / 137.9  
 = 0.029

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

Total Number of Bolts per BasePlate	Nbolts	2
Total Number of Bolts in Tension/Baseplate	Nbt	1
Bolt Material Specification	SA-193 B7	
Bolt Allowable Stress	Stba	172.38 N./mm <sup>2</sup>

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Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	7.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.0	kN
Maximum Transverse Force	Ft	2.0	kN
Maximum Longitudinal Force	F1	4.1	kN
Saddle Bolted to Steel Foundation		Yes	

#### Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )  
 = 4 / ( 2 \* 2.17 \* 2 )  
 = 4.7 N./mm<sup>2</sup>. Must be less than 103.4 N./mm<sup>2</sup>.

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

##### Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

##### Bolt Area due to Shear Load [Bltarears]:

= F1 / (Stba \* Nbolts)  
 = 4.06 / (172.38 \* 2.0)  
 = 0.1177 cm<sup>2</sup>

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

##### Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments  
 = 500.0 \* 2.03 + 0.0  
 = 1014.38 N-m

##### Eccentricity (e):

= Rmom / QO  
 = 1014.38 / 7.95  
 = 127.62 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis  
 = 370.0 / 2 - 85.0  
 = 100.00 mm.

K1 = 3 (e - 0.5 \* Bplen)  
 = 3 (127.62 - 0.5 \* 370.0)  
 = -172.14 mm.

K2 = 6 \* n1 \* At / Bpwid \* (f + e)  
 = 6 \* 1.0 \* 2.17 / 150.0 \* (100.0 + 127.62)  
 = 1976.19 mm.<sup>2</sup>

K3 = -K2 \* (0.5 \* Bplen + f)  
 = -1976.19 \* (0.5 \* 370.0 + 100.0)  
 = -563214.38 mm.<sup>3</sup>

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

$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$   
 $Y^3 + -172.14 * Y^2 + 1976.19 * Y + -563214.38 = 0$   
 Y = 178.72 mm.

Num = (Bplen / 2 - Y / 3 - e)

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$$= (370.0/2 - 178.72/3 - 127.62)$$

$$= -2.19$$

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

$$= (370.0/2 - 178.72/3 + 100.0)$$

$$= 225.43$$

Total Bolt Tension Force [Tforce]:

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

$$= -7.95 * -2.19/225.43$$

$$= 0.08 \text{ kN}$$

Bolt Area Required due to Transverse Load [Bltareart]:

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

$$= 0.08 / (172.38 * 1.0)$$

$$= 0.0045 \text{ cm}^2$$

Required Area of a Single Bolt [Bltarear]:

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

$$= \max[0.0, 0.1177, 0.0045]$$

$$= 0.1177 \text{ cm}^2$$

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

Bearing Pressure (fc)

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

$$= 2(7.95 + 0.08) / (178.72 * 150.0)$$

$$= 5.99 \text{ bars}$$

Distance from Baseplate Edge to the Web [ADIST]:

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

$$= (370.0 - 319.2) / 2$$

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

Overturning Moment due To Bolt Tension [Mt]:

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

$$= 0.08 * 25.4$$

$$= 1.96 \text{ N-m}$$

Equivalent Bearing Pressure (f1):

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

$$= 5.99 * (178.72 - 25.4) / 178.72$$

$$= 5.13 \text{ bars}$$

Overturning Moment due to Bearing Pressure [Mc]:

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

$$= (25.4^2 * 150.0 / 6) * (5.13 + 2 * 5.99)$$

$$= 27.60 \text{ N-m}$$

Baseplate Required Thickness [Treq]:

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

$$= (6 * \max(1.96, 27.6) / (150.0 * 162.38))^{1/2}$$

$$= 2.6071 \text{ mm.}$$

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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

**Note:**

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

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

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

$$= \min( 140.0 + 1.56 \cdot \sqrt{ 197.5563 \cdot 8.1125 }, 2 \cdot 500.0 )$$

$$= 202.4521 \text{ mm.}$$

### Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		217.19	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		217.19	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		10.24	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----		
Long. Stress at Top of Midspan	37.19	217.19
Long. Stress at Bottom of Midspan	42.00	217.19
Long. Stress at Top of Saddles	47.25	217.19
Long. Stress at Bottom of Saddles	35.36	217.19
-----		
Tangential Shear in Shell	4.91	173.75
Circ. Stress at Horn of Saddle	13.89	325.79
Circ. Compressive Stress in Shell	0.47	217.19
-----		

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 \cdot ( 0.6/2 + 0 ) \cdot 500.0/366.5236$$

$$= 1.2 \text{ kN}$$

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

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

$$= \max( 0.09, 0.0, 0 ) \cdot 500.0/1980.0005$$

$$= 0.0 \text{ kN}$$

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

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

$$= 9 + \max( 0.0, 1, 0, 0 )$$

$$= 10.2 \text{ kN}$$

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

Vertical Load (including saddle weight)	10.56	kN
Transverse Shear Load Saddle	0.29	kN
Longitudinal Shear Load Saddle	0.09	kN

Hydrostatic Test Pressure at center of Vessel: 32.519 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	

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

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

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{(R^2 - h^2)}{(2a \cdot L)} \right) / \left( 1 + \frac{(4h^2)}{(3L)} \right) \right] \\
 &= -10 \cdot 500.0 \left[ 1 - \left( 1 - \frac{500.0}{2908.0} + \frac{(197.556^2 - 0.0^2)}{(2 \cdot 500.0 \cdot 2908.0)} \right) / \left( 1 + \frac{(4 \cdot 0.0)}{(3 \cdot 2908.0)} \right) \right] \\
 &= -811.8 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{(R^2 - h^2)}{(L^2)} \right) / \left( 1 + \frac{(4h^2)}{(3L)} \right) - \frac{4a}{L} \\
 &= \frac{10 \cdot 2908}{4} \left( 1 + 2 \frac{(198^2 - 0^2)}{(2908^2)} \right) / \left( 1 + \frac{(4 \cdot 0)}{(3 \cdot 2908)} \right) - \frac{4 \cdot 500}{2908} \\
 &= 2393.6 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) - 2393.6 / (\pi \cdot 197.6^2 \cdot 8.113) \\
 &= 37.19 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) + 2393.6 / (\pi \cdot 197.6^2 \cdot 8.113) \\
 &= 42.00 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) - 811.8 / (0.1066 \cdot \pi \cdot 197.6^2 \cdot 8.113) \\
 &= 47.25 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M_1 / (K_1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) + 811.8 / (0.1923 \cdot \pi \cdot 197.6^2 \cdot 8.113) \\
 &= 35.36 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{(L + (4 \cdot h^2 / 3))} \\
 &= \frac{10(2908.0 - 2 \cdot 500.0)}{(2908.0 + (4 \cdot 0.0 / 3))} \\
 &= 6.7 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{K_2 \cdot T}{(R_m \cdot t)} \\
 &= \frac{1.1707 \cdot 6.72}{(197.5563 \cdot 8.1125)} \\
 &= 4.91 \text{ N./mm}^2
 \end{aligned}$$

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

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

$$= 0.78 * \text{sqrt}( 197.556 * 8.113 )$$

$$= 31.226 \text{ mm.}$$

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

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

$$= - 0.7603 * 10 * 0.1 / ( 8.113 * ( 140.0 + 31.23 + 31.23 ) )$$

$$= -0.47 \text{ N./mm}^2$$

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

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

$$= -10 / ( 4 * 8.113 * ( 140.0 + 31.226 + 31.226 ) ) -$$

$$3 * 0.0529 * 10 / ( 2 * 8.113^2 )$$

$$= -13.89 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min( 140.0 + 1.56 * \text{sqrt}( 197.556 * 8.113 ), 2 * 500.0 )$$

$$= 202.45 \text{ mm.}$$

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

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below  $I_o$  is  $I$  for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	$I_o$
Shell	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:

$$= AY / A$$

$$= 396.752 / 86.878$$

$$= 115.996 \text{ mm.}$$

Angle [beta]:

$$= 180 - \text{Saddle Angle} / 2$$

$$= 180 - 120.0 / 2$$

$$= 120.0$$

Saddle Splitting Coefficient [K1]:

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

$$= ( 1 + \cos(120.0) - 0.5 * \sin(120.0)^2 ) / ( \pi - 2.094 + \sin(120.0) \cos(120.0) )$$

$$= 0.2035$$

Saddle Splitting Force [Fh]:

$$= K1 * Q$$

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$$= 0.204 * 10.238$$

$$= 2.0836 \text{ kN}$$

$$\text{Tension Stress, } S_t = ( F_h / A_s ) = 0.3175 \text{ N./mm}^2$$

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

Saddle Splitting Dimension [d]:

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

$$= 500.0 - 193.5 * \sin(1.0472) / 1.0472$$

$$= 339.977 \text{ mm.}$$

$$\text{Bending Moment, } M = F_h * d = 708.6639 \text{ N-m}$$

$$\text{Bending Stress, } S_b = ( M * C_1 / I ) = 0.6264 \text{ N./mm}^2$$

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

**Minimum Thickness of Baseplate per Moss:**

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

$$= ( 3(10 + 0.3)150.0 / ( 2 * 370.0 * 137.9 ) )^{1/2}$$

$$= 6.824 \text{ mm.}$$

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

Web Length Dimension [ Web Length ]:

$$= 2 * \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 * \cos( 90 - 120.0/2 ) ( 190.5 + 11.113 + 10.0 )$$

$$= 366.524 \text{ mm.}$$

Distance between Ribs [e]:

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

$$= 366.5236 / ( 2 - 1 )$$

$$= 366.524 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * B_{\text{pwid}} / 2$$

$$= 366.5236 * 150.0 / 2$$

$$= 274.893 \text{ cm}^2$$

Axial Load [P]:

$$= A_p * B_p$$

$$= 274.9 * 0.02$$

$$= 5.071 \text{ kN}$$

Area of the Rib and Web [Ar]:

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

$$= 13.0 + 18.326$$

$$= 31.326 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P / A_r$$

$$= 5.1 / 31.3262$$

$$= 1.619 \text{ N./mm}^2$$

**Check of Outside Ribs:**

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.

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Totals ... | ... | ... | 31.3 | 106663.1 | 557. |

**Rib dimension [D]:**

= Saddle Width - Web Thickness  
 = 140.0 - 10.0  
 = 130.000 mm.

**Distance to Centroid from Datum [ytot]:**

= AY / A  
 = 106663.086/31.326  
 = 34.049 mm.

**Distance to Centroid [C1]:**

= max( ytot, Saddle Width - ytot )  
 = max( 34.049, 140.0 - 34.049 )  
 = 105.951 mm.

**Radius of Gyration [r]:**

= sqrt( Total Inertia / Total Area )  
 = sqrt( 557.3/31.326 )  
 = 42.177 mm.

**Intermediate Term [Cc]:**

= sqrt( 2 \* pi<sup>2</sup> \* Elastic Modulus / Yield Stress )  
 = sqrt( 2 \* pi<sup>2</sup> \* 0.19994E+09/206.9 )  
 = 138.135

**Slenderness ratio [KL/r]:**

= KL/r  
 = 1 \* 69.477/42.177  
 = 1.647

**Bending Moment [Rm]:**

= Fl / ( 2 \* Bplen ) \* e \* L / 2  
 = 0.1 / ( 2 \* 370.0 ) \* 366.524 \* 69.48/2  
 = 1.517 N-m

**Compressive Allowable, KL/r < Cc ( 1.6473 < 138.1347 ) per AISC E2-1 [Sca]:**

= ( 1 - (KL/r)<sup>2</sup> / (2 \* Cc<sup>2</sup>) ) Fy / ( 5/3 + 3 \* (KL/r) / (8 \* Cc) - (KL/r<sup>3</sup>) / (8 \* Cc<sup>3</sup>) )  
 = ( 1 - ( 1.65 )<sup>2</sup> / (2 \* 138.13<sup>2</sup>) ) 207 /  
 ( 5/3 + 3 \* (1.65) / (8 \* 138.13) - ( 1.65<sup>3</sup>) / (8 \* 138.13<sup>3</sup>) )  
 = 123.8 N./mm<sup>2</sup>

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

= Sc/Sca + ( Rm \* C1 / I ) / Sba  
 = 1.62/123.77 + ( 1.52 \* 105.951/5572630 ) / 137.9  
 = 0.013

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

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
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	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load Q0 (Weight)	Q0	9.4	kN

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Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.3	kN
Maximum Longitudinal Force	F1	0.1	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:  
 = Shear Force / ( 2 \* Bolt Area \* Number of Bolts )  
 = 0.3 / ( 2 \* 2.17 \* 2 )  
 = 0.3 N./mm<sup>2</sup>. Must be less than 103.4 N./mm<sup>2</sup>.

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

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

Bolt Area due to Shear Load [Bltarears]:  
 = F1 / (Stba \* Nbolts)  
 = 0.09 / (172.38 \* 2.0)  
 = 0.0026 cm<sup>2</sup>

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

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 500.0 \* 0.29 + 0.0  
 = 143.72 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 143.72 / 9.38  
 = 15.31 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, 0.0026, 0.0]  
 = 0.0026 cm<sup>2</sup>

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

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

Minimum Wear Plate Width to be considered in analysis [b1]:  
 = min( b + 1.56 \* sqrt( Rm \* t ), 2a )  
 = min( 140.0 + 1.56 \* sqrt( 197.5563 \* 8.1125 ), 2 \* 500.0 )  
 = 202.4521 mm.

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

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees

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Shell Allowable Stress used in Calculation	217.19	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation	217.19	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 9.52 kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----		
Long. Stress at Top of Midspan	37.36	217.19
Long. Stress at Bottom of Midspan	41.84	217.19
Long. Stress at Top of Saddles	46.71	217.19
Long. Stress at Bottom of Saddles	35.65	217.19
-----		
Tangential Shear in Shell	4.56	173.75
Circ. Stress at Horn of Saddle	12.92	325.79
Circ. Compressive Stress in Shell	0.44	217.19
-----		

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

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * ( 0.6/2 + 0 ) * 500.0/366.5236$$

$$= 1.2 \text{ kN}$$

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

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

$$= \max( 0.09, 0.0, 0 ) * 500.0/1980.0005$$

$$= 0.0 \text{ kN}$$

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

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

$$= 8 + \max( 0.0, 1, 0, 0 )$$

$$= 9.5 \text{ kN}$$

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

Vertical Load (including saddle weight)	9.84	kN
Transverse Shear Load Saddle Ft	0.29	kN
Longitudinal Shear Load Saddle	0.09	kN

Hydrostatic Test Pressure at center of Vessel: 32.519 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	

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

Moment per Equation 4.15.3 [M1]:

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

$$= -10 * 500.0 [ 1 - ( 1 - 500.0 / 2908.0 + ( 197.556^2 - 0.0^2 ) / ( 2 * 500.0 * 2908.0 ) ) / ( 1 + ( 4 * 0.0 ) / ( 3 * 2908.0 ) ) ]$$

$$= -754.9 \text{ N-m}$$

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Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= Q \cdot L / 4(1+2(R^2-h^2)/(L^2)) / (1+(4h^2)/(3L)) - 4a/L \\
 &= 10 \cdot 2908 / 4(1+2(198^2-0^2)/(2908^2)) / (1+(4 \cdot 0) / (3 \cdot 2908)) - 4 \cdot 500 / 2908 \\
 &= 2225.9 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) - 2225.9 / (\pi \cdot 197.6^2 \cdot 8.113) \\
 &= 37.36 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) + 2225.9 / (\pi \cdot 197.6^2 \cdot 8.113) \\
 &= 41.84 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) - 754.9 / (0.1066 \cdot \pi \cdot 197.6^2 \cdot 8.113) \\
 &= 46.71 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 32.519 \cdot 197.556 / (2 \cdot 8.113) + 754.9 / (0.1923 \cdot \pi \cdot 197.6^2 \cdot 8.113) \\
 &= 35.65 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Q(L-2a) / (L+(4 \cdot h^2/3)) \\
 &= 10(2908.0 - 2 \cdot 500.0) / (2908.0 + (4 \cdot 0.0/3)) \\
 &= 6.2 \text{ kN}
 \end{aligned}$$

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

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot 6.25 / (197.5563 \cdot 8.1125) \\
 &= 4.56 \text{ N./mm}^2
 \end{aligned}$$

Decay Length (4.15.22) [x1,x2]:

$$\begin{aligned}
 &= 0.78 \cdot \sqrt{R_m \cdot t} \\
 &= 0.78 \cdot \sqrt{197.556 \cdot 8.113} \\
 &= 31.226 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= -K5 \cdot Q \cdot k / (t \cdot (b + X1 + X2)) \\
 &= -0.7603 \cdot 10 \cdot 0.1 / (8.113 \cdot (140.0 + 31.23 + 31.23)) \\
 &= -0.44 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= -Q / (4 \cdot t \cdot (b + X1 + X2)) - 3 \cdot K7 \cdot Q / (2 \cdot t^2) \\
 &= -10 / (4 \cdot 8.113 \cdot (140.0 + 31.226 + 31.226)) - \\
 &\quad 3 \cdot 0.0529 \cdot 10 / (2 \cdot 8.113^2) \\
 &= -12.92 \text{ N./mm}^2
 \end{aligned}$$

Effective reinforcing plate width (4.15.1) [B1]:

$$\begin{aligned}
 &= \min(b + 1.56 \cdot \sqrt{R_m \cdot t}, 2a) \\
 &= \min(140.0 + 1.56 \cdot \sqrt{197.556 \cdot 8.113}, 2 \cdot 500.0) \\
 &= 202.45 \text{ mm.}
 \end{aligned}$$

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

Baseplate Length Bplen 370.0000 mm.

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Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	mm.
Friction Coefficient	mu	0.400	

Note: In the tables below  $I_o$  is  $I$  for the rectangle + Area \* Centroid Distance<sup>2</sup>

## Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	$I_o$
Shell	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

## Distance to Centroid [C1]:

$$= AY / A$$

$$= 396.752/86.878$$

$$= 115.996 \text{ mm.}$$

## Angle [beta]:

$$= 180 - \text{Saddle Angle}/2$$

$$= 180 - 120.0/2$$

$$= 120.0$$

## Saddle Splitting Coefficient [K1]:

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

$$= ( 1 + \cos(120.0) - 0.5 \sin^2(120.0) ) / ( \pi - 2.094 + \sin(120.0) \cos(120.0) )$$

$$= 0.2035$$

## Saddle Splitting Force [Fh]:

$$= K1 * Q$$

$$= 0.204 * 9.52$$

$$= 1.9376 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh/As ) = 0.2952 \text{ N./mm}^2$$

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

## Saddle Splitting Dimension [d]:

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

$$= 500.0 - 193.5 * \sin(1.0472) / 1.0472$$

$$= 339.977 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 658.9939 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M * C1 / I ) = 0.5825 \text{ N./mm}^2$$

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

## Minimum Thickness of Baseplate per Moss:

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

$$= ( 3(10 + 0.3)150.0 / ( 2 * 370.0 * 137.9 ) )^{1/2}$$

$$= 6.588 \text{ mm.}$$

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

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Web Length Dimension [ Web Length ]:

$$\begin{aligned}
 &= 2 * \cos( 90 - \text{Saddle Angle}/2 )( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} ) \\
 &= 2 * \cos( 90 - 120.0/2 )( 190.5 + 11.113 + 10.0 ) \\
 &= 366.524 \text{ mm.}
 \end{aligned}$$

Distance between Ribs [e]:

$$\begin{aligned}
 &= \text{Web Length} / ( \text{Nr ribs} - 1 ) \\
 &= 366.5236 / ( 2 - 1 ) \\
 &= 366.524 \text{ mm.}
 \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned}
 &= e * \text{Bpwid} / 2 \\
 &= 366.5236 * 150.0 / 2 \\
 &= 274.893 \text{ cm}^2
 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned}
 &= \text{Ap} * \text{Bp} \\
 &= 274.9 * 0.02 \\
 &= 4.715 \text{ kN}
 \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned}
 &= \text{Rib Area} + \text{Web Area} \\
 &= 13.0 + 18.326 \\
 &= 31.326 \text{ cm}^2
 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned}
 &= P / \text{Ar} \\
 &= 4.7 / 31.3262 \\
 &= 1.505 \text{ N./mm}^2
 \end{aligned}$$

### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

Rib dimension [D]:

$$\begin{aligned}
 &= \text{Saddle Width} - \text{Web Thickness} \\
 &= 140.0 - 10.0 \\
 &= 130.000 \text{ mm.}
 \end{aligned}$$

Distance to Centroid from Datum [ytot]:

$$\begin{aligned}
 &= \text{AY} / \text{A} \\
 &= 106663.086 / 31.326 \\
 &= 34.049 \text{ mm.}
 \end{aligned}$$

Distance to Centroid [C1]:

$$\begin{aligned}
 &= \max( \text{ytot}, \text{Saddle Width} - \text{ytot} ) \\
 &= \max( 34.049, 140.0 - 34.049 ) \\
 &= 105.951 \text{ mm.}
 \end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned}
 &= \sqrt{ \text{Total Inertia} / \text{Total Area} } \\
 &= \sqrt{ 557.3 / 31.326 } \\
 &= 42.177 \text{ mm.}
 \end{aligned}$$

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Intermediate Term [Cc]:  
 $= \sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}}$   
 $= \sqrt{2 * \pi^2 * 0.19994\text{E}+09/206.9}$   
 $= 138.135$

Slenderness ratio [KL/r]:  
 $= KL/r$   
 $= 1 * 74.274/42.177$   
 $= 1.761$

Bending Moment [Rm]:  
 $= F1 / (2 * Bplen) * e * L / 2$   
 $= 0.1 / (2 * 370.0) * 366.524 * 74.27/2$   
 $= 1.622 \text{ N-m}$

Compressive Allowable,  $KL/r < Cc$  (  $1.761 < 138.1347$  ) per AISC E2-1 [Sca]:  
 $= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r^3) / (8 * Cc^3))$   
 $= (1 - (1.76)^2 / (2 * 138.13^2)) 207 /$   
 $(5/3 + 3 * (1.76) / (8 * 138.13) - (1.76^3) / (8 * 138.13^3))$   
 $= 123.7 \text{ N./mm}^2$

**AISC Unity Check of Outside Ribs ( must be  $\leq 1$  )**  
 $= Sc/Sca + (Rm * C1 / I) / Sba$   
 $= 1.51/123.74 + (1.62 * 105.951/5572630) / 137.9$   
 $= 0.012$

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

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
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	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.1705	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.3	kN
Maximum Longitudinal Force	F1	0.1	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [ $\tau_{ub}$ ]:  
 $= \text{Shear Force} / (2 * \text{Bolt Area} * \text{Number of Bolts})$   
 $= 0.3 / (2 * 2.17 * 2)$   
 $= 0.3 \text{ N./mm}^2$ . Must be less than  $103.4 \text{ N./mm}^2$ .

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

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

Bolt Area due to Shear Load [Bltarears]:  
 $= F1 / (Stba * Nbolts)$   
 $= 0.09 / (172.38 * 2.0)$   
 $= 0.0026 \text{ cm}^2$

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

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Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 500.0 * 0.29 + 0.0 \\ &= 143.72 \text{ N-m} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / QO \\ &= 143.72/8.67 \\ &= 16.58 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction} \end{aligned}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[Bltarearl, Bltarears, Bltareart] \\ &= \max[0.0, 0.0026, 0.0] \\ &= 0.0026 \text{ cm}^2 \end{aligned}$$

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**Nozzle Calculation Summary:**

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T2	...	OK	...	OK	7.16	OK	Passed
T1	...	OK	...	OK	7.16	OK	Passed
S2	...	OK	...	OK	7.16	OK	Passed
S1	...	OK	...	OK	7.16	OK	Passed
S3	...	OK	...	OK	6.42	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	T2	210.000	90.000	150.862
20	T1	210.000	270.000	150.862
40	S2	661.175	90.000	150.862
40	S1	3195.175	90.000	150.862
40	S3	661.175	270.000	102.068
60	T4	3691.350	90.000	63.875
60	T3	3691.350	270.000	70.225

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

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

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

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**Input, Nozzle Desc: T2 From: 20**

Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		210.00	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

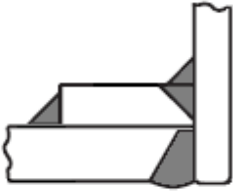
**Type of Element Connected to the Shell : Nozzle**

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. 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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	188.9000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: T2**

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

Actual Outside Diameter Used in Calculation	3.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

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

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

$$= (25.0 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.0)$$

$$= 4.1560 \text{ mm.}$$

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

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

$$= (25.0 \cdot 44.45) / (118 \cdot 1.0 + 0.4 \cdot 25.0)$$

$$= 0.9346 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.4135 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		20.2812	mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr4]:

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

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

$$= 1.000$$

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Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	0.507	NA
Area in Shell	A1	2.984	5.106	NA
Area in Nozzle Wall	A2	2.353	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	14.506	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.

The area available with the given pad is Sufficient.

Area Required [A]:

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

$$= ( 75.4309 * 4.156 * 1.0 + 2 * 6.7345 * 4.156 * 1.0 * (1 - 1.0) )$$

$$= 3.135 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 75.431( 1.0 * 8.1125 - 1.0 * 4.156 ) - 2 * 6.735$$

$$( 1.0 * 8.1125 - 1.0 * 4.156 ) * ( 1 - 1.0 )$$

$$= 2.984 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 20.28 ) * ( 6.73 - 0.93 ) * 1.0$$

$$= 2.353 \text{ cm}^2$$

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

$$= W_o^2 * fr3 + (W_i - can / 0.707)^2 * fr2 + W_p^2 * fr4$$

$$= 8.0^2 * 1.0 + (0.0)^2 * 1.0 + 0.0^2 * 1.0$$

$$= 0.640 \text{ cm}^2$$

Area Available in Element [A5]:

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

$$= ( 150.8618 - 88.9 ) * 10.0 * 1.0$$

$$= 6.196 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $ta = 3.9346 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 7.1560 \text{ mm.}$   
 Wall Thickness  $tb1 = \max(trb1, tr16b) = 7.1560 \text{ mm.}$   
 Wall Thickness  $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$   
 Wall Thickness per table UG-45  $tb3 = 7.8000 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 7.8, max( 7.156, 4.5 ) ]  
 = 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.9346, 7.156 )  
 = 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	55.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	239.7 N./mm <sup>2</sup>	Passed
Occasional	:	6.4,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	27.3,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

**Nozzle Neck to Flange Weld, Curve: B**

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.512, Temp. Reduction = 31 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds Tmin 6.7345 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.7000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

##### Weld Load [W]:

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

$$= \max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 * (1.0 * 8.1125 - 4.156) )118 )$$

$$= 8.06 \text{ kN}$$

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

##### Weld Load [W1]:

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

$$= ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118$$

$$= 108.33 \text{ kN}$$

##### Weld Load [W2]:

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

$$= ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118$$

$$= 48.16 \text{ kN}$$

##### Weld Load [W3]:

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

$$= ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118$$

$$= 121.21 \text{ kN}$$

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

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

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

$$= ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118$$

$$= 65. \text{ kN}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 188.9 * 8.0 * 0.49 * 118$$

$$= 137. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 41.0827 ) * ( 9.7345 - 3.0 ) * 0.7 * 118$$

$$= 72. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= ( \pi/2 ) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138$$

$$= 142. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 88.9 * ( 8.3344 - 3.0 ) * 0.74 * 118$$

$$= 65. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 137 + 72 ) = 209 \text{ kN}$$

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

$$= ( 65 + 142 + 65 + 0 ) = 272 \text{ kN}$$

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

$$= ( 137 + 65 + 0 ) = 202 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 208 kN , must exceed W = 8 kN or W1 = 108 kN  
 Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN  
 Path 3-3 = 202 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 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	381.000 mm.
Vessel Thickness	Tv	11.113 mm.
Design Temperature	T1	190.0 °C
Vessel Material		SA-106 B
Vessel UNS Number		K03006
Vessel Cold S.I. Allowable	Smc	117.90 N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	117.90 N./mm <sup>2</sup>

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-106 B

Attachment Type Type Round

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	188.900	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

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

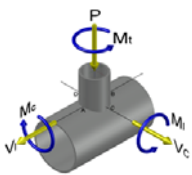
Radial Load (SUS)	P	3.2	kN
Longitudinal Shear (SUS)	Vl	3.2	kN
Circumferential Shear (SUS)	Vc	3.2	kN
Circumferential Moment (SUS)	Mc	1100.0	N-m
Longitudinal Moment (SUS)	Ml	1100.0	N-m
Torsional Moment (SUS)	Mt	1300.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - \text{ca} ) ) \\
 &= 88.9 + 2 * 1.65 * \text{sqrt}( 197.556 ( 11.113 - 3.0 ) ) \\
 &= 221.010 \text{ mm.}
 \end{aligned}$$

**WRC 107 Stress Calculation for SUSTained loads:**

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.2	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

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Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.192	4C	1.931	(A,B)
N(PHI) / ( P/Rm )	0.192	3C	1.667	(C,D)
M(PHI) / ( P )	0.192	2C1	0.083	(A,B)
M(PHI) / ( P )	0.192	1C	0.111	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.192	3A	0.339	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.192	1A	0.096	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.192	3B	1.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.192	1B	0.046	(A,B,C,D)
N(x) / ( P/Rm )	0.192	3C	1.667	(A,B)
N(x) / ( P/Rm )	0.192	4C	1.931	(C,D)
M(x) / ( P )	0.192	1C1	0.113	(A,B)
M(x) / ( P )	0.192	2C	0.081	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.192	4A	0.535	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.192	2A	0.055	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.192	4B	0.342	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML		-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML		-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
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		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear		7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.		52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.418	4C	2.460	(A,B)

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N(PHI) / ( P/Rm )	0.418	3C	1.198	(C,D)
M(PHI) / ( P )	0.418	2C1	0.014	(A,B)
M(PHI) / ( P )	0.418	1C !	0.059	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.418	3A	0.869	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.418	1A	0.068	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.418	3B	1.572	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.418	1B	0.012	(A,B,C,D)
N(x) / ( P/Rm )	0.418	3C	1.198	(A,B)
N(x) / ( P/Rm )	0.418	4C	2.460	(C,D)
M(x) / ( P )	0.418	1C1	0.030	(A,B)
M(x) / ( P )	0.418	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.418	4A	2.422	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.418	2A	0.029	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.418	4B	0.816	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.418	2B	0.020	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-4.9	-4.9	-4.9	-4.9	-2.4	-2.4	-2.4	-2.4
Circ. Bend. P		-4.0	4.0	-4.0	4.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.2	-7.2	7.2	7.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-82.6	82.6	82.6	-82.6
Circ. Memb. ML		-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Circ. Bend. ML		-14.9	14.9	14.9	-14.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-36.8	0.9	19.1	-2.8	-109.5	90.2	70.2	-60.5
-----									
Long. Memb. P		-2.4	-2.4	-2.4	-2.4	-4.9	-4.9	-4.9	-4.9
Long. Bend. P		-8.7	8.7	-8.7	8.7	-8.7	8.7	-8.7	8.7
Long. Memb. MC		0.0	0.0	0.0	0.0	-20.1	-20.1	20.1	20.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-35.5	35.5	35.5	-35.5
Long. Memb. ML		-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-42.3	24.0	20.1	-11.4	-69.2	19.2	41.9	-11.5
-----									
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		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		4.2	4.2	1.5	1.5	1.5	1.5	4.2	4.2
-----									
Str. Int.		44.6	24.7	21.2	11.6	109.5	90.3	70.8	60.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)		-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)		-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)		12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)		-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)		-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
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)		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)		14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)		38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	Passed

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

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)		-18.0	-18.0	8.1	8.1	-9.6	-9.6	4.8	4.8
Circ. Q (SUS)		-18.9	18.9	10.9	-10.9	-99.9	99.9	65.4	-65.4
Long. Pm (SUS)		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)		-9.2	-9.2	4.4	4.4	-25.0	-25.0	15.2	15.2
Long. Q (SUS)		-33.1	33.1	15.7	-15.7	-44.2	44.2	26.7	-26.7
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)		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)		40.5	43.0	66.6	69.1	48.8	51.3	63.3	65.8
Pm+Pl+Q (Total)		35.7	63.5	77.6	58.2	51.3	151.2	128.9	19.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	69.10	176.86	Passed
Pm+Pl+Q (TOTAL)	151.17	353.71	Passed

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

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**Input, Nozzle Desc: T1 From: 20**

Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		210.00	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

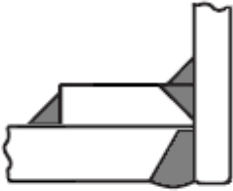
**Type of Element Connected to the Shell : Nozzle**

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. 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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: T1**

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

Actual Outside Diameter Used in Calculation	3.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

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

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

$$= (25.04 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.04)$$

$$= 4.1623 \text{ mm.}$$

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

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

$$= (25.04 \cdot 44.45) / (118 \cdot 1.0 + 0.4 \cdot 25.04)$$

$$= 0.9360 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.4135 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		20.2812	mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr4]:

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

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

$$= 1.000$$

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Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.140	0.507	NA
Area in Shell	A1	2.980	5.106	NA
Area in Nozzle Wall	A2	2.352	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	4.647	4.647	NA
TOTAL AREA AVAILABLE	Atot	10.619	12.957	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.

The area available with the given pad is Sufficient.

Area Required [A]:

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

$$= ( 75.4309 * 4.1623 * 1.0 + 2 * 6.7345 * 4.1623 * 1.0 * (1 - 1.0) )$$

$$= 3.140 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 75.431( 1.0 * 8.1125 - 1.0 * 4.162 ) - 2 * 6.735$$

$$( 1.0 * 8.1125 - 1.0 * 4.1623 ) * ( 1 - 1.0 )$$

$$= 2.980 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 20.28 ) * ( 6.73 - 0.94 ) * 1.0$$

$$= 2.352 \text{ cm}^2$$

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

$$= W_o^2 * fr3 + ( W_i - can / 0.707 )^2 * fr2 + W_p^2 * fr4$$

$$= 8.0^2 * 1.0 + ( 0.0 )^2 * 1.0 + 0.0^2 * 1.0$$

$$= 0.640 \text{ cm}^2$$

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

$$= ( \min( D_p, D_L ) - ( \text{Nozzle OD} ) ) ( \min( t_p, Tlwp, t_e ) ) * fr4 * 0.75$$

$$= ( 150.8618 - 88.9 ) 10.0 * 1.0 * 0.75$$

$$= 4.647 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $t_a = 3.9360 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 7.1623 \text{ mm.}$   
 Wall Thickness  $tb1 = \max( trb1, tr16b ) = 7.1623 \text{ mm.}$   
 Wall Thickness  $tb2 = \max( trb2, tr16b ) = 4.5000 \text{ mm.}$   
 Wall Thickness per table UG-45  $tb3 = 7.8000 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 7.8, max( 7.1623, 4.5 ) ]  
 = 7.1623 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.936, 7.1623 )  
 = 7.1623 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	55.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	239.7 N./mm <sup>2</sup>	Passed
Occasional	:	6.4,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	27.3,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

**Nozzle Neck to Flange Weld, Curve: B**

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.513, Temp. Reduction = 31 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating = 25.04/51.10 = 0.490

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 6.7345 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.7000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

##### Weld Load [W]:

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

$$= \max( 0, (3.1397 - 2.9797 + 2 * 6.7345 * 1.0 * (1.0 * 8.1125 - 4.1623) )118 )$$

$$= 8.16 \text{ kN}$$

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

##### Weld Load [W1]:

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

$$= ( 2.352 + 4.6471 + 0.64 - 0.0 * 1.0 ) * 118$$

$$= 90.06 \text{ kN}$$

##### Weld Load [W2]:

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

$$= ( 2.352 + 0.0 + 0.64 + ( 1.0927 ) ) * 118$$

$$= 48.16 \text{ kN}$$

##### Weld Load [W3]:

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

$$= ( 2.352 + 0.0 + 0.64 + 4.6471 + ( 1.0927 ) ) * 118$$

$$= 102.94 \text{ kN}$$

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

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

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

$$= ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118$$

$$= 65. \text{ kN}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 214.3 * 8.0 * 0.49 * 118$$

$$= 156. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= ( 3.1416 * 41.0827 ) * ( 9.7345 - 3.0 ) * 0.7 * 118$$

$$= 72. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= ( \pi/2 ) * Dlo * Wgpn * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 88.9 * 10.0 * 0.74 * 138$$

$$= 142. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 88.9 * ( 8.3344 - 3.0 ) * 0.74 * 118$$

$$= 65. \text{ kN}$$

**Strength of Failure Paths:**

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 156 + 72 ) = 227 \text{ kN}$$

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

$$= ( 65 + 142 + 65 + 0 ) = 272 \text{ kN}$$

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

$$= ( 156 + 65 + 0 ) = 221 \text{ kN}$$

**Summary of Failure Path Calculations:**

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 90 kN  
 Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN  
 Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 102 kN

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

The Drop for this Nozzle is : 5.2584 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 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	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	190.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	117.90	N./mm <sup>2</sup>

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-106 B

Attachment Type Type Round

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Tag no:E-PK6101-1 AB OIL COOLER

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.037	bars
Include Pressure Thrust		No	

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

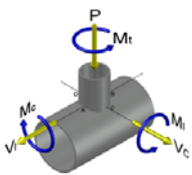
Radial Load (SUS)	P	3.2	kN
Longitudinal Shear (SUS)	Vl	3.2	kN
Circumferential Shear (SUS)	Vc	3.2	kN
Circumferential Moment (SUS)	Mc	1100.0	N-m
Longitudinal Moment (SUS)	Ml	1100.0	N-m
Torsional Moment (SUS)	Mt	1300.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 88.9 + 2 * 1.65 * \text{sqrt}( 197.556 ( 11.113 - 3.0 ) ) \\
 &= 221.010 \text{ mm.}
 \end{aligned}$$

**WRC 107 Stress Calculation for SUSTained loads:**

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.2	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

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 Nozzle Calcs.: T1 Nozl: 9 8:06am Dec 23,2021

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.192	4C	1.931	(A,B)
N(PHI) / ( P/Rm )	0.192	3C	1.667	(C,D)
M(PHI) / ( P )	0.192	2C1	0.083	(A,B)
M(PHI) / ( P )	0.192	1C	0.111	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.192	3A	0.339	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.192	1A	0.096	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.192	3B	1.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.192	1B	0.046	(A,B,C,D)
N(x) / ( P/Rm )	0.192	3C	1.667	(A,B)
N(x) / ( P/Rm )	0.192	4C	1.931	(C,D)
M(x) / ( P )	0.192	1C1	0.113	(A,B)
M(x) / ( P )	0.192	2C	0.081	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.192	4A	0.535	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.192	2A	0.055	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.192	4B	0.342	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML		-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML		-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
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		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear		7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.		52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.475	4C	2.209	(A,B)

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N(PHI) / ( P/Rm )	0.475	3C	1.004	(C,D)
M(PHI) / ( P )	0.475	2C1	0.010	(A,B)
M(PHI) / ( P )	0.475	1C !	0.059	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.475	3A	0.764	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.475	1A	0.065	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.475	3B	1.311	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.475	1B	0.010	(A,B,C,D)
N(x) / ( P/Rm )	0.475	3C	1.004	(A,B)
N(x) / ( P/Rm )	0.475	4C	2.209	(C,D)
M(x) / ( P )	0.475	1C1	0.023	(A,B)
M(x) / ( P )	0.475	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.475	4A	2.479	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.475	2A	0.028	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.475	4B	0.698	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.475	2B	0.016	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

### Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb.	ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
-----									
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend.	P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb.	ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
-----									
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	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear		3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
-----									
Str. Int.		33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

### WRC 107/537 Stress Summations:

#### Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)

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Nozzle Calcs.: T1 Noz1: 9 8:06am Dec 23,2021

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Circ. Pl (SUS)		-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)		-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)		12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)		-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)		-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
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)		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Pm+Pl (SUS)		14.8	17.3	33.3	35.8	21.6	24.1	26.9	29.3
Pm+Pl+Q (Total)		38.0	57.6	54.4	35.2	36.7	80.7	71.4	18.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.06	117.90	Passed
Pm+Pl (SUS)	35.75	176.86	Passed
Pm+Pl+Q (TOTAL)	80.71	353.71	Passed

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

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Circ. Pl (SUS)		-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)		-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)		-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)		-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
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)		2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)		58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Pm+Pl (SUS)		44.6	47.1	63.7	66.2	50.9	53.4	62.2	64.7
Pm+Pl+Q (Total)		33.6	61.4	71.4	58.5	36.3	140.3	114.7	22.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	61.00	117.90	Passed
Pm+Pl (SUS)	66.22	176.86	Passed
Pm+Pl+Q (TOTAL)	140.30	353.71	Passed

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

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**Input, Nozzle Desc: S2 From: 40**

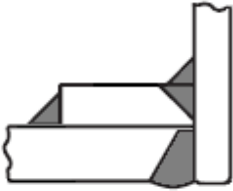
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		661.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

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

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. 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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	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	3.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (25.0 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.0)$   
 $= 4.1560 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (25.0 \cdot 44.45) / (118 \cdot 1.0 + 0.4 \cdot 25.0)$   
 $= 0.9346 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.4091 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		20.2812	mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 117.9 )$   
 $= 1.000$

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Weld Strength Reduction Factor [fr3]:

$$= \min( fr2, fr4 )$$

$$= \min( 1.0, 1.0 )$$

$$= 1.000$$

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	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.

The area available with the given pad is Sufficient.

Area Required [A]:

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

$$= ( 75.4309 * 4.156 * 1.0 + 2 * 6.7345 * 4.156 * 1.0 * (1 - 1.0) )$$

$$= 3.135 \text{ cm}^2$$

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 75.431( 1.0 * 8.1125 - 1.0 * 4.156 ) - 2 * 6.735$$

$$( 1.0 * 8.1125 - 1.0 * 4.156 ) * ( 1 - 1.0 )$$

$$= 2.984 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= ( 2 * 20.28 ) * ( 6.73 - 0.93 ) * 1.0$$

$$= 2.353 \text{ cm}^2$$

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

$$= W_o^2 * fr3 + ( W_i - can / 0.707 )^2 * fr2 + W_p^2 * fr4$$

$$= 8.0^2 * 1.0 + ( 0.0 )^2 * 1.0 + 0.0^2 * 1.0$$

$$= 0.640 \text{ cm}^2$$

Area Available in Element [A5]:

$$= ( \min( D_p, D_L ) - ( \text{Nozzle OD} ) ) * ( \min( t_p, Tlwp, t_e ) ) * fr4$$

$$= ( 150.8618 - 88.9 ) * 10.0 * 1.0$$

$$= 6.196 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures  $t_a = 3.9346 \text{ mm.}$   
 Wall Thickness per UG16(b),  $tr16b = 4.5000 \text{ mm.}$   
 Wall Thickness, shell/head, internal pressure  $trb1 = 7.1560 \text{ mm.}$   
 Wall Thickness  $tb1 = \max( trb1, tr16b ) = 7.1560 \text{ mm.}$   
 Wall Thickness  $tb2 = \max( trb2, tr16b ) = 4.5000 \text{ mm.}$   
 Wall Thickness per table UG-45  $tb3 = 7.8000 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 7.8, max( 7.156, 4.5 ) ]  
 = 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.9346, 7.156 )  
 = 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	55.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	239.7 N./mm <sup>2</sup>	Passed
Occasional	:	6.4,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	27.1,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

**Nozzle Neck to Flange Weld, Curve: B**

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.512, Temp. Reduction = 31 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: S2

Intermediate Calc. for nozzle/shell Welds Tmin 6.7345 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.7000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 * \\
 &\quad (1.0 * 8.1125 - 4.156) )118) \\
 &= 8.06 \text{ kN}
 \end{aligned}$$

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

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118 \\
 &= 108.33 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118 \\
 &= 48.16 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118 \\
 &= 121.21 \text{ kN}
 \end{aligned}$$

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

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

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118 \\
 &= 65. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:  
 = (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.1416/2.0 ) \* 214.3 \* 8.0 \* 0.49 \* 118  
 = 156. kN

Shear, Nozzle Wall [Snw]:  
 = (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 41.0827 ) \* ( 9.7345 - 3.0 ) \* 0.7 \* 118  
 = 72. kN

Tension, Pad Groove Weld [Tpgw]:  
 = ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.1416/2 ) \* 88.9 \* 10.0 \* 0.74 \* 138  
 = 142. kN

Tension, Shell Groove Weld [Tngw]:  
 = (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 88.9 \* ( 8.3344 - 3.0 ) \* 0.74 \* 118  
 = 65. kN

**Strength of Failure Paths:**

PATH11 = ( SPEW + SNW ) = ( 156 + 72 ) = 227 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 65 + 142 + 65 + 0 ) = 272 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 156 + 65 + 0 ) = 221 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 108 kN  
 Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN  
 Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.  
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 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	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2

Note:  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-106 B

Attachment Type Type Round

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

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

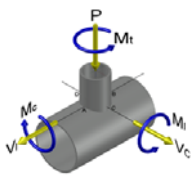
Radial Load (SUS)	P	3.2	kN
Longitudinal Shear (SUS)	Vl	3.0	kN
Circumferential Shear (SUS)	Vc	3.2	kN
Circumferential Moment (SUS)	Mc	1100.0	N-m
Longitudinal Moment (SUS)	Ml	1100.0	N-m
Torsional Moment (SUS)	Mt	1300.0	N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 88.9 + 2 * 1.65 * \text{sqrt}( 197.556 ( 11.113 - 3.0 ) ) \\
 &= 221.010 \text{ mm.}
 \end{aligned}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.0	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

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Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.192	4C	1.931	(A,B)
N(PHI) / ( P/Rm )	0.192	3C	1.667	(C,D)
M(PHI) / ( P )	0.192	2C1	0.083	(A,B)
M(PHI) / ( P )	0.192	1C	0.111	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.192	3A	0.339	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.192	1A	0.096	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.192	3B	1.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.192	1B	0.046	(A,B,C,D)
N(x) / ( P/Rm )	0.192	3C	1.667	(A,B)
N(x) / ( P/Rm )	0.192	4C	1.931	(C,D)
M(x) / ( P )	0.192	1C1	0.113	(A,B)
M(x) / ( P )	0.192	2C	0.081	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.192	4A	0.535	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.192	2A	0.055	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.192	4B	0.342	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML		-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML		-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
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	-1.2	-1.2	1.2	1.2
Shear MT		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear		7.0	7.0	4.5	4.5	4.6	4.6	7.0	7.0
Str. Int.		52.6	42.6	35.0	31.2	61.2	53.0	46.7	44.1

Dimensionless Parameters used : Gamma = 24.35

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.475	4C	2.209	(A,B)

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N(PHI) / ( P/Rm )	0.475	3C	1.004	(C,D)
M(PHI) / ( P )	0.475	2C1	0.010	(A,B)
M(PHI) / ( P )	0.475	1C !	0.059	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.475	3A	0.764	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.475	1A	0.065	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.475	3B	1.311	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.475	1B	0.010	(A,B,C,D)
N(x) / ( P/Rm )	0.475	3C	1.004	(A,B)
N(x) / ( P/Rm )	0.475	4C	2.209	(C,D)
M(x) / ( P )	0.475	1C1	0.023	(A,B)
M(x) / ( P )	0.475	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.475	4A	2.479	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.475	2A	0.028	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.475	4B	0.698	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.475	2B	0.016	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

### Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb.	ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
-----									
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend.	P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb.	ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
-----									
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	-1.1	-1.1	1.1	1.1
Shear	MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear		3.4	3.4	1.0	1.0	1.1	1.1	3.3	3.3
-----									
Str. Int.		33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

### WRC 107/537 Stress Summations:

#### Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)

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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)		-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)		-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)		12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)		-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)		-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
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	-1.2	-1.2	1.2	1.2
Shear Q (SUS)		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)		14.8	17.2	33.2	35.7	21.5	24.0	26.8	29.3
Pm+Pl+Q (Total)		38.1	57.5	54.4	35.2	36.8	80.7	71.3	18.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.68	353.71	Passed

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

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)		-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)		-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)		-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)		-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
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	-1.1	-1.1	1.1	1.1
Shear Q (SUS)		2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)		44.5	47.0	63.6	66.1	50.8	53.3	62.1	64.6
Pm+Pl+Q (Total)		33.5	61.3	71.3	58.4	36.4	140.2	114.6	22.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	66.13	176.86	Passed
Pm+Pl+Q (TOTAL)	140.21	353.71	Passed

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

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**Input, Nozzle Desc: S1 From: 40**

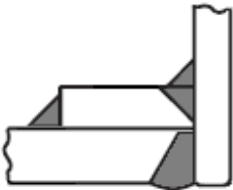
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3195.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

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

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. 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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	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	3.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (25.0 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.0)$   
 $= 4.1560$  mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (25.0 \cdot 44.45) / (118 \cdot 1.0 + 0.4 \cdot 25.0)$   
 $= 0.9346$  mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.4091 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		20.2812	mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:  
 = min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	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.  
 The area available with the given pad is Sufficient.

Area Required [A]:  
 = ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 75.4309\*4.156\*1.0+2\*6.7345\*4.156\*1.0\*(1-1.0) )  
 = 3.135 cm<sup>2</sup>

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:  
 = d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 75.431( 1.0 \* 8.1125 - 1.0 \* 4.156 ) - 2 \* 6.735  
 ( 1.0 \* 8.1125 - 1.0 \* 4.156 ) \* ( 1 - 1.0 )  
 = 2.984 cm<sup>2</sup>

Area Available in Nozzle Wall Projecting Outward [A2]:  
 = ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 20.28 ) \* ( 6.73 - 0.93 ) \* 1.0  
 = 2.353 cm<sup>2</sup>

Area Available in Welds [A41 + A42 + A43]:  
 = Wo<sup>2</sup> \* fr3 + (Wi-can/0.707)<sup>2</sup> \* fr2 + Wp<sup>2</sup> \* fr4  
 = 8.0<sup>2</sup> \* 1.0 + (0.0)<sup>2</sup> \* 1.0 + 0.0<sup>2</sup> \* 1.0  
 = 0.640 cm<sup>2</sup>

Area Available in Element [A5]:  
 = (min(Dp,DL)-(Nozzle OD))\*(min(tp,Tlwp,te)) \* fr4  
 = ( 150.8618 - 88.9 ) \* 10.0 \* 1.0  
 = 6.196 cm<sup>2</sup>

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

Wall Thickness for Internal/External pressures ta = 3.9346 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 7.1560 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 7.1560 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 7.8000 mm.

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Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1,tb2) ]  
 = min[ 7.8, max( 7.156, 4.5 ) ]  
 = 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 3.9346, 7.156 )  
 = 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	55.1,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	239.7 N./mm <sup>2</sup>	Passed
Occasional	:	6.4,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	27.3,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

**Nozzle Neck to Flange Weld, Curve: B**

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.512, Temp. Reduction = 31 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: S1

Intermediate Calc. for nozzle/shell Welds Tmin 6.7345 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.7000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 * \\
 &\quad (1.0 * 8.1125 - 4.156) )118) \\
 &= 8.06 \text{ kN}
 \end{aligned}$$

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

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118 \\
 &= 108.33 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118 \\
 &= 48.16 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118 \\
 &= 121.21 \text{ kN}
 \end{aligned}$$

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

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

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118 \\
 &= 65. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:  
 = (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.1416/2.0 ) \* 214.3 \* 8.0 \* 0.49 \* 118  
 = 156. kN

Shear, Nozzle Wall [Snw]:  
 = (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 41.0827 ) \* ( 9.7345 - 3.0 ) \* 0.7 \* 118  
 = 72. kN

Tension, Pad Groove Weld [Tpgw]:  
 = ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.1416/2 ) \* 88.9 \* 10.0 \* 0.74 \* 138  
 = 142. kN

Tension, Shell Groove Weld [Tngw]:  
 = (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 88.9 \* ( 8.3344 - 3.0 ) \* 0.74 \* 118  
 = 65. kN

**Strength of Failure Paths:**

PATH11 = ( SPEW + SNW ) = ( 156 + 72 ) = 227 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 65 + 142 + 65 + 0 ) = 272 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 156 + 65 + 0 ) = 221 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 108 kN  
 Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN  
 Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.  
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 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	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2

Note:  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B

Attachment Type Type Round

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

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

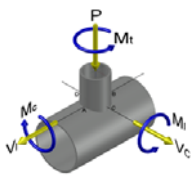
Radial Load (SUS)	P	3.2	kN
Longitudinal Shear (SUS)	Vl	3.2	kN
Circumferential Shear (SUS)	Vc	3.2	kN
Circumferential Moment (SUS)	Mc	1100.0	N-m
Longitudinal Moment (SUS)	Ml	1100.0	N-m
Torsional Moment (SUS)	Mt	1300.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - \text{ca} ) ) \\
 &= 88.9 + 2 * 1.65 * \text{sqrt}( 197.556 ( 11.113 - 3.0 ) ) \\
 &= 221.010 \text{ mm.}
 \end{aligned}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.2	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

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Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.192	4C	1.931	(A,B)
N(PHI) / ( P/Rm )	0.192	3C	1.667	(C,D)
M(PHI) / ( P )	0.192	2C1	0.083	(A,B)
M(PHI) / ( P )	0.192	1C	0.111	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.192	3A	0.339	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.192	1A	0.096	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.192	3B	1.207	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.192	1B	0.046	(A,B,C,D)
N(x) / ( P/Rm )	0.192	3C	1.667	(A,B)
N(x) / ( P/Rm )	0.192	4C	1.931	(C,D)
M(x) / ( P )	0.192	1C1	0.113	(A,B)
M(x) / ( P )	0.192	2C	0.081	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.192	4A	0.535	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.192	2A	0.055	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.192	4B	0.342	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P		-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC		0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML		-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML		-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P		-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P		-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC		0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC		0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML		-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
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		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear		7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.		52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.475	4C	2.209	(A,B)

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N(PHI) / ( P/Rm )	0.475	3C	1.004	(C,D)
M(PHI) / ( P )	0.475	2C1	0.010	(A,B)
M(PHI) / ( P )	0.475	1C !	0.059	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.475	3A	0.764	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.475	1A	0.065	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.475	3B	1.311	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.475	1B	0.010	(A,B,C,D)
N(x) / ( P/Rm )	0.475	3C	1.004	(A,B)
N(x) / ( P/Rm )	0.475	4C	2.209	(C,D)
M(x) / ( P )	0.475	1C1	0.023	(A,B)
M(x) / ( P )	0.475	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.475	4A	2.479	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.475	2A	0.028	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.475	4B	0.698	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.475	2B	0.016	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb.	ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
-----									
Tot. Circ. Str.		-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
-----									
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend.	P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb.	ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
-----									
Tot. Long. Str.		-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
-----									
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	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
-----									
Tot. Shear		3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
-----									
Str. Int.		33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)		-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)		-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)		12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)		-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)		-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
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)		5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)		14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)		38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	Passed

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

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)		-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)		-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)		-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)		-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
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)		2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)		44.5	47.0	63.6	66.1	50.8	53.3	62.1	64.6
Pm+Pl+Q (Total)		33.5	61.3	71.3	58.4	36.3	140.2	114.6	22.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	66.13	176.86	Passed
Pm+Pl+Q (TOTAL)	140.21	353.71	Passed

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

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**Input, Nozzle Desc: S3 From: 40**

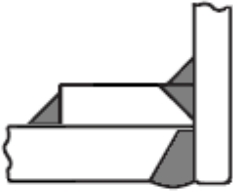
Pressure for Reinforcement Calculations	P	25.033	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		661.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

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

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

**Reinforcement CALCULATION, Description: S3**

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

Actual Outside Diameter Used in Calculation	2.375 in.
Actual Thickness Used in Calculation	0.301 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (25.03 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.03)$   
 $= 4.1615 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (25.03 \cdot 30.1625) / (118 \cdot 1.0 + 0.4 \cdot 25.03)$   
 $= 0.6350 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.3261 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	102.0684	mm.
Parallel to Vessel Wall, opening length	d	51.0342	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		20.2812	mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 117.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 117.9 )$   
 $= 1.000$

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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	2.124	0.785	NA
Area in Shell	A1	2.016	2.570	NA
Area in Nozzle Wall	A2	1.627	1.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	8.457	9.136	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.  
 The area available with the given pad is Sufficient.

Area Required [A]:  
 = ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 51.0342\*4.1615\*1.0+2\*4.6454\*4.1615\*1.0\*(1-1.0) )  
 = 2.124 cm^2

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:  
 = d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 51.034( 1.0 \* 8.1125 - 1.0 \* 4.162 ) - 2 \* 4.645  
 ( 1.0 \* 8.1125 - 1.0 \* 4.1615 ) \* ( 1 - 1.0 )  
 = 2.016 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:  
 = ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 20.28 ) \* ( 4.65 - 0.64 ) \* 1.0  
 = 1.627 cm^2

Area Available in Welds [A41 + A42 + A43]:  
 = Wo^2 \* fr3 + (Wi-can/0.707)^2 \* fr2 + Wp^2 \* fr4  
 = 8.0^2 \* 1.0 + (0.0)^2 \* 1.0 + 0.0^2 \* 1.0  
 = 0.640 cm^2

Area Available in Element [A5]:  
 = (min(Dp,DL)-(Nozzle OD))\*(min(tp,Tlwp,te)) \* fr4  
 = ( 102.0684 - 60.325 ) \* 10.0 \* 1.0  
 = 4.174 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.6350 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 7.1615 mm.  
 Wall Thickness tb1 = max(trb1, tr16b) = 7.1615 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 6.4200 mm.

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Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 6.42, \max( 7.1615, 4.5 ) ]$   
 $= 6.4200 \text{ mm.}$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( ta, tb )$   
 $= \max( 3.635, 6.42 )$   
 $= 6.4200 \text{ mm.}$

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.6,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	232.2 N./mm <sup>2</sup>	Passed
Occasional	:	6.3,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

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

**Nozzle Neck to Flange Weld, Curve: B**

Govrn. thk,  $t_g = 7.645$ ,  $t_r = 0.635$ ,  $c = 3.0 \text{ mm.}$ ,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.137$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk,  $t_g = 7.645$ ,  $t_r = 0.635$ ,  $c = 3.0 \text{ mm.}$ ,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.137$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk,  $t_g = 7.645$ ,  $t_r = 0.635$ ,  $c = 3.0 \text{ mm.}$ ,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.137$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

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

Govrn. thk,  $t_g = 10.0$ ,  $c = 3.0 \text{ mm.}$ ,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.513$ , Temp. Reduction = 31 °C  
 Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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

Govrn. thk,  $t_g = 7.645$ ,  $t_r = 0.635$ ,  $c = 3.0 \text{ mm.}$ ,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * (E^*) / (t_g - c) = 0.137$ , Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C  
 Governing MDMT of the Nozzle : -104 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

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

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating = 25.03/51.10 = 0.490

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: S3

Intermediate Calc. for nozzle/shell Welds Tmin 4.6454 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 9.7000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	3.2518 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (2.1238 - 2.0164 + 2 * 4.6454 * 1.0 * \\
 &\quad (1.0 * 8.1125 - 4.1615) )118) \\
 &= 5.59 \text{ kN}
 \end{aligned}$$

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

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 1.6267 + 4.1743 + 0.64 - 0.0 * 1.0 ) * 118 \\
 &= 75.94 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 1.6267 + 0.0 + 0.64 + ( 0.7537 ) ) * 118 \\
 &= 35.61 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 1.6267 + 0.0 + 0.64 + 4.1743 + ( 0.7537 ) ) * 118 \\
 &= 84.82 \text{ kN}
 \end{aligned}$$

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

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

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 60.325 * 8.0 * 0.49 * 118 \\
 &= 44. \text{ kN}
 \end{aligned}$$

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Shear, Pad Element Weld [Spew]:  
 = (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.1416/2.0 ) \* 160.325 \* 8.0 \* 0.49 \* 118  
 = 116. kN

Shear, Nozzle Wall [Snw]:  
 = (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 27.8398 ) \* ( 7.6454 - 3.0 ) \* 0.7 \* 118  
 = 34. kN

Tension, Pad Groove Weld [Tpgw]:  
 = ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.1416/2 ) \* 60.325 \* 10.0 \* 0.74 \* 138  
 = 97. kN

Tension, Shell Groove Weld [Tngw]:  
 = (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 60.325 \* ( 8.3344 - 3.0 ) \* 0.74 \* 118  
 = 44. kN

**Strength of Failure Paths:**

PATH11 = ( SPEW + SNW ) = ( 116 + 34 ) = 150 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 44 + 97 + 44 + 0 ) = 185 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 116 + 44 + 0 ) = 160 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 149 kN , must exceed W = 5 kN or W1 = 75 kN  
 Path 2-2 = 184 kN , must exceed W = 5 kN or W2 = 35 kN  
 Path 3-3 = 160 kN , must exceed W = 5 kN or W3 = 84 kN

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

The Drop for this Nozzle is : 2.4030 mm.  
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.5155 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	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2

Note:  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-106 B

Attachment Type Type Round

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Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.
Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	160.325	mm.
Design Internal Pressure	Dp	25.033	bars
Include Pressure Thrust		No	

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

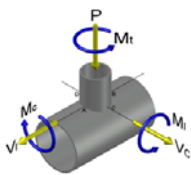
Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control No  
WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
Compute Pressure Stress per WRC-368 No  
Local Loads applied at end of Nozzle/Attachment No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



## Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 60.325 + 2 * 1.65 * \text{sqrt}( 197.556 ( 11.113 - 3.0 ) ) \\
 &= 192.435 \text{ mm.}
 \end{aligned}$$

## WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 11.18

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

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Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.130	4C	2.080	(A,B)
N(PHI) / ( P/Rm )	0.130	3C	1.966	(C,D)
M(PHI) / ( P )	0.130	2C1	0.117	(A,B)
M(PHI) / ( P )	0.130	1C	0.148	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.130	3A	0.236	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.130	1A	0.101	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.130	3B	0.907	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.130	1B	0.054	(A,B,C,D)
N(x) / ( P/Rm )	0.130	3C	1.966	(A,B)
N(x) / ( P/Rm )	0.130	4C	2.080	(C,D)
M(x) / ( P )	0.130	1C1	0.154	(A,B)
M(x) / ( P )	0.130	2C	0.118	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.130	4A	0.337	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.130	2A	0.059	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.130	4B	0.236	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.130	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		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P		-4.3	4.3	-4.3	4.3	-5.4	5.4	-5.4	5.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-28.0	28.0	28.0	-28.0
Circ. Memb. ML		-3.7	-3.7	3.7	3.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-15.0	15.0	15.0	-15.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-24.1	14.4	13.3	-8.0	-35.5	31.4	22.5	-22.7
Long. Memb. P		-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P		-5.6	5.6	-5.6	5.6	-4.3	4.3	-4.3	4.3
Long. Memb. MC		0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-16.3	16.3	16.3	-16.3
Long. Memb. ML		-1.0	-1.0	1.0	1.0	0.0	0.0	0.0	0.0
Long. Bend. ML		-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-32.1	28.0	18.7	-18.9	-23.1	18.1	12.2	-11.7
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		4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Tot. Shear		6.0	6.0	3.7	3.7	3.7	3.7	6.0	6.0
Str. Int.		35.3	30.2	20.5	20.0	36.5	32.3	25.3	25.3

Dimensionless Parameters used : Gamma = 24.35

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

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.355	4C	2.777	(A,B)

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N(PHI) / ( P/Rm )	0.355	3C	1.477	(C,D)
M(PHI) / ( P )	0.355	2C1	0.018	(A,B)
M(PHI) / ( P )	0.355	1C !	0.059	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.355	3A	0.979	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.355	1A	0.073	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.355	3B	1.919	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.355	1B	0.016	(A,B,C,D)
N(x) / ( P/Rm )	0.355	3C	1.477	(A,B)
N(x) / ( P/Rm )	0.355	4C	2.777	(C,D)
M(x) / ( P )	0.355	1C1	0.039	(A,B)
M(x) / ( P )	0.355	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.355	4A	2.259	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.355	2A	0.031	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.355	4B	0.924	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.355	2B	0.026	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.5	-3.5	-3.5	-3.5	-1.8	-1.8	-1.8	-1.8
Circ. Bend. P		-3.3	3.3	-3.3	3.3	-10.8	10.8	-10.8	10.8
Circ. Memb. MC		0.0	0.0	0.0	0.0	-3.5	-3.5	3.5	3.5
Circ. Memb. MC		0.0	0.0	0.0	0.0	-37.8	37.8	37.8	-37.8
Circ. Memb. ML		-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Circ. Bend. ML		-8.2	8.2	8.2	-8.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-21.8	1.3	8.3	-1.5	-53.9	43.2	28.6	-25.3
-----									
Long. Memb. P		-1.8	-1.8	-1.8	-1.8	-3.5	-3.5	-3.5	-3.5
Long. Bend. P		-7.1	7.1	-7.1	7.1	-5.4	5.4	-5.4	5.4
Long. Memb. MC		0.0	0.0	0.0	0.0	-8.0	-8.0	8.0	8.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-15.9	15.9	15.9	-15.9
Long. Memb. ML		-3.3	-3.3	3.3	3.3	0.0	0.0	0.0	0.0
Long. Bend. ML		-13.7	13.7	13.7	-13.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-26.0	15.7	8.0	-5.1	-32.8	9.8	15.0	-5.9
-----									
Shear VC		1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Tot. Shear		2.5	2.5	0.5	0.5	0.5	0.5	2.5	2.5
-----									
Str. Int.		27.1	16.1	8.7	5.2	53.9	43.2	29.1	25.7

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

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		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		25.5	28.1	25.5	28.1	25.5	28.1	25.5	28.1
Circ. Pl (SUS)		-4.9	-4.9	2.6	2.6	-2.0	-2.0	-0.1	-0.1
Circ. Q (SUS)		-19.3	19.3	10.7	-10.7	-33.5	33.5	22.6	-22.6
Long. Pm (SUS)		12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)		-2.0	-2.0	-0.1	-0.1	-2.5	-2.5	0.3	0.3
Long. Q (SUS)		-30.0	30.0	18.8	-18.8	-20.6	20.6	11.9	-11.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q (SUS)		4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Pm (SUS)		25.5	28.1	25.5	28.1	25.5	28.1	25.5	28.1
Pm+Pl (SUS)		20.8	23.3	28.2	30.7	23.6	26.1	25.6	28.0
Pm+Pl+Q (Total)		23.9	47.6	40.3	27.1	13.8	59.9	49.5	12.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.05	117.90	Passed
Pm+Pl (SUS)	30.74	176.86	Passed
Pm+Pl+Q (TOTAL)	59.92	353.71	Passed

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

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Circ. Pl (SUS)		-10.3	-10.3	3.4	3.4	-5.3	-5.3	1.6	1.6
Circ. Q (SUS)		-11.6	11.6	4.9	-4.9	-48.5	48.5	27.0	-27.0
Long. Pm (SUS)		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)		-5.1	-5.1	1.4	1.4	-11.5	-11.5	4.6	4.6
Long. Q (SUS)		-20.8	20.8	6.5	-6.5	-21.3	21.3	10.4	-10.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Pm (SUS)		58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Pm+Pl (SUS)		48.2	50.7	61.9	64.4	53.2	55.7	60.2	62.7
Pm+Pl+Q (Total)		36.8	62.6	66.8	59.5	8.3	104.2	87.3	36.1

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 Nozzle Calcs.: S3 Noz1: 12 8:06am Dec 23,2021

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.99	117.90	Passed
Pm+Pl (SUS)	64.38	176.86	Passed
Pm+Pl+Q (TOTAL)	104.20	353.71	Passed

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

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**Input, Nozzle Desc: T4 From: 60**

Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3691.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

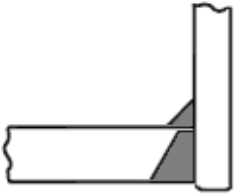
**Type of Element Connected to the Shell : Nozzle**

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	14.3000	mm.
Flange Material		SA-350 LF2	
Flange Type		Slip on	
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	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

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

**Reinforcement CALCULATION, Description: 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 0.563 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(25.0 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.0)$   
 = 4.1560 mm.

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]  
 =  $R \cdot (\exp([P / (S_n \cdot E)] - 1) - 1)$  per Appendix 1-2 (a)(1)  
 =  $12.525 \cdot (\exp([25.0 / (137.9 \cdot 1.0)] - 1))$   
 = 0.2292 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2879 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	63.8750	mm.
Parallel to Vessel Wall	Rn+tn+t	31.9375	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	20.2812	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 117.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 117.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.041	0.168	NA
Area in Shell	A1	1.536	2.628	NA

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Area in Nozzle Wall	A2	4.491	4.467	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.991	8.059	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 25.05 * 4.156 * 1.0 + 2 * 11.3 * 4.156 * 1.0 * (1 - 1.0) ) \\
 &= 1.041 \text{ cm}^2
 \end{aligned}$$

#### Reinforcement Areas per Figure UG-37.1

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

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 38.825( 1.0 * 8.1125 - 1.0 * 4.156 ) - 2 * 11.3 \\
 &\quad ( 1.0 * 8.1125 - 1.0 * 4.156 ) * ( 1 - 1.0 ) \\
 &= 1.536 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 20.28 )( 11.3 - 0.23 ) 1.0 \\
 &= 4.491 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= ( Wo^2 - \text{Area Lost} ) * fr2 + ( (Wi - can / 0.707)^2 - \text{Area Lost} ) * fr2 \\
 &= ( 10.0^2 - 0.0356 ) * 1.0 + ( 0.0^2 - 0.0 ) * 1.0 \\
 &= 0.964 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.2879 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.1560 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.1560 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]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.22, \max( 7.156, 4.5 ) ] \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.2879, 6.22 ) \\
 &= 6.2200 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

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

Nozzle Neck to Flange Weld (Impact tested) :

#### Note:

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

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Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 11.113, tr = 4.156, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.512$ , Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C  
 Min Metal Temp. w/o impact per UG-20(f) -29 °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) -79 °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 = 25.00/51.10 = 0.489

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

Weld Size Calculations, Description: T4

Intermediate Calc. for nozzle/shell Welds Tmin 9.7000 mm.

**Results Per UW-16.1:**

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

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

Weld Load [W]:  
 $= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$   
 $= \max( 0, (1.0411 - 1.5361 + 2 * 11.3 * 1.0 * (1.0 * 8.1125 - 4.156) ) 118 )$   
 $= 4.71 \text{ kN}$

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

Weld Load [W1]:  
 $= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv$   
 $= ( 4.4906 + 0.0 + 0.9644 - 0.0 * 1.0 ) * 118$   
 $= 64.31 \text{ kN}$

Weld Load [W2]:  
 $= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$   
 $= ( 4.4906 + 0.0 + 0.9644 + ( 1.8334 ) ) * 118$   
 $= 85.93 \text{ kN}$

Weld Load [W3]:  
 $= (A2+A3+A4+A5+(2*tn*t*fr1))*S$   
 $= ( 4.4906 + 0.0 + 0.9644 + 0.0 + ( 1.8334 ) ) * 118$   
 $= 85.93 \text{ kN}$

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### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= ( 3.1416/2.0 ) * 47.65 * 10.0 * 0.49 * 118$$

$$= 43. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( D_{lr} + D_{lo} ) / 4 ) * ( Thk - Can ) * 0.7 * S_n$$

$$= ( 3.1416 * 18.175 ) * ( 14.3 - 3.0 ) * 0.7 * 138$$

$$= 62. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= ( 3.1416/2.0 ) * 47.65 * ( 10.0 - 3.0 ) * 0.74 * 138$$

$$= 53. \text{ kN}$$

### Strength of Failure Paths:

$$PATH11 = ( SONW + SNW ) = ( 43 + 62 ) = 106 \text{ kN}$$

$$PATH22 = ( Sonw + Tpgw + Tngw + Sinw )$$

$$= ( 43 + 0 + 53 + 0 ) = 97 \text{ kN}$$

$$PATH33 = ( Sonw + Tngw + Sinw )$$

$$= ( 43 + 53 + 0 ) = 97 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 105 kN , must exceed W = 4 kN or W1 = 64 kN

Path 2-2 = 96 kN , must exceed W = 4 kN or W2 = 85 kN

Path 3-3 = 96 kN , must exceed W = 4 kN or W3 = 85 kN

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

The Drop for this Nozzle is : 1.4957 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 212.6082 mm.

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**Input, Nozzle Desc: T3 From: 60**

Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	117.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3691.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

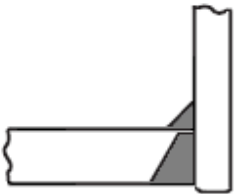
**Type of Element Connected to the Shell : Nozzle**

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		SA-350 LF2	
Flange Type		Slip on	
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	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

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

**Reinforcement CALCULATION, Description: 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]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(25.04 \cdot 193.5) / (118 \cdot 1.0 - 0.6 \cdot 25.04)$   
 = 4.1623 mm.

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]  
 =  $R \cdot (\exp([P / (S_n \cdot E)] - 1) - 1)$  per Appendix 1-2 (a)(1)  
 =  $15.7 \cdot (\exp([25.04 / (137.9 \cdot 1.0)] - 1) - 1)$   
 = 0.2877 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) D1 70.2250 mm.  
 Parallel to Vessel Wall Rn+tn+t 35.1125 mm.  
 Normal to Vessel Wall (Thickness Limit), no pad Tlnp 20.2812 mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 117.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 117.9)$   
 = 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	1.307	0.211	NA
Area in Shell	A1	1.534	2.628	NA

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Area in Nozzle Wall	A2	4.467	4.458	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.965	8.051	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]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{UG-37(c)} \\
 &= ( 31.4 * 4.1623 * 1.0 + 2 * 11.3 * 4.1623 * 1.0 * (1 - 1.0) ) \\
 &= 1.307 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 38.825( 1.0 * 8.1125 - 1.0 * 4.162 ) - 2 * 11.3 \\
 &\quad ( 1.0 * 8.1125 - 1.0 * 4.1623 ) * ( 1 - 1.0 ) \\
 &= 1.534 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 20.28 )( 11.3 - 0.29 ) 1.0 \\
 &= 4.467 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= ( Wo^2 - \text{Area Lost} ) * fr2 + ( (Wi - can / 0.707)^2 - \text{Area Lost} ) * fr2 \\
 &= ( 10.0^2 - 0.0356 ) * 1.0 + ( 0.0^2 - 0.0 ) * 1.0 \\
 &= 0.964 \text{ cm}^2
 \end{aligned}$$

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 = 7.1623 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.1623 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]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 7.1623, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

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 Neck to Flange Weld (Impact tested) :

Note:

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

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Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.513$ , Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C  
 Min Metal Temp. w/o impact per UG-20(f) -29 °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) -79 °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 = 25.04/51.10 = 0.490

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

#### Weld Size Calculations, Description: T3

Intermediate Calc. for nozzle/shell Welds Tmin 9.7000 mm.

#### Results Per UW-16.1:

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

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

Weld Load [W]:  
 $= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$   
 $= \max( 0, (1.307 - 1.5337 + 2 * 11.3 * 1.0 * (1.0 * 8.1125 - 4.1623) ) 118 )$   
 $= 7.85 \text{ kN}$

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

Weld Load [W1]:  
 $= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv$   
 $= ( 4.4669 + 0.0 + 0.9644 - 0.0 * 1.0 ) * 118$   
 $= 64.03 \text{ kN}$

Weld Load [W2]:  
 $= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$   
 $= ( 4.4669 + 0.0 + 0.9644 + ( 1.8334 ) ) * 118$   
 $= 85.65 \text{ kN}$

Weld Load [W3]:  
 $= (A2+A3+A4+A5+(2*tn*t*fr1))*S$   
 $= ( 4.4669 + 0.0 + 0.9644 + 0.0 + ( 1.8334 ) ) * 118$   
 $= 85.65 \text{ kN}$

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### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= ( 3.1416/2.0 ) * 54.0 * 10.0 * 0.49 * 118 \\
 &= 49. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( D_{lr} + D_{lo} ) / 4 ) * ( Thk - Can ) * 0.7 * S_n \\
 &= ( 3.1416 * 21.35 ) * ( 14.3 - 3.0 ) * 0.7 * 138 \\
 &= 73. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * (W_{gnvi} - Cas) * 0.74 * S_{ng} \\
 &= ( 3.1416/2.0 ) * 54.0 * ( 10.0 - 3.0 ) * 0.74 * 138 \\
 &= 61. \text{ kN}
 \end{aligned}$$

### Strength of Failure Paths:

$$\begin{aligned}
 \text{PATH11} &= ( \text{SONW} + \text{SNW} ) = ( 49 + 73 ) = 122 \text{ kN} \\
 \text{PATH22} &= ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 49 + 0 + 61 + 0 ) = 110 \text{ kN} \\
 \text{PATH33} &= ( \text{Sonw} + \text{Tngw} + \text{Sinw} ) \\
 &= ( 49 + 61 + 0 ) = 110 \text{ kN}
 \end{aligned}$$

### Summary of Failure Path Calculations:

Path 1-1 = 122 kN , must exceed W = 7 kN or W1 = 64 kN  
 Path 2-2 = 109 kN , must exceed W = 7 kN or W2 = 85 kN  
 Path 3-3 = 109 kN , must exceed W = 7 kN or W3 = 85 kN

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

The Drop for this Nozzle is : 1.9231 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0356 mm.

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**Nozzle Schedule:**

Flg	Nominal or Actual	Schd or FVC	Flg Type	Nozzle O/Dia	Wall Thk	Reinforcing Pad Diameter	Cut Thk	Length
Class   Description	Size	Type		in	mm.	mm.	mm.	mm.
T4	0.750 in	Actual	SlipOn	1.876	14.300	...	...	212.61   300
T3	1.000 in	Actual	SlipOn	2.126	14.300	...	...	213.04   300
S3	2.000 in	160	WNF	2.375	8.738	160.32	10.00	213.52
T2	3.000 in	160	WNF	3.500	11.125	188.90	10.00	216.37
T1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37
S2	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37
S1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37

*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	10.000	10.000	...	...	...
T3	SA-350 LF2	10.000	10.000	...	...	...
S3	SA-106 B	8.334	8.000	8.000	10.000	...
T2	SA-106 B	8.334	8.000	8.000	10.000	...
T1	SA-106 B	8.334	8.000	8.000	10.000	...
S2	SA-106 B	8.334	8.000	8.000	10.000	...
S1	SA-106 B	8.334	8.000	8.000	10.000	...

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	3641.350	90.0	200.00	0.00	CHANNEL 002

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T3	3641.350	270.0	200.00	0.00	CHANNEL 002
S3	611.175	270.0	200.00	0.00	SHELL
T2	160.000	90.0	200.00	0.00	CHANNEL 01
T1	160.000	270.0	200.00	0.00	CHANNEL 01
S2	611.175	90.0	200.00	0.00	SHELL
S1	3145.175	90.0	200.00	0.00	SHELL

**Weld Sizes for Slip On/Socket Weld Nozzle Flanges per UW-21:**

Nozzle to Flange Fillet Weld Leg dimension [xmin]:  
 = min( 1.4 \* tn, Hub Thickness )

*The Nozzle Wall thicknesses shown below are in the corroded condition. Hubs are considered to be straight.*

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Noz. O/Dia in	Wall Thk mm.	Hub Thk mm.	Throat Thk mm.	xmin Thk mm.
T4	0.750 in	Actua	SlipOn	1.876	11.300	10.033	7.023	10.033
T3	1.000 in	Actua	SlipOn	2.126	11.300	9.652	6.756	9.652

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**Input Echo, Tubesheet Number 1, Description: TUBE SHEET**

**Shell Data:**

**Main Shell Description: SHELL**

Shell Maximum Design Pressure	Psd,max	25.00	bars
Shell Maximum Operating Pressure	Psox,max	25.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.7000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	381.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°C
Shell Material		SA-106 B	

**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-106 B

Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Ss	117.90	N./mm <sup>2</sup>
Shell Allowable Stress at Ambient		117.90	N./mm <sup>2</sup>

**Channel Description: CHANNEL 01**

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	25.00	bars
Channel Maximum Operating Pressure	Ptox,max	25.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	12.7000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	381.000	mm.
Channel Design Temperature	TEMPC	190.00	°C
Channel Material		SA-106 B	

**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-106 B

Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Sc	117.90	N./mm <sup>2</sup>
Channel Allowable Stress at Ambient		117.90	N./mm <sup>2</sup>

**Tube Data:**

Number of Tube Holes	Nt	166	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	3000.00	mm.
Straight Tube Length (bet. inner tubsht faces) L		2908.00	mm.
Design Temperature of the Tubes		190.00	°C
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is this a Welded Tube		No	
Tube Material Specification used	Smls. tube		
Tube Allowable Stress at Temperature		92.39	N./mm <sup>2</sup>
Tube Allowable Stress At Ambient		92.39	N./mm <sup>2</sup>
Tube Yield Stress At design Temperature	Syt	154.50	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		b-1	
Radius to Outermost Tube Hole Center	ro	173.770	mm.
Largest Center-to-Center Tube Distance	Ul	34.9000	mm.
Length of Expanded Portion of Tube	ltx	35.0000	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-266 2	

#### 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-266 2

Tubesheet Material UNS Number		K03506	
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	46.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	515.000	mm.

#### Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	444.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	378.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	0.00	mm.
Step 1 Depth on the Shellside	hs1	0.00	mm.
Step 2 Diameter on the Shellside	ds2	378.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		378.00	mm.

Note: Tubesheet diameter is now: 378.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	128.0	cm <sup>2</sup>
---------------------------	----	-------	-----------------

#### Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	571.000	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	

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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	56.96	°C
Mean Tube Metal Temp. along Tube length	Ttm	49.96	°C
Junction Stress Reduction option		Perform Plastic Calculation	

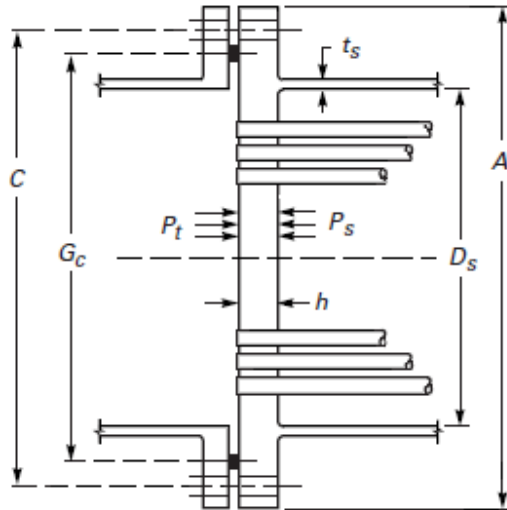
#### Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	515.000	mm.
Flange Inside Diameter	B	381.000	mm.
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	mm.
Small end Hub thk.	g0	10.0000	mm.
Large end Hub thk.	g1	17.0000	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	6.0000	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	473.000	mm.
Nominal Bolt Diameter	dB	19.0500	mm.
Type of Thread Series		UNC Thread Series	
Number of Bolts	n	28	

**Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange**



**Configuration b:**

193 B7	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	30.0000 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**

**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	57.0 °C	0.0000118233 /°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	57.0 °C	0.20065E+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

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## Tubes - TM-1 Carbon Steels with C&lt;= 0.3%

Th. Exp. Coeff.	Metal Temp. along Len	50.0 °C	0.0000117780 /°C
Elastic Mod. at Design Temperature	190.0 °C		0.19308E+09 KPa.
Elastic Mod. at Metal Temp. along Len	50.0 °C		0.20105E+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 &amp; Low Alloy Steels, Group 1

## TubeSheet - TM-1 Carbon Steels with C&lt;= 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:

$$= (P*(D/2-CAE)) / (S*E+0.4*P) \text{ per Appendix 1-1 (a)(1)}$$

$$= (26.03*(19.05/2-0.0))/(92.39*1.0+0.4*26.03)$$

$$= 0.2654 + 0.0000 = 0.2654 \text{ mm.}$$

## Tube Required Thickness under External Pressure (Shellside pressure) :

External Pressure Chart	CS-1	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	2908.00	9.04	50.0000	0.0134693	93.80
EMAWP = (2.167/(D/T)-0.0833)*B = 146.7815 bars						

## Results for Req'd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.5486	19.05	2908.00	34.73	50.0000	0.0009121	67.81
EMAWP = (4*B)/(3*(D/T)) = ( 4 *67.811 )/( 3 *34.7278 ) = 26.0338 bars						

## Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.5486 mm.
Allowable Internal Pressure at Corroded thickness	224.32 bars
Required Internal Design Pressure	26.03 bars
Allowable External Pressure at Corroded thickness	146.78 bars
Required External Design Pressure	26.03 bars
Required Thickness due to Shell Side pressure	0.5486 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.

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Effective Gasket Width,  $b = \text{SQRT}(b_0) * 2.5$  7.966 mm.  
 Gasket Reaction Diameter,  $G = G_0 - 2.0 * b$  428.068 mm.

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

Distance Across Corners for Nuts 35.128 mm.  
 Circular Wrench End Diameter a 52.388 mm.

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	50.206	54.555	
Radial Distance between Hub and Bolts:	20.637	33.300	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	52.959	68.100

Flange Design Bolt Load, Seating Condition W : 902.83 kN  
 Flange Design Bolt Load, Operating Condition Wm1: 622.88 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]:  
 $= l_{tx} / h$  ( modified for corrosion if present )  
 $= 35.0 / 46.0 = 0.7609$  ( must be  $0 \leq \rho \leq 1$  )

Compute the Effective Tube Hole Diameter [d\*]:  
 $= \text{Max}( dt - 2tt * ( Et/E ) ( StT/S ) ( \rho ), dt - 2tt )$   
 $= \text{Max}( 19.05 - 2 * 2.108 * ( .19308E+09 / .19308E+09 ) * ( 92/137 ) * ( 0.761 ), 19.05 - 2 * 2.108 )$   
 $= 16.9008$  mm.

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:  
 $= 2 * r_o + dt = 2 * 173.77 + 19.05 = 366.59$  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]:  
 $= Do / 2 = 366.59 / 2 = 183.295$  mm.

Compute the Effective Tube Pitch [p\*]:  
 $= p / \text{sqrt}( 1 - 4 * \text{min}( AL * CNV\_factor, 4 * Do * p ) / ( \text{Pi} * Do^2 ) )$   
 $= 24.0 / \text{sqrt}( 1 - 4 * \text{min}( 128.0 * 100.0, 4 * 366.59 * 24.0 ) / ( 3.141 * 366.59^2 ) )$   
 $= 25.6026$  mm.

Compute the Effective Ligament Efficiency for Bending [mu\*]:  
 $= (p^* - d^*) / p^* = (25.6026 - 16.9008) / 25.6026 = 0.3399$

Compute the Ratio [Rhos]:  
 $= as / ao = 190.5 / 183.295 = 1.039308$

Compute the Ratio [Rhoc]:  
 $= ac / ao = 214.0342 / 183.295 = 1.167704$

Compute Parameter [xt]:  
 $= 1 - Nt * ( ( dt - 2 * tt ) / ( 2 * ao ) )^2$

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$$= 1 - 166 * ((19.05 - 2 * 2.108) / (2 * 183.295))^2 = 0.7282$$

Determine Parameter [xs]:

$$= 1 - Nt * ( dt / (2 * ao) )^2$$

$$= 1 - 166 * ( 19.05 / (2 * 183.295) )^2 = 0.5517$$

Determine the Value [h'g]:

$$= \text{Max}(( hg - \text{CATC} ), 0 ) \quad (\text{For pressure only cases})$$

$$= \text{Max}(( 5.0 - 0.0 ), 0 ) = 5.0 \text{ mm.}$$

### UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:

$$= \pi * ts * ( Ds + ts ) Es / L$$

$$= 3.1416 * 12.7 * ( 381.0 + 12.7 ) .19308E+09 / 2908.0$$

$$= 1042931072.0000 \text{ KPa.} * \text{mm.}$$

Determine the Axial Tube Stiffness [Kt]:

$$= \pi * tt * ( Dt - tt ) Et / L$$

$$= 3.1416 * 2.108 * ( 19.05 - 2.108 ) .19308E+09 / 2908.0$$

$$= 7449408.0000 \text{ KPa.} * \text{mm.}$$

Compute the Stiffness Factor [Ks,t]:

$$= Ks / ( Nt * Kt ) = 0.10429E+1 / ( 166 * 7449408 ) = 0.84338$$

Rigidity Ratio [J]:

$$= 1 / ( 1 + Ks / Kj )$$

$$= 1 / ( 1 + 0.10429E+1 / 0.0 ) = 1. \quad (= 1 \text{ if No Exp. Jt.})$$

Compute Shell Coefficient [betas]:

$$= (( 12 * (1 - \nu s^2) )^{0.25}) / (( Ds + ts ) * ts )^{0.5}$$

$$= (( 12 * (1 - 0.3^2) )^{0.25}) / (( 381.0 + 12.7 ) * 12.7 )^{0.5}$$

$$= 0.0257 \text{ 1/mm.}$$

Determine Shell Coefficient [ks]:

$$= \text{betas} * Es * ts^3 / ( 6 * (1 - \nu s^2) )$$

$$= 0.026 * 0.19308E+09 * 12.7^3 / ( 6 * (1 - 0.3^2) )$$

$$= 18621754.0000 \text{ bars*mm.}^2$$

Determine Shell Coefficient [Lambdas]:

$$= (6 * Ds * ks) / (h^3) * (1 + h * \text{betas} + 0.5 * (h * \text{betas})^2)$$

$$= 6 * 381.0 * 18621754 / (46.0^3) * (1 + 46.0 * 0.026 + 0.699)$$

$$= 1260346.6250 \text{ bars}$$

Determine Shell Coefficient [deltaS]:

$$= Ds^2 / (4 * Es * Ts) * (1 - \nu s / 2)$$

$$= 381.0^2 / (4 * 0.19308E+09 * 12.7) * (1 - 0.3 / 2)$$

$$= 0.0125790816 \text{ mm./N./mm}^2$$

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.

$$h/p = 1.916667 ; \quad \mu^* = 0.339881$$

$$E^*/E = 0.336955 ; \quad \nu^* = 0.328482 ; \quad E^* = 65058264. \text{ KPa.}$$

Compute the Tube Bundle Stiffness Factor [Xa]:

$$= ((24 * (1 - \nu^* 2) * Nt * Et * tt * (dt - tt) * ao^2) / ( E^* * L * H^3 ))^{0.25}$$

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$$= ((24 * (1 - 0.328^2) * 166 * .19308E+09 * 2.108 * (19.05 - 2.108) * 183.295^2) / (65058264 * 2908.0 * 46.0^3))^{0.25}$$

$$= 2.5859$$

Values from Table UHX-13.1

$$Z_d = 0.083130 ; Z_v = 0.131082 ; Z_m = 0.580632$$

$$Z_a = 0.137874E+01 ; Z_w = 0.131082$$

#### UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:

$$= A/D_o = 378.0/366.59 = 1.0311$$

Compute Coefficient [F]:

$$= (1 - \nu^*) / (E^*) * (\text{Lambdas} + \text{Lambdac} + E * \ln(K))$$

$$= (1 - 0.33) / (65058264) * (1260346 + 0.0 + 0.19308E+09 * \ln(1.03))$$

$$= 1.3620$$

Compute Parameter [Phi]:

$$= (1 + \nu^*) * F = (1 + 0.3285) * 1.362 = 1.8094$$

Compute Parameter [Q1]:

$$= (\text{Rhos} - 1 - \text{Phi} * Z_v) / (1 + \text{Phi} * Z_m)$$

$$= (1.0393 - 1 - 1.8094 * 0.1311) / (1 + 1.8094 * 0.5806)$$

$$= -0.096494138$$

Compute Parameter [Qz1]:

$$= (Z_d + Q1 * Z_w) / 2 * X_a^4$$

$$= (0.08313 + -0.09649 * 0.13108) / 2 * 2.58587^4 = 1.5757$$

Compute Parameter [Qz2]:

$$= (Z_v + Q1 * Z_m) / 2 * X_a^4$$

$$= (0.13108 + -0.09649 * 0.58063) / 2 * 2.58587^4 = 1.6779$$

Compute Parameter [U]:

$$= (Z_w + (\text{Rhos} - 1) * Z_m) * X_a^4 / (1 + \text{Phi} * Z_m)$$

$$= (0.1311 + (1.0393 - 1) * 0.5806) * 2.58587^4 / (1 + 1.8094 * 0.5806)$$

$$= 3.3559$$

#### UHX-13.5.5 Step 5:

Determine factor [gamab]:

$$= (G_c - C) / D_o \text{ (config b)}$$

$$= (428.0685 - 473.0) / 366.59 = -0.12257$$

Compute Parameter [gamma]:

$$= 0.000 \text{ mm. (For Pressure only cases)}$$

Calculate Parameter [OmegaS]:

$$= \text{rhos} * k_s * \text{Betas} * \text{deltaS} (1 + h * \text{Betas})$$

$$= 1.0393 * 18621754 * 0.0257 * 0.012579 (1 + 46.0 * 0.0257)$$

$$= 1366.0907 \text{ mm.}^2$$

Calculate Parameter [Omega\*S]:

$$= A_o^2 * (\text{Rhos}^2 - 1) * (\text{Rhos} - 1) / 4 - \text{OmegaS}$$

$$= 183.295^2 * (1.039^2 - 1) * (1.039 - 1) / 4 - 1366.091$$

$$= -1339.6246 \text{ mm.}^2$$

Calculate Parameter [OmegaC]:

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$$= \text{rhoc} * \text{kc} * \text{Betac} * \text{deltaC} ( 1 + \text{h} * \text{Betac} )$$

$$= 1.1677 * 0.0 * 0.0 * 0. ( 1 + 46.0 * 0.0 )$$

$$= 0.0000 \text{ mm.}^2$$

Calculate Parameter [ $\Omega$ \*C]:

$$= \text{ao}^2 [ ( \text{Rhoc}^2 + 1 ) * ( \text{Rhoc} - 1 ) / 4 - ( \text{Rhos} - 1 ) / 2 ] - \Omega \text{C}$$

$$= 183.295^2 [ ( 1.1677^2 + 1 ) * ( 1.1677 - 1 ) / 4 - ( 1.03931 - 1 ) / 2 ] - 0.$$

$$= 2668.9180 \text{ mm.}^2$$

Compute the Pressure [P\*S]:

= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P\*C]:

= 0 For Pressure only cases or Configurations b,c,d,B,C,D

#### UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

$$= \text{Ps} * \{ \text{xs} + 2( 1 - \text{xs} ) \text{nut} + [ 2 / \text{Kst} ( \text{Ds} / \text{Do} )^2 ] \text{nus} -$$

$$[ ( \text{rhos}^2 - 1 ) / ( \text{J} * \text{Kst} ) ] - [ ( 1 - \text{J} ) / ( 2 \text{J} * \text{Kst} ) ] [ ( \text{Dj}^2 - ( \text{Ds} )^2 ) / \text{Do}^2 ] \}$$

$$= 25.0 * \{ 0.552 + 2( 1 - 0.552 ) 0.3 +$$

$$[ 2 / 0.843 ( 381.0 / 366.59 )^2 ] 0.3 -$$

$$[ ( 1.039^2 - 1 ) / ( 1.0 * 0.843 ) ] -$$

$$[ ( 1 - 1.0 ) / ( 2 * 1.0 * 0.843 ) ] [ ( 0.0^2 - ( 381.0 )^2 ) / 366.59^2 ] \}$$

$$= 37.3523 \text{ bars}$$

Compute the Pressure [P't]:

$$= [ \text{xt} + 2( 1 - \text{xt} ) \text{nut} + 1 / ( \text{J} * \text{Kst} ) ] * \text{Pt}$$

$$= [ 0.728 + 2( 1 - 0.728 ) 0.3 +$$

$$1 / ( 1. * 0.843 ) ] * 25.0$$

$$= 51.9244 \text{ bars}$$

Compute the Pressure [Pgama]:

$$= \text{Nt} * \text{Kt} * \text{gama} / ( \text{pi} * \text{ao}^2 )$$

$$= 166 * 7449408 * 0.0 / ( 3.142 * 183.295^2 ) = 0.0 \text{ bars}$$

Compute the Pressure [Pw]:

$$= -\text{gamab} * \text{U} * \text{W} * / ( 2 * \text{pi} * \text{ao}^2 )$$

$$= -0.123 * 3.356 * 622.88 / ( 2 * 3.142 * 183.295^2 )$$

$$= 12.1371 \text{ bars}$$

Calculate the Pressure [Prim]:

$$= - ( \text{U} / \text{ao}^2 ) ( \Omega \text{S} * \text{Ps} - \Omega \text{C} * \text{Pt} )$$

$$= - ( 3.356 / 183.295^2 ) ( -2.076 * 25.0 - 4.137 * 25.0 )$$

$$= 10.0100 \text{ bars}$$

Calculate the Pressure [POmega]:

$$= \text{U} / \text{ao}^2 ( \Omega \text{S} * \text{P*s} - \Omega \text{C} * \text{P*c} )$$

$$= 3.356 / 183.295^2 ( 2.1174 * 0.0 - 0.0 * 0.0 )$$

$$= 0.0000 \text{ bars}$$

Determine the Effective Pressure [Pe]:

$$= \text{J} * \text{Kst} / ( 1 + \text{J} * \text{Kst} * ( \text{Qz1} + ( \text{Rhos} - 1 ) * \text{Qz2} ) ) *$$

$$( \text{P's} - \text{P't} + \text{Pgama} + \text{Pw} + \text{Prim} )$$

$$= 0.1000\text{E}+01 * 0.843 / ( 1 + 1.0 * 0.843 * ( 1.576 + ( 1.039 -$$

$$1 ) * 1.678 ) ) * ( 37.352 - 51.924 + 0.0 + 12.137 + 10.01 )$$

$$= 2.6792 \text{ bars}$$

#### UHX-13.5.7 Step 7:

Determine Factor [Q2]:

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$$= [((\Omega * S * P_s - \Omega * C * P_t) - (\Omega * P * s - \Omega * c * P * c)) * CNV\_FAC + W * \gamma / (2 * \pi)] / (1 + \Phi * Z_m)$$

$$= [( (-1339.625 * 25.0 - 2668.918 * 25.0) - (1366.091 * 0.0 - 0.0 * 0.0) ) * 0. + 622.9 * (-0.123 / (2 * 3.141))] / (1 + 1.80937 * 0.58063)$$

$$= -10.812397003 \text{ kN}$$

Calculate Factor [Q3]:

$$= Q_1 + 2 * Q_2 / (P_e * a_o^2)$$

$$= -0.096 + 2 * -10.812 / (2.679 * 183.295^2)$$

$$= -2.498946$$

Fm Value from Table UHX-13.1 = 1.249473

The Tubesheet Bending Stress - Original Thickness [Sigma]:

$$= (1.5 * F_m / \mu * ) * (2 * a_o / (H - h'g))^2 * P_e$$

$$= (1.5 * 1.2495 / 0.3399) * (2 * 183.295 / (46.0 - 5.0))^2 * 2.68$$

$$= 118.1185 \text{ N./mm}^2$$

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 [Sigma\_f]:

$$= (1.5 * F_m / \mu * ) * (2 * a_o / (h - h'g))^2 * P_e$$

$$= (1.5 * 0.5146 / 0.3399) * (2 * 183.295 / (32.983 - 5.0))^2 * 5.31$$

$$= 206.8425 \text{ N./mm}^2$$

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:

$$= h + C_{ats} + C_{atc} = 32.9827 + 0.0 + 0.0 = 32.9827 \text{ mm.}$$

**UHX-13.5.8 Step 8:**

Shear Stress check [Tau\_limit]:

$$= 1.6 * S * \mu * h / a_o$$

$$= 1.6 * 137.9 * 0.206 * 46.0 / 183.29$$

$$= 11.4205 \text{ N./mm}^2$$

The Shear Stress is not required to be computed; [Pe] <= Tau\_limit

*Note: Tubesheet Shear Stress is probably low, use the following req. thk:*

$$\text{Tubesheet thickness (Incl. Corr.)} = 3.8684 \text{ mm.}$$

$$\text{Tubesheet Shear Stress} = 29.7726 \text{ N./mm}^2$$

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd]:

$$= \text{Max}(H_{reqB}, H_{reqS}) = \text{Max}(32.9827, 3.8684) = 32.9827 \text{ mm.}$$

**UHX-13.5.9 Step 9:**

The Ftmin and Ftmax Coefficients from Table UHX-13.2:

$$F_{tmin} = -5.4647, F_{tmax} = 6.3486$$

First Extreme Tube Axial Stress from among all the tubes [Sigma1]:

$$= (P_s * x_s - P_t * x_t) - P_e * F_{tmin} / (X_t - X_s)$$

$$= (25.0 * 0.5517 - 25.0 * 0.7282) - (2.679) * (-5.465) / (0.7282 - 0.5517)$$

$$= 5.7976 \text{ N./mm}^2$$

Second Extreme value of Tube Axial Stress from among all the tubes [Sigma2]:

$$= (P_s * x_s - P_t * x_t) - P_e * F_{tmax} / (X_t - X_s)$$

$$= (25.0 * 0.5517 - 25.0 * 0.7282) - (2.679) * 6.349 /$$

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$$( 0.7282 - 0.5517 ) )$$

$$= -12.1399 \text{ N./mm}^2$$

Maximum Tube Axial Stress [Sigmat,max]:

$$= \text{MAX}( \text{abs}(\text{Sigmat1}), \text{abs}(\text{Sigmat2}) ) = 12.14 \text{ N./mm}^2$$

The Allowable Tube Stress, [SigmatA]:

$$= \text{Sot} = 92.3930 \text{ N./mm}^2$$

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:

$$= \text{Max}( (3.25 - 0.25*(Zd + Q3*Zw)*Xa^4 ), 1.25 )$$

$$= \text{Max}( (3.25 - 0.25*( 0.083 + -2.499 * 0.131 ) * 2.586^4 ), 1.25 )$$

$$= 2.0000 \text{ (Should be } \leq 2 \text{ )}$$

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]:

$$= ( 2 * \text{PI}^2 * \text{Et}/\text{Syt} )^{.5}$$

$$= ( 2 * 3.14^2 * 0.19308\text{E}+09/154 )^{.5} = 157.0623$$

Determine the Factor [Ft]:

$$= k * L/r = 0.8 * 571.0/6.036 = 75.6781$$

The Buckling Allowable Stress [Stb]:

$$= \text{Sy,t}/\text{Fs} * ( 1 - \text{Ft}/(2*\text{Ct}) )$$

$$= 154/2.0 * ( 1 - 75.678/(2*157.062 ) )$$

$$= 58.641 \text{ N./mm}^2 \text{ (Never greater than Sot)}$$

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:

$$= \text{Sigmat,max} * \text{Tube Area} = 12.14 * 1.122 = 1.36 \text{ kN}$$

### Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

$$= 3.1415 * t * ( do - t ) * \text{Sa}$$

$$= 3.1415 * 2.108 * ( 19.05 - 2.108 ) * 92.39 = 10.365 \text{ kN}$$

Fillet Weld Strength [Ff]:

$$= 0.55 * 3.1415 * \text{af} * (do + 0.67*\text{af}) * \text{Sw} \text{ (but not } > \text{ Ft)}$$

$$= 0.55 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 92.39$$

$$= 4.8021 \text{ kN}$$

Groove Weld Strength [Fg]:

$$= 0.85 * 3.1415 * \text{ag} * (do + 0.67*\text{ag}) * \text{Sw} \text{ (but not } > \text{ Ft)}$$

$$= 0.85 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 92.39$$

$$= 7.4214 \text{ kN}$$

Max. Allow. Tube-Tubesheet Joint load, Lmax

$$= \text{Ft} = 10.3654 \text{ kN}$$

Design Strength Ratio [fd]:

$$= 1.0000$$

Weld Strength Factor [fw]:

$$= \text{Sot} / ( \text{Min}(\text{Sot}, \text{S}) ) = 1.0000$$

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Min Weld Length [ar]:

$$= 2 * ( ( (0.75 * do)^2 + 1.07*t*(do - t)* fw * fd ) )^{1/2} - 0.75 * do$$

$$= 2.5600 \text{ mm.}$$

Minimum Required Fillet Weld Leg afr 1.2800 mm.  
 Minimum Required Groove Weld Leg agr 1.2800 mm.

Tube-Tubesheet Jt allowable, 10.37 is >= tube strength 10.37 kN

Note: This tube-tubesheet joint is a Full Strength joint

### UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:

$$= Ss * Esw = 117.9 * 1.0 = 117.9 \text{ N./mm}^2$$

Axial Membrane Stress in Shell [Sigmas,m]:

$$= ao^2 / ((Ds+ts)*ts) * [Pe + (Rhos^2-1)(Ps-Pt)] + as^2 * Pt / ((Ds+ts)*ts)$$

$$= 183.295^2 / ((381.0 + 12.7) * 12.7) * [2.68 + (1.039^2 - 1) * (25.0 - 25.0)] + 190.5^2 * 25.0 / ((381.0 + 12.7) * 12.7)$$

$$= 19.9466 \text{ N./mm}^2$$

### UHX-13.5.11 Step 11:

Note:

For a given Shell thickness of 12.7 mm., the minimum Shell length adjacent to the tubesheet should be 125.209 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:

$$= ao^2 / ((Ds+ts)*ts) [Pe + (Rhos^2-1)(Ps-Pt)] + as^2 * Pt / ((Ds+ts)*ts)$$

$$= 183.295^2 / ((381.0 + 12.7) * 12.7) [2.68 + (1.039^2 - 1) * (25.0 - 25.0)] + 190.5^2 * 25.0 / ((381.0 + 12.7) * 12.7)$$

$$= 19.9466 \text{ N./mm}^2$$

The Shell Bending Stress due to Joint Interaction [Sigmasb]:

$$= 6 * ks / ts^2 \{ betas[\delta S * Ps + as^2 * PstarS / (Es * ts)] + 6(1 - \nu^2) / (E^*) (ao/h)^3 (1 + h * betas / 2) [Pe(Zv + Zm * Q1) + 2/ao^2 * Zm * Q2] \}$$

$$= 6 * 18621754 / 12.7^2 \{ 0.026 [ 0.013 * 25.0 + 190.5^2 * 0.0 / (.24521E+1) ] + 6(1 - 0.33^2) / (65058264) (183.29/46.0)^3 (1 + 46.0 * 0.03/2) [ 2.7 ( 0.131 + 0.581 * -0.096 ) + 2/183.29^2 * 0.581 * -10.812 ] \}$$

$$= -146.9078 \text{ N./mm}^2$$

Shell Stress Summation vs. Allowable

$$abs(\text{Sigmasm}) + abs(\text{Sigmasb}) \leq 1.5 * Ss$$

$$abs(19.9) + abs(-146.9) \leq 176.86 \text{ N./mm}^2$$

166.85 must be < or = 176.86 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	118.1 <=	206.9 N./mm <sup>2</sup>	Ok
Tubesheet Shear Stress	2.6 <=	110.3 N./mm <sup>2</sup>	Ok

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Maximum Tube Stress	12.1	<=	92.4	N./mm <sup>2</sup>	Ok
Minimum Tube Stress (Buckling)	-12.1	<=	-58.6	N./mm <sup>2</sup>	Ok
Maximum Force on any one Tube	1.4	<=	10.4	kN	Ok
Axial Membrane Stress in Shell	19.9	<=	117.9	N./mm <sup>2</sup>	Ok
Shell Stress (jt. inter.)	166.9	<=	176.9	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 :	32.983	46.000	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	26.909	25.552	106	207	12	110	Ps+Pt-Th	D1 Ok
D2uc	19.550	...	43	207	15	110	Ps+Pt-Th	D2 Ok
D3uc	32.983	...	118	207	3	110	Ps+Pt-Th	D3 Ok
D4uc	5.925	...	2	207	...	110	Ps+Pt-Th	D4 Ok
O1uc	8.512	...	113	428	19	110	Ps+Pt+Th	O1 Ok
O2uc	12.554	...	99	428	10	110	Ps+Pt+Th	O2 Ok
O3uc	6.688	...	110	428	5	110	Ps+Pt+Th	O3 Ok
O4uc	7.403	...	70	428	4	110	Ps+Pt+Th	O4 Ok
D1c	36.730	25.552	141	207	10	110	Ps+Pt-Th-c	D1 Ok
D2c	19.386	...	41	207	15	110	Ps+Pt-Th-c	D2 Ok
D3c	38.937	...	150	207	5	110	Ps+Pt-Th-c	D3 Ok
D4c	9.810	...	2	207	...	110	Ps+Pt-Th-c	D4 Ok
O1c	21.418	...	157	428	16	110	Ps+Pt+Th-c	O1 Ok
O2c	24.361	...	142	428	14	110	Ps+Pt+Th-c	O2 Ok
O3c	25.812	...	165	428	1	110	Ps+Pt+Th-c	O3 Ok
O4c	20.018	...	112	428	...	110	Ps+Pt+Th-c	O4 Ok
Max:	38.9374	25.552	mm.	0.726		0.174	(Str. Ratio)	

**Load Case Definitions:**

[Ps &amp; 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)

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[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	8	117	...	...	:	...	...	...	...	Ok
D2uc	11	117	...	...	:	...	...	...	...	Ok
D3uc	20	117	...	...	:	...	...	...	...	Ok
D4uc	1	117	-1	-114	:	...	...	...	...	Ok
O1uc	3	416	...	...	:	...	...	...	...	Ok
O2uc	8	416	...	...	:	...	...	...	...	Ok
O3uc	14	416	...	...	:	...	...	...	...	Ok
O4uc	3	416	-3	-114	:	...	...	...	...	Ok
D1c	14	117	...	...	:	...	...	...	...	Ok
D2c	13	117	...	...	:	...	...	...	...	Ok
D3c	28	117	...	...	:	...	...	...	...	Ok
D4c	1	117	-1	-111	:	...	...	...	...	Ok
O1c	9	416	...	...	:	...	...	...	...	Ok
O2c	14	416	...	...	:	...	...	...	...	Ok
O3c	23	416	...	...	:	...	...	...	...	Ok
O4c	...	416	...	...	:	...	...	...	...	Ok
Max RATIO		0.238		0.023	:	...		...		

**Tube, Shell and Channel Stress Summary:**

Case#	Tube Stresses				Tube Loads		Shell Stress		Channel Stress		Pass Fail
	Ten	Allwd	Cmp	Allwd	Ld	Allwd	Stress	Allwd	Stress	Allwd	
D1uc	16	92	-16	-64	2	10	245	416	...	...	Ok
D2uc	4	92	-4	-58	...	10	102	176	...	...	Ok
D3uc	12	92	-12	-58	1	10	167	176	...	...	Ok
D4uc	...	92	...	-92	...	10	3	176	...	...	Ok
O1uc	19	184	-17	-60	2	20	324	416	...	...	Ok
O2uc	9	184	-3	-58	1	20	110	416	...	...	Ok
O3uc	16	184	-13	-92	2	20	249	416	...	...	Ok
O4uc	12	184	-7	-92	1	20	190	416	...	...	Ok
D1c	21	92	-21	-92	2	10	317	416	...	...	Ok
D2c	7	92	-4	-58	1	10	141	176	...	...	Ok
D3c	15	92	-15	-58	2	10	206	416	...	...	Ok
D4c	...	92	...	-92	...	10	3	176	...	...	Ok
O1c	24	184	-24	-92	3	20	416	416	...	...	Ok
O2c	9	184	-4	-58	1	20	131	416	...	...	Ok
O3c	18	184	-18	-92	2	20	310	416	...	...	Ok
O4c	13	184	-10	-58	1	20	237	416	...	...	Ok
Max RATIO		0.231		0.282		0.231		1.000		...	

**Summary of Thickness Comparisons for 16 Load Cases:**

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	38.937	46.000	Ok
Tubesheet Thickness Flanged Extension :	25.552	30.000	Ok
Tube Thickness :	0.549	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

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Min Shell length of thk, (12.700) adj. to tubesheet: 125.209 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 : -0.245 mm.  
 Due to Pressure Shell Compresses by : -0.045 mm.  
 Due to Pressure + Thermal Shell Compresses by : -0.290 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	39.548	1.000	124.138	1.000
Tubesheet Shear Stress	193.537	1.000	191.922	1.000
Tube Tensile Stress	109.468	1.000	369.622	1.000
Tube Compressive Stress	100.151	1.000	367.600	1.000
Tube-Tubesheet Joint load	109.468	1.000	369.623	1.000
Shell Stress (Axial, Junction)	24.791	0.996	77.604	1.000
Tube Pressure Stress	224.322	1.000	146.781	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc
Minimum MAWP	24.791		77.604	

**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	50.222	1.000	124.861	0.988
Tubesheet Shear Stress	243.700	1.000	198.340	1.000
Tube Tensile Stress	142.986	1.000	575.419	1.000
Tube Compressive Stress	116.473	1.000	488.954	1.000
Tube-Tubesheet Joint load	142.986	1.000	575.419	1.000
Shell Stress (Axial, Junction)	43.960	1.000	124.861	1.000
Tube Pressure Stress	224.322	1.000	149.973	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc
Minimum MAPnc	37.739		124.861	

(\*) All load cases were analyzed to compute the MAWP for determining the test pressure.

**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):  
 = max( tubesheet thk/4, min( tubesheet thk, shell thickness ) )  
 = max( 46.0/4, min( 46.0, 12.7 ) )  
 = 12.700 mm.

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -21 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -40 °C

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Min Metal Temp. w/o impact per UG-20(f) -29 °C

**Channel Side MDMT calculation:**

Governing thickness for the channel side:

= tubesheet thickness/4  
 = 46.0/4  
 = 11.500 mm.

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -24 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -43 °C  
 Min Metal Temp. w/o impact per UG-20(f) -29 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

= max(  $p_t$ /Tubeside MAPnc,  $p_s$ /Shellside MAPnc ), must be  $\leq 1$   
 = max( 25.0/37.74, 25.0/124.86 )  
 = 0.662

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**Minimum Design Metal Temperature Results Summary :**

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
SHELL	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
S2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S1	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S3	[1]	B	-29	-48	-29	0.513	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Tubesheet: SS	[13]	B	-21	-40	-29	0.662	12.700	1.00	No
Warmest MDMT:			-21	-40					
BODY FLANGE 0	[11]	B	-29	-48	-29	0.436	10.000	1.00	No
BODY FLANGE 0	[11]	B	-26	-48	-29	0.436	11.113	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 1	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
CHANNEL 01	[8]	B	-26	-47	-29	0.622	11.113	1.00	No
CHANNEL 002	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 002	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
T2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T1	[1]	B	-29	-48	-29	0.513	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T4	[1]	B	-26	-48	-29	0.512	11.113	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	B	-26	-48	-29	0.513	11.113	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: CS	[14]	B	-24	-43	-29	0.662	11.500	1.00	No
Bolting	[21]		-48						
Bolting	[21]		-48						
Warmest MDMT:			-24	-43					
Exchanger Side			Computed MDMT °C		Required MDMT °C			Pass/Fail	
Shell			-40.0		-10.0			Pass	
Channel/Tube			-43.0		-10.0			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

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[15] - Nozzle Material  
[16] - Shell or Head Material  
[17] - Impact Testing required  
[18] - Impact Testing not required, see UCS-66(b)(3)  
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations  
[21] - Bolting Material

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 8:06am Dec 23,2021

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

Diameter Spec : 381.000 mm. ID  
 Vessel Design Length, Tangent to Tangent 3902.35 mm.  
 Specified Datum Line Distance 50.00 mm.  
 Shell Side Design Temperature 120 °C  
 Channel Side Design Temperature 190 °C  
 Shell Side Design Pressure 25.000 bars  
 Channel Side Design Pressure 25.000 bars  
 Wind Design Code ASCE-2010  
 Earthquake Design Code ASCE 7-2010

**Materials of Construction:**

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-106 B	...	...	K03006	No	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-266 2	...	...	K03506	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Tubes	SA-179	...	...	K01200	No	No
Tubesheet	SA-266 2	...	...	K03506	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.

Impact Tested is based on material selection and material data properties.

**Element Pressures and MAWP (bars & mm.):**

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
HEAD 1	25.038	1.10	No Calc	3.0000	No	No
CHANNEL 01	25.038	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 01	25.037	1.10	No Calc	3.0000	N/A	No
SHELL	25.033	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 002	25.037	1.10	No Calc	3.0000	N/A	No
CHANNEL 002	25.038	1.10	No Calc	3.0000	N/A	No
HEAD 002	25.038	1.10	No Calc	3.0000	No	No

Liquid Level: 381.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 1.000

**Element Types and Properties:**

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	0.0	50.0	14.0	11.1	6.4	4.5	1.00	0.85

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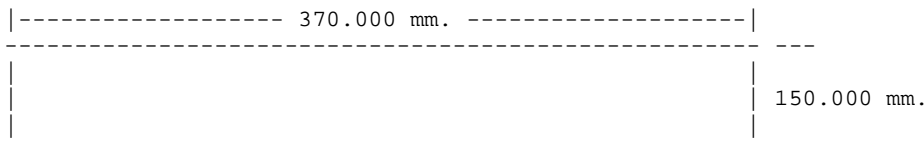
Vessel Design Summary: Step: 24 8:06am Dec 23,2021

Cylinder	321.0	321.0	12.7	11.1	7.2	4.3	1.00	1.00
Body Flg	395.0	74.0	79.0	48.0	45.1	45.1	1.00	1.00
Cylinder	3355.2	2908.0	12.7	11.1	7.2	6.1	1.00	1.00
Body Flg	3435.4	74.0	79.0	48.0	41.4	41.4	1.00	1.00
Cylinder	3802.4	321.0	12.7	11.1	7.2	4.3	1.00	1.00
Ellipse	3852.4	50.0	14.0	11.1	6.4	4.5	1.00	1.00

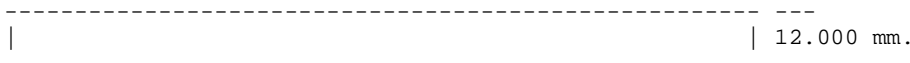
**Saddle Parameters:**

Saddle Width	140.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	500.000	mm.
Wear Pad Width	200.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	500.000	mm.
Baseplate Length	370.000	mm.
Baseplate Thickness	12.000	mm.
Baseplate Width	150.000	mm.
Number of Ribs (including outside ribs)	2	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	275.000	mm.
Number of Bolts in Baseplate	2	

**Baseplate Sketch**



**Baseplate Plan View**



**Baseplate Side View**

Maximum Tensile Bolt Load 0. kN

**Summary of Maximum Saddle Loads, Operating Case :**

Maximum Vertical Saddle Load	16.96	kN
Maximum Transverse Saddle Shear Load	2.03	kN
Maximum Longitudinal Saddle Shear Load	4.06	kN

**Summary of Maximum Saddle Loads, Operating Case, Un-Factored :**

Maximum Vertical Saddle Load	20.52	kN
Maximum Transverse Saddle Shear Load	8.30	kN
Maximum Longitudinal Saddle Shear Load	5.79	kN

**Summary of Maximum Saddle Loads, Hydrotest Case :**

Maximum Vertical Saddle Load	10.56	kN
Maximum Transverse Saddle Shear Load	0.29	kN
Maximum Longitudinal Saddle Shear Load	0.09	kN

**Local Stress Analysis Results:**

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Description	Analysis Type	Max Stress Ratio	Pass Fail
T2	WRC-107/537	0.517	Passed
T1	WRC-107/537	0.517	Passed
S2	WRC-107/537	0.517	Passed
S1	WRC-107/537	0.517	Passed
S3	WRC-107/537	0.517	Passed

**Weights:**

Fabricated - Bare W/O Removable Internals	1437.2 kg.
Shop Test - Fabricated + Water ( Full )	1840.7 kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	1437.2 kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	1437.2 kg.
Empty - Fab. + Intls. + Details + Wghts.	1437.2 kg.
Operating - Empty + Operating Liquid (No CA)	1816.4 kg.
Field Test - Empty Weight + Water (Full)	1731.9 kg.

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