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	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
	DOCUMENT TITLE: Mechanical Calculation for Economizer	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0030	Rev. No.: D1

Regarding last meeting with vendor, please revise calculation as per thermal calculation comment for considering 1.1x748000 for flowrate and duty of 1750 kw and please size all equipment inside package for mentioned design duty of chiller

DOCUMENT TITLE:

Mechanical Calculation for Economizer

(E-PK6101-3)

PURCHASER'S COMMENT/APPROVAL STATUS					Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)				Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)				
3	NF: Approved With Comments (Fabrication not Proceed)				Item No. (Tag No.): (E-PK6101-3)
4	RJ: Rejected				
5	NR: Not be Returned				
Date: 06.03.2022					Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0030-D1
Signature: A.AB					
					
D1	06.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
REV	DATE ISSUE	PREPARED	CHECKED	APPROVED	



DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT



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15	x	x			
16	x	x			
17	x	x			
18	x	x			
19	x	x			
20	x	x			
21	x	x			
22	x	x			
23	x	x			
24	x	x			
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26	x	x			
27	x	x			
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46	x	x			
47	x	x			
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54	x	x			
55	x	x			
56	x	x			
57	x	x			
58	x	x			
59	x	x			
60	x	x			
61	x	x			
62	x	x			
63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			



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86	x	x			
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88	x	x			
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132	x	x			
133	x	x			
134	x	x			
135	x	x			
136	x	x			
137	x	x			
138	x	x			
139	x	x			
140	x	x			



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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Feb 6,2022 11:20pm

PV Elite 2018 SP2, June 2018

Note:

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

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 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
 Tag no:E-PK6101-3 ECONOMIZER
 PV Elite 2018 SP2 Licensee: SPLM Licensed User
 FileName : Calculation Book for ECONOMIZER E-PK6101-3
 Input Echo: Step: 1 11:20pm Feb 6,2022

PV Elite Vessel Analysis Program: Input Data

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
 DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
 Tag no:E-PK6101-3 ECONOMIZER

Exchanger Design Pressures and Temperatures

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

Type of Hydrotest	UG-99(b) Note [36]
Hydrotest Position	Horizontal
Projection of Nozzle from Vessel Top	0 mm.
Projection of Nozzle from Vessel Bottom	0 mm.
Type of Construction	Welded
Special Service	None
Degree of Radiography	RT-3
Use Higher Longitudinal Stresses (Flag)	Y
Select t for Internal Pressure (Flag)	N
Select t for External Pressure (Flag)	N
Select t for Axial Stress (Flag)	N
Select Location for Stiff. Rings (Flag)	N
Consider Vortex Shedding	N
Perform a Corroded Hydrotest	Y
Is this a Heat Exchanger	Yes
User Defined Hydro. Press. (Used if > 0)	0 bars
User defined MAWP	0 bars
User defined MAPnc	0 bars

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	200 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 mm.
Percent Wind for Hydrotest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Input Echo: Step: 1 11:20pm Feb 6,2022

Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.250	
Table Value Fa		1.000	
Table Value Fv		1.300	
Short Period Acceleration value Ss		0.900	
Long Period Acceleration Value Sl		0.537	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		B	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		0.390	

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

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

Configuration Directives:

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

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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	HEAD 1	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	581	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Input Echo: Step: 1 11:20pm Feb 6,2022

Material Name	SA-516 70	[Normalized]
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrottest	235.81	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	30.988	mm.
Yield Stress, Operating	235.23	N./mm ²
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Liquid	
Detail ID	1	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	581	mm.
Liquid Density	0.0005998	kg./cm ³

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	-145.25	mm.
Height/Length of Insulation	195.25	mm.
Thickness of Insulation	80	mm.
Density	0.00024	kg./cm ³

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	CHANNEL 01	
Distance "FROM" to "TO"	407	mm.
Inside Diameter	581	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	10	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
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	581	mm.
Liquid Density	0.000531	kg./cm ³

Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 40	

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Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	407	mm.
Thickness of Insulation	80	mm.
Density	0.00024	kg./cm ³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T4	
Dist. from "FROM" Node / Offset dist	203	mm.
Nozzle Diameter	0.75	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.04826	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	203	mm.
Nozzle Diameter	4	in.
Nozzle Schedule	120	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.2988	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	BODY FLANGE	01
Distance "FROM" to "TO"	88	mm.
Flange Inside Diameter	581	mm.
Element Thickness	62	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-350 LF2	[Impact Tested]
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrotest	223.4	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	31.75	mm.
Yield Stress, Operating	222.82	N./mm ²
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03011	
Class / Thickness / Grade	1::	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		

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Grade of ANSI B16.5/B16.47 Flange

Weld is pre-Heated No

Element From Node	30
Detail Type	Liquid
Detail ID	3
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	581 mm.
Liquid Density	0.0005998 kg./cm ³

Element From Node	30
Detail Type	Insulation
Detail ID	Ins: 40
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	88 mm.
Thickness of Insulation	80 mm.
Density	0.00024 kg./cm ³

Element From Node	40
Element To Node	50
Element Type	Cylinder
Description	SHELL
Distance "FROM" to "TO"	5880 mm.
Inside Diameter	581 mm.
Element Thickness	10 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	10 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Allowable Stress, Ambient	137.9 N./mm ²
Allowable Stress, Operating	137.9 N./mm ²
Allowable Stress, Hydrotest	235.81 N./mm ²
Material Density	0.00775 kg./cm ³
P Number Thickness	30.988 mm.
Yield Stress, Operating	235.23 N./mm ²
UCS-66 Chart Curve Designation	D
External Pressure Chart Name	CS-2
UNS Number	K02700
Product Form	Plate
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Weld is pre-Heated	No

Element From Node	40
Detail Type	Saddle
Detail ID	Fixed Saddle
Dist. from "FROM" Node / Offset dist	940 mm.
Width of Saddle	150 mm.
Height of Saddle at Bottom	600 mm.
Saddle Contact Angle	120.0
Height of Composite Ring Stiffener	0 mm.
Width of Wear Plate	225 mm.
Thickness of Wear Plate	10 mm.
Contact Angle, Wear Plate (degrees)	132.0

Element From Node	40
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Detail Type	Saddle	
Detail ID	Sliding Saddle	
Dist. from "FROM" Node / Offset dist	4940	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	600	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	225	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	581	mm.
Liquid Density	0.0005998	kg./cm ³
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	5880	mm.
Thickness of Insulation	80	mm.
Density	0.00024	kg./cm ³
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	196	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5568	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	5680	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5568	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S3	
Dist. from "FROM" Node / Offset dist	146	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1175	kN
Grade of Attached Flange	GR 1.1	

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Input Echo: Step: 1 11:20pm Feb 6,2022

Nozzle Matl	SA-350 LF2	[Impact Tested]
Element From Node	40	
Detail Type	Weight	
Detail ID	WEIGHT BAFFLE	
Dist. from "FROM" Node / Offset dist	2940	mm.
Miscellaneous Weight	1.4709	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"	88	mm.
Flange Inside Diameter	581	mm.
Element Thickness	62	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-350 LF2	[Impact Tested]
Allowable Stress, Ambient	137.9	N./mm ²
Allowable Stress, Operating	137.9	N./mm ²
Allowable Stress, Hydrotest	223.4	N./mm ²
Material Density	0.00775	kg./cm ³
P Number Thickness	31.75	mm.
Yield Stress, Operating	222.82	N./mm ²
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03011	
Class / Thickness / Grade	1::	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	581	mm.
Liquid Density	0.0005998	kg./cm ³

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	88	mm.
Thickness of Insulation	80	mm.
Density	0.00024	kg./cm ³

Element From Node	60
Element To Node	70

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Input Echo: Step: 1 11:20pm Feb 6,2022

Element Type	Cylinder
Description	CHANNEL 002
Distance "FROM" to "TO"	407 mm.
Inside Diameter	581 mm.
Element Thickness	10 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	10 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
Allowable Stress, Ambient	137.9 N./mm ²
Allowable Stress, Operating	137.9 N./mm ²
Allowable Stress, Hydrotest	235.81 N./mm ²
Material Density	0.00775 kg./cm ³
P Number Thickness	30.988 mm.
Yield Stress, Operating	235.23 N./mm ²
UCS-66 Chart Curve Designation	D
External Pressure Chart Name	CS-2
UNS Number	K02700
Product Form	Plate
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Weld is pre-Heated	No
Element From Node	60
Detail Type	Liquid
Detail ID	5
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	581 mm.
Liquid Density	0.0005998 kg./cm ³
Element From Node	60
Detail Type	Insulation
Detail ID	Ins: 40
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	407 mm.
Thickness of Insulation	80 mm.
Density	0.00024 kg./cm ³
Element From Node	60
Detail Type	Nozzle
Detail ID	T2
Dist. from "FROM" Node / Offset dist	200 mm.
Nozzle Diameter	6 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle (Used if > 0)	0.5568 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	60
Detail Type	Nozzle
Detail ID	T3
Dist. from "FROM" Node / Offset dist	203 mm.
Nozzle Diameter	1 in.
Nozzle Schedule	None
Nozzle Class	300

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Input Echo: Step: 1 11:20pm Feb 6,2022

Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle (Used if > 0)	0.05845 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	70
Element To Node	80
Element Type	Elliptical
Description	HEAD 002
Distance "FROM" to "TO"	50 mm.
Inside Diameter	581 mm.
Element Thickness	10 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	12 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.1 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Normalized]
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	581 mm.
Liquid Density	0.0005998 kg./cm ³

Element From Node	70
Detail Type	Insulation
Detail ID	Ins: 40
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Insulation	195.25 mm.
Thickness of Insulation	80 mm.
Density	0.00024 kg./cm ³

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 XY Coordinate Calculations: Step: 2 11:20pm Feb 6,2022

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		457	...	407	...
BODY FLANGE 01		545	...	88	...
SHELL		6493.18	...	5880	...
BODY FLANGE 002		6587.35	...	88	...
CHANNEL 002		7056.35	...	407	...
HEAD 002		7106.35	...	50	...

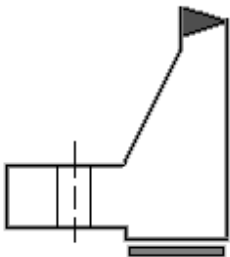
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 Flg Calc [Int P]: FLANGE Flng: 3 11:20pm Feb 6,2022

Flange Input Data Values Description: FLANGE :

BODY FLANGE 01

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.03	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	581.000	mm.
Flange Outside Diameter	A	715.000	mm.
Flange Thickness	t	62.0000	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-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm ²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm ²
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm ²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm ²
Diameter of Bolt Circle	C	673.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		32	
Flange Face Outside Diameter	Fod	647.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm ²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	6.4000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm ²



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Hub Small End Required Thickness due to Internal Pressure:

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

$$= (23.03 \cdot (581.0/2 + 3.0)) / (137.9 \cdot 1.0 - 0.6 \cdot 23.03) + Ca$$

$$= 7.9524 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 \cdot 1.0 \cdot 7.0) / (293.5 + 0.6 \cdot 7.0)$$

$$= 32.423 \text{ bars}$$

Corroded Flange Thickness, $t_c = T - c_i$	59.000	mm.
Corroded Flange ID, $B_{cor} = B + 2 \cdot F_{cor}$	587.000	mm.
Corroded Large Hub, $g_{1Cor} = g_1 - c_i$	14.000	mm.
Corroded Small Hub, $g_{0Cor} = g_0 - c_i$	7.000	mm.
Code R Dimension, $R = ((C - B_{cor}) / 2) - g_{1Cor}$	29.000	mm.
Gasket Contact Width, $N = (G_o - G_i) / 2$	15.000	mm.
Basic Gasket Width, $b_o = N / 2$	7.500	mm.
Effective Gasket Width, $b = C_b \cdot \text{sqrt}(b_o)$	6.901	mm.
Gasket Reaction Diameter, $G = G_o - 2 \cdot b$	627.198	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 \cdot G^2 \cdot P_{eq}$$

$$= 0.785 \cdot 627.1979^2 \cdot 23.034$$

$$= 711.639 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

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

$$= 2 \cdot 6.9011 \cdot 3.1416 \cdot 627.1979 \cdot 3.78 \cdot 23.03$$

$$+ 2.0 \cdot 559.0 \cdot 3.2 \cdot 3.75 \cdot 23.0342$$

$$= 267.687 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

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

$$= 3.1416 \cdot 587.0^2 \cdot 23.0342 / 4$$

$$= 623.343 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - H_d$$

$$= 712 - 623$$

$$= 88.296 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(712 + 268 + 0, 0)$$

$$= 979.326 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

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

$$= 62.05 \cdot 6.9011 \cdot 3.1416 \cdot 627.198 + 62.05 \cdot 3.2 \cdot 559.0$$

$$= 954.707 \text{ kN}$$

Required Bolt Area [Am]:

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

$$= \text{Maximum of } 979/172, 955/172$$

$$= 56.819 \text{ cm}^2$$

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

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

$$= 2 \cdot 19.05 + 6 \cdot 59.0 / (3.78 + 0.5)$$

$$= 120.810 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 673.0 \cdot \sin(3.142/32)$$

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= 65.966 mm.

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

= max(sqrt(Bs/(2a + t)), 1)
 = max(sqrt(65.966/(2 * 19.05 + 59.0)), 1)
 = 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm ²	56.819	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	65.966	120.810

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

= Ab * Sa/(γ * Pi * (Go + Gi))
 = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0))
 = 4.403 mm.

Flange Design Bolt Load, Gasket Seating [W]:

= Sa * (Am + Ab) / 2
 = 172.38 * (56.8185 + 62.3483) / 2
 = 1026.98 kN

Gasket Load for the Operating Condition [HG]:

= Wm1 - H
 = 979 - 712
 = 267.69 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

= (C - G) / 2
 = (673.0 - 627.1979) / 2
 = 22.9011 mm.

Distance to Face Pressure Reaction [ht]:

= (R + g1 + hg) / 2
 = (29.0 + 14.0 + 22.9011) / 2
 = 32.9505 mm.

Distance to End Pressure Reaction [hd]:

= R + (g1 / 2)
 = 29.0 + (14.0 / 2.0)
 = 36.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	623.	36.0000	1.0000	22449.
Face Pressure, Mt	88.	32.9505	1.0000	2911.
Gasket Load, Mg	268.	22.9011	1.0000	6133.
Gasket Seating, Matm	1027.	22.9011	1.0000	23529.
Total Moment for Operation, Mop				31493. N-m
Total Moment for Gasket seating, Matm				23529. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			64.101 mm.	
Hub Ratio, h/h0 = HL / H0			0.406	
Thickness Ratio, g1/g0 = (g1Cor/goCor)			2.000	

Flange Factors for Integral Flange:

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Flg Calc [Int P]: FLANGE Flng: 3 11:20pm Feb 6,2022

Factor F		0.847
Factor V		0.257
Factor f		1.586
Factors from Figure 2-7.1		K = 1.218
	T = 1.832	U = 10.940
	Y = 9.955	Z = 5.135
	d = 0.13358E+06 mm. ³	e = 0.0132 mm. ⁻¹
Stress Factors		ALPHA = 1.779
	BETA = 2.039	GAMMA = 0.972
	DELTA = 1.537	Lamda = 2.509

Longitudinal Hub Stress, Operating [SHo]:

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

$$= (1.5858 * 31493 / 587.0) / (2.5089 * 14.0^2)$$

$$= 172.96 \text{ N./mm}^2$$

Longitudinal Hub Stress, Seating [SHa]:

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

$$= (1.5858 * 23529 / 587.0) / (2.5089 * 14.0^2)$$

$$= 129.22 \text{ N./mm}^2$$

Radial Flange Stress, Operating [SRo]:

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

$$= (2.0393 * 31493 / 587.0) / (2.5089 * 59.0^2)$$

$$= 12.52 \text{ N./mm}^2$$

Radial Flange Stress, Seating [SRa]:

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

$$= (2.0393 * 23529 / 587.0) / (2.5089 * 59.0^2)$$

$$= 9.36 \text{ N./mm}^2$$

Tangential Flange Stress, Operating [STo]:

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

$$= (9.9551 * 31493 / (59.0^2 * 587.0)) - 5.1351 * 13$$

$$= 89.08 \text{ N./mm}^2$$

Tangential Flange Stress, Seating [STa]:

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

$$= (9.9551 * 23529 / (59.0^2 * 587.0)) - 5.1351 * 9$$

$$= 66.55 \text{ N./mm}^2$$

Average Flange Stress, Operating [SAo]:

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

$$= (173 + \max(13, 89)) / 2$$

$$= 131.02 \text{ N./mm}^2$$

Average Flange Stress, Seating [SAa]:

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

$$= (129 + \max(9, 67)) / 2$$

$$= 97.88 \text{ N./mm}^2$$

Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 979 / 62.3483$$

$$= 157.09 \text{ N./mm}^2$$

Bolt Stress, Seating [BSa]:

$$= (Wm2 / Ab)$$

$$= (955 / 62.3483)$$

$$= 153.14 \text{ N./mm}^2$$

Flange Stress Analysis Results: N./mm²

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed

Longitudinal Hub	173.	207.	129.	207.

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Flg Calc [Int P]: FLANGE Flng: 3 11:20pm Feb 6,2022

Radial Flange	13.	138.	9.	138.
Tangential Flange	89.	138.	67.	138.
Maximum Average	131. |	138. |	98. |	138. |
Bolting	157. |	172. |	153. |	172. |

Minimum Required Flange Thickness	60.173	mm.
Estimated M.A.W.P. (Operating)	24.244	bars
Estimated Finished Weight of Flange at given Thk.	70.6	kg.
Estimated Unfinished Weight of Forging at given Thk	93.0	kg.

Flange Rigidity Based on Required Thickness [ASME]:

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

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

$$= 52.14 * 23528.5/1.0 * 999.68 * 0.257/(2.356 * 202713 * 7.0^2 * 64.101 * 0.3)$$

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

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

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

$$= 52.14 * 31492.8/1.0 * 999.68 * 0.257/(2.356 * 196612 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.967 \quad (\text{should be } \leq 1)$$

Flange Rigidity Based on Given Thickness [ASME]:

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

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

$$= 52.14 * 23528.5/1.0 * 999.68 * 0.257/(2.509 * 202713 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.658 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 31492.8/1.0 * 999.68 * 0.257/(2.509 * 196612 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.908 \quad (\text{should be } \leq 1)$$

Minimum Design Metal Temperature Results:

Note:

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

Impact Test Temperature provided per Specification -46 °C

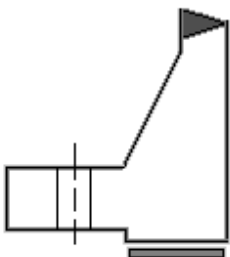
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 Flg Calc [Int P]: New Flange Flng: 4 11:20pm Feb 6,2022

Flange Input Data Values Description: New Flange :

BODY FLANGE 002

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.03	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	581.000	mm.
Flange Outside Diameter	A	715.000	mm.
Flange Thickness	t	62.0000	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-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm ²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm ²
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm ²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm ²
Diameter of Bolt Circle	C	673.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		32	
Flange Face Outside Diameter	Fod	647.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm ²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	6.4000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm ²



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Hub Small End Required Thickness due to Internal Pressure:

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

$$= (23.03*(581.0/2+3.0))/(137.9*1.0-0.6*23.03)+Ca$$

$$= 7.9524 \text{ mm.}$$

Hub Small End Hub MAWP:

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

$$= (137.9 * 1.0 * 7.0)/(293.5 + 0.6 * 7.0)$$

$$= 32.423 \text{ bars}$$

Corroded Flange Thickness, $t_c = T - c_i$	59.000	mm.
Corroded Flange ID, $B_{cor} = B + 2 * F_{cor}$	587.000	mm.
Corroded Large Hub, $g_{1Cor} = g_1 - c_i$	14.000	mm.
Corroded Small Hub, $g_{0Cor} = g_0 - c_i$	7.000	mm.
Code R Dimension, $R = ((C - B_{cor}) / 2) - g_{1Cor}$	29.000	mm.
Gasket Contact Width, $N = (G_o - G_i) / 2$	15.000	mm.
Basic Gasket Width, $b_o = N / 2$	7.500	mm.
Effective Gasket Width, $b = C_b \text{ sqrt}(b_o)$	6.901	mm.
Gasket Reaction Diameter, $G = G_o - 2 * b$	627.198	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

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

$$= 0.785 * 627.1979^2 * 23.034$$

$$= 711.639 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

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

$$= 2 * 6.9011 * 3.1416 * 627.1979 * 3.78 * 23.03$$

$$+ 2.0 * 559.0 * 3.2 * 3.75 * 23.0342$$

$$= 267.687 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

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

$$= 3.1416 * 587.0^2 * 23.0342 / 4$$

$$= 623.343 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - H_d$$

$$= 712 - 623$$

$$= 88.296 \text{ kN}$$

Operating Bolt Load [Wm1]:

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

$$= \max(712 + 268 + 0, 0)$$

$$= 979.326 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

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

$$= 62.05 * 6.9011 * 3.1416 * 627.198 + 62.05 * 3.2 * 559.0$$

$$= 954.707 \text{ kN}$$

Required Bolt Area [Am]:

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

$$= \text{Maximum of } 979/172, 955/172$$

$$= 56.819 \text{ cm}^2$$

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

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

$$= 2 * 19.05 + 6 * 59.0 / (3.78 + 0.5)$$

$$= 120.810 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 673.0 * \sin(3.142/32)$$

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= 65.966 mm.

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

= max(sqrt(Bs/(2a + t)), 1)
 = max(sqrt(65.966/(2 * 19.05 + 59.0)), 1)
 = 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm ²	56.819	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	65.966	120.810

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

= Ab * Sa/(γ * Pi * (Go + Gi))
 = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0))
 = 4.403 mm.

Flange Design Bolt Load, Gasket Seating [W]:

= Sa * (Am + Ab) / 2
 = 172.38 * (56.8185 + 62.3483) / 2
 = 1026.98 kN

Gasket Load for the Operating Condition [HG]:

= Wm1 - H
 = 979 - 712
 = 267.69 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

= (C - G) / 2
 = (673.0 - 627.1979) / 2
 = 22.9011 mm.

Distance to Face Pressure Reaction [ht]:

= (R + g1 + hg) / 2
 = (29.0 + 14.0 + 22.9011) / 2
 = 32.9505 mm.

Distance to End Pressure Reaction [hd]:

= R + (g1 / 2)
 = 29.0 + (14.0 / 2.0)
 = 36.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	623.	36.0000	1.0000	22449.
Face Pressure, Mt	88.	32.9505	1.0000	2911.
Gasket Load, Mg	268.	22.9011	1.0000	6133.
Gasket Seating, Matm	1027.	22.9011	1.0000	23529.
Total Moment for Operation, Mop				31493. N-m
Total Moment for Gasket seating, Matm				23529. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)			64.101 mm.	
Hub Ratio, h/h0 = HL / H0			0.406	
Thickness Ratio, g1/g0 = (g1Cor/goCor)			2.000	

Flange Factors for Integral Flange:

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Factor F 0.847
 Factor V 0.257
 Factor f 1.586
 Factors from Figure 2-7.1 K = 1.218
 T = 1.832 U = 10.940
 Y = 9.955 Z = 5.135
 d = 0.13358E+06 mm.³ e = 0.0132 mm.⁻¹
 Stress Factors ALPHA = 1.779
 BETA = 2.039 GAMMA = 0.972
 DELTA = 1.537 Lamda = 2.509

Longitudinal Hub Stress, Operating [SHo]:
 = (f * Mop / Bcor) / (L * g1²)
 = (1.5858*31493/587.0)/(2.5089*14.0²)
 = 172.96 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
 = (f * Matm / Bcor) / (L * g1²)
 = (1.5858*23529/587.0)/(2.5089*14.0²)
 = 129.22 N./mm²

Radial Flange Stress, Operating [SRo]:
 = (Beta * Mop / Bcor) / (L * t²)
 = (2.0393*31493/587.0)/(2.5089*59.0²)
 = 12.52 N./mm²

Radial Flange Stress, Seating [SRa]:
 = (Beta * Matm/Bcor) / (L * t²)
 = (2.0393*23529/587.0)/(2.5089*59.0²)
 = 9.36 N./mm²

Tangential Flange Stress, Operating [STo]:
 = (Y * Mo / (t² * Bcor)) - Z * SRO
 = (9.9551*31493/(59.0²*587.0))-5.1351*13
 = 89.08 N./mm²

Tangential Flange Stress, Seating [STa]:
 = (y * Matm / (t² * Bcor)) - Z * SRA
 = (9.9551*23529/(59.0²*587.0))-5.1351*9
 = 66.55 N./mm²

Average Flange Stress, Operating [SAo]:
 = (SHo + max(SRO, STo)) / 2
 = (173+max(13,89))/2
 = 131.02 N./mm²

Average Flange Stress, Seating [SAa]:
 = (SHa + max(SRA, STa)) / 2
 = (129+max(9,67))/2
 = 97.88 N./mm²

Bolt Stress, Operating [BSo]:
 = Wm1 / Ab
 = 979/62.3483
 = 157.09 N./mm²

Bolt Stress, Seating [BSa]:
 = (Wm2 / Ab)
 = (955/62.3483)
 = 153.14 N./mm²

Flange Stress Analysis Results: N./mm²

	Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
----- Longitudinal Hub	173.	207.	129.	207.

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Radial Flange	13.	138.	9.	138.
Tangential Flange	89.	138.	67.	138.
Maximum Average	131.	138.	98.	138.
Bolting	157. |	172. |	153. |	172. |

Minimum Required Flange Thickness	60.173	mm.
Estimated M.A.W.P. (Operating)	24.244	bars
Estimated Finished Weight of Flange at given Thk.	70.6	kg.
Estimated Unfinished Weight of Forging at given Thk	93.0	kg.

Flange Rigidity Based on Required Thickness [ASME]:

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

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

$$= 52.14 * 23528.5/1.0 * 999.68 * 0.257 / (2.356 * 202713 * 7.0^2 * 64.101 * 0.3)$$

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

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

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

$$= 52.14 * 31492.8/1.0 * 999.68 * 0.257 / (2.356 * 196612 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.967 \quad (\text{should be } \leq 1)$$

Flange Rigidity Based on Given Thickness [ASME]:

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

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

$$= 52.14 * 23528.5/1.0 * 999.68 * 0.257 / (2.509 * 202713 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.658 \quad (\text{should be } \leq 1)$$

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

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

$$= 52.14 * 31492.8/1.0 * 999.68 * 0.257 / (2.509 * 196612 * 7.0^2 * 64.101 * 0.3)$$

$$= 0.908 \quad (\text{should be } \leq 1)$$

Minimum Design Metal Temperature Results:

Note:

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

Impact Test Temperature provided per Specification -46 °C

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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 ²
HEAD 1		23.034	12	3	581	137.9
CHANNEL 01		23.03	10	3	581	137.9
BODY FLANGE 01		23.034	79	3	581	137.9
SHELL		23.034	10	3	581	137.9
BODY FLANGE 002		23.034	79	3	581	137.9
CHANNEL 002		23.034	10	3	581	137.9
HEAD 002		23.034	12	3	581	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
HEAD 1		23	No Calc	No Calc	10	7.8451
CHANNEL 01		23	No Calc	No Calc	10	7.95159
BODY FLANGE 01		23	No Calc	No Calc	62	60.1726
SHELL		23	No Calc	No Calc	10	7.95245
BODY FLANGE 002		23	No Calc	No Calc	62	60.1726
CHANNEL 002		23	No Calc	No Calc	10	7.95245
HEAD 002		23	No Calc	No Calc	10	7.8451

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note:

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

Shell Side MAWP = 44.133 bars
 Shell Side MAPnc = 51.100 bars
 Channel Side MAWP = 25.277 bars
 Channel Side MAPnc = 25.277 bars

Note:

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

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 125 °C

HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

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$$= (23.034 * 587.0 * 0.987) / (2 * 137.9 * 1.0 - 0.2 * 23.034)$$

$$= 4.8451 + 3.0000 = 7.8451 \text{ mm.}$$

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

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

$$= (23.034 * (0.987 * 587.0 + 0.2 * 7.0)) / (2 * 1.0 * 7.0)$$

$$= 95.519 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.034 * 293.5) / (137.9 * 1.0 - 0.6 * 23.034) + 3.0$$

$$= 7.952 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

[Less Operating Hydrostatic Head Pressure of 0.034 bars](#)

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

$$= (137.9 * 1.0 * 9.0) / (293.5 + 0.6 * 9.0)$$

$$= 41.520 - 0.034 = 41.485 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (587.0 / (2 * 148.25))^2) / 6$$

$$= 0.986578$$

Percent Elong. per UCS-79, VIII-1-01-57 $(75 * t_{nom} / R_f) * (1 - R_f / R_o)$ 8.590 %

[Note: Please Check Requirements of UCS-79 as Elongation is > 5%.](#)

MDMT Calculations in the Knuckle Portion:

Govrn. thk, $t_g = 10.0$, $t_r = 4.845$, $c = 3.0$ mm., $E^* = 1.0$
 Thickness Ratio = $t_r * (E^*) / (t_g - c) = 0.692$, Temp. Reduction = 17 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, $t_g = 12.0$, $t_r = 4.952$, $c = 3.0$ mm., $E^* = 1.0$
 Thickness Ratio = $t_r * (E^*) / (t_g - c) = 0.55$, Temp. Reduction = 27 °C

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

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 125 °C

[CHANNEL 01](#)

[Material UNS Number: K02700](#)

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.03 * 293.5) / (137.9 * 1.0 - 0.6 * 23.03)$$

$$= 4.9516 + 3.0000 = 7.9516 \text{ mm.}$$

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

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

$$= (23.03 * (293.5 + 0.6 * 7.0)) / (1.0 * 7.0)$$

$$= 97.951 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 $(50 * t_{nom} / R_f) * (1 - R_f / R_o)$ 1.692 %

Minimum Design Metal Temperature Results:

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Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr * (E^*) / (tg - c) = 0.707$, Temp. Reduction = 16 °C

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

Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. D at 125 °C

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
 = $(P * R) / (S * E - 0.6 * P)$ per UG-27 (c) (1)
 = $(23.034 * 293.5) / (137.9 * 1.0 - 0.6 * 23.034)$
 = $4.9524 + 3.0000 = 7.9524$ mm.

Actual stress at given pressure and thickness, corroded [Sact]:
 = $(P * (R + 0.6 * t)) / (E * t)$
 = $(23.034 * (293.5 + 0.6 * 7.0)) / (1.0 * 7.0)$
 = 97.967 N./mm²

% Elongation per Table UG-79-1 ($50 * t_{nom} / R_f * (1 - R_f / R_o)$) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr * (E^*) / (tg - c) = 0.707$, Temp. Reduction = 16 °C

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

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 125 °C

CHANNEL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
 = $(P * R) / (S * E - 0.6 * P)$ per UG-27 (c) (1)
 = $(23.034 * 293.5) / (137.9 * 1.0 - 0.6 * 23.034)$
 = $4.9524 + 3.0000 = 7.9524$ mm.

Actual stress at given pressure and thickness, corroded [Sact]:
 = $(P * (R + 0.6 * t)) / (E * t)$
 = $(23.034 * (293.5 + 0.6 * 7.0)) / (1.0 * 7.0)$
 = 97.967 N./mm²

% Elongation per Table UG-79-1 ($50 * t_{nom} / R_f * (1 - R_f / R_o)$) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr * (E^*) / (tg - c) = 0.707$, Temp. Reduction = 16 °C

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

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 125 °C

HEAD 002

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Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (23.034 \cdot 587.0 \cdot 0.987) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.034)$$

$$= 4.8451 + 3.0000 = 7.8451 \text{ mm.}$$

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

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

$$= (23.034 \cdot (0.987 \cdot 587.0 + 0.2 \cdot 7.0)) / (2 \cdot 1.0 \cdot 7.0)$$

$$= 95.519 \text{ N./mm}^2$$

Straight Flange Required Thickness:

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

$$= (23.034 \cdot 293.5) / (137.9 \cdot 1.0 - 0.6 \cdot 23.034) + 3.0$$

$$= 7.952 \text{ mm.}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.034 bars

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

$$= (137.9 \cdot 1.0 \cdot 9.0) / (293.5 + 0.6 \cdot 9.0)$$

$$= 41.520 - 0.034 = 41.485 \text{ bars}$$

Factor K, corroded condition [Kcor]:

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

$$= (2 + (587.0 / (2 \cdot 148.25))^2) / 6$$

$$= 0.986578$$

Percent Elong. per UCS-79, VIII-1-01-57 $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$ 8.590 %

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

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 4.845, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr \cdot (E^*) / (tg - c) = 0.692$, Temp. Reduction = 17 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr \cdot (E^*) / (tg - c) = 0.55$, Temp. Reduction = 27 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °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	= 1.30 * M.A.W.P. * Sa/S	57.373 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	66.430 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	48.547 bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.775 bars
Pressure per App 27-4	= 1.30 * M.A.W.P. * Sa/S	57.373 bars

Exchanger Channel Side Hydrostatic Test Pressures:

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Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	32.860	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	32.803	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	27.804	bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.775	bars
Pressure per App 27-4	= 1.30 * M.A.W.P. * Sa/S	32.860	bars

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

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

$$= 1.3 * 23.0 * 1.0$$

$$= 29.900 \text{ bars}$$

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

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

$$= 1.3 * 23.0 * 1.0$$

$$= 29.900 \text{ bars}$$

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

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

Stresses on Elements due to Test Pressure (N./mm² & bars):

From To	Stress	Allowable	Ratio	Pressure
HEAD 1	124.2	235.8	0.527	29.96
CHANNEL 01	127.4	235.8	0.540	29.96
SHELL	127.4	235.8	0.540	29.96
CHANNEL 002	127.4	235.8	0.540	29.96
HEAD 002	124.2	235.8	0.527	29.96

Stress ratios for Nozzle and Pad Materials (N./mm²):

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

Stress ratios for Pressurized Vessel Elements (N./mm²):

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

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HEAD 002	137.90	137.90	1.000

Minimum			1.000

Stress ratios for Exchanger Materials (N./mm²):

Description	Ambient	Operating	Ratio

Tube Material	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000

Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm²):

Description	Ambient	Operating	Ratio

T4	5.13	223.40	0.023
T1	24.22	217.19	0.112
S2	36.99	217.19	0.170
S1	36.99	217.19	0.170
S3	8.05	223.40	0.036
T2	36.99	217.19	0.170
T3	5.96	223.40	0.027

Elements Suitable for Internal Pressure.

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External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm ²
10	20	No Calc	601	7	0.0016177	98.7135
20	30	505.417	601	7	0.0020537	104.349
30	40	No Calc	...	59	No Calc	No Calc
40	50	5880	601	7	0.00016747	16.7432
50	60	No Calc	...	59	No Calc	No Calc
60	70	505.417	601	7	0.0020537	104.349
70	80	No Calc	601	7	0.0016177	98.7135

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	10	4.60484	1.1	12.7742
20	30	10	4.83369	1.1	16.2041
30	40	62	49.4792	1.1	No Calc
40	50	10	8.13291	1.1	2.60002
50	60	62	49.4792	1.1	No Calc
60	70	10	4.83369	1.1	16.2041
70	80	10	4.60484	1.1	12.7742
Minimum					2.600

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	505.417	12031.9	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	5880	131539	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	505.417	12031.9	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 125 °C

HEAD 1

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
7.000	601.00	85.86	0.0016177	98.71

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$$EMAP = B / (K0 * D / t) = 98.7135 / (0.9 * 85.8571) = 12.7742 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.605	601.00	374.49	0.0003709	37.08

$$EMAP = B / (K0 * D / t) = 37.0789 / (0.9 * 374.4927) = 1.1001 \text{ bars}$$

*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]:

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

$$= (1.837 * 587.0 * 0.987) / (2 * 137.9 * 1.0 - 0.2 * 1.837)$$

$$= 0.3858 + 3.0000 = 3.3858 \text{ mm.}$$

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

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

$$= ((2 * 137.9 * 1.0 * 7.0) / (0.987 * 587.0 + 0.2 * 7.0)) / 1.67$$

$$= 19.913 \text{ bars}$$

Maximum Allowable External Pressure [MAEP]:

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

$$= \min(12.77, 19.9128)$$

$$= 12.774 \text{ bars}$$

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

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

CHANNEL 01

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	505.42	85.86	0.8410	0.0020537	104.35

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 104.3486) / (3 * 85.8571) = 16.2041 \text{ bars}$$

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.834	601.00	505.42	327.75	0.8410	0.0002705	27.04

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 27.043) / (3 * 327.7541) = 1.1001 \text{ bars}$$

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	12031.87	85.86	20.0198	0.0001535	15.35

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 15.3457) / (3 * 85.8571) = 2.383 \text{ bars}$$

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

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	5880.00	85.86	9.7837	0.0001675	16.74

$$EMAP = (4 * B) / (3 * (D / t)) = (4 * 16.7432) / (3 * 85.8571) = 2.6 \text{ bars}$$

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Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.133	601.00	5880.00	117.09	9.7837	0.0000966	9.66

EMAP = $(4*B)/(3*(D/t)) = (4*9.6607)/(3*117.0875) = 1.1$ bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	131538.89	85.86	50.0000	0.0001516	15.15

EMAP = $(4*B)/(3*(D/t)) = (4*15.1537)/(3*85.8571) = 2.3532$ bars

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

CHANNEL 002

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	505.42	85.86	0.8410	0.0020537	104.35

EMAP = $(4*B)/(3*(D/t)) = (4*104.3486)/(3*85.8571) = 16.2041$ bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.834	601.00	505.42	327.75	0.8410	0.0002705	27.04

EMAP = $(4*B)/(3*(D/t)) = (4*27.043)/(3*327.7541) = 1.1001$ bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	12031.87	85.86	20.0198	0.0001535	15.35

EMAP = $(4*B)/(3*(D/t)) = (4*15.3457)/(3*85.8571) = 2.383$ bars

Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 125 °C

HEAD 002

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
7.000	601.00	85.86	0.0016177	98.71

EMAP = $B/(K0*D/t) = 98.7135/(0.9 * 85.8571) = 12.7742$ bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.605	601.00	374.49	0.0003709	37.08

EMAP = $B/(K0*D/t) = 37.0789/(0.9 * 374.4927) = 1.1001$ bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

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

$$= (1.837*587.0*0.987)/(2*137.9*1.0-0.2*1.837)$$

$$= 0.3858 + 3.0000 = 3.3858 \text{ mm.}$$

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

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

$$= ((2*137.9*1.0*7.0)/(0.987*587.0+0.2*7.0))/1.67$$

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= 19.913 bars

Maximum Allowable External Pressure [MAEP]:

= min(MAEP, MAWP)
= min(12.77, 19.9128)
= 12.774 bars

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

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 Element and Detail Weights: Step: 7 11:20pm Feb 6,2022

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	47.807	38935.4	35.8552	40014.4	2.39035
20	30	58.5682	107923	41.2058	110164	2.92841
30	40	88.5944	28277.5	84.1151	28420.6	4.42972
40	50	846.145	841010	595.307	873380	42.3073
50	60	88.5944	28277.5	84.1151	28420.6	4.42972
60	70	58.5682	107923	41.2058	110164	2.92841
70	80	47.807	38935.4	35.8552	40014.4	2.39035
Total		1236	1191281.88	917	1230577.00	61

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	23.347	-48.4167	-0.00002	1
10	Insl	13.6455	-47.625	...	Ins: 40
20	Liqd	57.2924	203.5	...	2
20	Insl	16.717	203.5	...	Ins: 40
20	Nozl	5.16718	203	300.025	T4
20	Nozl	31.9986	203	347.65	T1
30	Liqd	16.9561	44	...	3
30	Insl	4.53732	44	...	Ins: 40
40	Sadl	60.6827	940	435.25	Fixed Saddle
40	Sadl	60.6827	4940	435.25	Sliding Saddle
40	Liqd	504.298	2940	...	4
40	Insl	241.513	2940	...	Ins: 40
40	Nozl	59.6222	196	374.637	S2
40	Nozl	59.6222	5680	374.637	S1
40	Nozl	12.585	146	315.9	S3
40	Wght	150	2940	...	WEIGHT BAFFLE
50	Liqd	16.9561	44	...	5
50	Insl	4.53732	44	...	Ins: 40
60	Liqd	64.7144	203.5	...	5
60	Insl	16.717	203.5	...	Ins: 40
60	Nozl	59.6222	200	374.637	T2
60	Nozl	6.25877	203	303.2	T3
70	Liqd	23.347	98.4167	-0.00002	6
70	Insl	13.6455	97.625	...	Ins: 40
30	FTsh	140.973	125	...	TUBE SHEET
30	Tube	2317.4	3094	...	
30	RTsh	140.973	6063	...	

Total Weight of Each Detail Type

Total Weight of Saddles	121.4
Total Weight of Liquid	706.9
Total Weight of Insulation	311.3
Total Weight of Nozzles	234.9
Total Weight of Weights	150.0

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Element and Detail Weights: Step: 7 11:20pm Feb 6,2022

Total Weight of Exchanger Components	2599.3
Total Weight of Liquid in Tubes	313.4

Sum of the Detail Weights	4437.2 kg.

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
1297.9	4403.5	1297.9	4403.5	1297.9	4714.8
121.4	1190.6	121.4	...	121.4	706.9
234.9	...	234.9	...	...	...
...	447.7	...	311.3	...	...
...	...	...	...	311.3	...
...
...	...	...	...	234.9	313.4
2599.3	...	2599.3	...	...	...
150.0	...	150.0	...	...	...
...	...	...	...	2599.3	...
...	...	...	...	150.0	...
4403.5	6041.8	4403.5	4714.8	4714.8	5735.1

Miscellaneous Weight Percent: 5.0 %

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

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	4403.5 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	6041.8 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	4403.5 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	4714.8 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	4714.8 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	5735.1 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	5400.8 kg.
Field Test Wt.	- Empty Weight + Water (Full)	6058.0 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	448017.0 Cm3
Weight of Ope Liq in tubes :	313.4 kg.
Weight of Water in tubes :	447.7 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	4917.99
20	30	7684.56
30	40	3640.82
40	50	111020

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50	60	3640.82
60	70	7684.56
70	80	4917.99

Total 143506.844 cm²

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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
T4	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	45.8	51.1	125	300	GR 1.1	...	...	...	...
S2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S1	45.8	51.1	125	300	GR 1.1	...	...	...	...
S3	45.8	51.1	125	300	GR 1.1	...	...	...	...
T2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T3	45.8	51.1	125	300	GR 1.1	...	...	...	...

Shellside Flange Rating

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

Channelside Flange Rating

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

Selected Method for Derating ANSI Flange MAWP: None Selected

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

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

How the 50% Stress Method Works:

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

The DNV Method:

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

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 Wind Load Calculation: Step: 9 11:20pm Feb 6,2022

Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed	[V] 200 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 mm.
Percent Wind for Hydrottest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.
Distance Upwind of Crest Lh	0 mm.
Distance from Crest to the Vessel x	0 mm.
Type of Terrain (Hill, Escarpment)	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000

Wind Analysis Results

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

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

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

Force Coefficient	[Cf] 0.616
Structure Height to Diameter ratio	9.906

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]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 600.0 + 123000. = 123600.008 \text{ mm.} \\
 &= 405.512 \text{ ft. Imperial Units}
 \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z \text{ (405.512 ft.) } > 15 \text{ ft.} \\
 &= 2.01 * (z / Zg) ^ { 2 / \text{Alpha} } \\
 &= 2.01 * (405.512 / 900.0) ^ { 2 / 9.5 } \\
 &= 1.699
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

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

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

Topographical Factor [Kzt]:
 = (1 + K1 * K2 * K3)²
 = (1 + 0.0* 0.0* 0.0)²
 = 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
 = max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
 = max(16, 0.00256 * 1.699 * 1.0 * 0.95 * 124.278²)
 = 63.8 psf [311.67] Kgs/m²

Force on the first element [F]:
 = qz * G * Cf * WindArea
 = 63.834 * 0.85 * 0.616 * 2.005
 = 67.0 lbs. [0.3] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m ²
HEAD 1	*****	0.000	0.000	0.000	1.699	1.000	311.670
CHANNEL 01	*****	0.000	0.000	0.000	1.699	1.000	311.670
BODY FLANGE 01	*****	0.000	0.000	0.000	1.699	1.000	311.670
SHELL	*****	0.000	0.000	0.000	1.699	1.000	311.670
BODY FLANGE 002	*****	0.000	0.000	0.000	1.699	1.000	311.670
CHANNEL 002	*****	0.000	0.000	0.000	1.699	1.000	311.670
HEAD 002	*****	0.000	0.000	0.000	1.699	1.000	311.670

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm ²	Elevation mm.	Pressure Kgs/m ²	Force kN
WEIGHT BAFFLE	0.00	125940.00	311.67	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm ²	Wind Pressure Kgs/m ²	Element Wind Load kN
10	20	123600	913.2	1862.66	311.67	0.17888
20	30	123600	913.2	3716.72	311.67	0.35694
30	40	123600	889.2	782.496	311.67	0.075149
40	50	123600	913.2	53696.2	311.67	5.15683
50	60	123600	889.2	782.496	311.67	0.075149
60	70	123600	913.2	3716.72	311.67	0.35694
70	80	123600	913.2	1862.66	311.67	0.17888

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

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

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 Earthquake Load Calculation: Step: 10 11:20pm Feb 6,2022

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		0.900
Long Period Acceleration Value S1		0.537
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		B
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.390

Seismic Analysis Results:

$$Sms = Fa * Ss = 1.0 * 0.9 = 0.9$$

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

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

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

$$= \text{Max}(0.48, 0.39)$$

$$= 0.480$$

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

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

$$= \text{Max}(0.372, 0.624)$$

$$= 0.624$$

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

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

$$= 0.020 * (2.9216^{0.75})$$

$$= 0.045 \text{ seconds}$$

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

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

$$= 0.030$$

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

$$= \text{Minimum Value of } (1.4 * 0.045, 0.03) \text{ per 12.8.2}$$

$$= 0.030$$

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

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

$$= 0.3 * Sds * W * I$$

$$= 0.3 * 0.48 * 53 * 1.25$$

$$= 9.533 \text{ kN}$$

Vertical load per 12.4-4, [YEq]:

$$= 0.2 * Sds * W$$

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$$= 0.2 * 0.48 * 53 = 5.08 \text{ kN}$$

Final Base Shear, $V = 6.67 \text{ kN}$
 Final Vertical Load, $YEq = 3.56 \text{ kN}$

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	290.5	5.88444	0.74144
20	30	290.5	5.88444	0.74144
30	40	290.5	5.88444	0.74144
40	Sadl	290.5	5.88444	0.74144
Sadl	50	290.5	5.88444	0.74144
40	50	290.5	5.88444	0.74144
50	60	290.5	5.88444	0.74144
60	70	290.5	5.88444	0.74144
70	80	290.5	5.88444	0.74144

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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Shop/Field Installation Options :

Insulation is installed in the Field.

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

Center of Gravity of Saddles	3553.176 mm.
Center of Gravity of Liquid	3586.333 mm.
Center of Gravity of Insulation	3552.272 mm.
Center of Gravity of Nozzles	3804.880 mm.
Center of Gravity of Added Weights (Operating)	3553.176 mm.
Center of Gravity of Added Weights (Empty)	3553.176 mm.
Center of Gravity of Tubesheet(s)	3551.000 mm.
Center of Gravity of Tubes	3551.000 mm.
Center of Gravity of Bare Shell New and Cold	3548.732 mm.
Center of Gravity of Bare Shell Corroded	3547.492 mm.
Vessel CG in the Operating Condition	3566.223 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3564.007 mm.
Vessel CG in the Test Condition	3560.619 mm.

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

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 Horizontal Vessel Analysis (Ope.): Step: 12 11:20pm Feb 6,2022

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

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	thetal	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm ²
Shell Allowable Stress used in Calculation		137.90	N./mm ²
Head Allowable Stress used in Calculation		137.90	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		39.17	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm ²	N./mm ²	

Long. Stress at Top of Midspan	39.03	137.90	
Long. Stress at Bottom of Midspan	58.64	137.90	
Long. Stress at Top of Saddles	79.11	137.90	
Long. Stress at Bottom of Saddles	32.05	137.90	

Tangential Shear in Shell	14.61	110.32	
Circ. Stress at Horn of Saddle	13.35	172.38	
Circ. Compressive Stress in Shell	1.92	137.90	

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * (6.4/2 + 0) * 600.0/514.4191$$

$$= 11.2 \text{ kN}$$

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

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

$$= \max(0.62, 0.0, 0) * 600.0/4000.0$$

$$= 0.1 \text{ kN}$$

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

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

$$= \max(6.67, 0.0, 0) * 600.0/4000.0$$

$$= 1.0 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * (7/2 + 0) * 600.0/514.4191$$

$$= 11.7 \text{ kN}$$

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Load Combination Results for Q + Wind or Seismic [Q]:
 = Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
 = 27 + Max(0.1, 11, 1, 12)
 = 39.2 kN

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	39.76	kN
Transverse Shear Load Saddle	3.34	kN
Longitudinal Shear Load Saddle	6.67	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

$$\begin{aligned}
 &= -Q \cdot a \left[1 - \left(1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left(1 + \frac{4h^2}{3L} \right) \right] \\
 &= -39 \cdot 992.0 \left[1 - \left(1 - \frac{992.0}{5880.0} + \frac{297.0^2 - 0.0^2}{2 \cdot 992.0 \cdot 5880.0} \right) / \left(1 + \frac{4 \cdot 0.0}{3 \cdot 5880.0} \right) \right] \\
 &= -6263.5 \text{ N-m}
 \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left(1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left(1 + \frac{4h^2}{3L} \right) - 4a/L \\
 &= \frac{39 \cdot 5880}{4} \left(1 + 2 \frac{297^2 - 0^2}{5880^2} \right) / \left(1 + \frac{4 \cdot 0}{3 \cdot 5880} \right) - 4 \cdot 992 / 5880 \\
 &= 19023.0 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 23.017 \cdot 297.0 / (2 \cdot 7.0) - 19023.0 / (\pi \cdot 297.0^2 \cdot 7.0) \\
 &= 39.03 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 23.017 \cdot 297.0 / (2 \cdot 7.0) + 19023.0 / (\pi \cdot 297.0^2 \cdot 7.0) \\
 &= 58.64 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 23.017 \cdot 297.0 / (2 \cdot 7.0) - 6263.5 / (0.1066 \cdot \pi \cdot 297.0^2 \cdot 7.0) \\
 &= 79.11 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 23.017 \cdot 297.0 / (2 \cdot 7.0) + 6263.5 / (0.1923 \cdot \pi \cdot 297.0^2 \cdot 7.0) \\
 &= 32.05 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{L + (4 \cdot h^2 / 3)} \\
 &= \frac{39(5880.0 - 2 \cdot 992.0)}{5880.0 + (4 \cdot 0.0 / 3)} \\
 &= 26.0 \text{ kN}
 \end{aligned}$$

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

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

$$= 1.1707 * 25.95 / (297.0 * 7.0)$$

$$= 14.61 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

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

$$= 0.78 * \text{sqrt}(297.0 * 7.0)$$

$$= 35.565 \text{ mm.}$$

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

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

$$= - 0.7603 * 39 * 0.1 / (7.0 * (150.0 + 35.56 + 35.56))$$

$$= -1.92 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \text{min}(150.0 + 1.56 * \text{sqrt}(297.0 * 7.0), 2 * 992.0)$$

$$= 221.13 \text{ mm.}$$

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

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

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

$$= 1.0000$$

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

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

$$= - 0.7603 * 39 * 0.1 / (221.13(7.0 + 1.0 * 10.0))$$

$$= -0.79 \text{ N./mm}^2$$

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

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

$$= -39 / (4(7.0 + 1.0 * 10.0) 221.13) -$$

$$3 * 0.053 * 39 / (2(7.0 + 1.0 * 10.0)^2)$$

$$= -13.35 \text{ N./mm}^2$$

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

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

$$= 0.000012 * 4000.0 * (125.0 - 21.1)$$

$$= 5.096 \text{ mm.}$$

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

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

$$\text{Value } I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay) = 0.165E+05 \text{ cm}^4$$

$$\text{Value } As = \text{Sumof}(A) - \text{Ashell} = 78.6 \text{ cm}^2$$

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

$$F_h = K1 * Q = 0.2035 * 39.166 = 7.9712 \text{ kN}$$

$$\begin{aligned} \text{Tension Stress, } S_t &= (F_h / A_s) = 1.0136 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2 \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\theta) / \theta \\ &= 600.0 - 293.5 * \sin(1.0472) / 1.0472 \\ &= 357.277 \text{ mm.} \end{aligned}$$

$$\text{Bending Moment, } M = F_h * d = 2849.0820 \text{ N-m}$$

$$\begin{aligned} \text{Bending Stress, } S_b &= (M * C1 / I) = 2.2859 \text{ N./mm}^2 \\ \text{Allowed Stress, } S_a &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= (3(Q + \text{Saddle_Wt}) \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2} \\ &= (3(39 + 0.6)180.0 / (4 * 545.0 * 137.9))^{1/2} \\ &= 8.452 \text{ mm.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$\begin{aligned} &= \text{Web Length} / (\text{Nr ribs} - 1) \\ &= 542.9979 / (4 - 1) \\ &= 180.999 \text{ mm.} \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned} &= e * B_{pwid} / 2 \\ &= 181.0 * 180.0 / 2 \\ &= 162.899 \text{ cm}^2 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned} &= A_p * B_p \\ &= 162.9 * 0.04 \\ &= 6.504 \text{ kN} \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 14.0 + 9.05 \\ &= 23.050 \text{ cm}^2 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned} &= P / A_r \\ &= 6.5 / 23.05 \\ &= 2.822 \text{ N./mm}^2 \end{aligned}$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

$$\begin{aligned} &= F1 / (2 * B_{plen}) * e * r1 / 2 \\ &= 6.7 / (2 * 545.0) * 181.0 * 427.25 / 2 \\ &= 236.808 \text{ N-m} \end{aligned}$$

Compressive Allowable, $KL/R < C_c$ (12.2313 < 138.1347) per AISC E2-1 [Sca]:

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$$\begin{aligned}
&= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3)) \\
&= (1 - (12.23)^2 / (2 * 138.13^2)) * 207 / \\
&\quad (5/3 + 3 * (12.23) / (8 * 138.13) - (12.23^3) / (8 * 138.13^3)) \\
&= 121.215 \text{ N./mm}^2
\end{aligned}$$

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

$$\begin{aligned}
&= Sc/Sca + (Rm * Distance Side/I) / Sba \\
&= 2.82/121.21 + (236.81 * 75.0/2812500) / 137.9 \\
&= 0.069
\end{aligned}$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

Compressive Allowable, KL/R < Cc (9.5652 < 138.1347) per AISC E2-1 [Sca]:

$$\begin{aligned}
&= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3)) \\
&= (1 - (9.57)^2 / (2 * 138.13^2)) * 207 / \\
&\quad (5/3 + 3 * (9.57) / (8 * 138.13) - (9.57^3) / (8 * 138.13^3)) \\
&= 121.916 \text{ N./mm}^2
\end{aligned}$$

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

$$\begin{aligned}
&= Sc/Sca + (Rm * Distance Center/I) / Sba \\
&= 4.0/121.92 + (314.65 * 75.0/282.675) / 137.9 \\
&= 0.093
\end{aligned}$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification		SA-193 B7
Bolt Allowable Stress	Stba	172.38 N./mm ²
Bolt Corrosion Allowance	Bca	0.0 mm.
Distance from Bolts to Edge	Edgedis	72.0 mm.
Nominal Bolt Diameter	Bnd	24.0000 mm.
Thread Series	Series	TEMA Metric
BasePlate Allowable Stress	S	108.25 N./mm ²
Area Available in a Single Bolt	BltArea	3.1275 cm ²
Saddle Load QO (Weight)	QO	28.1 kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.0 kN
Maximum Transverse Force	Ft	3.3 kN
Maximum Longitudinal Force	F1	11.4 kN
Saddle Bolted to Steel Foundation		Yes

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

$$\begin{aligned}
&= F1 / (Stba * Nbolts) \\
&= 11.37 / (172.38 * 4.0) \\
&= 0.1650 \text{ cm}^2
\end{aligned}$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

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

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$$= 600.0 * 3.34 + 0.0$$

$$= 2002.70 \text{ N-m}$$

Eccentricity (e):

$$= R_{mom} / QO$$

$$= 2002.7/28.09$$

$$= 71.28 \text{ mm.} < B_{plen}/6 \text{ --> No Uplift in Transverse direction}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

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

$$= \max[0.0, 0.165, 0.0]$$

$$= 0.1650 \text{ cm}^2$$

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

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

Input and Calculated Values:

Vessel Mean Radius	Rm	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm ²
Shell Allowable Stress used in Calculation		137.90	N./mm ²
Head Allowable Stress used in Calculation		137.90	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		39.51	kN

Horizontal Vessel Analysis Results:	Actual	Allowable
	N./mm ²	N./mm ²

Long. Stress at Top of Midspan	38.94	137.90
Long. Stress at Bottom of Midspan	58.72	137.90
Long. Stress at Top of Saddles	79.38	137.90
Long. Stress at Bottom of Saddles	31.90	137.90

Tangential Shear in Shell	14.74	110.32
Circ. Stress at Horn of Saddle	13.47	172.38
Circ. Compressive Stress in Shell	1.94	137.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * (6.4/2 + 0) * 600.0/514.4191$$

$$= 11.2 \text{ kN}$$

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

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

$$= \max(0.62, 11.37, 0) * 600.0/4000.0$$

$$= 1.7 \text{ kN}$$

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

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

$$= \max(6.67, 11.37, 0) * 600.0/4000.0$$

$$= 1.7 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * (7/2 + 0) * 600.0/514.4191$$

$$= 11.7 \text{ kN}$$

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

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

$$= 28 + \text{Max}(2, 11, 2, 12)$$

$$= 39.5 \text{ kN}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	40.11 kN
Transverse Shear Load Saddle	3.34 kN
Longitudinal Shear Load Saddle	11.37 kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

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

$$= -40*992.0 [1 - (1 - 992.0/5880.0 + (297.0^2 - 0.0^2) / (2*992.0*5880.0)) / (1 + (4*0.0) / (3*5880.0))]$$

$$= -6318.8 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

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

$$= 40*5880/4 (1 + 2(297^2 - 0^2)/(5880^2)) / (1 + (4*0)/(3*5880)) - 4*992/5880$$

$$= 19190.8 \text{ N-m}$$

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

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

$$= 23.017 * 297.0 / (2 * 7.0) - 19190.8 / (\pi * 297.0^2 * 7.0)$$

$$= 38.94 \text{ N./mm}^2$$

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

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

$$= 23.017 * 297.0 / (2 * 7.0) + 19190.8 / (\pi * 297.0^2 * 7.0)$$

$$= 58.72 \text{ N./mm}^2$$

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

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

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$$= 23.017 * 297.0 / (2 * 7.0) - 6318.8 / (0.1066 * \pi * 297.0^2 * 7.0)$$

$$= 79.38 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [σ_4]:

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

$$= 23.017 * 297.0 / (2 * 7.0) + 6318.8 / (0.1923 * \pi * 297.0^2 * 7.0)$$

$$= 31.90 \text{ N./mm}^2$$

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

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

$$= 40(5880.0 - 2 * 992.0) / (5880.0 + (4 * 0.0 / 3))$$

$$= 26.2 \text{ kN}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) [τ_2]:

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

$$= 1.1707 * 26.18 / (297.0 * 7.0)$$

$$= 14.74 \text{ N./mm}^2$$

Decay Length (4.15.22) [x_1, x_2]:

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

$$= 0.78 * \sqrt{297.0 * 7.0}$$

$$= 35.565 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [σ_6]:

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

$$= -0.7603 * 40 * 0.1 / (7.0 * (150.0 + 35.56 + 35.56))$$

$$= -1.94 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min(150.0 + 1.56 * \sqrt{297.0 * 7.0}, 2 * 992.0)$$

$$= 221.13 \text{ mm.}$$

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

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

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

$$= 1.0000$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [$\sigma_{6,r}$]:

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

$$= -0.7603 * 40 * 0.1 / (221.13(7.0 + 1.0 * 10.0))$$

$$= -0.80 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, $L \geq 8R_m$ (4.15.27) [$\sigma_{7,r}$]:

$$= -Q / (4(t + \eta * t_r) b_1) - 3 * K_7 * Q / (2(t + \eta * t_r)^2)$$

$$= -40 / (4(7.0 + 1.0 * 10.0) 221.13) -$$

$$3 * 0.053 * 40 / (2(7.0 + 1.0 * 10.0)^2)$$

$$= -13.47 \text{ N./mm}^2$$

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

B | D | Y | A | AY | Io |

Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

Value C1 = Sumof (Ay) / Sumof (A) = 132. mm.
 Value I = Sumof (Io) - C1*Sumof (Ay) = 0.165E+05 cm**4
 Value As = Sumof (A) - Ashell = 78.6 cm^2

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

$Fh = K1 * Q = 0.2035 * 39.512 = 8.0415 \text{ kN}$

Tension Stress, St = (Fh/As) = 1.0225 N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:

= B - R * sin(theta) / theta
 = 600.0 - 293.5 * sin(1.0472) / 1.0472
 = 357.277 mm.

Bending Moment, M = Fh * d = 2874.2144 N-m

Bending Stress, Sb = (M * C1 / I) = 2.3060 N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss:

= (3 (Q + Saddle_Wt) BasePlateWidth / (4 * BasePlateLength * AllStress))^{1/2}
 = (3 (40 + 0.6) 180.0 / (4 * 545.0 * 137.9))^{1/2}
 = 8.488 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

= Web Length / (Nr ribs - 1)
 = 542.9979 / (4 - 1)
 = 180.999 mm.

Baseplate Pressure Area [Ap]:

= e * Bpwid / 2
 = 181.0 * 180.0 / 2
 = 162.899 cm^2

Axial Load [P]:

= Ap * Bp
 = 162.9 * 0.04
 = 6.561 kN

Area of the Rib and Web [Ar]:

= Rib Area + Web Area
 = 14.0 + 9.05
 = 23.050 cm^2

Compressive Stress [Sc]:

= P / Ar
 = 6.6 / 23.05
 = 2.847 N./mm^2

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

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	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

$$= F_l / (2 * B_{plen}) * e * r_l / 2$$

$$= 11.4 / (2 * 545.0) * 181.0 * 427.25 / 2$$

$$= 403.598 \text{ N-m}$$

Compressive Allowable, $KL/R < C_c$ (12.2313 < 138.1347) per AISC E2-1 [Sca]:

$$= (1 - (Kl_r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl_r) / (8 * C_c) - (Kl_r^3) / (8 * C_c^3))$$

$$= (1 - (12.23)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (12.23) / (8 * 138.13) - (12.23^3) / (8 * 138.13^3))$$

$$= 121.215 \text{ N./mm}^2$$

AISC Unity Check of Outside Ribs (must be ≤ 1)

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

$$= 2.85 / 121.21 + (403.6 * 75.0 / 2812500) / 137.9$$

$$= 0.102$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

Compressive Allowable, $KL/R < C_c$ (9.5652 < 138.1347) per AISC E2-1 [Sca]:

$$= (1 - (Kl_r)^2 / (2 * C_c^2)) * F_y / (5/3 + 3 * (Kl_r) / (8 * C_c) - (Kl_r^3) / (8 * C_c^3))$$

$$= (1 - (9.57)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (9.57) / (8 * 138.13) - (9.57^3) / (8 * 138.13^3))$$

$$= 121.916 \text{ N./mm}^2$$

AISC Unity Check of Inside Ribs (must be ≤ 1)

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

$$= 4.03 / 121.92 + (536.27 * 75.0 / 282.675) / 137.9$$

$$= 0.136$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification	SA-193 B7	
Bolt Allowable Stress	Stba	172.38 N./mm ²
Bolt Corrosion Allowance	Bca	0.0 mm.
Distance from Bolts to Edge	Edgedis	72.0 mm.
Nominal Bolt Diameter	Bnd	24.0000 mm.
Thread Series	Series	TEMA Metric
BasePlate Allowable Stress	S	108.25 N./mm ²
Area Available in a Single Bolt	BltArea	3.1275 cm ²
Saddle Load QO (Weight)	QO	28.4 kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.7 kN
Maximum Transverse Force	Ft	3.3 kN
Maximum Longitudinal Force	Fl	11.4 kN
Saddle Bolted to Steel Foundation		Yes

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

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Bolt Area due to Shear Load [Bltarears]:

$$\begin{aligned} &= F1 / (Stba * Nbolts) \\ &= 11.37 / (172.38 * 4.0) \\ &= 0.1650 \text{ cm}^2 \end{aligned}$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 600.0 * 3.34 + 0.0 \\ &= 2002.70 \text{ N-m} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / QO \\ &= 2002.7 / 28.43 \\ &= 70.41 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction} \end{aligned}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\ &= \max[0.0, 0.165, 0.0] \\ &= 0.1650 \text{ cm}^2 \end{aligned}$$

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

Horizontal Vessel Stress Calculations : Test Case

Input and Calculated Values:

Vessel Mean Radius	Rm	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	thetal	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm ²
Shell Allowable Stress used in Calculation		235.81	N./mm ²
Head Allowable Stress used in Calculation		235.81	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		32.60	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm ²	N./mm ²	

Long. Stress at Top of Midspan	55.34	235.81	
Long. Stress at Bottom of Midspan	71.66	235.81	
Long. Stress at Top of Saddles	88.70	235.81	
Long. Stress at Bottom of Saddles	49.53	235.81	

Tangential Shear in Shell	12.16	188.65	
Circ. Stress at Horn of Saddle	11.11	353.71	
Circ. Compressive Stress in Shell	1.60	235.81	

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

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

$$= 3.0 * (2.1/2 + 0) * 600.0/514.4191$$

$$= 3.7 \text{ kN}$$

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

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

$$= \max(0.21, 0.0, 0) * 600.0/4000.0$$

$$= 0.0 \text{ kN}$$

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

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

$$= \max(1.33, 0.0, 0) * 600.0/4000.0$$

$$= 0.2 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * (1/2 + 0) * 600.0/514.4191$$

$$= 2.3 \text{ kN}$$

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Load Combination Results for Q + Wind or Seismic [Q]:
 = Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
 = 29 + Max(0.0, 4, 0.2, 2)
 = 32.6 kN

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	33.20	kN
Transverse Shear Load Saddle	1.05	kN
Longitudinal Shear Load Saddle	1.33	kN

Hydrostatic Test Pressure at center of Vessel: 29.929 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

$$\begin{aligned}
 &= -Q \cdot a \left[1 - \left(1 - \frac{a}{L} + \frac{R^2 - h^2}{2a \cdot L} \right) / \left(1 + \frac{4h^2}{3L} \right) \right] \\
 &= -33 \cdot 992.0 \left[1 - \left(1 - \frac{992.0}{5880.0} + \frac{297.0^2 - 0.0^2}{2 \cdot 992.0 \cdot 5880.0} \right) / \left(1 + \frac{4 \cdot 0.0}{3 \cdot 5880.0} \right) \right] \\
 &= -5213.5 \text{ N-m}
 \end{aligned}$$

Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left(1 + 2 \frac{R^2 - h^2}{L^2} \right) / \left(1 + \frac{4h^2}{3L} \right) - 4a/L \\
 &= \frac{33 \cdot 5880}{4} \left(1 + 2 \frac{297^2 - 0^2}{5880^2} \right) / \left(1 + \frac{4 \cdot 0}{3 \cdot 5880} \right) - 4 \cdot 992 / 5880 \\
 &= 15833.9 \text{ N-m}
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.929 \cdot 297.0 / (2 \cdot 7.0) - 15833.9 / (\pi \cdot 297.0^2 \cdot 7.0) \\
 &= 55.34 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.929 \cdot 297.0 / (2 \cdot 7.0) + 15833.9 / (\pi \cdot 297.0^2 \cdot 7.0) \\
 &= 71.66 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.929 \cdot 297.0 / (2 \cdot 7.0) - 5213.5 / (0.1066 \cdot \pi \cdot 297.0^2 \cdot 7.0) \\
 &= 88.70 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.929 \cdot 297.0 / (2 \cdot 7.0) + 5213.5 / (0.1923 \cdot \pi \cdot 297.0^2 \cdot 7.0) \\
 &= 49.53 \text{ N./mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{L + (4 \cdot h^2 / 3)} \\
 &= \frac{33(5880.0 - 2 \cdot 992.0)}{5880.0 + (4 \cdot 0.0 / 3)} \\
 &= 21.6 \text{ kN}
 \end{aligned}$$

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 Horizontal Vessel Analysis (Test): Step: 13 11:20pm Feb 6,2022

Shear Stress in the shell no rings, not stiffened (4.15.14) [τ_2]:

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

$$= 1.1707 * 21.6 / (297.0 * 7.0)$$

$$= 12.16 \text{ N./mm}^2$$

Decay Length (4.15.22) [x_1, x_2]:

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

$$= 0.78 * \text{sqrt}(297.0 * 7.0)$$

$$= 35.565 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [σ_6]:

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

$$= - 0.7603 * 33 * 0.1 / (7.0 * (150.0 + 35.56 + 35.56))$$

$$= -1.60 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min(150.0 + 1.56 * \text{sqrt}(297.0 * 7.0), 2 * 992.0)$$

$$= 221.13 \text{ mm.}$$

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

$$= 1.0000 \text{ Materials are the same, test case}$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [σ_6, r]:

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

$$= - 0.7603 * 33 * 0.1 / (221.13(7.0 + 1.0 * 10.0))$$

$$= -0.66 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, $L \geq 8R_m$ (4.15.27) [σ_7, r]:

$$= -Q / (4(t + \eta * t_r) b_1) - 3 * K_7 * Q / (2(t + \eta * t_r)^2)$$

$$= -33 / (4(7.0 + 1.0 * 10.0) 221.13) -$$

$$3 * 0.053 * 33 / (2(7.0 + 1.0 * 10.0)^2)$$

$$= -11.11 \text{ N./mm}^2$$

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

$$\text{Value } C_1 = \text{Sumof}(Ay) / \text{Sumof}(A) = 132. \text{ mm.}$$

$$\text{Value } I = \text{Sumof}(Io) - C_1 * \text{Sumof}(Ay) = 0.165E+05 \text{ cm}^4$$

$$\text{Value } A_s = \text{Sumof}(A) - A_{\text{shell}} = 78.6 \text{ cm}^2$$

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

$$F_h = K_1 * Q = 0.2035 * 32.6 = 6.6349 \text{ kN}$$

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$$\begin{aligned} \text{Tension Stress, } St &= (Fh/As) = 0.8437 \text{ N./mm}^2 \\ \text{Allowed Stress, } Sa &= 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2 \end{aligned}$$

Saddle Splitting Dimension [d]:

$$\begin{aligned} &= B - R * \sin(\text{theta}) / \text{theta} \\ &= 600.0 - 293.5 * \sin(1.0472) / 1.0472 \\ &= 357.277 \text{ mm.} \end{aligned}$$

$$\text{Bending Moment, } M = Fh * d = 2371.4509 \text{ N-m}$$

$$\begin{aligned} \text{Bending Stress, } Sb &= (M * C1 / I) = 1.9026 \text{ N./mm}^2 \\ \text{Allowed Stress, } Sa &= 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2 \end{aligned}$$

Minimum Thickness of Baseplate per Moss:

$$\begin{aligned} &= (3(Q + \text{Saddle_Wt}) \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2} \\ &= (3(33 + 0.6)180.0 / (4 * 545.0 * 137.9))^{1/2} \\ &= 7.722 \text{ mm.} \end{aligned}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

$$\begin{aligned} &= \text{Web Length} / (\text{Nr ribs} - 1) \\ &= 542.9979 / (4 - 1) \\ &= 180.999 \text{ mm.} \end{aligned}$$

Baseplate Pressure Area [Ap]:

$$\begin{aligned} &= e * \text{Bpwid} / 2 \\ &= 181.0 * 180.0 / 2 \\ &= 162.899 \text{ cm}^2 \end{aligned}$$

Axial Load [P]:

$$\begin{aligned} &= Ap * Bp \\ &= 162.9 * 0.03 \\ &= 5.413 \text{ kN} \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 14.0 + 9.05 \\ &= 23.050 \text{ cm}^2 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned} &= P/Ar \\ &= 5.4/23.05 \\ &= 2.349 \text{ N./mm}^2 \end{aligned}$$

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

$$\begin{aligned} &= Fl / (2 * \text{Bplen}) * e * r1 / 2 \\ &= 1.3 / (2 * 545.0) * 181.0 * 427.25 / 2 \\ &= 47.362 \text{ N-m} \end{aligned}$$

Compressive Allowable, $KL/R < Cc$ (12.2313 < 138.1347) per AISC E2-1 [Sca]:

$$\begin{aligned} &= (1 - (Klr)^2 / (2 * Cc^2)) * Fy / (5/3 + 3 * (Klr) / (8 * Cc) - (Klr^3) / (8 * Cc^3)) \\ &= (1 - (12.23)^2 / (2 * 138.13^2)) * 207 / \\ &\quad (5/3 + 3 * (12.23) / (8 * 138.13) - (12.23^3) / (8 * 138.13^3)) \\ &= 121.215 \text{ N./mm}^2 \end{aligned}$$

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

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

$$= 2.35/121.21 + (47.36 * 75.0/2812500)/137.9$$

$$= 0.029$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

Compressive Allowable, $KL/R < Cc$ (9.5652 < 138.1347) per AISC E2-1 [Sca]:

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

$$= (1 - (9.57)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (9.57) / (8 * 138.13) - (9.57^3) / (8 * 138.13^3))$$

$$= 121.916 \text{ N./mm}^2$$

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

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

$$= 3.33/121.92 + (62.93 * 75.0/282.675)/137.9$$

$$= 0.039$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4
Total Number of Bolts in Tension/Baseplate	Nbt	2
Bolt Material Specification		SA-193 B7
Bolt Allowable Stress	Stba	172.38 N./mm ²
Bolt Corrosion Allowance	Bca	0.0 mm.
Distance from Bolts to Edge	Edgedis	72.0 mm.
Nominal Bolt Diameter	Bnd	24.0000 mm.
Thread Series	Series	TEMA Metric
BasePlate Allowable Stress	S	108.25 N./mm ²
Area Available in a Single Bolt	BltArea	3.1275 cm ²
Saddle Load QO (Weight)	QO	29.5 kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2 kN
Maximum Transverse Force	Ft	1.1 kN
Maximum Longitudinal Force	F1	1.3 kN
Saddle Bolted to Steel Foundation		Yes

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

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

$$= 1.33 / (172.38 * 4.0)$$

$$= 0.0194 \text{ cm}^2$$

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

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

$$= 600.0 * 1.05 + 0.0$$

$$= 631.76 \text{ N-m}$$

Eccentricity (e):

$$= Rmom / QO$$

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= 631.76/29.51
 = 21.40 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, 0.0194, 0.0]
 = 0.0194 cm²

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

Input and Calculated Values:

Vessel Mean Radius	Rm	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm ²
Shell Allowable Stress used in Calculation		235.81	N./mm ²
Head Allowable Stress used in Calculation		235.81	N./mm ²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		32.82	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm ²	N./mm ²	

Long. Stress at Top of Midspan	55.28	235.81	
Long. Stress at Bottom of Midspan	71.71	235.81	
Long. Stress at Top of Saddles	88.87	235.81	
Long. Stress at Bottom of Saddles	49.43	235.81	

Tangential Shear in Shell	12.25	188.65	
Circ. Stress at Horn of Saddle	11.19	353.71	
Circ. Compressive Stress in Shell	1.61	235.81	

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
 = Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
 = 3.0 * (2.1/2 + 0) * 600.0/514.4191
 = 3.7 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
 = max(Fl, Friction Load, Sum of X Forces) * B / Ls
 = max(0.21, 0.0, 0) * 600.0/4000.0
 = 0.0 kN

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

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

$$= \max(1.33, 0.0, 0) * 600.0/4000.0$$

$$= 0.2 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

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

$$= 3.0 * (1/2 + 0) * 600.0/514.4191$$

$$= 2.3 \text{ kN}$$

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

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

$$= 29 + \max(0.0, 4, 0.2, 2)$$

$$= 32.8 \text{ kN}$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	33.42 kN
Transverse Shear Load Saddle	1.05 kN
Longitudinal Shear Load Saddle	1.33 kN

Hydrostatic Test Pressure at center of Vessel: 29.929 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

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

$$= -33 * 992.0 [1 - (1 - 992.0 / 5880.0 + (297.0^2 - 0.0^2) / (2 * 992.0 * 5880.0)) / (1 + (4 * 0.0) / (3 * 5880.0))]$$

$$= -5248.8 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

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

$$= 33 * 5880 / 4 (1 + 2(297^2 - 0^2) / (5880^2)) / (1 + (4 * 0) / (3 * 5880)) - 4 * 992 / 5880$$

$$= 15941.0 \text{ N-m}$$

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

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

$$= 29.929 * 297.0 / (2 * 7.0) - 15941.0 / (\pi * 297.0^2 * 7.0)$$

$$= 55.28 \text{ N./mm}^2$$

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

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

$$= 29.929 * 297.0 / (2 * 7.0) + 15941.0 / (\pi * 297.0^2 * 7.0)$$

$$= 71.71 \text{ N./mm}^2$$

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

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

$$= 29.929 * 297.0 / (2 * 7.0) - 5248.8 / (0.1066 * \pi * 297.0^2 * 7.0)$$

$$= 88.87 \text{ N./mm}^2$$

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Longitudinal Stress at Bottom of Shell at Support (4.15.11) [σ^4]:

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

$$= 29.929 * 297.0 / (2 * 7.0) + -5248.8 / (0.1923 * \pi * 297.0^2 * 7.0)$$

$$= 49.43 \text{ N./mm}^2$$

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

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

$$= 33(5880.0 - 2 * 992.0) / (5880.0 + (4 * 0.0 / 3))$$

$$= 21.7 \text{ kN}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) [τ_2]:

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

$$= 1.1707 * 21.75 / (297.0 * 7.0)$$

$$= 12.25 \text{ N./mm}^2$$

Decay Length (4.15.22) [x_1, x_2]:

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

$$= 0.78 * \sqrt{297.0 * 7.0}$$

$$= 35.565 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [σ_6]:

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

$$= -0.7603 * 33 * 0.1 / (7.0 * (150.0 + 35.56 + 35.56))$$

$$= -1.61 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

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

$$= \min(150.0 + 1.56 * \sqrt{297.0 * 7.0}, 2 * 992.0)$$

$$= 221.13 \text{ mm.}$$

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

$$= 1.0000 \text{ Materials are the same, test case}$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [σ_6, r]:

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

$$= -0.7603 * 33 * 0.1 / (221.13(7.0 + 1.0 * 10.0))$$

$$= -0.66 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, $L \geq 8Rm$ (4.15.27) [σ_7, r]:

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

$$= -33 / (4(7.0 + 1.0 * 10.0)221.13) - 3 * 0.053 * 33 / (2(7.0 + 1.0 * 10.0)^2)$$

$$= -11.19 \text{ N./mm}^2$$

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05

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Totals ... | ... | ... | 99. | 1314431. | 0.339E+05 |

Value $C1 = \text{Sumof}(Ay) / \text{Sumof}(A)$ = 132. mm.
 Value $I = \text{Sumof}(Io) - C1 * \text{Sumof}(Ay)$ = 0.165E+05 cm**4
 Value $As = \text{Sumof}(A) - \text{Ashell}$ = 78.6 cm^2

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

$Fh = K1 * Q = 0.2035 * 32.821 = 6.6797 \text{ kN}$

Tension Stress, $St = (Fh / As)$ = 0.8494 N./mm^2
 Allowed Stress, $Sa = 0.6 * \text{Yield Str}$ = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:

= $B - R * \sin(\theta) / \theta$
 = $600.0 - 293.5 * \sin(1.0472) / 1.0472$
 = 357.277 mm.

Bending Moment, $M = Fh * d$ = 2387.4902 N-m

Bending Stress, $Sb = (M * C1 / I)$ = 1.9155 N./mm^2
 Allowed Stress, $Sa = 2/3 * \text{Yield Str}$ = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss:

= $(3 * (Q + \text{Saddle_Wt}) * \text{BasePlateWidth} / (4 * \text{BasePlateLength} * \text{AllStress}))^{1/2}$
 = $(3 * (33 + 0.6) * 180.0 / (4 * 545.0 * 137.9))^{1/2}$
 = 7.748 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

= $\text{Web Length} / (\text{Nrings} - 1)$
 = $542.9979 / (4 - 1)$
 = 180.999 mm.

Baseplate Pressure Area [Ap]:

= $e * \text{Bpwid} / 2$
 = $181.0 * 180.0 / 2$
 = 162.899 cm^2

Axial Load [P]:

= $Ap * Bp$
 = $162.9 * 0.03$
 = 5.450 kN

Area of the Rib and Web [Ar]:

= $\text{Rib Area} + \text{Web Area}$
 = $14.0 + 9.05$
 = 23.050 cm^2

Compressive Stress [Sc]:

= P / Ar
 = $5.5 / 23.05$
 = 2.365 N./mm^2

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
-----	-----	-----	-----	-----	-----	-----
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

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$$= F1 / (2 * Bplen) * e * r1 / 2$$

$$= 1.3 / (2 * 545.0) * 181.0 * 427.25 / 2$$

$$= 47.362 \text{ N-m}$$

Compressive Allowable, $KL/R < Cc$ (12.2313 < 138.1347) per AISC E2-1 [Sca]:

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

$$= (1 - (12.23)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (12.23) / (8 * 138.13) - (12.23^3) / (8 * 138.13^3))$$

$$= 121.215 \text{ N./mm}^2$$

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

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

$$= 2.36 / 121.21 + (47.36 * 75.0 / 2812500) / 137.9$$

$$= 0.029$$

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

Compressive Allowable, $KL/R < Cc$ (9.5652 < 138.1347) per AISC E2-1 [Sca]:

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

$$= (1 - (9.57)^2 / (2 * 138.13^2)) * 207 /$$

$$(5/3 + 3 * (9.57) / (8 * 138.13) - (9.57^3) / (8 * 138.13^3))$$

$$= 121.916 \text{ N./mm}^2$$

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

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

$$= 3.35 / 121.92 + (62.93 * 75.0 / 282.675) / 137.9$$

$$= 0.040$$

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm ²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	72.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm ²
Area Available in a Single Bolt	BltArea	3.1275	cm ²
Saddle Load QO (Weight)	QO	29.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.1	kN
Maximum Longitudinal Force	F1	1.3	kN
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

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

$$= 1.33 / (172.38 * 4.0)$$

$$= 0.0194 \text{ cm}^2$$

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Horizontal Vessel Analysis (Test): Step: 13 11:20pm Feb 6,2022

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

$$\begin{aligned} &= B * Ft + \text{Sum of X Moments} \\ &= 600.0 * 1.05 + 0.0 \\ &= 631.76 \text{ N-m} \end{aligned}$$

Eccentricity (e):

$$\begin{aligned} &= Rmom / QO \\ &= 631.76/29.73 \\ &= 21.24 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction} \end{aligned}$$

Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[Bltarearl, Bltarears, Bltareart] \\ &= \max[0.0, 0.0194, 0.0] \\ &= 0.0194 \text{ cm}^2 \end{aligned}$$

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 Nozzle Summary: Step: 22 11:20pm Feb 6,2022

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T4	...	OK	...	OK	6.22	OK	Passed
T1	...	OK	...	OK	7.95	OK	Passed
S2	...	OK	...	OK	7.94	OK	Passed
S1	...	OK	...	OK	7.94	OK	Passed
S3	...	OK	...	OK	7.80	OK	Passed
T2	...	OK	...	OK	7.94	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	T4	253.000	90.000	61.550
20	T1	253.000	270.000	201.662
40	S2	809.175	90.000	310.145
40	S1	6293.175	90.000	310.145
40	S3	759.175	270.000	113.600
60	T2	6849.351	90.000	310.145
60	T3	6852.351	270.000	68.000

The nozzle spacing is computed by the following:

= Sqrt(ll² + lc²) where
 ll - Arc length along the inside vessel surface in the long. direction.
 lc - Arc length along the inside vessel surface in the circ. direction

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

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 Nozzle Calcs.: T4 Nozl: 8 11:20pm Feb 6,2022

INPUT VALUES, Nozzle Description: T4 From : 20

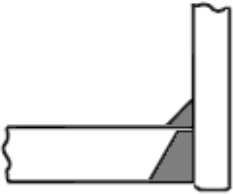
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm ²
Allowable Stress At Ambient	Sna	137.90	N./mm ²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		0.7500	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.2500	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: T4

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

Actual Inside Diameter Used in Calculation 0.750 in.
 Actual Thickness Used in Calculation 0.561 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.0 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\
 &= 4.9450 \text{ mm.}
 \end{aligned}$$

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

$$\begin{aligned}
 &= R \left(\exp\left(\frac{P}{S_n \cdot E}\right) - 1 \right) \text{ per Appendix 1-2 (a) (1)} \\
 &= 12.525 \left(\exp\left(\frac{23.0}{137.9 \cdot 1.0}\right) - 1 \right) \\
 &= 0.2107 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.2845 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	61.5500	mm.
Parallel to Vessel Wall	Rn+tn+t	30.7750	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	17.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 137.9 / 137.9) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 137.9 / 137.9) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned}
 &= \min(fr2, fr4) \\
 &= \min(1.0, 1.0) \\
 &= 1.000
 \end{aligned}$$

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.239	0.230	NA
Area in Shell	A1	0.750	1.886	NA
Area in Nozzle Wall	A2	3.864	3.838	NA

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Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.244	6.354	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

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

$$= (25.05 * 4.945 * 1.0 + 2 * 11.25 * 4.945 * 1.0 * (1 - 1.0))$$

$$= 1.239 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 36.5(1.0 * 7.0 - 1.0 * 4.945) - 2 * 11.25$$

$$(1.0 * 7.0 - 1.0 * 4.945) * (1 - 1.0)$$

$$= 0.750 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= (2 * 17.5) (11.25 - 0.21) 1.0$$

$$= 3.864 \text{ cm}^2$$

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

$$= (Wo^2 - \text{Area Lost}) * fr2 + ((Wi - can / 0.707)^2 - \text{Area Lost}) * fr2$$

$$= (8.0^2 - 0.01) * 1.0 + (0.0^2 - 0.0) * 1.0$$

$$= 0.630 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.2845 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9450 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9450 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]:

$$= \min[tb3, \max(tb1, tb2)]$$

$$= \min[6.22, \max(7.945, 4.5)]$$

$$= 6.2200 \text{ mm.}$$

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

$$= \max(ta, tb)$$

$$= \max(3.2845, 6.22)$$

$$= 6.2200 \text{ mm.}$$

Available Nozzle Neck Thickness = 14.2500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*) / (tg - c) = 0.706, Temp. Reduction = 16 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Weld Size Calculations, Description: T4

Intermediate Calc. for nozzle/shell Welds Tmin 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.9000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max(0, (1.2387 - 0.7501 + 2 * 11.25 * 1.0 * \\
 &\quad (1.0 * 7.0 - 4.945))138) \\
 &= 13.11 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2)*Sv \\
 &= (3.8638 + 0.0 + 0.63 - 0.0 * 1.0) * 138 \\
 &= 61.96 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= (3.8638 + 0.0 + 0.63 + (1.575)) * 138 \\
 &= 83.68 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= (3.8638 + 0.0 + 0.63 + 0.0 + (1.575)) * 138 \\
 &= 83.68 \text{ kN}
 \end{aligned}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= (3.1416/2.0) * 47.55 * 8.0 * 0.49 * 138 \\
 &= 40. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * (Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn \\
 &= (3.1416 * 18.15) * (14.25 - 3.0) * 0.7 * 138 \\
 &= 62. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= (3.1416/2.0) * 47.55 * (10.0 - 3.0) * 0.74 * 138 \\
 &= 53. \text{ kN}
 \end{aligned}$$

Strength of Failure Paths:

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PATH11 = (SONW + SNW) = (40 + 62) = 102 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (40 + 0 + 53 + 0) = 94 kN
PATH33 = (Sonw + Tngw + Sinw)
= (40 + 53 + 0) = 94 kN

Summary of Failure Path Calculations:

Path 1-1 = 102 kN , must exceed W = 13 kN or W1 = 61 kN
Path 2-2 = 93 kN , must exceed W = 13 kN or W2 = 83 kN
Path 3-3 = 93 kN , must exceed W = 13 kN or W3 = 83 kN

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

The Drop for this Nozzle is : 0.9745 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 210.9745 mm.

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 Nozzle Calcs.: T1 Nozl: 9 11:20pm Feb 6,2022

INPUT VALUES, Nozzle Description: T1 From : 20

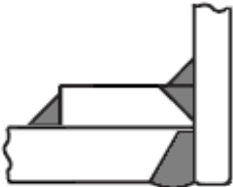
Pressure for Reinforcement Calculations	P	23.030	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		4.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	120	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	230.0000	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		57.8500	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T1

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

Actual Outside Diameter Used in Calculation	4.500 in.
Actual Thickness Used in Calculation	0.383 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.03 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.03) \\
 &= 4.9516 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.03 \cdot 57.15) / (118 \cdot 1.0 + 0.4 \cdot 23.03) \\
 &= 1.1077 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.4740 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	201.6618 mm.
Parallel to Vessel Wall, opening length	d	100.8309 mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		17.5000 mm.

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min(1, S_p / S_v) \\
 &= \min(1, 137.9 / 137.9) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

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$$= \min(0.855, 1.0)$$

$$= 0.855$$

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required Ar	5.089	0.942	NA
Area in Shell A1	2.025	5.108	NA
Area in Nozzle Wall A2	1.684	1.873	NA
Area in Inward Nozzle A3	0.000	0.000	NA
Area in Welds A41+A42+A43	0.545	0.545	NA
Area in Element A5	6.552	6.552	NA
TOTAL AREA AVAILABLE Atot	10.806	14.079	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.

The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness

Based on given Pad Thickness: 125.4341 10.0000 mm.

Based on given Pad Diameter: 230.0000 1.2745 mm.

Based on Shell or Nozzle Thickness: 125.7377 9.7345 mm.

Area Required [A]:

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

$$= (100.8309 \cdot 4.9516 \cdot 1.0 + 2 \cdot 6.7345 \cdot 4.9516 \cdot 1.0 \cdot (1 - 0.86))$$

$$= 5.089 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 100.831(1.0 \cdot 7.0 - 1.0 \cdot 4.952) - 2 \cdot 6.735$$

$$(1.0 \cdot 7.0 - 1.0 \cdot 4.9516) \cdot (1 - 0.855)$$

$$= 2.025 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= (2 \cdot Tlwp) \cdot (tn - trn) \cdot fr2$$

$$= (2 \cdot 17.5) \cdot (6.73 - 1.11) \cdot 0.855$$

$$= 1.684 \text{ cm}^2$$

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

$$= (Wo^2 - Ar \text{ Lost}) \cdot Fr3 + ((Wi - can/0.707)^2 - Ar \text{ Lost}) \cdot fr2 + Wp^2 \cdot fr4$$

$$= (0.6375) \cdot 0.86 + (0.0) \cdot 0.86 + 0.0^2 \cdot 1.0$$

$$= 0.545 \text{ cm}^2$$

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

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

$$= (201.6618 - 114.3) \cdot 10.0 \cdot 1.0 \cdot 0.75$$

$$= 6.552 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures $ta = 4.1077 \text{ mm.}$

Wall Thickness per UG16(b), $tr16b = 4.5000 \text{ mm.}$

Wall Thickness, shell/head, internal pressure $trb1 = 7.9516 \text{ mm.}$

Wall Thickness $tb1 = \max(trb1, tr16b) = 7.9516 \text{ mm.}$

Wall Thickness $tb2 = \max(trb2, tr16b) = 4.5000 \text{ mm.}$

Wall Thickness per table UG-45 $tb3 = 8.2578 \text{ mm.}$

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Determine Nozzle Thickness candidate [tb]:
 = min[tb3, max(tb1,tb2)]
 = min[8.258, max(7.9516, 4.5)]
 = 7.9516 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
 = max(ta, tb)
 = max(4.1077, 7.9516)
 = 7.9516 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	: 51.4,	Allowable	: 117.9 N./mm ²	Passed
Expansion	: 0.0,	Allowable	: 243.4 N./mm ²	Passed
Occasional	: 8.1,	Allowable	: 156.8 N./mm ²	Passed
Shear	: 24.8,	Allowable	: 82.5 N./mm ²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.164, 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, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-45 °C

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

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0

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Nozzle Calcs.: T1 Nozl: 9 11:20pm Feb 6,2022

Thickness Ratio = $tr * (E^*) / (tg - c) = 0.164$, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
 Governing MDMT of the Reinforcement Pad : -45 °C
 Governing MDMT of all the sub-joints of this Junction : -45 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C
 Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

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

Design Pressure/Ambient Rating = 23.03/51.10 = 0.451

Note:

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

Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 6.7345 mm.
 Intermediate Calc. for pad/shell Welds TminPad 7.0000 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	3.5000 = 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]:**

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

$$= \max(0, (5.0894 - 2.0255 + 2 * 6.7345 * 0.855 * (1.0 * 7.0 - 4.9516)) 138)$$

$$= 45.50 \text{ kN}$$

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

Weld Load [W1]:

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

$$= (1.6838 + 6.5521 + 0.5451 - 0.0 * 0.86) * 138$$

$$= 121.08 \text{ kN}$$
Weld Load [W2]:

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

$$= (1.6838 + 0.0 + 0.5472 + (0.8061)) * 138$$

$$= 41.88 \text{ kN}$$
Weld Load [W3]:

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

$$= (1.6838 + 0.0 + 0.5451 + 6.5521 + (0.8061)) * 138$$

$$= 132.20 \text{ kN}$$
Strength of Connection Elements for Failure Path Analysis**Shear, Outward Nozzle Weld [Sonw]:**

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

$$= (3.1416/2.0) * 114.3 * 8.0 * 0.49 * 118$$

$$= 83. \text{ kN}$$

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Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 230.0 * 8.0 * 0.49 * 138$$

$$= 195. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 53.7827) * (9.7345 - 3.0) * 0.7 * 118$$

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

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 114.3 * 10.0 * 0.74 * 138$$

$$= 183. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 114.3 * (10.0 - 3.0) * 0.74 * 138$$

$$= 128. \text{ kN}$$

Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (195 + 94) = 289 \text{ kN}$$

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

$$= (83 + 183 + 128 + 0) = 394 \text{ kN}$$

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

$$= (195 + 128 + 0) = 324 \text{ kN}$$

Summary of Failure Path Calculations:

Path 1-1 = 289 kN , must exceed W = 45 kN or W1 = 121 kN
 Path 2-2 = 394 kN , must exceed W = 45 kN or W2 = 41 kN
 Path 3-3 = 323 kN , must exceed W = 45 kN or W3 = 132 kN

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

The Drop for this Nozzle is : 5.6770 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6770 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm ²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm ²
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	114.300	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm ²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm ²

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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Nozzle Calcs.: T1 Noz1: 9 11:20pm Feb 6,2022

Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	230.000	mm.
Design Internal Pressure	Dp	23.030	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	4.0	kN
Longitudinal Shear (SUS)	Vl	4.0	kN
Circumferential Shear (SUS)	Vc	4.0	kN
Circumferential Moment (SUS)	Mc	1700.0	N-m
Longitudinal Moment (SUS)	Ml	1700.0	N-m
Torsional Moment (SUS)	Mt	2100.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 114.3 + 2 * 1.65 * \text{sqrt}(297.0 (10.0 - 3.0))$$

$$= 264.767 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	4.0	kN
Circumferential Shear	VC	4.0	kN
Longitudinal Shear	VL	4.0	kN
Circumferential Moment	MC	1700.0	N-m
Longitudinal Moment	ML	1700.0	N-m
Torsional Moment	MT	2100.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.166	4C	3.000	(A,B)
N(PHI) / (P/Rm)	0.166	3C	2.539	(C,D)
M(PHI) / (P)	0.166	2C1	0.077	(A,B)
M(PHI) / (P)	0.166	1C	0.107	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.166	3A	0.597	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.166	1A	0.095	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.166	3B	1.885	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.166	1B	0.044	(A,B,C,D)
N(x) / (P/Rm)	0.166	3C	2.539	(A,B)
N(x) / (P/Rm)	0.166	4C	3.000	(C,D)
M(x) / (P)	0.166	1C1	0.112	(A,B)
M(x) / (P)	0.166	2C	0.077	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.166	4A	0.893	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.166	2A	0.052	(A,B,C,D)

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N(x) / (ML/(Rm**2 * Beta)) 0.166 4B 0.568 (A,B,C,D)
 M(x) / (ML/(Rm * Beta)) 0.166 2B 0.069 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-2.3	-2.3	-2.3	-2.3	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P		-6.4	6.4	-6.4	6.4	-8.9	8.9	-8.9	8.9
Circ. Memb. MC		0.0	0.0	0.0	0.0	-4.0	-4.0	4.0	4.0
Circ. Memb. MC		0.0	0.0	0.0	0.0	-67.0	67.0	67.0	-67.0
Circ. Memb. ML		-12.5	-12.5	12.5	12.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-31.1	31.1	31.1	-31.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-52.3	22.7	34.9	-14.6	-81.8	69.9	60.0	-56.1
Long. Memb. P		-2.0	-2.0	-2.0	-2.0	-2.3	-2.3	-2.3	-2.3
Long. Bend. P		-9.3	9.3	-9.3	9.3	-6.4	6.4	-6.4	6.4
Long. Memb. MC		0.0	0.0	0.0	0.0	-5.9	-5.9	5.9	5.9
Long. Bend. MC		0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML		-3.8	-3.8	3.8	3.8	0.0	0.0	0.0	0.0
Long. Bend. ML		-48.7	48.7	48.7	-48.7	0.0	0.0	0.0	0.0
Tot. Long. Str.		-63.7	52.3	41.2	-37.7	-51.2	34.7	33.8	-26.7
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		6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tot. Shear		7.3	7.3	4.7	4.7	4.7	4.7	7.3	7.3
Str. Int.		67.3	54.0	43.7	38.6	82.5	70.6	61.9	57.8

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.339	4C	4.173	(A,B)
N(PHI) / (P/Rm)	0.339	3C	1.862	(C,D)
M(PHI) / (P)	0.339	2C1	0.012	(A,B)
M(PHI) / (P)	0.339	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.339	3A	1.336	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.339	1A	0.064	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.339	3B	2.607	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.339	1B	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.339	3C	1.862	(A,B)
N(x) / (P/Rm)	0.339	4C	4.173	(C,D)
M(x) / (P)	0.339	1C1	0.030	(A,B)
M(x) / (P)	0.339	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.339	4A	4.079	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.339	2A	0.025	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.339	4B	1.423	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.339	2B	0.016	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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Nozzle Calcs.: T1 Nozl: 9 11:20pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-8.0	-8.0	-8.0	-8.0	-3.6	-3.6	-3.6	-3.6
Circ. Bend.	P	-5.9	5.9	-5.9	5.9	-30.9	30.9	-30.9	30.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-10.9	-10.9	10.9	10.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-131.6	131.6	131.6	-131.6
Circ. Memb.	ML	-21.2	-21.2	21.2	21.2	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-55.3	-3.2	27.3	-1.0	-177.0	148.1	107.9	-93.4
Long. Memb.	P	-3.6	-3.6	-3.6	-3.6	-8.0	-8.0	-8.0	-8.0
Long. Bend.	P	-14.7	14.7	-14.7	14.7	-15.9	15.9	-15.9	15.9
Long. Memb.	MC	0.0	0.0	0.0	0.0	-33.1	-33.1	33.1	33.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-52.3	52.3	52.3	-52.3
Long. Memb.	ML	-11.6	-11.6	11.6	11.6	0.0	0.0	0.0	0.0
Long. Bend.	ML	-32.6	32.6	32.6	-32.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-62.4	32.1	25.8	-9.9	-109.4	27.1	61.5	-11.3
Shear	VC	1.6	1.6	-1.6	-1.6	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.6	-1.6	1.6	1.6
Shear	MT	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Tot. Shear		5.2	5.2	2.0	2.0	2.0	2.0	5.2	5.2
Str. Int.		65.1	36.8	28.7	10.3	177.0	148.1	108.5	93.7

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl	(SUS)	-14.8	-14.8	10.1	10.1	-5.9	-5.9	2.0	2.0
Circ. Q	(SUS)	-37.5	37.5	24.7	-24.7	-75.9	75.9	58.0	-58.0
Long. Pm	(SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl	(SUS)	-5.7	-5.7	1.8	1.8	-8.2	-8.2	3.6	3.6
Long. Q	(SUS)	-58.0	58.0	39.4	-39.4	-43.0	43.0	30.2	-30.2
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)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Pm	(SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl	(SUS)	24.0	26.3	48.8	51.1	32.8	35.1	40.7	43.0
Pm+Pl+Q	(Total)	46.1	75.9	75.0	45.7	44.9	111.3	99.8	19.5

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Nozzle Calcs.: T1 Nozl: 9 11:20pm Feb 6,2022

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.95	137.90	Passed
Pm+Pl (SUS)	51.14	206.85	Passed
Pm+Pl+Q (TOTAL)	111.28	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		95.4	97.7	95.4	97.7	95.4	97.7	95.4	97.7
Circ. Pl (SUS)		-29.2	-29.2	13.1	13.1	-14.4	-14.4	7.3	7.3
Circ. Q (SUS)		-26.0	26.0	14.1	-14.1	-162.5	162.5	100.6	-100.6
Long. Pm (SUS)		47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)		-15.1	-15.1	8.0	8.0	-41.2	-41.2	25.1	25.1
Long. Q (SUS)		-47.2	47.2	17.9	-17.9	-68.2	68.2	36.4	-36.4
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.6	1.6	-1.6	-1.6	-1.6	-1.6	1.6	1.6
Shear Q (SUS)		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Pm (SUS)		95.4	97.7	95.4	97.7	95.4	97.7	95.4	97.7
Pm+Pl (SUS)		66.3	68.6	108.6	110.9	81.0	83.3	102.8	105.1
Pm+Pl+Q (Total)		55.8	96.2	122.8	96.8	81.7	245.8	203.6	37.2

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.73	137.90	Passed
Pm+Pl (SUS)	110.93	206.85	Passed
Pm+Pl+Q (TOTAL)	245.85	413.70	Passed

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INPUT VALUES, Nozzle Description: S2 From : 40

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized] SA-516 70			
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		809.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

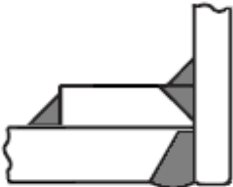
Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	290.0000	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		60.8625	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S2

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

Actual Outside Diameter Used in Calculation	6.625 in.
Actual Thickness Used in Calculation	0.378 in.

Nozzle input data check completed without errors.

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

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

$$= (23.0 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$$

$$= 4.9450 \text{ mm.}$$

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

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

$$= (23.0 \cdot 84.1375) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$$

$$= 1.6287 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	310.1452	mm.
Parallel to Vessel Wall, opening length	d	155.0726	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		17.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 0.855$$

Weld Strength Reduction Factor [fr4]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr3]:

$$= \min(fr2, fr4)$$

$$= \min(0.855, 1.0)$$

$$= 0.855$$

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	187.6997	10.0000 mm.
Based on given Pad Diameter:	290.0000	1.5958 mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012 mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
= 7.763 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 155.073(1.0 * 7.0 - 1.0 * 4.945) - 2 * 6.601
(1.0 * 7.0 - 1.0 * 4.945) * (1 - 0.855)
= 3.147 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 17.5) * (6.6 - 1.63) * 0.855
= 1.488 cm^2

Area Available in Welds [A41 + A42 + A43]:
= (Wo^2 - Ar Lost)*Fr3+((Wi-can/0.707)^2 - Ar Lost)*fr2 + Wp^2*fr4
= (0.6375) * 0.86 + (0.0) * 0.86 + 203.2^2 * 1.0
= 1.185 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (290.0 - 168.275) * 10.0 * 1.0
= 12.172 cm^2

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

Wall Thickness for Internal/External pressures	ta = 4.6287 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9450 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:

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= min[tb3, max(tb1,tb2)]
 = min[9.22, max(7.945, 4.5)]
 = 7.9450 mm.

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

= max(ta, tb)
 = max(4.6287, 7.945)
 = 7.9450 mm.

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	55.9,	Allowable	:	117.9 N./mm ²	Passed
Expansion	:	0.0,	Allowable	:	238.8 N./mm ²	Passed
Occasional	:	13.0,	Allowable	:	156.8 N./mm ²	Passed
Shear	:	24.1,	Allowable	:	82.5 N./mm ²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-45 °C

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
 Governing MDMT of the Reinforcement Pad : -45 °C
 Governing MDMT of all the sub-joints of this Junction : -45 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:

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

Weld Size Calculations, Description: S2

Intermediate Calc. for nozzle/shell Welds Tmin 6.6012 mm.
 Intermediate Calc. for pad/shell Welds TminPad 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 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]:

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

$$= \max(0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 * (1.0 * 7.0 - 4.945)))138)$$

$$= 66.84 \text{ kN}$$

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

Weld Load [W1]:

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

$$= (1.488 + 12.1725 + 1.1851 - 0.0 * 0.86) * 138$$

$$= 204.70 \text{ kN}$$

Weld Load [W2]:

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

$$= (1.488 + 0.0 + 0.5472 + (0.7902)) * 138$$

$$= 38.96 \text{ kN}$$

Weld Load [W3]:

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

$$= (1.488 + 0.0 + 1.1851 + 12.1725 + (0.7902)) * 138$$

$$= 215.60 \text{ kN}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

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

$$= (3.1416/2.0) * 168.275 * 8.0 * 0.49 * 118$$

$$= 122. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

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$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 290.0 * 8.0 * 0.49 * 138$$

$$= 246. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 80.8369) * (9.6012 - 3.0) * 0.7 * 118$$

$$= 138. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 168.275 * 10.0 * 0.74 * 138$$

$$= 270. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 168.275 * (10.0 - 3.0) * 0.74 * 138$$

$$= 189. \text{ kN}$$

Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (246 + 138) = 385 \text{ kN}$$

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

$$= (122 + 270 + 189 + 0) = 581 \text{ kN}$$

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

$$= (246 + 189 + 0) = 435 \text{ kN}$$

Summary of Failure Path Calculations:

Path 1-1 = 384 kN , must exceed W = 66 kN or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm ²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm ²
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm ²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm ²
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	mm.

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Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	6.0	kN
Longitudinal Shear (SUS)	Vl	6.0	kN
Circumferential Shear (SUS)	Vc	6.0	kN
Circumferential Moment (SUS)	Mc	3800.0	N-m
Longitudinal Moment (SUS)	Ml	3800.0	N-m
Torsional Moment (SUS)	Mt	4700.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 168.275 + 2 * 1.65 * \text{sqrt}(297.0 (10.0 - 3.0))$$

$$= 318.742 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML		-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P		-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P		-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC		0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC		0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML		-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML		-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
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		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear		7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.		77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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Nozzle Calcs.: S2

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Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML		-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P		-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P		-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML		-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC		1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear		7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.		76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)		-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)		-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)		19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)		-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)		-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)		16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)		56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

Stress Summation Comparison (N./mm²):

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Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)		-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)		-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)		47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)		-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)		-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)		59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)		56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

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INPUT VALUES, Nozzle Description: S1 From : 40

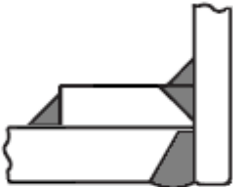
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6293.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	290.0000	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		60.8625	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	6.625 in.
Actual Thickness Used in Calculation	0.378 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.0 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\
 &= 4.9450 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.0 \cdot 84.1375) / (118 \cdot 1.0 + 0.4 \cdot 23.0) \\
 &= 1.6287 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	310.1452	mm.
Parallel to Vessel Wall, opening length	d	155.0726	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		17.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min(1, S_p / S_v) \\
 &= \min(1, 137.9 / 137.9) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned}
 &= \min(fr2, fr4) \\
 &= \min(0.855, 1.0) \\
 &= 0.855
 \end{aligned}$$

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Nozzle Calcs.: S1 Nozl: 11 11:20pm Feb 6,2022

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	187.6997	10.0000 mm.
Based on given Pad Diameter:	290.0000	1.5958 mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012 mm.

Area Required [A]:

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

$$= (155.0726 * 4.945 * 1.0 + 2 * 6.6012 * 4.945 * 1.0 * (1 - 0.86))$$

$$= 7.763 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 155.073(1.0 * 7.0 - 1.0 * 4.945) - 2 * 6.601$$

$$(1.0 * 7.0 - 1.0 * 4.945) * (1 - 0.855)$$

$$= 3.147 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= (2 * 17.5) * (6.6 - 1.63) * 0.855$$

$$= 1.488 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Wp^2 * fr4$$

$$= (0.6375) * 0.86 + (0.0) * 0.86 + 203.2^2 * 1.0$$

$$= 1.185 \text{ cm}^2$$

Area Available in Element [A5]:

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

$$= (290.0 - 168.275) * 10.0 * 1.0$$

$$= 12.172 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 4.6287 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9450 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:

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= min[tb3, max(tb1,tb2)]
 = min[9.22, max(7.945, 4.5)]
 = 7.9450 mm.

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

= max(ta, tb)
 = max(4.6287, 7.945)
 = 7.9450 mm.

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	55.9,	Allowable	:	117.9 N./mm ²	Passed
Expansion	:	0.0,	Allowable	:	238.8 N./mm ²	Passed
Occasional	:	13.0,	Allowable	:	156.8 N./mm ²	Passed
Shear	:	24.1,	Allowable	:	82.5 N./mm ²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-45 °C

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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Nozzle Calcs.: S1 Nozl: 11 11:20pm Feb 6,2022

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
 Governing MDMT of the Reinforcement Pad : -45 °C
 Governing MDMT of all the sub-joints of this Junction : -45 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

*Note:**Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.***Weld Size Calculations, Description: S1**

Intermediate Calc. for nozzle/shell Welds Tmin 6.6012 mm.
 Intermediate Calc. for pad/shell Welds TminPad 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 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]:

$$\begin{aligned}
 &= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max(0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 * \\
 &\quad (1.0 * 7.0 - 4.945))138) \\
 &= 66.84 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= (1.488 + 12.1725 + 1.1851 - 0.0 * 0.86) * 138 \\
 &= 204.70 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= (1.488 + 0.0 + 0.5472 + (0.7902)) * 138 \\
 &= 38.96 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= (1.488 + 0.0 + 1.1851 + 12.1725 + (0.7902)) * 138 \\
 &= 215.60 \text{ kN}
 \end{aligned}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= (3.1416/2.0) * 168.275 * 8.0 * 0.49 * 118 \\
 &= 122. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

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$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 290.0 * 8.0 * 0.49 * 138$$

$$= 246. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 80.8369) * (9.6012 - 3.0) * 0.7 * 118$$

$$= 138. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 168.275 * 10.0 * 0.74 * 138$$

$$= 270. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 168.275 * (10.0 - 3.0) * 0.74 * 138$$

$$= 189. \text{ kN}$$

Strength of Failure Paths:

$$\text{PATH11} = (\text{SPEW} + \text{SNW}) = (246 + 138) = 385 \text{ kN}$$

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

$$= (122 + 270 + 189 + 0) = 581 \text{ kN}$$

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

$$= (246 + 189 + 0) = 435 \text{ kN}$$

Summary of Failure Path Calculations:

Path 1-1 = 384 kN , must exceed W = 66 kN or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm ²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm ²
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm ²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm ²
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	mm.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:E-PK6101-3 ECONOMIZER

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: S1 Nozl: 11 11:20pm Feb 6,2022

Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	6.0	kN
Longitudinal Shear (SUS)	Vl	6.0	kN
Circumferential Shear (SUS)	Vc	6.0	kN
Circumferential Moment (SUS)	Mc	3800.0	N-m
Longitudinal Moment (SUS)	Ml	3800.0	N-m
Torsional Moment (SUS)	Mt	4700.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(t - ca))$$

$$= 168.275 + 2 * 1.65 * \text{sqrt}(297.0 (10.0 - 3.0))$$

$$= 318.742 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML		-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P		-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P		-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC		0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC		0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML		-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML		-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
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		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear		7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.		77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Tag no:E-PK6101-3 ECONOMIZER

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: S1 Nozl: 11 11:20pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML		-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P		-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P		-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML		-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC		1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear		7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.		76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)		-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)		-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)		19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)		-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)		-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)		16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)		56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

Stress Summation Comparison (N./mm²):

Tag no:E-PK6101-3 ECONOMIZER

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: S1 Nozl: 11 11:20pm Feb 6,2022

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)		-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)		-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)		47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)		-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)		-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)		59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)		56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

INPUT VALUES, Nozzle Description: S3 From : 40

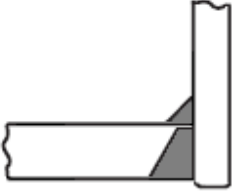
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		759.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm ²
Allowable Stress At Ambient	Sna	137.90	N./mm ²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S3

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

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
 = $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$ per UG-27 (c) (1)
 = $(23.03 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.03)$
 = 4.9524 mm.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
 = $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$ per UG-27 (c) (1)
 = $(23.03 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.03)$
 = 0.4792 mm.

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

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

Parallel to Vessel Wall (Diameter Limit)	Dl	113.6000	mm.
Parallel to Vessel Wall, opening length	d	56.8000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	17.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

= $\min(fr2, fr4)$
 = $\min(1.0, 1.0)$
 = 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.813	1.458	NA
Area in Shell	A1	1.163	1.061	NA
Area in Nozzle Wall	A2	4.592	4.621	NA

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:E-PK6101-3 ECONOMIZER

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: S3 Nozl: 12 11:20pm Feb 6,2022

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	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.395	6.322	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]:

$$\begin{aligned}
 &= (d * tr * F + 2 * tn * tr * F * (1 - fr1)) \text{ UG-37(c)} \\
 &= (56.8 * 4.9524 * 1.0 + 2 * 13.6 * 4.9524 * 1.0 * (1 - 1.0)) \\
 &= 2.813 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d (E1 * t - F * tr) - 2 * tn (E1 * t - F * tr) * (1 - fr1) \\
 &= 56.8 (1.0 * 7.0 - 1.0 * 4.952) - 2 * 13.6 \\
 &\quad (1.0 * 7.0 - 1.0 * 4.9524) * (1 - 1.0) \\
 &= 1.163 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= (2 * tlnp) (tn - trn) fr2 \\
 &= (2 * 17.5) (13.6 - 0.48) 1.0 \\
 &= 4.592 \text{ cm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= Wo^2 * fr2 + (Wi - can / 0.707)^2 * fr2 \\
 &= 8.0^2 * 1.0 + (0.0)^2 * 1.0 \\
 &= 0.640 \text{ cm}^2
 \end{aligned}$$

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

Wall Thickness for Internal/External pressures	ta = 3.4792 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9524 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9524 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[tb3, \max(tb1, tb2)] \\
 &= \min[7.8, \max(7.9524, 4.5)] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max(ta, tb) \\
 &= \max(3.4792, 7.8) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

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

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 16.5, Allowable	: 137.9 N./mm ²	Passed
Expansion	: 0.0, Allowable	: 328.2 N./mm ²	Passed
Occasional	: 1.9, Allowable	: 183.4 N./mm ²	Passed
Shear	: 8.1, Allowable	: 96.5 N./mm ²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for

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the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = $tr * (E^*) / (tg - c) = 0.707$, Temp. Reduction = 16 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

Design Pressure/Ambient Rating = $23.03/51.10 = 0.451$

Weld Size Calculations, Description: S3

Intermediate Calc. for nozzle/shell Welds Tmin 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$4.9000 = 0.7 * t_{min}$	$5.6560 = 0.7 * W_o$ mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max(0, (2.813 - 1.163 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 7.0 - 4.9524))138) \\
 &= 30.43 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2) * Sv \\
 &= (4.5923 + 0.0 + 0.64 - 0.0 * 1.0) * 138 \\
 &= 72.15 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= (4.5923 + 0.0 + 0.64 + (1.904)) * 138 \\
 &= 98.40 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= (4.5923 + 0.0 + 0.64 + 0.0 + (1.904)) * 138 \\
 &= 98.40 \text{ kN}
 \end{aligned}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw} \\
 &= (3.1416/2.0) * 84.0 * 8.0 * 0.49 * 138 \\
 &= 71. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 35.2) * (16.6 - 3.0) * 0.7 * 138$$

$$= 145. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416 / 2.0) * 84.0 * (10.0 - 3.0) * 0.74 * 138$$

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

Strength of Failure Paths:

$$PATH11 = (SONW + SNW) = (71 + 145) = 216 \text{ kN}$$

$$PATH22 = (Sonw + Tpgw + Tngw + Sinw)$$

$$= (71 + 0 + 94 + 0) = 166 \text{ kN}$$

$$PATH33 = (Sonw + Tngw + Sinw)$$

$$= (71 + 94 + 0) = 166 \text{ kN}$$

Summary of Failure Path Calculations:

Path 1-1 = 216 kN , must exceed W = 30 kN or W1 = 72 kN
 Path 2-2 = 165 kN , must exceed W = 30 kN or W2 = 98 kN
 Path 3-3 = 165 kN , must exceed W = 30 kN or W3 = 98 kN

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

The Drop for this Nozzle is : 3.0522 mm.
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0522 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm ²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm ²
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm ²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm ²
Design Internal Pressure	Dp	23.034	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	500.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	400.0	N-m

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Use Interactive Control No
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No
 Compute Pressure Stress per WRC-368 No
 Local Loads applied at end of Nozzle/Attachment No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}(297.0 (10.0 - 3.0))$$

$$= 234.467 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	500.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	400.0	N-m

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.124	4C	7.046	(A,B)
N(PHI) / (P/Rm)	0.124	3C	5.702	(C,D)
M(PHI) / (P)	0.124	2C1	0.068	(A,B)
M(PHI) / (P)	0.124	1C	0.101	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.124	3A	1.535	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.124	1A	0.090	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.124	3B	4.748	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.124	1B	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.124	3C	5.702	(A,B)
N(x) / (P/Rm)	0.124	4C	7.046	(C,D)
M(x) / (P)	0.124	1C1	0.106	(A,B)
M(x) / (P)	0.124	2C	0.068	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.124	4A	2.341	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.124	2A	0.047	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.124	4B	1.458	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.124	2B	0.060	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-6.8	-6.8	-6.8	-6.8	-5.5	-5.5	-5.5	-5.5
Circ. Bend.	P	-16.6	16.6	-16.6	16.6	-24.7	24.7	-24.7	24.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-10.0	-10.0	10.0	10.0

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Circ. Memb. MC	0.0	0.0	0.0	0.0	-149.4	149.4	149.4	-149.4
Circ. Memb. ML	-24.8	-24.8	24.8	24.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-52.5	52.5	52.5	-52.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-100.7	37.4	54.0	-17.8	-189.7	158.6	129.3	-120.2
Long. Memb. P	-5.5	-5.5	-5.5	-5.5	-6.8	-6.8	-6.8	-6.8
Long. Bend. P	-25.9	25.9	-25.9	25.9	-16.6	16.6	-16.6	16.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.3	-15.3	15.3	15.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-78.9	78.9	78.9	-78.9
Long. Memb. ML	-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-80.6	80.6	80.6	-80.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-119.6	93.3	56.9	-52.6	-117.6	73.4	70.8	-53.7
Shear VC	2.2	2.2	-2.2	-2.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.2	-2.2	2.2	2.2
Shear MT	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Tot. Shear	7.3	7.3	3.0	3.0	3.0	3.0	7.3	7.3
Str. Int.	122.1	94.3	58.7	52.8	189.8	158.7	130.2	121.0

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Circ. Pl (SUS)		-31.6	-31.6	18.1	18.1	-15.5	-15.5	4.6	4.6
Circ. Q (SUS)		-69.0	69.0	35.9	-35.9	-174.1	174.1	124.7	-124.7
Long. Pm (SUS)		47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)		-13.1	-13.1	2.1	2.1	-22.1	-22.1	8.5	8.5
Long. Q (SUS)		-106.4	106.4	54.7	-54.7	-95.5	95.5	62.3	-62.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		2.2	2.2	-2.2	-2.2	-2.2	-2.2	2.2	2.2
Shear Q (SUS)		5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Pm (SUS)		95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Pm+Pl (SUS)		64.0	66.3	113.6	115.9	80.0	82.3	100.1	102.4
Pm+Pl+Q (Total)		72.6	146.0	149.6	85.0	94.6	256.4	225.2	25.2

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.75	137.90	Passed
Pm+Pl (SUS)	115.89	206.85	Passed
Pm+Pl+Q (TOTAL)	256.44	413.70	Passed

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INPUT VALUES, Nozzle Description: T2 From : 60

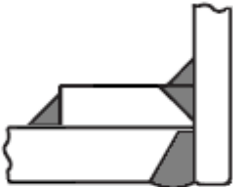
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6849.35	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm ²
Allowable Stress At Ambient	Sna	117.90	N./mm ²
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm ²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm ²
Diameter of Pad along vessel surface	Dp	290.0000	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		60.8625	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: T2

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

Actual Outside Diameter Used in Calculation 6.625 in.
 Actual Thickness Used in Calculation 0.378 in.

Nozzle input data check completed without errors.

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

$$\begin{aligned}
 &= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P) \text{ per UG-27 (c) (1)} \\
 &= (23.0 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.0) \\
 &= 4.9450 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P) \text{ per Appendix 1-1 (a) (1)} \\
 &= (23.0 \cdot 84.1375) / (118 \cdot 1.0 + 0.4 \cdot 23.0) \\
 &= 1.6287 \text{ mm.}
 \end{aligned}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

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

Parallel to Vessel Wall (Diameter Limit)	D1	310.1452	mm.
Parallel to Vessel Wall, opening length	d	155.0726	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		17.5000	mm.

Weld Strength Reduction Factor [fr1]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr2]:

$$\begin{aligned}
 &= \min(1, S_n / S_v) \\
 &= \min(1, 117.9 / 137.9) \\
 &= 0.855
 \end{aligned}$$

Weld Strength Reduction Factor [fr4]:

$$\begin{aligned}
 &= \min(1, S_p / S_v) \\
 &= \min(1, 137.9 / 137.9) \\
 &= 1.000
 \end{aligned}$$

Weld Strength Reduction Factor [fr3]:

$$\begin{aligned}
 &= \min(fr2, fr4) \\
 &= \min(0.855, 1.0) \\
 &= 0.855
 \end{aligned}$$

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Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.763	1.439	NA
Area in Shell	A1	3.147	7.913	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	23.068	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	187.6997	10.0000 mm.
Based on given Pad Diameter:	290.0000	1.5958 mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012 mm.

Area Required [A]:

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

$$= (155.0726 * 4.945 * 1.0 + 2 * 6.6012 * 4.945 * 1.0 * (1 - 0.86))$$

$$= 7.763 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 155.073(1.0 * 7.0 - 1.0 * 4.945) - 2 * 6.601$$

$$(1.0 * 7.0 - 1.0 * 4.945) * (1 - 0.855)$$

$$= 3.147 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

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

$$= (2 * 17.5) * (6.6 - 1.63) * 0.855$$

$$= 1.488 \text{ cm}^2$$

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

$$= (Wo^2 - Ar Lost) * Fr3 + ((Wi - can / 0.707)^2 - Ar Lost) * fr2 + Wp^2 * fr4$$

$$= (0.6375) * 0.86 + (0.0) * 0.86 + 203.2^2 * 1.0$$

$$= 1.185 \text{ cm}^2$$

Area Available in Element [A5]:

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

$$= (290.0 - 168.275) * 10.0 * 1.0$$

$$= 12.172 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 4.6287 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9450 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:

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= min[tb3, max(tb1,tb2)]
 = min[9.22, max(7.945, 4.5)]
 = 7.9450 mm.

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

= max(ta, tb)
 = max(4.6287, 7.945)
 = 7.9450 mm.

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	55.9,	Allowable	:	117.9 N./mm ²	Passed
Expansion	:	0.0,	Allowable	:	238.8 N./mm ²	Passed
Occasional	:	13.0,	Allowable	:	156.8 N./mm ²	Passed
Shear	:	24.1,	Allowable	:	82.5 N./mm ²	Passed

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note:

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

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-45 °C

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY**DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**Tag no:E-PK6101-3 **ECONOMIZER**

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: T2 Noz1: 13 11:20pm Feb 6,2022

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Governing MDMT of the Nozzle : -104 °C
 Governing MDMT of the Reinforcement Pad : -45 °C
 Governing MDMT of all the sub-joints of this Junction : -45 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
 Flange MDMT with Temp reduction per UCS-66(i) (2) -48 °C
 Flange MDMT with Temp reduction per UCS-66(i) (3) -104 °C

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

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:

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

Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds Tmin 6.6012 mm.
 Intermediate Calc. for pad/shell Welds TminPad 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 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]:

$$\begin{aligned}
 &= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max(0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 * \\
 &\quad (1.0 * 7.0 - 4.945))138) \\
 &= 66.84 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= (1.488 + 12.1725 + 1.1851 - 0.0 * 0.86) * 138 \\
 &= 204.70 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= (1.488 + 0.0 + 0.5472 + (0.7902)) * 138 \\
 &= 38.96 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= (1.488 + 0.0 + 1.1851 + 12.1725 + (0.7902)) * 138 \\
 &= 215.60 \text{ kN}
 \end{aligned}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= (3.1416/2.0) * 168.275 * 8.0 * 0.49 * 118 \\
 &= 122. \text{ kN}
 \end{aligned}$$

Shear, Pad Element Weld [Spew]:

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$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= (3.1416/2.0) * 290.0 * 8.0 * 0.49 * 138$$

$$= 246. kN$$

Shear, Nozzle Wall [Snw]:

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

$$= (3.1416 * 80.8369) * (9.6012 - 3.0) * 0.7 * 118$$

$$= 138. kN$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpn * 0.74 * Seg$$

$$= (3.1416/2) * 168.275 * 10.0 * 0.74 * 138$$

$$= 270. kN$$

Tension, Shell Groove Weld [Tngw]:

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

$$= (3.1416/2.0) * 168.275 * (10.0 - 3.0) * 0.74 * 138$$

$$= 189. kN$$

Strength of Failure Paths:

$$PATH11 = (SPEW + SNW) = (246 + 138) = 385 kN$$

$$PATH22 = (Sonw + Tpgw + Tngw + Sinw)$$

$$= (122 + 270 + 189 + 0) = 581 kN$$

$$PATH33 = (Spew + Tngw + Sinw)$$

$$= (246 + 189 + 0) = 435 kN$$

Summary of Failure Path Calculations:

Path 1-1 = 384 kN , must exceed W = 66 kN or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm ²
Vessel Hot S.I. Allowable	Smh	137.90	N./mm ²
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm ²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm ²
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	mm.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:E-PK6101-3 ECONOMIZER

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: T2 Nozl: 13 11:20pm Feb 6,2022

Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	6.0	kN
Longitudinal Shear (SUS)	Vl	6.0	kN
Circumferential Shear (SUS)	Vc	6.0	kN
Circumferential Moment (SUS)	Mc	3800.0	N-m
Longitudinal Moment (SUS)	Ml	3800.0	N-m
Torsional Moment (SUS)	Mt	4700.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}(\text{Rmean}(\text{t} - \text{ca}))$$

$$= 168.275 + 2 * 1.65 * \text{sqrt}(297.0 (10.0 - 3.0))$$

$$= 318.742 \text{ mm.}$$

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC		0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML		-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P		-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P		-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC		0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC		0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML		-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML		-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
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		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear		7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.		77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: T2

Noz1: 13 11:20pm Feb 6,2022

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P		-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML		-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML		-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P		-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P		-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC		0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML		-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML		-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC		1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL		0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear		7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.		76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)		-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)		-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)		19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)		-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)		-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)		16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)		56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

Stress Summation Comparison (N./mm²):

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Nozzle Calcs.: T2

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Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)		-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)		-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)		47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)		-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)		-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)		5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)		59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)		56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Nozzle Calcs.: T3

Nozl: 14 11:20pm Feb 6,2022

INPUT VALUES, Nozzle Description: T3 From : 60

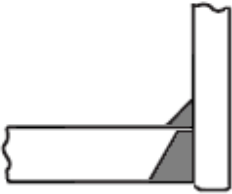
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm ²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm ²
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6852.35	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm ²
Allowable Stress At Ambient	Sna	137.90	N./mm ²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	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)



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: T3

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

Actual Inside Diameter Used in Calculation 1.000 in.
 Actual Thickness Used in Calculation 0.563 in.

Nozzle input data check completed without errors.

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

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

$$= (23.03 \cdot 293.5) / (138 \cdot 1.0 - 0.6 \cdot 23.03)$$

$$= 4.9524 \text{ mm.}$$

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

$$= R \left(\exp\left(\frac{P}{S_n \cdot E}\right) - 1 \right) \text{ per Appendix 1-2 (a) (1)}$$

$$= 15.7 \left(\exp\left(\frac{23.03}{137.9 \cdot 1.0}\right) - 1 \right)$$

$$= 0.2645 \text{ mm.}$$

Required Nozzle thickness under External Pressure per UG-28 : 0.3056 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	68.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	34.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	17.5000	mm.

Weld Strength Reduction Factor [fr1]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [fr2]:

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

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

$$= 1.000$$

Weld Strength Reduction Factor [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	1.555	0.288	NA
Area in Shell	A1	0.749	1.891	NA
Area in Nozzle Wall	A2	3.862	3.848	NA

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Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.242	6.369	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

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

$$= (31.4 * 4.9524 * 1.0 + 2 * 11.3 * 4.9524 * 1.0 * (1 - 1.0))$$

$$= 1.555 \text{ cm}^2$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

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

$$= 36.6(1.0 * 7.0 - 1.0 * 4.952) - 2 * 11.3$$

$$(1.0 * 7.0 - 1.0 * 4.9524) * (1 - 1.0)$$

$$= 0.749 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

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

$$= (2 * 17.5) (11.3 - 0.26) 1.0$$

$$= 3.862 \text{ cm}^2$$

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

$$= (Wo^2 - \text{Area Lost}) * fr2 + ((Wi - can / 0.707)^2 - \text{Area Lost}) * fr2$$

$$= (8.0^2 - 0.01) * 1.0 + (0.0^2 - 0.0) * 1.0$$

$$= 0.630 \text{ cm}^2$$

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

Wall Thickness for Internal/External pressures	ta = 3.3056 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 7.9524 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 7.9524 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$= \min[tb3, \max(tb1, tb2)]$$

$$= \min[6.42, \max(7.9524, 4.5)]$$

$$= 6.4200 \text{ mm.}$$

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

$$= \max(ta, tb)$$

$$= \max(3.3056, 6.42)$$

$$= 6.4200 \text{ mm.}$$

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
 Thickness Ratio = tr * (E*) / (tg - c) = 0.707, Temp. Reduction = 16 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

Design Pressure/Ambient Rating = 23.03/51.10 = 0.451

Weld Size Calculations, Description: T3

Intermediate Calc. for nozzle/shell Welds Tmin 7.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.9000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

$$\begin{aligned}
 &= \max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max(0, (1.5551 - 0.7494 + 2 * 11.3 * 1.0 * \\
 &\quad (1.0 * 7.0 - 4.9524))138) \\
 &= 17.49 \text{ kN}
 \end{aligned}$$

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

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4 - (Wi-Can/.707)^2*fr2)*Sv \\
 &= (3.8624 + 0.0 + 0.63 - 0.0 * 1.0) * 138 \\
 &= 61.95 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= (3.8624 + 0.0 + 0.63 + (1.582)) * 138 \\
 &= 83.76 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= (3.8624 + 0.0 + 0.63 + 0.0 + (1.582)) * 138 \\
 &= 83.76 \text{ kN}
 \end{aligned}$$

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= (3.1416/2.0) * 54.0 * 8.0 * 0.49 * 138 \\
 &= 46. \text{ kN}
 \end{aligned}$$

Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * (Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn \\
 &= (3.1416 * 21.35) * (14.3 - 3.0) * 0.7 * 138 \\
 &= 73. \text{ kN}
 \end{aligned}$$

Tension, Shell Groove Weld [Tngw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= (3.1416/2.0) * 54.0 * (10.0 - 3.0) * 0.74 * 138 \\
 &= 61. \text{ kN}
 \end{aligned}$$

Strength of Failure Paths:

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$$\text{PATH11} = (\text{SONW} + \text{SNW}) = (46 + 73) = 119 \text{ kN}$$

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

$$= (46 + 0 + 61 + 0) = 106 \text{ kN}$$

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

$$= (46 + 61 + 0) = 106 \text{ kN}$$

Summary of Failure Path Calculations:

Path 1-1 = 119 kN , must exceed W = 17 kN or W1 = 61 kN

Path 2-2 = 106 kN , must exceed W = 17 kN or W2 = 83 kN

Path 3-3 = 106 kN , must exceed W = 17 kN or W3 = 83 kN

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

The Drop for this Nozzle is : 1.2575 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 211.2574 mm.

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Nozzle Schedule:

Flg	Nominal or	Schd	Flg	Nozzle	Wall	Reinforcing Pad	Cut
Class	Actual	or FVC	Type	O/Dia	Thk	Diameter	Thk
Description	Size	Type		in	mm.	mm.	mm.
T4	0.750 in	Actual	LWN	1.872	14.250	...	...
T3	1.000 in	Actual	LWN	2.126	14.300	...	...
S3	2.000 in	Actual	LWN	3.307	16.600	...	...
T1	4.000 in	120	WNF	4.500	11.125	230.00	10.00
S2	6.000 in	80	WNF	6.625	10.973	290.00	10.00
S1	6.000 in	80	WNF	6.625	10.973	290.00	10.00
T2	6.000 in	80	WNF	6.625	10.973	290.00	10.00

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:
 Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T4	SA-350 LF2	10.000	8.000	...	...	...
T3	SA-350 LF2	10.000	8.000	...	...	...
S3	SA-350 LF2	10.000	8.000	...	...	...
T1	SA-333 6	10.000	8.000	8.000	10.000	...
S2	SA-333 6	10.000	8.000	8.000	10.000	...
S1	SA-333 6	10.000	8.000	8.000	10.000	...
T2	SA-333 6	10.000	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	203.000	90.0	200.00	0.00	CHANNEL 01
T3	6802.351	270.0	200.00	0.00	CHANNEL 002

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S3	709.175	270.0	200.00	0.00	SHELL
T1	203.000	270.0	200.00	0.00	CHANNEL 01
S2	759.175	90.0	200.00	0.00	SHELL
S1	6243.176	90.0	200.00	0.00	SHELL
T2	6799.351	90.0	200.00	0.00	CHANNEL 002

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Input Echo, Tubesheet Number 1, Description: TUBE SHEET

Shell Data:

Main Shell Description: SHELL

Shell Maximum Design Pressure	Psd,max	23.00	bars
Shell Maximum Operating Pressure	Psox,max	23.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	10.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	581.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	125.00	°C
Shell Material		SA-516 70	

Note:

Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
 Make sure that material properties at this temperature are not
 time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm ²
Shell Allowable Stress at Ambient		137.90	N./mm ²

Channel Description: CHANNEL 01

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	23.00	bars
Channel Maximum Operating Pressure	Ptox,max	23.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	581.000	mm.
Channel Design Temperature	TEMPC	125.00	°C
Channel Material		SA-516 70	

Note:

Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
 Make sure that material properties at this temperature are not
 time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm ²
Channel Allowable Stress at Ambient		137.90	N./mm ²

Tube Data:

Number of Tube Holes	Nt	241	
Tube Wall Thickness	et	2.7700	mm.
Tube Outside Diameter	D	25.4000	mm.
Total Straight Tube Length	Lt	6000.00	mm.
Straight Tube Length (bet. inner tubsht faces) L		5876.00	mm.
Design Temperature of the Tubes		125.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used	Smls. & wld. tube		
Tube Allowable Stress at Temperature		117.90	N./mm ²
Tube Allowable Stress At Ambient		117.90	N./mm ²
Tube Yield Stress At design Temperature	Syt	216.71	N./mm ²
Tube Pitch (Center to Center Spacing)	P	32.0000	mm.
Tube Layout Pattern		Triangular	

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Fillet Weld Leg	af	2.0000	mm.
Groove Weld Leg	ag	2.0000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		f	
Radius to Outermost Tube Hole Center	ro	270.770	mm.
Largest Center-to-Center Tube Distance	Ul	40.0000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.
Area of Tube Layout	Ap	226.8	cm ²

Tubesheet Data:

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	125.00	°C
Tubesheet Material		SA-350 LF2	

Note:

Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
 Make sure that material properties at this temperature are not
 time-dependent for Material: SA-350 LF2

Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm ²
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm ²
Thickness of Tubesheet	h	62.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	715.000	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	644.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	578.00	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	578.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		644.00	mm.

Note: Tubesheet diameter is now: 644.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	226.8	cm ²
---------------------------	----	-------	-----------------

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	600.000	mm.
Tube End condition corresponding to Span (l)	k	1.00	

Ignore Radial Thermal Exp. effects (UHX-13.8/14.6) YES

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

Tubesheet Metal Temp. at Rim	T'	21.11	°C
Shell Metal Temp. at Tubesheet	T'S	21.11	°C
Channel Metal Temp. at Tubesheet	T'C	21.11	°C
Perform Differential Pressure Design		N	
Run Multiple Load Cases		YES	

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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	28.02	°C
Mean Tube Metal Temp. along Tube length	Ttm	20.44	°C
Junction Stress Reduction option	Perform Plastic Calculation		

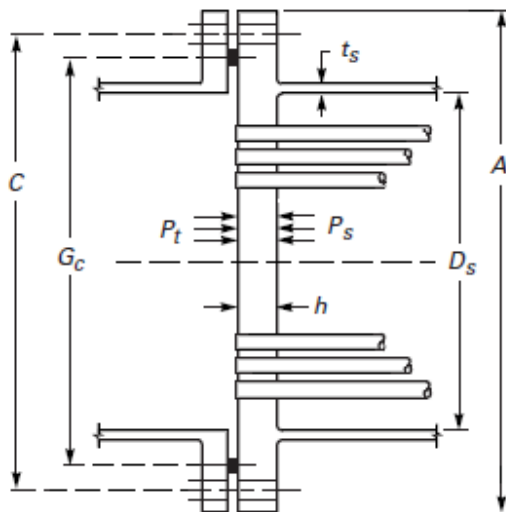
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side	Channel	
Flange Outside Diameter	A	715.000 mm.
Flange Inside Diameter	B	581.000 mm.
Flange Face Outside Diameter	Fod	647.000 mm.
Flange Face Inside Diameter	Fid	581.000 mm.
Gasket Outside Diameter	Go	641.000 mm.
Gasket Inside Diameter	Gi	611.000 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 ²
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	559.000 mm.
Width of Partition Gasket	wp	6.4000 mm.
Partition Gasket Factor,	mPart	3.7500
Partition Gasket Design Seating Stress	yPart	62.05 N./mm ²
Partition Gasket Facing Sketch	Code Sketch 1a	
Partition Gasket Column for Gasket Seating	Code Column II	

Bolting Information:

Diameter of Bolt Circle	C	673.000 mm.
Nominal Bolt Diameter	dB	19.0500 mm.
Type of Thread Series	UNC Thread Series	
Number of Bolts	n	32

Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange



Configuration b:

Bolt Material

SA-

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Bolt Allowable Stress At Temperature	Sb	172.38	N./mm ²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm ²
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	46.0000	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	28.0 °C	0.0000115937 /°C
Elastic Mod. at Design Temperature	125.0 °C	0.19660E+09 KPa.
Th. Exp. Coeff. Metal Temp. at Tubsht	21.1 °C	0.0000115190 /°C
Elastic Mod. at Metal Temp. along Len	28.0 °C	0.20231E+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	125.0 °C	0.19660E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

Tubes - TE-1 Carbon & Low Alloy Steels, Group 1
 Tubes - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. along Len	20.4 °C	0.0000115094 /°C
Elastic Mod. at Design Temperature	125.0 °C	0.19660E+09 KPa.
Elastic Mod. at Metal Temp. along Len	20.4 °C	0.20275E+09 KPa.
Elastic Mod. at Tubsht. Design Temp.	125.0 °C	0.19660E+09 KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09 KPa.

TubeSheet - TE-1 Carbon & Low Alloy Steels, Group 1
 TubeSheet - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. at Rim	21.1 °C	0.0000115190 /°C
Elastic Mod. at Design Temperature	125.0 °C	0.19660E+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:

$$= (P*(D/2-CAE)) / (S*E+0.4*P) \text{ per Appendix 1-1 (a) (1)}$$

$$= (24.03*(25.4/2-0.0))/(117.9*1.0+0.4*24.03)$$

$$= 0.2568 + 0.0000 = 0.2568 \text{ mm.}$$

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Tube Required Thickness under External Pressure (Shellside pressure) :

External Pressure Chart CS-2 at 125.00 °C
 Elastic Modulus for Material 199943392.00 KPa.

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.7700	25.40	5876.00	9.17	50.0000	0.0130823	122.73

EMAWP = (2.167/(D/T)-0.0833)*B = 187.7951 bars

Results for Reqd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.6452	25.40	5876.00	39.37	50.0000	0.0007098	70.96

EMAWP = (4*B)/(3*(D/T)) = (4 *70.9602)/(3 *39.3677) = 24.0319 bars

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.6452	mm.
Allowable Internal Pressure at Corroded thickness	281.73	bars
Required Internal Design Pressure	24.03	bars
Allowable External Pressure at Corroded thickness	187.80	bars
Required External Design Pressure	24.03	bars
Required Thickness due to Shell Side pressure	0.6452	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	15.000	mm.
Basic Gasket Width,	b0 = N / 2.0	7.500	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	6.899	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	627.203	mm.

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

= 2a + 6t/(m + 0.5)
 = 2 * 19.05 + 6 * 46.0/(3.78 + 0.5)
 = 102.586 mm.

Actual Circumferential Bolt Spacing [Bs]:

= C * sin(pi / n)
 = 673.0 * sin(3.142/32)
 = 65.966 mm.

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

= max(sqrt(Bs/(2a + t)), 1)
 = max(sqrt(65.966/(2 * 19.05 + 46.0)), 1)
 = 1.0000

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 ²	56.730	62.348	
Radial Distance between Hub and Bolts:	20.637	36.000	
Radial Distance between Bolts and the Ed	20.637	21.000	

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Circumferential Spacing between the Bolt 44.450 65.966 102.586

Flange Design Bolt Load, Seating Condition W : 1026.22 kN
 Flange Design Bolt Load, Operating Condition Wm1: 977.80 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)
 = $0.0/62.0 = 0.0$ (must be $0 \leq \rho \leq 1$)

Compute the Effective Tube Hole Diameter [d*]:
 = $\text{Max}(dt - 2tt * (Et/E) (StT/S) (\rho), dt - 2tt)$
 = $\text{Max}(25.4 - 2 * 2.77 * (.19660E+09 / .19660E+09) * (117/137) * (0.0) , 25.4 - 2 * 2.77)$
 = 25.4000 mm.

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
 = $2 * r_o + dt = 2 * 270.77 + 25.4 = 566.94$ mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
 = $(p - dt) / p = (32.0 - 25.4) / 32.0 = 0.2062$

Compute the Equivalent Outer Tube Limit Radius [ao]:
 = $Do / 2 = 566.94 / 2 = 283.47$ mm.

Compute the Effective Tube Pitch [p*]:
 = $p / \sqrt{1 - 4 * \min(AL * CNV_factor, 4 * Do * p) / (\pi * Do^2)}$
 = $32.0 / \sqrt{1 - 4 * \min(226.77 * 100.0, 4 * 566.94 * 32.0) / (3.141 * 566.94^2)}$
 = 33.5420 mm.

Compute the Effective Ligament Efficiency for Bending [mu*]:
 = $(p^* - d^*) / p^* = (33.542 - 25.4) / 33.542 = 0.2427$

Compute the Ratio [Rhos]:
 = $as / ao = 290.5 / 283.47 = 1.0248$

Compute the Ratio [Rhoc]:
 = $ac / ao = 313.6014 / 283.47 = 1.106295$

Compute Parameter [xt]:
 = $1 - Nt * ((dt - 2 * tt) / (2 * ao))^2$
 = $1 - 241 * ((25.4 - 2 * 2.77) / (2 * 283.47))^2 = 0.7043$

Determine Parameter [xs]:
 = $1 - Nt * (dt / (2 * ao))^2$
 = $1 - 241 * (25.4 / (2 * 283.47))^2 = 0.5163$

Determine the Value [h'g]:
 = $\text{Max}((hg - CATC), 0)$ (For pressure only cases)
 = $\text{Max}((5.0 - 0.0), 0) = 5.0$ mm.

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
 = $\pi * t_s (D_s + t_s) E_s / L$

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$$= 3.1416 * 10.0 (581.0 + 10.0) .19660E+09/5876.0$$

$$= 621211456.0000 \text{ KPa. } * \text{ mm.}$$

Determine the Axial Tube Stiffness [Kt]:

$$= \pi * t t (D t - t t) E t / L$$

$$= 3.1416 * 2.77 (25.4 - 2.77) .19660E+09/5876.0$$

$$= 6588953.0000 \text{ KPa. } * \text{ mm.}$$

Compute the Stiffness Factor [Ks,t]:

$$= K s / (N t * K t) = 0.62121E+09 / (241 * 6588953) = 0.39121$$

Rigidity Ratio [J]:

$$= 1 / (1 + K s / K j)$$

$$= 1 / (1 + 0.62121E+09 / 0.0) = 1. (= 1 \text{ if No Exp. } J t .)$$

Compute Shell Coefficient [betas]:

$$= ((12 * (1 - \nu s^2))^{0.25}) / ((D s + t s) * t s)^{0.5}$$

$$= ((12 * (1 - 0.3^2))^{0.25}) / ((581.0 + 10.0) * 10.0)^{0.5}$$

$$= 0.0236 \text{ 1/mm.}$$

Determine Shell Coefficient [ks]:

$$= \text{betas} * E s * t s^3 / (6 * (1 - \nu s^2))$$

$$= 0.024 * 0.19660E+09 * 10.0^3 / (6 * (1 - 0.3^2))$$

$$= 8514383.0000 \text{ bars*mm.}^2$$

Determine Shell Coefficient [Lambdas]:

$$= (6 * D s * k s) / (h^3) * (1 + h * \text{betas} + 0.5 * (h * \text{betas})^2)$$

$$= 6 * 581.0 * 8514383 / (62.0^3) * (1 + 62.0 * 0.024 + 1.075)$$

$$= 440960.5312 \text{ bars}$$

Determine Shell Coefficient [deltaS]:

$$= D s^2 / (4 * E s * T s) * (1 - \nu s / 2)$$

$$= 581.0^2 / (4 * 0.19660E+09 * 10.0) * (1 - 0.3 / 2)$$

$$= 0.0364839621 \text{ mm./N./mm}^2$$

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.

$$h/p = 1.937500 ; \mu^* = 0.242740$$

$$E^*/E = 0.209541 ; \nu^* = 0.401441 ; E^* = 41195736. \text{ KPa.}$$

Compute the Tube Bundle Stiffness Factor [Xa]:

$$= ((24 * (1 - \nu^*) * N t * E t * t t * (d t - t t) * a o^2) / (E^* * L * H^3))^{0.25}$$

$$= ((24 * (1 - 0.401^2) * 241 * .19660E+09 * 2.77 * (25.4 - 2.77) * 283.47^2) / (41195736 * 5876.0 * 62.0^3))^{0.25}$$

$$= 3.0209$$

Values from Table UHX-13.1

$$Z d = 0.053417 ; Z v = 0.102619 ; Z m = 0.487516$$

$$Z a = 0.225057E+01 ; Z w = 0.102619$$

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:

$$= A / D o = 644.0 / 566.94 = 1.1359$$

Compute Coefficient [F]:

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$$= (1 - \nu^*) / (E^*) * (\text{Lambdas} + \text{Lambdac} + E * \ln(K))$$

$$= (1 - 0.4) / (41195736) * (440960.53 + 0.0 + 0.19660E+09 * \ln(1.14))$$

$$= 1.0048$$

Compute Parameter [Phi]:

$$= (1 + \nu^*) * F = (1 + 0.4014) * 1.0048 = 1.4081$$

Compute Parameter [Q1]:

$$= (\text{Rhos} - 1 - \text{Phi} * \text{Zv}) / (1 + \text{Phi} * \text{Zm})$$

$$= (1.0248 - 1 - 1.4081 * 0.1026) / (1 + 1.4081 * 0.4875)$$

$$= -0.070975378$$

Compute Parameter [Qz1]:

$$= (\text{Zd} + \text{Q1} * \text{Zw}) / 2 * \text{Xa}^4$$

$$= (0.05342 + -0.07098 * 0.10262) / 2 * 3.02093^4 = 1.9211$$

Compute Parameter [Qz2]:

$$= (\text{Zv} + \text{Q1} * \text{Zm}) / 2 * \text{Xa}^4$$

$$= (0.10262 + -0.07098 * 0.48752) / 2 * 3.02093^4 = 2.8324$$

Compute Parameter [U]:

$$= (\text{Zw} + (\text{Rhos} - 1) * \text{Zm}) * \text{Xa}^4 / (1 + \text{Phi} * \text{Zm})$$

$$= (0.1026 + (1.0248 - 1) * 0.4875) * 3.02093^4 / (1 + 1.4081 * 0.4875)$$

$$= 5.6648$$

UHX-13.5.5 Step 5:

Determine factor [gamab]:

$$= (\text{Gc} - \text{C}) / \text{Do} \text{ (config b)}$$

$$= (627.2029 - 673.0) / 566.94 = -0.08078$$

Compute Parameter [gamma]:

$$= 0.000 \text{ mm. (For Pressure only cases)}$$

Calculate Parameter [OmegaS]:

$$= \text{rhos} * \text{ks} * \text{Betas} * \text{deltaS} (1 + \text{h} * \text{Betas})$$

$$= 1.0248 * 8514383 * 0.0236 * 0.036484 (1 + 62.0 * 0.0236)$$

$$= 1856.4623 \text{ mm.}^2$$

Calculate Parameter [Omega*S]:

$$= \text{Ao}^2 * (\text{Rhos}^2 - 1) * (\text{Rhos} - 1) / 4 - \text{OmegaS}$$

$$= 283.47^2 * (1.025^2 - 1) * (1.025 - 1) / 4 - 1856.462$$

$$= -1831.4454 \text{ mm.}^2$$

Calculate Parameter [OmegaC]:

$$= \text{rhoc} * \text{kc} * \text{Betac} * \text{deltaC} (1 + \text{h} * \text{Betac})$$

$$= 1.1063 * 0.0 * 0.0 * 0. (1 + 62.0 * 0.0)$$

$$= 0.0000 \text{ mm.}^2$$

Calculate Parameter [Omega*C]:

$$= \text{ao}^2 [(\text{Rhoc}^2 + 1) * (\text{Rhoc} - 1) / 4 - (\text{Rhoc} - 1) / 2] - \text{OmegaC}$$

$$= 283.47^2 [(1.10629^2 + 1) * (1.10629 - 1) / 4 - (1.10629 - 1) / 2] - 0.$$

$$= 3752.3599 \text{ mm.}^2$$

Compute the Pressure [P*S]:

$$= 0 \text{ For Pressure only cases or Configurations d,e,f,A,B,C,D}$$

Compute the Pressure [P*C]:

$$= 0 \text{ For Pressure only cases or Configurations b,c,d,B,C,D}$$

UHX-13.5.6 Step 6:

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Compute the Pressure [P's]:

$$\begin{aligned}
 &= P_s * \{ x_s + 2(1 - x_s) \text{nut} + [2/Kst(Ds/Do)^2] \text{nus} - \\
 &\quad [(\text{rhos}^2 - 1)/(J * Kst)] - [(1 - J)/(2J * Kst)] [(Dj^2 - (Ds)^2)/Do^2] \} \\
 &= 23.0 * \{ 0.516 + 2(1 - 0.516) * 0.3 + \\
 &\quad [2/0.391 (581.0/566.94)^2] * 0.3 - \\
 &\quad [(1.025^2 - 1)/(1.0 * 0.391)] - \\
 &\quad [(1 - 1.0)/(2 * 1.0 * 0.391)] [(0.0^2 - (581.0)^2)/566.94^2] \} \\
 &= 52.6442 \text{ bars}
 \end{aligned}$$

Compute the Pressure [P't]:

$$\begin{aligned}
 &= [x_t + 2(1 - x_t) \text{nut} + 1/(J * Kst)] * P_t \\
 &= [0.704 + 2(1 - 0.704) * 0.3 + \\
 &\quad 1/(1.0 * 0.391)] * 23.0 \\
 &= 79.0717 \text{ bars}
 \end{aligned}$$

Compute the Pressure [Pgama]:

$$\begin{aligned}
 &= N_t * K_t * \text{gama} / (\text{pi} * a_o^2) \\
 &= 241 * 6588953 * 0.0 / (3.142 * 283.47^2) = 0.0 \text{ bars}
 \end{aligned}$$

Compute the Pressure [Pw]:

$$\begin{aligned}
 &= -\text{gamab} * U * W * / (2 * \text{pi} * a_o^2) \\
 &= -0.081 * 5.665 * 977.8 / (2 * 3.142 * 283.47^2) \\
 &= 8.8624 \text{ bars}
 \end{aligned}$$

Calculate the Pressure [Prim]:

$$\begin{aligned}
 &= -(U/a_o^2) (\text{Omega} * S * P_s - \text{Omega} * C * P_t) \\
 &= -(5.665/283.47^2) (-2.839 * 23.0 - 5.816 * 23.0) \\
 &= 9.0537 \text{ bars}
 \end{aligned}$$

Calculate the Pressure [POmega]:

$$\begin{aligned}
 &= U/a_o^2 (\text{Omega} * S * P_s - \text{Omega} * C * P_t) \\
 &= 5.665/283.47^2 (2.8775 * 0.0 - 0.0 * 0.0) \\
 &= 0.0000 \text{ bars}
 \end{aligned}$$

Determine the Effective Pressure [Pe]:

$$\begin{aligned}
 &= J * Kst / (1 + J * Kst * (\text{Qz1} + (\text{Rhos} - 1) * \text{Qz2})) * \\
 &\quad (P's - P't + \text{Pgama} + Pw + \text{Prim}) \\
 &= 0.1000E+01 * 0.391 / (1 + 1.0 * 0.391 * (1.921 + (1.025 - \\
 &\quad 1) * 2.832)) * (52.644 - 79.072 + 0.0 + 8.862 + 9.054) \\
 &= -1.8717 \text{ bars}
 \end{aligned}$$

UHX-13.5.7 Step 7:

Determine Factor [Q2]:

$$\begin{aligned}
 &= [((\text{Omega} * S * P_s - \text{Omega} * C * P_t) - (\text{Omega} * S * P_s - \text{Omega} * C * P_t)) \text{CNV_FAC} + \\
 &\quad W * \text{gamab} / (2 * \text{pi})] / (1 + \text{Phi} * Z_m) \\
 &= [((-1831.445 * 23.0 - 3752.36 * 23.0) - \\
 &\quad (1856.462 * 0.0 - 0.0 * 0.0)) * 0. + \\
 &\quad 977.8 * -0.081 / (2 * 3.141)] / (1 + 1.4081 * 0.48752) \\
 &= -15.069016457 \text{ kN}
 \end{aligned}$$

Calculate Factor [Q3]:

$$\begin{aligned}
 &= Q1 + 2 * Q2 / (\text{Pe} * a_o^2) \\
 &= -0.071 + 2 * -15.069 / (-1.872 * 283.47^2) \\
 &= 1.932976
 \end{aligned}$$

Fm Value from Table UHX-13.1 = 0.990604

The Tubesheet Bending Stress - Original Thickness [Sigma]:

$$\begin{aligned}
 &= (1.5 * F_m / \mu *) * (2 * a_o / (H - h'g))^2 * \text{Pe} \\
 &= (1.5 * 0.9906 / 0.2427) * (2 * 283.47 / (62.0 - 5.0))^2 * -1.87
 \end{aligned}$$

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$$= -113.3509 \text{ N./mm}^2$$

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]:

$$= (1.5 * F_m / \mu^*) * (2 * a_o / (h - h'g)^2 * P_e)$$

$$= (1.5 * 12.1082 / 0.2427) * (2 * 283.47 / (45.39 - 5.0)^2 * 0.14)$$

$$= 206.8445 \text{ N./mm}^2$$

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReq_B]:

$$= h + C_{ats} + C_{atc} = 45.3899 + 0.0 + 0.0 = 45.3899 \text{ mm.}$$

UHX-13.5.8 Step 8:

Shear Stress check [Tau_{limit}]:

$$= 1.6 * S * \mu * h / a_o$$

$$= 1.6 * 137.9 * 0.206 * 62.0 / 283.47$$

$$= 9.9532 \text{ N./mm}^2$$

The Shear Stress is not required to be computed; [Pe] <= Tau_{limit}

Note: Tubesheet Shear Stress is probably low, use the following req. thk:

$$\text{Tubesheet thickness (Incl. Corr.)} = 3.8100 \text{ mm.}$$

$$\text{Tubesheet Shear Stress} = 31.9994 \text{ N./mm}^2$$

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreq_d]:

$$= \text{Max}(H_{reqB}, H_{reqS}) = \text{Max}(45.3899, 3.81) = 45.3899 \text{ mm.}$$

UHX-13.5.9 Step 9:

The Ft_{min} and Ft_{max} Coefficients from Table UHX-13.2:

$$F_{tmin} = -6.5552, F_{tmax} = 10.4845$$

First Extreme Tube Axial Stress from among all the tubes [Sigma_{t1}]:

$$= ((P_s * x_s - P_t * x_t) - P_e * F_{tmin}) / (X_t - X_s)$$

$$= ((23.0 * 0.5163 - 23.0 * 0.7043) - (-1.872) * -6.555) /$$

$$(0.7043 - 0.5163))$$

$$= -8.8265 \text{ N./mm}^2$$

Second Extreme value of Tube Axial Stress from among all the tubes [Sigma_{t2}]:

$$= ((P_s * x_s - P_t * x_t) - P_e * F_{tmax}) / (X_t - X_s)$$

$$= ((23.0 * 0.5163 - 23.0 * 0.7043) - (-1.872) * 10.485) /$$

$$(0.7043 - 0.5163))$$

$$= 8.1382 \text{ N./mm}^2$$

Maximum Tube Axial Stress [Sigma_{t,max}]:

$$= \text{MAX}(\text{abs}(\text{Sigma}_{t1}), \text{abs}(\text{Sigma}_{t2})) = 8.826 \text{ N./mm}^2$$

The Allowable Tube Stress, [Sigma_A]:

$$= S_{ot} = 117.9045 \text{ N./mm}^2$$

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:

$$= \text{Max}((3.25 - 0.25 * (Z_d + Q_3 * Z_w) * X_a^4), 1.25)$$

$$= \text{Max}((3.25 - 0.25 * (0.053 + 1.933 * 0.103) * 3.021^4), 1.25)$$

$$= 1.2500 \text{ (Should be } \leq 2 \text{)}$$

Determine the Factor [rt]:

$$= ((dt^2 + (dt - 2*tt)^2)^{.5}) / 4$$

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$$= ((25.4^2 + (25.4 - 2*2.77)^2)^{.5}) / 4 = 8.0606 \text{ mm.}$$

Determine the Factor [Ct]:

$$= (2 * \text{PI}^2 * E_t / S_{yt})^{0.5}$$

$$= (2 * 3.14^2 * 0.19660\text{E}+09 / 216)^{0.5} = 133.8224$$

Determine the Factor [Ft]:

$$= k * L/r = 1.0 * 600.0 / 8.061 = 74.4359$$

The Buckling Allowable Stress [Stb]:

$$= S_{y,t} / F_s * (1 - F_t / (2 * C_t))$$

$$= 216 / 1.25 * (1 - 74.436 / (2 * 133.822))$$

$$= 117.905 \text{ N./mm}^2 \quad (\text{Never greater than } S_{ot})$$

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:

$$= \text{Sigmat,max} * \text{Tube Area} = 8.83 * 1.9693 = 1.74 \text{ kN}$$

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

$$= 3.1415 * t * (d_o - t) * S_a$$

$$= 3.1415 * 2.77 * (25.4 - 2.77) * 117.9 = 23.217 \text{ kN}$$

Fillet Weld Strength [Ff]:

$$= 0.55 * 3.1415 * a_f * (d_o + 0.67 * a_f) * S_w \quad (\text{but not } > F_t)$$

$$= 0.55 * 3.1415 * 2.0 * (25.4 + 0.67 * 2.0) * 117.9$$

$$= 10.8943 \text{ kN}$$

Groove Weld Strength [Fg]:

$$= 0.85 * 3.1415 * a_g * (d_o + 0.67 * a_g) * S_w \quad (\text{but not } > F_t)$$

$$= 0.85 * 3.1415 * 2.0 * (25.4 + 0.67 * 2.0) * 117.9$$

$$= 16.8366 \text{ kN}$$

Max. Allow. Tube-Tubesheet Joint load, Lmax

$$= F_t = 23.2171 \text{ kN}$$

Design Strength Ratio [fd]:

$$= 1.0000$$

Weld Strength Factor [fw]:

$$= S_{ot} / (\text{Min}(S_{ot}, S)) = 1.0000$$

Min Weld Length [ar]:

$$= 2 * ((0.75 * d_o)^2 + 1.07 * t * (d_o - t) * f_w * f_d)^{1/2} - 0.75 * d_o$$

$$= 3.3717 \text{ mm.}$$

Minimum Required Fillet Weld Leg	afr	1.6859 mm.
Minimum Required Groove Weld Leg	agr	1.6859 mm.

Tube-Tubesheet Jt allowable, 23.22 is \geq tube strength 23.22 kN

Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:

$$= S_s * E_{sw} = 137.9 * 1.0 = 137.9 \text{ N./mm}^2$$

Axial Membrane Stress in Shell [Sigmas,m]:

$$= a_o^2 / ((D_s + t_s) * t_s) * [P_e + (\rho_{hos}^2 - 1) (P_s - P_t)] + a_s^2 * P_t / ((D_s + t_s) * t_s)$$

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$$= 283.47^2 / ((581.0 + 10.0) * 10.0) * [-1.87 + (1.025^2 - 1) (23.0 - 23.0)] + 290.5^2 * 23.0 / ((581.0 + 10.0) * 10.0)$$

$$= 30.2992 \text{ N./mm}^2$$

UHX-13.5.11 Step 11:

Note:

For a given Shell thickness of 10.0 mm., the minimum Shell length adjacent to the tubesheet should be 137.202 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:

$$= ao^2 / ((Ds+ts) * ts) [Pe + (Rhos^2 - 1) (Ps - Pt)] + as^2 * Pt / ((Ds+ts) * ts)$$

$$= 283.47^2 / ((581.0 + 10.0) * 10.0) [-1.87 + (1.025^2 - 1) (23.0 - 23.0)] + 290.5^2 * 23.0 / ((581.0 + 10.0) * 10.0)$$

$$= 30.2992 \text{ N./mm}^2$$

The Shell Bending Stress due to Joint Interaction [Sigmasb]:

$$= 6 * ks / ts^2 \{ betas [\delta s * Ps + as^2 * PstarS / (Es * ts)] + 6(1 - \nu^2) / (E^*) (ao/h)^3 (1 + h * betas / 2) [Pe (Zv + Zm * Q1) + 2 / ao^2 * Zm * Q2] \}$$

$$= 6 * 8514383 / 10.0^2 \{ 0.024 [0.036 * 23.0 + 290.5^2 * 0.0 / (.19660E+1)] + 6(1 - 0.4^2) / (41195736) (283.47 / 62.0)^3 (1 + 62.0 * 0.02 / 2) [-1.9 (0.103 + 0.488 * -0.071) + 2 / 283.47^2 * 0.488 * -15.069] \}$$

$$= -100.8277 \text{ N./mm}^2$$

Shell Stress Summation vs. Allowable

$$abs(\text{Sigmasm}) + abs(\text{Sigmasb}) \leq 1.5 * Ss$$

$$abs(30.3) + abs(-100.8) \leq 206.85 \text{ N./mm}^2$$

$$131.13 \text{ must be } < \text{ or } = 206.85 \text{ N./mm}^2$$

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	113.4	206.9 N./mm ²	Ok
Tubesheet Shear Stress	2.1	110.3 N./mm ²	Ok
Maximum Tube Stress	8.8	117.9 N./mm ²	Ok
Minimum Tube Stress (Buckling)	-8.8	-117.9 N./mm ²	Ok
Maximum Force on any one Tube	1.7	23.2 kN	Ok
Axial Membrane Stress in Shell	30.3	137.9 N./mm ²	Ok
Shell Stress (jt. inter.)	131.1	206.9 N./mm ²	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	45.390	62.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.686	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.686	2.000	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

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Case#	--Reqd. Tbsht	Thk. + CA Extnsn	---- Tubesheet Bend	Stresses Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	43.480	22.721	125	207	16	110	Ps+Pt-Th	D1 Ok
D2uc	25.729	...	55	207	14	110	Ps+Pt-Th	D2 Ok
D3uc	45.390	...	113	207	2	110	Ps+Pt-Th	D3 Ok
D4uc	7.089	...	3	207	...	110	Ps+Pt-Th	D4 Ok
O1uc	11.066	...	127	446	23	110	Ps+Pt+Th	O1 Ok
O2uc	19.129	...	79	446	8	110	Ps+Pt+Th	O2 Ok
O3uc	19.360	...	106	446	10	110	Ps+Pt+Th	O3 Ok
O4uc	7.318	...	55	446	6	110	Ps+Pt+Th	O4 Ok
D1c	52.094	22.721	153	207	18	110	Ps+Pt-Th-c	D1 Ok
D2c	23.287	...	52	207	15	110	Ps+Pt-Th-c	D2 Ok
D3c	50.809	...	135	207	3	110	Ps+Pt-Th-c	D3 Ok
D4c	9.810	...	3	207	...	110	Ps+Pt-Th-c	D4 Ok
O1c	31.953	...	159	446	24	110	Ps+Pt+Th-c	O1 Ok
O2c	28.747	...	98	446	10	110	Ps+Pt+Th-c	O2 Ok
O3c	32.964	...	137	446	9	110	Ps+Pt+Th-c	O3 Ok
O4c	24.552	...	73	446	4	110	Ps+Pt+Th-c	O4 Ok
Max:	52.0941	22.721 mm.		0.737		0.214	(Str. Ratio)	

Load Case Definitions:

[Ps & Pt]:
 Shell-side and Tube-side Design or Operating Pressures
 derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the
 Load Case Tables

[(+)-Th]:
 With or Without Thermal Expansion, Tt,mx & Ts,mx

[c]:
 With or Without Corrosion Allowance

[D1, D2, D3]:
 Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:
 Design Load Case using the Minimum (Vacuum) Pressures (if specified)

[O1, O2, O3, O4]:
 Operating Load Cases using the Maximum and Minimum Operating Pressures and
 Operating Temperatures

Shell Axial Membrane Stress Summary:

Case#	---- Ten	Shell Stresses Allwd	Cmp	---- Allwd	:	---- Ten	Shell Band Stress Allwd	Cmp	---- Allwd	: Pass Fail
D1uc	11	137	...	...	:	...	...	...	...	Ok
D2uc	18	137	...	...	:	...	...	...	...	Ok
D3uc	30	137	...	...	:	...	...	...	...	Ok
D4uc	1	137	-1	-117	:	...	...	...	...	Ok
O1uc	3	470	...	...	:	...	...	...	...	Ok
O2uc	11	470	:	Ok
O3uc	21	470	:	Ok
O4uc	7	470	-7	-117	:	Ok
D1c	16	137	:	Ok
D2c	25	137	:	Ok
D3c	43	137	:	Ok

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D4c	2	137	-2	-111	Ok
O1c	7	470	Ok	
O2c	19	470	Ok	
O3c	33	470	Ok	
O4c	6	470	-6	-111	Ok	

Max RATIO	0.313		0.059			

Tube, Shell and Channel Stress Summary:

Case#	Ten	Allwd	Cmp	Allwd	Tube Loads Ld	Allwd	Shell Stress	Allwd	Channel Stress	Allwd	Pass Fail
D1uc	15	117	-15	-85	3	23	275	470	...	...	Ok
D2uc	6	117	-5	-78	1	23	182	206	...	...	Ok
D3uc	9	117	-9	-117	2	23	131	206	...	...	Ok
D4uc	...	117	...	-117	...	23	2	206	...	...	Ok
O1uc	20	235	-15	-79	4	46	314	470	...	...	Ok
O2uc	5	235	...	...	1	46	33	470	...	...	Ok
O3uc	16	235	-9	-114	3	46	176	470	...	...	Ok
O4uc	10	235	-4	-106	2	46	141	470	...	...	Ok
D1c	18	117	-18	-101	3	23	332	470	...	...	Ok
D2c	8	117	-7	-78	2	23	254	470	...	...	Ok
D3c	11	117	-10	-117	2	23	129	206	...	...	Ok
D4c	...	117	...	-117	...	23	2	206	...	...	Ok
O1c	24	235	-18	-93	5	46	365	470	...	...	Ok
O2c	4	235	...	...	1	46	91	470	...	...	Ok
O3c	18	235	-11	-117	3	46	171	470	...	...	Ok
O4c	10	235	-5	-117	2	46	154	470	...	...	Ok

Max RATIO	0.149		0.196		0.149		0.879		...		

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	52.094	62.000	Ok
Tubesheet Thickness Flanged Extension :	22.721	46.000	Ok
Tube Thickness :	0.645	2.770	Ok
Tube-Tubesheet Fillet Weld Leg :	1.686	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.686	2.000	Ok

Min Shell length of thk, (10.000) adj. to tubesheet: 137.202 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 : -0.517 mm.
 Due to Pressure Shell Compresses by : -0.083 mm.
 Due to Pressure + Thermal Shell Compresses by : -0.599 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	30.656	1.000	93.613	1.000
Tubesheet Shear Stress	131.633	1.000	178.646	1.000
Tube Tensile Stress	157.026	1.000	378.619	1.000
Tube Compressive Stress	80.553	0.625	303.073	1.000
Tube-Tubesheet Joint load	157.026	1.000	378.620	1.000
Shell Stress (Axial, Junction)	30.656	1.000	44.133	1.000
Tube Pressure Stress	281.725	1.000	187.794	1.000

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Tubesheet Extension Stress	25.277	...	No Calc	No Calc
Minimum MAWP	25.277		44.133	

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	36.997	1.000	93.613	1.000
Tubesheet Shear Stress	162.333	1.000	187.178	1.000
Tube Tensile Stress	187.847	1.000	483.423	1.000
Tube Compressive Stress	150.580	1.000	413.832	1.000
Tube-Tubesheet Joint load	187.847	1.000	483.415	1.000
Shell Stress (Axial, Junction)	36.997	1.000	69.170	1.000
Tube Pressure Stress	281.725	1.000	187.794	1.000
Tubesheet Extension Stress	25.277	...	No Calc	No Calc
Minimum MAPnc	25.277		69.170	

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(62.0/4, min(62.0, 10.0))
 = 15.500 mm.

Thickness Ratio = 0.91, Temperature Reduction per Fig. UCS 66.1 = 5 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-46 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

Channel Side MDMT calculation:

Governing thickness for the channel side:
 = tubesheet thickness/4
 = 62.0/4
 = 15.500 mm.

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

Impact Test Temperature provided per Specification	-46 °C
--	--------

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:
 = max(pt/Tubeside MAPnc, ps/Shellside MAPnc), must be <= 1
 = max(23.0/25.28, 23.0/69.17)
 = 0.910

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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]	D	-48	-48	-29	0.707	10.000	1.00	No
S2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	D	-48	-48		0.707	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: SS	[13]	D	-46	-48	-29	0.910	15.500	1.00	No
Warmest MDMT:			-29	-45					
BODY FLANGE 0	[11]	!	-46	-46		0.950	10.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.950	10.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 1	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
CHANNEL 01	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
CHANNEL 002	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 002	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
T4	[1]	D	-48	-48		0.706	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
T1	[1]	B	-29	-45	-29	0.707	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	D	-48	-48		0.707	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: CS	[14]	!	-46	-46		0.910	15.500	1.00	No
Warmest MDMT:			-29	-45					
Exchanger Side			Computed MDMT °C	Required MDMT °C				Pass/Fail	
	Shell		-45	-45				Pass	
	Channel/Tube		-45	-45				Pass	

Notes:

- [!] - This was an impact tested material.
- [1] - Governing Nozzle Weld.
- [4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
- [5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
- [6] - MDMT Calculations at the Shell/Head Joint.
- [7] - MDMT Calculations for the Straight Flange.
- [8] - Cylinder/Cone/Flange Junction MDMT.
- [9] - Calculations in the Spherical Portion of the Head.
- [10] - Calculations in the Knuckle Portion of the Head.
- [11] - Calculated (Body Flange) Flange MDMT.
- [12] - Calculated Flat Head MDMT per UCS-66.3
- [13] - Tubesheet MDMT, shell side, if applicable
- [14] - Tubesheet MDMT, tube side, if applicable
- [15] - Nozzle Material
- [16] - Shell or Head Material
- [17] - Impact Testing required

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[18] - Impact Testing not required, see UCS-66(b)(3)

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:

Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

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ASME Code, Section VIII Division 1, 2017

Diameter Spec : 581.000 mm. ID
 Vessel Design Length, Tangent to Tangent 7106.35 mm.
 Specified Datum Line Distance 50.00 mm.
 Shell Material SA-516 70 [Normalized]
 Nozzle Material SA-350 LF2 [Impact Tested]
 Nozzle Material SA-333 6 [Impact Tested]
 Re-Pad Material SA-516 70
 Shell Side Design Temperature 125 °C
 Channel Side Design Temperature 125 °C
 Shell Side Design Pressure 23.000 bars
 Channel Side Design Pressure 23.000 bars
 Wind Design Code ASCE-2010
 Earthquake Design Code ASCE 7-2010

Element Pressures and MAWP (bars):

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
HEAD 1	23.034	1.10No Calc	70	3.0000	No
CHANNEL 01	23.030	1.10No Calc	70	3.0000	N/A
BODY FLANGE 01	23.034	1.10No Calc	70	3.0000	N/A
SHELL	23.034	1.10No Calc	70	3.0000	N/A
BODY FLANGE 002	23.034	1.10No Calc	70	3.0000	N/A
CHANNEL 002	23.034	1.10No Calc	70	3.0000	N/A
HEAD 002	23.034	1.10No Calc	70	3.0000	No

Liquid Level: 581.00 mm. Dens.: 0.001 kg./cm³ Sp. Gr.: 0.600

Element Types and Properties:

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	Reqd Thk Int.	Thk Ext.	Joint Eff Long	Joint Eff Circ
Ellipse	0.0	50.0	12.0	7.8	4.6	1.00	1.00
Cylinder	407.0	407.0	10.0	8.0	4.8	1.00	1.00
Body Flg	495.0	88.0	79.0	60.2	49.5	1.00	1.00
Cylinder	6443.2	5880.0	10.0	8.0	8.1	1.00	1.00
Body Flg	6537.4	88.0	79.0	60.2	49.5	1.00	1.00
Cylinder	7006.4	407.0	10.0	8.0	4.8	1.00	1.00
Ellipse	7056.4	50.0	12.0	7.8	4.6	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

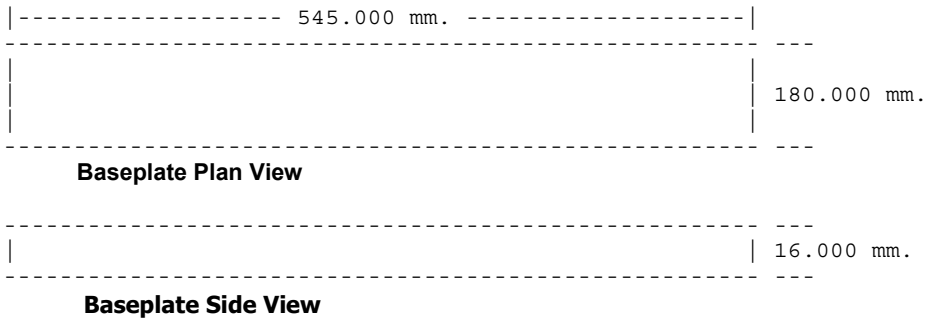
Saddle Parameters:

Saddle Width 150.000 mm.
 Saddle Bearing Angle 120.000 deg.
 Centerline Dimension 600.000 mm.
 Wear Pad Width 225.000 mm.
 Wear Pad Thickness 10.000 mm.
 Wear Pad Bearing Angle 132.000 deg.
 Distance from Saddle to Tangent 992.000 mm.
 Baseplate Length 545.000 mm.

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Baseplate Thickness	16.000	mm.
Baseplate Width	180.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	273.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch



Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	40.11	kN
Maximum Transverse Saddle Shear Load	3.34	kN
Maximum Longitudinal Saddle Shear Load	11.37	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	33.42	kN
Maximum Transverse Saddle Shear Load	1.05	kN
Maximum Longitudinal Saddle Shear Load	1.33	kN

Weights:

Fabricated - Bare W/O Removable Internals	4403.5	kg.
Shop Test - Fabricated + Water (Full)	6041.8	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	4403.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	4714.8	kg.
Empty - Fab. + Intls. + Details + Wghts.	4714.8	kg.
Operating - Empty + Operating Liquid (No CA)	5735.1	kg.
Field Test - Empty Weight + Water (Full)	6058.0	kg.

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Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Feb 06 23:18:11 2018.

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- [Load Case Report](#)
- [Solution Data](#)
- [ASME Code Stress Output Plots](#)
- [Stress Results - Notes](#)
- [ASME Overstressed Areas](#)
- [Highest Primary Stress Ratios](#)
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- [Allowable Loads](#)
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Model Notes
Model Notes

Input Echo:

```

Model Type                : Cylindrical Shell

Parent Geometry
  Parent Outside Diam.    :      601.000 mm.
  Thickness                :         8.000 mm.
  Fillet Along Shell      :         6.000 mm.

Parent Properties:
  Cold Allowable          :         174.4 MPa
  Hot Allowable           :         156.5 MPa
  Material DB # 7005218.
  Ultimate Tensile (Amb) :         482.6 MPa
  Yield Strength (Amb)    :         262.0 MPa
  Yield Strength (Hot)    :         235.1 MPa
  Elastic Modulus (Amb)   :        202720.0 MPa
  Poissons Ratio          :             0.300
  Expansion Coefficient   :    0.1227E-04 mm./mm./deg.
  Weight Density          :    0.0000E+00 N /cu.mm. (NOT USED)

Nozzle Geometry
  Nozzle Outside Diam.    :        168.300 mm.
  Thickness                :             6.600 mm.
  
```

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FileName : Calculation Book for ECONOMIZER E-PK6101-3

Vessel Design Summary: Step: 24 11:20pm Feb 6,2022

Length : 200.000 mm.
 Nozzle Weld Length : 6.000 mm.
 RePad Width : 60.000 mm.
 RePad Thickness : 10.000 mm.
 RePad Weld Leg : 6.000 mm.
 Nozzle Tilt Angle : 0.000 deg.
 Distance from Top : 203.000 mm.
 Distance from Bottom : 204.000 mm.

Nozzle Properties
 Cold Allowable : 160.7 MPa
 Hot Allowable : 144.1 MPa
 Material DB # 7002618.
 Ultimate Tensile (Amb) : 413.7 MPa
 Yield Strength (Amb) : 241.3 MPa
 Yield Strength (Hot) : 216.5 MPa
 Elastic Modulus (Amb) : 202720.0 MPa
 Poissons Ratio : 0.300
 Expansion Coefficient : 0.1227E-04 mm./mm./deg.
 Weight Density : 0.0000E+00 N /cu.mm. (NOT USED)

Design Operating Cycles : 7000.
 Ambient Temperature (Deg.) : 21.10

Uniform thermal expansion produces no stress in this geometry.
 Any thermal loads will come through operating forces and moments applied through the nozzle.

Nozzle Inside Temperature : 125.00 deg.
 Nozzle Outside Temperature : 125.00 deg.
 Vessel Inside Temperature : 125.00 deg.
 Vessel Outside Temperature : 125.00 deg.

Nozzle Pressure : 2.300 MPa
 Vessel Pressure : 2.300 MPa

Operating Pressure : 2.3 MPa

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 1.000

User Defined Load Input Echo:
 Loads are given at the End of Nozzle
 Loads are defined in Global Coordinates

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OPER:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OCC:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0

FEA Model Loads:
 These are the actual loads applied to the FEA model.
 These are the User Defined Loads translated to the end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OPER:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OCC:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

Vessel Centerline Vector : 0.000 1.000 0.000

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Nozzle Orientation Vector : 1.000 0.000 0.000

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Load Case Report
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Load Case Report \$X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE 10 LOAD CASES ANALYZED ARE:

1 WEIGHT ONLY (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/----- Loads in Case 1
Loads due to Weight

2 SUSTAINED (Wgt+Pr)

Sustained case run to satisfy local primary membrane and bending stress limits.

/----- Loads in Case 2
Loads due to Weight
Pressure Case 1

3 OPERATING

Case run to compute the operating stresses used in secondary, peak and range calculations as needed.

/----- Loads in Case 3
Pressure Case 1
Loads from (Operating)

4 RANGE (Fatigue Calc Performed)

Case run to get the RANGE of stresses. as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

/----- Combinations in Range Case 4
Plus Stress Results from CASE 3
Minus Stress Results from CASE 1

5 OCCASIONAL

Occasional load case established per the requirements of the Code.

/----- Loads in Case 5
Loads due to Weight
Pressure Case 1
Loads from (Occasional)

6 Program Generated -- Force Only

Case run to compute sif's and flexibilities.

/----- Loads in Case 6
Loads from (Axial)

7 Program Generated -- Force Only

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Case run to compute sif's and flexibilities.
 /----- Loads in Case 7
 Loads from (Inplane)

8 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
 /----- Loads in Case 8
 Loads from (Outplane)

9 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
 /----- Loads in Case 9
 Loads from (Torsion)

10 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
 /----- Loads in Case 10
 Pressure Case 1

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Solution Data
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Solution Data

Maximum Solution Row Size = 558
 Number of Nodes = 2082
 Number of Elements = 686
 Number of Solution Cases = 9

Summation of Loads per Case

Case #	FX	FY	FZ
1	6000.	6001.	5999.
2	2223.	640963.	5999.
3	2223.	640963.	5999.
4	8223.	646963.	11999.
5	462333.	0.	0.
6	0.	3.	0.
7	0.	0.	-3.
8	0.	0.	0.
9	-3777.	634962.	0.

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ASME Code Stress Output Plots
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ASME Code Stress Output Plots \$X

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Vessel Design Summary: Step: 24 11:20pm Feb 6,2022

- 1) P1 < SPL (SUS,Membrane) Case 2
- 2) Qb < SPS (SUS,Bending) Case 2
- 3) P1+Pb+Q < SPS (SUS,Inside) Case 2
- 4) P1+Pb+Q < SPS (SUS,Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
- 6) P1+Pb+Q < SPS (OPE,Inside) Case 3
- 7) P1+Pb+Q < SPS (OPE,Outside) Case 3
- 8) Membrane < User (OPE,Membrane) Case 3
- 9) Bending < User (OPE,Bending) Case 3
- 10) S1+S2+S3 < 4S (OPE,S1+S2+S3) Case 3
- 11) P1+Pb+Q+F < Sa (SIF,Outside) Case 6
- 12) P1+Pb+Q+F < Sa (SIF,Outside) Case 7
- 13) P1+Pb+Q+F < Sa (SIF,Outside) Case 8
- 14) P1+Pb+Q+F < Sa (SIF,Outside) Case 9
- 15) P1+Pb+Q+F < Sa (SIF,Outside) Case 10
- 16) P1 < SPL (OCC,Membrane) Case 5
- 17) Qb < 3(Smh) (OCC,Bending) Case 5
- 18) P1+Pb+Q < SPS (OCC,Inside) Case 5
- 19) P1+Pb+Q < SPS (OCC,Outside) Case 5
- 20) P1+Pb+Q < SPS (EXP,Inside) Case 4
- 21) P1+Pb+Q < SPS (EXP,Outside) Case 4
- 22) P1+Pb+Q+F < Sa (EXP,Inside) Case 4
- 23) P1+Pb+Q+F < Sa (EXP,Outside) Case 4

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Stress Results - Notes

FE/Pipe Version 10.0

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\$P

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2013-2015 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 1.000000
Assume pressure increases all other stresses.
- Assume free end displacements of attached pipe
(e.g. thermal loads) are secondary within the limits

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of nozzle reinforcement.

- Use Equivalent Stress (Von Mises).
- Include S1+S2+S3 evaluation for operating stress.
 Include S1+S2+S3 evaluation in primary case evaluation.
 Assume bending stress not local primary for S1+S2+S3.
- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas
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ASME Overstressed Areas \$X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
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Highest Primary Stress Ratios \$X

Pad/Header at Junction

P1	SPL	Primary Membrane Load Case 2
92	235	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

39%

Branch at Junction

P1	SPL	Primary Membrane Load Case 2
122	216	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

56%

Branch Transition

P1	SPL	Primary Membrane Load Case 2
66	216	Plot Reference:
MPa	MPa	1) P1 < SPL (SUS,Membrane) Case 2

30%

Pad Outer Edge Weld

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 Vessel Design Summary: Step: 24 11:20pm Feb 6,2022

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2
 235 497 Plot Reference:
 MPa MPa 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

47%

Header Outside Pad Area

Pl SPL Primary Membrane Load Case 2
 92 235 Plot Reference:
 MPa MPa 1) Pl < SPL (SUS,Membrane) Case 2

39%

Branch removed from Junction

Pl SPL Primary Membrane Load Case 2
 67 216 Plot Reference:
 MPa MPa 1) Pl < SPL (SUS,Membrane) Case 2

30%

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Highest Secondary Stress Ratios
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Highest Secondary Stress Ratios \$X

Pad/Header at Junction

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5
 190 497 Plot Reference:
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

38%

Branch at Junction

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5
 426 458 Plot Reference:
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

92%

Branch Transition

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5
 138 458 Plot Reference:
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

30%

Pad Outer Edge Weld

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 5
 282 497 Plot Reference:
 MPa MPa 19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

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56%

Header Outside Pad Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
148	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

29%

Branch removed from Junction

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
142	458	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

30%

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Highest Fatigue Stress Ratios

FE/Pipe Version 10.0	Jobname: NOZZLE	\$P
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Highest Fatigue Stress Ratios

\$X

Pad/Header at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
64	0.000 Life	Stress Concentration Factor = 1.350
MPa	0.221 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 2.3176E8
Allowable		"B31" Fatigue Stress Allowable = 413.6
289.9		MarkI Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 4,630,829.
		WRC 474 99% Probability Cycles = 1,075,784.
22%		WRC 474 95% Probability Cycles = 1,493,590.
		BS5500 Allowed Cycles(Curve F) = 803,995.
		Membrane-to-Bending Ratio = 2.816
		Bending-to-PL+PB+Q Ratio = 0.262
		Plot Reference:
		22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Branch at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
54	0.000 Life	Stress Concentration Factor = 1.350
MPa	0.188 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 6.8014E9
Allowable		"B31" Fatigue Stress Allowable = 381.0
289.9		MarkI Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 17,936,688.
		WRC 474 99% Probability Cycles = 4,166,851.
18%		WRC 474 95% Probability Cycles = 5,785,148.
		BS5500 Allowed Cycles(Curve F) = 1,317,435.
		Membrane-to-Bending Ratio = 0.224
		Bending-to-PL+PB+Q Ratio = 0.817
		Plot Reference:
		23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Branch Transition

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Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4
 26 0.000 Life Stress Concentration Factor = 1.000
 MPa 0.088 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 1.0000E11
 Allowable "B31" Fatigue Stress Allowable = 381.0
 289.9 MPa Markl Fatigue Stress Allowable = 287.5
 WRC 474 Mean Cycles to Failure = 69,291,424.
 WRC 474 99% Probability Cycles = 16,097,027.
 8% WRC 474 95% Probability Cycles = 22,348,696.
 BS5500 Allowed Cycles(Curve F) = 5,119,459.
 Membrane-to-Bending Ratio = 0.527
 Bending-to-PL+PB+Q Ratio = 0.655
 Plot Reference:
 22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Pad Outer Edge Weld

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4
 122 0.049 Life Stress Concentration Factor = 1.350
 MPa 0.422 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 143,391.
 Allowable "B31" Fatigue Stress Allowable = 413.6
 289.9 MPa Markl Fatigue Stress Allowable = 287.5
 WRC 474 Mean Cycles to Failure = 1,147,895.
 WRC 474 99% Probability Cycles = 266,666.
 42% WRC 474 95% Probability Cycles = 370,233.
 BS5500 Allowed Cycles(Curve F) = 115,710.
 Membrane-to-Bending Ratio = 0.661
 Bending-to-PL+PB+Q Ratio = 0.602
 Plot Reference:
 23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4
 50 0.000 Life Stress Concentration Factor = 1.000
 MPa 0.173 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 3.2198E10
 Allowable "B31" Fatigue Stress Allowable = 413.6
 289.9 MPa Markl Fatigue Stress Allowable = 287.5
 WRC 474 Mean Cycles to Failure = 6,905,774.
 WRC 474 99% Probability Cycles = 1,604,274.
 17% WRC 474 95% Probability Cycles = 2,227,332.
 BS5500 Allowed Cycles(Curve F) = 679,651.
 Membrane-to-Bending Ratio = 1.749
 Bending-to-PL+PB+Q Ratio = 0.364
 Plot Reference:
 22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

Branch removed from Junction

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4
 18 0.000 Life Stress Concentration Factor = 1.000
 MPa 0.062 Stress Strain Concentration Factor = 1.000
 Cycles Allowed for this Stress = 1.0000E11
 Allowable "B31" Fatigue Stress Allowable = 381.0
 289.9 MPa Markl Fatigue Stress Allowable = 287.5
 WRC 474 Mean Cycles to Failure = 1.8734E8
 WRC 474 99% Probability Cycles = 43,520,172.
 6% WRC 474 95% Probability Cycles = 60,422,280.
 BS5500 Allowed Cycles(Curve F) = 18,924,234.
 Membrane-to-Bending Ratio = 7.450
 Bending-to-PL+PB+Q Ratio = 0.118
 Plot Reference:
 22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

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Highest Occasional Stress Ratios
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Highest Occasional Stress Ratios \$X

Pad/Header at Junction

P1	SPL	Primary Membrane Load Case 5
109	235	Plot Reference:
MPa	MPa	16) P1 < SPL (OCC,Membrane) Case 5
46%		
Qb	3(Smh)	Primary Bending Load Case 5
123	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5
24%		
P1+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
149	497	Plot Reference:
MPa	MPa	18) P1+Pb+Q < SPS (OCC,Inside) Case 5
29%		
P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
190	497	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5
38%		

Branch at Junction

P1	SPL	Primary Membrane Load Case 5
199	216	Plot Reference:
MPa	MPa	16) P1 < SPL (OCC,Membrane) Case 5
92%		
Qb	3(Smh)	Primary Bending Load Case 5
363	458	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5
79%		
P1+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
354	458	Plot Reference:
MPa	MPa	18) P1+Pb+Q < SPS (OCC,Inside) Case 5
77%		
P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
426	458	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5
92%		

Branch Transition

P1	SPL	Primary Membrane Load Case 5
110	216	Plot Reference:
MPa	MPa	16) P1 < SPL (OCC,Membrane) Case 5
50%		
Qb	3(Smh)	Primary Bending Load Case 5

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61	458	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

13%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
122	458	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

26%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
138	458	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

30%

Pad Outer Edge Weld

Pl	SPL	Primary Membrane Load Case 5
129	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

54%

Qb	3(Smh)	Primary Bending Load Case 5
191	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

38%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
147	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

29%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
282	497	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

56%

Header Outside Pad Area

Pl	SPL	Primary Membrane Load Case 5
102	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5

43%

Qb	3(Smh)	Primary Bending Load Case 5
116	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5

23%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
148	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

29%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
112	497	Plot Reference:
MPa	MPa	19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

22%

Branch removed from Junction

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P1	SPL	Primary Membrane Load Case 5
111	216	Plot Reference:
MPa	MPa	16) P1 < SPL (OCC,Membrane) Case 5
51%		
Qb	3(Smh)	Primary Bending Load Case 5
37	458	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5
7%		
P1+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
142	458	Plot Reference:
MPa	MPa	18) P1+Pb+Q < SPS (OCC,Inside) Case 5
30%		
P1+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 5
98	458	Plot Reference:
MPa	MPa	19) P1+Pb+Q < SPS (OCC,Outside) Case 5
21%		

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Stress Intensification Factors
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Stress Intensification Factors \$X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	4.825	3.574	7.148	1.436
Inplane :	2.732	2.024	4.048	1.398
Outplane:	4.296	3.182	6.364	1.398
Torsion :	0.667	0.931	0.989	0.817
Pressure:	1.417	1.050	2.100	1.084

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from PDo/2T. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

Pipe OD : 168.300 mm.
 Pipe Thk: 6.600 mm.
 Z approx: 135535.625 cu.mm.
 Z exact : 130437.461 cu.mm.

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.809	0.701	0.794	0.176	0.140

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 8.692
 Header Pressure i-factor = 2.873

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The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

B31.3 (Branch)			
Peak Stress Sif	0.000	Axial	
	2.962	Inplane	
	3.675	Outplane	
	1.000	Torsional	
B31.1 (Branch)			
Peak Stress Sif	0.000	Axial	
	3.675	Inplane	
	3.675	Outplane	
	3.675	Torsional	
WRC 330 (Branch)			
Peak Stress Sif	0.000	Axial	
	4.454	Inplane	
	3.675	Outplane	
	4.454	Torsional	

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Allowable Loads
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Allowable Loads \$X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	201489.	54556.	81834.
Inplane Moment (mm. N)	13843928.	2650550.	5622666.
Outplane Moment (mm. N)	8804816.	1685765.	3576047.
Torsional Moment (mm. N)	56667544.	15343557.	23015336.
Pressure (MPa)	5.45	2.30	2.30
PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	203085.	50102.	75153.
Inplane Moment (mm. N)	13953564.	2434135.	5163580.
Outplane Moment (mm. N)	8874546.	1548124.	3284067.
Torsional Moment (mm. N)	30319114.	7479818.	11219728.
Pressure (MPa)	5.96	2.30	2.30

NOTES:

- 1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.
- 2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.
- 3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

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based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

- 4) Secondary allowable loads are limits for expansion and operating piping loads.
- 5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

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Flexibilities
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Flexibilities \$X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 168.300 mm.
Wall Thickness = 6.600 mm.

Axial Translational Stiffness = 567645. N /mm.
Inplane Rotational Stiffness = 91352064. mm. N /deg
Outplane Rotational Stiffness = 41939760. mm. N /deg
Torsional Rotational Stiffness = 1333581440. mm. N /deg

Intersection Flexibility Factors for Branch/Nozzle

:

Find axial stiffness: $K = 3EI/(kd)^3$ N /mm.
Find bending and torsional stiffnesses: $K = EI/(kd)$ mm. N per radian.
The EI product is 0.22282E+13 N mm.^2
The value of (d) to use is: 161.700 mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor (k) = 1.407
Inplane Flexibility Factor (k) = 2.633
Outplane Flexibility Factor (k) = 5.734
Torsional Flexibility Factor (k) = 0.180

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