طرح نگهداشت و افزایش تولید 27 مخزن

THERMAL/MECHANICAL CALCULATION BOOK FOR GLYCOL REFLUX CONDENSER (E-100)

نگهداشت و افزایش تولید میدان نفتی بینک

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Status:

IFA: Issued For Approval
IFI: Issued For Information
AFC: Approved For Construction

REVISION RECORD SHEET

PAGE	V00	V01	V02	V03	V04
1	X	X			
2	X	X			
3	X	X			
4	X	X			
5	X	X			
6	X	X			
7	X	X			
8	X	X			
9	X	X			
10	X	X			
11	X	X			
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13	X	X			
14	X	X			
15	X	X			
16	X	X			
17	X	X			
18	X	X			
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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version      : 2019

Analysis Performed by :

Job File               : C:\USERS\TECHNICAL2\DESKTOP\E-100.Pvdb

Date of Analysis       : Feb 25,2025   8:23am

PV Elite 2020, January 2020
```

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 273.050 mm. OD		
Vessel Design Length, Tangent to Tangent	2025.68	mm.
Distance of Bottom Tangent above Grade	100.00	mm.
Distance of Base above Grade	100.00	mm.
Specified Datum Line Distance	0.00	mm.
Shell Side Design Temperature	152	°C
Channel Side Design Temperature	100	°C
Shell Side Design Pressure	6.600	bars
Channel Side Design Pressure	8.500	bars
Shell Side Hydrostatic Test Pressure	11.325	bars
Channel Side Hydrostatic Test Pressure	11.050	bars
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-312 TP316L	...	...	S31603	No	No
Head	SA-403 316L	...	...	S31603	No	No
Flange	SA-182 F316L	...	<= 5	S31603	No	No
Nozzle	SA-182 F316L	...	<= 5	S31603	No	No
Nozzle Flg	SA-182 F316L	...	<= 5	S31603	No	No
Tubes	SA-213 TP316L	...	...	S31603	No	No
Tubesheet	SA-182 F316L	...	<= 5	S31603	No	No
Flg Bolting	SA-193 B8M	1	...	S31600	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Shell FLG.	6.641	1.03	11.900	0.0000	N/A	?
Shell Barrel	6.641	1.03	53.000	0.0000	N/A	?
Shell FLG.	6.641	1.03	11.900	0.0000	N/A	?
Channel FLG.	8.541	1.03	13.300	0.0000	N/A	?
Channel Barrel	8.531	1.03	58.800	0.0000	N/A	?
Channel Cover	8.511	1.03	72.200	0.0000	No	?

Liquid Level: 415.81 mm. Dens.: 999.542 kg/m³ Sp. Gr.: 1.000

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Body Flg	108.0	101.6	...	30.2	...	...	1.00	1.00
Cylinder	1508.0	1400.0	9.3	8.1	1.5	1.9	1.00	1.00
Body Flg	1609.6	101.6	...	30.2	...	...	1.00	1.00
Body Flg	1775.7	101.6	...	30.2	...	...	1.00	1.00
Cylinder	1975.7	200.0	9.3	8.1	1.5	1.0	1.00	1.00
Ellipse	2025.7	50.0	9.3	8.1	1.5	1.5	1.00	1.00

Factored Loads:

Un-Factored Loads:

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
S2 (2in)	WRC-107/537	0.297	n/a	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	390.5	kg.
Shop Test	- Fabricated + Water (Full)	474.0	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	401.5	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	401.5	kg.
Empty	- Fab. + Intls. + Details + Wghts.	401.5	kg.
Operating	- Empty + Operating Liquid (No CA)	435.8	kg.
Field Test	- Empty Weight + Water (Full)	485.1	kg.

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Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
S2 (2in)	11.9	OK	...	OK	1.50	OK	Passed
V (1in)	13.2	OK	...	OK	1.50	OK	Passed
T1	13.2	OK	...	OK	1.50	OK	Passed
T1	13.2	OK	...	OK	1.50	OK	Passed
T2	13.2	OK	...	OK	1.50	OK	Passed
T2	13.2	OK	...	OK	1.50	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles        :          11.9 Nozzle  : S2 (2in)  [Shellside]
Minimum MAWP Nozzles        :          13.2 Nozzle  : V (1in)  [Tubeside]
```

Note: MAWPs (Internal Case) shown above are at the High Point.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	S2 (2in)	1407.950	0.000	101.600
50	V (1in)	1875.675	0.000	67.224
60	T1	0.000	0.000	67.224
60	T2	0.000	180.000	67.224

The nozzle spacing is computed by the following:

= Sqrt($ll^2 + lc^2$) 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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Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	BODY FLANGE: 30.2mm. THK X 254.5mm. OD	SA-182 F316L
1	CYLINDER: 9.3mm. THK X 256.8mm. ID X 1400.0mm.	SA-312 TP316L
2	BODY FLANGE: 30.2mm. THK X 256.8mm. OD	SA-182 F316L
1	CYLINDER: 9.3mm. THK X 256.8mm. ID X 200.0mm.	SA-312 TP316L
1	ELLIPTICAL HEAD: 2.0 X 1, 9.3mm. THK X 256.8mm. ID X 50.0mm.	SA-403 316L
3	INSULATION: 101mm X 40mm THK	
1	INSULATION: 1400mm X 40mm THK	
1	TUBESHEET: 406mm X 54mm THK	SA-182 F316L
44	TUBES: 1400mm X 19mm DIA X 1mm THK	SA-213 TP316L
1	INSULATION: 200mm X 40mm THK	
1	INSULATION: 118mm X 40mm THK	
1	GASKET: 317mm. OD X 287mm. ID	...
12	BODY FLANGE BOLTS: 24mm. DIA	SA-193 B8M
24	NUTS FOR BODY FLANGE BOLTS: 24mm. DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Reinforcing Pad Thk mm	Cut Length in	Flg Class
V (1in)	1.000 in	Actual	LW	2.008	12.800	...	...	160.6	150
T1	1.000 in	Actual	LW	2.008	12.800	...	...	169.4	150
T2	1.000 in	Actual	LW	2.008	12.800	...	...	169.4	150
S2 (2in)	2.000 in	Actual	LW	3.248	15.850	...	...	164.9	150

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
V (1in)	SA-182 F316L	8.112	10.000	...	...	...
T1	SA-182 F316L	8.112	10.000	...	...	...
T2	SA-182 F316L	8.112	10.000	...	...	...
S2 (2in)	SA-182 F316L	8.112	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
V (1in)	1875.675	0.0	150.00	0.00	Channel Barrel
T1	...	0.0	150.00	0.00	Channel Cover
T2	...	180.0	150.00	0.00	Channel Cover
S2 (2in)	1407.950	0.0	150.00	0.00	Shell Barrel

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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
Nozzle Flg	[5]		-196						
Nozzle Flg	[5]		-196						
Shell Barrel	[16]		-196						
S2 (2in)	[15]		-196						
Nozzle Flg	[5]		-196						
Tubesheet: SS	[13]		-196						
Warmest MDMT:			-196						
Nozzle Flg	[5]		-196						
Channel Barre	[16]		-196						
Channel Cover	[16]		-196						
V (1in)	[15]		-196						
Nozzle Flg	[5]		-196						
T1	[15]		-196						
Nozzle Flg	[5]		-196						
T2	[15]		-196						
Nozzle Flg	[5]		-196						
Warmest MDMT:			-196						

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-196.0	5.0	Pass
Channel/Tube	-196.0	5.0	Pass

Notes:

[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations

[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

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

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

Warning: Shell FLG. and Channel FLG.
There are mating flanges in this model that have different design pressures. This will generate different bolt loads. If a tubesheet is in between these flanges, PV Elite will compute the mating flange loads for you. If there is not a tubesheet physically separating these flanges, you must enter in the mating flange loads into the flange dialog.

Warning:
There is a flange in this model connected to an element whose temperature is different. The bolt allowable stress is based on it's parent design temperature. You may need to manually adjust the operating bolt allowable stress to a value based upon a representative maximum temperature the bolts will be subject to.

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PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	6.6	bars
Channel Side Design Pressure	8.4997	bars
Shell Side Design Temperature	152.0	°C
Channel Side Design Temperature	100.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Lethal	
Service Type, Channel Side	Lethal	
MDMT (CET), Shell Side	5.0	°C
MDMT (CET), Tube Side	5.0	°C
User defined MAWP, Shell Side	11.85	bars
User defined MAWP, Channel Side	13.25	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Use Higher Longitudinal Stresses (Flag)	N	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

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

Load Case 18		FS+BS+IP+OW	
Load Case 19		FS+BS+EP+OW	
Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	232	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		100	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	
Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.250	
Table Value Fa		1.000	
Table Value Fv		1.330	
Short Period Acceleration value Ss		1.125	
Long Period Acceleration Value Sl		0.460	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		D	
Component Elevation Ratio	z/h	1.000	
Amplification Factor	Ap	1.000	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		1.020	
User Value of Sd1 (used if > 0)		0.385	
Design Pressure + Static Head		Y	
Consider MAP New and Cold in Noz. Design		N	
Consider External Loads for Nozzle Des.		Y	
Use ASME VIII-1 Appendix 1-9		N	
Material Database Year	Current w/Addenda or Code Year		

Configuration Directives:

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

```
 Using Metric Material Databases, ASME II D                No
 Calculate B31.3 type stress for Nozzles with Loads       Yes
 Reduce the MDMT due to lower membrane stress             Yes
 Consider Longitudinal Stress in MDMT calcs. (Div. 1)     Yes
```

Complete Listing of Vessel Elements and Details:

```
Element From Node                                        10
Element To Node                                          20
Element Type                                        Flange
Description                                      Shell FLG.
Distance "FROM" to "TO"                               101.6  mm.
Flange Inside Diameter                                254.51  mm.
Element Thickness                                     30.226  mm.
Internal Corrosion Allowance                               0  mm.
Nominal Thickness                                          0  mm.
External Corrosion Allowance                               0  mm.
Design Internal Pressure                                 6.6  bars
Design Temperature Internal Pressure                     152  °C
Design External Pressure                               1.034  bars
Design Temperature External Pressure                     100  °C
Effective Diameter Multiplier                            1.2
Material Name                                   SA-182 F316L
    Allowable Stress, Ambient                          115.1  N./mm²
    Allowable Stress, Operating                         87.2  N./mm²
    Allowable Stress, Hydrotest                        155.1  N./mm²
    Material Density                                  8027.2  kg/m³
    P Number Thickness                                     0  mm.
    Yield Stress, Operating                            130.4  N./mm²
    External Pressure Chart Name                        HA-4
    UNS Number                                        S31603
    Class / Thickness / Grade     :: <= 5
    Product Form                                    Forgings
Perform Flange Stress Calculation (Y/N)                     Y
Weight of Standard Flange                                   0  kN
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                         No

    Element From Node                                      10
    Detail Type                                     Insulation
    Detail ID                                          Ins: 10
    Dist. from "FROM" Node / Offset dist                    0  mm.
    Height/Length of Insulation                         101.6  mm.
    Thickness of Insulation                                40  mm.
    Density                                               125  kg/m³

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

Element From Node                                        20
Element To Node                                          30
Element Type                                       Cylinder
Description                                     Shell Barrel
Distance "FROM" to "TO"                                1400  mm.
```

Element Outside Diameter	273.05	mm.
Element Thickness	8.1121	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	9.271	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	6.6	bars
Design Temperature Internal Pressure	152	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-312 TP316L	
Allowable Stress, Ambient	115.1	N./mm²
Allowable Stress, Operating	87.2	N./mm²
Allowable Stress, Hydrotest	155.1	N./mm²
Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	130.4	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	1400	mm.
Thickness of Insulation	40	mm.
Density	125	kg/m³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	S2 (2in)	
Dist. from "FROM" Node / Offset dist	1300	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.07334	kN
Grade of Attached Flange	GR 2.3	
Nozzle Matl	SA-182 F316L	
Element From Node	20	
Detail Type	Weight	
Detail ID	BAFFLE	
Dist. from "FROM" Node / Offset dist	700	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	0	mm.

Element From Node	30	

```
Element To Node                                          40
Element Type                                       Flange
Description                                      Shell FLG.
Distance "FROM" to "TO"                              101.6  mm.
Flange Inside Diameter                              256.83  mm.
Element Thickness                                   30.226  mm.
Internal Corrosion Allowance                             0  mm.
Nominal Thickness                                        0  mm.
External Corrosion Allowance                             0  mm.
Design Internal Pressure                               6.6  bars
Design Temperature Internal Pressure                   152  °C
Design External Pressure                             1.034  bars
Design Temperature External Pressure                   100  °C
Effective Diameter Multiplier                          1.2
Material Name                                  SA-182 F316L
    Allowable Stress, Ambient                        115.1  N./mm²
    Allowable Stress, Operating                       87.2  N./mm²
    Allowable Stress, Hydrotest                      155.1  N./mm²
    Material Density                                8027.2  kg/m³
    P Number Thickness                                    0  mm.
    Yield Stress, Operating                          130.4  N./mm²
    External Pressure Chart Name                      HA-4
    UNS Number                                      S31603
    Class / Thickness / Grade     :: <= 5
    Product Form                                   Forgings
Perform Flange Stress Calculation (Y/N)                   Y
Weight of Standard Flange                                 0  kN
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                       No

    Element From Node                                    30
    Detail Type                                   Insulation
    Detail ID                                     Ins: 30
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                       101.6  mm.
    Thickness of Insulation                              40  mm.
    Density                                             125  kg/m³

    Element From Node                                    30
    Detail Type                                      Weight
    Detail ID                                 WGHT:[1 OF 1]
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Miscellaneous Weight                                  0  kN
    Offset from Element Centerline                        0  mm.

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

Element From Node                                        40
Element To Node                                          50
Element Type                                       Flange
Description                                    Channel FLG.
Distance "FROM" to "TO"                              101.6  mm.
Flange Inside Diameter                              256.83  mm.
Element Thickness                                   30.226  mm.
```

```
Internal Corrosion Allowance                              0  mm.
Nominal Thickness                                         0  mm.
External Corrosion Allowance                              0  mm.
Design Internal Pressure                                8.5  bars
Design Temperature Internal Pressure                    100  °C
Design External Pressure                              1.034  bars
Design Temperature External Pressure                    100  °C
Effective Diameter Multiplier                           1.2
Material Name                                   SA-182 F316L
Perform Flange Stress Calculation (Y/N)                   Y
Weight of Standard Flange                                 0  kN
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                       No

    Element From Node                                    40
    Detail Type                                      Liquid
    Detail ID                                   Liquid: 40
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Liquid                           101.6  mm.
    Liquid Density                                   999.54  kg/m³

    Element From Node                                    40
    Detail Type                                  Insulation
    Detail ID                                      Ins: 40
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Height/Length of Insulation                       101.6  mm.
    Thickness of Insulation                              40  mm.
    Density                                             125  kg/m³

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

Element From Node                                        50
Element To Node                                          60
Element Type                                       Cylinder
Description                                  Channel Barrel
Distance "FROM" to "TO"                                200  mm.
Element Outside Diameter                              273.05  mm.
Element Thickness                                     8.1121  mm.
Internal Corrosion Allowance                               0  mm.
Nominal Thickness                                      9.271  mm.
External Corrosion Allowance                               0  mm.
Design Internal Pressure                                 8.5  bars
Design Temperature Internal Pressure                     100  °C
Design External Pressure                               1.034  bars
Design Temperature External Pressure                     100  °C
Effective Diameter Multiplier                            1.2
Material Name                                   SA-312 TP316L
    Allowable Stress, Ambient                         115.15  N./mm²
    Allowable Stress, Operating                        96.67  N./mm²
    Allowable Stress, Hydrotest                       155.14  N./mm²
    Material Density                                  8027.2  kg/m³
    P Number Thickness                                     0  mm.
    Yield Stress, Operating                           144.88  N./mm²
    External Pressure Chart Name                        HA-4
```

```
    UNS Number                                      S31603
    Product Form                                 Smls. pipe
Efficiency, Longitudinal Seam                          1.0
Efficiency, Circumferential Seam                       1.0
Weld is pre-Heated                                      No

    Element From Node                                   50
    Detail Type                                     Liquid
    Detail ID                                   Liquid: 50
    Dist. from "FROM" Node / Offset dist                 0  mm.
    Height/Length of Liquid                            200  mm.
    Liquid Density                                  999.54  kg/m³

    Element From Node                                   50
    Detail Type                                 Insulation
    Detail ID                                      Ins: 50
    Dist. from "FROM" Node / Offset dist                 0  mm.
    Height/Length of Insulation                        200  mm.
    Thickness of Insulation                             40  mm.
    Density                                            125  kg/m³

    Element From Node                                   50
    Detail Type                                     Nozzle
    Detail ID                                     V (1in)
    Dist. from "FROM" Node / Offset dist               100  mm.
    Nozzle Diameter                                      1  in.
    Nozzle Schedule                                   None
    Nozzle Class                                       150
    Layout Angle                                       0.0
    Blind Flange (Y/N)                                   N
    Weight of Nozzle ( Used if > 0 )               0.03314  kN
    Grade of Attached Flange                        GR 2.3
    Nozzle Matl                                 SA-182 F316L

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

Element From Node                                       60
Element To Node                                         70
Element Type                                     Elliptical
Description                                   Channel Cover
Distance "FROM" to "TO"                                 50  mm.
Element Outside Diameter                            273.05  mm.
Element Thickness                                   8.1121  mm.
Internal Corrosion Allowance                             0  mm.
Nominal Thickness                                    9.271  mm.
External Corrosion Allowance                             0  mm.
Design Internal Pressure                               8.5  bars
Design Temperature Internal Pressure                   100  °C
Design External Pressure                             1.034  bars
Design Temperature External Pressure                   100  °C
Effective Diameter Multiplier                          1.2
Material Name                                   SA-403 316L
    Allowable Stress, Ambient                        115.1  N./mm²
    Allowable Stress, Operating                      115.1  N./mm²
    Allowable Stress, Hydrotest                      155.1  N./mm²
```

Material Density	8027.2	kg/m³
P Number Thickness	0	mm.
Yield Stress, Operating	144.9	N./mm²
External Pressure Chart Name	HA-4	
UNS Number	S31603	
Product Form	Smls. & wld. fittings	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	60	
Detail Type	Liquid	
Detail ID	Liquid: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	114.21	mm.
Liquid Density	999.54	kg/m³
Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	118.26	mm.
Thickness of Insulation	40	mm.
Density	125	kg/m³
Element From Node	60	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	80	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03314	kN
Grade of Attached Flange	GR 2.3	
Nozzle Matl	SA-182 F316L	
Element From Node	60	
Detail Type	Nozzle	
Detail ID	T2	
Dist. from "FROM" Node / Offset dist	80	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03314	kN
Grade of Attached Flange	GR 2.3	
Nozzle Matl	SA-182 F316L	

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XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Shell FLG.		...	107.95	...	101.6
Shell Barrel		...	1507.95	...	1400
Shell FLG.		...	1609.55	...	101.6
Channel FLG.		...	1775.68	...	101.6
Channel Barrel		...	1975.68	...	200
Channel Cover		...	2025.68	...	50

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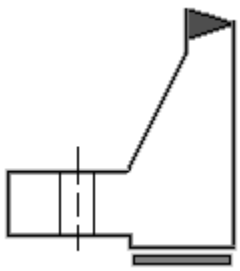
Flange Input Data Values **Description: FLANGE :**

Shell FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	6.64	bars
Design Temperature		152	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	254.508	mm.
Flange Outside Diameter	A	406.400	mm.
Flange Thickness	t	30.2260	mm.
Thickness of Hub at Small End	go	9.2710	mm.
Thickness of Hub at Large End	g1	23.9871	mm.
Length of Hub	h	71.3740	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	87.20	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.10	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	107.06	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	361.950	mm.
Nominal Bolt Diameter	a	24.0000	mm.
Type of Threads		TEMA Metric	
Number of Bolts		12	
Flange Face Outside Diameter	Fod	323.850	mm.
Flange Face Inside Diameter	Fid	254.508	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	317.500	mm.
Gasket Inside Diameter	Gi	287.274	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Axial Force on Flange		14.00	kN
Bending Moment on Flange		0.00	N-m
Flange Class		150	
Flange Grade		GR 2.3	
Flange Series	Series	A	



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Hub Small End Required Thickness due to Internal Pressure:

```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (6.64*(255/2+0))/(87.2*1-0.6*6.64)+Ca
  = 0.9736 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (87.2 * 1 * 9.27 )/(127 + 0.6 * 9.27 )
  = 60.865 bars
```

```
 Corroded Flange ID,       Bcor = B+2*Fcor                 254.508  mm.
 Corroded Large Hub,      g1Cor = g1-ci                     23.987  mm.
 Corroded Small Hub,      g0Cor = go-ci                      9.271  mm.
 Code R Dimension,            R = (C-B)/2 - g1              29.734  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2             15.113  mm.
 Basic Gasket Width,         bo = N / 2                      7.557  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)                6.927  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b               303.646  mm.

 Original Design Pressure for Flange                         6.641  bars
 Axial Force Equiv. Pressure (4*max(F,0)/(pi*G^2))           1.933  bars
 Bending Moment Equiv. Pressure (16*abs(M)/(pi*G^3))         0.000  bars
                                                         ---------
 Final Equivalent Design Pressure                            8.574  bars
```

Note:
Per ASME NC-3658.1(b), the equivalent pressure is used only to compute the Hydrostatic End Load H. The original design pressure is used in the remaining calculations.

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.79 * 304² * 8.57
  = 62.087 kN
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P
  = 2 * 6.93 * 3.14 * 304 * 3 * 6.64
```

```
  = 26.328 kN
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.14 * 255² *6.64/4
  = 33.783 kN
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 62.1 - 33.8
  = 28.304 kN
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 62.1 + 26.3 + 0, 0 )
  = 88.416 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*6.93*3.141*304+0*0*0
  = 455.577 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 88.4/107, 456/130
  = 35.148 cm²
```

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 37.5  * 130/(68.9 * 3.14 * (318 + 287 ) )
  = 3.714 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 130 * ( 35.1 + 37.5 )/2
  = 471.01 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 88.4 - 62.1
  = 26.33 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 362 - 304 )/2
  = 29.1520 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 29.7 + 24 + 29.2 )/2
  = 41.4365 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 29.7 + ( 24/2.0 )
  = 41.7275 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	34.	41.7275	1.0943	1543.
Face Pressure,	Mt	28.	41.4365	1.0943	1284.
Gasket Load,	Mg	26.	29.1520	1.0943	840.
Gasket Seating,	Matm	471.	29.1520	1.0943	15032.

Total Moment for Operation, Mop 3668. N-m
Total Moment for Gasket seating, Matm 15032. N-m

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

Estimated Finished Weight of Flange at given Thk. 27.2 kg.
Estimated Unfinished Weight of Forging at given Thk 64.3 kg.

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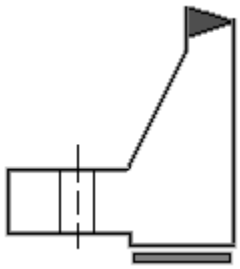
Flange Input Data Values **Description: New Flange :**

Shell FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	6.64	bars
Design Temperature		152	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	256.826	mm.
Flange Outside Diameter	A	406.400	mm.
Flange Thickness	t	30.2260	mm.
Thickness of Hub at Small End	go	9.2710	mm.
Thickness of Hub at Large End	g1	23.9871	mm.
Length of Hub	h	71.3740	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	87.20	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.10	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	107.06	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	361.950	mm.
Nominal Bolt Diameter	a	24.0000	mm.
Type of Threads		TEMA Metric	
Number of Bolts		12	
Flange Face Outside Diameter	Fod	323.850	mm.
Flange Face Inside Diameter	Fid	256.826	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	317.500	mm.
Gasket Inside Diameter	Gi	287.274	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Flange Class		150	
Flange Grade		GR 2.3	
Flange Series	Series	A	



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Hub Small End Required Thickness due to Internal Pressure:
```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (6.64*(257/2+0))/(87.2*1-0.6*6.64)+Ca
= 0.9825 mm.
```

Hub Small End Hub MAWP:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (87.2 * 1 * 9.27 )/(128 + 0.6 * 9.27 )
= 60.338 bars
```

```
Corroded Flange ID,      Bcor = B+2*Fcor              256.826  mm.
Corroded Large Hub,     g1Cor = g1-ci                  23.987  mm.
Corroded Small Hub,     g0Cor = go-ci                   9.271  mm.
Code R Dimension,           R = (C-B)/2 - g1           28.575  mm.

Gasket Contact Width,       N = (Go - Gi) / 2          15.113  mm.
Basic Gasket Width,        bo = N / 2                   7.557  mm.
Effective Gasket Width,     b = Cb sqrt(bo)             6.927  mm.
Gasket Reaction Diameter,   G = Go - 2 * b             303.646  mm.
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.79 * 304² * 6.64
= 48.087 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * Pi * G * m * P
= 2 * 6.93 * 3.14 * 304 * 3 * 6.64
= 26.328 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
= Pi * Bcor² * P  / 4
= 3.14 * 257² *6.64/4
= 34.401 kN
```
Pressure Force on Flange Face [Ht]:
```
= H - Hd
= 48.1 - 34.4
= 13.686 kN
```
Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
```

```
  = max( 48.1 + 26.3 + 0, 0 )
  = 74.416 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.9*6.93*3.141*304+0*0*0
  = 455.577 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 74.4/107, 456/130
  = 35.148 cm²
```

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 37.5  * 130/(68.9 * 3.14 * (318 + 287 ) )
  = 3.714 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 130 * ( 35.1 + 37.5 )/2
  = 471.01 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 74.4 - 48.1
  = 26.33 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 362 - 304 )/2
  = 29.1520 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 28.6 + 24 + 29.2 )/2
  = 40.8570 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 28.6 + ( 24/2.0 )
  = 40.5685 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	34.	40.5685	1.0943	1528.
Face Pressure,	Mt	14.	40.8570	1.0943	612.
Gasket Load,	Mg	26.	29.1520	1.0943	840.
Gasket Seating,	Matm	471.	29.1520	1.0943	15032.

```
Total Moment for Operation,      Mop                                  2980. N-m
Total Moment for Gasket seating, Matm                                15032. N-m
```

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

```
Estimated Finished Weight of Flange at given Thk.       27.1 kg.
Estimated Unfinished Weight of Forging at given Thk     63.5 kg.
```

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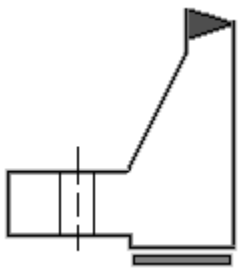
Flange Input Data Values **Description: New Flange :**

Channel FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	8.54	bars
Design Temperature		100	°C
Internal Corrosion Allowance	ci	0.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	256.826	mm.
Flange Outside Diameter	A	406.400	mm.
Flange Thickness	t	30.2260	mm.
Thickness of Hub at Small End	go	9.2710	mm.
Thickness of Hub at Large End	g1	23.9871	mm.
Length of Hub	h	71.3740	mm.
Flange Material		SA-182 F316L	
Flange Material UNS number		S31603	
Flange Allowable Stress At Temperature	Sfo	96.67	N./mm²
Flange Allowable Stress At Ambient	Sfa	115.15	N./mm²
Bolt Material		SA-193 B8M	
Bolt Allowable Stress At Temperature	Sb	107.06	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Diameter of Bolt Circle	C	361.950	mm.
Nominal Bolt Diameter	a	24.0000	mm.
Type of Threads		TEMA Metric	
Number of Bolts		12	
Flange Face Outside Diameter	Fod	323.850	mm.
Flange Face Inside Diameter	Fid	256.826	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	317.500	mm.
Gasket Inside Diameter	Gi	287.274	mm.
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Length of Partition Gasket	lp	127.0000	mm.
Width of Partition Gasket	tp	10.0000	mm.
Partition Gasket Factor	mPart	2.5000	
Partition Gasket Design Seating Stress	yPart	25.00	N./mm²
Flange Class		150	
Flange Grade		GR 2.3	
Flange Series	Series	A	



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Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (8.54*(257/2+0))/(96.7*1-0.6*8.54)+Ca
  = 1.1406 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (96.7 * 1 * 9.27 )/(128 + 0.6 * 9.27 )
  = 66.891 bars
```

```
 Corroded Flange ID,      Bcor = B+2*Fcor                256.826  mm.
 Corroded Large Hub,     g1Cor = g1-ci                    23.987  mm.
 Corroded Small Hub,     g0Cor = go-ci                     9.271  mm.
 Code R Dimension,           R = (C-B)/2 - g1             28.575  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2            15.113  mm.
 Basic Gasket Width,        bo = N / 2                     7.557  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)               6.927  mm.
 Gasket Reaction Diameter,   G = Go (Self-Energizing)    317.500  mm.
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 318² * 8.54
  = 67.618 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 6.93 * 3.14 * 318 * 0 * 8.54
    + 2.0 * 127 * 5 * 2.5 * 8.54
  = 2.712 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 257² *8.54/4
  = 44.244 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 67.6 - 44.2
  = 23.374 kN
```
Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 67.6 + 2.71 + 0, 0 )
  = 70.330 kN
  = 74.416 kN, Mating Flange Load Governs
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 0*6.93*3.141*318+25*5*127
  = 15.874 kN
  = 455.577 kN, Mating Flange Load Governs
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 74.4/107, 456/130
  = 35.148 cm²
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 130 * ( 35.1 + 37.5 )/2
  = 471.01 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 74.4 - 67.6
  = 6.80 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 362 - 318 )/2
  = 22.2250 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 28.6 + 24 + 22.2 )/2
  = 37.3935 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 28.6 + ( 24/2.0 )
  = 40.5685 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	44.	40.5685	1.0943	1965.
Face Pressure,	Mt	23.	37.3935	1.0943	957.
Gasket Load,	Mg	7.	22.2250	1.0943	165.
Gasket Seating,	Matm	471.	22.2250	1.0943	11460.

Total Moment for Operation, Mop 3087. N-m
Total Moment for Gasket seating, Matm 11460. N-m

You chose not to perform Stress Calculations on this Standard Flange.
The pressure rating of the flange will be used to check code compliance.

Estimated Finished Weight of Flange at given Thk. 27.1 kg.
Estimated Unfinished Weight of Forging at given Thk 63.5 kg.

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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./mm²
Shell FLG.		6.6408	...	...	254.51	87.2
Shell Barrel		6.6408	9.271	...	273.05	87.2
Shell FLG.		6.6408	...	...	256.83	87.2
Channel FLG.		8.5408	...	...	256.83	96.67
Channel Barrel		8.5308	9.271	...	273.05	96.67
Channel Cover		8.5112	9.271	...	273.05	115.1

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.
Shell FLG.		6.6	11.9	15.9	30.226	No Calc
Shell Barrel		6.6	53	70.1	8.11212	1.5
Shell FLG.		6.6	11.9	15.9	30.226	No Calc
Channel FLG.		8.5	13.3	15.9	30.226	No Calc
Channel Barrel		8.5	58.8	70.1	8.11212	1.5
Channel Cover		8.5	72.2	72.3	8.11212	1.5

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     =            11.9 bars
Shell Side MAPnc    =            15.9 bars
Channel Side  MAWP  =            13.2 bars
Channel Side  MAPnc =            15.9 bars
```

Elements Suitable for Design Internal Pressure.

<u>Internal Pressure Calculation Results:</u>

ASME Code, Section VIII Division 1, 2019

<u>Cylindrical Shell From 20 To 30 SA-312 TP316L at 152 °C</u>

Shell Barrel
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:

```
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (6.64*137)/(87.2*1+0.4*6.64)
= 1.0366 + 0.0000 = 1.0366 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.041 bars

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (87.2*1*8.11)/(137-0.4*8.11)
= 53.1 - 0.041 = 53  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (115*1*8.11)/(137-0.4*8.11)
= 70.1 bars
```

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

```
= (P*(Ro-0.4*t))/(E*t)
= (6.64*((137-0.4*8.11))/(1*8.11)
= 10.911 N./mm²
```

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

Cylindrical Shell From 50 To 60 SA-312 TP316L at 100 °C

Channel Barrel
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:

```
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (8.53*137)/(96.7*1+0.4*8.53)
= 1.2006 + 0.0000 = 1.2006 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.031 bars

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (96.7*1*8.11)/(137-0.4*8.11)
= 58.8 - 0.031 = 58.8  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (115*1*8.11)/(137-0.4*8.11)
= 70.1 bars
```

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

```
= (P*(Ro-0.4*t))/(E*t)
= (8.53*((137-0.4*8.11))/(1*8.11)
= 14.017 N./mm²
```

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

Elliptical Head From 60 To 70 SA-403 316L at 100 °C

Channel Cover
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
```
= (P*Do*Kcor)/(2*S*E+2*P*(Kcor-0.1)) per Appendix 1-4 (c)
= (8.51*273*1)/(2*115*1+2*8.51*(1-0.1))
= 1.0024 + 0.0000 = 1.0024 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.006 bars
```
= (2*S*E*t)/(Kcor*Do-2*t*(Kcor-0.1)) per Appendix 1-4 (c)
= (2*115*1*8.11)/(1*273-2*8.11*(1-0.1))
= 72.3 - 0.0063 = 72.2  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
= (2*S*E*t)/(K*Do-2*t*(K-0.1)) per Appendix 1-4 (c)
= (2*115*1*8.11)/(1*273-2*8.11*(1-0.1))
= 72.3 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(Kcor*Do-2*t*(Kcor-0.1)))/(2*E*t)
= (8.51*(1*273-2*8.11*(1-0.1)))/(2*1*8.11)
= 13.551 N./mm²
```

Straight Flange Required Thickness:
```
= (P*Ro)/(S*E+0.4*P) + ca   per Appendix 1-1 (a)(1)
= (8.51*137)/(115*1+0.4*8.51)+0
= 1.006 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.006 bars
```
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (115 * 1 * 9.27 )/(137 - 0.4 * 9.27 )
= 80.3 - 0.0063 = 80.3  bars
```

SA-403 316L, Min Metal Temp without impact per UHA-51: -196 °C

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          20.334  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       11.325  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.670  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          17.206  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     10.890  bars
Pressure per App 27-4  = M.A.W.P.                        11.850  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          17.225  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       11.050  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.670  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          14.575  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     12.155  bars
Pressure per App 27-4  = M.A.W.P.                        13.250  bars
```

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

```
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 6.6 * 1.32
= 11.325 bars
```

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

```
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 8.5 * 1
= 11.050 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
Shell Barrel	18.7	155.1	0.120	11.35
Channel Barrel	18.2	155.1	0.117	11.08
Channel Cover	17.6	155.1	0.114	11.08

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
S2 (2in)	Nozzle	115.15	87.18	1.321
V (1in)	Nozzle	115.15	96.67	1.191
T1	Nozzle	115.15	96.67	1.191
T2	Nozzle	115.15	96.67	1.191
Minimum				1.191

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

Description	Ambient	Operating	Ratio
Shell FLG.	115.10	87.20	1.320
Shell Barrel	115.10	87.20	1.320
Shell FLG.	115.10	87.20	1.320
Channel FLG.	115.15	96.67	1.191

Channel Barrel	115.15	96.67	1.191
Channel Cover	115.10	115.10	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	115.15	87.18	1.321
Tubesheet Material	115.15	87.18	1.321
Minimum			1.321

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

Description	Ambient	Operating	Ratio
S2 (2in)	2.50	155.14	0.016
V (1in)	1.76	155.14	0.011
T1	1.76	155.14	0.011
T2	1.76	155.14	0.011

Elements Suitable for Test 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./mm²
10	20	No Calc	...	30.226	No Calc	No Calc
20	30	1603.2	273.05	8.11212	0.0011419	58.6617
30	40	No Calc	...	30.226	No Calc	No Calc
40	50	No Calc	...	30.226	No Calc	No Calc
50	60	373.002	273.05	8.11212	0.005061	76.4896
60	70	No Calc	273.05	8.11212	0.0041263	74.1804

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	30.226	No Calc	1.034	No Calc
20	30	8.11212	1.90549	1.034	23.2
30	40	30.226	No Calc	1.034	No Calc
40	50	30.226	No Calc	1.034	No Calc
50	60	8.11212	1.02405	1.034	30.3
60	70	8.11212	1.5	1.034	24.5
Minimum					23.2

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	1603.2	35499.3	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	373.002	9498	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2019

Cylindrical Shell From 20 to 30 Ext. Chart: HA-4 at 100 °C

Shell Barrel

Elastic Modulus from Chart: HA-4 at 100 °C: 186872176.000 KPa.

```
                                                |                                |
Results for Maximum Allowable Ext. Pressure     |                           MAEP |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  8.112 |     273.05 |     1603.20 |     33.66 |    5.8715 |  0.0011419 |    58.66 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*58.7 )/(3*33.7 ) = 23.2 bars

                                                |                                |
Results for Required Thickness                  |                            Tca |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  1.905 |     273.05 |     1603.20 |    143.30 |    5.8715 |  0.0001189 |    11.11 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*11.1 )/(3*143 ) = 1.03 bars

                                                |                                |
Results for Maximum Stiffened Length            |                           Slen |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  8.112 |     273.05 |    35499.31 |     33.66 |   50.0000 |  0.0009977 |    56.93 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*56.9 )/(3*33.7 ) = 22.6 bars

-------------------------------------------------------------------------------------------------
```

Cylindrical Shell From 50 to 60 Ext. Chart: HA-4 at 100 °C

Channel Barrel

Elastic Modulus from Chart: HA-4 at 100 °C: 186872176.000 KPa.

```
                                                |                                |
Results for Maximum Allowable Ext. Pressure     |                           MAEP |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  8.112 |     273.05 |      373.00 |     33.66 |    1.3661 |  0.0050610 |    76.49 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*76.5 )/(3*33.7 ) = 30.3 bars

                                                |                                |
Results for Required Thickness                  |                            Tca |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  1.024 |     273.05 |      373.00 |    266.64 |    1.3661 |  0.0002213 |    20.68 |
-----------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*20.7 )/(3*267 ) = 1.03 bars

                                                |                                |
Results for Maximum Stiffened Length            |                           Slen |
-----------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
```

```
  8.112 |      273.05 |      9498.01 |      33.66 |    34.7849 |  0.0009980 |     56.94 |
-----------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*56.9 )/(3*33.7 ) = 22.6 bars

-----------------------------------------------------------------------------------------
```

Elliptical Head From 60 to 70 Ext. Chart: HA-4 at 100 °C

Channel Cover

Elastic Modulus from Chart: HA-4 at 100 °C: 186872176.000 KPa.

```
                                                |                                |
Results for Maximum Allowable Ext. Pressure     |                           MAEP |
-----------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                         Factor B |
  8.112 |     273.05 |       33.66 | 0.0041263 |                            74.18 |
-----------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 74.2/(0.9 *33.7 ) = 24.5 bars

                                                |                                |
Results for Required Thickness                  |                            Tca |
-----------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                         Factor B |
  0.731 |     273.05 |      373.42 | 0.0003719 |                            34.75 |
-----------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 34.8/(0.9 *373 ) = 1.03 bars
```

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

Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.73*257*1)/(2*115*1-0.2*1.73)
  = 0.1927 + 0.0000 = 0.1927 mm.
```

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*115*1*8.11)/(1*257+0.2*8.11))/1.67
  = 43.3 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 24.5, 43.3 )
  = 24.486 bars
```

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

```
-----------------------------------------------------------------------------------------
```

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Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	27.2456	5169.69	27.2456	5169.69	2.72456
20	30	87.0991	38900.6	87.0991	38900.6	8.70991
30	40	27.0891	5264.28	27.0891	5264.28	2.70891
40	50	27.0891	5264.28	27.0891	5264.28	2.70891
50	60	12.4427	10362.7	12.4427	10362.7	1.24427
60	70	9.41758	4808.54	9.41758	4808.54	0.94176
Total		190	69770.13	190	69770.13	19

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	Insl	0.76995	...	50.8	Ins: 10
20	Insl	6.88452	...	700	Ins: 20
20	Nozl	8.22666	153.813	1300	S2 (2in)
20	Wght	50	...	700	BAFFLE
30	Insl	0.7643	...	50.8	Ins: 30
30	Wght	...	...	...	WGHT:[1 OF 1]
40	Liqd	5.26107	...	50.8	Liquid: 40
40	Insl	0.7643	...	50.8	Ins: 40
50	Liqd	10.3564	...	100	Liquid: 50
50	Insl	0.9835	...	100	Ins: 50
50	Nozl	3.71765	141.113	100	V (1in)
60	Liqd	4.8056	...	82.103	Liquid: 60
60	Insl	0.85445	...	59.1312	Ins: 60
60	Nozl	3.71765	...	175.23	T1
60	Nozl	3.71765	...	175.23	T2
30	FTsh	56.9068	...	135.45	ts
30	Tube	54.7688	...	-592.05	Tubes

Total Weight of Each Detail Type:

Liquid	20.4
Insulation	11.0
Nozzles	19.4
Weights	50.0
Exchanger Components	111.7
Liquid in Tubes	13.8
Sum of the Detail Weights	226.3 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	209.4	209.4	209.4	209.4	209.4	209.4
Nozzles	19.4	19.4	19.4	19.4	19.4	19.4
Wld Weights	50.0	50.0	50.0	50.0	50.0	50.0
Exchanger	111.7	111.7	111.7	111.7	111.7	111.7
Insulation	...	...	11.0	11.0	11.0	11.0
Ope. Liquid	...	...	...	...	...	20.4
Tube Ope Lqd	...	...	...	...	...	13.8
Test Liquid	...	69.7	...	...	...	...
Tube Tst Lqd	...	13.8	...	...	...	...
Totals	390.5	474.0	401.5	401.5	401.5	435.8

Field Installation Options:

Miscellaneous Weight Percent: 10.0 %

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

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	390.5 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	474.0 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	401.5 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	401.5 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	401.5 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	435.8 kg.
Field Test Wt.	- Empty Weight + Water (Full)	485.1 kg.
Mass of the Upper 1/3 of the Vertical Vessel		138.4 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	13854.0 Cm.
Weight of Ope Liq in tubes :	13.8 kg.
Weight of Water in tubes :	13.8 kg.

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

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	1852.59
20	30	12111.3
30	40	1848.48
40	50	1848.48
50	60	1730.19

```
   60|  70|          1254.5 |
----------------------------
  Total          20645.553 cm²
```

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kg.
10	20	30.7401	30.7401	35.9066	...	30.7401
20	30	160.92	160.92	199.797	12.4132	160.92
30	40	142.238	142.238	147.499	...	142.238
40	50	30.5623	35.8234	35.8234	...	30.5623
50	60	18.3882	28.7446	28.7446	5.14639	18.3882
60	70	18.6491	23.4547	23.4547	...	18.6491

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	401.498	421.921	471.225
20	30	370.758	391.181	435.319
30	40	209.837	230.261	235.522
40	50	67.5995	88.0226	88.0226
50	60	37.0372	52.1993	52.1993
60	70	18.6491	23.4547	23.4547

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

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. N-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m
10	20	17.5596	17.5596	17.5596
20	30	17.5596	17.5596	17.5596
30	40	5.14639	5.14639	5.14639
40	50	5.14639	5.14639	5.14639
50	60	5.14639	5.14639	5.14639
60	70	...	...	...

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Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
S2 (2in)	11.97	15.90	152	150	GR 2.3	...	...	...	...
V (1in)	13.30	15.90	100	150	GR 2.3	...	...	...	...
T1	13.30	15.90	100	150	GR 2.3	...	...	...	...
T2	13.30	15.90	100	150	GR 2.3	...	...	...	...

Shellside Flange Rating

```
Lowest Flange Pressure Rating was (Ope)[ShellSide]:     11.968  bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]:     15.900  bars
```

Channelside Flange Rating

```
Lowest Flange Pressure Rating was (Ope)[TubeSide ]:     13.300  bars
Lowest Flange Pressure Rating was (Amb)[TubeSide ]:     15.900  bars
```

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

Warning:
There are nozzles in this model, but no flange MAWPs were de-rated. Be sure this is what you intended. There is a check box in the nozzle dialog that instructs PV Elite to perform the de-rating for each nozzle flange. See ASME VIII-1, UG-44(b) for more information.

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Shop/Field Installation Options :

Insulation is installed in the Shop.

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

```
Center of Gravity of the Liquid                          1879.678 mm.
Center of Gravity of the Insulation                      1061.110 mm.
Center of Gravity of the Nozzles                         1782.722 mm.
Center of Gravity of the Added Weights (Operating)        807.950 mm.
Center of Gravity of the Added Weights (Empty)            807.950 mm.
Center of Gravity of the Tubesheet(s)                    1643.400 mm.
Center of Gravity of the Tubes                            915.900 mm.

Center of Gravity of Bare Shell New and Cold             1065.552 mm.
Center of Gravity of Bare Shell Corroded                 1065.552 mm.

Vessel CG in the Operating Condition                     1157.830 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition       1129.454 mm.
```

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Input, Nozzle Desc: S2 (2in) **From: 20**

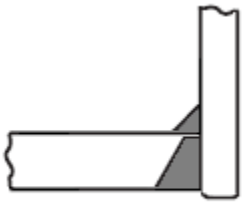
Pressure for Reinforcement Calculations	P	6.600	bars
Temperature for Internal Pressure	Temp	152	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-312 TP316L	
Shell Allowable Stress at Temperature	Sv	87.20	N./mm²
Shell Allowable Stress At Ambient	Sva	115.10	N./mm²
Inside Diameter of Cylindrical Shell	D	254.51	mm.
Design Length of Section	L	1603.2001	mm.
Shell Finished (Minimum) Thickness	t	8.1121	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1407.95	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	87.18	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	15.8500	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.1121	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

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: S2 (2in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.624  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (6.6*127)/(87.2*1-0.6*6.6)
  = 0.9676 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 25.4(exp([6.6/(87.2*1]-1)
  = 0.1930 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3482 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   101.6000  mm.
Parallel to Vessel Wall, opening length              d    50.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    20.2803  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 87.2/87.2 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 87.2/87.2 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
```

```
= min( 1, 1 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
-------------------------------------------------------------
Area Required             Ar |     0.492|     0.484|        NA|
Area in Shell             A1 |     3.629|     3.153|        NA|
Area in Nozzle Wall       A2 |     6.349|     6.286|        NA|
Area in Inward Nozzle     A3 |     0.000|     0.000|        NA|
Area in Welds    A41+A42+A43 |     0.998|     0.998|        NA|
Area in Element           A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE    Atot |    10.976|    10.437|        NA|
```

The External 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]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(50.8*1.91*1+2*15.8*1.91*1(1-1))
= 0.484 cm²
```

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 )
= 50.8 ( 1 * 8.11 - 1 * 1.91 ) - 2 * 15.8
  ( 1 * 8.11 - 1 * 1.91 ) * ( 1 - 1 )
= 3.153 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 20.3 )( 15.8 - 0.35 )1
= 6.286 cm²
```

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

```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 10² - 0.002 ) * 1 + ( 0² -0 ) * 1
= 0.998 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.3482 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 0.9676 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                     tb3 = 4.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
```

```
  = min[ 4.8, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 0.35, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 15.8500 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  :     10.9,  Allowable :     87.2 N./mm²  Passed
 Expansion  :      0.0,  Allowable :    242.0 N./mm²  Passed
 Occasional :      0.4,  Allowable :    116.0 N./mm²  Passed
 Shear      :      2.8,  Allowable :     61.0 N./mm²  Passed
```

Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: S2 (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.48 - 3.15 + 2 * 15.8 * 1 *
    (1 * 8.11 - 1.91 ) )87.2 )
  = max( 0, -6.12) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.29 + 0 + 1 - 0 * 1 ) * 87.2
  = 63.51 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.29 + 0 + 1 + ( 2.57 ) ) * 87.2
  = 85.93 kN
```

Weld Load [W3]:

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

```
= ( 6.29 + 0 + 1 + 0 + ( 2.57 ) ) * 87.2
= 85.93 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.14/2.0 ) * 82.5 * 10 * 0.49 * 87.2
= 55. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.14 * 33.3 ) * ( 15.8 - 0 ) * 0.7 * 87.2
= 101. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.14/2.0 ) * 82.5 * ( 8.11 - 0 ) * 0.74 * 87.2
= 68. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 55.4 + 101 ) = 157 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 55.4 + 0 + 67.8 + 0 ) = 123 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 55.4 + 67.8 + 0 ) = 123 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 156 kN , must exceed W = 0 kN  or W1 = 63 kN
Path 2-2 = 123 kN , must exceed W = 0 kN  or W2 = 85 kN
Path 3-3 = 123 kN , must exceed W = 0 kN  or W3 = 85 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   11.9  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 6.8712 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 164.9833 mm.

Input Echo, WRC107/537 Item 1, Description: S2 (2in) :

```
Diameter Basis for Vessel                  Vbasis      ID
Cylindrical or Spherical Vessel            Cylsph      Cylindrical
Internal Corrosion Allowance                  Cas      0.0000  mm.
Vessel Diameter                                Dv     254.508  mm.
Vessel Thickness                               Tv       8.112  mm.

Design Temperature                             T1       152.0  °C
Vessel Material                                 SA-312 TP316L
Vessel UNS Number                                      S31603
```

```
Vessel Cold S.I. Allowable                    Smc      115.10  N./mm²
Vessel Hot  S.I. Allowable                    Smh       87.20  N./mm²

Attachment Type                              Type      Round

Diameter Basis for Nozzle                   Nbasis      ID
Corrosion Allowance for Nozzle                 Can      0.0000  mm.
Nozzle Diameter                                 Dn      50.800  mm.
Nozzle Thickness                                Tn      15.850  mm.
Nozzle Material                                   SA-182 F316L
Nozzle UNS Number                                       S31603
Nozzle Cold S.I. Allowable                    SNmc      115.15  N./mm²
Nozzle Hot  S.I. Allowable                    SNmh       87.18  N./mm²

Design Internal Pressure                        Dp       6.600  bars
Include Pressure Thrust                                     No
```

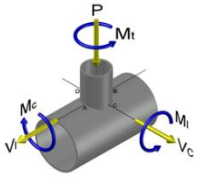
External Forces and Moments in WRC 107/537 Convention:

```
Radial Load             (SUS)                    P         2.8  kN
Longitudinal Shear      (SUS)                   Vl         2.8  kN
Circumferential Shear   (SUS)                   Vc        -2.1  kN
Circumferential Moment  (SUS)                   Mc      -280.0  N-m
Longitudinal Moment     (SUS)                   Ml      -360.0  N-m
Torsional Moment        (SUS)                   Mt      -420.0  N-m


Use Interactive Control                              No
WRC107 Version                             Version   March  1979

Include Pressure Stress Indices per Div. 2                 No
Compute Pressure Stress per WRC-368                        No
Local Loads applied at end of Nozzle/Attachment            No
```

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 82.5 + 2 * 1.65 * sqrt( 131.31 ( 8.112 - 0.0 ) )
  = 190.204 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                     P         2.8  kN
Circumferential Shear                          VC        -2.1  kN
```

Longitudinal Shear	VL	2.8	kN
Circumferential Moment	MC	-280.0	N-m
Longitudinal Moment	ML	-360.0	N-m
Torsional Moment	MT	-420.0	N-m

Dimensionless Parameters used : Gamma = 16.19

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.275	4C	2.406	(A,B)
N(PHI) / (P/Rm)	0.275	3C	1.725	(C,D)
M(PHI) / (P)	0.275	2C1	0.040	(A,B)
M(PHI) / (P)	0.275	1C !	0.068	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.275	3A	0.683	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.275	1A	0.084	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.275	3B	1.756	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.275	1B	0.029	(A,B,C,D)
N(x) / (P/Rm)	0.275	3C	1.725	(A,B)
N(x) / (P/Rm)	0.275	4C	2.406	(C,D)
M(x) / (P)	0.275	1C1	0.069	(A,B)
M(x) / (P)	0.275	2C !	0.040	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.275	4A	1.260	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.275	2A	0.042	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.275	4B	0.658	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.275	2B	0.048	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (N./mm²)

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-6.3	-6.3	-6.3	-6.3	-4.5	-4.5	-4.5	-4.5
Circ. Bend.	P	-10.2	10.2	-10.2	10.2	-17.4	17.4	-17.4	17.4
Circ. Memb.	MC	0.0	0.0	0.0	0.0	5.0	5.0	-5.0	-5.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	59.1	-59.1	-59.1	59.1
Circ. Memb.	ML	16.4	16.4	-16.4	-16.4	0.0	0.0	0.0	0.0
Circ. Bend.	ML	26.2	-26.2	-26.2	26.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.		26.1	-5.9	-59.3	13.7	42.1	-41.2	-86.0	66.9
Long. Memb.	P	-4.5	-4.5	-4.5	-4.5	-6.3	-6.3	-6.3	-6.3
Long. Bend.	P	-17.6	17.6	-17.6	17.6	-10.2	10.2	-10.2	10.2
Long. Memb.	MC	0.0	0.0	0.0	0.0	9.2	9.2	-9.2	-9.2
Long. Bend.	MC	0.0	0.0	0.0	0.0	30.0	-30.0	-30.0	30.0

Long. Memb. ML	6.2	6.2	-6.2	-6.2	0.0	0.0	0.0	0.0
Long. Bend. ML	43.5	-43.5	-43.5	43.5	0.0	0.0	0.0	0.0
Tot. Long. Str.	27.5	-24.2	-71.8	50.4	22.6	-16.9	-55.7	24.7
Shear VC	-2.0	-2.0	2.0	2.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Shear MT	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8
Tot. Shear	-6.8	-6.8	-2.8	-2.8	-7.5	-7.5	-2.2	-2.2
Str. Int.	33.7	26.5	72.4	50.6	44.6	43.3	86.1	67.1

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)	10.0	10.7	10.0	10.7	10.0	10.7	10.0	10.7
Circ. Pl (SUS)	10.1	10.1	-22.8	-22.8	0.4	0.4	-9.5	-9.5
Circ. Q (SUS)	16.0	-16.0	-36.5	36.5	41.7	-41.7	-76.5	76.5
Long. Pm (SUS)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Long. Pl (SUS)	1.6	1.6	-10.7	-10.7	2.9	2.9	-15.5	-15.5
Long. Q (SUS)	25.8	-25.8	-61.1	61.1	19.8	-19.8	-40.2	40.2
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-2.0	-2.0	2.0	2.0	-2.7	-2.7	2.7	2.7
Shear Q (SUS)	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8
Pm (SUS)	10.0	10.7	10.0	10.7	10.0	10.7	10.0	10.7
Pm+Pl (SUS)	20.4	21.1	13.3	12.6	12.1	12.6	12.2	12.8
Pm+Pl+Q (Total)	41.4	27.6	67.2	55.7	54.2	33.2	76.1	77.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	10.69	87.20	Passed
Pm+Pl (SUS)	21.08	130.80	Passed
Pm+Pl+Q (TOTAL)	77.74	261.60	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

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Input, Nozzle Desc: V (1in) **From: 50**

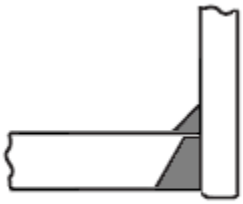
Pressure for Reinforcement Calculations	P	8.521	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-312 TP316L	
Shell Allowable Stress at Temperature	Sv	96.67	N./mm²
Shell Allowable Stress At Ambient	Sva	115.15	N./mm²
Inside Diameter of Cylindrical Shell	D	254.51	mm.
Design Length of Section	L	373.0022	mm.
Shell Finished (Minimum) Thickness	t	8.1121	mm.
Shell Internal Corrosion Allowance	c	0.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1875.68	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	96.67	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.1121	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

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: V (1in)

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.504  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (8.52*127)/(96.7*1-0.6*8.52)
  = 1.1277 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.7(exp([8.52/(96.7*1]-1)
  = 0.1124 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2635 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     67.2242  mm.
Parallel to Vessel Wall                        Rn+tn+t     33.6121  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     20.2803  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 96.7/96.7 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 96.7/96.7 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
```

```
  = min( 1, 1 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5      |    Design|  External|     Mapnc|
-------------------------------------------------------------
Area Required             Ar |     0.286|     0.130|        NA|
Area in Shell             A1 |     2.921|     2.965|        NA|
Area in Nozzle Wall       A2 |     5.146|     5.085|        NA|
Area in Inward Nozzle     A3 |     0.000|     0.000|        NA|
Area in Welds    A41+A42+A43 |     0.964|     0.964|        NA|
Area in Element           A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE    Atot |     9.032|     9.014|        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) ) UG-37(c)
  = (25.4*1.13*1+2*12.8*1.13*1*(1-1))
  = 0.286 cm²
```

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 )
  = 41.8 ( 1 * 8.11 - 1 * 1.13 ) - 2 * 12.8
    ( 1 * 8.11 - 1 * 1.13 ) * ( 1 - 1 )
  = 2.921 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 20.3 )( 12.8 - 0.11 )1
  = 5.146 cm²
```

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

```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10² - 0.036 ) * 1 + ( 0² -0 ) * 1
  = 0.964 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.2635 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 1.1277 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                     tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
```

```
  = min[ 3.42, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 0.26, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

SA-312 TP316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: V (1in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.29 - 2.92 + 2 * 12.8 * 1 *
    (1 * 8.11 - 1.13 ) )96.7 )
  = max( 0, -8.18) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 5.15 + 0 + 0.96 - 0 * 1 ) * 96.7
  = 59.07 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 5.15 + 0 + 0.96 + ( 2.08 ) ) * 96.7
  = 79.14 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 5.15 + 0 + 0.96 + 0 + ( 2.08 ) ) * 96.7
  = 79.14 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 51 * 10 * 0.49 * 96.7
  = 38. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.14 * 19.1 ) * ( 12.8 - 0 ) * 0.7 * 96.7
= 52. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.14/2.0 ) * 51 * ( 8.11 - 0 ) * 0.74 * 96.7
= 46. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 37.9 + 52 ) = 89.9 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 37.9 + 0 + 46.5 + 0 ) = 84.4 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 37.9 + 46.5 + 0 ) = 84.4 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 0 kN  or W1 = 59 kN
Path 2-2 = 84 kN , must exceed W = 0 kN  or W2 = 79 kN
Path 3-3 = 84 kN , must exceed W = 0 kN  or W3 = 79 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   13.3  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 2.5811 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 160.6932 mm.

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Input, Nozzle Desc: T1 **From: 60**

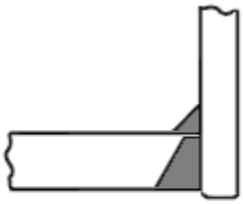
Pressure for Reinforcement Calculations	P	8.501	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-403 316L	
Shell Allowable Stress at Temperature	Sv	115.10	N./mm²
Shell Allowable Stress At Ambient	Sva	115.10	N./mm²
Inside Diameter of Elliptical Head	D	256.83	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	8.1121	mm.
Head Internal Corrosion Allowance	c	0.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	80.0000	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	96.67	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.1121	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.504  in.
```

Nozzle input data check completed without errors.

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

```
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (8.5*257*1)/( 2*115*1-0.2*8.5)
= 0.9492 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 12.7(exp([8.5/(96.7*1]-1)
= 0.1122 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2635 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     69.2530  mm.
Parallel to Vessel Wall                        Rn+tn+t     34.6265  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     20.2803  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 96.7/115 )
= 0.840
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 96.7/115 )
= 0.840
```

Weld Strength Reduction Factor [fr3]:
```
= min( fr2, fr4 )
= min( 0.84, 1 )
= 0.840
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.299	0.236	NA
Area in Shell	A1	2.702	2.494	NA
Area in Nozzle Wall	A2	4.492	4.439	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.810	0.810	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.004	7.743	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 67.82 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(27.4*1.5*1+2*12.8*1.5*1(1-0.84))
= 0.236 cm²
```

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 )
= 41.8 ( 1 * 8.11 - 1 * 1.5 ) - 2 * 12.8
  ( 1 * 8.11 - 1 * 1.5 ) * ( 1 - 0.84 )
= 2.494 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
= ( 2 * 20.3 )( 12.8 - 0.26 )0.84/sin( 74.2 )
= 4.439 cm²
```

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 10² - 0.036 ) * 0.84 + ( 0² -0 ) * 0.84
= 0.810 cm²
```

SA-403 316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

<u>Weld Size Calculations, Description: T1</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.24 - 2.49 + 2 * 12.8 * 0.84 *
    (1 * 8.11 - 1.5 ) )115 )
  = max( 0, -9.63) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.44 + 0 + 0.81 - 0 * 0.84 ) * 115
  = 60.41 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.44 + 0 + 0.81 + ( 1.74 ) ) * 115
  = 80.48 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.44 + 0 + 0.81 + 0 + ( 1.74 ) ) * 115
  = 80.48 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 55.1 * 10 * 0.49 * 96.7
  = 41. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 20.6 ) * ( 12.8 - 0 ) * 0.7 * 96.7
  = 56. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 55.1 * ( 8.11 - 0 ) * 0.74 * 115
  = 60. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 41 + 56.1 ) = 97.1 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 41 + 0 + 59.8 + 0 ) = 101 kN
  PATH33 = ( Sonw + Tngw + Sinw )
```

= (41 + 59.8 + 0) = 101 kN

Summary of Failure Path Calculations:

```
Path 1-1 = 97 kN , must exceed W = 0 kN  or W1 = 60 kN
Path 2-2 = 100 kN , must exceed W = 0 kN  or W2 = 80 kN
Path 3-3 = 100 kN , must exceed W = 0 kN  or W3 = 80 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   13.3  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.504  in.
```

Nozzle input data check completed without errors.

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

```
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (8.5*257*1)/( 2*115*1-0.2*8.5)
= 0.9492 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 12.7(exp([8.5/(96.7*1]-1)
= 0.1122 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2635 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     67.2242  mm.
Parallel to Vessel Wall                        Rn+tn+t     33.6121  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     20.2803  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.280	0.221	NA
Area in Shell	A1	2.702	2.494	NA
Area in Nozzle Wall	A2	4.322	4.271	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.810	0.810	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.834	7.575	NA

The External 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]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(25.4*1.5*1+2*12.8*1.5*1(1-0.84))
  = 0.221 cm²
```

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 )
  = 41.8 ( 1 * 8.11 - 1 * 1.5 ) - 2 * 12.8
    ( 1 * 8.11 - 1 * 1.5 ) * ( 1 - 0.84 )
  = 2.494 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 20.3 )( 12.8 - 0.26 )0.84
  = 4.271 cm²
```

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

```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10² - 0.036 ) * 0.84 + ( 0² -0 ) * 0.84
  = 0.810 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.2635 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 0.9492 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                     tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 3.42, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 0.26, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

<u>Weld Size Calculations, Description: T1</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.22 - 2.49 + 2 * 12.8 * 0.84 *
    (1 * 8.11 - 1.5 ) )115 )
  = max( 0, -9.80) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.27 + 0 + 0.81 - 0 * 0.84 ) * 115
  = 58.47 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.27 + 0 + 0.81 + ( 1.74 ) ) * 115
  = 78.55 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.27 + 0 + 0.81 + 0 + ( 1.74 ) ) * 115
  = 78.55 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 51 * 10 * 0.49 * 96.7
  = 38. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 19.1 ) * ( 12.8 - 0 ) * 0.7 * 96.7
  = 52. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 51 * ( 8.11 - 0 ) * 0.74 * 115
  = 55. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 37.9 + 52 ) = 89.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 37.9 + 0 + 55.3 + 0 ) = 93.3 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 37.9 + 55.3 + 0 ) = 93.3 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 0 kN  or W1 = 58 kN
Path 2-2 = 93 kN , must exceed W = 0 kN  or W2 = 78 kN
Path 3-3 = 93 kN , must exceed W = 0 kN  or W3 = 78 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   13.3  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 10.8320 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.4289 mm.

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Input, Nozzle Desc: T2 **From: 60**

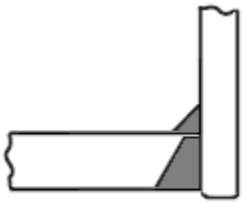
Pressure for Reinforcement Calculations	P	8.501	bars
Temperature for Internal Pressure	Temp	100	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-403 316L	
Shell Allowable Stress at Temperature	Sv	115.10	N./mm²
Shell Allowable Stress At Ambient	Sva	115.10	N./mm²
Inside Diameter of Elliptical Head	D	256.83	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	8.1121	mm.
Head Internal Corrosion Allowance	c	0.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	80.0000	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-182 F316L	
Material UNS Number		S31603	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	96.67	N./mm²
Allowable Stress At Ambient	Sna	115.15	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		180.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.8000	mm.
Flange Material		SA-182 F316L	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.1121	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 2.3	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)



Insert/Set-in Nozzle No Pad, no Inside projection

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.504  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
  = (8.5*257*1)/( 2*115*1-0.2*8.5)
  = 0.9492 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.7(exp([8.5/(96.7*1]-1)
  = 0.1122 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2635 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     69.2530  mm.
Parallel to Vessel Wall                        Rn+tn+t     34.6265  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     20.2803  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 96.7/115 )
  = 0.840
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 96.7/115 )
  = 0.840
```

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.84, 1)
= 0.840

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.299	0.236	NA
Area in Shell	A1	2.702	2.494	NA
Area in Nozzle Wall	A2	4.492	4.439	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.810	0.810	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.004	7.743	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 67.82 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(27.4*1.5*1+2*12.8*1.5*1(1-0.84))
= 0.236 cm²

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)
= 41.8 (1 * 8.11 - 1 * 1.5) - 2 * 12.8
(1 * 8.11 - 1 * 1.5) * (1 - 0.84)
= 2.494 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 20.3)(12.8 - 0.26)0.84/sin(74.2)
= 4.439 cm²

Note: See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10² - 0.036) * 0.84 + (0² -0) * 0.84
= 0.810 cm²

SA-403 316L, Min Metal Temp without impact per UHA-51: -196 °C

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: T2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.24 - 2.49 + 2 * 12.8 * 0.84 *
    (1 * 8.11 - 1.5 ) )115 )
  = max( 0, -9.63) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.44 + 0 + 0.81 - 0 * 0.84 ) * 115
  = 60.41 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.44 + 0 + 0.81 + ( 1.74 ) ) * 115
  = 80.48 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.44 + 0 + 0.81 + 0 + ( 1.74 ) ) * 115
  = 80.48 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 55.1 * 10 * 0.49 * 96.7
  = 41. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 20.6 ) * ( 12.8 - 0 ) * 0.7 * 96.7
  = 56. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 55.1 * ( 8.11 - 0 ) * 0.74 * 115
  = 60. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 41 + 56.1 ) = 97.1 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 41 + 0 + 59.8 + 0 ) = 101 kN
  PATH33 = ( Sonw + Tngw + Sinw )
```

```
= ( 41 + 59.8 + 0 ) = 101 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 97 kN , must exceed W = 0 kN  or W1 = 60 kN
Path 2-2 = 100 kN , must exceed W = 0 kN  or W2 = 80 kN
Path 3-3 = 100 kN , must exceed W = 0 kN  or W3 = 80 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   13.3  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2019, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.504  in.
```

Nozzle input data check completed without errors.

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

```
= (P*D*K)/(2*Sv*E-0.2*P) Appendix 1-4(c)
= (8.5*257*1)/( 2*115*1-0.2*8.5)
= 0.9492 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 12.7(exp([8.5/(96.7*1]-1)
= 0.1122 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2635 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     67.2242  mm.
Parallel to Vessel Wall                        Rn+tn+t     33.6121  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     20.2803  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.280	0.221	NA
Area in Shell	A1	2.702	2.494	NA
Area in Nozzle Wall	A2	4.322	4.271	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.810	0.810	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	7.834	7.575	NA

The External 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]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(25.4*1.5*1+2*12.8*1.5*1(1-0.84))
  = 0.221 cm²
```

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 )
  = 41.8 ( 1 * 8.11 - 1 * 1.5 ) - 2 * 12.8
    ( 1 * 8.11 - 1 * 1.5 ) * ( 1 - 0.84 )
  = 2.494 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 20.3 )( 12.8 - 0.26 )0.84
  = 4.271 cm²
```

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

```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10² - 0.036 ) * 0.84 + ( 0² -0 ) * 0.84
  = 0.810 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.2635 mm.
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 0.9492 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 1.5000 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 1.5000 mm.
Wall Thickness per table UG-45                     tb3 = 3.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 3.42, max( 1.5, 1.5 ) ]
  = 1.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 0.26, 1.5 )
  = 1.5000 mm.
```

Available Nozzle Neck Thickness = 12.8000 mm. --> OK

<u>Weld Size Calculations, Description: T2</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      9.2710  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (0.22 - 2.49 + 2 * 12.8 * 0.84 *
    (1 * 8.11 - 1.5 ) )115 )
  = max( 0, -9.80) kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.27 + 0 + 0.81 - 0 * 0.84 ) * 115
  = 58.47 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.27 + 0 + 0.81 + ( 1.74 ) ) * 115
  = 78.55 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.27 + 0 + 0.81 + 0 + ( 1.74 ) ) * 115
  = 78.55 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 51 * 10 * 0.49 * 96.7
  = 38. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 19.1 ) * ( 12.8 - 0 ) * 0.7 * 96.7
  = 52. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 51 * ( 8.11 - 0 ) * 0.74 * 115
  = 55. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 37.9 + 52 ) = 89.9 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 37.9 + 0 + 55.3 + 0 ) = 93.3 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 37.9 + 55.3 + 0 ) = 93.3 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 0 kN  or W1 = 58 kN
Path 2-2 = 93 kN , must exceed W = 0 kN  or W2 = 78 kN
Path 3-3 = 93 kN , must exceed W = 0 kN  or W3 = 78 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   13.3  bars
```

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

```
Nozzle is O.K. for the External Pressure           1.03  bars
```

The Drop for this Nozzle is : 10.8320 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.4289 mm.

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Input Echo, Tubesheet Number 1, Description: ts

Shell Data:

Main Shell Description: Shell Barrel

Shell Maximum Design Pressure	Psd,max	6.60	bars
Shell Maximum Operating Pressure	Psox,max	6.60	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	9.2710	mm.
Shell Internal Corrosion Allowance	cas	0.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	254.508	mm.
Shell Temperature for Internal Pressure	Ts	152.00	°C
Shell Material		SA-312 TP316L	
Shell Material UNS Number		S31603	
Shell Allowable Stress at Temperature	Ss	87.18	N./mm²
Shell Allowable Stress at Ambient		115.15	N./mm²

Channel Description: Channel Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	8.50	bars
Channel Maximum Operating Pressure	Ptox,max	8.50	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	9.2710	mm.
Channel Corrosion Allowance	cac	0.0000	mm.
Inside Diameter of Channel	Dc	254.508	mm.
Channel Design Temperature	TEMPC	152.00	°C
Channel Material		SA-312 TP316L	
Channel Material UNS Number		S31603	
Channel Allowable Stress at Temperature	Sc	87.18	N./mm²
Channel Allowable Stress at Ambient		115.15	N./mm²

Tube Data:

Number of Tube Holes	Nt	44	
Tube Wall Thickness	et	1.6500	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	1400.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	1345.00	mm.
Design Temperature of the Tubes		152.00	°C
Tube Material		SA-213 TP316L	
Tube Material UNS Number		S31603	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		87.18	N./mm²
Tube Allowable Stress At Ambient		115.15	N./mm²
Tube Yield Stress At design Temperature	Syt	130.43	N./mm²
Tube Pitch (Center to Center Spacing)	P	28.5000	mm.
Tube Layout Pattern		Square	
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	
Radius to Outermost Tube Hole Center	ro	108.823	mm.
Largest Center-to-Center Tube Distance	Ul	57.1500	mm.
Length of Expanded Portion of Tube	ltx	40.0000	mm.
Distance from Channel Side where Exp. Starts		12.0000	mm.
Min. Distance from Shell Side where Exp. Stops		3.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.
Area of Tube Layout	Ap	294.2	cm²
Perimeter of Tube Layout	Cp	628.5	mm.

Tubesheet Data:

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	152.00	°C
Tubesheet Material		SA-182 F316L	
Tubesheet Material UNS Number		S31603	
Tubesheet Allowable Stress at Temperature	S	87.18	N./mm²
Tubesheet Allowable Stress at Ambient	Tt	115.15	N./mm²
Thickness of Tubesheet	h	55.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	0.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	0.0000	mm.
Tubesheet Outside Diameter	A	406.400	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	320.60	mm.
Step 1 Depth on the Tubeside	ht1	7.00	mm.
Step 2 Diameter on the Tubeside	dt2	251.40	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	320.60	mm.
Step 1 Depth on the Shellside	hs1	7.00	mm.
Step 2 Diameter on the Shellside	ds2	251.40	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		320.60	mm.

Note: Tubesheet diameter is now: 320.600 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	317.500	mm.
Area of the Untubed Lanes	AL	137.7	cm²
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0340	bars
Channel Side Min. Design Pressure	Ptd,min	1.0340	bars

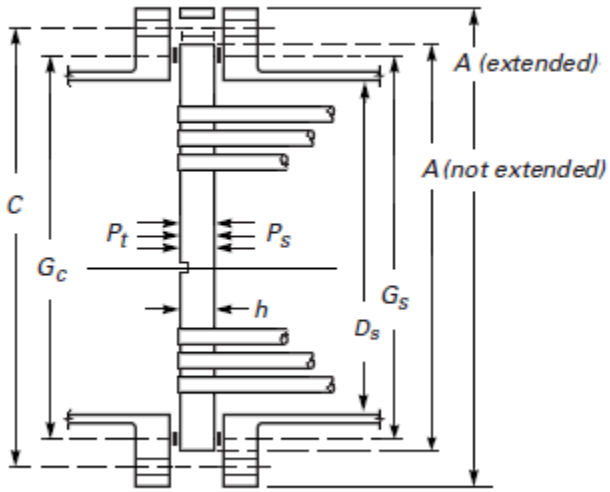
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	406.400	mm.
Flange Inside Diameter	B	256.826	mm.
Flange Face Outside Diameter	Fod	323.850	mm.
Flange Face Inside Diameter	Fid	256.826	mm.
Gasket Outside Diameter	Go	317.500	mm.
Gasket Inside Diameter	Gi	287.274	mm.
Small end Hub thk.	g0	9.2710	mm.
Large end Hub thk.	g1	23.9871	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm²
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.1750	mm.
Full face Gasket Flange Option	Program Selects		

Bolting Information:

Diameter of Bolt Circle	C	361.950	mm.
Nominal Bolt Diameter	dB	24.0000	mm.
Type of Thread Series	TEMA Metric Thread		
Number of Bolts	n	12	
Bolt Material	SA-193 B8M		
Bolt Allowable Stress At Temperature	Sb	120.31	N./mm²
Bolt Allowable Stress At Ambient	Sa	129.63	N./mm²
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		74.42	kN
Alternate Flange Seating Bolt Load, Wm2		455.58	kN
Alternate Flange Design Bolt Load, W		471.01	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	31.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Material Group G

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      152.0 °C      0.18592E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

Channel - TM-1 Material Group G

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      152.0 °C      0.18592E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

Tubes - TM-1 Material Group G

```
-----------------------------------------------------------------
Elastic Mod. at Tubsht. Design Temp.    152.0 °C      0.18592E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

TubeSheet - TM-1 Material Group G

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      152.0 °C      0.18592E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.19512E+09 KPa.
```

Tube Required Thickness under Internal Pressure (Tubeside pressure):

Thickness Due to Internal Pressure:

```
= (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (9.53*(19/2-0)/(87.2*1+0.4*9.53)
= 0.1037 + 0.0000 = 0.1037 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     HA-4            at       152.00  °C
Elastic Modulus for Material                   182017440.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA        ODCA     SLEN       D/T       L/D   Factor A        B
  1.6500      19.05   1453.82     11.55   50.0000  0.0082522        72.23
EMAWP = (4*B)/(3*(D/T)) = ( 4 *72.2 )/( 3 *11.5 ) = 83.4 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
     TCA        ODCA     SLEN       D/T       L/D   Factor A        B
  0.3407      19.05   1453.82     55.92   50.0000  0.0003518        32.02
EMAWP = (4*B)/(3*(D/T)) = ( 4 *32 )/( 3 *55.9 ) = 7.63 bars
```

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.          0.3407  mm.
Allowable Internal Pressure at Corroded thickness          162.26  bars
Required Internal Design Pressure                            9.53  bars
Allowable External Pressure at Corroded thickness           83.41  bars
Required External Design Pressure                            7.63  bars
Required Thickness due to Shell Side pressure              0.3407  mm.
```

Detailed Results for load Case D1 un-corr. (Psd,min + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

```
Gasket Contact Width,       N = (Goc-Gic) / 2            15.113  mm.
Basic Gasket Width,        b0 = N / 2.0                   7.557  mm.
Effective Gasket Width,     b = SQRT(b0) * 2.5            6.925  mm.
Gasket Reaction Diameter,   G = Go (Self-Energizing)    317.500  mm.


Flange Design Bolt Load, Seating Condition    W  :      471.01  kN
Flange Design Bolt Load, Operating Condition  Wm1:       69.99  kN
```

Required Tubesheet Flanged Extension thk. per UHX-9 (operating) [hr_opr]:

```
= sqrt( 1.9 * WM1 * hg / ( S * G ) )
= sqrt( 1.9 * 70 * 29.1/( 87.2 * 304 ) )
= 12.102 mm.
```

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:
```
= sqrt( 1.9 * W * hg / ( Sa * G ) )
= sqrt( 1.9 * 471 * 29.1/( 115 * 304 ) )
= 27.316 mm.
```

```
Gasket Reaction Diameter (Gc or Gs as applicable):     317.500  mm.
```

<u>Results for ASME U-tube Tubesheet Calculations for Configuration d,</u>
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
```
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.33 ) * (237/(0.8 * 87.2 )) * [-1.03 - 8.5 ] + 0
= 2.4476 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
= 2 * ro + dt
= 2 * 109 + 19 = 237 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
= (p - dt) / p
= (28.5 - 19 )/28.5 = 0.33
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
= Gs / Do (Configurations d, e, f)
= 318/237 = 1.34
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 318/237 = 1.34
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 237²/16 * [ (1.34 - 1) * (1.34² + 1) * -1.03 -
  (1.34 - 1) * (1.34² + 1) * 8.5 ]
= -31902.8730 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
```
= ltx/h = 40/55 = 0.73 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19 -2*1.65 *(185923552/185923552 )*
     ( 87.2/87.2 )*(0.73 ), 19 -2*1.65 )
= 16.6500 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 28.5/sqrt( 1 - 4 * min( 138 *100, 4*237 *28.5 )
  (3.141* 237²) )
= 34.3833 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
= (p* - d*)/p* = (34.4 - 16.6 )/34.4 = 0.52
```

E*/E, nu* for Square pattern from Fig. UHX-11.4.

```
 h/p =   1.929824 ;  mu* =   0.515754
E*/E =   0.604944 ;  nu* =   0.304637 ;  E* = 112473384. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
= A/Do = 321/237 = 1.35
```

Determine Coefficient [F]:

```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.3 )/112473384 * ( 185923552 * ln(1.35 ) )
= 0.3488
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= -31903 + 70 * (318 - 304 )/(2 * pi * 237 )
= -25382.4043 bars*mm.²
```

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

```
= ((M*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
= ((-25382 ) - 237²/32 * 0.35 * (-1.03 - 8.5 ) )/(1 + 0.35 )
= -14502.6973 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -14503 + 237²/64 * (3 + 0.3 )(-1.03 - 8.5 )
= -42083.1055 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
= Max( abs(Mp), abs(Mo) )
= Max( abs(-14503 ), abs(-42083 ) )
= 42083.1055 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
```
= 6 * M / ( (mu*) * ( h - hg')² )
= 6 * 42083/( (0.52 ) * ( 55 - 5 )² )
= 19.5840 N./mm²
```

The Allowable Tubesheet Bending Stress [SigmaAll]:
```
= 2 * S = 2 * 87.2 = 174 N./mm²
```

Tubesheet Bending Stress at Final Thickness [Sigma]:
```
= 6 * M / ( (mu*) * ( h - hg')²
= 6 * 42397/( (0.54 ) * ( 21.4 - 5 )²
= 174.1978 N./mm²
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:
```
= H + CATS + CATC = 21.4 + 0 + 0 = 21.4 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
```
= Max( HreqB, HreqS ) = Max( 21.4, 2.45 ) = 21.4 mm.
```

UHX-12.5.9 Step 9:

```
abs(Ps - Pt) = abs(-1.03 - 8.5 ) = 9.53 bars
```

Shear Stress check [Tau_limit]:
```
= 3.2 * S * mu * h/Do
= 3.2 * 87.2 * 0.33 * 55/237 = 215 bars
```

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
```
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.33)*(237/55)*[-1.03-8.5]N./mm²
= 3.09 N./mm²
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
```
= pi( do - t )t
= pi( 19 - 1.65 )1.65
= 0.902 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
= 3.1415 * t * ( do - t ) * Sa
= 3.1415 * 1.65 * ( 19 - 1.65 ) * 87.2 = 7.86 kN
```

Fillet Weld Strength [Ff]:
```
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
= 6.1426  kN
```

Groove Weld Strength [Fg]:

```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
  = 7.8627  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 7.8627 kN
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.0748  mm.

 Minimum Required Fillet Weld Leg            afr      1.0374  mm.
 Minimum Required Groove Weld Leg            agr      1.0374  mm.

 Tube-Tubesheet Jt allowable, 7.86 is >= tube strength 7.86 kN
```

Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D1 un-corr. (Psd,min + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	19.6	<=	174.4 N./mm²	Ok
Tubesheet shear stress	3.1	<=	69.5 N./mm²	Ok

Thickness results for loadcase D1 un-corr. (Psd,min + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	21.416	55.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.037	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.037	2.000	Ok

Detailed Results for load Case D2 un-corr. (Psd,max + Ptd,min)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

```
 Gasket Contact Width,       N = (Goc-Gic) / 2            15.113  mm.
```

```
Basic Gasket Width,          b0 = N / 2.0                    7.557  mm.
Effective Gasket Width,       b = SQRT(b0) * 2.5             6.925  mm.
Gasket Reaction Diameter,     G = Go-2.0*b                 303.651  mm.


Flange Design Bolt Load, Seating Condition    W  :       471.01  kN
Flange Design Bolt Load, Operating Condition  Wm1:        73.95  kN
```

<u>Results for ASME U-tube Tubesheet Calculations for Configuration d,</u>
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:

```
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.33 ) * (237/(0.8 * 87.2 )) * [6.6 - -1.03 ] + 0
= 1.9598 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

```
= 2 * ro + dt
= 2 * 109 + 19 = 237 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
= (p - dt) / p
= (28.5 - 19 )/28.5 = 0.33
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 304/237 = 1.28
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 318/237 = 1.34
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 237²/16 * [ (1.28 - 1) * (1.28² + 1) * 6.6 -
  (1.34 - 1) * (1.34² + 1) * -1.03 ]
= 20756.1230 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:

```
= ltx/h = 40/55 = 0.73 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:

```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19 -2*1.65 *(185923552/185923552 )*
     ( 87.2/87.2 )*(0.73 ), 19 -2*1.65 )
```

```
  = 16.6500 mm.
```

Compute the Effective Tube Pitch [p*]:

```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 28.5/sqrt( 1 - 4 * min( 138 *100, 4*237 *28.5 )
    (3.141* 237²) )
  = 34.3833 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
  = (p* - d*)/p* = (34.4 - 16.6 )/34.4 = 0.52
```

E*/E, nu* for Square pattern from Fig. UHX-11.4.

```
   h/p =   1.929824 ;  mu* =   0.515754
  E*/E =   0.604944 ;  nu* =   0.304637 ;  E* = 112473384. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 321/237 = 1.35
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.3 )/112473384 * ( 185923552 * ln(1.35 ) )
  = 0.3488
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = 20756 + 74 * (318 - 304 )/(2 * pi * 237 )
  = 27645.2520 bars*mm.²
```

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

```
  = ((M*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
  = ((27645 ) - 237²/32 * 0.35 * (6.6 - -1.03 ) )/(1 + 0.35 )
  = 17040.5820 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = 17041 + 237²/64 * (3 + 0.3 )(6.6 - -1.03 )
  = 39124.5781 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(17041 ), abs(39125 ) )
  = 39124.5781 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
```
= 6 * M / ( (mu*) * ( h - hg')² )
= 6 * 39125/( (0.52 ) * ( 55 - 5 )² )
= 18.2072 N./mm²
```

The Allowable Tubesheet Bending Stress [SigmaAll]:
```
= 2 * S = 2 * 87.2 = 174 N./mm²
```

Tubesheet Bending Stress at Final Thickness [Sigma]:
```
= 6 * M / ( (mu*) * ( h - hg')²
= 6 * 39446/( (0.54 ) * ( 20.8 - 5 )²
= 174.1465 N./mm²
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:
```
= H + CATS + CATC = 20.8 + 0 + 0 = 20.8 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
```
= Max( HreqB, HreqS ) = Max( 20.8, 1.96 ) = 20.8 mm.
```

UHX-12.5.9 Step 9:

```
abs(Ps - Pt) = abs(6.6 - -1.03 ) = 7.63 bars
```

Shear Stress check [Tau_limit]:
```
= 3.2 * S * mu * h/Do
= 3.2 * 87.2 * 0.33 * 55/237 = 215 bars
```

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
```
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.33)*(237/55)*[6.6--1.03]N./mm²
= 2.48 N./mm²
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
```
= pi( do - t )t
= pi( 19 - 1.65 )1.65
= 0.902 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
= 3.1415 * t * ( do - t ) * Sa
= 3.1415 * 1.65 * ( 19 - 1.65 ) * 87.2 = 7.86 kN
```

Fillet Weld Strength [Ff]:
```
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
= 6.1426  kN
```

Groove Weld Strength [Fg]:

```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
  = 7.8627  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 7.8627 kN
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.0748  mm.

 Minimum Required Fillet Weld Leg            afr      1.0374  mm.
 Minimum Required Groove Weld Leg            agr      1.0374  mm.

 Tube-Tubesheet Jt allowable, 7.86 is >= tube strength 7.86 kN
```

Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D2 un-corr. (Psd,max + Ptd,min):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	18.2	<=	174.4 N./mm²	Ok
Tubesheet shear stress	2.5	<=	69.5 N./mm²	Ok

Thickness results for loadcase D2 un-corr. (Psd,max + Ptd,min):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	20.837	55.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.037	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.037	2.000	Ok

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, 2019

```
 Gasket Contact Width,       N = (Goc-Gic) / 2            15.113  mm.
```

```
Basic Gasket Width,          b0 = N / 2.0                    7.557  mm.
Effective Gasket Width,       b = SQRT(b0) * 2.5             6.925  mm.
Gasket Reaction Diameter,     G = Go-2.0*b                 303.651  mm.


Flange Design Bolt Load, Seating Condition    W  :       471.01  kN
Flange Design Bolt Load, Operating Condition  Wm1:        73.95  kN
```

<u>Results for ASME U-tube Tubesheet Calculations for Configuration d,</u>
Per Edition 2019, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:

```
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.33 ) * (237/(0.8 * 87.2 )) * [6.6 - 8.5 ] + 0
= 0.4878 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:

```
= 2 * ro + dt
= 2 * 109 + 19 = 237 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
= (p - dt) / p
= (28.5 - 19 )/28.5 = 0.33
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 304/237 = 1.28
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 318/237 = 1.34
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 237²/16 * [ (1.28 - 1) * (1.28² + 1) * 6.6 -
  (1.34 - 1) * (1.34² + 1) * 8.5 ]
= -11146.7471 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:

```
= ltx/h = 40/55 = 0.73 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:

```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19 -2*1.65 *(185923552/185923552 )*
     ( 87.2/87.2 )*(0.73 ), 19 -2*1.65 )
```

```
  = 16.6500 mm.
```

Compute the Effective Tube Pitch [p*]:

```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 28.5/sqrt( 1 - 4 * min( 138 *100, 4*237 *28.5 )
    (3.141* 237²) )
  = 34.3833 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
  = (p* - d*)/p* = (34.4 - 16.6 )/34.4 = 0.52
```

E*/E, nu* for Square pattern from Fig. UHX-11.4.

```
   h/p =   1.929824 ;  mu* =   0.515754
  E*/E =   0.604944 ;  nu* =   0.304637 ;  E* = 112473384. KPa.
```

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 321/237 = 1.35
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.3 )/112473384 * ( 185923552 * ln(1.35 ) )
  = 0.3488
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = -11147 + 74.4 * (318 - 304 )/(2 * pi * 237 )
  = -4214.3696 bars*mm.²
```

Note: W is the maximum of the bolt loads between the shell and channel sides.*

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

```
  = ((M*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
  = ((-4214 ) - 237²/32 * 0.35 * (6.6 - 8.5 ) )/(1 + 0.35 )
  = -2264.4336 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = -2264 + 237²/64 * (3 + 0.3 )(6.6 - 8.5 )
  = -7760.8442 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(-2264 ), abs(-7761 ) )
```

```
= 7760.8442 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

```
= 6 * M / ( (mu*) * ( h - hg')² )
= 6 * 7761/( (0.52 ) * ( 55 - 5 )² )
= 3.6116 N./mm²
```

The Allowable Tubesheet Bending Stress [SigmaAll]:

```
= 2 * S = 2 * 87.2 = 174 N./mm²
```

Tubesheet Bending Stress at Final Thickness [Sigma]:

```
= 6 * M / ( (mu*) * ( h - hg')²
= 6 * 7747/( (0.54 ) * ( 12 - 5 )²
= 173.8903 N./mm²
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:

```
= H + CATS + CATC = 12 + 0 + 0 = 12 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:

```
= Max( HreqB, HreqS ) = Max( 12, 0.49 ) = 12 mm.
```

UHX-12.5.9 Step 9:

```
abs(Ps - Pt) = abs(6.6 - 8.5 ) = 1.9 bars
```

Shear Stress check [Tau_limit]:

```
= 3.2 * S * mu * h/Do
= 3.2 * 87.2 * 0.33 * 55/237 = 215 bars
```

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:

```
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.33)*(237/55)*[6.6-8.5]N./mm²
= 0.62 N./mm²
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:

```
= pi( do - t )t
= pi( 19 - 1.65 )1.65
= 0.902 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

```
= 3.1415 * t * ( do - t ) * Sa
= 3.1415 * 1.65 * ( 19 - 1.65 ) * 87.2 = 7.86 kN
```

Fillet Weld Strength [Ff]:

```
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
```

```
  = 0.55 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
  = 6.1426  kN
```

Groove Weld Strength [Fg]:

```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2 * (19 + 0.67*2 ) * 87.2
  = 7.8627  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 7.8627 kN
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.0748  mm.

 Minimum Required Fillet Weld Leg            afr      1.0374  mm.
 Minimum Required Groove Weld Leg            agr      1.0374  mm.

 Tube-Tubesheet Jt allowable, 7.86 is >= tube strength 7.86 kN
```

Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	3.6	<=	174.4 N./mm²	Ok
Tubesheet shear stress	0.6	<=	69.5 N./mm²	Ok

Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	12.024	55.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.037	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.037	2.000	Ok

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 3 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	21.416	27.316	20	174	3	70	Ps+Pt D1	Ok
D2uc	20.837	...	18	174	2	70	Ps+Pt D2	Ok
D3uc	12.024	...	4	174	1	70	Ps+Pt D3	Ok
Max:	21.4159	27.316 mm.		0.112		0.045	(Str. Ratio)	

Load Case Definitions:

[Ps & Pt]:
Shell-side and Tube-side Design or Operating Pressures
derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the
Load Case Tables

[c]:
With or Without Corrosion Allowance

[D1, D2, D3]:
Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:
Design Load Case using the Minimum (Vacuum) Pressures (if specified)

Note:
Because there was no net pressure differential across the tubesheet due to
the specified pressures psd,min and ptd,min; load case D4 was not processed as
the resulting tubesheet bending stress would be zero.

Summary of Thickness Comparisons for 3 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	21.416	55.000	Ok
Tubesheet Thickness Flanged Extension :	27.316	31.000	Ok
Tube Thickness :	0.341	1.650	Ok
Tube-Tubesheet Fillet Weld Leg :	1.037	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.037	2.000	Ok

Note: This is a full strength Tube to Tubesheet Joint.

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	86.087	1.000	72.654	1.000
Tubesheet Shear Stress	270.803	1.000	269.600	0.995
Tube Pressure Stress	162.257	1.000	83.413	1.000
Tubesheet Extension Stress	48.789	...	No Calc	No Calc
Minimum MAWP	48.789		72.654	

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	113.700	1.000	95.959	1.000
Tubesheet Shear Stress	283.135	1.000	283.135	1.000
Tube Pressure Stress	214.303	1.000	107.747	1.000
Tubesheet Extension Stress	59.072	...	No Calc	No Calc
Minimum MAPnc	59.072		95.959	

(*) Only the design load cases were analyzed to compute the MAWP for determining the test pressure.

SA-182 F316L, Min Metal Temp without impact per UHA-51: -196 °C

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Vertical Hydrotest Case

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          20.334  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       11.325  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.670  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          17.206  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     10.890  bars
Pressure per App 27-4  = M.A.W.P.                        11.850  bars
```

User defined Hydrostatic Test Pressures:

```
Shell Side  Test Pressure at  High Point                 11.350  bars
Channel Side Test Pressure at High Point                 11.080  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          17.225  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       11.050  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       20.670  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          14.575  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     12.155  bars
Pressure per App 27-4  = M.A.W.P.                        13.250  bars
```

Vertical Test performed per: User Hydro Pressure

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

Stresses on Elements due to Test Pressure (N./mm^2 & bars):

From To	Stress	Allowable	Ratio	Pressure
Shell Barrel	19.0	155.1	0.122	11.54
Channel Barrel	18.3	155.1	0.118	11.11
Channel Cover	17.7	155.1	0.114	11.09

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
S2 (2in)	Nozzle	115.15	87.18	1.321
V (1in)	Nozzle	115.15	96.67	1.191
T1	Nozzle	115.15	96.67	1.191
T2	Nozzle	115.15	96.67	1.191
Minimum				1.191

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

Description	Ambient	Operating	Ratio
Shell FLG.	115.10	87.20	1.320
Shell Barrel	115.10	87.20	1.320
Shell FLG.	115.10	87.20	1.320
Channel FLG.	115.15	96.67	1.191
Channel Barrel	115.15	96.67	1.191
Channel Cover	115.10	115.10	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	115.15	87.18	1.321
Tubesheet Material	115.15	87.18	1.321
Minimum			1.321

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

Description	Ambient	Operating	Ratio
S2 (2in)	2.51	155.14	0.016
V (1in)	1.77	155.14	0.011
T1	1.77	155.14	0.011
T2	1.77	155.14	0.011

Elements Suitable for Test Pressure.

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Combination Load Cases

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

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

General Notes:

Case types HI and HE are in the Corroded condition.

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

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

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

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.38	87.20	-0.96	75.82	0.0044	0.0126
20	0.64	87.20	-1.72	71.23	0.0074	0.0241
50		96.67	-0.10	80.71		0.0012

60	115.10	-0.03	80.71	0.0004

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	2.23	87.20	-2.71	75.82	0.0255	0.0357
20	3.90	87.20	-4.81	71.23	0.0447	0.0675
50	0.06	96.67	-0.15	80.71	0.0006	0.0018
60		115.10	-0.04	80.71		0.0005

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.36	87.20	-0.97	75.82	0.0042	0.0128
20	0.64	87.20	-1.72	71.23	0.0074	0.0241
50		96.67	-0.10	80.71		0.0012
60		115.10	-0.03	80.71		0.0004

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	2.48	87.20	-2.99	75.82	0.0284	0.0395
20	4.37	87.20	-5.29	71.23	0.0502	0.0742
50	0.09	96.67	-0.18	80.71	0.0010	0.0022
60	0.00	115.10	-0.05	80.71	0.0000	0.0006

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	155.10	0.00	117.45	0.0000	0.0000
20	0.00	155.10	0.00	110.43	0.0000	0.0000
50	0.00	155.14	0.00	110.43	0.0000	0.0000
60	0.00	155.10	0.00	110.43	0.0000	0.0000

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	155.10	0.00	117.45	0.0000	0.0000
20	0.00	155.10	0.00	110.43	0.0000	0.0000
50	0.00	155.14	0.00	110.43	0.0000	0.0000
60	0.00	155.10	0.00	110.43	0.0000	0.0000

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio

10	0.36	87.20	-0.97	75.82	0.0042	0.0128
20	5.73	87.20		71.23	0.0658	
50	6.55	96.67		80.71	0.0678	
60	6.54	115.10		80.71	0.0568	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	2.48	87.20	-2.99	75.82	0.0284	0.0395
20	9.47	87.20	-0.20	71.23	0.1086	0.0028
50	6.65	96.67		80.71	0.0688	
60	6.56	115.10		80.71	0.0570	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.36	87.20	-0.97	75.82	0.0042	0.0128
20		87.20	-2.62	71.23		0.0367
50		96.67	-1.00	80.71		0.0124
60		115.10	-0.93	80.71		0.0115

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	2.48	87.20	-2.99	75.82	0.0284	0.0395
20	3.48	87.20	-6.19	71.23	0.0399	0.0868
50		96.67	-1.08	80.71		0.0133
60		115.10	-0.94	80.71		0.0117

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	155.10	0.00	117.45	0.0000	0.0000
20	8.74	155.10		110.43	0.0563	
50	8.53	155.14		110.43	0.0550	
60	8.53	155.10		110.43	0.0550	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	155.10	0.00	117.45	0.0000	0.0000
20	8.74	155.10		110.43	0.0563	
50	8.53	155.14		110.43	0.0550	
60	8.53	155.10		110.43	0.0550	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.31	75.82		0.0041
20	4.59	87.20		71.23	0.0527	
50	6.52	96.67		80.71	0.0674	
60	6.53	115.10		80.71	0.0567	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.30	75.82		0.0040
20	4.55	87.20		71.23	0.0522	
50	6.50	96.67		80.71	0.0673	
60	6.53	115.10		80.71	0.0567	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.33	75.82		0.0043
20	4.59	87.20		71.23	0.0527	
50	6.52	96.67		80.71	0.0674	
60	6.53	115.10		80.71	0.0567	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.31	75.82		0.0041
20	4.59	87.20		71.23	0.0527	
50	6.52	96.67		80.71	0.0674	
60	6.53	115.10		80.71	0.0567	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.33	75.82		0.0043
20		87.20	-0.58	71.23		0.0081
50		96.67	-0.07	80.71		0.0008
60		115.10	-0.03	80.71		0.0003

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.28	75.82		0.0037
20	4.68	87.20		71.23	0.0536	
50	6.53	96.67		80.71	0.0675	

60	6.54	115.10		80.71	0.0568

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		87.20	-0.28	75.82		0.0037
20		87.20	-1.39	71.23		0.0196
50		96.67	-0.95	80.71		0.0118
60		115.10	-0.92	80.71		0.0114

Absolute Maximum of the all of the Stress Ratio's 0.1086

Governing Element: Shell Barrel
Governing Load Case 8 : IP+OW+EQ+FS+BS

Element Description	Long Pressure Stress	Weight + Axial Load Stress	Eccentric Moment Stress	Wind or Earthquake Stress	Combined Stress	Which Side
Shell Barrel	...	-0.3	...	2.7	2.5	+ Tens
Shell Barrel	...	-0.3	-0.0	-2.7	-3.0	- Comp
Shell Barrel	5.1	-0.5	...	4.8	9.5	+ Tens
Shell Barrel	5.1	-0.5	-0.0	-4.8	-0.2	- Comp
Channel Barrel	6.6	-0.0	...	0.1	6.7	+ Tens
Channel Barrel	6.6	-0.0	-0.0	-0.1	...	- Comp
Channel Cover	6.6	-0.0	...	...	6.6	+ Tens
Channel Cover	6.6	-0.0	...	-0.0	...	- Comp

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Lifting WRC

Input Echo, 107/537 Item 1, Description: New WRC 107/537

```
Diameter Basis for Vessel                    Vbasis      ID
Cylindrical or Spherical Vessel              Cylsph      Cylindrical
Internal Corrosion Allowance                    Cas      0.0000  mm.
Vessel Diameter                                  Dv     254.600  mm.
Vessel Thickness                                 Tv       9.270  mm.

Design Temperature                                         85.00  C
Vessel Material                                     SA-312 TP316L
Vessel UNS Number                                          S31603
Vessel Cold S.I. Allowable                      Smc      115.15  N./mm^2
Vessel Hot  S.I. Allowable                      Smh      115.15  N./mm^2

Attachment Type                                 Type     Rectangular
Parameter C11                                    C11       10.00  mm.
Parameter C22                                    C22      110.00  mm.

Thickness of Reinforcing Pad                    Tpad       8.000  mm.
Pad Parameter C11P                              C11p      85.000  mm.
Pad Parameter C22P                              C22p     165.000  mm.

Design Internal Pressure                         Dp       0.000  bars
Include Pressure Thrust                                      No
```

External Forces and Moments in WRC 107/537 Convention:

```
Radial Load             (SUS)                     P         0.0  Kgf
Longitudinal Shear      (SUS)                    Vl       391.0  Kgf
Circumferential Shear   (SUS)                    Vc         0.0  Kgf
Circumferential Moment  (SUS)                    Mc         0.0  Kg-m.
Longitudinal Moment     (SUS)                    Ml        47.0  Kg-m.
Torsional Moment        (SUS)                    Mt         0.0  Kg-m.


Use Interactive Control                                  No
WRC107 Version                               Version     March 1979 ( B1 & B2 )

Include Pressure Stress Indices per Div. 2                  No
Compute Pressure Stress per WRC-368                         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".

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	Kgf
Circumferential Shear	VC	0.0	Kgf
Longitudinal Shear	VL	391.0	Kgf
Circumferential Moment	MC	0.0	Kg-m.
Longitudinal Moment	ML	47.0	Kg-m.
Torsional Moment	MT	0.0	Kg-m.

Dimensionless Parameters used : Gamma = 7.87

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979 B1/B2	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.193	4C		1.414	(A,B)
N(PHI) / (P/Rm)	0.193	3C		1.264	(C,D)
M(PHI) / (P)	0.104	2C1		0.161	(A,B)
M(PHI) / (P)	0.104	1C		0.190	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.082	3A	!	0.064	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.107	1A		0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.182	3B	!	0.741	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.164	1B1		0.054	(A,B,C,D)
N(x) / (P/Rm)	0.152	3C		1.380	(A,B)
N(x) / (P/Rm)	0.152	4C		1.468	(C,D)
M(x) / (P)	0.159	1C1		0.149	(A,B)
M(x) / (P)	0.159	2C		0.115	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.082	4A	!	0.096	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.151	2A		0.060	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.182	4B	!	0.191	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.226	2B1		0.074	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
 Circ. Bend. P  |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Circ. Memb. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Circ. Memb. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Circ. Memb. ML |     -4.0|     -4.0|      4.0|      4.0|      0.0|      0.0|
0.0|      0.0|
 Circ. Bend. ML |    -22.6|     22.6|     22.6|    -22.6|      0.0|      0.0|
0.0|      0.0|
                |
|
 Tot. Circ. Str.|    -26.6|     18.6|     26.6|    -18.6|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------
-----------
 Long. Memb. P  |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. P  |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Memb. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Memb. ML |     -1.8|     -1.8|      1.8|      1.8|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. ML |    -22.4|     22.4|     22.4|    -22.4|      0.0|      0.0|
0.0|      0.0|
                |
|
 Tot. Long. Str.|    -24.3|     20.6|     24.3|    -20.6|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------
-----------
       Shear VC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
       Shear VL |      0.0|      0.0|      0.0|      0.0|     -1.0|     -1.0|
1.0|      1.0|
       Shear MT |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
                |
|
      Tot. Shear|      0.0|      0.0|      0.0|      0.0|     -1.0|     -1.0|
1.0|      1.0|
 ---------------------------------------------------------------------------------
-----------
      Str. Int. |     26.6|     20.6|     26.6|     20.6|      2.0|      2.0|
2.0|      2.0|

 Dimensionless Parameters used :   Gamma =   14.23
```

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979 B1/B2	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.588	4C	!	1.550	(A,B)
N(PHI) / (P/Rm)	0.588	3C	!	0.868	(C,D)
M(PHI) / (P)	0.414	2C1		0.023	(A,B)
M(PHI) / (P)	0.414	1C	!	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.402	3A	!	0.605	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.438	1A		0.072	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.501	3B	!	1.095	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.474	1B1		0.015	(A,B,C,D)
N(x) / (P/Rm)	0.507	3C	!	0.868	(A,B)
N(x) / (P/Rm)	0.507	4C	!	1.550	(C,D)
M(x) / (P)	0.521	1C1	!	0.031	(A,B)
M(x) / (P)	0.521	2C	!	0.031	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.402	4A	!	1.418	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.545	2A	!	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.501	4B	!	0.556	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.560	2B1	!	0.025	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	ML	-5.4	-5.4	5.4	5.4	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-7.8	7.8	7.8	-7.8	0.0	0.0	0.0	0.0

```
                |
|
 Tot. Circ. Str.|    -13.3|      2.4|     13.3|     -2.4|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------------
-----------
 Long. Memb. P  |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. P  |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Memb. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. MC |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Memb. ML |     -4.1|     -4.1|      4.1|      4.1|      0.0|      0.0|
0.0|      0.0|
 Long. Bend. ML |    -10.7|     10.7|     10.7|    -10.7|      0.0|      0.0|
0.0|      0.0|
                |
|
 Tot. Long. Str.|    -14.8|      6.7|     14.8|     -6.7|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------------
-----------
       Shear VC |      0.0|      0.0|      0.0|      0.0|      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 |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
                |
|
      Tot. Shear|      0.0|      0.0|      0.0|      0.0|     -1.3|     -1.3|
1.3|      1.3|
 ---------------------------------------------------------------------------------------
-----------
      Str. Int. |     14.8|      6.7|     14.8|      6.7|      2.5|      2.5|
2.5|      2.5|

 ---------------------------------------------------------------------------------------
-----------
```

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pl (SUS)	-4.0	-4.0	4.0	4.0	0.0	0.0	0.0	0.0
Circ. Q (SUS)	-22.6	22.6	22.6	-22.6	0.0	0.0	0.0	0.0
Long. Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pl (SUS)	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Q (SUS)	-22.4	22.4	22.4	-22.4	0.0	0.0	0.0	0.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm+Pl (SUS)	4.0	4.0	4.0	4.0	2.0	2.0	2.0	2.0
Pm+Pl+Q (Total)	26.6	20.6	26.6	20.6	2.0	2.0	2.0	2.0

Vessel Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result

```
 Pm (SUS)        |          0.00            115.15       |      Passed      |
 Pm+Pl (SUS)     |          4.00            172.72       |      Passed      |
 Pm+Pl+Q (TOTAL)|         26.55            345.44       |      Passed      |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

```
 ---------------------------------------------------------------------------------------
-----------
```

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

```
                |                    Stress Intensity Values at
|
 Type of        |
|
 Stress    Load |       Au        Al        Bu        Bl        Cu        Cl        Du
Dl|
 ---------------------------------------------------------------------------------------
-----------
 Circ. Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Circ. Pl (SUS) |     -5.4|     -5.4|      5.4|      5.4|      0.0|      0.0|
0.0|      0.0|
 Circ. Q  (SUS) |     -7.8|      7.8|      7.8|     -7.8|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------------
-----------
 Long. Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Long. Pl (SUS) |     -4.1|     -4.1|      4.1|      4.1|      0.0|      0.0|
0.0|      0.0|
 Long. Q  (SUS) |    -10.7|     10.7|     10.7|    -10.7|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------------
-----------
 Shear Pm (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Shear Pl (SUS) |      0.0|      0.0|      0.0|      0.0|     -1.3|     -1.3|
1.3|      1.3|
 Shear Q  (SUS) |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 Pm (SUS)       |      0.0|      0.0|      0.0|      0.0|      0.0|      0.0|
0.0|      0.0|
 ---------------------------------------------------------------------------------------
-----------
 Pm+Pl (SUS)    |      5.4|      5.4|      5.4|      5.4|      2.5|      2.5|
2.5|      2.5|
 ---------------------------------------------------------------------------------------
-----------
```

```
 Pm+Pl+Q (Total)|      14.8|       6.7|      14.8|       6.7|       2.5|       2.5|
2.5|       2.5|
```

Vessel Stress Summation Comparison (N./mm^2):

```
 Type of        |     Max. S.I.     S.I. Allowable     |      Result     |
 Stress Int.    |                                      |                 |
 ---------------------------------------------------------------------------
 Pm (SUS)       |          0.00            115.15      |      Passed     |
 Pm+Pl (SUS)    |          5.44            172.72      |      Passed     |
 Pm+Pl+Q (TOTAL)|         14.76            345.44      |      Passed     |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

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Lifting Lug Calculation - E-100

Lifting Lug Calculation

Tag No.: E-100
Equipment: Reflux Condensor
Reference: Pressure Vessel Design Manual By Dennis R.Moss

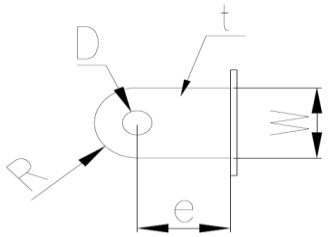
A: Lifting Lug For Heat Exchanger

A1: Loads

Wt. of Exchanger =	391	Kg
Material =	SA-240 316L	
Yield Stress =	149.6	Mpa
Allowable Stress =	101	Mpa
Impact Factor =	2	
Sling Angle (θ) =	90	
NO. of Lifting Points =	2	
Total Vertical Wt. (Fv) =	7.67	KN
Total Load at Lifting Point (Ft) =	3.84	KN

A2: Dimentions

Lug Thickness (t) =	10	mm
Plate Thickness =	9.27	mm
Radius (R) =	55	mm
e =	120	mm
Lug Width (W) =	110	mm
Hole (D) =	38	mm



A3: Stress Analysis

Bearing Stress:

Bearing Area =	3.8	cm^2	Ab=Dxt
Alowable Bearing Stress =	134.64	Mpa	0.9xFy
Bearing Stess (fp) =	10.1	Mpa	(O.K !!)

Shear Stress: (At Top of Lug)

Shear Area =	3.6	cm^2	As=(W-D/2)xt
Alloawable Shear Stress =	59.84	Mpa	0.4xFy
Actual shear streess(fv) =	10.7	Mpa	**(O.K !!)**

Shear Stress: (At Pin Hole)

Shear Area =	7.2	cm^2	As=2x(W-D/2)xt
Alloawable Shear Stress =	59.84	Mpa	0.4xFy
Actual shear streess(fv) =	5.3	Mpa	**(O.K !!)**

Tensile Stress:

Tensile Area =	7.2	cm^2	At=2x(W-D/2)xt
Alloawable Tensile Stress =	89.76	Mpa	0.6xFy
Actual Tensile streess(ft) =	5.3	Mpa	**(O.K !!)**

Bending Stress:

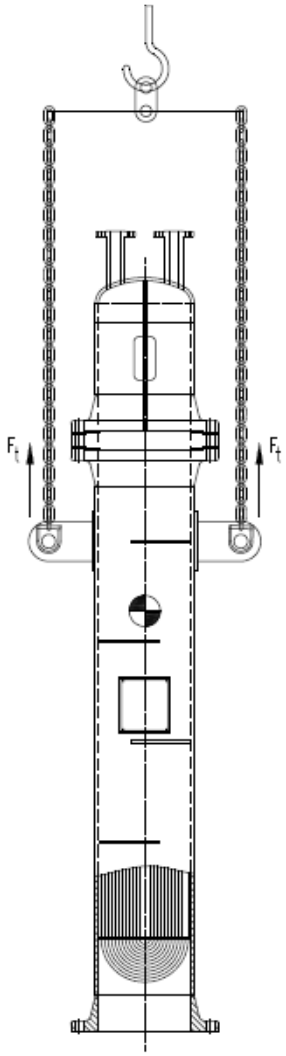
Section Modulus =	20.2	cm^3	Z=t*W^2/6
Alloawable Bending Stress =	89.76	Mpa	0.6xFy
Bending moment (M) =	46.0	KN.cm	
Actual Bending streess(fb) =	22.8	Mpa	**(O.K !!)**

Combined Stress:

Combined Tensile & Bending Stress			
Stress Ratio, [(ft/Ft) + (fb/Fb)] ≤ 1	0.31		**(O.K !!)**
Combined Tensile & Shear Stress	19.2	Mpa	fcr = √(ft^2 + 3fv^2)
fc ≤ S allowable	101.0		**(O.K !!)**

A4: Weld Calculation

Weld leg Size =	7	mm	**(OK !!)**
Shear Load Due Fv	17.44	N/mm	
Shear Load Due M	114.1	N/mm	
Total Load	115.4	N/mm	
Allowable Shear	82.3	Mpa	
Require Weld Size	2.0	mm	



Pass Partition Plate Calculation - E-100

Item No.:	E-100

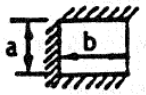
Stationary Pass Partition Input Data Values

Shell Inside Diameter,	ID= 255	mm
Pressure Drop across Pass Partition,	q= .50	bar
Design Temperature,	T= 152	˚C
Three / Two Sides Fixed	Three	
Pass Partition Length	L= 414	mm
Pass Partition Dimension,	a= 255	mm
Pass Partition Dimension,	b= 414	mm
Corrosion allowance,	C= 0	mm
(TEMA RCB-1.518 Pass partition plates are not required to have corrosion allowance.)		
Pass Partition Material,	SA-240 316L	Alloy Mat.
Allowable Stress in Tension, at Design Temperature,	S = 87.6	N/mm²

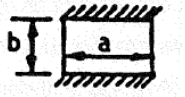
TEMA TABLE RCB-9.1.3.1M NOMINAL PASS PARTITION PLATE THICKNESS

Shell ID	Min. Thk. (mm)	
	Carbon Steel	Alloy Mat.
Up to 600	10	6
600-1500	12	10
1500-2500	16	12

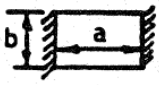
TEMA TABLE RCB-9.1.3.2 PASS PARTITION DIMENSION FACTORS



Three sides fixed
One side simply supported



Long sides fixed
Short sides simply supported



Short sides fixed
Long sides simply supported

a/b	Beta	a/b	Beta	a/b	Beta
0.25	0.02	1	0.4182	1	0.4182
0.5	0.081	1.2	0.4626	1.2	0.5208
0.75	0.173	1.4	0.486	1.4	0.5988
1	0.307	1.6	0.4968	1.6	0.654
1.5	0.539	1.8	0.4971	1.8	0.6912
2	0.657	2	0.4973	2	0.7146
3	0.718	infi.	0.5	infi.	0.75

Stationary Pass Partition Plate Calculation For Item No.:E-100		
Pass Partition Input Data Values		
Shell Inside Diameter,	ID =	254.6 mm
Pressure Drop across Pass Partition,	q =	0.5 bar
Design Temperature,	T =	152 ˚C
Pass Partition Dimension,	a =	254.6 mm
Pass Partition Dimension,	b =	414 mm
Corrosion allowance,	c =	0 mm
Pass Partition Material,		SA-240 316L
Allowable Stress in Tension, at Design Temperature,	S	87.6 N/mm²
TEMA RCB-9.131 Minimum Thickness of Pass Partition Plate		
t min,	tmin	6 mm
TEMA RCB-9.132 Pass Partition Plate Formula		
Pass Partition Dimension,	a/b	0.61
Three sides fixed One side simply supported	Beta	0.1233
tmin, tmin = b*(q*Beta/(1.5*S))1/2 + C	tmin	2.84 mm
Pass partition minimum weld size, w = 0.75*t	w	4.50
The pass partition plate thickness of 6 mm is adequate.		
The pass partition fillet weld size of 5 mm is adequate.		