AFTER COOLER MECHANICAL STRENGHT CALCULATION FOR EMERGENCY INSTRUMENT AIR COMPRESSOR

Rev.	Date	Purpose of Issue	Prepared	Checked	Approved	AC Code
04	13/07/2022	Approved for Construction	KP	CL	JR	
03	16/06/2022	For approval	KP	LdM	JR	
02	09/05/2022	For approval	KP	LdM	JR	
01	05/05/2022	For approval	KP	LdM	JR	
00	17/02/2022	For approval	KP	LdM	JR	

Class: 1 | Phase: P

TABULATION OF REVISED PAGES

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6.	X	X	X	X	X
7.	X	X	X	X	X
8.	X	X	X	X	X
9.	X	X	X	X	X
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11.	X	X	X	X	X
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15	X	X	X	X	X
16	X	X	X	X	X
17	X	X	X	X	X
18	X	X	X	X	X
19	X	X	X	X	X
20	X	X	X	X	X
21	X	X	X	X	X
22	X	X	X	X	X
23	X	X	X	X	X
24	X	X	X	X	X
25	X	X	X	X	X
26	X	X	X	X	X
27	X	X	X	X	X
28	X	X	X	X	X
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30	X	X	X	X	X
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Strength Calculation PV-Elite
IWS-Monje Heat Exchangers GmbH
Wittener Str. 102, 44789 Bochum, Germany

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   Reference # : Project 17811
    Revision # : 00
   Client Name : Airpack Nederland BV
     Drawing # : K12-3102
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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
 ASME Code Version      : 2021

 Analysis Performed by : IWS-Monj Heat Exchangers GmbH

 Job File              : Y:\Airpack\BK12-3102-L800_Airpack-17811_Rev00.pvdb

 Date of Analysis      : May 5,2022    11:11am
```

PV Elite 24, January 2022

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2021

Diameter Spec : 160.000 x 141.300 mm OD

Vessel Design Length, Tangent to Tangent	962.85	mm
Specified Datum Line Distance	0.00	mm
Shell Side Design Temperature	210	°C
Channel Side Design Temperature	95	°C
Shell Side Design Pressure	2.500	MPa
Channel Side Design Pressure	1.000	MPa
Shop Shell Side Test Pressure	3.750	MPa
Shop Channel Side Test Pressure	1.500	MPa
Wind Design Code	No Wind Loads	
Earthquake Design Code	No Seismic	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	No
Shell	SA-312 TP316	...	...	S31600	No	No
Cover	SA-516 70	...	...	K02700	No	No
Flange	SA-516 70	...	...	K02700	No	No
Flange	SA-182 F316	...	> 5	S31600	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-312 TP316	...	...	S31600	No	No
Nozzle Flg	SA-182 F316	...	> 5	S31600	No	No
Tubes	SB-111 O61	O61	...	C70600	No	No
Tubesheet	SB-148 M01	M01	...	C95200	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No

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

Element Pressures and MAWP (MPa & mm):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Total Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Channel head flat	1.000	0.10	26.000	1.0000	N/A	No
Channel head cylinder	1.000	0.10	22.000	1.0000	N/A	No
Channel head flange	1.000	0.10	2.000	1.0000	N/A	No
Shell flange ring 1	1.000	0.10	2.000	0.0000	N/A	No
Main Shell	2.500	0.10	6.000	0.0000	N/A	No
Shell flange ring 2	1.000	0.10	2.000	0.0000	N/A	No
Cover head	1.000	0.10	3.000	1.0000	N/A	No

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
Wld Flat	27.0	27.0	27.0	27.0	6.1	...	1.00	1.00
Cylinder	57.0	30.0	13.0	13.0	3.5	1.3	1.00	1.00
Body Flg	57.0	18.0	18.0	18.0	14.2	10.4	1.00	1.00
Body Flg	134.5	36.0	...	18.0	12.1	7.0	1.00	1.00
Cylinder	888.3	753.8	...	3.4	1.5	1.0	1.00	1.00
Body Flg	924.3	36.0	...	18.0	12.1	7.0	1.00	1.00
Body Flg	962.8	25.0	...	25.0	10.0	6.9	1.00	1.00

Weights:

Fabricated - Bare W/O Removable Internals	55.5	kg
Shop Test - Fabricated + Water (Full)	67.2	kg
Shipping - Fab. + Rem. Intls.+ Shipping App.	55.5	kg
Erected - Fab. + Rem. Intls.+ Insul. (etc)	55.5	kg
Empty - Fab. + Intls. + Details + Wghts.	55.5	kg
Operating - Empty + Operating Liquid (No CA)	55.5	kg
Field Test - Empty Weight + Water (Full)	67.2	kg

Nozzle Calculation Summary (MPa & mm):

Description	MAWP	Ext	MAPNC	UG-45	[tr]	Weld Path	Areas or Stresses
Noz N1 Fr10 - T	1	...	...	OK	4.12	OK	No Calc[*]
Noz N2 Fr10	1	...	...	OK	4.12	OK	No Calc[*]
Noz N3 - Shell	2	...	...	OK	1.50	OK	No Calc[*]
Noz N4 - Shell	2	...	...	OK	1.50	OK	No Calc[*]

Nozzle MAWP Summary:

Minimum MAWP Nozzles : 2 Nozzle : Noz N3 - Shell [Shellside]
Minimum MAWP Nozzles : 1 Nozzle : Noz N1 Fr10 - T [Tubeside]

[*] - This was a small opening and the areas were not computed.

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

Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate mm	Layout Angle deg	Dia. Limit mm
10	Noz N1 Fr10 - Tu	0.000	90.000	92.000
10	Noz N2 Fr10	0.000	270.000	92.000
50	Noz N3 - Shelli	206.525	270.000	104.600
50	Noz N4 - Shello	826.525	90.000	104.600

The nozzle spacing is computed by the following:

= sqrt(ll² + lc²) where

ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected!

Checking Multiple Nozzles on Flat Head per ASME Sec. VIII Div. 1 UG-39

Comparing Nozzles on Element: Channel head flat

UG-39 Average Nozzle Diameter and Ligament Checks:

Nozzle Pair Description	Avg. dia. mm	Head Dia. /4 mm	Ligament Width mm	Min. dn /4 mm
Noz N1 Fr10 - Tu & No	32	40	52	8

UG-39 Nozzle Spacing and Average Area Checks:

Nozzle Pair Description	Center Spacing mm	Avg. dia. * 1.25 mm	Avg. Area Available mm^2	Avg. Area Reqd. mm^2
Noz N1 Fr10 - Tu & No	92	40	No Calc	No Calc

UG-39 Nozzle Diameter and Distance to Edge Checks:

Nozzle Description	Nozzle dia. mm	Head Dia. /2 mm	Distance from Edge mm	Nozzle dia./4 mm
Noz N1 Fr10 - Tu	32	80	27	8
Noz N2 Fr10	32	80	27	8

No Multiple Nozzle spacing violations detected!

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia mm	Wall Thk mm	Reinforcing Pad Diameter	Reinforcing Pad Thk mm	Cut Length mm	Flg Class
Noz N1 Fr10 - Tu	40 mm	Actual	None	40.0	5.000	...	...	7	...
Noz N2 Fr10	40 mm	Actual	None	40.0	5.000	...	...	7	...
Noz N3 - Shell i	60 mm	Actual	WNF	60.3	4.000	...	...	4	300
Noz N4 - Shell o	60 mm	Actual	WNF	60.3	4.000	...	...	4	300

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
Noz N1 Fr10	SA-106 B	...	10.000	...	...	...
Noz N2 Fr10	SA-106 B	...	10.000	...	...	...
Noz N3 - Sh	SA-312 TP316	...	10.000	...	...	...
Noz N4 - Sh	SA-312 TP316	3.400	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
Noz N1 Fr10 - Tu	...	90.0	50.00	0.00	Channel head fla
Noz N2 Fr10	...	270.0	50.00	0.00	Channel head fla
Noz N3 - Shell i	206.525	270.0	39.00	0.00	Main Shell
Noz N4 - Shell o	826.525	90.0	39.00	0.00	Main Shell

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	FLAT HEAD: 27.0mm THK X 160.0mm OD	SA-516 70
1	CYLINDER: 13.0mm THK X 134.0mm ID X 30.0mm	SA-516 70
1	BODY FLANGE: 18.0mm THK X 220.0mm OD	SA-516 70
2	BODY FLANGE: 18.0mm THK X 220.0mm OD	SA-182 F316
1	CYLINDER: 3.4mm THK X 134.5mm ID X 753.8mm	SA-312 TP316
1	BODY FLANGE: 25.0mm THK X 220.0mm OD	SA-516 70
1	TUBESHEET: 165.0mm X 28.0mm THK	SB-148 M01
72	TUBES: 830.0mm X 8.0mm DIA X 0.5mm THK	SB-111 O61
1	FLOATING TUBESHEET: 132.2mm X 28.0mm THK	SB-148 M01
2	GASKET: 165.0mm OD X 155.0mm ID	...
8	BODY FLANGE BOLTS: 12.0mm DIA	SA-193 B7
16	NUTS FOR BODY FLANGE BOLTS: 12.0mm DIA	...
1	NAMEPLATE	...

Minimum Design Metal Temperature Results Summary (°C):

Description	Notes	Curve	Basic MDMT	Reduced MDMT	UG-20(f) MDMT	Thickness ratio	Gov Thk mm	E*	PWHT reqd
Main Shell	[16]		-196						
Noz N3 - Shel	[15]		-196						
Nozzle Flg	[5]		-196						
Noz N4 - Shel	[15]		-196						
Nozzle Flg	[5]		-196						
Nozl. Bolting	[22]		-48			1.000	63.500	1.00	No
Tubesheet: SS	[13]		-18						No
Warmest MDMT:			-18						
Shell flange	[11]		-196						
Shell flange	[11]		-196						
Cover head	[11]	B	-29	-48	-29	0.381	6.250	1.00	No
Channel head	[12]	B	-21	-104	-29	0.196	13.000	1.00	No
Channel head c	[8]	B	-21	-104	-29	0.208	13.000	1.00	No
Noz N1 Fr10 -	[1]	B	-29	-104	-29	0.042	5.000	1.00	No
Noz N2 Fr10	[1]	B	-29	-104	-29	0.042	5.000	1.00	No
Tubesheet: CS	[14]		-18						No
Bolting	[21]		-48						
Warmest MDMT:			-18	-48					

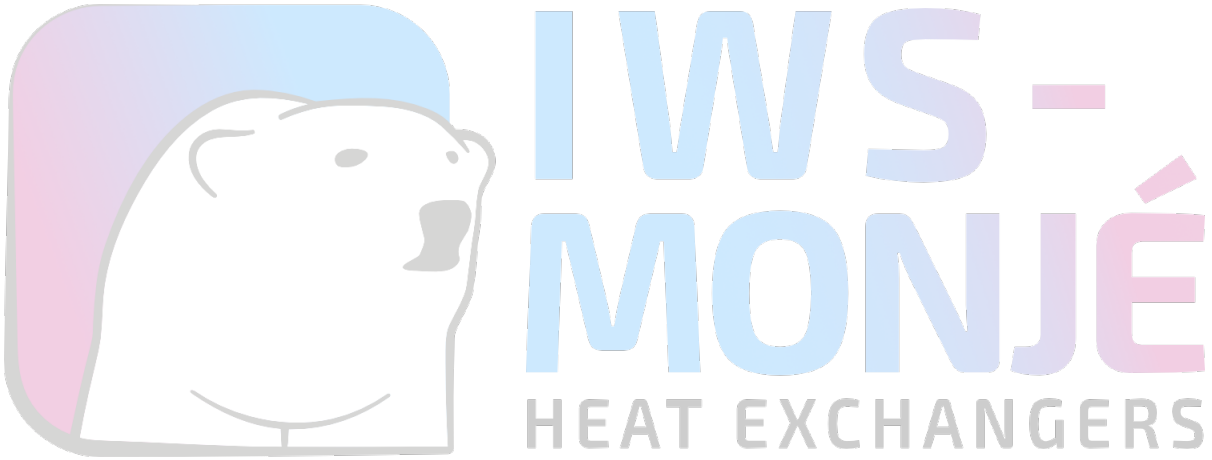
Exchanger Side	Computed MDMT	Required MDMT	Pass/Fail
Shell	-18.0	-10.0	Pass
Channel/Tube	-18.0	-10.0	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ASME 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] - Body Flange Bolting Material
[22] - Nozzle Flange Bolting Material
[23] - Stiffening Ring to Shell Weld

[24] - Saddle to Shell Weld

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.



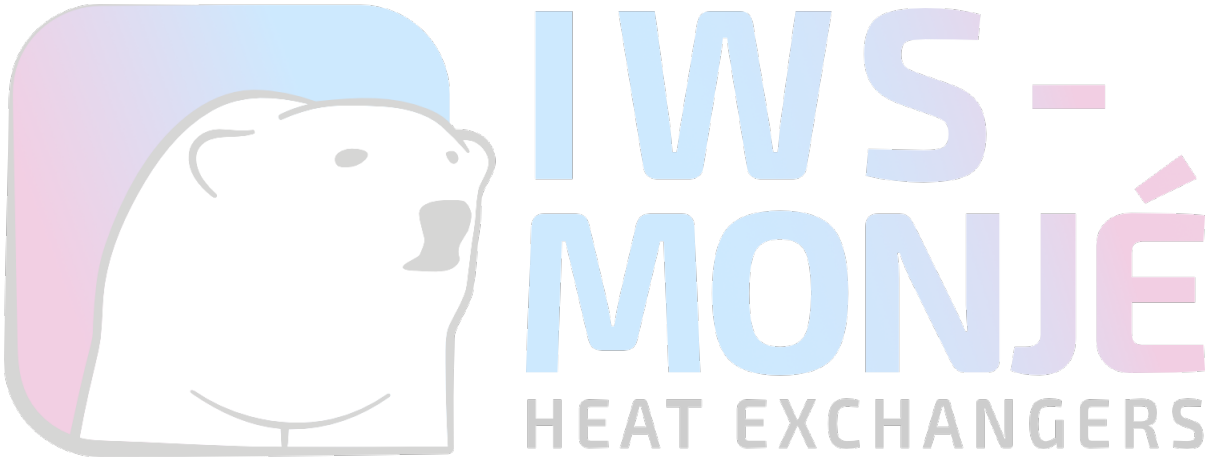
Class From To : Basic Element Checks.

Class From To: Check of Additional Element Data

Please insure the C factor entered is in accordance with Figure UG-34.

There were no geometry errors or warnings.

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



Units used in this Analysis (SI_ASME_Unicode):

Name	System Unit	Constant	User Unit
Length	Feet	304.8000	mm
Force	Pounds	4.4480	N
Mass	Pounds	0.4536	kg
Area	sq. inches	645.1600	mm^2
Moment	ft. lbs.	1356.3000	N-mm
Stress	lbs./sq.in.	0.0069	MPa
Temperature	Degrees F	0.5556	°C
Pressure	psig	0.0069	MPa
Elast. Modulus	lbs./sq.in.	0.0069	MPa
Pipe Density	lbs./cu.in.	0.0277	kg/cm^3
Ins. Density	lbs./cu.ft.	0.1602E-04	kg/cm^3
Fluid Density	lbs./cu.ft.	0.1602E-04	kg/cm^3
Wind Speed	miles/hr	1.6093	km/hr
Tray Weight	lbs./sq.ft.	0.0005	kgs/cm^2
Inertia	in.**4	416231.0000	mm^4
G Load	G's	1.0000	g's
Wind Load	lbs./sq.ft.	0.0479	kPa
Elevation	Feet	304.8000	mm
Volume	in.**3	0.0164	ltr
Diameter	inches	25.4000	mm
Thickness	inches	25.4000	mm

PV Elite Vessel Analysis Program: Input Data

Strength Calculation PV-Elite
IWS-Monje Heat Exchangers GmbH
Wittener Str. 102, 44789 Bochum, Germany

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	2.5	MPa
Channel Side Design Pressure	1	MPa
Shell Side Design Temperature	210.0	°C
Channel Side Design Temperature	95.0	°C
Radiography, Shell Side	RT-3	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Air/Water/Steam	
Service Type, Channel Side	Air/Water/Steam	
MDMT (CET), Shell Side	-10.0	°C
MDMT (CET), Tube Side	-10.0	°C
User defined MAWP, Shell Side	2.5	MPa
User defined MAWP, Channel Side	1	MPa
User defined MAPnc, Shell Side	2.5	MPa
User defined MAPnc, Channel Side	1	MPa
User defined Test Pres., Shell Side	3.75	MPa
User defined Test Pres., Channel Side	1.5	MPa

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

Shop Pressure Test:

Type of Pressure Test	User Entered Pressure
Pressure Test Position	Horizontal
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
Load Case 20	BL+IP+OW
Wind Design Code	No Wind Loads
Seismic Design Code	No Seismic
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
Perform Blast Load Analysis	No
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 Calculations	Yes

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Flat	
Description	Channel head flat	
Distance "FROM" to "TO"	27	mm
Element Outside Diameter	160	mm
Element Thickness	27	mm
Internal Corrosion Allowance	1	mm
Nominal Thickness	27	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	95	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	95	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	137.9	MPa
Allowable Stress, Hydrotest	179.27	MPa
Material Density	0.00775	kg/cm^3
P Number Thickness	31.75	mm
Yield Stress, Operating	239.7	MPa
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Flat Head Attachment Factor	0.2	
Small diameter if Non-Circular	0	mm
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr10 - Tu	
Dist. from "FROM" Node / Offset dist	46	mm
Nozzle Diameter	40	mm
Nozzle Schedule	40	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	3.0184	N
Grade of Attached Flange	None	
Nozzle Matl	SA-106 B	

Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N2 Fr10	
Dist. from "FROM" Node / Offset dist	46	mm
Nozzle Diameter	40	mm
Nozzle Schedule	40	

Nozzle Class	None	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	SA-106 B	

Element From Node	20	
Element To Node	30	
Element Type Cylinder	! Atype	
Description	Channel head cylinder	
Distance "FROM" to "TO"	30	mm
Element Outside Diameter	160	mm
Element Thickness	13	mm
Internal Corrosion Allowance	1	mm
Nominal Thickness	13	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	95	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	95	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Channel head flange	
Distance "FROM" to "TO"	18	mm
Flange Inside Diameter	132.6	mm
Element Thickness	18	mm
Internal Corrosion Allowance	1	mm
Nominal Thickness	18	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	95	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	95	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-516 70	
Perform Flange Stress Calculation (Y/N)	Y	
Weld is pre-Heated	No	

Element From Node	40	
Element To Node	50	
Element Type	Flange	
Description	Shell flange ring 1	
Distance "FROM" to "TO"	36	mm

Flange Inside Diameter	133	mm
Element Thickness	18	mm
Internal Corrosion Allowance	0	mm
Nominal Thickness	0	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	210	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	210	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-182 F316	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	131.56	MPa
Allowable Stress, Hydrotest	179.27	MPa
Material Density	0.008027	kg/cm^3
P Number Thickness	0	mm
Yield Stress, Operating	146.59	MPa
External Pressure Chart Name	HA-2	
UNS Number	S31600	
Class / Thickness / Grade	:: > 5	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weld is pre-Heated	No	

Element From Node	50	
Element To Node	60	
Element Type Cylinder	! Atype	
Description	Main Shell	
Distance "FROM" to "TO"	753.8	mm
Element Outside Diameter	141.3	mm
Element Thickness	3.4	mm
Internal Corrosion Allowance	0	mm
Nominal Thickness	0	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	2.5	MPa
Design Temperature Internal Pressure	210	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	210	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-312 TP316	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	132.2	MPa
Allowable Stress, Hydrotest	179.3	MPa
Material Density	0.008027	kg/cm^3
P Number Thickness	0	mm
Yield Stress, Operating	146.6	MPa
External Pressure Chart Name	HA-2	
UNS Number	S31600	
Product Form	Smls. & wld. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	50	
Detail Type	Nozzle	

Detail ID	Noz N3 - Shell i	
Dist. from "FROM" Node / Offset dist	72	mm
Nozzle Diameter	60.3	mm
Nozzle Schedule	40	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 2.2	
Nozzle Matl	SA-312 TP316	
Element From Node	50	
Detail Type	Nozzle	
Detail ID	Noz N4 - Shell o	
Dist. from "FROM" Node / Offset dist	692	mm
Nozzle Diameter	60.3	mm
Nozzle Schedule	40	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 2.2	
Nozzle Matl	SA-312 TP316	

Element From Node	60	
Element To Node	70	
Element Type	Flange	
Description	Shell flange ring 2	
Distance "FROM" to "TO"	36	mm
Flange Inside Diameter	133	mm
Element Thickness	18	mm
Internal Corrosion Allowance	0	mm
Nominal Thickness	0	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	210	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	210	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-182 F316	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	131.6	MPa
Allowable Stress, Hydrotest	179.3	MPa
Material Density	0.008027	kg/cm^3
P Number Thickness	0	mm
Yield Stress, Operating	146.6	MPa
External Pressure Chart Name	HA-2	
UNS Number	S31600	
Class / Thickness / Grade	:: > 5	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weld is pre-Heated	No	

Element From Node	70	
Element To Node	80	
Element Type	Flange	
Description	Cover head	
Distance "FROM" to "TO"	25	mm
Flange Outside Diameter	220	mm
Element Thickness	25	mm
Internal Corrosion Allowance	1	mm
Nominal Thickness	0	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	95	°C
Design External Pressure	0.1013	MPa
Design Temperature External Pressure	95	°C
Effective Diameter Multiplier	1.0	
Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	137.9	MPa
Allowable Stress, Hydrotest	179.3	MPa
Material Density	0.00775	kg/cm^3
P Number Thickness	30.988	mm
Yield Stress, Operating	239.7	MPa
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Perform Flange Stress Calculation (Y/N)	Y	
Weld is pre-Heated	No	

XY Coordinate Calculations:

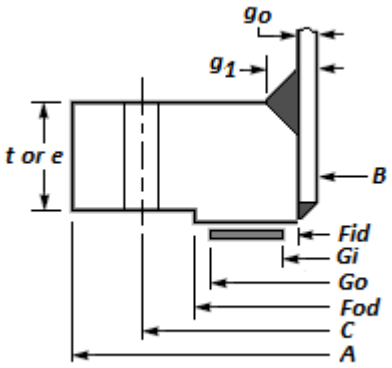
From	To	X (Horiz.) mm	Y (Vert.) mm	DX (Horiz.) mm	DY (Vert.) mm
Channel head fl		27	...	27	...
Channel head cy		57	...	30	...
Channel head fl		57	...	-18	...
Shell flange ri		134.525	...	36	...
Main Shell		888.325	...	753.8	...
Shell flange ri		924.325	...	36	...
Cover head		962.85	...	25	...

PV Elite includes an 1/8 inch (3.175mm) raised face and gasket thicknesses for girth flanges and tubesheet thicknesses where applicable in the Tangent to Tangent length calculation. The calculated dimensions are based on the given element lengths. Due to variability in manufacturing (weld gaps etc.), the Tangent to Tangent length may not be exact.

Flange Input Data Values **Description: Channel Fla. :**

Channel head flange

Flange Type		Integral Ring	
Design Pressure	P	1.00	MPa
Design Temperature		95	°C
Internal Corrosion Allowance	ci	1.0000	mm
External Corrosion Allowance	ce	0.0000	mm
Use Corrosion Allowance in Thickness Calcs.		Yes	
Attached Shell Inside Diameter	B	132.6000	mm
Integral Ring Inside Diameter		158.6000	mm
Flange Outside Diameter	A	220.000	mm
Flange Thickness	t	18.0000	mm
Flange Material		SA-516 70	
Flange Material UNS number		K02700	
Flange Allowable Stress At Temperature	Sfo	137.90	MPa
Flange Allowable Stress At Ambient	Sfa	137.90	MPa
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	MPa
Bolt Allowable Stress At Ambient	Sa	172.38	MPa
Length of Weld Leg at Back of Ring	tw	0.0000	mm
Diameter of Bolt Circle	C	179.600	mm
Nominal Bolt Diameter	a	12.0000	mm
Type of Threads		TEMA Thread Series	
Number of Bolts		4	
Flange Face Outside Diameter	Fod	165.000	mm
Flange Face Inside Diameter	Fid	155.000	mm
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	165.000	mm
Gasket Inside Diameter	Gi	155.000	mm
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	MPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	2.0000	mm



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Corroded Flange Thickness,	tc = T-ci	17.000	mm
Corroded Flange ID,	Bcor = B+2*Fcor	134.600	mm
Corroded Large Hub,	g1Cor = g1-ci	0.000	mm
Corroded Small Hub,	g0Cor = go-ci	0.000	mm
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	22.500	mm
Gasket Contact Width,	N = (Go - Gi) / 2	5.000	mm
Basic Gasket Width,	bo = N / 2	2.500	mm
Effective Gasket Width,	b = bo	2.500	mm
Gasket Reaction Diameter,	G = Go (Self-Energizing)	165.000	mm

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 165.0² * 1.
= 21380.648 N

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * pi * G * m * P
= 2 * 2.5 * pi * 165.0 * 0.0 * 1.
= 0.000 N

Hydrostatic End Load at Flange ID [Hd]:
= pi * Bcor² * P / 4
= pi * 134.6² * 1./4
= 14227.976 N

Pressure Force on Flange Face [Ht]:
= H - Hd
= 21381 - 14228
= 7152.672 N

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(21381 + 0 + 0, 0)
= 21380.648 N

Gasket Seating Bolt Load [Wm2]:
= y * b * pi * G + yPart * bPart * lp
= 0.0*2.5*pi*165.0+0.0*0.0*0.0
= 0.000 N

Required Bolt Area [Am]:
= max(Wm1/Sb, Wm2/Sa)
= max(21381/172, 0/172)
= 124.046 mm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 12.7 + 6 * 17.0/(0.0 + 0.5)
= 229.400 mm

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 179.6 * sin(pi/4)
= 126.996 mm

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(126.996/(2 * 12.7 + 17.0)), 1)
= 1.7307

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

Distance Across Corners for Nuts		24.613	mm
Circular Wrench End Diameter	a	38.100	mm

	Minimum	Actual	Maximum
Bolt Area:	124.046	325.161	
Radial Distance between Hub and Bolts:	15.875	23.500	
Radial Distance between Bolts and Edge:	15.875	20.200	
Circ. Spacing between the Bolts:	31.750	126.996	229.400

Flange Design Bolt Load, Gasket Seating [W]:
= Sa(Am + Ab) / 2
= 172.38(124.0462 + 325.1606)/2
= 38712.72 N

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 21381 - 21381
= 0.00 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (179.6 - 165.0)/2
= 7.3000 mm

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2

= (22.5 + 0.0 + 7.3)/2
= 14.9000 mm

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 22.5 +(0.0/2.0)
= 22.5000 mm

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	14228.	22.5000	1.7307	554261.
Face Pressure,	Mt	7153.	14.9000	1.7307	184520.
Gasket Load,	Mg	0.	7.3000	1.7307	0.
Gasket Seating,	Matm	38713.	7.3000	1.7307	489289.

Total Moment for Operation, Mop 738781. N-mm
Total Moment for Gasket seating, Matm 489289. N-mm

Effective Hub Length, ho = sqrt(Bcor*goCor) 0.000 mm
Hub Ratio, h/h0 = Defined as 0 0.000
Thickness Ratio, g1/g0 = Defined as 0.0 0.000
Factors from Figure 2-7.1 K = 1.634
T = 1.653 U = 4.535
Y = 4.126 Z = 2.197

Tangential Flange Stress, Operating [Sto]:
= (Y * Mop)/(t² * Bcor)
= (4.1264*738781)/(17.0²*134.6)
= 78.34 MPa

Tangential Flange Stress, Seating [STa]:
= (Y * Matm)/(t² * Bcor)
= (4.1264*489289)/(17.0²*134.6)
= 51.89 MPa

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 21381/325.1606
= 65.76 MPa

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (0/325.1606)
= 0.00 MPa

Flange Stress Analysis Results: MPa

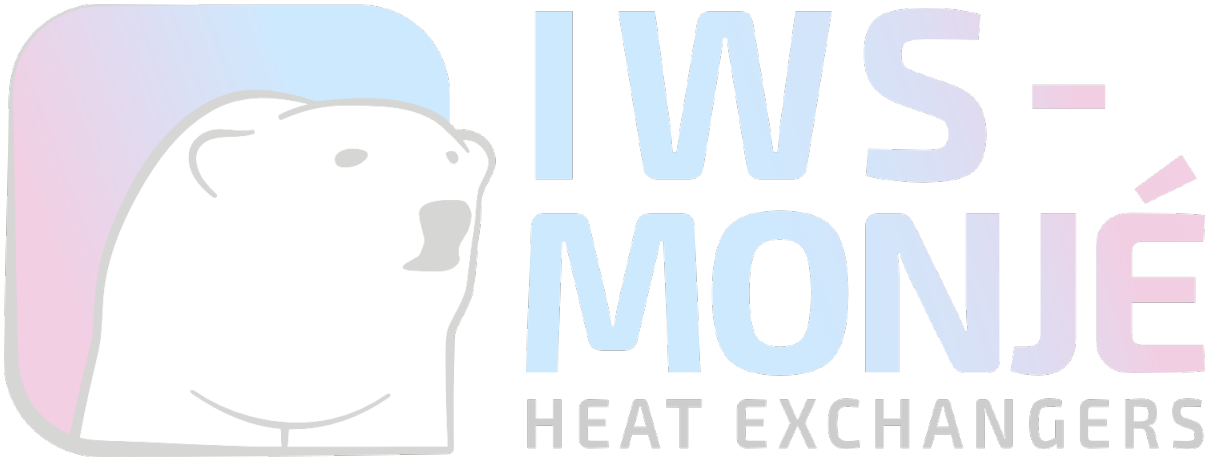
	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Tangential Flange	78.34	137.90	51.89	137.90
Bolting	65.76	172.38	0.00	172.38

Minimum Required Flange Thickness 14.249 mm
Estimated M.A.W.P. (Operating) 2 MPa

Estimated Finished Weight of Flange at given Thk. 3.4 kg
Estimated Unfinished Weight of Forging at given Thk 3.4 kg

Required Fillet Weld Leg size for Slip on Flanges:

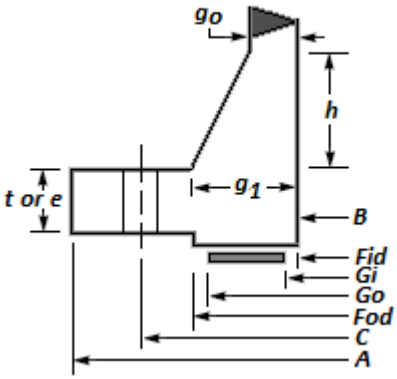
= max(tn, (6 mm or 1/4 inch)) no hub size given
= max(12.0, 6.0)
= 12.000 mm



Flange Input Data Values **Description: Shell Fl. 1 :**

Shell flange ring 1

Flange Type		Integral Weld Neck	
Design Pressure	P	1.00	MPa
Design Temperature		210	°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	133.000	mm
Flange Outside Diameter	A	220.000	mm
Flange Thickness	t	18.0000	mm
Thickness of Hub at Small End	go	3.4000	mm
Thickness of Hub at Large End	g1	4.5000	mm
Length of Hub	h	18.0000	mm
Flange Material		SA-182 F316	
Flange Material UNS number		S31600	
Flange Allowable Stress At Temperature	Sfo	131.56	MPa
Flange Allowable Stress At Ambient	Sfa	137.90	MPa
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	MPa
Bolt Allowable Stress At Ambient	Sa	172.38	MPa
Diameter of Bolt Circle	C	179.600	mm
Nominal Bolt Diameter	a	12.0000	mm
Type of Threads		TEMA Thread Series	
Number of Bolts		4	
Flange Face Outside Diameter	Fod	165.000	mm
Flange Face Inside Diameter	Fid	155.000	mm
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	165.000	mm
Gasket Inside Diameter	Gi	155.000	mm
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	MPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	2.0000	mm



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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)
= (1.*(133.0/2+0.0))/(131.56*1.0-0.6*1.)+Ca
= 0.5078 mm

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (131.56 * 1.0 * 3.4)/(66.5 + 0.6 * 3.4)
= 6.526 MPa

Corroded Flange ID,	Bcor = B+2*Fcor	133.000	mm
Corroded Large Hub,	g1Cor = g1-ci	4.500	mm
Corroded Small Hub,	g0Cor = go-ci	3.400	mm
Code R Dimension,	R = (C-B)/2 - g1	18.800	mm
Gasket Contact Width,	N = (Go - Gi) / 2	5.000	mm
Basic Gasket Width,	bo = N / 2	2.500	mm
Effective Gasket Width,	b = bo	2.500	mm
Gasket Reaction Diameter,	G = Go (Self-Energizing)	165.000	mm

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 165.0² * 1.
= 21380.648 N

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * pi * G * m * P
= 2 * 2.5 * pi * 165.0 * 0.0 * 1.
= 0.000 N

Hydrostatic End Load at Flange ID [Hd]:
= pi * Bcor² * P / 4
= pi * 133.0² * 1./4
= 13891.725 N

Pressure Force on Flange Face [Ht]:
= H - Hd
= 21381 - 13892
= 7488.922 N

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(21381 + 0 + 0, 0)
= 21380.648 N

Gasket Seating Bolt Load [Wm2]:
= y * b * pi * G + yPart * bPart * lp
= 0.0*2.5*pi*165.0+0.0*0.0*0.0
= 0.000 N

Required Bolt Area [Am]:
= max(Wm1/Sb, Wm2/Sa)
= max(21381/172, 0/172)
= 124.046 mm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 12.7 + 6 * 18.0/(0.0 + 0.5)
= 241.400 mm

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 179.6 * sin(pi/4)
= 126.996 mm

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(126.996/(2 * 12.7 + 18.0)), 1)
= 1.7106

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

	Minimum	Actual	Maximum
Bolt Area:	124.046	325.161	
Radial Distance between Hub and Bolts:	*20.637*	*18.800*	
Radial Distance between Bolts and Edge:	15.875	20.200	
Circ. Spacing between the Bolts:	31.750	126.996	241.400

Flange Design Bolt Load, Gasket Seating [W]:
= Sa(Am + Ab) / 2
= 172.38(124.0462 + 325.1606)/2
= 38712.72 N

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 21381 - 21381
= 0.00 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (179.6 - 165.0)/2
= 7.3000 mm

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (18.8 + 4.5 + 7.3)/2
= 15.3000 mm

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 18.8 +(4.5/2.0)
= 21.0500 mm

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	13892.	21.0500	1.7106	500421.
Face Pressure, Mt	7489.	15.3000	1.7106	196082.
Gasket Load, Mg	0.	7.3000	1.7106	0.
Gasket Seating, Matm	38713.	7.3000	1.7106	483619.

Total Moment for Operation, Mop 696503. N-mm
Total Moment for Gasket seating, Matm 483619. N-mm

Effective Hub Length, ho = sqrt(Bcor*goCor) 21.265 mm
Hub Ratio, h/h0 = HL / H0 0.846
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.324

Flange Factors for Integral Flange:

Factor F				0.835
Factor V				0.330
Factor f				1.000
Factors from Figure 2-7.1			K =	1.654
	T =	1.645	U =	4.431
	Y =	4.032	Z =	2.152
	e =	0.0393 1/mm	d =	3305.564 mm³
Stress Factors			Alpha =	1.707
	Beta =	1.942	Gamma =	1.038
	Delta =	1.764	Lambda =	2.802

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*696503/133.0)/(2.8021*4.5²)
= 92.26 MPa

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*483619/133.0)/(2.8021*4.5²)
= 64.06 MPa

Radial Flange Stress, Operating [SRo]:
= (beta * Mop / Bcor) / (L * t²)
= (1.9424*696503/133.0)/(2.8021*18.0²)
= 11.20 MPa

Radial Flange Stress, Seating [SRa]:
= (beta * Matm/Bcor) / (L * t²)
= (1.9424*483619/133.0)/(2.8021*18.0²)
= 7.78 MPa

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (4.0324*696503/(18.0²*133.0))-2.152*11
= 41.05 MPa

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (4.0324*483619/(18.0²*133.0))-2.152*8
= 28.50 MPa

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (92+max(11,41))/2
= 66.66 MPa

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (64+max(8,29))/2
= 46.28 MPa

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 21381/325.1606
= 65.76 MPa

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (0/325.1606)
= 0.00 MPa

Flange Stress Analysis Results: MPa

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	92.26	197.34	64.06	206.85
Radial Flange	11.20	131.56	7.78	137.90
Tangential Flange	41.05	131.56	28.50	137.90
Maximum Average	66.66	131.56	46.28	137.90
Bolting	65.76	172.38	0.00	172.38

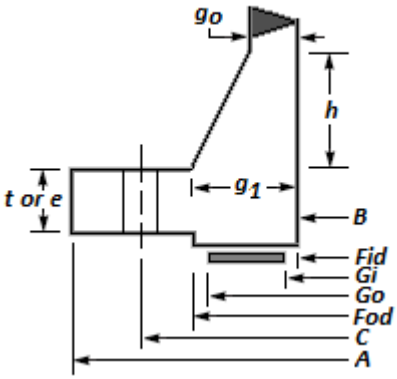
Minimum Required Flange Thickness 12.141 mm
Estimated M.A.W.P. (Operating) 2 MPa
Estimated Finished Weight of Flange at given Thk. 3.7 kg
Estimated Unfinished Weight of Forging at given Thk 7.0 kg

SA-182 F316, Min Metal Temp without impact per UHA-51: -196 °C

Flange Input Data Values **Description: Shell Fl. 2 :**

Shell flange ring 2

Flange Type		Integral Weld Neck	
Design Pressure	P	1.00	MPa
Design Temperature		210	°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	133.000	mm
Flange Outside Diameter	A	220.000	mm
Flange Thickness	t	18.0000	mm
Thickness of Hub at Small End	go	3.4000	mm
Thickness of Hub at Large End	g1	4.5000	mm
Length of Hub	h	18.0000	mm
Flange Material		SA-182 F316	
Flange Material UNS number		S31600	
Flange Allowable Stress At Temperature	Sfo	131.60	MPa
Flange Allowable Stress At Ambient	Sfa	137.90	MPa
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	MPa
Bolt Allowable Stress At Ambient	Sa	172.38	MPa
Diameter of Bolt Circle	C	179.600	mm
Nominal Bolt Diameter	a	12.0000	mm
Type of Threads		TEMA Thread Series	
Number of Bolts		4	
Flange Face Outside Diameter	Fod	165.000	mm
Flange Face Inside Diameter	Fid	155.000	mm
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	165.000	mm
Gasket Inside Diameter	Gi	155.000	mm
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	MPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	2.0000	mm



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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)
= (1.*(133.0/2+0.0))/(131.6*1.0-0.6*1.)+Ca
= 0.5076 mm

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (131.6 * 1.0 * 3.4)/(66.5 + 0.6 * 3.4)
= 6.528 MPa

Corroded Flange ID,	Bcor = B+2*Fcor	133.000	mm
Corroded Large Hub,	g1Cor = g1-ci	4.500	mm
Corroded Small Hub,	g0Cor = go-ci	3.400	mm
Code R Dimension,	R = (C-B)/2 - g1	18.800	mm
Gasket Contact Width,	N = (Go - Gi) / 2	5.000	mm
Basic Gasket Width,	bo = N / 2	2.500	mm
Effective Gasket Width,	b = bo	2.500	mm
Gasket Reaction Diameter,	G = Go (Self-Energizing)	165.000	mm

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 165.0² * 1.
= 21380.648 N

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * pi * G * m * P
= 2 * 2.5 * pi * 165.0 * 0.0 * 1.
= 0.000 N

Hydrostatic End Load at Flange ID [Hd]:
= pi * Bcor² * P / 4
= pi * 133.0² * 1./4
= 13891.725 N

Pressure Force on Flange Face [Ht]:
= H - Hd
= 21381 - 13892
= 7488.922 N

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(21381 + 0 + 0, 0)
= 21380.648 N

Gasket Seating Bolt Load [Wm2]:
= y * b * pi * G + yPart * bPart * lp
= 0.0*2.5*pi*165.0+0.0*0.0*0.0
= 0.000 N

Required Bolt Area [Am]:
= max(Wm1/Sb, Wm2/Sa)
= max(21381/172, 0/172)
= 124.046 mm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 12.7 + 6 * 18.0/(0.0 + 0.5)
= 241.400 mm

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 179.6 * sin(pi/4)
= 126.996 mm

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(126.996/(2 * 12.7 + 18.0)), 1)
= 1.7106

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

	Minimum	Actual	Maximum
Bolt Area:	124.046	325.161	
Radial Distance between Hub and Bolts:	*20.637*	*18.800*	
Radial Distance between Bolts and Edge:	15.875	20.200	
Circ. Spacing between the Bolts:	31.750	126.996	241.400

Flange Design Bolt Load, Gasket Seating [W]:
= Sa(Am + Ab) / 2
= 172.38(124.0462 + 325.1606)/2
= 38712.72 N

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 21381 - 21381
= 0.00 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (179.6 - 165.0)/2
= 7.3000 mm

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (18.8 + 4.5 + 7.3)/2
= 15.3000 mm

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 18.8 +(4.5/2.0)
= 21.0500 mm

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	13892.	21.0500	1.7106	500421.
Face Pressure, Mt	7489.	15.3000	1.7106	196082.
Gasket Load, Mg	0.	7.3000	1.7106	0.
Gasket Seating, Matm	38713.	7.3000	1.7106	483619.

Total Moment for Operation, Mop 696503. N-mm
Total Moment for Gasket seating, Matm 483619. N-mm

Effective Hub Length, ho = sqrt(Bcor*goCor) 21.265 mm
Hub Ratio, h/h0 = HL / H0 0.846
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.324

Flange Factors for Integral Flange:

Factor F				0.835
Factor V				0.330
Factor f				1.000
Factors from Figure 2-7.1			K =	1.654
	T =	1.645	U =	4.431
	Y =	4.032	Z =	2.152
	e =	0.0393 1/mm	d =	3305.564 mm³
Stress Factors			Alpha =	1.707
	Beta =	1.942	Gamma =	1.038
	Delta =	1.764	Lambda =	2.802

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*696503/133.0)/(2.8021*4.5²)
= 92.26 MPa

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*483619/133.0)/(2.8021*4.5²)
= 64.06 MPa

Radial Flange Stress, Operating [SRo]:
= (beta * Mop / Bcor) / (L * t²)
= (1.9424*696503/133.0)/(2.8021*18.0²)
= 11.20 MPa

Radial Flange Stress, Seating [SRa]:
= (beta * Matm/Bcor) / (L * t²)
= (1.9424*483619/133.0)/(2.8021*18.0²)
= 7.78 MPa

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (4.0324*696503/(18.0²*133.0))-2.152*11
= 41.05 MPa

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (4.0324*483619/(18.0²*133.0))-2.152*8
= 28.50 MPa

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (92+max(11,41))/2
= 66.66 MPa

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (64+max(8,29))/2
= 46.28 MPa

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 21381/325.1606
= 65.76 MPa

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (0/325.1606)
= 0.00 MPa

Flange Stress Analysis Results: MPa

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	92.26	197.40	64.06	206.85
Radial Flange	11.20	131.60	7.78	137.90
Tangential Flange	41.05	131.60	28.50	137.90
Maximum Average	66.66	131.60	46.28	137.90
Bolting	65.76	172.38	0.00	172.38

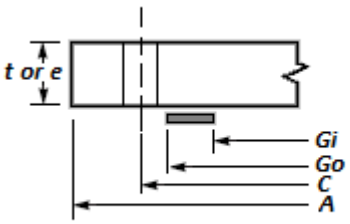
Minimum Required Flange Thickness 12.141 mm
Estimated M.A.W.P. (Operating) 2 MPa
Estimated Finished Weight of Flange at given Thk. 3.7 kg
Estimated Unfinished Weight of Forging at given Thk 7.0 kg

SA-182 F316, Min Metal Temp without impact per UHA-51: -196 °C

Flange Input Data Values **Description:** Cover head :

Cover head

Flange Type		Blind	
Design Pressure	P	1.00	MPa
Design Temperature		95	°C
Internal Corrosion Allowance	ci	1.0000	mm
External Corrosion Allowance	ce	0.0000	mm
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Outside Diameter	A	220.000	mm
Flange Thickness	t	25.0000	mm
Flange Material		SA-516 70	
Flange Material UNS number		K02700	
Flange Allowable Stress At Temperature	Sfo	137.90	MPa
Flange Allowable Stress At Ambient	Sfa	137.90	MPa
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	MPa
Bolt Allowable Stress At Ambient	Sa	172.38	MPa
Diameter of the Load Reaction, Long Span	D	0.000	mm
Diameter of the Load Reaction, Short Span	d	0.000	mm
Perimeter along the Center of the Bolts	L	564.230	mm
Diameter of Bolt Circle	C	179.600	mm
Nominal Bolt Diameter	a	12.0000	mm
Type of Threads		TEMA Thread Series	
Number of Bolts		4	
Flange Face Outside Diameter	Fod	165.000	mm
Flange Face Inside Diameter	Fid	155.000	mm
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	165.000	mm
Gasket Inside Diameter	Gi	155.000	mm
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	MPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	2.0000	mm



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Gasket Contact Width,	N = (Go - Gi) / 2	5.000	mm
Basic Gasket Width,	bo = N / 2	2.500	mm
Effective Gasket Width,	b = bo	2.500	mm
Gasket Reaction Diameter,	G = Go (Self-Energizing)	165.000	mm

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 165.0² * 1.
= 21380.648 N

Contact Load on Gasket Surfaces [Hp]:
= 2 * b * pi * G * m * P
= 2 * 2.5 * pi * 165.0 * 0.0 * 1.
= 0.000 N

Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(21381 + 0 + 0, 0)
= 21380.648 N

Gasket Seating Bolt Load [Wm2]:
= y * b * pi * G + yPart * bPart * lp
= 0.0*2.5*pi*165.0+0.0*0.0*0.0
= 0.000 N

Required Bolt Area [Am]:
= max(Wm1/Sb, Wm2/Sa)
= max(21381/172, 0/172)
= 124.046 mm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 12.7 + 6 * 24.0/(0.0 + 0.5)
= 313.400 mm

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 179.6 * sin(pi/4)
= 126.996 mm

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(126.996/(2 * 12.7 + 24.0)), 1)
= 1.6034

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

	Minimum	Actual	Maximum
Bolt Area:	124.046	325.161	
Radial Distance between Bolts and Edge:	15.875	20.200	
Circ. Spacing between the Bolts:	31.750	126.996	313.400

Flange Design Bolt Load, Gasket Seating [W]:
= Sa(Am + Ab) / 2
= 172.38(124.0462 + 325.1606)/2
= 38712.72 N

Gasket Load for the Operating Condition [HG]:
= Wm1
= 21380.65 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (179.6 - 165.0)/2
= 7.3000 mm

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:
= 1.9 * Wm1 * hG * Bsc/(t² * G) + C * Z * Peq * G²/t²
= 1.9*21381*7.3*1.6034/(24.0²*165.0)+0.3*1.0*1.*165.0²/24.0²
= 19.18 MPa

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:
= 1.9 * W * hG * Bsc/ (t² * G)
= 1.9*38713*7.3*1.603/(24.0²*165.0)
= 9.06 MPa

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 21381/325.1606
= 65.76 MPa

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (0/325.1606)
= 0.00 MPa

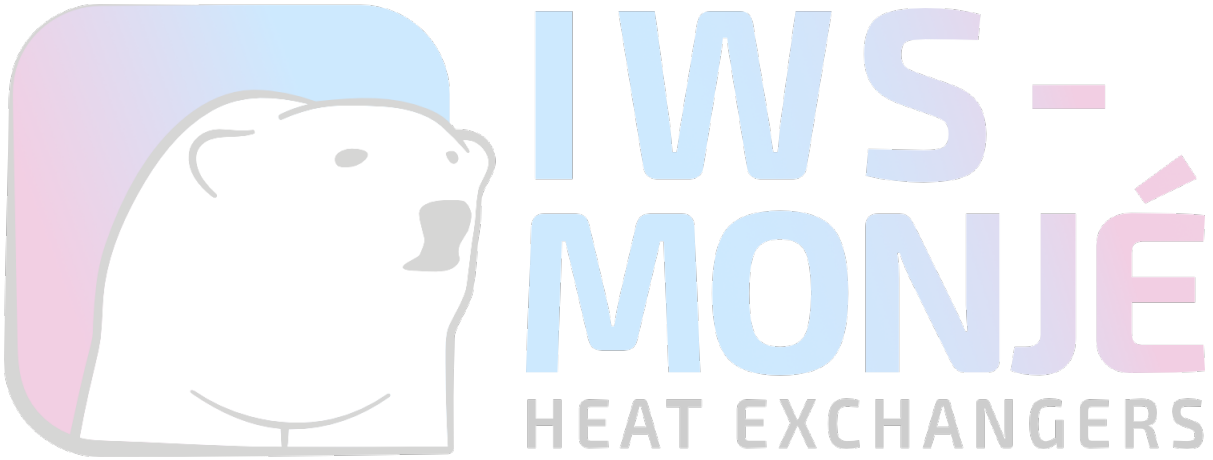
Flange Stress Analysis Results: MPa

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Tangential Flange	19.18	137.90	9.06	137.90
Bolting	65.76	172.38	0.00	172.38

Reqd. Blind Flange Thickness at Center	9.951 mm
Reqd. Blind Flange Thickness at Gasket	7.151 mm
Estimated M.A.W.P. (Operating)	3 MPa
Estimated Finished Weight of Flange at given Thk.	7.4 kg
Estimated Unfinished Weight of Forging at given Thk	7.4 kg

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.381, Temperature Reduction per Fig. UCS 66.1 = 56 °C

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



Internal Pressure Results Summary:

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd MPa	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) MPa
Channel head fla		1	27	1	160	137.9
Channel head cyl		1	13	1	160	137.9
Channel head fla		1	18	1	132.6	137.9
Shell flange rin		1	...	...	133	131.56
Main Shell		2.5	...	...	141.3	132.2
Shell flange rin		1	...	...	133	131.6
Cover head		1	...	1	220	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure MPa	M.A.W.P. Corroded MPa	M.A.P. New & Cold MPa	Minimum Thickness mm	Required Thickness mm
Channel head fla		1	25.958	27.9932	27	6.10314
Channel head cyl		1	22.0053	23.9666	13	3.5
Channel head fla		1	1.76016	1.95811	18	14.2494
Shell flange rin		1	1.97362	2.06878	18	12.1412
Main Shell		2.5	6.48694	6.76663	3.4	1.5
Shell flange rin		1	1.97425	2.06878	18	12.1412
Cover head		1	2.62127	2.62127	25	9.95133

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     =              2 MPa
Shell Side MAPnc    =              2 MPa
Channel Side  MAWP  =              1 MPa
Channel Side  MAPnc =              1 MPa
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Welded Flat Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 95 °C

Channel head flat

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= d * sqrt(Z*C*P/(S*E)) per UG-34 (c)(3)
= 134.0*sqrt(1.0*0.2*1./(137.9*1.0))
= 5.1031 + 1.0000 = 6.1031 mm

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (t/d)²*((S*E)/(C*Z)) per UG-34 (c)(3)
= ((26.0)/134.0)²*((137.9*1.0)/(0.2*1.0))
= 26 MPa

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (t/d)²*((S*E)/(C*Z)) per UG-34 (c)(3)
= (27.0/134.0)²*((137.9*1.0)/(0.2*1.0))
= 28 MPa

Actual stress at given pressure and thickness, corroded [Sact]:
= (Z*C*P)/(((t/d)²)*E)
= (1.0*0.2*1.)/((((26.0)/134.0)²)*1.0)
= 5.312 MPa

Minimum Design Metal Temperature Results:

tg = 13.0, tg_sr = 27.0, tr = 5.103, c = 1.0 mm, E✱ = 1.0
Thickness Ratio = tr * E✱/(tg_sr - c) = 0.196, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-21 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 95 °C

Channel head cylinder

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (1.*80.0)/(137.9*1.0+0.4*1.)
= 0.5785 + 1.0000 = 1.5785 mm

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 2.5000 mm per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (137.9*1.0*12.0)/(80.0-0.4*12.0)
= 22 MPa

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (137.9*1.0*13.0)/(80.0-0.4*13.0)
= 24 MPa

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Ro-0.4*t))/(E*t)
= (1.*((80.0-0.4*12.0))/(1.0*12.0)
= 6.267 MPa

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 8.844 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 13.0, tr = 2.5, c = 1.0 mm, E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.208, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -21 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -104 °C
Min Metal Temp. w/o impact per UG-20(f)                 -29 °C
```

Cylindrical Shell From 50 To 60 SA-312 TP316 at 210 °C

Main Shell

Longitudinal Joint: User Defined

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
= (P*Ro) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (2.5*70.65)/(132.2*1.0+0.4*2.5)
= 1.3260 + 0.0000 = 1.3260 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]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (132.2*1.0*3.4)/(70.65-0.4*3.4)
= 6 MPa

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(Ro-0.4*t) per Appendix 1-1 (a)(1)
= (137.9*1.0*3.4)/(70.65-0.4*3.4)
= 7 MPa

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Ro-0.4*t))/(E*t)
= (2.5*((70.65-0.4*3.4))/(1.0*3.4)
= 50.949 MPa

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          3.390  MPa
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S        3.390  MPa
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       3.248  MPa
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          2.869  MPa
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     3.575  MPa
Pressure per App 27-4  = M.A.W.P.                        2.500  MPa
```

User defined Hydrostatic Test Pressures:

```
Shell Side  Test Pressure at  High Point                 3.750  MPa
Channel Side Test Pressure at High Point                 1.500  MPa
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          1.300  MPa
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S        1.300  MPa
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       1.298  MPa
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          1.100  MPa
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     1.430  MPa
Pressure per App 27-4  = M.A.W.P.                        1.000  MPa
```

Horizontal 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 (MPa):

From To	Stress	Allowable	Ratio	Pressure
Channel head flat	7.4	179.3	0.041	1.50
Channel head cylinde	8.6	179.3	0.048	1.50
Main Shell	76.5	179.3	0.426	3.75

Stress ratios for Nozzle and Pad Materials (MPa):

Description	Pad/Nozzle	Ambient	Operating	Ratio
Noz N1 Fr10 - Tu	Nozzle	117.90	117.90	1.000
Noz N2 Fr10	Nozzle	117.90	117.90	1.000
Noz N3 - Shell i	Nozzle	117.22	112.32	1.044
Noz N4 - Shell o	Nozzle	117.22	112.32	1.044
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (MPa):

Description	Ambient	Operating	Ratio
Channel head flat	137.90	137.90	1.000
Channel head cylinde	137.90	137.90	1.000
Channel head flange	137.90	137.90	1.000
Shell flange ring 1	137.90	131.56	1.048
Main Shell	137.90	132.20	1.043

Shell flange ring 2	137.90	131.60	1.048
Cover head	137.90	137.90	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (MPa):

Description	Ambient	Operating	Ratio
Tube Material	68.95	59.71	1.155
Tubesheet Material	115.15	97.91	1.176
Minimum			1.155

Hoop Stress in Nozzle Wall during Pressure Test (MPa):

Description	Ambient	Operating	Ratio
Noz N1 Fr10 - Tu	5.41	153.28	0.035
Noz N2 Fr10	5.41	153.28	0.035
Noz N3 - Shell i	26.78	152.38	0.176
Noz N4 - Shell o	26.78	152.38	0.176

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm	Outside Diameter mm	Corroded Thickness mm	Factor A	Factor B MPa
10	20	No Calc	...	26	No Calc	No Calc
20	30	30	160	12	0.096675	122.731
30	40	No Calc	...	17	No Calc	No Calc
40	50	No Calc	...	18	No Calc	No Calc
50	60	753.8	141.3	3.4	0.00082629	58.4069
60	70	No Calc	...	18	No Calc	No Calc
70	80	No Calc	...	24	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm	External Required T. mm	External Design Pressure MPa	External M.A.W.P. MPa
10	20	27	No Calc	0.1013	No Calc
20	30	13	1.25164	0.1013	12.2731
30	40	18	10.4394	0.1013	No Calc
40	50	18	6.9596	0.1013	No Calc
50	60	3.4	0.95704	0.1013	1.87387
60	70	18	6.9596	0.1013	No Calc
70	80	25	6.9342	0.1013	No Calc
Minimum					2

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm	Allowable Length Bet. Stiffeners mm	Ring Inertia Required mm^4	Ring Inertia Available mm^4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	30	3634.68	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	753.8	55631.4	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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Welded Flat Head

Channel head flat

Note: This element's required thickness was computed in the internal Pressure Report using the maximum of the Internal and External pressures.

Cylindrical Shell From 50 to 60 Ext. Chart: HA-2 at 210 °C

Main Shell
Elastic Modulus from Chart: HA-2 at 210 °C: 178099 MPa

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
3.400	141.30	753.80	41.56	5.3347	0.0008263	58.41

MAEP = (4*B)/(3*(Do/t)) = (4*58.4069)/(3*41.5588) = 1.8739 MPa

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.957	141.30	753.80	147.64	5.3347	0.0001260	11.22

MAEP = (4*B)/(3*(Do/t)) = (4*11.2178)/(3*147.6435) = 0.1013 MPa

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
3.400	141.30	55631.38	41.56	50.0000	0.0006433	54.15

MAEP = (4*B)/(3*(Do/t)) = (4*54.1462)/(3*41.5588) = 1.7372 MPa

---

Element and Detail Weights:

From	To	Element Metal Wgt. kg	Element ID Volume ltr	Corroded Metal Wgt. kg	Corroded ID Volume ltr	Extra due Misc % kg
10	20	4.20749	...	4.05166	...	...
20	30	1.39592	0.42315	1.29731	0.43588	...
30	40	3.37665	...	3.37665	...	...
40	50	3.73074	0.50023	3.73074	0.50023	...
50	60	8.9129	7.98337	8.9129	7.98337	...
60	70	3.73074	0.50023	3.73074	0.50023	...
70	80	7.36555	...	7.36555	...	...
Total		32	9.41	32	9.42	0

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	Z Offset Dtl. Cent. mm	Description
10	Nozl	0.30781	...	100	...	Noz N1 Fr10 - Tu
10	Nozl	0.32816	...	-100	...	Noz N2 Fr10
50	Nozl	4.92907	72	-97.4	...	Noz N3 - Shell i
50	Nozl	4.92907	692	97.4	...	Noz N4 - Shell o
30	FTsh	3.79983	36	...	...	Tubesheet fix
30	Tube	6.29457	437	...	...	Tubes
30	FlTs	2.16206	852	...	...	

Total Weight of Each Detail Type:

Nozzles	10.5	
Exchanger Components	12.3	
Sum of the Detail Weights	22.8	kg

Weight Summation Results: (kg)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	32.7	32.7	32.7	32.7	32.7	32.7
Nozzles	10.5	10.5	10.5	10.5	10.5	10.5
Exchanger	12.3	12.3	12.3	12.3	12.3	12.3
Test Liquid	...	9.4	...	...	...	...
Tube Tst Lqd	...	2.3	...	...	...	...
Totals	55.5	67.2	55.5	55.5	55.5	55.5

Weight Summary:

Fabricated Wt. - Bare Weight without Removable Internals 55.5 kg

Shop Test Wt.	- Fabricated Weight + Water (Full)	67.2 kg
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	55.5 kg
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	55.5 kg
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	55.5 kg
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	55.5 kg
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	55.2 kg
Field Test Wt.	- Empty Weight + Water (Full)	67.2 kg

Exchanger Tube Data

Volume of Exchanger tubes :	2.3 ltr
Weight of Ope Liq in tubes :	0.0 kg
Weight of Water in tubes :	2.3 kg

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

Outside Surface Areas of Elements:

From	To	Surface Area mm^2
10	20	...
20	30	15079.6
30	40	36644.5
40	50	44591
50	60	334617
60	70	44591
70	80	55292
Total		530815.312 mm^2

Nozzle Flange MAWP Results: (MPa & °C)

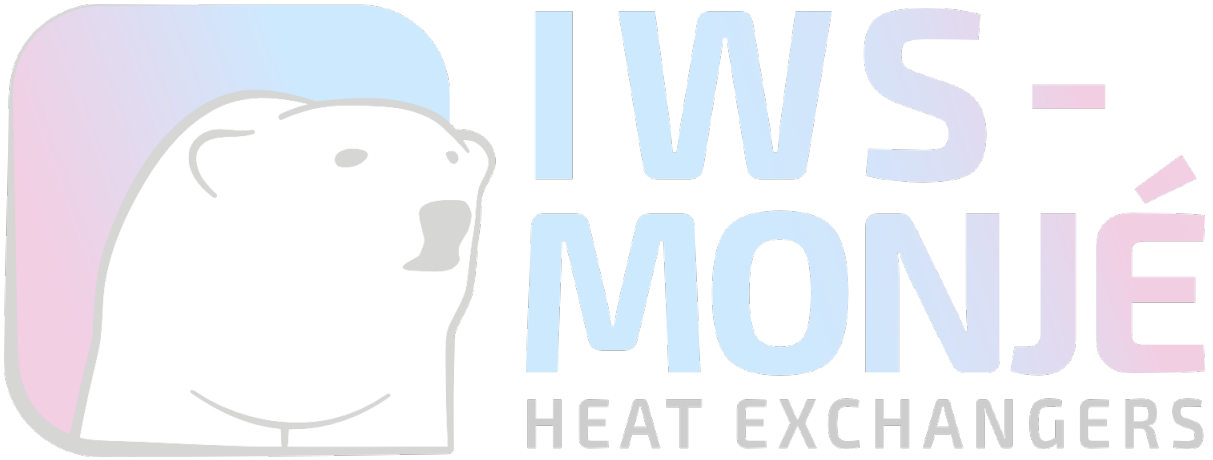
Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
Noz N3 - Shell	3.52	4.96	210	300	GR 2.2	...	...	...	...
Noz N4 - Shell	3.52	4.96	210	300	GR 2.2	...	...	...	...

Shellside Flange Rating

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 3.524 MPa
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 4.960 MPa

Channelside Flange Rating

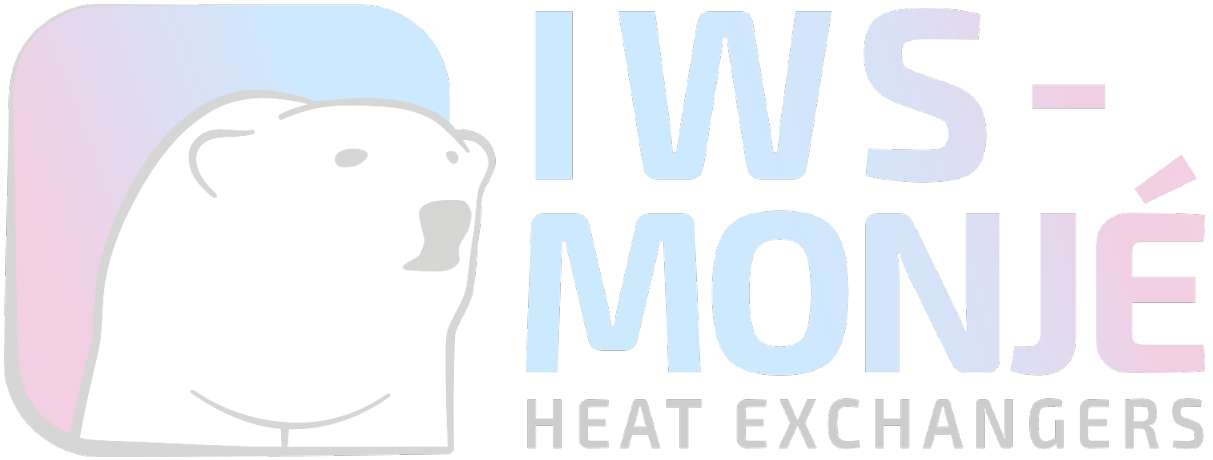
Pressure Ratings are per ASME B16.5 2017 Metric Edition



Shop/Field Installation Options :

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

Center of Gravity of the Nozzles	485.222 mm
Center of Gravity of the Tubesheet(s)	406.920 mm
Center of Gravity of the Tubes	512.000 mm
Center of Gravity of Bare Shell New and Cold	478.350 mm
Center of Gravity of Bare Shell Corroded	481.907 mm
Vessel CG in the Operating Condition	477.871 mm
Vessel CG in the Fabricated (Shop/Empty) Condition	475.792 mm



Input, Nozzle Desc: Noz N1 Fr10 - Tube inlet From: 10

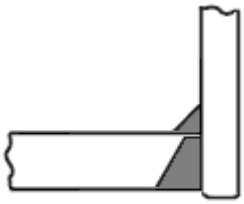
Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	95	°C
Parent Material		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	MPa
Parent Allowable Stress At Ambient	Sva	137.90	MPa
Outside Diameter of Flat Head	D	160.00	mm
Large Diameter of Flat Head	Dl	160.0000	mm
Flat Head Attachment Factor	F	0.20	
Head Finished (Minimum) Thickness	t	27.0000	mm
Head Internal Corrosion Allowance	c	1.0000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	46.0000	mm
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Parent : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		Outside	
Layout Angle		90.00	deg
Diameter		40.0000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.0000	mm
Corrosion Allowance	can	1.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	50.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm

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: Noz N1 Fr10 - Tube inlet

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          40.000  mm.
Actual Thickness Used in Calculation                  5.000  mm
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Welded Flat Head, tr [Int. Press]
```
  = d * sqrt(Z*C*P/(Sv*E)) per UG-34 (c)(3)
  = 134.0*sqrt(1.0*0.2*1./(138*1.0))
  = 5.1031 mm
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 1.*20.0/(118*1.0+0.4*1.)
  = 0.1691 mm
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl    92.0000  mm
Parallel to Vessel Wall                       Rn+tn+t   46.0000  mm
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   10.0000  mm
```

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N1 Fr10 - T.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1691 mm
Wall Thickness per UG16(b),                      tr16b = 3.5000 mm
Wall Thickness, shell/head, internal pressure     trb1 = 6.1031 mm
Wall Thickness                 tb1 = max(trb1, tr16b) = 6.1031 mm
Wall Thickness                 tb2 = max(trb2, tr16b) = 3.5000 mm
Wall Thickness per table UG-45                    tb3 = 4.1200 mm
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.12, max( 6.1031, 3.5 ) ]
  = 4.1200 mm
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(1.1691, 4.12)
= 4.1200 mm

Available Nozzle Neck Thickness = 5.0000 mm --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 5.0, tr = 0.169, c = 1.0 mm, E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.042, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C

Weld Size Calculations, Description: Noz N1 Fr10 - T

Intermediate Calc. for nozzle/shell Welds Tmin 4.0000 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.8000 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 1 MPa

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

The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.0508 mm

Input, Nozzle Desc: Noz N2 Fr10 From: 10

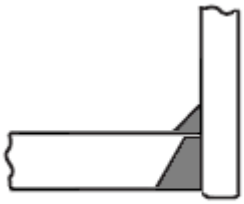
Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	95	°C
Parent Material		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	MPa
Parent Allowable Stress At Ambient	Sva	137.90	MPa
Outside Diameter of Flat Head	D	160.00	mm
Large Diameter of Flat Head	Dl	160.0000	mm
Flat Head Attachment Factor	F	0.20	
Head Finished (Minimum) Thickness	t	27.0000	mm
Head Internal Corrosion Allowance	c	1.0000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	46.0000	mm
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Parent : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		Outside	
Layout Angle		270.00	deg
Diameter		40.0000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.0000	mm
Corrosion Allowance	can	1.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	50.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm

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: Noz N2 Fr10

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          40.000  mm.
Actual Thickness Used in Calculation                  5.000  mm
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Welded Flat Head, tr [Int. Press]
```
  = d * sqrt(Z*C*P/(Sv*E)) per UG-34 (c)(3)
  = 134.0*sqrt(1.0*0.2*1./(138*1.0))
  = 5.1031 mm
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 1.*20.0/(118*1.0+0.4*1.)
  = 0.1691 mm
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl    92.0000  mm
Parallel to Vessel Wall                       Rn+tn+t   46.0000  mm
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   10.0000  mm
```

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N2 Fr10.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 1.1691 mm
Wall Thickness per UG16(b),                      tr16b = 3.5000 mm
Wall Thickness, shell/head, internal pressure     trb1 = 6.1031 mm
Wall Thickness                 tb1 = max(trb1, tr16b) = 6.1031 mm
Wall Thickness                 tb2 = max(trb2, tr16b) = 3.5000 mm
Wall Thickness per table UG-45                    tb3 = 4.1200 mm
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 4.12, max( 6.1031, 3.5 ) ]
  = 4.1200 mm
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(1.1691, 4.12)
= 4.1200 mm

Available Nozzle Neck Thickness = 5.0000 mm --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 5.0, tr = 0.169, c = 1.0 mm, E✱ = 1.0
Thickness Ratio = tr * E✱/(tg - c) = 0.042, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -29 °C
Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C

Weld Size Calculations, Description: Noz N2 Fr10

Intermediate Calc. for nozzle/shell Welds Tmin 4.0000 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.8000 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 1 MPa

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

The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.0508 mm

Input, Nozzle Desc: Noz N3 - Shell inlet From: 50

Pressure for Reinforcement Calculations	P	2.5000	MPa
Temperature for Internal Pressure	Temp	210	°C
Design External Pressure	Pext	0.10	MPa
Temperature for External Pressure	Tempex	210	°C
Parent Material		SA-312 TP316	
Parent Allowable Stress at Temperature	Sv	132.20	MPa
Parent Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	134.50	mm
Design Length of Section	L	753.8000	mm
Shell Finished (Minimum) Thickness	t	3.4000	mm
Shell Internal Corrosion Allowance	c	0.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		206.52	mm
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Parent : Nozzle

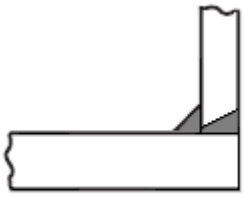
Material		SA-312 TP316	
Material UNS Number		S31600	
Material Specification/Type		Wld. pipe	
Allowable Stress at Temperature	Sn	132.14	MPa
Allowable Stress At Ambient	Sna	137.90	MPa

Note: The allowables above have been divided by 0.85, see UG-37 [S].

Diameter Basis (for tr calc only)		Outside	
Layout Angle		270.00	deg
Diameter		60.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	4.0000	mm
Flange Type		Weld Neck Flange	
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	39.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	0.0000	mm
Flange Class		300	
Flange Grade		GR 2.2	

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Reinforcement CALCULATION, Description: Noz N3 - Shell inlet

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          60.300  mm.
Actual Thickness Used in Calculation                  4.000  mm
```

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)
  = 2.5*67.25/(132*1.0-0.6*2.5)
  = 1.2863 mm
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 2.5*30.15/(132*1.0+0.4*2.5)
  = 0.5661 mm
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl   104.6000  mm
Parallel to Vessel Wall, opening length            d    52.3000  mm
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    8.5000  mm
```

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N3 - Shell.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 0.5661 mm
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm
Wall Thickness, shell/head, internal pressure     trb1 = 1.2863 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(0.5661, 1.5)
= 1.5000 mm

Available Nozzle Neck Thickness = 4.0000 mm --> OK

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: Noz N3 - Shell

Intermediate Calc. for nozzle/shell Welds Tmin 3.4000 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.3800 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 2 MPa

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

The Drop for this Nozzle is : 7.1373 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 49.5373 mm

Input, Nozzle Desc: Noz N4 - Shell outlet From: 50

Pressure for Reinforcement Calculations	P	2.5000	MPa
Temperature for Internal Pressure	Temp	210	°C
Design External Pressure	Pext	0.10	MPa
Temperature for External Pressure	Tempex	210	°C
Parent Material		SA-312 TP316	
Parent Allowable Stress at Temperature	Sv	132.20	MPa
Parent Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	134.50	mm
Design Length of Section	L	753.8000	mm
Shell Finished (Minimum) Thickness	t	3.4000	mm
Shell Internal Corrosion Allowance	c	0.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		826.53	mm
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Parent : Nozzle

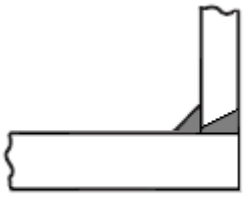
Material		SA-312 TP316	
Material UNS Number		S31600	
Material Specification/Type		Wld. pipe	
Allowable Stress at Temperature	Sn	132.14	MPa
Allowable Stress At Ambient	Sna	137.90	MPa

Note: The allowables above have been divided by 0.85, see UG-37 [S].

Diameter Basis (for tr calc only)		Outside	
Layout Angle		90.00	deg
Diameter		60.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	4.0000	mm
Flange Type		Weld Neck Flange	
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	39.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	3.4000	mm
Flange Class		300	
Flange Grade		GR 2.2	

The Pressure Design option was Design Pressure + static head.

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



Abutting/Set-on Nozzle No Pad

Reinforcement CALCULATION, Description: Noz N4 - Shell outlet

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          60.300  mm.
Actual Thickness Used in Calculation                  4.000  mm
```

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)
  = 2.5*67.25/(132*1.0-0.6*2.5)
  = 1.2863 mm
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 2.5*30.15/(132*1.0+0.4*2.5)
  = 0.5661 mm
```

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl   104.6000  mm
Parallel to Vessel Wall, opening length            d    52.3000  mm
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    8.5000  mm
```

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N4 - Shell.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 0.5661 mm
Wall Thickness per UG16(b),                      tr16b = 1.5000 mm
Wall Thickness, shell/head, internal pressure     trb1 = 1.2863 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(0.5661, 1.5)
= 1.5000 mm

Available Nozzle Neck Thickness = 4.0000 mm --> OK

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: Noz N4 - Shell

Intermediate Calc. for nozzle/shell Welds Tmin 3.4000 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.3800 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 2 MPa

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

The Drop for this Nozzle is : 7.1373 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 49.5373 mm