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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2019

Analysis Performed by : #Replace this text with your company name and th

Job File              : D:\ JAM-PETROELECTRIC\CHILLER-Rev.01

Date of Analysis      : May 21,2024   12:29pm

PV Elite 23, January 2021
```

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 600.000 x 600.000 x 925.000 mm. ID		
Vessel Design Length, Tangent to Tangent	3563.53	mm.
Specified Datum Line Distance	0.00	mm.
Shell Side Design Temperature	120	°C
Channel Side Design Temperature	85	°C
Shell Side Design Pressure	22.000	bars
Channel Side Design Pressure	6.800	bars
Shop Shell Side Test Pressure	28.600	bars
Shop Channel Side Test Pressure	8.840	bars
Wind Design Code	UBC	
Earthquake Design Code	UBC-97	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	Yes	No
Head	SA-516 70	...	...	K02700	Yes	No
Cone	SA-516 70	...	...	K02700	Yes	No
Flange	SA-266 2	...	...	K03506	No	No
Flange	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-333 6	...	...	K03006	No	Yes
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Tubes	SA-334 6	...	...	K03006	No	Yes
Tubesheet	SA-350 LF2	1	...	K03011	No	Yes
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz 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 (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
CH. Head	6.854	1.00	32.100	3.0000	No	No
CH. Barrel	6.854	1.03	31.400	3.0000	N/A	No
CH. Flange	6.854	1.03	14.600	3.0000	N/A	No
SH. Flange	22.031	1.03	23.400	3.0000	N/A	No
Port Barrel	22.032	1.03	40.200	3.0000	N/A	No
SH. Cone	22.048	1.03	22.800	3.0000	N/A	No
SH. Barrel	22.048	1.03	26.300	3.0000	N/A	No
SH. Head	22.048	1.03	26.800	3.0000	No	No

Liquid Level: 925.00 mm. Dens.: 0.001 kg./cm³ Sp. Gr.: 0.533

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	50.0	50.0	12.0	10.0	4.5	4.6	1.00	1.00
Cylinder	350.0	300.0	10.0	10.0	4.5	4.7	1.00	1.00
Body Flg	435.0	85.0	90.0	60.0	58.2	57.3	1.00	1.00
Body Flg	598.5	85.0	90.0	60.0	57.9	53.5	1.00	1.00
Cylinder	748.5	150.0	12.0	12.0	7.9	4.1	1.00	1.00
Conical	1313.5	565.0	12.0	12.0	11.7	8.6	1.00	1.00
Cylinder	3513.5	2200.0	12.0	12.0	10.5	7.8	1.00	1.00
Ellipse	3563.5	50.0	14.0	12.0	10.4	5.5	1.00	1.00

Saddle Parameters:

Saddle Width	140.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	750.000	mm.
Wear Pad Width	300.000	mm.
Wear Pad Thickness	12.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	800.000	mm.
Baseplate Length	900.000	mm.
Baseplate Thickness	15.000	mm.
Baseplate Width	170.000	mm.
Number of Ribs (including outside ribs)	3	
Rib Thickness	12.000	mm.
Web Thickness	12.000	mm.
Height of Center Web	367.500	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------- 900.000 mm. --------------------|
----------------------------------------------------- ---
|                                                    |
|                                                    | 170.000 mm.
|                                                    |
----------------------------------------------------- ---
```

Baseplate Plan View

```
----------------------------------------------------- ---
|                                                    | 15.000 mm.
----------------------------------------------------- ---
```

Baseplate Side View

Maximum Tensile Bolt Load	114.	Kgf

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	4630.43	Kgf
Maximum Transverse Saddle Shear Load	481.01	Kgf
Maximum Longitudinal Saddle Shear Load	962.03	Kgf

Summary of Maximum Saddle Loads, Operating Case, Un-Factored:

Maximum Vertical Saddle Load	5180.88	Kgf
Maximum Transverse Saddle Shear Load	1284.39	Kgf
Maximum Longitudinal Saddle Shear Load	1374.33	Kgf

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	4025.37	Kgf
Maximum Transverse Saddle Shear Load	78.72	Kgf
Maximum Longitudinal Saddle Shear Load	37.89	Kgf

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
S2 (6in.)	WRC-107/537	0.833	n/a	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	2800.6	kg.
Shop Test	- Fabricated + Water (Full)	4834.0	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	2800.6	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	2973.9	kg.
Empty	- Fab. + Intls. + Details + Wghts.	2973.9	kg.
Operating	- Empty + Operating Liquid (No CA)	4198.2	kg.
Field Test	- Empty Weight + Water (Full)	4766.1	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1 (3in.)	16.6	...	...	OK	4.50	OK	No Calc[*]
T1 (3in.)	16.6	...	...	OK	4.50	OK	No Calc[*]
T2 (3in.)	16.6	...	...	OK	4.51	OK	No Calc[*]
T2 (3in.)	16.6	...	...	OK	4.51	OK	No Calc[*]
S1 (4in.)	22.8	OK	...	OK	8.26	OK	Passed
S2 (6in.)	26.3	OK	...	OK	9.22	OK	Passed
V (2in.)	26.3	...	...	OK	7.80	OK	No Calc[*]
D (2in.)	26.3	...	...	OK	7.80	OK	No Calc[*]
PSV (3in.)	26.3	...	...	OK	7.80	OK	No Calc[*]
LG1 (2in.)	26.3	...	...	OK	6.42	OK	No Calc[*]
LG2 (2in.)	26.3	...	...	OK	6.42	OK	No Calc[*]

Nozzle MAWP Summary:

Minimum MAWP Nozzles : 22.8 Nozzle : S1 (4in.) [Shellside]
Minimum MAWP Nozzles : 16.6 Nozzle : T2 (3in.) [Tubeside]

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

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

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T1 (3in.)	200.000	108.819	163.130
20	T2 (3in.)	200.000	251.181	163.130
60	S1 (4in.)	898.525	270.000	201.662
70	S2 (6in.)	2413.525	90.000	310.145
70	V (2in.)	3363.526	90.000	113.600
70	D (2in.)	3363.526	270.000	113.600
70	PSV (3in.)	1483.525	90.000	150.862
70	LG1 (2in.)	1913.525	90.000	102.068
70	LG2 (2in.)	1913.525	270.000	102.068

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!

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Pad Thk mm	Cut Length mm	Flg Class
V (2in.)	2.000 in	Actual	LW	3.307	16.600	...	...	213.9	300
D (2in.)	2.000 in	Actual	LW	3.307	16.600	...	...	213.9	300
LG1 (2in.)	2.000 in	160	WN	2.375	8.738	...	...	162.9	300
LG2 (2in.)	2.000 in	160	WN	2.375	8.738	...	...	162.9	300
T1 (3in.)	3.000 in	80	WN	3.500	7.620	190.00	10.00	230.4	150
T2 (3in.)	3.000 in	80	WN	3.500	7.620	190.00	10.00	230.4	150
PSV (3in.)	3.000 in	160	WN	3.500	11.125	190.00	12.00	214.1	300
S1 (4in.)	4.000 in	120	WN	4.500	11.125	220.00	12.00	196.8	300
S2 (6in.)	6.000 in	80	WN	6.625	10.973	300.00	12.00	199.7	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
V (2in.)	SA-350 LF2	12.000	10.000	...	...	...
D (2in.)	SA-350 LF2	12.000	10.000	...	...	...
LG1 (2in.)	SA-333 6	12.000	10.000	...	...	...
LG2 (2in.)	SA-333 6	12.000	10.000	...	...	...
T1 (3in.)	SA-106 B	10.000	10.000	8.000	10.000	...
T2 (3in.)	SA-106 B	10.000	10.000	8.000	10.000	...
PSV (3in.)	SA-333 6	12.000	10.000	10.000	12.000	...
S1 (4in.)	SA-333 6	12.000	10.000	10.000	12.000	...
S2 (6in.)	SA-333 6	12.000	10.000	10.000	12.000	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
V (2in.)	3363.525	90.0	200.00	0.00	SH. Barrel
D (2in.)	3363.525	270.0	200.00	0.00	SH. Barrel
LG1 (2in.)	1913.525	90.0	150.00	0.00	SH. Barrel
LG2 (2in.)	1913.525	270.0	150.00	0.00	SH. Barrel
T1 (3in.)	200.000	108.8	200.00	0.00	CH. Barrel
T2 (3in.)	200.000	251.2	200.00	0.00	CH. Barrel
PSV (3in.)	1483.525	90.0	200.00	0.00	SH. Barrel
S1 (4in.)	898.525	270.0	180.00	0.00	SH. Cone
S2 (6in.)	2413.525	90.0	180.00	0.00	SH. Barrel

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	ELLIPTICAL HEAD: 2.0 X 1, 12.0mm. THK X 600.0mm. ID X 50.0mm.	SA-516 70
1	CYLINDER: 10.0mm. THK X 600.0mm. ID X 300.0mm.	SA-516 70
1	BODY FLANGE: 90.0mm. THK X 760.0mm. OD	SA-266 2
1	BODY FLANGE: 90.0mm. THK X 760.0mm. OD	SA-350 LF2
1	CYLINDER: 12.0mm. THK X 600.0mm. ID X 150.0mm.	SA-516 70
1	CONE: 12.0mm. THK X 925.0mm. ID X 565.0mm.	SA-516 70
1	CYLINDER: 12.0mm. THK X 925.0mm. ID X 2200.0mm.	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 14.0mm. THK X 925.0mm. ID X 50.0mm.	SA-516 70
1	INSULATION: 200mm X 60mm THK	
1	INSULATION: 300mm X 60mm THK	
1	INSULATION: 85mm X 60mm THK	
1	TUBESHEET: 650mm X 60mm THK	SA-350 LF2
376	TUBES: 2300mm X 19mm DIA X 1mm THK	SA-334 6
1	INSULATION: 84mm X 60mm THK	
1	INSULATION: 150mm X 60mm THK	
1	INSULATION: 565mm X 60mm THK	
2	SADDLE: 140mm X 120 DEG	SA-516 70
1	INSULATION: 2200mm X 60mm THK	
1	INSULATION: 281mm X 60mm THK	
1	GASKET: 650mm. OD X 624mm. ID	...
20	BODY FLANGE BOLTS: 22mm. DIA	SA-193 B7
40	NUTS FOR BODY FLANGE BOLTS: 22mm. DIA	...
1	NAMEPLATE	...

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
SH. Flange	[11]	!	-46	-46		0.566	12.000	1.00	No
Port Barrel	[8]	D	-48	-48	-29	0.562	12.000	1.00	No
SH. Cone	[8]	D	-48	-48	-29	0.998	12.000	1.00	No
SH. Barrel	[8]	D	-48	-48	-29	0.863	12.000	1.00	No
SH. Head	[10]	D	-48	-48	-29	0.849	12.000	1.00	No
SH. Head	[7]	D	-48	-48	-29	0.706	14.000	1.00	No
S1 (4in.)	[1]	D	-48	-48	-29	0.716	12.000	1.00	No
Nozzle Flg	[5]	!	-46	-89					
S2 (6in.)	[1]	D	-48	-48	-29	0.833	12.000	1.00	No
Nozzle Flg	[5]	!	-46	-89					
V (2in.)	[1]	D	-48	-48	-29	0.833	12.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
D (2in.)	[1]	D	-48	-48	-29	0.835	12.000	1.00	No
Nozzle Flg	[5]	!	-46	-46					
PSV (3in.)	[1]	D	-48	-48	-29	0.833	12.000	1.00	No
Nozzle Flg	[5]	!	-46	-89					
LG1 (2in.)	[1]	D	-46	-104		0.104	7.645	1.00	No
Nozzle Flg	[5]	!	-46	-89					
LG2 (2in.)	[1]	D	-46	-104		0.104	7.645	1.00	No
Nozzle Flg	[5]	!	-46	-89					
Tubesheet: SS	[13]	!	-46	-46		0.838	15.000	1.00	No
Warmest MDMT:			-46	-46					
CH. Flange	[11]	C	-44	-48	-29	0.466	10.000	1.00	No
CH. Head	[10]	D	-48	-48	-29	0.454	10.000	1.00	No
CH. Head	[7]	D	-48	-48	-29	0.359	12.000	1.00	No
CH. Barrel	[8]	D	-48	-48	-29	0.462	10.000	1.00	No
T1 (3in.)	[1]	B	-8	-104	-29	0.070	6.668	1.00	No
Nozzle Flg	[5]	A	-18	-104					
T2 (3in.)	[1]	B	-8	-104	-29	0.070	6.668	1.00	No
Nozzle Flg	[5]	A	-18	-104					
Tubesheet: CS	[14]	!	-46	-46		0.838	15.000	1.00	No
Bolting	[21]		-48						
Warmest MDMT:			-8	-46					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-46.0	-45.0	Pass
Channel/Tube	-46.0	-29.0	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] - Body Flange Bolting Material
[22] - Nozzle Flange 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.

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

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

Warning: CH. Flange and SH. Flange

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.

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

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	22	bars
Channel Side Design Pressure	6.8	bars
Shell Side Design Temperature	120.0	°C
Channel Side Design Temperature	85.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-45.0	°C
MDMT (CET), Tube Side	-29.0	°C
User defined MAWP, Shell Side	0	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

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

Shop Pressure Test:

Type of Pressure Test	UG-99(b) Note [35]
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

Wind Design Code	UBC-94/97	
UBC Design Wind Speed	125	Km/hr
UBC Exposure Constant	D: Flat, unobstructed	
UBC Importance Factor	1.0	
UBC Base Elevation	20000	mm.
UBC Percent Wind for Hydrotest	33.0	

```
Using User defined Wind Press. Vs Elev.                  N
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                               UBC 1997
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)                 5
UBC Importance Factor                                1.250
UBC Seismic Coefficient Ca                           0.400
UBC Seismic Coefficient Cv                           0.560
UBC Seismic Coefficient Nv                           1.000
UBC Horizontal Force Factor                          3.000
Apply Allowables per paragraph 1612.3.2                 No

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                                    Elliptical
Description                                       CH. Head
Distance "FROM" to "TO"                                 50  mm.
Inside Diameter                                        600  mm.
Element Thickness                                       10  mm.
Internal Corrosion Allowance                             3  mm.
Nominal Thickness                                       12  mm.
External Corrosion Allowance                             0  mm.
Design Internal Pressure                               6.8  bars
Design Temperature Internal Pressure                    85  °C
Design External Pressure                                 1  bars
Design Temperature External Pressure                    85  °C
Effective Diameter Multiplier                          1.2
Material Name                                  SA-516 70 [Normalized]
    Allowable Stress, Ambient                        137.9  N./mm²
    Allowable Stress, Operating                      137.9  N./mm²
    Allowable Stress, Hydrotest                      235.8  N./mm²
    Material Density                               0.00775  kg./cm³
    P Number Thickness                              30.988  mm.
    Yield Stress, Operating                          241.8  N./mm²
    UCS-66 Chart Curve Designation                       D
    External Pressure Chart Name                      CS-2
    UNS Number                                      K02700
    Product Form                                     Plate
Efficiency, Longitudinal Seam                          1.0
```

```
Efficiency, Circumferential Seam                     1.0
Elliptical Head Factor                               2.0
Weld is pre-Heated                                    No

    Element From Node                                 10
    Detail Type                                   Liquid
    Detail ID                                 Liquid: 10
    Dist. from "FROM" Node / Offset dist               0  mm.
    Height/Length of Liquid                          600  mm.
    Liquid Density                             0.0009181  kg./cm³

    Element From Node                                 10
    Detail Type                               Insulation
    Detail ID                                    Ins: 10
    Dist. from "FROM" Node / Offset dist            -150  mm.
    Height/Length of Insulation                      200  mm.
    Thickness of Insulation                           60  mm.
    Density                                      0.00023  kg./cm³

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

Element From Node                                     20
Element To Node                                       30
Element Type                                    Cylinder
Description                                   CH. Barrel
Distance "FROM" to "TO"                              300  mm.
Inside Diameter                                      600  mm.
Element Thickness                                     10  mm.
Internal Corrosion Allowance                           3  mm.
Nominal Thickness                                     10  mm.
External Corrosion Allowance                           0  mm.
Design Internal Pressure                             6.8  bars
Design Temperature Internal Pressure                  85  °C
Design External Pressure                          1.0342  bars
Design Temperature External Pressure                  85  °C
Effective Diameter Multiplier                        1.2
Material Name                                 SA-516 70 [Normalized]
Efficiency, Longitudinal Seam                        1.0
Efficiency, Circumferential Seam                     1.0
Weld is pre-Heated                                    No

    Element From Node                                 20
    Detail Type                                   Liquid
    Detail ID                                 Liquid: 20
    Dist. from "FROM" Node / Offset dist               0  mm.
    Height/Length of Liquid                          600  mm.
    Liquid Density                             0.0009181  kg./cm³

    Element From Node                                 20
    Detail Type                               Insulation
    Detail ID                                    Ins: 20
    Dist. from "FROM" Node / Offset dist               0  mm.
    Height/Length of Insulation                      300  mm.
    Thickness of Insulation                           60  mm.
    Density                                      0.00023  kg./cm³

    Element From Node                                 20
    Detail Type                                   Nozzle
    Detail ID                                  T1 (3in.)
    Dist. from "FROM" Node / Offset dist             150  mm.
    Nozzle Diameter                                    3  in.
    Nozzle Schedule                                   80
    Nozzle Class                                     150
    Layout Angle                                 108.819
    Blind Flange (Y/N)                                 N
    Weight of Nozzle ( Used if > 0 )              11.862  Kgf
```

```
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                     SA-106 B

    Element From Node                                     20
    Detail Type                                       Nozzle
    Detail ID                                     T2 (3in.)
    Dist. from "FROM" Node / Offset dist                 150  mm.
    Nozzle Diameter                                        3  in.
    Nozzle Schedule                                       80
    Nozzle Class                                         150
    Layout Angle                                     251.181
    Blind Flange (Y/N)                                     N
    Weight of Nozzle ( Used if > 0 )                  11.862  Kgf
    Grade of Attached Flange                          GR 1.1
    Nozzle Matl                                     SA-106 B

    Element From Node                                     20
    Detail Type                                       Weight
    Detail ID                                    PASS PAR.0
    Dist. from "FROM" Node / Offset dist                 150  mm.
    Miscellaneous Weight                                  70  Kgf
    Offset from Element Centerline                         0  mm.

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

Element From Node                                         30
Element To Node                                           40
Element Type                                        Flange
Description                                       CH. Flange
Distance "FROM" to "TO"                                   85  mm.
Flange Inside Diameter                                   600  mm.
Element Thickness                                         60  mm.
Internal Corrosion Allowance                               3  mm.
Nominal Thickness                                         90  mm.
External Corrosion Allowance                               0  mm.
Design Internal Pressure                                 6.8  bars
Design Temperature Internal Pressure                      85  °C
Design External Pressure                              1.0342  bars
Design Temperature External Pressure                      85  °C
Effective Diameter Multiplier                            1.2
Material Name                                       SA-266 2
    Allowable Stress, Ambient                          137.9  N./mm²
    Allowable Stress, Operating                        137.9  N./mm²
    Allowable Stress, Hydrotest                        223.4  N./mm²
    Material Density                                 0.00775  kg./cm³
    P Number Thickness                                30.988  mm.
    Yield Stress, Operating                            229.2  N./mm²
    UCS-66 Chart Curve Designation                         C
    External Pressure Chart Name                        CS-2
    UNS Number                                        K03506
    Product Form                                    Forgings
Perform Flange Stress Calculation (Y/N)                    Y
Weight of Standard Flange                                  0  Kgf
Class of Standard Flange
Grade of Standard Flange
Weld is pre-Heated                                        No

    Element From Node                                     30
    Detail Type                                       Liquid
    Detail ID                                     Liquid: 30
    Dist. from "FROM" Node / Offset dist                   0  mm.
    Height/Length of Liquid                              600  mm.
    Liquid Density                                 0.0009181  kg./cm³

    Element From Node                                     30
    Detail Type                                   Insulation
```

```
    Detail ID                                     Ins: 30
    Dist. from "FROM" Node / Offset dist                0  mm.
    Height/Length of Insulation                        85  mm.
    Thickness of Insulation                            60  mm.
    Density                                       0.00023  kg./cm³

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

Element From Node                                      40
Element To Node                                        50
Element Type                                     Flange
Description                                   SH. Flange
Distance "FROM" to "TO"                                85  mm.
Flange Inside Diameter                                600  mm.
Element Thickness                                      60  mm.
Internal Corrosion Allowance                            3  mm.
Nominal Thickness                                      90  mm.
External Corrosion Allowance                            0  mm.
Design Internal Pressure                               22  bars
Design Temperature Internal Pressure                  120  °C
Design External Pressure                           1.0342  bars
Design Temperature External Pressure                  120  °C
Effective Diameter Multiplier                         1.2
Material Name                                 SA-350 LF2 [Impact Tested]
    Allowable Stress, Ambient                       137.9  N./mm²
    Allowable Stress, Operating                     137.9  N./mm²
    Allowable Stress, Hydrotest                     223.4  N./mm²
    Material Density                              0.00775  kg./cm³
    P Number Thickness                             30.988  mm.
    Yield Stress, Operating                         223.6  N./mm²
    UCS-66 Chart Curve Designation          Impact Tested
    External Pressure Chart Name                     CS-2
    UNS Number                                     K03011
    Class / Thickness / Grade                         1::
    Product Form                                 Forgings
Perform Flange Stress Calculation (Y/N)                 Y
Weight of Standard Flange                               0  Kgf
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                           600  mm.
    Liquid Density                              0.0005329  kg./cm³

    Element From Node                                  40
    Detail Type                                Insulation
    Detail ID                                     Ins: 40
    Dist. from "FROM" Node / Offset dist                0  mm.
    Height/Length of Insulation                        85  mm.
    Thickness of Insulation                            60  mm.
    Density                                       0.00023  kg./cm³

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

Element From Node                                      50
Element To Node                                        60
Element Type                                     Cylinder
Description                                   Port Barrel
Distance "FROM" to "TO"                               150  mm.
Inside Diameter                                       600  mm.
Element Thickness                                      12  mm.
Internal Corrosion Allowance                            3  mm.
```

```
Nominal Thickness                                         12  mm.
External Corrosion Allowance                               0  mm.
Design Internal Pressure                                  22  bars
Design Temperature Internal Pressure                     120  °C
Design External Pressure                              1.0342  bars
Design Temperature External Pressure                     120  °C
Effective Diameter Multiplier                            1.2
Material Name                                      SA-516 70 [Normalized]
    Allowable Stress, Ambient                          137.9  N./mm²
    Allowable Stress, Operating                        137.9  N./mm²
    Allowable Stress, Hydrotest                        235.8  N./mm²
    Material Density                                 0.00775  kg./cm³
    P Number Thickness                                30.988  mm.
    Yield Stress, Operating                              236  N./mm²
    UCS-66 Chart Curve Designation                         D
    External Pressure Chart Name                        CS-2
    UNS Number                                        K02700
    Product Form                                       Plate
Efficiency, Longitudinal Seam                            1.0
Efficiency, Circumferential Seam                         1.0
Weld is pre-Heated                                        No

    Element From Node                                     50
    Detail Type                                       Liquid
    Detail ID                                     Liquid: 50
    Dist. from "FROM" Node / Offset dist                   0  mm.
    Height/Length of Liquid                              600  mm.
    Liquid Density                                 0.0005329  kg./cm³

    Element From Node                                     50
    Detail Type                                   Insulation
    Detail ID                                        Ins: 50
    Dist. from "FROM" Node / Offset dist                   0  mm.
    Height/Length of Insulation                          150  mm.
    Thickness of Insulation                               60  mm.
    Density                                          0.00023  kg./cm³

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

Element From Node                                         60
Element To Node                                           70
Element Type                                         Conical
Description                                         SH. Cone
Distance "FROM" to "TO"                                  565  mm.
Inside Diameter                                          600  mm.
Element Thickness                                         12  mm.
Internal Corrosion Allowance                               3  mm.
Nominal Thickness                                         12  mm.
External Corrosion Allowance                               0  mm.
Design Internal Pressure                                  22  bars
Design Temperature Internal Pressure                     120  °C
Design External Pressure                              1.0342  bars
Design Temperature External Pressure                     120  °C
Effective Diameter Multiplier                            1.2
Material Name                                      SA-516 70 [Normalized]
Efficiency, Longitudinal Seam                            1.0
Efficiency, Circumferential Seam                         1.0
Cone Diameter at "To" End                                925  mm.
Design Length of Cone                                    565  mm.
Half Apex Angle of Cone                                 30.0  degrees
Toriconical (Y/N)                                          N
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                             925  mm.
     Liquid Density                                0.0005329  kg./cm³

     Element From Node                                    60
     Detail Type                                  Insulation
     Detail ID                                       Ins: 60
     Dist. from "FROM" Node / Offset dist                  0  mm.
     Height/Length of Insulation                         565  mm.
     Thickness of Insulation                              60  mm.
     Density                                         0.00023  kg./cm³

     Element From Node                                    60
     Detail Type                                      Nozzle
     Detail ID                                     S1 (4in.)
     Dist. from "FROM" Node / Offset dist                150  mm.
     Nozzle Diameter                                       4  in.
     Nozzle Schedule                                     120
     Nozzle Class                                        300
     Layout Angle                                      270.0
     Blind Flange (Y/N)                                    N
     Weight of Nozzle ( Used if > 0 )                 25.056  Kgf
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                    SA-333 6 [Impact Tested]

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

 Element From Node                                        70
 Element To Node                                          80
 Element Type                                       Cylinder
 Description                                      SH. Barrel
 Distance "FROM" to "TO"                                2200  mm.
 Inside Diameter                                         925  mm.
 Element Thickness                                        12  mm.
 Internal Corrosion Allowance                              3  mm.
 Nominal Thickness                                        12  mm.
 External Corrosion Allowance                              0  mm.
 Design Internal Pressure                                 22  bars
 Design Temperature Internal Pressure                    120  °C
 Design External Pressure                             1.0342  bars
 Design Temperature External Pressure                    120  °C
 Effective Diameter Multiplier                           1.2
 Material Name                                     SA-516 70 [Normalized]
 Efficiency, Longitudinal Seam                           1.0
 Efficiency, Circumferential Seam                        1.0
 Weld is pre-Heated                                       No

     Element From Node                                    70
     Detail Type                                      Saddle
     Detail ID                                   Left Saddle
     Dist. from "FROM" Node / Offset dist                230  mm.
     Width of Saddle                                     140  mm.
     Height of Saddle at Bottom                          750  mm.
     Saddle Contact Angle                              120.0
     Height of Composite Ring Stiffener                    0  mm.
     Width of Wear Plate                                 300  mm.
     Thickness of Wear Plate                              12  mm.
     Contact Angle, Wear Plate (degrees)               132.0
     Friction coefficient                         0.30000001
     Moment Factor                                       3.0
     Dimension E at base (optional)                        0  mm.
     Circumferential Eff. over Saddle                    1.0
     Circumferential Eff. at Midspan                     1.0
     Tangent to Tangent dist. (optional)                   0  mm.

     Element From Node                                    70
```

```
Detail Type                                      Saddle
Detail ID                                  Right Saddle
Dist. from "FROM" Node / Offset dist               1650  mm.
Width of Saddle                                     140  mm.
Height of Saddle at Bottom                          750  mm.
Saddle Contact Angle                              120.0
Height of Composite Ring Stiffener                    0  mm.
Width of Wear Plate                                 300  mm.
Thickness of Wear Plate                              12  mm.
Contact Angle, Wear Plate (degrees)               132.0
Friction coefficient                         0.30000001
Moment Factor                                       3.0
Dimension E at base (optional)                        0  mm.
Circumferential Eff. over Saddle                    1.0
Circumferential Eff. at Midspan                     1.0
Tangent to Tangent dist. (optional)                   0  mm.

Element From Node                                    70
Detail Type                                      Liquid
Detail ID                                    Liquid: 70
Dist. from "FROM" Node / Offset dist                  0  mm.
Height/Length of Liquid                             925  mm.
Liquid Density                                0.0005329  kg./cm³

Element From Node                                    70
Detail Type                                  Insulation
Detail ID                                       Ins: 70
Dist. from "FROM" Node / Offset dist                  0  mm.
Height/Length of Insulation                        2200  mm.
Thickness of Insulation                              60  mm.
Density                                         0.00023  kg./cm³

Element From Node                                    70
Detail Type                                      Nozzle
Detail ID                                     S2 (6in.)
Dist. from "FROM" Node / Offset dist               1100  mm.
Nozzle Diameter                                       6  in.
Nozzle Schedule                                      80
Nozzle Class                                        300
Layout Angle                                       90.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                 47.688  Kgf
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                    SA-333 6 [Impact Tested]

Element From Node                                    70
Detail Type                                      Nozzle
Detail ID                                      V (2in.)
Dist. from "FROM" Node / Offset dist               2050  mm.
Nozzle Diameter                                       2  in.
Nozzle Schedule                                    None
Nozzle Class                                        300
Layout Angle                                       90.0
Blind Flange (Y/N)                                    N
Weight of Nozzle ( Used if > 0 )                 9.9881  Kgf
Grade of Attached Flange                         GR 1.1
Nozzle Matl                                  SA-350 LF2 [Impact Tested]

Element From Node                                    70
Detail Type                                      Nozzle
Detail ID                                      D (2in.)
Dist. from "FROM" Node / Offset dist               2050  mm.
Nozzle Diameter                                       2  in.
Nozzle Schedule                                    None
Nozzle Class                                        300
Layout Angle                                      270.0
```

```
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 9.9881  Kgf
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                  SA-350 LF2 [Impact Tested]

    Element From Node                                    70
    Detail Type                                      Nozzle
    Detail ID                                    PSV (3in.)
    Dist. from "FROM" Node / Offset dist                170  mm.
    Nozzle Diameter                                       3  in.
    Nozzle Schedule                                     160
    Nozzle Class                                        300
    Layout Angle                                       90.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 16.474  Kgf
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                    SA-333 6 [Impact Tested]

    Element From Node                                    70
    Detail Type                                      Nozzle
    Detail ID                                    LG1 (2in.)
    Dist. from "FROM" Node / Offset dist                600  mm.
    Nozzle Diameter                                       2  in.
    Nozzle Schedule                                     160
    Nozzle Class                                        300
    Layout Angle                                       90.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 6.0973  Kgf
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                    SA-333 6 [Impact Tested]

    Element From Node                                    70
    Detail Type                                      Nozzle
    Detail ID                                    LG2 (2in.)
    Dist. from "FROM" Node / Offset dist                600  mm.
    Nozzle Diameter                                       2  in.
    Nozzle Schedule                                     160
    Nozzle Class                                        300
    Layout Angle                                      270.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 8.7691  Kgf
    Grade of Attached Flange                         GR 1.1
    Nozzle Matl                                    SA-333 6 [Impact Tested]

    Element From Node                                    70
    Detail Type                                      Weight
    Detail ID                                 BUNDLE MISS.0
    Dist. from "FROM" Node / Offset dist                100  mm.
    Miscellaneous Weight                                100  Kgf
    Offset from Element Centerline                      160  mm.

    Element From Node                                    70
    Detail Type                                      Weight
    Detail ID                                 BUNDLE MISS.0
    Dist. from "FROM" Node / Offset dist               1250  mm.
    Miscellaneous Weight                                100  Kgf
    Offset from Element Centerline                      160  mm.

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

 Element From Node                                       80
 Element To Node                                         90
 Element Type                                       Elliptical
 Description                                        SH. Head
 Distance "FROM" to "TO"                                 50  mm.
 Inside Diameter                                        925  mm.
```

Element Thickness	12	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	22	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.0342	bars
Design Temperature External Pressure	120	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	80	
Detail Type	Liquid	
Detail ID	Liquid: 80	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	925	mm.
Liquid Density	0.0005329	kg./cm³

Element From Node	80	
Detail Type	Insulation	
Detail ID	Ins: 80	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	281.25	mm.
Thickness of Insulation	60	mm.
Density	0.00023	kg./cm³

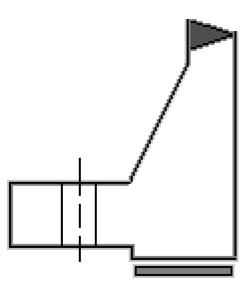
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
CH. Head		50	...	50	...
CH. Barrel		350	...	300	...
CH. Flange		435	...	85	...
SH. Flange		598.525	...	85	...
Port Barrel		748.525	...	150	...
SH. Cone		1313.53	...	565	...
SH. Barrel		3513.53	...	2200	...
SH. Head		3563.53	...	50	...

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

CH. Flange

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	6.85	bars
Design Temperature		85	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	600.000	mm.
Flange Outside Diameter	A	760.000	mm.
Flange Thickness	t	60.0000	mm.
Thickness of Hub at Small End	go	10.0000	mm.
Thickness of Hub at Large End	g1	15.0000	mm.
Length of Hub	h	25.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm²
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Diameter of Bolt Circle	C	705.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	653.000	mm.
Flange Face Inside Diameter	Fid	600.000	mm.
Flange Facing Sketch		2, Code Sketch 1b	
Gasket Outside Diameter	Go	650.000	mm.
Gasket Inside Diameter	Gi	624.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	69.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	4.5000	mm.



ASME Code, Section VIII Division 1, 2019

Hub Small End Required Thickness due to Internal Pressure:
```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (6.85*(600/2+3))/(138*1-0.6*6.85)+Ca
= 4.5106 mm.
```

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

```
  = (138 * 1 * 7 )/(303 + 0.6 * 7 )
  = 31.421 bars

 Corroded Flange Thickness, tc = T-ci                       57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                  606.000  mm.
 Corroded Large Hub,      g1Cor = g1-ci                     12.000  mm.
 Corroded Small Hub,      g0Cor = go-ci                      7.000  mm.
 Code R Dimension,            R = ((C-Bcor)/2)-g1cor        37.500  mm.

 Gasket Contact Width,        N = (Go - Gi) / 2             13.000  mm.
 Basic Gasket Width,         bo = N / 2                      6.500  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)                6.425  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b               637.151  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 637² * 6.85
  = 22285.168 Kgf
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 6.42 * 3.14 * 637 * 3 * 6.85
  = 5392.977 Kgf
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 606² *6.85/4
  = 20159.355 Kgf
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 22285 - 20159
  = 2125.812 Kgf
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 22285 + 5393 + 0, 0 )
  = 27678.143 Kgf
  = 88967.883 Kgf, Mating Flange Load Governs
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 69*6.42*3.141*637+0*0*0
  = 90480.758 Kgf
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 88968/172, 90481/172
  = 51.477 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.2 + 6 * 57/(3 + 0.5)
  = 142.164 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 705 * sin( 3.14/20 )
  = 110.286 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 110/( 2 * 22.2 + 57 )), 1 )
  = 1.0426
```

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

	Minimum	Actual	Maximum

```
 Bolt Area, cm²                                 51.477     54.064
 Radial Distance between Hub and Bolts:         31.750     37.500
 Radial Distance between Bolts and Edge:        23.812     27.500
 Circ. Spacing between the Bolts:               52.400    110.286    142.164
 -------------------------------------------------------------------------
```

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 54.1  * 172/(69 * 3.14 *(650 + 624 ) )
  = 3.375 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172 *( 51.5 + 54.1 )/2
  = 92754.98 Kgf
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 88968 - 22285
  = 66682.71 Kgf
```

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 705 - 637 )/2
  = 33.9246 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 37.5 + 12 + 33.9 )/2
  = 41.7123 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 37.5 +( 12/2.0 )
  = 43.5000 mm.
```

Summary of Moments for Internal Pressure: (Kg-m.)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	20159.	43.5000	1.0426	914.
Face Pressure, Mt	2126.	41.7123	1.0426	92.
Gasket Load, Mg	66683.	33.9246	1.0426	2359.
Gasket Seating, Matm	92755.	33.9246	1.0426	3281.

```
 Total Moment for Operation,      Mop                           3365. Kg-m.
 Total Moment for Gasket seating, Matm                          3281. Kg-m.

 Effective Hub Length, ho = sqrt(Bcor*goCor)          65.131  mm.
 Hub Ratio,          h/h0 = HL / H0                    0.384
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.714
```

Flange Factors for Integral Flange:
```
 Factor F                                              0.858
 Factor V                                              0.302
 Factor f                                              1.217
 Factors from Figure 2-7.1                    K =      1.254
                    T =      1.817            U =      9.566
                    Y =      8.705            Z =      4.491
                    d = 0.10120E+06 mm.³        e =     0.0132 mm.^-1
 Stress Factors                           ALPHA =      1.751
                 BETA =      2.001        GAMMA =      0.964
                DELTA =      1.830        Lamda =      2.794
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.22*3365/606)/(2.79*12²)
```

= 164.79 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.22*3281/606)/(2.79*12²)
  = 160.65 N./mm²
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2*3365/606)/(2.79*57²)
  = 12.01 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2*3281/606)/(2.79*57²)
  = 11.71 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (8.7*3365/(57²*606))-4.49*12
  = 91.99 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (8.7*3281/(57²*606))-4.49*11.7
  = 89.68 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (165+max(12,92))/2
  = 128.39 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (161+max(11.7,89.7))/2
  = 125.16 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 88968/54.1
  = 161.38 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (90481/54.1)
  = 164.12 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	164.79	206.85	160.65	206.85
Radial Flange	12.01	137.90	11.71	137.90
Tangential Flange	91.99	137.90	89.68	137.90
Maximum Average	128.39	137.90	125.16	137.90
Bolting	161.38	172.38	164.12	172.38

```
 Minimum Required Flange Thickness [Rigidity]          58.242 mm.
 Estimated M.A.W.P. ( Operating )                        14.7 bars
 Estimated Finished Weight of Flange at given Thk.       84.1 kg.
 Estimated Unfinished Weight of Forging at given Thk    112.6 kg.
```

<u>Flange Rigidity Based on Required Thickness [ASME]:</u>

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*3310/1.05*9807*0.3/(2.61*202713*7²*65.1*0.3)
  = 0.956   (should be <= 1)
```

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*3395/1.05*9807*0.3/(2.61*199054*7^2*65.1*0.3)$
$= 0.999$ (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*3281/1.04*9807*0.3/(2.79*202713*7^2*65.1*0.3)$
$= 0.895$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*3365/1.04*9807*0.3/(2.79*199054*7^2*65.1*0.3)$
$= 0.935$ (should be <= 1)

Minimum Design Metal Temperature Results:

Thickness Ratio = 0.47, Temperature Reduction per Fig. UCS 66.1 = 37 °C

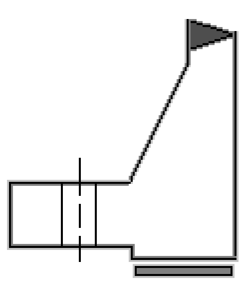
```
Min Metal Temp. w/o impact per UCS-66, Curve C             -44 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

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

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

SH. Flange

```
 Description of Flange Geometry (Type)          Integral Weld Neck
 Design Pressure                         P            22.03  bars
 Design Temperature                                     120  °C
 Internal Corrosion Allowance           ci           3.0000  mm.
 External Corrosion Allowance           ce           0.0000  mm.
 Use Corrosion Allowance in Thickness Calcs.            Yes

 Flange Inside Diameter                  B          600.000  mm.
 Flange Outside Diameter                 A          760.000  mm.
 Flange Thickness                        t          60.0000  mm.
 Thickness of Hub at Small End          go          12.0000  mm.
 Thickness of Hub at Large End          g1          18.0000  mm.
 Length of Hub                           h          25.0000  mm.

 Flange Material                                SA-350 LF2
 Flange Material UNS number                         K03011
 Flange Allowable Stress At Temperature  Sfo        137.90  N./mm²
 Flange Allowable Stress At Ambient      Sfa        137.90  N./mm²

 Bolt Material                                   SA-193 B7
 Bolt Allowable Stress At Temperature    Sb         172.38  N./mm²
 Bolt Allowable Stress At Ambient        Sa         172.38  N./mm²

 Diameter of Bolt Circle                 C          705.000  mm.
 Nominal Bolt Diameter                   a          22.2250  mm.
 Type of Threads                        TEMA Thread Series
 Number of Bolts                                        20

 Flange Face Outside Diameter           Fod         653.000  mm.
 Flange Face Inside Diameter            Fid         600.000  mm.
 Flange Facing Sketch                    2, Code Sketch 1b

 Gasket Outside Diameter                Go          650.000  mm.
 Gasket Inside Diameter                 Gi          624.000  mm.
 Gasket Factor                           m           3.0000
 Gasket Design Seating Stress            y            69.00  N./mm²

 Column for Gasket Seating               2, Code Column II
 Gasket Thickness                       tg           4.5000  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)
  = (22*(600/2+3))/(138*1-0.6*22)+Ca
  = 7.8880 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
```

```
  = (138 * 1 * 9 )/(303 + 0.6 * 9 )
  = 40.241 bars

 Corroded Flange Thickness, tc = T-ci                       57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                  606.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                      15.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                       9.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor         34.500  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2              13.000  mm.
 Basic Gasket Width,        bo = N / 2                       6.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)                 6.425  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b                637.151  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 637² * 22
  = 71632.844 Kgf
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 6.42 * 3.14 * 637 * 3 * 22
  = 17335.039 Kgf
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 606² *22/4
  = 64799.688 Kgf
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 71633 - 64800
  = 6833.158 Kgf
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 71633 + 17335 + 0, 0 )
  = 88967.883 Kgf
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 69*6.42*3.141*637+0*0*0
  = 90480.758 Kgf
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 88968/172, 90481/172
  = 51.477 cm²
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.2 + 6 * 57/(3 + 0.5)
  = 142.164 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 705 * sin( 3.14/20 )
  = 110.286 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 110/( 2 * 22.2 + 57 )), 1 )
  = 1.0426
```

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

	Minimum	Actual	Maximum
Bolt Area, cm²	51.477	54.064	

```
Radial Distance between Hub and Bolts:      31.750     34.500
Radial Distance between Bolts and Edge:     23.812     27.500
Circ. Spacing between the Bolts:            52.400    110.286    142.164
-------------------------------------------------------------------------
```

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

```
= Ab * Sa/( y * Pi * (Go + Gi) )
= 54.1  * 172/(69 * 3.14 *(650 + 624 ) )
= 3.375 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
= Sa * ( Am + Ab ) / 2
= 172 *( 51.5 + 54.1 )/2
= 92754.98 Kgf
```

Gasket Load for the Operating Condition [HG]:

```
= Wm1 - H
= 88968 - 71633
= 17335.04 Kgf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
= (C - G ) / 2
= ( 705 - 637 )/2
= 33.9246 mm.
```

Distance to Face Pressure Reaction [ht]:

```
= ( R + g1 + hg ) / 2
= ( 34.5 + 15 + 33.9 )/2
= 41.7123 mm.
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 34.5 +( 15/2.0 )
= 42.0000 mm.
```

Summary of Moments for Internal Pressure: (Kg-m.)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	64800.	42.0000	1.0426	2838.
Face Pressure, Mt	6833.	41.7123	1.0426	297.
Gasket Load, Mg	17335.	33.9246	1.0426	613.
Gasket Seating, Matm	92755.	33.9246	1.0426	3281.

```
Total Moment for Operation,      Mop                           3748. Kg-m.
Total Moment for Gasket seating, Matm                          3281. Kg-m.

Effective Hub Length, ho = sqrt(Bcor*goCor)          73.851  mm.
Hub Ratio,          h/h0 = HL / H0                    0.339
Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.667
```

Flange Factors for Integral Flange:

```
Factor F                                              0.868
Factor V                                              0.326
Factor f                                              1.295
Factors from Figure 2-7.1                    K =      1.254
                  T =      1.817             U =      9.566
                  Y =      8.705             Z =      4.491
                  d = 0.17564E+06 mm.³        e =     0.0118 mm.^-1
Stress Factors                           ALPHA =      1.670
               BETA =      1.893         GAMMA =      0.919
              DELTA =      1.054         Lamda =      1.973
```

Longitudinal Hub Stress, Operating [SHo]:

```
= ( f * Mop / Bcor ) / ( L * g1² )
= (1.3*3748/606)/(1.97*15²)
= 176.95 N./mm²
```

Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.3*3281/606)/(1.97*15²)
  = 154.89 N./mm²
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (1.89*3748/606)/(1.97*57²)
  = 17.91 N./mm²
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (1.89*3281/606)/(1.97*57²)
  = 15.68 N./mm²
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (8.7*3748/(57²*606))-4.49*17.9
  = 82.07 N./mm²
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (8.7*3281/(57²*606))-4.49*15.7
  = 71.84 N./mm²
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (177+max(17.9,82.1))/2
  = 129.51 N./mm²
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (155+max(15.7,71.8))/2
  = 113.37 N./mm²
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 88968/54.1
  = 161.38 N./mm²
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (90481/54.1)
  = 164.12 N./mm²
```

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	176.95	206.85	154.89	206.85
Radial Flange	17.91	137.90	15.68	137.90
Tangential Flange	82.07	137.90	71.84	137.90
Maximum Average	129.51	137.90	113.37	137.90
Bolting	161.38	172.38	164.12	172.38

```
Minimum Required Flange Thickness                      57.937 mm.
Estimated M.A.W.P. ( Operating )                         23.5 bars
Estimated Finished Weight of Flange at given Thk.        85.1 kg.
Estimated Unfinished Weight of Forging at given Thk     112.6 kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*3315/1.05*9807*0.33/(1.85*202713*9²*73.9*0.3)
  = 0.779   (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*3787/1.05*9807*0.33/(1.85*196922*9²*73.9*0.3)
  = 0.916   (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

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

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14*3281/1.04*9807*0.33/(1.97*202713*9²*73.9*0.3)
  = 0.730   (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14*3748/1.04*9807*0.33/(1.97*196922*9²*73.9*0.3)
  = 0.858   (should be <= 1)
```

Minimum Design Metal Temperature Results:

Note:

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

```
 Impact Test Temperature provided per Specification         -46 °C
```

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

Internal Pressure Results Summary:

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
CH. Head		6.8543	12	3	600	137.9
CH. Barrel		6.8543	10	3	600	137.9
CH. Flange		6.854	90	3	600	137.9
SH. Flange		22.031	90	3	600	137.9
Port Barrel		22.032	12	3	600	137.9
SH. Cone		22.048	12	3	925	137.9
SH. Barrel		22.048	12	3	925	137.9
SH. Head		22.048	14	3	925	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
CH. Head		6.8	32.1	45.8	10	4.5
CH. Barrel		6.8	31.4	45.1	10	4.51065
CH. Flange		6.8	14.6	23.5	60	58.2422
SH. Flange		22	23.4	23.5	60	57.9374
Port Barrel		22	40.2	53.9	12	7.888
SH. Cone		22	22.8	30.6	12	11.6866
SH. Barrel		22	26.3	35.2	12	10.5153
SH. Head		22	26.8	35.7	12	10.3917

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      =          22.8 bars
Shell Side MAPnc     =          23.5 bars
Channel Side  MAWP   =          14.6 bars
Channel Side  MAPnc  =          19.6 bars
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 85 °C

CH. Head
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
 = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
 = (6.85*606*0.99)/(2*138*1-0.2*6.85)
 = 1.4873 + 3.0000 = 4.4873 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 0.054 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*7)/(0.99*606+0.2*7)
  = 32.2 - 0.054 = 32.1  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*10)/(1*600+0.2*10)
  = 45.8 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (6.85*(0.99*606+0.2*7))/(2*1*7)
  = 29.354 N./mm²
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (6.85*303)/(138*1-0.6*6.85)+3
  = 4.511 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.054 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 9 )/(303 + 0.6 * 9 )
  = 40.2 - 0.054 = 40.2  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 +( 606/( 2 * 153 ))²)/6
  = 0.986992
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 8.333 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10, tr = 3.18, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.45, Temp. Reduction = 39 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12, tr = 3.24, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.36, Temp. Reduction = 71 °C

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

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 85 °C

CH. Barrel
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (6.85*303)/(138*1-0.6*6.85)
  = 1.5106 + 3.0000 = 4.5106 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.054 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138*1*7)/(303+0.6*7)
```

= 31.4 - 0.054 = 31.4 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*10)/(300+0.6*10)
= 45.1 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (6.85*(303+0.6*7))/(1*7)
= 30.082 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.639 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10, tr = 3.24, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.46, Temp. Reduction = 38 °C

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

Cylindrical Shell From 50 To 60 SA-516 70 , UCS-66 Crv. D at 120 °C

Port Barrel
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (22*303)/(138*1-0.6*22)
= 4.8880 + 3.0000 = 7.8880 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.032 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*9)/(303+0.6*9)
= 40.2 - 0.032 = 40.2 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*12)/(300+0.6*12)
= 53.9 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (22*(303+0.6*9))/(1*9)
= 75.499 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.961 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 12, tr = 5.06, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.56, Temp. Reduction = 26 °C

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

Conical Section From 60 To 70 SA-516 70 , UCS-66 Crv. D at 120 °C

SH. Cone
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
= (22*932)/(2*0.87*(138*1-0.6*22))

```
= 8.6866 + 3.0000 = 11.6866 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.048 bars

```
= (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
= (2*138*1*9*0.87)/(932+1.2*9*0.87)
= 22.8 - 0.048 = 22.8  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
= (2*138*1*12*0.87)/(925+1.2*12*0.87)
= 30.6 bars
```

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

```
= (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
= (22*(932+1.2*9*0.87))/(2*1*9*0.87)
= 133.144 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.955 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 12, tr = 8.98, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 1, Temp. Reduction = 0 °C

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

Cylindrical Shell From 70 To 80 SA-516 70 , UCS-66 Crv. D at 120 °C

SH. Barrel
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (22*466)/(138*1-0.6*22)
= 7.5153 + 3.0000 = 10.5153 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.048 bars

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*9)/(466+0.6*9)
= 26.4 - 0.048 = 26.3  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138*1*12)/(462+0.6*12)
= 35.2 bars
```

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

```
= (P*(R+0.6*t))/(E*t)
= (22*(466+0.6*9))/(1*9)
= 115.369 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.281 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 12, tr = 7.77, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.86, Temp. Reduction = 8 °C

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

Elliptical Head From 80 To 90 SA-516 70 , UCS-66 Crv. D at 120 °C

SH. Head
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (22*931*0.99)/(2*138*1-0.2*22)
  = 7.3917 + 3.0000 = 10.3917 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.048 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*9)/(0.99*931+0.2*9)
  = 26.8 - 0.048 = 26.8  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*138*1*12)/(1*925+0.2*12)
  = 35.7 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (22*(0.99*931+0.2*9))/(2*1*9)
  = 113.296 N./mm²
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (22*466)/(138*1-0.6*22)+3
  = 10.515 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.048 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (138 * 1 * 11 )/(466 + 0.6 * 11 )
  = 32.1 - 0.048 = 32.1  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 +( 931/( 2 * 234 ))²)/6
  = 0.991489
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 6.393 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 12, tr = 7.64, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.85, Temp. Reduction = 8 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 14, tr = 7.77, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.71, Temp. Reduction = 16 °C

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

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S         29.624  bars
```

```
 Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S       28.600  bars
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       30.501  bars
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          25.066  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     31.460  bars
 Pressure per App 27-4  = M.A.W.P.                        22.788  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          19.018  bars
 Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S        8.840  bars
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       25.480  bars
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          16.092  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)      9.724  bars
 Pressure per App 27-4  = M.A.W.P.                        14.629  bars
```

UG-99(b) Note 35, Test Pressure Calculation [Shell Side]:

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 22 * 1
  = 28.600 bars
```

UG-99(b) Note 35, Test Pressure Calculation [Channel Side]:

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 6.8 * 1
  = 8.840 bars
```

Horizontal Test performed per: UG-99b (Note 35)

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
CH. Head	38.1	235.8	0.162	8.90
CH. Barrel	39.1	235.8	0.166	8.90
Port Barrel	98.2	235.8	0.416	28.66
SH. Cone	173.3	235.8	0.735	28.69
SH. Barrel	150.1	235.8	0.637	28.69
SH. Head	147.4	235.8	0.625	28.69

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1 (3in.)	Nozzle	117.90	117.90	1.000
T1 (3in.)	Pad	137.90	137.90	1.000
T2 (3in.)	Nozzle	117.90	117.90	1.000
T2 (3in.)	Pad	137.90	137.90	1.000
S1 (4in.)	Nozzle	117.90	117.90	1.000
S1 (4in.)	Pad	137.90	137.90	1.000
S2 (6in.)	Nozzle	117.90	117.90	1.000
S2 (6in.)	Pad	137.90	137.90	1.000
V (2in.)	Nozzle	137.90	137.90	1.000
D (2in.)	Nozzle	137.90	137.90	1.000
PSV (3in.)	Nozzle	117.90	117.90	1.000
PSV (3in.)	Pad	137.90	137.90	1.000
LG1 (2in.)	Nozzle	117.90	117.90	1.000
LG2 (2in.)	Nozzle	117.90	117.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
CH. Head	137.90	137.90	1.000
CH. Barrel	137.90	137.90	1.000
CH. Flange	137.90	137.90	1.000
SH. Flange	137.90	137.90	1.000
Port Barrel	137.90	137.90	1.000
SH. Cone	137.90	137.90	1.000
SH. Barrel	137.90	137.90	1.000
SH. Head	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
T1 (3in.)	10.43	217.19	0.048
T2 (3in.)	10.43	217.19	0.048
S1 (4in.)	23.20	217.20	0.107
S2 (6in.)	35.42	217.19	0.163
V (2in.)	7.71	223.40	0.035
D (2in.)	7.71	223.40	0.035
PSV (3in.)	17.79	217.19	0.082
LG1 (2in.)	17.48	217.19	0.080
LG2 (2in.)	17.48	217.19	0.080

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 N./mm²
10	20	No Calc	620	7	0.0015681	97.9287
20	30	400	620	7	0.0026194	109.396
30	40	No Calc	...	57	No Calc	No Calc
40	50	No Calc	...	57	No Calc	No Calc
50	60	150	624	9	0.012325	122.731
60	70	2892.08	952.713	9	0.00030613	30.6064
70	80	2892.08	949	9	0.00038034	38.0256
80	90	No Calc	949	9	0.0013172	93.319

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	4.57853	1	12.3
20	30	10	4.65419	1.03419	16.5
30	40	60	57.277	1.03419	No Calc
40	50	60	53.5432	1.03419	No Calc
50	60	12	4.10182	1.03419	23.6
60	70	12	8.61227	1.03419	3.34
70	80	12	7.84861	1.03419	4.81
80	90	12	5.45716	1.03419	9.83
Minimum					3.34

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	400	11389	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	150	3156.37	No Calc	No Calc
60	70	2892.08	2892.08	No Calc	No Calc
70	80	2892.08	61083.1	No Calc	No Calc
80	90	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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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	50.6331	42419.1	37.9748	43560.2	3.03799
20	30	44.5585	84838.2	31.3443	86543.5	2.67351
30	40	123.873	33032.9	118.807	33175	7.43237
40	50	124.828	33032.9	119.762	33175	7.48967
50	60	26.8228	26340.9	20.2156	27193.6	1.60936
60	70	147.993	201391	111.49	206101	8.87957
70	80	602.315	1272183	453.181	1291428	36.1389
80	90	130.511	137226	102.544	139693	7.83066
Total		1251	1830464.25	995	1860870.12	75

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	Liqd	38.9339	-50	0.18167E-04	...	Liquid: 10
10	Insl	10.0491	-50	...	...	Ins: 10
20	Liqd	77.8679	150	...	...	Liquid: 20
20	Insl	8.84351	150	...	...	Ins: 20
20	Nozl	12.5737	150	326.037	-111.113	T1 (3in.)
20	Nozl	12.5737	150	-326.037	-111.113	T2 (3in.)
20	Wght	70	150	...	...	PASS PAR.
30	Liqd	30.3189	42.5	...	...	Liquid: 30
30	Insl	4.60465	42.5	...	...	Ins: 30
40	Liqd	17.5991	42.5	...	...	Liquid: 40
40	Insl	4.64015	42.5	...	...	Ins: 40
50	Liqd	14.0338	75	...	...	Liquid: 50
50	Insl	4.44777	75	...	...	Ins: 50
60	Liqd	107.296	217.188	-81.25	...	Liquid: 60
60	Insl	23.6443	282.5	...	...	Ins: 60
60	Nozl	26.5597	150	-519.65	...	S1 (4in.)
70	Sadl	105.632	230	594.25	...	Left Saddle
70	Sadl	105.632	1650	594.25	...	Right Saddle
70	Liqd	677.787	1100	...	...	Liquid: 70
70	Insl	96.2295	1100	...	...	Ins: 70
70	Nozl	50.5487	1100	546.637	...	S2 (6in.)
70	Nozl	10.5874	2050	487.9	...	V (2in.)
70	Nozl	10.5874	2050	-487.9	...	D (2in.)
70	Nozl	17.4622	170	506.95	...	PSV (3in.)
70	Nozl	6.46311	600	485.017	...	LG1 (2in.)
70	Nozl	9.29522	600	-485.017	...	LG2 (2in.)
70	Wght	100	100	...	160	BUNDLE MISS.
70	Wght	100	1250	...	160	BUNDLE MISS.
80	Liqd	73.1104	127.083	...	...	Liquid: 80
80	Insl	20.8513	140.625	...	...	Ins: 80
30	FTsh	110.743	124	...	...	Tubesheet
30	Tube	725.306	1244	...	...	Tubes

Total Weight of Each Detail Type:

Saddles	211.3
Liquid	1036.9

Insulation	173.3
Nozzles	156.7
Weights	270.0
Exchanger Components	836.0
Liquid in Tubes	187.4
Sum of the Detail Weights	2871.6 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	1326.6	1326.6	1326.6	1326.6	1326.6	1326.6
Saddles	211.3	211.3	211.3	211.3	211.3	211.3
Nozzles	156.7	156.7	156.7	156.7	156.7	156.7
Wld Weights	270.0	270.0	270.0	270.0	270.0	270.0
Exchanger	836.0	836.0	836.0	836.0	836.0	836.0
Insulation	...	...	...	173.3	173.3	173.3
Ope. Liquid	...	...	...	...	...	1036.9
Tube Ope Lqd	...	...	...	...	...	187.4
Test Liquid	...	1829.3	...	...	...	...
Tube Tst Lqd	...	204.0	...	...	...	...
Totals	2800.6	4834.0	2800.6	2973.9	2973.9	4198.2

Field Installation Options:
Insulation installed before lifting.

Miscellaneous Weight Percent: 6.0 %

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	2800.6 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	4834.0 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	2800.6 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	2973.9 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	2973.9 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	4198.2 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	3926.6 kg.
Field Test Wt.	- Empty Weight + Water (Full)	4766.1 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	204161.0 Cm.
Weight of Ope Liq in tubes :	187.4 kg.
Weight of Water in tubes :	204.0 kg.

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

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	5200.96
20	30	5843.36
30	40	4352.68

40	50	4357.39
50	60	2940.53
60	70	14594.9
70	80	65590.2
80	90	11341.8
Total		114221.789 cm^2

Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	50%	DNV
T1 (3in.)	18.15	19.60	85	150	GR 1.1	...	...	...	...
T2 (3in.)	18.15	19.60	85	150	GR 1.1	...	...	...	...
S1 (4in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
S2 (6in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
V (2in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
D (2in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
PSV (3in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
LG1 (2in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...
LG2 (2in.)	46.00	51.10	120	300	GR 1.1	...	...	...	...

Shellside Flange Rating
Lowest Flange Pressure Rating was (Ope)[ShellSide]: 46.000 bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 51.100 bars

Channelside Flange Rating
Lowest Flange Pressure Rating was (Ope)[TubeSide]: 18.150 bars
Lowest Flange Pressure Rating was (Amb)[TubeSide]: 19.600 bars

Pressure Ratings are per 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.

Wind Load Calculation Results:

Wind Analysis Results per UBC 1994 or UBC 1997

Importance Factor as Entered by the User is	1.000	
Wind Stagnation Pressure (qs) from Table 16-F	75.6	Kgs/m²
Pressure Coefficient from Table 16-H	Cq 0.800	
User Entered Basic Wind Speed	125.0	Km/hr

P(height) = Ce(height,Exp) * Cq * qs * Imp Fact. [18-1](1994) or [20-1](1997)

The values of Ce are shown as the in the table below:

Element	Ce
CH. Head	1.7635
CH. Barrel	1.7635
CH. Flange	1.7635
SH. Flange	1.7635
Port Barrel	1.7635
SH. Cone	1.7635
SH. Barrel	1.7635
SH. Head	1.7635

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force Kgf
PASS PAR.	0.00	20750.00	106.62	0.00
BUNDLE MISS.	0.00	20750.00	106.62	0.00
BUNDLE MISS.	0.00	20750.00	106.62	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load Kgf
10	20	20750	888	1722.63	106.618	18.3664
20	30	20750	888	2664	106.618	28.4032
30	40	20750	864	734.4	106.618	7.83008
40	50	20750	864	734.4	106.618	7.83008
50	60	20750	892.8	1339.2	106.618	14.2784
60	70	20750	1087.8	6146.07	106.618	65.5286
70	80	20750	1282.8	28221.6	106.618	300.895
80	90	20750	1282.8	3187.46	106.618	33.9843

Earthquake Load Calculation Results:

Earthquake Analysis Results per UBC 1997

```
The UBC Zone Factor for the Vessel is ............    0.4000
The Importance Factor as Specified by the User is      1.250
The UBC Force Factor as Specified by the User is ..    3.000
The UBC Total Weight (W) for the Vessel is ........   3926.6  Kgf
The UBC Total Shear (V) for the Vessel is .........    962.0  Kgf
The UBC Seismic Coefficient Value Ca is ...........    0.400
The UBC Seismic Coefficient Value Cv is ...........    0.560
The UBC Near Source Factor Nv ( used with zone 4 ).    1.000
```

Note: The base shear printed above has been modified
by the user defined Earthquake scalar.

Calculation Steps for Computing the design Base Shear (V) per UBC 1997

Computation of V per equation (34-1):

```
V = 0.7 * Ca * I * W
V = 0.7 * 0.4 * 1.25 * 3927
V = 1374.3 Kgf
```

Computation of V per equation (30-5):

```
V = 2.5 * Ca * I * W / R
V = 2.5 * 0.4 * 1.25 * 3927/3
V = 1636.1 Kgf
```

The computed base shear is the minimum of V from 34-1 and 30-5.

Computation of V per equation (34-2), minimum V. V cannot be less than
this value !

```
V = 0.56 * Ca * I * W
V = 0.56 * 0.4 * 1.25 * 3927
V = 1099.5 Kgf
```

In Zone 4, the Base Shear V may also not be less than the following(34-3):

```
V = 1.6 * Z * Nv * I * W / R
V = 1.6 * 0.4 * 1 * 1.25 * 3927/3
V = 1047.1 Kgf
```

```
Total Adjusted Base Shear V:
 = V * Scalar Multiplier = 1374.3 * 0.7000 = 962.0 Kgf
```

Next Sum the earthquake weights times their heights (wi*hi):

```
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 118.
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 236.
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 353.
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 471.
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 589.
Current Sum = Prev. Sum + Wght 393. * Hght 300.000 = 707.
Current Sum = Prev. Sum + Wght 393. * Hght 462.500 = 888.
Current Sum = Prev. Sum + Wght 393. * Hght 462.500 = 1070.
Current Sum = Prev. Sum + Wght 393. * Hght 462.500 = 1252.
Current Sum = Prev. Sum + Wght 393. * Hght 462.500 = 1433.
```

Compute the load at each level based on equation 30-15 and multiply
by the load case scalar. The sum will be the total adjusted shear.

```
Fx = ( V * wx * hx / ( sum of ( wi * hi ))) * EqFact
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
```

```
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
Fx = [(1374.) * 393. * 300.000 / 1433.]*.7000 = 79.
Fx = [(1374.) * 393. * 462.500 / 1433.]*.7000 = 122.
Fx = [(1374.) * 393. * 462.500 / 1433.]*.7000 = 122.
Fx = [(1374.) * 393. * 462.500 / 1433.]*.7000 = 122.
Fx = [(1374.) * 393. * 462.500 / 1433.]*.7000 = 122.
```

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight Kgf	Element Ope Load Kgf
10	20	300	392.665	79.0708
20	30	300	392.665	79.0708
30	40	300	392.665	79.0708
40	50	300	392.665	79.0708
50	60	300	392.665	79.0708
60	70	300	392.665	79.0708
70	Sadl	462.5	392.665	121.901
Sadl	80	462.5	392.665	121.901
70	80	462.5	392.665	121.901
80	90	462.5	392.665	121.901

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

Shop/Field Installation Options :

Insulation is installed in the Field before being lifted.

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

```
Center of Gravity of the Saddles                          2253.525 mm.
Center of Gravity of the Liquid                           1977.348 mm.
Center of Gravity of the Insulation                       1970.300 mm.
Center of Gravity of the Nozzles                          1775.768 mm.
Center of Gravity of the Added Weights (Operating)        1524.833 mm.
Center of Gravity of the Added Weights (Empty)            1524.833 mm.
Center of Gravity of the Tubesheet(s)                      474.000 mm.
Center of Gravity of the Tubes                            1594.000 mm.

Center of Gravity of Bare Shell New and Cold              1781.005 mm.
Center of Gravity of Bare Shell Corroded                  1725.221 mm.

Vessel CG in the Operating Condition                      1753.492 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition        1691.546 mm.
Vessel CG in the Test Condition                           1842.804 mm.
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

```
Vessel Mean Radius                              Rm      470.00  mm.
Shell Thickness used in this Case                t      12.000  mm.
Stiffened Vessel Length per 4.15.6               L     3050.00  mm.
Distance from Saddle to Vessel tangent   a1 or a      800.00  mm.

Saddle Width                               b1 or b      140.00  mm.
Saddle Bearing Angle                delta or theta      120.00  degrees

Wear Plate Width                          b2 or b1      300.00  mm.
Wear Plate Bearing Angle          delta2 or theta1      132.00  degrees
Wear Plate Thickness                      e2 or tr        12.0  mm.
Wear Plate Allowable Stress               fw or Sr      137.90  N./mm²

Shell Allowable Stress used in Calculation              137.90  N./mm²
Head Allowable Stress used in Calculation               137.90  N./mm²
Circumferential Efficiency in Plane of Saddle             1.00
Circumferential Efficiency at Mid-Span                    1.00

Distance from Saddle Base to Centerline          B      750.00  mm.
Coefficient of Friction                         mu        0.30

Saddle Force Q, Operating Case                         4524.79  Kgf

Pressure used in Analysis                        P      22.024  bars

Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                          N./mm² |       N./mm² |
----------------------------------------------------------------
Long. Stress at Top    of Midspan          57.52 |       137.90 |
Long. Stress at Bottom of Midspan          57.50 |       137.90 |
Long. Stress at Top    of Saddles          69.08 |       137.90 |
Long. Stress at Bottom of Saddles          51.10 |       137.90 |
----------------------------------------------------------------
Tangential Shear in Shell                   5.84 |       110.32 |
Circ. Stress at Horn of Saddle             12.02 |       172.37 |
Circ. Compressive Stress in Shell           0.67 |       137.90 |
----------------------------------------------------------------
```

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

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3( 477/2 + 0 ) * 750/843
 = 637.0 Kgf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
 = max( Fl, Sum of X Forces) * B / Ls
 = max( 115, 0 ) * 750/1420
 = 60.7 Kgf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:

```
 = max( Fl, Sum of X Forces ) * B / Ls
 = max( 962, 0 ) * 750/1420
 = 508.1 Kgf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 962/2 + 0 ) * 750/843
  = 1284.4 Kgf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 3240 + max( 60.7, 637, 508, 1284 )
  = 4524.8 Kgf
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 1 * 1046( 0 +( 0.9 * 1.2 ))
  = 1126.093 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		4630.43	Kgf
Transverse Shear Load Saddle	Ft	481.01	Kgf
Longitudinal Shear Load Saddle		962.03	Kgf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 925/2 + 12 + 12 )sin( 120/2 ), 2*470 )
  = 842.643 mm.
```

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -4525*800[1-(1-800/3050+(470²-0²)/
    (2*800*3050))/(1+(4*0)/(3*3050))]
  = -785.6 Kg-m.
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 4525*3050/4(1+2(470²-0²)/(3050²))/(1+(4*0)/
    (3*3050))-4*800/3050
  = -5.8 Kg-m.
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 22 * 470/(2*9 ) - -5.82/(pi*470²*9 )
  = 57.52 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 22 * 470/(2 * 9 ) + -5.82/(pi * 470² * 9 )
  = 57.50 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 22*470/(2*9)--786/(0.11*pi*470²*9)
  = 69.08 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 22*470/(2*9)+-786/(0.19*pi*470²*9)
  = 51.10 N./mm²
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 4525( 3050 - 2 * 800 )/(3050 +( 4 * 0/3))
  = 2151.1 Kgf
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.17 * 2151/( 470 * 9 )
  = 5.84 N./mm²
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 470 * 9 )
  = 50.730 mm.
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a   )
  = min( 140 + 1.56 * sqrt( 470 * 9 ), 2 * 800 )
  = 241.46 mm.
```

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
```
  = min( Sr/S, 1 )
  = min( 138/138, 1 )
  = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = -0.76 * 4525 * 0.1/( 241( 9 + 1 * 12 ) )
  = -0.67 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -4525/(4(9 + 1 * 12 )241 ) -
     12*0.053*4525*470/(3050(9+1*12)²)
  = -12.02 N./mm²
```

Distance between Saddle Supports [Ls]:
```
  = 1420.0 mm.
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.12232E-04 * 1420( 120 - 21.1 )
  = 1.718 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	900.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	367.5	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

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

	B	D	Y	A	AY	Io
Shell	401.0	9.0	4.5	36.1	16239.4	0.295E+04
Wearplate	300.0	12.0	15.0	36.0	54000.0	0.231E+04
Web	12.0	248.5	145.2	29.8	433135.5	0.229E+04
BasePlate	170.0	15.0	277.0	25.5	706350.0	0.846E+04
Totals	...	...	...	127.4	1209724.9	0.160E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 476/127
  = 94.949 mm.
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.09 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2 * 4525
  = 920.8936 Kgf

 Tension Stress, St = ( Fh/As )       =         0.9889  N./mm²
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm²
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 750 - 466 * sin(120/2)/1.05
  = 365.035 mm.

 Bending Moment, M  = Fh * d          =       336.1647  Kg-m.

 Bending Stress, Sb = ( M * C1 / I  ) =         1.9557  N./mm²
 Allowed Stress, Sa = 2/3 * Yield Str =       137.9000  N./mm²
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(4525 + 106 )170/( 4 * 900 * 138 ))½
  = 6.830 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120/2 )( 462 + 12 + 12 )
  = 842.643 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 843/( 3 - 1 )
  = 421.321 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 421 * 170/2
  = 358.123 cm²
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
```

= 4525/(900 * 170)
= 2.957 Kgf/cm²

Axial Load [P]:
= Ap * Bp
= 358 * 2.96
= 1059.107 Kgf

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 15.4 + 25.3
= 40.639 cm²

Compressive Stress [Sc]:
= P/Ar
= 1059/40.6
= 2.556 N./mm²

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	140.0	...	16.8	...	274.

Rib dimension [D]:
= Saddle Width - Web Thickness
= 140 - 12
= 128.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0/40.6
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 140/2
= 70.000 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(274/40.6)
= 25.985 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 750 - cos(120/2)(462 + 12 + 12) - 15
= 491.750 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 199943008/207)
= 138.135

Slenderness ratio [KL/r]:
= KL/r
= 1 * 492/26
= 18.925

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 962/(2 * 900) * 421 * 492/2
= 55.367 Kg-m.

Compressive Allowable, KL/r < Cc(18.9 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.9 )²/(2 * 138² ))207/
    ( 5/3+3*(18.9 )/(8* 138 )-( 18.9³)/(8*138³)
  = 119.3 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.56/119 +( 55.4 * 70/2744000 )/138
  = 0.122
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	128.0	0.0	15.4	0.0	274.
Web	421.3	12.0	0.0	50.6	0.0	6.07
Totals	...	...	...	65.9	...	280.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0/65.9
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 750 - cos( 486/2 )( 15 + 0 + 0 ) - 0
  = 248.500 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 280/65.9 )
  = 20.621 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 248/20.6
  = 12.051
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 962/( 2 * 900 )
  = 0.534 Kgf/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.53 * 421 * 248
  = 55.958 Kg-m.
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 56/40042
  = 13.705 N./mm²
```

Compressive Allowable, KL/r < Cc(12.1 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.1 )²/(2 * 138² ))207/
    ( 5/3+3*(12.1 )/(8* 138 )-( 12.1³)/(8*138³)
```

```
  = 121.3 N./mm²
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 3.13/121 +( 56 * 70/280 )/138
  = 0.125
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	283.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	120.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	3346.0	Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	508.1	Kgf
Maximum Transverse Force	Ft	481.0	Kgf
Maximum Longitudinal Force	Fl	962.0	Kgf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 962/( 2.17 * 4 )
  = 10.9 N./mm².  Must be less than 146.2 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 481/( 2.17 * 4 )
  = 5.4 N./mm².  Must be less than 146.2 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

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

Bolt Area due to Shear Load [Bltarears]:

```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 962/(146 * 4 )
  = 0.1613 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 750 * 481 + 0
  = 360.77 Kg-m.
```

Eccentricity (e):

```
  = Rmom / QO
  = 361/3346
  = 107.82 mm. < Bplen/6 --> No Uplift in Transverse direction
```

Bolt Area due to Transverse Load [Bltareart]:

```
  = 0 (No Uplift)
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.16, 0 ]
  = 0.1613 cm²
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Input and Calculated Values:

```
 Vessel Mean Radius                               Rm      470.00  mm.
 Shell Thickness used in this Case                 t      12.000  mm.
 Stiffened Vessel Length per 4.15.6                L     3050.00  mm.
 Distance from Saddle to Vessel tangent   a1 or a        600.00  mm.

 Saddle Width                             b1 or b        140.00  mm.
 Saddle Bearing Angle              delta or theta        120.00  degrees

 Wear Plate Width                         b2 or b1       300.00  mm.
 Wear Plate Bearing Angle        delta2 or theta1        132.00  degrees
 Wear Plate Thickness                     e2 or tr         12.0  mm.
 Wear Plate Allowable Stress              fw or Sr       137.90  N./mm²

 Inside Depth of Head                     Hi or h2       234.25  mm.

 Shell Allowable Stress used in Calculation              137.90  N./mm²
 Head Allowable Stress used in Calculation               137.90  N./mm²
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline         B       750.00  mm.
 Coefficient of Friction                        mu         0.30

 Saddle Force Q, Operating Case                         1759.37  Kgf

 Pressure used in Analysis                       P       22.024  bars

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                          N./mm² |       N./mm² |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         57.19 |       137.90 |
 Long. Stress at Bottom of Midspan         57.83 |       137.90 |
 Long. Stress at Top    of Saddles         61.09 |       137.90 |
 Long. Stress at Bottom of Saddles         55.53 |       137.90 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                  2.63 |       110.32 |
 Circ. Stress at Horn of Saddle             4.67 |       172.37 |
 Circ. Compressive Stress in Shell          0.26 |       137.90 |
 ----------------------------------------------------------------
```

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

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 477/2 + 0 ) * 750/843
  = 637.0 Kgf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 115, 0 ) * 750/1420
  = 60.7 Kgf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:

```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 962, 0 ) * 750/1420
  = 508.1 Kgf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 962/2 + 0 ) * 750/843
```

```
  = 1284.4 Kgf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 475 + max( 60.7, 637, 508, 1284 )
  = 1759.4 Kgf
```

Longitudinal Wind Force [Fl]:
```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 1 * 1046( 0 +( 0.9 * 1.2 ))
  = 1126.093 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		1865.00	Kgf
Transverse Shear Load Saddle	Ft	481.01	Kgf
Longitudinal Shear Load Saddle		962.03	Kgf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 925/2 + 12 + 12 )sin( 120/2 ), 2*470 )
  = 842.643 mm.
```

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -1759*600[1-(1-600/3050+(470²-234²)/
    (2*600*3050))/(1+(4*234)/(3*3050))]
  = -243.0 Kg-m.
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 1759*3050/4(1+2(470²-234²)/(3050²))/(1+(4*234)/
    (3*3050))-4*600/3050
  = 204.7 Kg-m.
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 22 * 470/(2*9 ) - 205/(pi*470²*9 )
  = 57.19 N./mm²
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 22 * 470/(2 * 9 ) + 205/(pi * 470² * 9 )
  = 57.83 N./mm²
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 22*470/(2*9)--243/(0.11*pi*470²*9)
  = 61.09 N./mm²
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
```

```
  = 22*470/(2*9)+-243/(0.19*pi*470²*9)
  = 55.53 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 1759( 3050 - 2 * 600 )/(3050 +( 4 * 234/3))
  = 968.0 Kgf
```

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

```
  = K2 * T / ( Rm * t )
  = 1.17 * 968/( 470 * 9 )
  = 2.63 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 470 * 9 )
  = 50.730 mm.
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 140 + 1.56 * sqrt( 470 * 9 ), 2 * 600 )
  = 241.46 mm.
```

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

```
  = min( Sr/S, 1 )
  = min( 138/138, 1 )
  = 1.0000
```

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

```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = -0.76 * 1759 * 0.1/( 241( 9 + 1 * 12 ) )
  = -0.26 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:

```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -1759/(4(9 + 1 * 12 )241 ) -
     12*0.053*1759*470/(3050(9+1*12)²)
  = -4.67 N./mm²
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	900.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	367.5	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

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

	B	D	Y	A	AY	Io
Shell	401.0	9.0	4.5	36.1	16239.4	0.295E+04
Wearplate	300.0	12.0	15.0	36.0	54000.0	0.231E+04
Web	12.0	248.5	145.2	29.8	433135.5	0.229E+04
BasePlate	170.0	15.0	277.0	25.5	706350.0	0.846E+04
Totals	...	...	...	127.4	1209724.9	0.160E+05

Distance to Centroid [C1]:

```
  = AY / A
  = 476/127
  = 94.949 mm.
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.09 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2 * 1759
  = 358.0696 Kgf

 Tension Stress, St = ( Fh/As )       =          0.3845  N./mm²
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm²
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 750 - 466 * sin(120/2)/1.05
  = 365.035 mm.

 Bending Moment, M  = Fh * d          =        130.7104  Kg-m.

 Bending Stress, Sb = ( M * C1 / I  ) =          0.7604  N./mm²
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm²
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(1759 + 106 )170/( 4 * 900 * 138 ))½
  = 4.335 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120/2 )( 462 + 12 + 12 )
  = 842.643 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 843/( 3 - 1 )
  = 421.321 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 421 * 170/2
  = 358.123 cm²
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 1759/( 900 * 170 )
  = 1.150 Kgf/cm²
```

Axial Load [P]:
```
  = Ap * Bp
  = 358 * 1.15
  = 411.811 Kgf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 15.4 + 25.3
  = 40.639 cm²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 412/40.6
  = 0.994 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	140.0	...	16.8	...	274.

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 140 - 12
  = 128.000 mm.
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0/40.6
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 274/40.6 )
  = 25.985 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 750 - cos( 120/2 )( 462 + 12 + 12 ) - 15
  = 491.750 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/207 )
  = 138.135
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 492/26
  = 18.925
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 962/( 2 * 900 ) * 421 * 492/2
  = 55.367 Kg-m.
```

Compressive Allowable, KL/r < Cc(18.9 < 138) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.9 )²/(2 * 138² ))207/
    ( 5/3+3*(18.9 )/(8* 138 )-( 18.9³)/(8*138³)
  = 119.3 N./mm²
```

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

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

```
  = 0.99/119 +( 55.4 * 70/2744000 )/138
  = 0.109
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	128.0	0.0	15.4	0.0	274.
Web	421.3	12.0	0.0	50.6	0.0	6.07
Totals	...	...	...	65.9	...	280.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0/65.9
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 750 - cos( 486/2 )( 15 + 0 + 0 ) - 0
  = 248.500 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 280/65.9 )
  = 20.621 mm.
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 248/20.6
  = 12.051
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 962/( 2 * 900 )
  = 0.534 Kgf/mm.
```

Moment at base of inner Rib [Mbase,c]:

```
  = Unit Force * e * L
  = 0.53 * 421 * 248
  = 55.958 Kg-m.
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 56/40042
  = 13.705 N./mm²
```

Compressive Allowable, KL/r < Cc(12.1 < 138) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.1 )²/(2 * 138² ))207/
    ( 5/3+3*(12.1 )/(8* 138 )-( 12.1³)/(8*138³)
  = 121.3 N./mm²
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1.22/121 +( 56 * 70/280 )/138
  = 0.109
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	283.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	120.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	580.6	Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	508.1	Kgf
Maximum Transverse Force	Ft	481.0	Kgf
Maximum Longitudinal Force	Fl	962.0	Kgf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 962/( 2.17 * 4 )
  = 10.9 N./mm².  Must be less than 146.2 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 481/( 2.17 * 4 )
  = 5.4 N./mm².  Must be less than 146.2 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:
```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 962/(146 * 4 )
  = 0.1613 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 750 * 481 + 0
  = 360.77 Kg-m.
```

Eccentricity (e):
```
  = Rmom / QO
  = 361/581
  = 621.35 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 900/2 - 120
   = 330.00 mm.
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 203402/21526
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(621 - 0.5*900 )
    = 514.04 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.45 * 4.34/170 *(330 + 621 )
    = 137727.18 mm.²
```

```
K3 = -K2 * (0.5 * Bplen + f)
   = -137727 *(0.5 * 900 + 330 )
   = -107427192.90 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + 514 * Y² + 137727 * Y + -107427200 = 0
Y  = 289.81 mm.

Num = (Bplen / 2 - Y / 3 - e)
    = (900/2 - 290/3 - 621 )
    = -267.95

Denom = (Bplen / 2 - Y / 3 + f)
      = (900/2 - 290/3 + 330 )
      = 683.40
```

Total Bolt Tension Force [Tforce]:

```
= - QO * Num / Denom
= - 581 * -268/683
= 227.65 Kgf
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
= Tforce / (Stba * Nbt)
= 228/( 283 * 2 )
= 0.0394 cm²
```

Required Area of a Single Bolt [Bltarear]:

```
= max[Bltarearl, Bltarears, Bltareart]
= max[0, 0.16, 0.039 ]
= 0.1613 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(581 + 228 )/(290 * 170 )
= 3.22 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
= (Bplen - Weblngth) / 2
= (900 - 849 )/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
= Tforce * Adist
= 228 * 25.4
= 5.78 Kg-m.
```

Equivalent Bearing Pressure (f1):

```
= fc * (Y - Adist) / Y
= 3.22 *(290 - 25.4 )/290
= 2.94 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 170/6) *(2.94 + 2 * 3.22 )
= 1.75 Kg-m.
```

Baseplate Required Thickness [Treq]:

```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(5.78,1.75/(170 * 162 ))½
= 3.5108 mm.
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Test Case

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

```
 Vessel Mean Radius                                Rm      470.00  mm.
 Shell Thickness used in this Case                  t      12.000  mm.
 Stiffened Vessel Length per 4.15.6                 L     3050.00  mm.
 Distance from Saddle to Vessel tangent      a1 or a      800.00  mm.

 Saddle Width                                 b1 or b      140.00  mm.
 Saddle Bearing Angle                  delta or theta      120.00  degrees

 Wear Plate Width                            b2 or b1      300.00  mm.
 Wear Plate Bearing Angle            delta2 or theta1      132.00  degrees
 Wear Plate Thickness                        e2 or tr        12.0  mm.
 Wear Plate Allowable Stress                 fw or Sr      137.90  N./mm²

 Shell Allowable Stress used in Calculation                235.81  N./mm²
 Head Allowable Stress used in Calculation                 235.81  N./mm²
 Circumferential Efficiency in Plane of Saddle               1.00
 Circumferential Efficiency at Mid-Span                      1.00

 Distance from Saddle Base to Centerline            B      750.00  mm.
 Coefficient of Friction                           mu        0.30

 Saddle Force Q, Test Case, no Ext. Forces                3919.74  Kgf

 Pressure used in Analysis                          P      28.646  bars

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                           N./mm² |       N./mm² |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan          74.81 |       235.81 |
 Long. Stress at Bottom of Midspan          74.79 |       235.81 |
 Long. Stress at Top    of Saddles          84.83 |       235.81 |
 Long. Stress at Bottom of Saddles          69.25 |       235.81 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                   5.06 |       139.65 |
 Circ. Stress at Horn of Saddle             10.41 |       353.71 |
 Circ. Compressive Stress in Shell           0.58 |       235.81 |
 ----------------------------------------------------------------
```

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

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 157/2 + 0 ) * 750/843
  = 210.2 Kgf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 37.9, 0 ) * 750/1420
  = 20.0 Kgf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 3710 + max( 20, 210, 0, 0 )
  = 3919.7 Kgf
```

Longitudinal Wind Force [Fl]:

```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 1 * 1046( 0 +( 0.9 * 1.2 ))
  = 1126.093 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)               4025.37  Kgf
 Transverse Shear Load Saddle            Ft              78.72  Kgf
 Longitudinal Shear Load Saddle                          37.89  Kgf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 925/2 + 12 + 12 )sin( 120/2 ), 2*470 )
  = 842.643 mm.
```

The Computed K values from Table 4.15.1:

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

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -3920*800[1-(1-800/3050+(470²-0²)/
    (2*800*3050))/(1+(4*0)/(3*3050))]
  = -680.6 Kg-m.
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 3920*3050/4(1+2(470²-0²)/(3050²))/(1+(4*0)/
    (3*3050))-4*800/3050
  = -5.0 Kg-m.
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 28.6 * 470/(2*9 ) - -5.04/(pi*470²*9 )
  = 74.81 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 28.6 * 470/(2 * 9 ) + -5.04/(pi * 470² * 9 )
  = 74.79 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 28.6*470/(2*9)--681/(0.11*pi*470²*9)
  = 84.83 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 28.6*470/(2*9)+-681/(0.19*pi*470²*9)
  = 69.25 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 3920( 3050 - 2 * 800 )/(3050 +( 4 * 0/3))
  = 1863.5 Kgf
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.17 * 1863/( 470 * 9 )
  = 5.06 N./mm²
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 470 * 9 )
  = 50.730 mm.
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 140 + 1.56 * sqrt( 470 * 9 ), 2 * 800 )
  = 241.46 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = -0.76 * 3920 * 0.1/( 241( 9 + 1 * 12 ) )
  = -0.58 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -3920/(4(9 + 1 * 12 )241 ) -
     12*0.053*3920*470/(3050(9+1*12)²)
  = -10.41 N./mm²
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	900.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	367.5	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

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

	B	D	Y	A	AY	Io
Shell	401.0	9.0	4.5	36.1	16239.4	0.295E+04
Wearplate	300.0	12.0	15.0	36.0	54000.0	0.231E+04
Web	12.0	248.5	145.2	29.8	433135.5	0.229E+04
BasePlate	170.0	15.0	277.0	25.5	706350.0	0.846E+04
Totals	...	...	...	127.4	1209724.9	0.160E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 476/127
  = 94.949 mm.
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
```

```
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.09 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.2 * 3920
  = 797.7523 Kgf

 Tension Stress, St = ( Fh/As )       =          0.8567  N./mm²
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm²
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 750 - 466 * sin(120/2)/1.05
  = 365.035 mm.

 Bending Moment, M  = Fh * d          =        291.2129  Kg-m.

 Bending Stress, Sb = ( M * C1 / I  ) =          1.6942  N./mm²
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(3920 + 106 )170/( 4 * 900 * 138 ))½
  = 6.368 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120/2 )( 462 + 12 + 12 )
  = 842.643 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 843/( 3 - 1 )
  = 421.321 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 421 * 170/2
  = 358.123 cm²
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 3920/( 900 * 170 )
  = 2.562 Kgf/cm²
```

Axial Load [P]:

```
  = Ap * Bp
  = 358 * 2.56
  = 917.484 Kgf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 15.4 + 25.3
  = 40.639 cm²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 917/40.6
  = 2.214 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	140.0	...	16.8	...	274.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 140 - 12
  = 128.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0/40.6
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 274/40.6 )
  = 25.985 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 750 - cos( 120/2 )( 462 + 12 + 12 ) - 15
  = 491.750 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/207 )
  = 138.135
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 492/26
  = 18.925
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 37.9/( 2 * 900 ) * 421 * 492/2
  = 2.181 Kg-m.
```

Compressive Allowable, KL/r < Cc(18.9 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.9 )²/(2 * 138² ))207/
    ( 5/3+3*(18.9 )/(8* 138 )-( 18.9³)/(8*138³)
  = 119.3 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.21/119 +( 2.18 * 70/2744000 )/138
  = 0.023
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	128.0	0.0	15.4	0.0	274.
Web	421.3	12.0	0.0	50.6	0.0	6.07
Totals	...	...	...	65.9	...	280.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0/65.9
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 750 - cos( 486/2 )( 15 + 0 + 0 ) - 0
  = 248.500 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 280/65.9 )
  = 20.621 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 248/20.6
  = 12.051
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 37.9/( 2 * 900 )
  = 0.021 Kgf/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.021 * 421 * 248
  = 2.204 Kg-m.
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 2.2/40042
  = 0.540 N./mm²
```

Compressive Allowable, KL/r < Cc(12.1 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.1 )²/(2 * 138² ))207/
    ( 5/3+3*(12.1 )/(8* 138 )-( 12.1³)/(8*138³)
  = 121.3 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 2.71/121 +( 2.2 * 70/280 )/138
  = 0.026
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	283.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	120.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	3815.2	Kgf

```
 Saddle Load QL (Wind/Seismic contribution)         QL        20.0  Kgf
 Maximum Transverse Force                           Ft        78.7  Kgf
 Maximum Longitudinal Force                         Fl        37.9  Kgf
 Saddle Bolted to Steel Foundation                              No
```

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 37.9/( 2.17 * 4 )
  = 0.4 N./mm².  Must be less than 146.2 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 78.7/( 2.17 * 4 )
  = 0.9 N./mm².  Must be less than 146.2 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:
```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 37.9/(146 * 4 )
  = 0.0064 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 750 * 78.7 + 0
  = 59.04 Kg-m.
```

Eccentricity (e):
```
  = Rmom / QO
  = 59/3815
  = 15.48 mm. < Bplen/6 --> No Uplift in Transverse direction
```

Bolt Area due to Transverse Load [Bltareart]:
```
  = 0 (No Uplift)
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.0064, 0 ]
  = 0.0064 cm²
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

Input and Calculated Values:

```
 Vessel Mean Radius                               Rm      470.00  mm.
 Shell Thickness used in this Case                 t      12.000  mm.
 Stiffened Vessel Length per 4.15.6                L     3050.00  mm.
 Distance from Saddle to Vessel tangent   a1 or a      600.00  mm.

 Saddle Width                               b1 or b      140.00  mm.
 Saddle Bearing Angle                 delta or theta      120.00  degrees

 Wear Plate Width                           b2 or b1      300.00  mm.
 Wear Plate Bearing Angle            delta2 or theta1      132.00  degrees
 Wear Plate Thickness                       e2 or tr        12.0  mm.
 Wear Plate Allowable Stress                fw or Sr      137.90  N./mm²

 Inside Depth of Head                       Hi or h2      234.25  mm.
```

```
 Shell Allowable Stress used in Calculation            235.81  N./mm²
 Head Allowable Stress used in Calculation             235.81  N./mm²
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Distance from Saddle Base to Centerline        B      750.00  mm.
 Coefficient of Friction                       mu        0.30

 Saddle Force Q, Test Case, no Ext. Forces            1123.38  Kgf

 Pressure used in Analysis                      P      28.646  bars

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                          N./mm² |       N./mm² |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         74.60 |       235.81 |
 Long. Stress at Bottom of Midspan         75.01 |       235.81 |
 Long. Stress at Top    of Saddles         77.09 |       235.81 |
 Long. Stress at Bottom of Saddles         73.54 |       235.81 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                  1.68 |       139.65 |
 Circ. Stress at Horn of Saddle             2.98 |       353.71 |
 Circ. Compressive Stress in Shell          0.17 |       235.81 |
 ----------------------------------------------------------------
```

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

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 157/2 + 0 ) * 750/843
  = 210.2 Kgf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 37.9, 0 ) * 750/1420
  = 20.0 Kgf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 913 + max( 20, 210, 0, 0 )
  = 1123.4 Kgf
```

Longitudinal Wind Force [Fl]:
```
  = WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
  = 1 * 1046( 0 +( 0.9 * 1.2 ))
  = 1126.093 N
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)              1229.01  Kgf
 Transverse Shear Load Saddle           Ft              78.72  Kgf
 Longitudinal Shear Load Saddle                         37.89  Kgf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = min( 2( ShellID/2 + t + WearPadThickness )sin( theta/2 ), 2*Rm )
  = min( 2( 925/2 + 12 + 12 )sin( 120/2 ), 2*470 )
  = 842.643 mm.
```

The Computed K values from Table 4.15.1:
```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
```

```
K7p = 0.0434
```

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -1123*600[1-(1-600/3050+(470²-234²)/
     (2*600*3050))/(1+(4*234)/(3*3050))]
  = -155.2 Kg-m.
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 1123*3050/4(1+2(470²-234²)/(3050²))/(1+(4*234)/
     (3*3050))-4*600/3050
  = 130.7 Kg-m.
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 28.6 * 470/(2*9 ) - 131/(pi*470²*9 )
  = 74.60 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 28.6 * 470/(2 * 9 ) + 131/(pi * 470² * 9 )
  = 75.01 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 28.6*470/(2*9)--155/(0.11*pi*470²*9)
  = 77.09 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 28.6*470/(2*9)+-155/(0.19*pi*470²*9)
  = 73.54 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 1123( 3050 - 2 * 600 )/(3050 +( 4 * 234/3))
  = 618.1 Kgf
```

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

```
  = K2 * T / ( Rm * t )
  = 1.17 * 618/( 470 * 9 )
  = 1.68 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 470 * 9 )
  = 50.730 mm.
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 140 + 1.56 * sqrt( 470 * 9 ), 2 * 600 )
  = 241.46 mm.
```

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

```
  = 1.0000 Materials are the same, test case
```

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

```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = -0.76 * 1123 * 0.1/( 241( 9 + 1 * 12 ) )
  = -0.17 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
= -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
= -1123/(4(9 + 1 * 12 )241 ) -
   12*0.053*1123*470/(3050(9+1*12)²)
= -2.98 N./mm²
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	900.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	367.5	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

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

	B	D	Y	A	AY	Io
Shell	401.0	9.0	4.5	36.1	16239.4	0.295E+04
Wearplate	300.0	12.0	15.0	36.0	54000.0	0.231E+04
Web	12.0	248.5	145.2	29.8	433135.5	0.229E+04
BasePlate	170.0	15.0	277.0	25.5	706350.0	0.846E+04
Totals	...	...	...	127.4	1209724.9	0.160E+05

Distance to Centroid [C1]:
```
= AY / A
= 476/127
= 94.949 mm.
```

Angle [beta]:
```
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0
```

Saddle Splitting Coefficient [K1]:
```
= ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
= ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.09 + sin(120 )cos(120 ) )
= 0.2035
```

Saddle Splitting Force [Fh]:
```
= K1 * Q
= 0.2 * 1123
= 228.6325 Kgf
```

```
Tension Stress, St = ( Fh/As )        =        0.2455  N./mm²
Allowed Stress, Sa = 0.6 * Yield Str =      124.1100  N./mm²
```

Saddle Splitting Dimension [d]:
```
= B - R * sin(theta/2)/(theta/2 in radians)
= 750 - 466 * sin(120/2)/1.05
= 365.035 mm.
```

```
Bending Moment, M  = Fh * d           =       83.4604  Kg-m.

Bending Stress, Sb = ( M * C1 / I  ) =        0.4855  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =      137.9000  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(1123 + 106 )170/( 4 * 900 * 138 ))½
  = 3.519 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:

```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120/2 )( 462 + 12 + 12 )
  = 842.643 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 843/( 3 - 1 )
  = 421.321 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 421 * 170/2
  = 358.123 cm²
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 1123/( 900 * 170 )
  = 0.734 Kgf/cm²
```

Axial Load [P]:

```
  = Ap * Bp
  = 358 * 0.73
  = 262.947 Kgf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 15.4 + 25.3
  = 40.639 cm²
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 263/40.6
  = 0.635 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	140.0	...	16.8	...	274.

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 140 - 12
  = 128.000 mm.
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0/40.6
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 274/40.6 )
  = 25.985 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 750 - cos( 120/2 )( 462 + 12 + 12 ) - 15
  = 491.750 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/207 )
  = 138.135
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 492/26
  = 18.925
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 37.9/( 2 * 900 ) * 421 * 492/2
  = 2.181 Kg-m.
```

Compressive Allowable, KL/r < Cc(18.9 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.9 )²/(2 * 138² ))207/
    ( 5/3+3*(18.9 )/(8* 138 )-( 18.9³)/(8*138³)
  = 119.3 N./mm²
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 0.63/119 +( 2.18 * 70/2744000 )/138
  = 0.009
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	128.0	0.0	15.4	0.0	274.
Web	421.3	12.0	0.0	50.6	0.0	6.07
Totals	...	...	...	65.9	...	280.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0/65.9
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 140/2
  = 70.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 750 - cos( 486/2 )( 15 + 0 + 0 ) - 0
  = 248.500 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 280/65.9 )
  = 20.621 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 248/20.6
  = 12.051
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 37.9/( 2 * 900 )
  = 0.021 Kgf/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.021 * 421 * 248
  = 2.204 Kg-m.
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 2.2/40042
  = 0.540 N./mm²
```

Compressive Allowable, KL/r < Cc(12.1 < 138) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.1 )²/(2 * 138² ))207/
    ( 5/3+3*(12.1 )/(8* 138 )-( 12.1³)/(8*138³)
  = 121.3 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 0.78/121 +( 2.2 * 70/280 )/138
  = 0.010
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	283.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	120.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	1018.8	Kgf
Saddle Load QL (Wind/Seismic contribution)	QL	20.0	Kgf
Maximum Transverse Force	Ft	78.7	Kgf
Maximum Longitudinal Force	Fl	37.9	Kgf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 37.9/( 2.17 * 4 )
  = 0.4 N./mm².  Must be less than 146.2 N./mm².
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 78.7/( 2.17 * 4 )
  = 0.9 N./mm².  Must be less than 146.2 N./mm².
```

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:

```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 37.9/(146 * 4 )
  = 0.0064 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 750 * 78.7 + 0
  = 59.04 Kg-m.
```

Eccentricity (e):

```
  = Rmom / QO
  = 59/1019
  = 57.95 mm. < Bplen/6 --> No Uplift in Transverse direction
```

Bolt Area due to Transverse Load [Bltareart]:

```
  = 0 (No Uplift)
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.0064, 0 ]
  = 0.0064 cm²
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

Conical Reinforcement Calculations, ASME VIII Div. 1, App. 1

Input Values:

SH. Cone

Design Internal Pressure, Small End		22.048	bars
Design Internal Pressure, Large End		22.048	bars
Temperature for Internal Pressure		120.0	°C
Design External Pressure		1.034	bars
Temperature for External Pressure		120.0	°C
Cone Material		SA-516 70	
Cone Allowable Stress at Temperature	Ss	137.90	N./mm²
Cone Allowable Stress At Ambient		137.90	N./mm²
Longitudinal Joint Efficiency of Cone		1.00	
Circumferential Joint Efficiency of Cone		1.00	
Actual Thickness of Cone	Tc	12.0000	mm.
Corrosion Allowance for Cone	Cac	3.0000	mm.
Diameter Basis for Cone and Cylinders		ID	
Diameter of Small End of Cone	Ds	600.000	mm.
Diameter of Large End of Cone	Dl	925.000	mm.
Half Apex Angle for Cone		30.00	degrees
Axial Length of Cone	Lc	565.000	mm.
Small End Cylinder Material		SA-516 70	
Small Cylinder Allowable Stress at Operating	Ss	137.90	N./mm²
Small Cylinder Allowable Stress At Ambient		137.90	N./mm²
Joint Efficiency of Small Cylinder	Es	1.0000	
Actual Thickness of Small Cylinder	Ts	12.0000	mm.
Corrosion Allowance for Small Cylinder	Cas	3.0000	mm.
Axial Length of Small Cylinder	Ls	150.000	mm.
Large End Cylinder Material		SA-516 70	
Large Cylinder Allowable Stress at Operating	Sl	137.90	N./mm²
Large Cylinder Allowable Stress At Ambient		137.90	N./mm²
Joint Efficiency of Large Cylinder	El	1.0000	
Actual Thickness of Large Cylinder	Tl	12.0000	mm.
Corrosion Allowance for Large Cylinder	Cal	3.0000	mm.
Axial Length of Large Cylinder	Ll	2892.083	mm.
Type of Reinforcement at Large End of Cone:		None	
Large End Reinforcing/Knuckle Material			
Large Reinforcing/Knuckle Allowable, Operating		137.90	N./mm²
Large Reinforcing/Knuckle Allowable, Ambient		137.90	N./mm²
Type of Reinforcement at Small End of Cone:		None	
Small End Reinforcing/Knuckle Material			
Small Reinforcing/Knuckle Allowable, Operating		137.90	N./mm²
Small Reinforcing/Knuckle Allowable, Ambient		137.90	N./mm²

Calculated Values:

Elastic Modulus Data from ASME Section II Part D at 120 °C

Elastic Modulus of Cone Material	0.197E+09 KPa.	at 119 °C
Elastic Modulus of Small Cylinder Material	0.197E+09 KPa.	at 119 °C
Elastic Modulus of Large Cylinder Material	0.197E+09 KPa.	at 119 °C
Elastic Modulus of Large End Reinforcement	0.197E+09 KPa.	at 119 °C
Elastic Modulus of Small End Reinforcement	0.197E+09 KPa.	at 119 °C

```
 Elastic Modulus Data from ASME Section II Part D at 120 °C

 Elastic Modulus of Cone Material                0.197E+09 KPa. at 119 °C
 Elastic Modulus of Small Cylinder Material      0.197E+09 KPa. at 119 °C
 Elastic Modulus of Large Cylinder Material      0.197E+09 KPa. at 119 °C
 Elastic Modulus of Large End Reinforcement      0.197E+09 KPa. at 119 °C
 Elastic Modulus of Small End Reinforcement      0.197E+09 KPa. at 119 °C
```

Axial forces and moments are not computed for Horizontal geometries.
Compute them manually and enter the loads using the Force/Moment dialog.
Place the loads at the ends of the cone as needed.

Note: Small end of the Cone is taken as a Line of Support

```
 Maximum Centroid Reinforcement Distance Large End    16.3373  mm.
 Maximum Centroid Reinforcement Distance Small End    13.2476  mm.
```

Note: No ring was found close enough to the large end to be considered.

Note: No ring was found close enough to the small end to be considered.

Reinforcement Calculations for Cone / Large Cylinder:

Required Area of Reinforcement for Large End Under Internal Pressure

```
 Large end ratio of pressure to allowable stress    P/Ss E1    0.01599
 Large end max. half apex angle w/o reinforcement    delta     30.000  degrees
 Large end actual half apex angle                    alpha     30.000  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Sr * Erl ), 1 )
  = max( 27.15E+09/( 138 * 196910448 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Large End All. Stress * Large End Elastic Modulus (Int. temp.)
   = 138 * 196910448
   = 27153948672.0 N./mm²^2
```

Decay Length, Cone Large End:

```
  = 2 * sqrt( RL( ts - ca ) )
  = 2 * sqrt( 466( 12 - 3 ) )
  = 129.453 mm.
```

Required Area of Reinforcement, Large End, Internal [Arl]:

```
  = k*QL*Rl/(Ss*E1))*(1-delta/alpha)*tan(alpha)
  = 1 * 52.3 * 466/( 138 * 1 ) *( 1 - 30/30 ) * 0.58
  = 0 cm²
```

Force per Length, Cone Large End [QL]:

```
  = P( Rl/2 ) + f1
  = 22( 466/2 ) + 0
  = 52.332 Kgf/mm.
```

Axial Load per Unit Circumference excluding Pressure [f1]:

```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = -0/(pi(931+12))+0/(pi(466+12/2)(466+12/2))
  = 0.0 Kgf/mm.
```

Area of Reinforcement Available in Large end Shell [Ael]:

```
  = (Ts-t)*sqrt(Rl*Ts)+(Tc-Tr)*sqrt(Rl*Tc/cos(alpha))
  = ( 9 - 7.52 ) * SQRT( 466 * 9 ) +
    ( 9 - 8.68 ) * SQRT( 466 * 9/0.87 )
  = 1.1850 cm²
```

Summary of Reinforcement area, Large end, Internal Pressure:

```
 Area of reinforcement required per App. 1-5(1)        0.0000  cm²
 Area of reinforcement in shell per App. 1-5(2)        1.1850  cm²
 Area of reinforcement in stiffening ring              0.0000  cm²
```

Required Area of Reinforcement for Large End Under External Pressure

```
 Large end ratio of pressure to allowable stress    P/Ss E1    0.00075
 Large end max. half apex angle w/o reinforcement     delta      1.875  degrees
 Large end actual half apex angle                     alpha     30.000  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Srl * Erl ), 1 )
  = max( 27.15E+09/( 138 * 196910448 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
   = 138 * 196910448
   = 27153948672.0 N./mm²^2

 Allowable Stress of Large End Material (Ext. Temp)   137.9  N./mm²
 Allowable Stress of Cone Material (Ext. Temp)        137.9  N./mm²
```

Required Area of Reinforcement, Large End, External [Arl]:

```
  = (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(delta/alpha)
  = (1*2.5*474*0.58/(138*1))*
    (1-1/4((1.03*474-2.5)/2.5)*(1.88/30)
  = 0.48 cm²
```

Force per Length, Cone Large End External Pressure [QL]:

```
  = Pext( Rl/2 ) + f1
  = 1.03( 474/2 ) + 0
  = 2.502 Kgf/mm.
```

Axial Load per Unit Circumference excluding Pressure [f1]:

```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = +0/(pi(949-12))+0/(pi(474-12/2)(474-12/2))
  = 0.0 Kgf/mm.
```

Available Area of Reinforcement, Large End, External [Ael]:

```
  = 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
  = 0.55 *( 949 * 9 )½ *( 9 + 9/0.87 )
  = 9.8570 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

```
 Area of reinforcement required per App. 1-8(1)        0.4798  cm²
 Area of reinforcement in shell per App. 1-8(2)        9.8570  cm²
 Area of reinforcement in stiffening ring              0.0000  cm²
```

Reinforcement Calculations for Cone / Small Cylinder:

Required Area of Reinforcement for Small End under Internal Pressure

```
 Small end ratio of pressure to allowable stress    P/Ss E1    0.01599
 Small end max. half apex angle w/o reinforcement     delta     11.096  degrees
 Small end actual half apex angle                     alpha     30.000  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 27.15E+09/( 138 * 196910448 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Small End All. Stress * Small End Elastic Modulus (Int. temp.)
   = 138 * 196910448
   = 27153948672.0 N./mm²^2
```

Decay Length, Cone Small End:
```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 303( 12 - 3 ) )
  = 73.109 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:
```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
  = 1 * 34.1 * 303/( 138 * 1 ) *( 1 - 11.1/30 )0.58
  = 2.67 cm²
```

Force per Length, Cone Small End [QS]:
```
  = P( Rs/2 ) + f2
  = 22( 303/2 ) + 0
  = 34.063 Kgf/mm.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = -0/(pi(606+12))+0/(pi(303+12/2)(303+12/2))
  = 0.0 Kgf/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(303 *9 )½*(( 9 -4.89 )+( 9 -5.65 )/0.87 )
  = 3.2496 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:
```
 Area of reinforcement required per App. 1-5(3)        2.6703  cm²
 Area of reinforcement in shell per App. 1-5(4)        3.2496  cm²
 Area of reinforcement in stiffening ring              0.0000  cm²
```

Required Area of Reinforcement for Small End Under External Pressure

```
 Allowable Stress of Small End Material (Ext. Temp)    137.9  N./mm²
 Allowable Stress of Cone Material (Ext. Temp)         137.9  N./mm²
```

Intermediate Value [k]:
```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 27.15E+09/( 138 * 196910448 ), 1 )
  = 1.0000
```

where [Y] is:
```
   = Small End All. Stress * Small End Elastic Modulus (Ext. temp.)
   = 138 * 196910448
   = 27153948672.0 N./mm²^2
```

Area of Reinforcement Required in Small End Shell [Ars]:
```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1*1.65*312*0.58/(138*1))
  = 0.211 cm²
```

Force per Length, Cone Small End [QS]:
```
  = Pext( Rs/2 ) + f2
  = 1.03( 312/2 ) + 0
  = 1.645 Kgf/mm.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = +0/(pi(624-12))+0/(pi(312-12/2)(312-12/2))
  = 0.0 Kgf/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(624*9)½*[(9-1.1)+(9-2.05)/0.87]
  = 6.5630 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.2108	cm²
Area of reinforcement in shell per App. 1-8(4)	6.5630	cm²
Area of reinforcement in stiffening ring	0.0000	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	33.21	cm²
Force per Unit Length on Shell / Cone Junction	2.99	Kgf/mm.
Actual Buckling Stress associated with this Force	4.13	N./mm²
Material Strain associated with this stress	0.000042	

Required Moment of Inertia, Small End, External Pressure [I's]:

= A * Ds² * Ats / 10.9
= 0.41944E-04 * 624 * 624 * 33.2/10.9
= 4975.36 mm.⁴

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	3.710	0.0000	0.000	6.3763	0.250	150.819
Con	4.283	11.8983	50.965	-5.5220	2.407	130.613
Sec	0.000	4.5000	0.000	1.8763	0.000	0.000
TOT	7.993		50.965		2.657	281.431

Centroid of Section 6.3763 Moment of Inertia 5.47

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.5472E+01	cm**4
Required Moment of Inertia (Small End)	0.4975E+00	cm**4

Note: The following calculations are only required per 1-5(g)(1) and do include external loads due to wind or seismic. These discontinuity stresses are computed at the shell/cone junction and do not include effects of local stiffening from a junction ring.

Results for Discontinuity Stresses per Bednar p. 236 2nd Edition

Stress Type	Stress	Allowable	Location
Tensile Stress	180.72	413.70	Small Cyl. Long.
Compres. Stress	-105.38	-413.70	Small Cyl. Long.
Membrane Stress	154.08	-206.85	Small End Tang.
Tensile Stress	186.54	413.70	Cone Longitudinal
Compres. Stress	-99.55	-413.70	Cone Longitudinal
Compres Stress	165.73	-206.85	Cone Tangential
Tensile Stress	327.88	413.70	Large Cyl. Long.
Compres. Stress	-212.74	-413.70	Large Cyl. Long.
Membrane Stress	-33.64	-206.85	Large End Tang.
Tensile Stress	336.79	413.70	Cone Longitudinal
Compres. Stress	-203.83	-413.70	Cone Longitudinal
Compres Stress	-15.83	-206.85	Cone Tangential

Note: An asterisk (*) denotes that this stress was not applicable for this combination of loads.

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	22.861	Thickness due to internal pressure, Cone Large End
MAPnc	30.576	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

Input, Nozzle Desc: T1 (3in.) From: 20

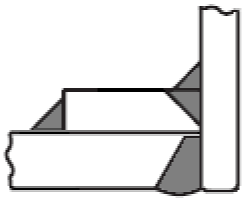
Pressure for Reinforcement Calculations	P	6.801	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	85	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Design Length of Section	L	400.0000	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	100.0000	mm.
Distance from Bottom/Left Tangent		200.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°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	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Outside	
Layout Angle		108.82	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.5500	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T1 (3in.)

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

```
Actual Outside Diameter Used in Calculation              3.500  in.
Actual Thickness Used in Calculation                     0.263  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)
  = (6.8*303)/(138*1-0.6*6.8)
  = 1.4990 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)
  = (6.8*44.5)/(118*1+0.4*6.8)
  = 0.2558 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)             Dl    173.5622  mm.
 Parallel to Vessel Wall, opening length               d     86.7811  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      17.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

*Taking a UG-36(c)(3)(a) exemption for nozzle: T1 (3in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.*

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

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

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

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

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 10, tr = 1.5, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.21, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, 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                              :  -104 °C
 Gov. MDMT of the Reinforcement Pad                   :  -104 °C
 Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -18 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 6.80/19.60 = 0.347
```

Weld Size Calculations, Description: T1 (3in.)

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675  mm.
 Intermediate Calc. for pad/shell Welds     TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld          2.5673 = 0.7 * tmin.   7.0700 = 0.7 * Wo mm.
 Pad Weld             3.5000 = 0.5*TminPad   5.6560 = 0.7 * Wp 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 Max. Allow. Pressure in Operating case    16.6   bars
```

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: T1 (3in.)

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

```
Actual Outside Diameter Used in Calculation           3.500  in.
Actual Thickness Used in Calculation                  0.263  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)
  = (6.8*303)/(138*1-0.6*6.8)
  = 1.4990 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)
  = (6.8*44.5)/(118*1+0.4*6.8)
  = 0.2558 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   163.1300  mm.
Parallel to Vessel Wall, opening length              d    81.5650  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

*Taking a UG-36(c)(3)(a) exemption for nozzle: T1 (3in.).
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 or
force the Appendix 1-10 computation in Nozzle Design Options.*

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

```
Wall Thickness for Internal/External pressures      ta = 3.3989 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 4.4990 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 4.5000 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.5, 4.5 ) ]
  = 4.5000 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4, 4.5 )
  = 4.5000 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

<u>Weld Size Calculations, Description: T1 (3in.)</u>

```
Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675   mm.
Intermediate Calc. for pad/shell Welds    TminPad       7.0000   mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
```

```
 Nozzle Weld          2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp 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 Max. Allow. Pressure in Operating case   16.6  bars
```

The Drop for this Nozzle is : 19.9089 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 230.4942 mm.

Input, Nozzle Desc: T2 (3in.) From: 20

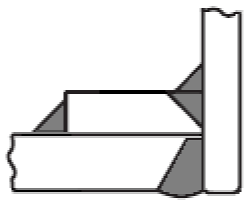
Pressure for Reinforcement Calculations	P	6.853	bars
Temperature for Internal Pressure	Temp	85	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	85	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	600.00	mm.
Design Length of Section	L	400.0000	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	100.0000	mm.
Distance from Bottom/Left Tangent		200.00	mm.
User Entered Minimum Design Metal Temperature		-29.00	°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	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Outside	
Layout Angle		251.18	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.5500	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T2 (3in.)

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

```
Actual Outside Diameter Used in Calculation            3.500  in.
Actual Thickness Used in Calculation                   0.263  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)
  = (6.85*303)/(138*1-0.6*6.85)
  = 1.5103 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)
  = (6.85*44.5)/(118*1+0.4*6.85)
  = 0.2578 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl    173.5622  mm.
Parallel to Vessel Wall, opening length               d     86.7811  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: T2 (3in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:B, Curve:A)

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A             -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)         -104 °C
```

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

Nozzle Neck to Pad Weld for the Nozzle, Curve: B

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

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

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 10, tr = 1.51, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.22, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104 °C
```

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

Govrn. thk, tg = 6.67, tr = 0.26, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.07, 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                               :  -104 °C
 Gov. MDMT of the Reinforcement Pad                    :  -104 °C
 Gov. MDMT of the nozzle to shell joint welded assembly :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -18 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 6.85/19.60 = 0.350
```

<u>Weld Size Calculations, Description: T2 (3in.)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.6675  mm.
 Intermediate Calc. for pad/shell Welds     TminPad    7.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp 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 Max. Allow. Pressure in Operating case   16.6  bars
```

<u>Note : Checking Nozzle in plane parallel to the vessel axis.</u>

Reinforcement CALCULATION, Description: T2 (3in.)

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

```
 Actual Outside Diameter Used in Calculation            3.500  in.
 Actual Thickness Used in Calculation                   0.263  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)
  = (6.85*303)/(138*1-0.6*6.85)
  = 1.5103 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)
  = (6.85*44.5)/(118*1+0.4*6.85)
  = 0.2578 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)             Dl   163.1300  mm.
 Parallel to Vessel Wall, opening length               d    81.5650  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

*Taking a UG-36(c)(3)(a) exemption for nozzle: T2 (3in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.*

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

```
 Wall Thickness for Internal/External pressures      ta = 3.3989 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 4.5103 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 4.5103 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 4.51, 4.5 ) ]
  = 4.5103 mm.
```

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

```
  = max( ta, tb )
  = max( 3.4, 4.51 )
  = 4.5103 mm.
```

Available Nozzle Neck Thickness = 6.6675 mm. --> OK

<u>Weld Size Calculations, Description: T2 (3in.)</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       3.6675   mm.
 Intermediate Calc. for pad/shell Welds    TminPad       7.0000   mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
```

```
 Nozzle Weld          2.5673 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp 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 Max. Allow. Pressure in Operating case   16.6  bars
```

The Drop for this Nozzle is : 19.9089 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 230.4942 mm.

Input, Nozzle Desc: S1 (4in.) From: 60

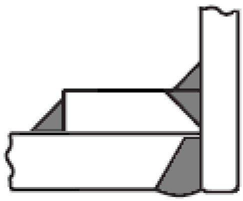
Pressure for Reinforcement Calculations	P	22.031	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cone at Nozzle Location	D	685.40	mm.
Equivalent Length of Conical Section	Le	2892.0833	mm.
Cone Half Apex Angle	Alpha	30.00	Degrees
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		898.52	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Outside	
Layout Angle		270.00	deg
Diameter		4.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		120	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	180.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	220.0000	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		52.8500	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S1 (4in.)

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

```
 Actual Outside Diameter Used in Calculation           4.500  in.
 Actual Thickness Used in Calculation                  0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Conical Transition, Tr [Int. Press]
```
  = (P*D)/(2*cos(a)*(Sv*E-0.6*P)) Appendix 1-4(e)
  = (22*(692+2*0))/   (2*0.87*(138*1-0.6*22))
  = 6.4481 mm.
```

Reqd Cone thickness at Nozzle Location under External Pres. : 8.6123 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)
  = (22*57.1)/(118*1+0.4*22)
  = 1.0601 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   201.6618  mm.
 Parallel to Vessel Wall, opening length              d   100.8309  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    22.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.85, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.628	2.884	NA
Area in Shell	A1	2.523	3.350	NA
Area in Nozzle Wall	A2	2.183	2.421	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	10.483	10.483	NA
TOTAL AREA AVAILABLE	Atot	16.045	17.109	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                 90.00  Degs.
```

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

```
SELECTION OF POSSIBLE REINFORCING PADS:   Diameter  Thickness
Based on given Pad Thickness:            123.1852    12.0000  mm.
Based on given Pad Diameter:             220.0000     1.2205  mm.
Based on Shell or Nozzle Thickness:      125.2530     9.7345  mm.
```

Area Required [A]:

```
 = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
 = (101*6.45*1+2*6.73*6.45*1*(1-0.85))
 = 6.628 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 )
 = 101( 1 * 9 - 1 * 6.45 ) - 2 * 6.73
   ( 1 * 9 - 1 * 6.45 ) *( 1 - 0.85 )
 = 2.523 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
 = ( 2 * Tlwp ) * ( tn - trn ) * fr2
 = ( 2 * 22.5 ) *( 6.73 - 1.06 ) * 0.85
 = 2.183 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
 = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
 = 10² * 0.85 +(0 )² * 0.85 + 0² * 1
 = 0.855 cm²
```

Area Available in Element [A5]:

```
 = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
 = ( 202 - 114 ) * 12 * 1
 = 10.483 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 4.0601 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.4481 mm.
Wall Thickness                tb1 = max(trb1, tr16b) = 9.4481 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.2999 mm.
Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 8.2578 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 8.26, max( 9.45, 4.5 ) ]
 = 8.2578 mm.
```

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

```
  = max( ta, tb )
  = max( 4.06, 8.26 )
  = 8.2578 mm.
```

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

```
 Impact Test Temperature provided per Specification          -46 °C

 Calculated Minimum Design Metal Temperature                -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

```
 Impact Test Temperature provided per Specification          -46 °C

 Calculated Minimum Design Metal Temperature                -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 9.73, tr = 1.06, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.16, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 12, tr = 6.45, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.72, Temp. Reduction = 16 °C

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

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

Govrn. thk, tg = 9.73, tr = 1.06, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.16, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

 Gov. MDMT of the Nozzle                                 :  -104 °C
 Gov. MDMT of the Reinforcement Pad                      :   -48 °C
 Gov. MDMT of the nozzle to shell joint welded assembly  :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -89 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 22.03/51.10 = 0.431
```

<u>Weld Size Calculations, Description: S1 (4in.)</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       6.7345  mm.
 Intermediate Calc. for pad/shell Welds    TminPad       9.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           4.7142 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld              4.5000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:

```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(6.63 - 2.52 + 2 * 6.73 * 0.85 *
    (1 * 9 - 6.45 ) )138 )
  = 6184.64 Kgf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.18 + 10.5 + 0.85 - 0 * 0.85 ) * 138
  = 19013.51 Kgf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.18 + 0 + 0.85 +( 1.04 ) ) * 138
  = 5729.49 Kgf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.18 + 0 + 0.85 + 10.5 +( 1.04 ) ) * 138
  = 20470.87 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 114 * 10 * 0.49 * 118
  = 10577. Kgf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.14/2.0 ) * 220 * 10 * 0.49 * 138
  = 23811. Kgf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 53.8 ) *( 9.73 - 3 ) * 0.7 * 118
  = 9576. Kgf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.14/2 ) * 114 * 12 * 0.74 * 138
  = 22419. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.14/2.0 ) * 114 *( 12 - 3 ) * 0.74 * 138
  = 16814. Kgf
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 23811 + 9576 ) = 33387 Kgf
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 10577 + 22419 + 16814 + 0 ) = 49810 Kgf
```

```
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 23811 + 16814 + 0 ) = 40625 Kgf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 33386 Kgf, must exceed W = 6184 Kgf or W1 = 19013 Kgf
 Path 2-2 = 49809 Kgf, must exceed W = 6184 Kgf or W2 = 5729 Kgf
 Path 3-3 = 40625 Kgf, must exceed W = 6184 Kgf or W3 = 20470 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   22.8  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 : 4.7989 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 196.7989 mm.

Input, Nozzle Desc: S2 (6in.) From: 70

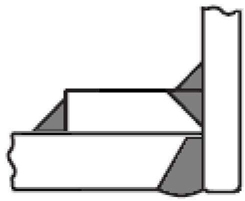
```
 Pressure for Reinforcement Calculations        P       22.000  bars
 Temperature for Internal Pressure           Temp          120  °C
 Design External Pressure                    Pext         1.03  bars
 Temperature for External Pressure         Tempex          120  °C

 Parent Material [Normalized]                       SA-516 70
 Parent Allowable Stress at Temperature        Sv       137.90  N./mm²
 Parent Allowable Stress At Ambient           Sva       137.90  N./mm²

 Inside Diameter of Cylindrical Shell           D       925.00  mm.
 Design Length of Section                       L    2892.0833  mm.
 Shell Finished (Minimum) Thickness             t      12.0000  mm.
 Shell Internal Corrosion Allowance             c       3.0000  mm.
 Shell External Corrosion Allowance            co       0.0000  mm.

 Distance from Bottom/Left Tangent                     2413.53  mm.

 User Entered Minimum Design Metal Temperature          -45.00  °C
```

Type of Element Connected to the Parent : Nozzle

```
 Material        [Impact Tested]                     SA-333 6
 Material UNS Number                                   K03006
 Material Specification/Type                 Smls. & wld. pipe
 Allowable Stress at Temperature               Sn       117.90  N./mm²
 Allowable Stress At Ambient                  Sna       117.90  N./mm²

 Diameter Basis (for tr calc only)                     Outside
 Layout Angle                                            90.00  deg
 Diameter                                               6.0000  in.

 Size and Thickness Basis                              Minimum
 Nominal Thickness                                          80

 Flange Material                                    SA-350 LF2
 Flange Type                                  Weld Neck Flange

 Corrosion Allowance                          can       3.0000  mm.
 Joint Efficiency of Shell Seam at Nozzle      E1         1.00
 Joint Efficiency of Nozzle Neck               En         1.00

 Outside Projection                            ho     180.0000  mm.
 Weld leg size between Nozzle and Pad/Shell    Wo      10.0000  mm.
 Groove weld depth between Nozzle and Vessel Wgnv      12.0000  mm.
 Inside Projection                              h       0.0000  mm.
 Weld leg size, Inside Element to Shell        Wi       0.0000  mm.

 Pad Material    [Normalized]                        SA-516 70
 Pad Allowable Stress at Temperature           Sp       137.90  N./mm²
 Pad Allowable Stress At Ambient              Spa       137.90  N./mm²
 Diameter of Pad along vessel surface          Dp     300.0000  mm.
 Thickness of Pad                              te      12.0000  mm.
 Weld leg size between Pad and Shell           Wp      10.0000  mm.
 Groove weld depth between Pad and Nozzle    Wgpn      12.0000  mm.
 Reinforcing Pad Width                                 65.8625  mm.

 Flange Class                                              300
 Flange Grade                                           GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S2 (6in.)

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

```
 Actual Outside Diameter Used in Calculation            6.625  in.
 Actual Thickness Used in Calculation                   0.378  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (22*466)/(138*1-0.6*22)
  = 7.4986 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)
  = (22*84.1)/(118*1+0.4*22)
  = 1.5584 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5566 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
 Parallel to Vessel Wall, opening length              d   155.0726  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    22.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 118/138 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 138/138 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.86, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	11.772	3.806	NA

```
 Area in Shell              A1 |     2.300|     6.358|        NA|
 Area in Nozzle Wall        A2 |     1.940|     2.326|        NA|
 Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
 Area in Welds    A41+A42+A43 |     1.612|     1.612|        NA|
 Area in Element            A5 |    15.807|    15.807|        NA|
 TOTAL AREA AVAILABLE     Atot |    21.659|    26.103|        NA|
```

The Internal Pressure Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

```
 SELECTION OF POSSIBLE REINFORCING PADS:   Diameter  Thickness
 Based on given Pad Thickness:            217.6076    12.0000  mm.
 Based on given Pad Diameter:             300.0000     4.4941  mm.
 Based on Shell or Nozzle Thickness:      229.9330     9.6012  mm.
```

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (155*7.5*1+2*6.6*7.5*1*(1-0.86))
  = 11.772 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 )
  = 155( 1 * 9 - 1 * 7.5 ) - 2 * 6.6
    ( 1 * 9 - 1 * 7.5 ) *( 1 - 0.86 )
  = 2.300 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 22.5 ) *( 6.6 - 1.56 ) * 0.86
  = 1.940 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = (1 ) * 0.86 +(0 ) * 0.86 + 75.7² * 1
  = 1.612 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 300 - 168 ) * 12 * 1
  = 15.807 cm²
```

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

```
 Wall Thickness for Internal/External pressures       ta = 4.5584 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 10.4986 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 10.4986 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.3493 mm.
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 10.5, 4.5 ) ]
  = 9.2200 mm.
```

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

```
  = max( ta, tb )
  = max( 4.56, 9.22 )
  = 9.2200 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained  :    14.9,  Allowable :    117.9 N./mm²  Passed
Expansion  :     0.0,  Allowable :    279.8 N./mm²  Passed
Occasional :    12.4,  Allowable :    156.8 N./mm²  Passed
Shear      :     6.5,  Allowable :     82.5 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.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

```
Impact Test Temperature provided per Specification          -46 °C

Calculated Minimum Design Metal Temperature                -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

```
Impact Test Temperature provided per Specification          -46 °C

Calculated Minimum Design Metal Temperature                -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 9.6, tr = 1.56, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.24, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 12, tr = 7.5, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.83, Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 9.6, tr = 1.56, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.24, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

Gov. MDMT of the Nozzle                                 :  -104 °C
Gov. MDMT of the Reinforcement Pad                      :   -48 °C
Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ASME B16.5/47 flange per Matl. Specification        -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)            -89 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
Design Pressure/Ambient Rating = 22.00/51.10 = 0.431
```

Weld Size Calculations, Description: S2 (6in.)

```
Intermediate Calc. for nozzle/shell Welds   Tmin       6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad      9.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
Nozzle Weld              4.6208 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
Pad Weld                 4.5000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0,(11.8 - 2.3 + 2 * 6.6 * 0.86 *
  (1 * 9 - 7.5 ) )138 )
= 13557.96 Kgf
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.94 + 15.8 + 1.61 - 0 * 0.86 ) * 138
= 27222.50 Kgf
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.94 + 0 + 0.86 +( 1.02 ) ) * 138
= 5359.09 Kgf
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.94 + 0 + 1.61 + 15.8 +( 1.02 ) ) * 138
= 28651.06 Kgf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.14/2.0 ) * 168 * 10 * 0.49 * 118
= 15572. Kgf
```

Shear, Pad Element Weld [Spew]:

```
= (pi/2) * DP * WP * 0.49 * SEW
= ( 3.14/2.0 ) * 300 * 10 * 0.49 * 138
= 32469. Kgf
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.14 * 80.8 ) *( 9.6 - 3 ) * 0.7 * 118
= 14109. Kgf
```

Tension, Pad Groove Weld [Tpgw]:

```
= ( pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.14/2 ) * 168 * 12 * 0.74 * 138
= 33006. Kgf
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
= ( 3.14/2.0 ) * 168 *( 12 - 3 ) * 0.74 * 138
= 24754. Kgf
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 32469 + 14109 ) = 46578 Kgf
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 15572 + 33006 + 24754 + 0 ) = 73332 Kgf
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 32469 + 24754 + 0 ) = 57224 Kgf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 46577 Kgf, must exceed W = 13557 Kgf or W1 = 27222 Kgf
 Path 2-2 = 73331 Kgf, must exceed W = 13557 Kgf or W2 = 5359 Kgf
 Path 3-3 = 57223 Kgf, must exceed W = 13557 Kgf or W3 = 28651 Kgf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   26.3  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 : 7.7175 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 199.7175 mm.

Input Echo, WRC107/537 Item 1, Description: S2 (6in.) :

```
 Diameter Basis for Vessel                 Vbasis      ID
 Cylindrical or Spherical Vessel           Cylsph      Cylindrical
 Internal Corrosion Allowance                 Cas      3.0000  mm.
 Vessel Diameter                               Dv     925.000  mm.
 Vessel Thickness                              Tv      12.000  mm.

 Design Temperature                            T1       120.0  °C
 Vessel Material                                   SA-516 70
 Vessel UNS Number                                     K02700
 Vessel Cold S.I. Allowable                   Smc      137.90  N./mm²
 Vessel Hot  S.I. Allowable                   Smh      137.90  N./mm²
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

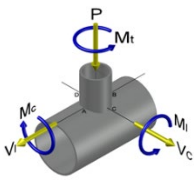
```
 Attachment Type                             Type      Round

 Diameter Basis for Nozzle                 Nbasis      OD
 Corrosion Allowance for Nozzle               Can      3.0000  mm.
 Nozzle Diameter                               Dn     168.275  mm.
 Nozzle Thickness                              Tn       9.601  mm.
 Nozzle Material                                     SA-333 6
 Nozzle UNS Number                                     K03006
 Nozzle Cold S.I. Allowable                  SNmc      117.90  N./mm²
 Nozzle Hot  S.I. Allowable                  SNmh      117.90  N./mm²

 Thickness of Reinforcing Pad                Tpad      12.000  mm.
 Diameter  of Reinforcing Pad                Dpad     300.000  mm.

 Design Internal Pressure                      Dp      22.000  bars
 Include Pressure Thrust                                   No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load              (SUS)                 P       856.6  Kgf
 Longitudinal Shear       (SUS)                Vl       856.6  Kgf
 Circumferential Shear    (SUS)                Vc       642.5  Kgf
 Circumferential Moment   (SUS)                Mc         0.3  Kg-m.
```

```
Longitudinal Moment      (SUS)                 Ml          0.3  Kg-m.
Torsional Moment         (SUS)                 Mt          0.4  Kg-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 ) )
= 168.275 + 2 * 1.65 * sqrt( 470.0 ( 12.0 - 3.0 ) )
= 382.902 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                   P         856.6  Kgf
Circumferential Shear                        VC         642.5  Kgf
Longitudinal Shear                           VL         856.6  Kgf
Circumferential Moment                       MC           0.3  Kg-m.
Longitudinal Moment                          ML           0.3  Kg-m.
Torsional Moment                             MT           0.4  Kg-m.

Dimensionless Parameters used :    Gamma =   22.67
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.155	4C	3.739	(A,B)
N(PHI) / (P/Rm)	0.155	3C	3.087	(C,D)
M(PHI) / (P)	0.155	2C1	0.073	(A,B)
M(PHI) / (P)	0.155	1C	0.106	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.155	3A	0.768	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.155	1A	0.093	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.155	3B	2.456	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.155	1B	0.042	(A,B,C,D)
N(x) / (P/Rm)	0.155	3C	3.087	(A,B)
N(x) / (P/Rm)	0.155	4C	3.739	(C,D)
M(x) / (P)	0.155	1C1	0.111	(A,B)
M(x) / (P)	0.155	2C	0.074	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.155	4A	1.170	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.155	2A	0.050	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.155	4B	0.742	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.155	2B	0.068	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-3.1	-3.1	-3.1	-3.1	-2.6	-2.6	-2.6	-2.6
Circ. Bend.	P	-8.4	8.4	-8.4	8.4	-12.1	12.1	-12.1	12.1
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	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-11.6	5.3	-11.5	5.2	-14.7	9.5	-14.7	9.5
Long. Memb.	P	-2.6	-2.6	-2.6	-2.6	-3.1	-3.1	-3.1	-3.1
Long. Bend.	P	-12.6	12.6	-12.6	12.6	-8.4	8.4	-8.4	8.4
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	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend.	ML	-0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-15.3	10.1	-15.2	10.0	-11.6	5.3	-11.5	5.2
Shear	VC	1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Shear	MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear		1.1	1.1	-1.1	-1.1	-1.5	-1.5	1.5	1.5
Str. Int.		15.6	10.3	15.5	10.3	15.3	10.0	15.3	10.0

Dimensionless Parameters used : Gamma = 52.22

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.279	4C	5.662	(A,B)
N(PHI) / (P/Rm)	0.279	3C	2.676	(C,D)
M(PHI) / (P)	0.279	2C1	0.015	(A,B)
M(PHI) / (P)	0.279	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.279	3A	1.741	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.279	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.279	3B	3.690	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.279	1B	0.011	(A,B,C,D)
N(x) / (P/Rm)	0.279	3C	2.676	(A,B)
N(x) / (P/Rm)	0.279	4C	5.662	(C,D)
M(x) / (P)	0.279	1C1	0.037	(A,B)
M(x) / (P)	0.279	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.279	4A	4.862	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.279	2A	0.025	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.279	4B	1.882	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.279	2B	0.017	(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./mm²)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							

Circ. Memb. P	-11.2	-11.2	-11.2	-11.2	-5.3	-5.3	-5.3	-5.3
Circ. Bend. P	-9.2	9.2	-9.2	9.2	-40.7	40.7	-40.7	40.7
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	-0.1	0.1	0.1	-0.1
Circ. Memb. ML	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-20.5	-2.0	-20.4	-2.0	-46.1	35.5	-45.9	35.3
Long. Memb. P	-5.3	-5.3	-5.3	-5.3	-11.2	-11.2	-11.2	-11.2
Long. Bend. P	-22.7	22.7	-22.7	22.7	-20.9	20.9	-20.9	20.9
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	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-28.1	17.4	-28.0	17.4	-32.2	9.7	-32.1	9.7
Shear VC	1.5	1.5	-1.5	-1.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	1.5	1.5	-1.5	-1.5	-2.0	-2.0	2.0	2.0
Str. Int.	28.4	19.7	28.3	19.6	46.4	35.6	46.2	35.5

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)	47.7	49.9	47.7	49.9	47.7	49.9	47.7	49.9
Circ. Pl (SUS)	-3.2	-3.2	-3.1	-3.1	-2.6	-2.6	-2.6	-2.6
Circ. Q (SUS)	-8.4	8.4	-8.4	8.4	-12.1	12.1	-12.1	12.1
Long. Pm (SUS)	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8
Long. Pl (SUS)	-2.6	-2.6	-2.6	-2.6	-3.1	-3.1	-3.1	-3.1
Long. Q (SUS)	-12.7	12.7	-12.6	12.6	-8.4	8.4	-8.4	8.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.1	1.1	-1.1	-1.1	-1.5	-1.5	1.5	1.5
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	47.7	49.9	47.7	49.9	47.7	49.9	47.7	49.9
Pm+Pl (SUS)	44.6	46.8	44.6	46.8	45.2	47.4	45.2	47.4
Pm+Pl+Q (Total)	36.2	55.2	36.2	55.2	33.1	59.5	33.2	59.4

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	49.89	137.90	Passed
Pm+Pl (SUS)	47.39	206.85	Passed
Pm+Pl+Q (TOTAL)	59.52	413.70	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./mm²)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Pm (SUS)	112.7	114.9	112.7	114.9	112.7	114.9	112.7	114.9
Circ. Pl (SUS)	-11.3	-11.3	-11.2	-11.2	-5.3	-5.3	-5.3	-5.3
Circ. Q (SUS)	-9.2	9.2	-9.2	9.2	-40.8	40.8	-40.6	40.6
Long. Pm (SUS)	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4
Long. Pl (SUS)	-5.3	-5.3	-5.3	-5.3	-11.3	-11.3	-11.2	-11.2
Long. Q (SUS)	-22.8	22.8	-22.7	22.7	-21.0	21.0	-20.9	20.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.5	1.5	-1.5	-1.5	-2.0	-2.0	2.0	2.0
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	112.7	114.9	112.7	114.9	112.7	114.9	112.7	114.9
Pm+Pl (SUS)	101.5	103.7	101.5	103.7	107.4	109.6	107.5	109.7
Pm+Pl+Q (Total)	92.2	112.9	92.3	112.9	66.7	150.4	66.9	150.3

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.91	137.90	Passed
Pm+Pl (SUS)	109.66	206.85	Passed
Pm+Pl+Q (TOTAL)	150.43	413.70	Passed

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

Input, Nozzle Desc: V (2in.) From: 70

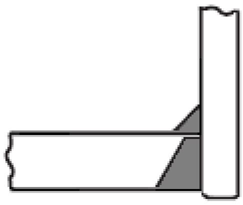
Pressure for Reinforcement Calculations	P	22.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	925.00	mm.
Design Length of Section	L	2892.0833	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3363.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: V (2in.)

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```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (22*466)/(138*1-0.6*22)
  = 7.4986 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (22*28.4)/(138*1-0.6*22)
  = 0.4575 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     22.5000  mm.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: V (2in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

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

```
 Wall Thickness for Internal/External pressures      ta = 3.4575 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.4986 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 10.4986 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.3493 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 10.5, 4.5 ) ]
  = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 3.46, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 12, tr = 7.5, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.83, Temp. Reduction = 9 °C

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

 Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

Weld Size Calculations, Description: V (2in.)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             6.0000 = Min per Code 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 Max. Allow. Pressure in Operating case   26.3  bars
```

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

The Drop for this Nozzle is : 1.9110 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.9110 mm.

Input, Nozzle Desc: D (2in.)   From: 70

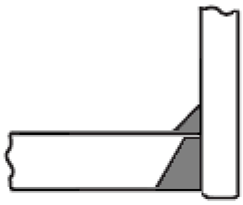
Pressure for Reinforcement Calculations	P	22.048	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	925.00	mm.
Design Length of Section	L	2892.0833	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3363.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		Inside	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: D (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                    0.654  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)
  = (22*466)/(138*1-0.6*22)
  = 7.5152 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (22*28.4)/(138*1-0.6*22)
  = 0.4585 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3862 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
 Parallel to Vessel Wall, opening length              d     56.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     22.5000  mm.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: D (2in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4585 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.5152 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 10.5152 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.3493 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 10.5, 4.5 ) ]
  = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 3.46, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 12, tr = 7.52, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.84, Temp. Reduction = 9 °C

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

 Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

<u>Weld Size Calculations, Description: D (2in.)</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             6.0000 = Min per Code 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 Max. Allow. Pressure in Operating case   26.4  bars
```

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

The Drop for this Nozzle is : 1.9110 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.9110 mm.

Input, Nozzle Desc: PSV (3in.) From: 70

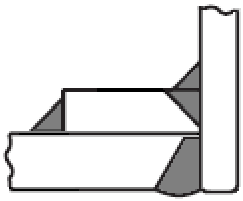
Pressure for Reinforcement Calculations	P	22.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	925.00	mm.
Design Length of Section	L	2892.0833	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1483.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Outside	
Layout Angle		90.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		50.5500	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: PSV (3in.)

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

```
Actual Outside Diameter Used in Calculation            3.500  in.
Actual Thickness Used in Calculation                   0.383  in.
```

Nozzle input data check completed without errors.

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

```
 = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
 = (22*466)/(138*1-0.6*22)
 = 7.4986 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)
 = (22*44.5)/(118*1+0.4*22)
 = 0.8233 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3989 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   150.8618  mm.
Parallel to Vessel Wall, opening length              d    75.4309  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    22.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: PSV (3in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

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

```
Wall Thickness for Internal/External pressures      ta = 3.8233 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 10.4986 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 10.4986 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.3493 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 7.8, max( 10.5, 4.5 ) ]
 = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 3.82, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

```
 Impact Test Temperature provided per Specification         -46 °C

 Calculated Minimum Design Metal Temperature               -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

```
 Impact Test Temperature provided per Specification         -46 °C

 Calculated Minimum Design Metal Temperature               -104 °C
```

Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 9.73, tr = 0.82, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.12, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 12, tr = 7.5, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.83, Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 9.73, tr = 0.82, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.12, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C

 Gov. MDMT of the Nozzle                               :  -104 °C
 Gov. MDMT of the Reinforcement Pad                    :   -48 °C
 Gov. MDMT of the nozzle to shell joint welded assembly :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification       -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -89 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 22.00/51.10 = 0.431
```

Weld Size Calculations, Description: PSV (3in.)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin       6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad      9.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld            4.7142 = 0.7 * tmin.  7.0700 = 0.7 * Wo mm.
 Pad Weld               4.5000 = 0.5*TminPad  7.0700 = 0.7 * Wp 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 Max. Allow. Pressure in Operating case   26.3  bars
```

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

The Drop for this Nozzle is : 2.1410 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 214.1409 mm.

Input, Nozzle Desc: LG1 (2in.) From: 70

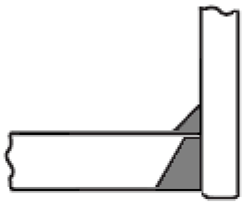
Pressure for Reinforcement Calculations	P	22.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	925.00	mm.
Design Length of Section	L	2892.0833	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1913.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	
Piping Exit Angle [North Clockwise reference]		270.0	deg
Bend Radius Multiplier		1.50	
Horizontal Run Length		550.0	mm.
Centerline Distance to Tangent		150.0	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: LG1 (2in.)

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

```
 Actual Inside Diameter Used in Calculation            1.773  in.
 Actual Thickness Used in Calculation                  0.301  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)
  = (22*466)/(138*1-0.6*22)
  = 7.4986 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (22*25.5)/(118*1-0.6*22)
  = 0.4815 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   102.0684  mm.
 Parallel to Vessel Wall, opening length              d    51.0342  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    11.6135  mm.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: LG1 (2in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4815 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.4986 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 10.4986 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.3493 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 10.5, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 3.48, 6.42 )
  = 6.4200 mm.
```

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

```
 Impact Test Temperature provided per Specification          -46 °C

 Calculated Minimum Design Metal Temperature                -104 °C
```

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

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

Govrn. thk, tg = 7.65, tr = 0.48, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.1, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -89 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 22.00/51.10 = 0.431
```

Weld Size Calculations, Description: LG1 (2in.)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      4.6454  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          3.2518 = 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 Max. Allow. Pressure in Operating case   26.3  bars
```

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

The Drop for this Nozzle is : 0.9846 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.9846 mm.

Input, Nozzle Desc: LG2 (2in.) From: 70

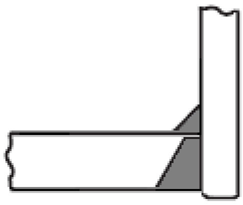
Pressure for Reinforcement Calculations	P	22.048	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	120	°C
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	137.90	N./mm²
Parent Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	925.00	mm.
Design Length of Section	L	2892.0833	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1913.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Parent : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		Inside	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness		160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	
Piping Exit Angle [North Clockwise reference]		90.0	deg
Bend Radius Multiplier		1.50	
Horizontal Run Length		550.0	mm.
Centerline Distance to Tangent		150.0	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: LG2 (2in.)

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

```
 Actual Inside Diameter Used in Calculation             1.773  in.
 Actual Thickness Used in Calculation                   0.301  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)
  = (22*466)/(138*1-0.6*22)
  = 7.5152 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (22*25.5)/(118*1-0.6*22)
  = 0.4826 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)             Dl   102.0684  mm.
 Parallel to Vessel Wall, opening length               d    51.0342  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    11.6135  mm.
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: LG2 (2in.).
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 or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4826 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 10.5152 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 10.5152 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.3493 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 10.5, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 3.48, 6.42 )
  = 6.4200 mm.
```

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

```
 Impact Test Temperature provided per Specification          -46 °C

 Calculated Minimum Design Metal Temperature                -104 °C
```

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

Govrn. thk, tg = 7.65, tr = 0.48, c = 3 mm., E* = 1
Thickness Ratio = tr *(E*)/(tg - c) = 0.1, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -48 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ASME B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -89 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
 Design Pressure/Ambient Rating = 22.05/51.10 = 0.431
```

Weld Size Calculations, Description: LG2 (2in.)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      4.6454  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           3.2518 = 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 Max. Allow. Pressure in Operating case   26.4  bars
```

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

The Drop for this Nozzle is : 0.9846 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.9846 mm.

Input Echo, Tubesheet Number 1, Description: Tubesheet

Shell Data:

Main Shell Description: Port Barrel

Shell Maximum Design Pressure	Psd,max	22.00	bars
Shell Maximum Operating Pressure	Psox,max	22.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	600.000	mm.
Shell Temperature for Internal Pressure	Ts	120.00	°C
Shell Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm^2
Shell Allowable Stress at Ambient		137.90	N./mm^2

Channel Description: CH. Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	6.80	bars
Channel Maximum Operating Pressure	Ptox,max	6.80	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	600.000	mm.
Channel Design Temperature	TEMPC	85.00	°C
Channel Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm^2
Channel Allowable Stress at Ambient		137.90	N./mm^2

Tube Data:

Number of Tube Holes	Nt	376	
Tube Wall Thickness	et	1.6500	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	2300.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	2240.00	mm.
Design Temperature of the Tubes		120.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. & wld. tube	
Tube Allowable Stress at Temperature		117.90	N./mm^2
Tube Allowable Stress At Ambient		117.90	N./mm^2
Tube Yield Stress At design Temperature	Syt	217.36	N./mm^2
Tube Pitch (Center to Center Spacing)	P	23.8130	mm.
Tube Layout Pattern		Triangular	
Radius to Outermost Tube Hole Center	ro	283.510	mm.
Largest Center-to-Center Tube Distance	Ul	52.3870	mm.
Length of Expanded Portion of Tube	ltx	57.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

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

Tubesheet Design Metal Temperature	T	120.00	°C
Tubesheet Material		SA-350 LF2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-350 LF2

Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm²
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm²
Thickness of Tubesheet	h	60.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	650.000	mm.
Dimension G for the Channel Side	Gc	637.151	mm.
Area of the Untubed Lanes	AL	425.5	cm²
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	

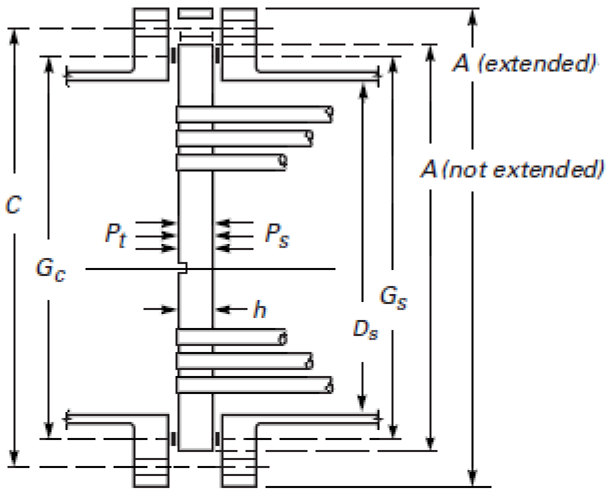
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	760.000	mm.
Flange Inside Diameter	B	600.000	mm.
Flange Face Outside Diameter	Fod	653.000	mm.
Flange Face Inside Diameter	Fid	600.000	mm.
Gasket Outside Diameter	Go	650.000	mm.
Gasket Inside Diameter	Gi	624.000	mm.
Small end Hub thk.	g0	12.0000	mm.
Large end Hub thk.	g1	18.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	69.00	N./mm²
Flange Facing Sketch		Code Sketch 1b	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	4.5000	mm.
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	705.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	20	
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		88967.88	Kgf
Alternate Flange Seating Bolt Load, Wm2		90480.76	Kgf
Alternate Flange Design Bolt Load, W		92754.98	Kgf
Tubesheet Integral with		None	
Tubesheet Extended as Flange		No	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
 ------------------------------------------------------------------
 Elastic Mod. at Design Temperature       120.0 °C      0.19691E+09 KPa.
 Elastic Mod. at Ambient Temperature       21.1 °C      0.20270E+09 KPa.
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
 ------------------------------------------------------------------
 Elastic Mod. at Design Temperature        85.0 °C      0.19904E+09 KPa.
 Elastic Mod. at Ambient Temperature       21.1 °C      0.20270E+09 KPa.
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 ------------------------------------------------------------------
 Elastic Mod. at Tubsht. Design Temp.     120.0 °C      0.19691E+09 KPa.
 Elastic Mod. at Ambient Temperature       21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
 ------------------------------------------------------------------
 Elastic Mod. at Design Temperature       120.0 °C      0.19691E+09 KPa.
 Elastic Mod. at Ambient Temperature       21.1 °C      0.20270E+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)
  = (6.8*(19/2-0)/(118*1+0.4*6.8)
  = 0.0548 + 0.0000 = 0.0548 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     CS-2              at        120.00   °C
 Elastic Modulus for Material                     199943392.00   KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A        B
   1.6500      19.05    2523.51      11.55    50.0000  0.0082522       122.73
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *123 )/( 3 *11.5 ) = 142 bars
```

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

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4699	19.05	2523.51	40.54	50.0000	0.0006692	66.90

```
EMAWP = (4*B)/(3*(D/T)) = ( 4 *66.9 )/( 3 *40.5 ) = 22 bars
```

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.4699	mm.
Allowable Internal Pressure at Corroded thickness	219.44	bars
Required Internal Design Pressure	6.80	bars
Allowable External Pressure at Corroded thickness	141.73	bars
Required External Design Pressure	22.00	bars
Required Thickness due to Shell Side pressure	0.4699	mm.

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	13.000	mm.
Basic Gasket Width,	b0 = N / 2.0	6.500	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	6.422	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	637.156	mm.

Flange Design Bolt Load, Seating Condition	W :	92754.98	Kgf
Flange Design Bolt Load, Operating Condition	Wm1:	88836.14	Kgf

<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/(min(0.8*S, 0.533*Sy)))[Ps - Pt] + Cats + Catc
= 1/(4 * 0.2 ) * (586/110 )[22 - 6.8 ] + 0
= 10.0934 mm.
```

UHX-12.5.1 Step 1:

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

```
= 2 * ro + dt
= 2 * 284 + 19 = 586 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:

```
= (p - dt) / p
= (23.8 - 19 )/23.8 = 0.2
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:

```
= Gs / Do (Configurations d, e, f)
= 637/586 = 1.09
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 637/586 = 1.09
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 586²/16 * [ (1.09 - 1) * (1.09² + 1) * 22 -
  (1.09 - 1) * (1.09² + 1) * 6.8 ]
= 62062.8672 bars*mm.²
```

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

Compute the Ratio [rho]:
```
  = ltx/h = 57/60 = 0.95 ( 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 *(196910448/196910448 )*
       ( 118/138 )*(0.95 ), 19 -2*1.65 )
  = 16.3696 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 23.8/sqrt( 1 - 4 * min( 425 *100, 4*586 *23.8 )
    (3.141* 586²) )
  = 25.9469 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (25.9 - 16.4 )/25.9 = 0.37
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
   h/p =   2.519632 ;  mu* =   0.369112
  E*/E =   0.372514 ;  nu* =   0.319336 ;  E* = 73351928. KPa.
```

Note: As h/p (2.520) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:
```
  = A/Do = 650/586 = 1.11
```

Determine Coefficient [F]:
```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.32 )/73351928 * ( 196910448 * ln(1.11 ) )
  = 0.1892
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = 62063 + 88968 * (637 - 637 )/(2 * pi * 586 )
  = 62062.8672 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)
  = ((62063 ) - 586²/32 * 0.19 * (22 - 6.8 ) )/(1 + 0.19 )
  = 26235.0996 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = 26235 + 586²/64 * (3 + 0.32 )(22 - 6.8 )
  = 297013.3750 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:
```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(26235 ), abs(297013 ) )
  = 297013.3750 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 297013/((0.37) * (60 - 5)²)
= 159.6132 N./mm²

The Allowable Tubesheet Bending Stress [SigmaAll]:
= 2 * S = 2 * 138 = 276 N./mm²

Tubesheet Bending Stress at Final Thickness [Sigma]:
= 6 * M / ((mu*) * (h - hg')²
= 6 * 297361/((0.37) * (46.6 - 5)²
= 275.7786 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 46.6 + 0 + 0 = 46.6 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(46.6, 10.1) = 46.6 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(22 - 6.8) = 15.2 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 60/586 = 90.4 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(586/60)*[22-6.8]N./mm²
= 18.56 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	159.6	<=	275.8 N./mm²	Ok
Tubesheet shear stress	18.6	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	46.562	60.000	Ok

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 6 Load Cases:

	--Reqd. Thk. + CA		---- Tubesheet	Stresses			Case	Pass/
Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type	Fail
D1uc	32.806	0.962	71	276	8	110	Ps+Pt D1	Ok
D2uc	55.009	3.111	231	276	27	110	Ps+Pt D2	Ok
D3uc	46.562	2.150	160	276	19	110	Ps+Pt D3	Ok
D1c	35.858	0.962	79	276	9	110	Ps+Pt-c D1	Ok
D2c	58.003	3.111	255	276	30	110	Ps+Pt-c D2	Ok
D3c	49.579	2.150	176	276	21	110	Ps+Pt-c D3	Ok
Max:	58.0031	3.111 mm.		0.925		0.271	(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 6 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	58.003	60.000	Ok
Tubesheet Thickness Flanged Extension :	3.111	50.000	Ok
Tube Thickness :	0.470	1.650	Ok

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	23.795	1.000	23.794	1.000
Tubesheet Shear Stress	81.319	1.000	81.319	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAWP	23.795		23.794	

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	26.264	1.000	26.264	1.000
Tubesheet Shear Stress	90.355	1.000	90.355	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAPnc	26.264		26.264	

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

Tubesheet MDMT Calculations:

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

Determine the governing MDMT considering the governing condition:

Governing thickness on the shell side per figure UCS-66.3 (c):
= tubesheet thickness/4

```
  = 60/4
  = 15.000 mm.
```

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

```
 Impact Test Temperature provided per Specification         -46 °C
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

```
  = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
  = max( 6.8/26.3, 22/26.3 )
  = 0.838
```

Input Echo, Tubesheet Number 2, Description: Tubesheet

Shell Data:

Main Shell Description: Port Barrel

Shell Maximum Design Pressure	Psd,max	22.00	bars
Shell Maximum Operating Pressure	Psox,max	22.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	600.000	mm.
Shell Temperature for Internal Pressure	Ts	-45.00	°C
Shell Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm²
Shell Allowable Stress at Ambient		137.90	N./mm²

Channel Description: CH. Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	6.80	bars
Channel Maximum Operating Pressure	Ptox,max	6.80	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	600.000	mm.
Channel Design Temperature	TEMPC	-29.00	°C
Channel Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm²
Channel Allowable Stress at Ambient		137.90	N./mm²

Tube Data:

Number of Tube Holes	Nt	376	
Tube Wall Thickness	et	1.6500	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	2300.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	2240.00	mm.
Design Temperature of the Tubes		-45.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used	Smls. & wld. tube		
Tube Allowable Stress at Temperature		117.90	N./mm²
Tube Allowable Stress At Ambient		117.90	N./mm²
Tube Yield Stress At design Temperature	Syt	241.32	N./mm²
Tube Pitch (Center to Center Spacing)	P	23.8130	mm.
Tube Layout Pattern		Triangular	
Radius to Outermost Tube Hole Center	ro	283.510	mm.
Largest Center-to-Center Tube Distance	Ul	52.3870	mm.
Length of Expanded Portion of Tube	ltx	57.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

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

Tubesheet Design Metal Temperature	T	-45.00	°C
Tubesheet Material		SA-350 LF2	
Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	223.40	N./mm²
Tubesheet Allowable Stress at Ambient	Tt	223.40	N./mm²
Thickness of Tubesheet	h	60.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	650.000	mm.
Dimension G for the Channel Side	Gc	637.151	mm.
Area of the Untubed Lanes	AL	425.5	cm²
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	

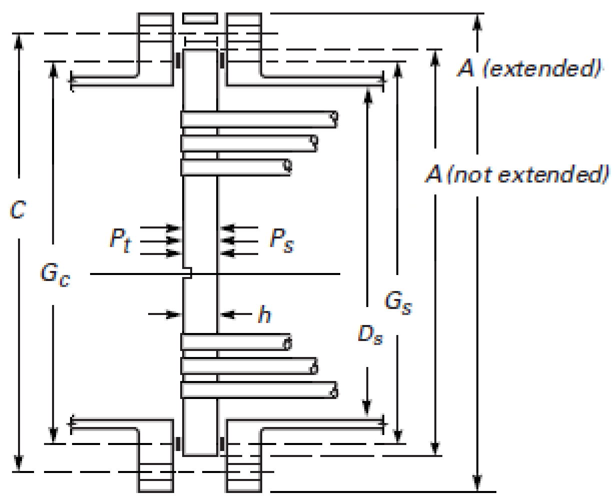
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	760.000	mm.
Flange Inside Diameter	B	600.000	mm.
Flange Face Outside Diameter	Fod	653.000	mm.
Flange Face Inside Diameter	Fid	600.000	mm.
Gasket Outside Diameter	Go	650.000	mm.
Gasket Inside Diameter	Gi	624.000	mm.
Small end Hub thk.	g0	12.0000	mm.
Large end Hub thk.	g1	18.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	69.00	N./mm²
Flange Facing Sketch		Code Sketch 1b	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	4.5000	mm.
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	705.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	20	
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm²
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm²
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		88967.88	Kgf
Alternate Flange Seating Bolt Load, Wm2		90480.76	Kgf
Alternate Flange Design Bolt Load, W		92754.98	Kgf
Tubesheet Integral with		None	
Tubesheet Extended as Flange		No	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      -45.0 °C      0.20704E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      -29.0 °C      0.20599E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Tubsht. Design Temp.    -45.0 °C      0.20704E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
-----------------------------------------------------------------
Elastic Mod. at Design Temperature      -45.0 °C      0.20704E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+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)
  = (6.8*(19/2-0)/(118*1+0.4*6.8)
  = 0.0548 + 0.0000 = 0.0548 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-2              at        -45.00   °C
Elastic Modulus for Material                      199943392.00   KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   1.6500      19.05    2523.51      11.55    50.0000   0.0082522       122.73
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *123 )/( 3 *11.5 ) = 142 bars
```

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

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4699	19.05	2523.51	40.54	50.0000	0.0006692	66.90

EMAWP = (4*B)/(3*(D/T)) = (4 *66.9)/(3 *40.5) = 22 bars

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.4699	mm.
Allowable Internal Pressure at Corroded thickness	219.44	bars
Required Internal Design Pressure	6.80	bars
Allowable External Pressure at Corroded thickness	141.73	bars
Required External Design Pressure	22.00	bars
Required Thickness due to Shell Side pressure	0.4699	mm.

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 6 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	28.074	0.594	79	447	8	132	Ps+Pt D1	Ok
D2uc	46.475	1.920	256	447	27	132	Ps+Pt D2	Ok
D3uc	39.472	1.327	177	447	19	132	Ps+Pt D3	Ok
D1c	31.041	0.594	88	447	9	132	Ps+Pt-c D1	Ok
D2c	49.489	1.920	284	447	30	132	Ps+Pt-c D2	Ok
D3c	42.502	1.327	196	447	21	132	Ps+Pt-c D3	Ok
Max:	49.4892	1.920	mm.	0.636		0.226	(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 6 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	49.489	60.000	Ok
Tubesheet Thickness Flanged Extension :	1.920	50.000	Ok
Tube Thickness :	0.470	1.650	Ok

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	34.584	1.000	34.583	1.000
Tubesheet Shear Stress	97.515	1.000	97.515	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAWP	34.584		34.583	

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	38.329	1.000	38.329	1.000
Tubesheet Shear Stress	108.358	1.000	108.358	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAPnc	38.329		38.329	

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

Input Echo, Tubesheet Number 3, Description: Tubesheet

Shell Data:

Main Shell Description: Port Barrel

Shell Maximum Design Pressure	Psd,max	28.60	bars
Shell Maximum Operating Pressure	Psox,max	28.60	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	600.000	mm.
Shell Temperature for Internal Pressure	Ts	20.00	°C
Shell Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm²
Shell Allowable Stress at Ambient		137.90	N./mm²

Channel Description: CH. Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	8.84	bars
Channel Maximum Operating Pressure	Ptox,max	8.84	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	600.000	mm.
Channel Design Temperature	TEMPC	20.00	°C
Channel Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm²
Channel Allowable Stress at Ambient		137.90	N./mm²

Tube Data:

Number of Tube Holes	Nt	376	
Tube Wall Thickness	et	1.6500	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	2300.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	2240.00	mm.
Design Temperature of the Tubes		20.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. & wld. tube	
Tube Allowable Stress at Temperature		117.90	N./mm²
Tube Allowable Stress At Ambient		117.90	N./mm²
Tube Yield Stress At design Temperature	Syt	241.32	N./mm²
Tube Pitch (Center to Center Spacing)	P	23.8130	mm.
Tube Layout Pattern		Triangular	
Radius to Outermost Tube Hole Center	ro	283.510	mm.
Largest Center-to-Center Tube Distance	Ul	52.3870	mm.
Length of Expanded Portion of Tube	ltx	57.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

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

```
 Tubesheet Design Metal Temperature            T       20.00  °C
 Tubesheet Material                               SA-350 LF2
 Tubesheet Material UNS Number                        K03011
 Tubesheet Allowable Stress at Temperature     S      223.40  N./mm²
 Tubesheet Allowable Stress at Ambient        Tt      223.40  N./mm²
 Thickness of Tubesheet                        h     60.0000  mm.
 Tubesheet Corr. Allowance (Shell side)     Cats      3.0000  mm.
 Tubesheet Corr. Allowance (Channel side)   Catc      3.0000  mm.
 Tubesheet Outside Diameter                    A     650.000  mm.

 Dimension G for the Channel Side             Gc     637.151  mm.
 Area of the Untubed Lanes                    AL       425.5  cm²

 Junction Stress Reduction option             Increase Tubesheet thickness
 Perform Differential Pressure Design                     NO
 Run Multiple Load Cases                                 YES
```

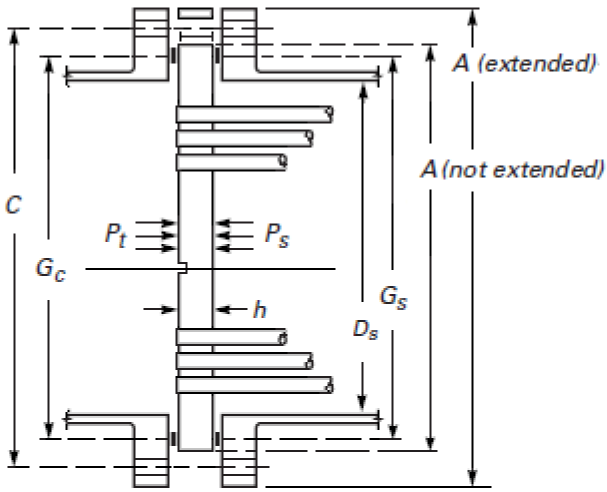
Additional Data for Gasketed Tubesheets:

```
 Tubesheet Gasket on which Side                         Both
 Flange Outside Diameter                       A     760.000  mm.
 Flange Inside Diameter                        B     600.000  mm.
 Flange Face Outside Diameter                Fod     653.000  mm.
 Flange Face Inside Diameter                 Fid     600.000  mm.
 Gasket Outside Diameter                      Go     650.000  mm.
 Gasket Inside Diameter                       Gi     624.000  mm.
 Small end Hub thk.                           g0     12.0000  mm.
 Large end Hub thk.                           g1     18.0000  mm.
 Gasket Factor,                                m        3.00
 Gasket Design Seating Stress                  y       69.00  N./mm²
 Flange Facing Sketch                         Code Sketch 1b
 Column for Gasket Seating                    Code Column II
 Gasket Thickness                             tg      4.5000  mm.
 Full face Gasket Flange Option              Program Selects
```

Bolting Information:

```
 Diameter of Bolt Circle                       C     705.000  mm.
 Nominal Bolt Diameter                        dB     22.2250  mm.
 Type of Thread Series                        TEMA Thread Series
 Number of Bolts                               n          20
 Bolt Material                                     SA-193 B7
 Bolt Allowable Stress At Temperature         Sb      172.38  N./mm²
 Bolt Allowable Stress At Ambient             Sa      172.38  N./mm²
 Weld between Flange and Shell/Channel                0.0000  mm.

 Alternate Flange Operating Bolt Load, Wm1         115486.97 Kgf
 Alternate Flange Seating Bolt Load, Wm2            90480.76 Kgf
 Alternate Flange Design Bolt Load, W              105258.09 Kgf

 Tubesheet Integral with                                None
 Tubesheet Extended as Flange                             No
```

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
-------------------------------------------------------------------
Elastic Mod. at Design Temperature       20.0 °C      0.20277E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
-------------------------------------------------------------------
Elastic Mod. at Design Temperature       20.0 °C      0.20277E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
-------------------------------------------------------------------
Elastic Mod. at Tubsht. Design Temp.     20.0 °C      0.20277E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
-------------------------------------------------------------------
Elastic Mod. at Design Temperature       20.0 °C      0.20277E+09 KPa.
Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+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)
  = (8.84*(19/2-0)/(118*1+0.4*8.84)
  = 0.0712 + 0.0000 = 0.0712 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-2             at        20.00   °C
Elastic Modulus for Material                      199943392.00   KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A         B
   1.6500      19.05    2523.51      11.55    50.0000  0.0082522       122.73
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *123 )/( 3 *11.5 ) = 142 bars
```

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

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   0.5187     19.05    2523.51      36.72    50.0000  0.0008156         78.79
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *78.8 )/( 3 *36.7 ) = 28.6 bars
```

Summary of Tube Required Thickness Results:

```
 Total Required Thickness including Corrosion all.              0.5187  mm.
 Allowable Internal Pressure at Corroded thickness              219.44  bars
 Required Internal Design Pressure                                8.84  bars
 Allowable External Pressure at Corroded thickness              141.73  bars
 Required External Design Pressure                               28.60  bars
 Required Thickness due to Shell Side pressure                  0.5187  mm.
```

U-Tube Tubesheet results per ASME UHX-12 2019

Results for 6 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	31.295	0.772	103	447	11	132	Ps+Pt D1	Ok
D2uc	52.337	2.497	333	447	35	132	Ps+Pt D2	Ok
D3uc	44.306	1.725	230	447	24	132	Ps+Pt D3	Ok
D1c	34.274	0.772	114	447	12	132	Ps+Pt-c D1	Ok
D2c	55.295	2.497	369	447	39	132	Ps+Pt-c D2	Ok
D3c	47.324	1.725	255	447	27	132	Ps+Pt-c D3	Ok
Max:	55.2952	2.497	mm.	0.827		0.293	(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 6 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	55.295	60.000	Ok
Tubesheet Thickness Flanged Extension :	2.497	50.000	Ok
Tube Thickness :	0.519	1.650	Ok

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	34.584	1.000	34.583	1.000
Tubesheet Shear Stress	97.515	1.000	97.515	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAWP	34.584		34.583	

Tubesheet MAPnc used to Compute Hydrotest Pressure:

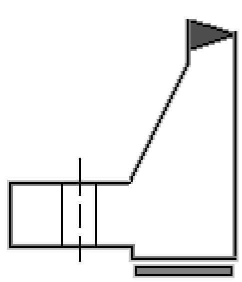
Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	38.329	1.000	38.329	1.000
Tubesheet Shear Stress	108.358	1.000	108.358	1.000
Tube Pressure Stress	219.436	1.000	141.727	1.000
Minimum MAPnc	38.329		38.329	

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

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

CH. Flange

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	8.89	bars
Design Temperature		20	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	600.000	mm.
Flange Outside Diameter	A	760.000	mm.
Flange Thickness	t	60.0000	mm.
Thickness of Hub at Small End	go	10.0000	mm.
Thickness of Hub at Large End	g1	15.0000	mm.
Length of Hub	h	25.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	223.40	N./mm²
Flange Allowable Stress At Ambient	Sfa	223.40	N./mm²
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	220.00	N./mm²
Bolt Allowable Stress At Ambient	Sa	220.00	N./mm²
Diameter of Bolt Circle	C	705.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	653.000	mm.
Flange Face Inside Diameter	Fid	600.000	mm.
Flange Facing Sketch		2, Code Sketch 1b	
Gasket Outside Diameter	Go	650.000	mm.
Gasket Inside Diameter	Gi	624.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	69.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	4.5000	mm.



Note:
The rigidity index calculation has been turned off. Please ensure the requirements of 2-14(a) are met.

ASME Code, Section VIII Division 1, 2019

Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)

```
  = (8.89*(600/2+3))/(223*1-0.6*8.89)+Ca
  = 4.2093 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (223 * 1 * 7 )/(303 + 0.6 * 7 )
  = 50.902 bars
```

```
 Corroded Flange Thickness, tc = T-ci                     57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                606.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                    12.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                     7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor       37.500  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2            13.000  mm.
 Basic Gasket Width,        bo = N / 2                     6.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)               6.425  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b              637.151  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.79 * 637² * 8.89
  = 28918.035 Kgf
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P
  = 2 * 6.42 * 3.14 * 637 * 3 * 8.89
  = 6998.121 Kgf
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.14 * 606² *8.89/4
  = 26159.504 Kgf
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 28918 - 26160
  = 2758.531 Kgf
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 28918 + 6998 + 0, 0 )
  = 35916.156 Kgf
  = 115620.258 Kgf, Mating Flange Load Governs
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 69*6.42*3.141*637+0*0*0
  = 90480.758 Kgf
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 115620/220, 90481/220
  = 51.539 cm²
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.2 + 6 * 57/(3 + 0.5)
  = 142.164 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 705 * sin( 3.14/20 )
  = 110.286 mm.
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 110/( 2 * 22.2 + 57 )), 1 )
```

= 1.0426

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

	Minimum	Actual	Maximum
Bolt Area, cm²	51.539	54.064	
Radial Distance between Hub and Bolts:	31.750	37.500	
Radial Distance between Bolts and Edge:	23.812	27.500	
Circ. Spacing between the Bolts:	52.400	110.286	142.164

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 54.1 * 220/(69 * 3.14 *(650 + 624))
= 4.307 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 220 *(51.5 + 54.1)/2
= 118452.40 Kgf

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 115620 - 28918
= 86702.22 Kgf

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (705 - 637)/2
= 33.9246 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (37.5 + 12 + 33.9)/2
= 41.7123 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 37.5 +(12/2.0)
= 43.5000 mm.

Summary of Moments for Internal Pressure: (Kg-m.)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	26160.	43.5000	1.0426	1186.
Face Pressure,	Mt	2759.	41.7123	1.0426	120.
Gasket Load,	Mg	86702.	33.9246	1.0426	3067.
Gasket Seating,	Matm	118452.	33.9246	1.0426	4190.

Total Moment for Operation, Mop 4373. Kg-m.
Total Moment for Gasket seating, Matm 4190. Kg-m.

Effective Hub Length, ho = sqrt(Bcor*goCor) 65.131 mm.
Hub Ratio, h/h0 = HL / H0 0.384
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.714

Flange Factors for Integral Flange:

Factor F 0.858
Factor V 0.302
Factor f 1.217
Factors from Figure 2-7.1 K = 1.254
T = 1.817 U = 9.566
Y = 8.705 Z = 4.491
d = 0.10120E+06 mm.³ e = 0.0132 mm.^-1

```
 Stress Factors                          ALPHA =      1.751
                  BETA =      2.001      GAMMA =      0.964
                 DELTA =      1.830      Lamda =      2.794
```

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.22*4373/606)/(2.79*12²)
= 214.13 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.22*4190/606)/(2.79*12²)
= 205.15 N./mm²

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (2*4373/606)/(2.79*57²)
= 15.60 N./mm²

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (2*4190/606)/(2.79*57²)
= 14.95 N./mm²

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (8.7*4373/(57²*606))-4.49*15.6
= 119.53 N./mm²

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (8.7*4190/(57²*606))-4.49*14.9
= 114.52 N./mm²

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (214+max(15.6,120))/2
= 166.83 N./mm²

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (205+max(14.9,115))/2
= 159.84 N./mm²

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 115620/54.1
= 209.73 N./mm²

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (90481/54.1)
= 164.12 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	214.13	335.10	205.15	335.10
Radial Flange	15.60	223.40	14.95	223.40
Tangential Flange	119.53	223.40	114.52	223.40
Maximum Average	166.83	223.40	159.84	223.40
Bolting	209.73	220.00	164.12	220.00

Minimum Required Flange Thickness 51.892 mm.
Estimated M.A.W.P. (Operating) 30 bars

```
Estimated Finished Weight of Flange at given Thk.       84.1 kg.
Estimated Unfinished Weight of Forging at given Thk    112.6 kg.
```

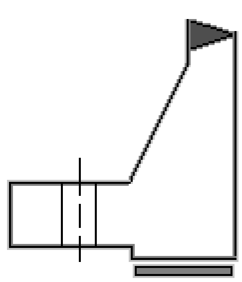
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.53, Temperature Reduction per Fig. UCS 66.1 = 29 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C             -44 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

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

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

```
SH. Flange

 Description of Flange Geometry (Type)           Integral Weld Neck
 Design Pressure                            P          28.63  bars
 Design Temperature                                       20  °C
 Internal Corrosion Allowance              ci         3.0000  mm.
 External Corrosion Allowance              ce         0.0000  mm.
 Use Corrosion Allowance in Thickness Calcs.             Yes

 Flange Inside Diameter                     B        600.000  mm.
 Flange Outside Diameter                    A        760.000  mm.
 Flange Thickness                           t        60.0000  mm.
 Thickness of Hub at Small End             go        12.0000  mm.
 Thickness of Hub at Large End             g1        18.0000  mm.
 Length of Hub                              h        25.0000  mm.

 Flange Material                                 SA-350 LF2
 Flange Material UNS number                          K03011
 Flange Allowable Stress At Temperature   Sfo         223.40  N./mm²
 Flange Allowable Stress At Ambient       Sfa         223.40  N./mm²

 Bolt Material                                    SA-193 B7
 Bolt Allowable Stress At Temperature      Sb         220.00  N./mm²
 Bolt Allowable Stress At Ambient          Sa         220.00  N./mm²

 Diameter of Bolt Circle                    C        705.000  mm.
 Nominal Bolt Diameter                      a        22.2250  mm.
 Type of Threads                           TEMA Thread Series
 Number of Bolts                                          20

 Flange Face Outside Diameter             Fod        653.000  mm.
 Flange Face Inside Diameter              Fid        600.000  mm.
 Flange Facing Sketch                       2, Code Sketch 1b

 Gasket Outside Diameter                   Go        650.000  mm.
 Gasket Inside Diameter                    Gi        624.000  mm.
 Gasket Factor                              m         3.0000
 Gasket Design Seating Stress               y          69.00  N./mm²

 Column for Gasket Seating                  2, Code Column II
 Gasket Thickness                          tg         4.5000  mm.
```



Note:
The rigidity index calculation has been turned off. Please ensure the requirements of 2-14(a) are met.

ASME Code, Section VIII Division 1, 2019

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

```
  = (28.6*(600/2+3))/(223*1-0.6*28.6)+Ca
  = 6.9136 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (223 * 1 * 9 )/(303 + 0.6 * 9 )
  = 65.191 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    57.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               606.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   15.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                    9.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      34.500  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2           13.000  mm.
 Basic Gasket Width,        bo = N / 2                    6.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)              6.425  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             637.151  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.79 * 637² * 28.6
  = 93092.109 Kgf
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P
  = 2 * 6.42 * 3.14 * 637 * 3 * 28.6
  = 22528.148 Kgf
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.14 * 606² *28.6/4
  = 84211.922 Kgf
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 93092 - 84212
  = 8880.184 Kgf
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 93092 + 22528 + 0, 0 )
  = 115620.258 Kgf
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 69*6.42*3.141*637+0*0*0
  = 90480.758 Kgf
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 115620/220, 90481/220
  = 51.539 cm²
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.2 + 6 * 57/(3 + 0.5)
  = 142.164 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 705 * sin( 3.14/20 )
  = 110.286 mm.
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 110/( 2 * 22.2 + 57 )), 1 )
  = 1.0426
```

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

	Minimum	Actual	Maximum
Bolt Area, cm^2	51.539	54.064	
Radial Distance between Hub and Bolts:	31.750	34.500	
Radial Distance between Bolts and Edge:	23.812	27.500	
Circ. Spacing between the Bolts:	52.400	110.286	142.164

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 54.1  * 220/(69 * 3.14 *(650 + 624 ) )
  = 4.307 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 220 *( 51.5 + 54.1 )/2
  = 118452.40 Kgf
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 115620 - 93092
  = 22528.15 Kgf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 705 - 637 )/2
  = 33.9246 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 34.5 + 15 + 33.9 )/2
  = 41.7123 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 34.5 +( 15/2.0 )
  = 42.0000 mm.
```

Summary of Moments for Internal Pressure: (Kg-m.)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	84212.	42.0000	1.0426	3688.
Face Pressure,	Mt	8880.	41.7123	1.0426	386.
Gasket Load,	Mg	22528.	33.9246	1.0426	797.
Gasket Seating,	Matm	118452.	33.9246	1.0426	4190.

```
 Total Moment for Operation,      Mop                           4871. Kg-m.
 Total Moment for Gasket seating, Matm                          4190. Kg-m.

 Effective Hub Length, ho = sqrt(Bcor*goCor)          73.851  mm.
 Hub Ratio,          h/h0 = HL / H0                    0.339
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.667
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.868
 Factor V                                              0.326
 Factor f                                              1.295
 Factors from Figure 2-7.1                   K =       1.254
                    T =      1.817           U =       9.566
                    Y =      8.705           Z =       4.491
                    d = 0.17564E+06 mm.³      e =     0.0118 mm.^-1
 Stress Factors                          ALPHA =       1.670
```

BETA = 1.893 GAMMA = 0.919
DELTA = 1.054 Lamda = 1.973

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.3*4871/606)/(1.97*15²)
= 229.96 N./mm²

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.3*4190/606)/(1.97*15²)
= 197.81 N./mm²

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (1.89*4871/606)/(1.97*57²)
= 23.27 N./mm²

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (1.89*4190/606)/(1.97*57²)
= 20.02 N./mm²

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (8.7*4871/(57²*606))-4.49*23.3
= 106.66 N./mm²

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (8.7*4190/(57²*606))-4.49*20
= 91.75 N./mm²

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (230+max(23.3,107))/2
= 168.31 N./mm²

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (198+max(20,91.7))/2
= 144.78 N./mm²

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 115620/54.1
= 209.73 N./mm²

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (90481/54.1)
= 164.12 N./mm²

Flange Stress Analysis Results: N./mm²

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	229.96	335.10	197.81	335.10
Radial Flange	23.27	223.40	20.02	223.40
Tangential Flange	106.66	223.40	91.75	223.40
Maximum Average	168.31	223.40	144.78	223.40
Bolting	209.73	220.00	164.12	220.00

Minimum Required Flange Thickness 50.622 mm.
Estimated M.A.W.P. (Operating) 30 bars
Estimated Finished Weight of Flange at given Thk. 85.1 kg.

```
 Estimated Unfinished Weight of Forging at given Thk    112.6 kg.
```

Minimum Design Metal Temperature Results:

Note:

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

```
 Impact Test Temperature provided per Specification         -46 °C
```

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

FEA for Nozzles T1 & T2 (3in.)

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Apr 17 11:30:56 2024.

- Model Notes
- Load Case Report
- Solution Data
- ASME Code Stress Output Plots
- Stress Results - Notes
- ASME Overstressed Areas
- Highest Primary Stress Ratios
- Highest Secondary Stress Ratios
- Highest Fatigue Stress Ratios
- Highest Stress Ratios Per Region
- Stress Intensification Factors
- Allowable Loads
- Compressive Stress Summary
- Flexibilities
- Graphical Results

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :     620.000 mm.
         Thickness              :       7.000 mm.

  Parent Properties:
         Cold Allowable         :       137.9 MPa
         Hot  Allowable         :       137.9 MPa
         Material DB # 1016422.
         Ultimate Tensile (Amb) :       482.6 MPa
         Yield Strength (Amb)   :       262.0 MPa
         Yield Strength (Hot)   :       242.0 MPa
         Elastic Modulus (Amb)  :    202720.0 MPa
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.1201E-04 mm./mm./deg.
         Weight Density         :  0.0000E+00  N /cu.mm.(NOT USED)

  Hillside Offset Distance      :     100.000 mm.

  Nozzle Geometry
         Nozzle Outside Diam.   :      88.900 mm.
         Thickness              :       6.668 mm.
```

```
       Length                 :     180.000 mm.
       RePad Width            :      50.550 mm.
       RePad Thickness        :      10.000 mm.
       Nozzle Tilt Angle      :       0.000 deg.
       Distance from Top      :       0.000 mm.
       Distance from Bottom   :       0.000 mm.

Nozzle Properties
       Cold Allowable         :       117.9 MPa
       Hot  Allowable         :       117.9 MPa
       Material DB # 1009922.
       Ultimate Tensile (Amb) :       413.7 MPa
       Yield Strength (Amb)   :       241.3 MPa
       Yield Strength (Hot)   :       222.7 MPa
       Elastic Modulus (Amb)  :    202720.0 MPa
       Poissons Ratio         :       0.300
       Expansion Coefficient  :  0.1201E-04 mm./mm./deg.
       Weight Density         :  0.0000E+00  N /cu.mm. (NOT USED)

Design Operating Cycles       :          0.
Ambient Temperature (Deg.)    :       21.10
```

Uniform thermal expansion produces no stress in this geometry. Any thermal loads will come through operating forces and moments applied through the nozzle.

```
Nozzle Inside  Temperature    :       85.00 deg.
Nozzle Outside Temperature    :       85.00 deg.
Vessel Inside  Temperature    :       85.00 deg.
Vessel Outside Temperature    :       85.00 deg.

Nozzle Pressure               :       0.680 MPa
Vessel Pressure               :       0.680 MPa

Operating Pressure            :         0.7 MPa
```

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 1.000

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the Nozzle/Header Junction
Loads are defined in Global Coordinates

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	-3600.0	3600.0	2700.0	810.0	540.0	700.0

FEA Model Loads:
These are the actual Attachment loads applied to the FEA model.
These are the User Defined Loads translated to the end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	-3600.0	3600.0	2700.0	324.0	540.0	52.0

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle connection to the shell. This will produce conservative results for external loads and may tend to produce more realistic inside surface pressure stresses.

No pad weld dimensions have been given for the pad connection to the shell. Few correlations have been performed to investigate the sensitivity of peak stresses to this value. Reasonable lengths have been assumed.

The cylinder length or nozzle/branch location was adjusted

```
so that a better mesh could be generated at each end of the
cylinder. The nozzle is now located  311.15 mm.
down the length of the cylinder and the total cylinder length
is  622.30 mm.

Vessel Centerline  Vector     :  1.000   0.000   0.000
Nozzle Orientation Vector     :  0.000   1.000   0.000
```

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```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             11:30am  APR 17,2024



Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   9  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

  4   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1

  5   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   5
        Loads from (Axial)

  6   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   6
        Loads from (Inplane)

  7   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   7
```

```
      Loads from (Outplane)

  8   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   8
        Loads from (Torsion)

  9   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   9
        Pressure Case    1
```

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```
Solution Data
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             11:30am  APR 17,2024
```

Solution Data

```
Maximum Solution Row Size =     636
Number of Nodes           =    2652
Number of Elements        =     876
Number of Solution Cases  =       8
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	-3600.	3600.	2700.
2	197092.	3038.	2700.
3	200692.	-562.	0.
4	0.	237524.	0.
5	3.	0.	1.
6	0.	0.	3.
7	0.	0.	0.
8	200692.	-562.	0.

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```
ASME Code Stress Output Plots
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             11:30am  APR 17,2024
```

ASME Code Stress Output Plots $X

```
    1) Pl < SPL (SUS,Membrane) Case 2

    2) Qb < SPS (SUS,Bending) Case 2

    3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

    4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

    5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

    6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

    7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

    8) Membrane < User (OPE,Membrane) Case 3
```

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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```
Stress Results - Notes
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            11:30am  APR 17,2024
```

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure =   1.000000
  Range cases use operating pressure. Primary cases
  use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            11:30am  APR 17,2024
```

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            11:30am  APR 17,2024




Highest Primary Stress Ratios                         $X


Header/Pad at Junction

       Pl            SPL     Primary Membrane Load Case 2
       42            242     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
           17%


Branch at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      168            464     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
           36%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 2
       30            223     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
           13%


Pad Outer Edge Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      116            504     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
           23%


Header/Pad removed from Junction

       Pl            SPL     Primary Membrane Load Case 2
       33            242     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
           13%


Branch removed from Junction

       Pl            SPL     Primary Membrane Load Case 2
       32            223     Min Prin. Stress = -30. (94% Neg, 40% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
           14%
```

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Highest Secondary Stress Ratios

Highest Secondary Stress Ratios $X

In combination case 4 the max range stress divided by the max component stress is 1.98. The case tensor components are in some directions additive and so the combination case will have HIGHER stresses than the largest of any of the individual cases by more than 50%.

Load Case	Combined/Max (Inside)	Combined/Max (Outside)
4	1.968	1.983

Header/Pad at Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
       85           504     Min Prin. Stress = -43. (81% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          16%
```

Branch at Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
      201           464     Min Prin. Stress = -145. (85% Neg, 29% NegHi)
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          43%
```

Branch Transition

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
       36           464     Min Prin. Stress = -30. (88% Neg, 66% NegHi)
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
           7%
```

Pad Outer Edge Weld

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      116           504     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
          23%
```

Header/Pad removed from Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
       46           504     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
           9%
```

Branch removed from Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
       46           464     Min Prin. Stress = -42. (91% Neg, 58% NegHi)
      MPa           MPa     Plot Reference:
                            15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          10%
```

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```
Highest Fatigue Stress Ratios                         $X


Header/Pad at Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      115     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.005 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 2.2279E9
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 7,592,540.
                             WRC 474 99% Probability Cycles = 1,763,816.
       0%                    WRC 474 95% Probability Cycles = 2,448,836.
                             BS5500 Allowed Cycles(Curve F) = 1,126,150.
                             Membrane-to-Bending Ratio = 0.459
                             Bending-to-PL+PB+Q Ratio = 0.685
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4


Branch at Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      271     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.011 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 98,775.
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 1,033,402.
                             WRC 474 99% Probability Cycles = 240,069.
       1%                    WRC 474 95% Probability Cycles = 333,305.
                             BS5500 Allowed Cycles(Curve F) = 85,077.
                             Membrane-to-Bending Ratio = 0.325
                             Bending-to-PL+PB+Q Ratio = 0.755
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch Transition

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       36     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.001 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.9594E8
                             WRC 474 99% Probability Cycles = 45,519,084.
       0%                    WRC 474 95% Probability Cycles = 63,197,524.
                             BS5500 Allowed Cycles(Curve F) = 20,613,216.
                             Membrane-to-Bending Ratio = 9.953
                             Bending-to-PL+PB+Q Ratio = 0.091
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Pad Outer Edge Weld

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      146     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.006 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 16,071,699.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 6,451,036.
                             WRC 474 99% Probability Cycles = 1,498,634.
       0%                    WRC 474 95% Probability Cycles = 2,080,665.
                             BS5500 Allowed Cycles(Curve F) = 540,636.
                             Membrane-to-Bending Ratio = 0.519
                             Bending-to-PL+PB+Q Ratio = 0.658
                             Plot Reference:
```

```
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Header/Pad removed from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       42     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.002 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.1606E8
                             WRC 474 99% Probability Cycles = 26,961,756.
       0%                    WRC 474 95% Probability Cycles = 37,433,004.
                             BS5500 Allowed Cycles(Curve F) = 9,328,373.
                             Membrane-to-Bending Ratio = 1.864
                             Bending-to-PL+PB+Q Ratio = 0.349
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch removed from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       46     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.002 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 86,172,024.
                             WRC 474 99% Probability Cycles = 20,018,544.
       0%                    WRC 474 95% Probability Cycles = 27,793,228.
                             BS5500 Allowed Cycles(Curve F) = 6,881,620.
                             Membrane-to-Bending Ratio = 3.189
                             Bending-to-PL+PB+Q Ratio = 0.239
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
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Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE               $P
Released Jan. 2021             11:30am  APR 17,2024



Highest Stress Ratios Per Region                      $X


Header/Pad at Junction

       Pl            SPL     Primary Membrane Load Case 2
       42            242     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            17%

       Qb            SPS     Primary Bending Load Case 2
       65            504     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
            12%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       75            504     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            14%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
       61            504     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            12%
```

```
 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
       42           552     Min Prin. Stress = -31. (67% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            7%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
       41           504     Min Prin. Stress = -7. (29% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            8%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
       13           504     Min Prin. Stress = -7. (29% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            2%

 Membrane          User     Component Evaluation Load Case 3
       24           504     Min Prin. Stress = -7. (29% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 3
            4%

  Bending          User     Component Evaluation Load Case 3
       19           504     Min Prin. Stress = -7. (29% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 3
            3%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
       85           504     Min Prin. Stress = -43. (81% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
           16%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
       64           504     Min Prin. Stress = -43. (81% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
           12%

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
      115     0.000 Life    Stress Concentration Factor = 1.350
      MPa     0.005 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 2.2279E9
Allowable                   "B31" Fatigue Stress Allowable = 689.5
 24,846.2                   Markl Fatigue Stress Allowable = 3378.5
      MPa                   WRC 474 Mean Cycles to Failure = 7,592,540.
                            WRC 474 99% Probability Cycles = 1,763,816.
       0%                   WRC 474 95% Probability Cycles = 2,448,836.
                            BS5500 Allowed Cycles(Curve F) = 1,126,150.
                            Membrane-to-Bending Ratio = 0.459
                            Bending-to-PL+PB+Q Ratio = 0.685
                            Plot Reference:
                            17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
       86     0.000 Life    Stress Concentration Factor = 1.350
      MPa     0.003 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 689.5
 24,846.2                   Markl Fatigue Stress Allowable = 3378.5
      MPa                   WRC 474 Mean Cycles to Failure = 21,273,600.
                            WRC 474 99% Probability Cycles = 4,942,045.
       0%                   WRC 474 95% Probability Cycles = 6,861,408.
                            BS5500 Allowed Cycles(Curve F) = 2,635,012.
                            Membrane-to-Bending Ratio = 0.330
                            Bending-to-PL+PB+Q Ratio = 0.752
                            Plot Reference:
                            18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch at Junction

       Pl           SPL     Primary Membrane Load Case 2
       55           223     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
      MPa           MPa     Plot Reference:
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```
                             1) Pl < SPL (SUS,Membrane) Case 2
            24%

      Qb             SPS     Primary Bending Load Case 2
     151             464     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
     MPa             MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
            32%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
     148             464     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
     MPa             MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            31%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
     168             464     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
     MPa             MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            36%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
      83             472     Min Prin. Stress = -119. (82% Neg, 40% NegHi)
     MPa             MPa     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            17%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 3
      33             464     Min Prin. Stress = -24. (63% Neg, 11% NegHi)
     MPa             MPa     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             7%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
      39             464     Min Prin. Stress = -24. (63% Neg, 11% NegHi)
     MPa             MPa     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             8%

 Membrane           User     Component Evaluation Load Case 3
      14             464     Min Prin. Stress = -24. (63% Neg, 11% NegHi)
     MPa             MPa     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 3
             2%

  Bending           User     Component Evaluation Load Case 3
      35             464     Min Prin. Stress = -24. (63% Neg, 11% NegHi)
     MPa             MPa     Plot Reference:
                             9) Bending < User (OPE,Bending) Case 3
             7%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
     154             464     Min Prin. Stress = -145. (85% Neg, 29% NegHi)
     MPa             MPa     Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            33%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
     201             464     Min Prin. Stress = -145. (85% Neg, 29% NegHi)
     MPa             MPa     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            43%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
     208      0.000 Life     Stress Concentration Factor = 1.350
     MPa      0.008 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 276,618.
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
     MPa                     WRC 474 Mean Cycles to Failure = 2,804,450.
                             WRC 474 99% Probability Cycles = 651,499.
      0%                     WRC 474 95% Probability Cycles = 904,525.
                             BS5500 Allowed Cycles(Curve F) = 188,899.
                             Membrane-to-Bending Ratio = 0.307
                             Bending-to-PL+PB+Q Ratio = 0.765
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
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     271     0.000 Life     Stress Concentration Factor = 1.350
     MPa     0.011 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 98,775.
Allowable                   "B31" Fatigue Stress Allowable = 589.5
 24,846.2                   Markl Fatigue Stress Allowable = 3378.5
     MPa                    WRC 474 Mean Cycles to Failure = 1,033,402.
                            WRC 474 99% Probability Cycles = 240,069.
      1%                    WRC 474 95% Probability Cycles = 333,305.
                            BS5500 Allowed Cycles(Curve F) = 85,077.
                            Membrane-to-Bending Ratio = 0.325
                            Bending-to-PL+PB+Q Ratio = 0.755
                            Plot Reference:
                            18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch Transition

      Pl            SPL     Primary Membrane Load Case 2
      30            223     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
     MPa            MPa     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
           13%

      Qb            SPS     Primary Bending Load Case 2
       9            464     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
     MPa            MPa     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
            1%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      32            464     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
     MPa            MPa     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            6%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      32            464     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
     MPa            MPa     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            6%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
      30            472     Min Prin. Stress = -26. (97% Neg, 78% NegHi)
     MPa            MPa     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            6%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
       8            464     Min Prin. Stress = -3. (57% Neg, 37% NegHi)
     MPa            MPa     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            1%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
       7            464     Min Prin. Stress = -3. (57% Neg, 37% NegHi)
     MPa            MPa     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            1%

 Membrane          User     Component Evaluation Load Case 3
       7            464     Min Prin. Stress = -3. (57% Neg, 37% NegHi)
     MPa            MPa     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 3
            1%

  Bending          User     Component Evaluation Load Case 3
       6            464     Min Prin. Stress = -3. (57% Neg, 37% NegHi)
     MPa            MPa     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 3
            1%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
      31            464     Min Prin. Stress = -30. (88% Neg, 66% NegHi)
     MPa            MPa     Plot Reference:
                            15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            6%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
      36            464     Min Prin. Stress = -30. (88% Neg, 66% NegHi)
```

```
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             7%

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
       31     0.000 Life    Stress Concentration Factor = 1.000
      MPa     0.001 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 589.5
 24,846.2                   Markl Fatigue Stress Allowable = 3378.5
      MPa                   WRC 474 Mean Cycles to Failure = 3.0174E8
                            WRC 474 99% Probability Cycles = 70,096,664.
       0%                   WRC 474 95% Probability Cycles = 97,320,392.
                            BS5500 Allowed Cycles(Curve F) = 41,067,668.
                            Membrane-to-Bending Ratio = 9.579
                            Bending-to-PL+PB+Q Ratio = 0.095
                            Plot Reference:
                            17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
       36     0.000 Life    Stress Concentration Factor = 1.000
      MPa     0.001 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 589.5
 24,846.2                   Markl Fatigue Stress Allowable = 3378.5
      MPa                   WRC 474 Mean Cycles to Failure = 1.9594E8
                            WRC 474 99% Probability Cycles = 45,519,084.
       0%                   WRC 474 95% Probability Cycles = 63,197,524.
                            BS5500 Allowed Cycles(Curve F) = 20,613,216.
                            Membrane-to-Bending Ratio = 9.953
                            Bending-to-PL+PB+Q Ratio = 0.091
                            Plot Reference:
                            18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Pad Outer Edge Weld

       Pl           SPL     Primary Membrane Load Case 2
       41           242     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
            17%

       Qb           SPS     Primary Bending Load Case 2
       81           504     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
            16%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
       54           504     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            10%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      116           504     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            23%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
       65           552     Min Prin. Stress = -10. (22% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            11%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
       32           504     Min Prin. Stress = -4. ( 6% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             6%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
       50           504     Min Prin. Stress = -4. ( 6% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            10%
```

```
 Membrane           User     Component Evaluation Load Case 3
      27             504     Min Prin. Stress = -4. ( 6% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 3
             5%

  Bending           User     Component Evaluation Load Case 3
      26             504     Min Prin. Stress = -4. ( 6% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             9) Bending < User (OPE,Bending) Case 3
             5%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
      56             504     Min Prin. Stress = -12. (41% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            11%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
     109             504     Min Prin. Stress = -12. (41% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            21%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      75      0.000 Life     Stress Concentration Factor = 1.350
     MPa      0.003 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
     MPa                     WRC 474 Mean Cycles to Failure = 48,120,244.
                             WRC 474 99% Probability Cycles = 11,178,770.
      0%                     WRC 474 95% Probability Cycles = 15,520,316.
                             BS5500 Allowed Cycles(Curve F) = 3,994,395.
                             Membrane-to-Bending Ratio = 1.610
                             Bending-to-PL+PB+Q Ratio = 0.383
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
     146      0.000 Life     Stress Concentration Factor = 1.350
     MPa      0.006 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 16,071,699.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
     MPa                     WRC 474 Mean Cycles to Failure = 6,451,036.
                             WRC 474 99% Probability Cycles = 1,498,634.
      0%                     WRC 474 95% Probability Cycles = 2,080,665.
                             BS5500 Allowed Cycles(Curve F) = 540,636.
                             Membrane-to-Bending Ratio = 0.519
                             Bending-to-PL+PB+Q Ratio = 0.658
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Header/Pad removed from Junction

      Pl             SPL     Primary Membrane Load Case 2
      33             242     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            13%

      Qb             SPS     Primary Bending Load Case 2
      18             504     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             3%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
      46             504     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             9%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      39             504     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
     MPa             MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
```

```
            7%

 S1+S2+S3           4S     Part 5 (5.3.2) Load Case 2
      54           552     Min Prin. Stress = -5. (25% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            9%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 3
      31           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            6%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 3
      34           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            6%

 Membrane         User     Component Evaluation Load Case 3
      28           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 3
            5%

  Bending         User     Component Evaluation Load Case 3
       8           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           9) Bending < User (OPE,Bending) Case 3
            1%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 4
      42           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            8%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 4
      42           504     Min Prin. Stress = -2. (23% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            8%

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
      42     0.000 Life    Stress Concentration Factor = 1.000
     MPa     0.002 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 689.5
 24,846.2                  Markl Fatigue Stress Allowable = 3378.5
     MPa                   WRC 474 Mean Cycles to Failure = 1.1774E8
                           WRC 474 99% Probability Cycles = 27,351,872.
      0%                   WRC 474 95% Probability Cycles = 37,974,628.
                           BS5500 Allowed Cycles(Curve F) = 9,493,398.
                           Membrane-to-Bending Ratio = 1.954
                           Bending-to-PL+PB+Q Ratio = 0.339
                           Plot Reference:
                           17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
      42     0.000 Life    Stress Concentration Factor = 1.000
     MPa     0.002 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 689.5
 24,846.2                  Markl Fatigue Stress Allowable = 3378.5
     MPa                   WRC 474 Mean Cycles to Failure = 1.1606E8
                           WRC 474 99% Probability Cycles = 26,961,756.
      0%                   WRC 474 95% Probability Cycles = 37,433,004.
                           BS5500 Allowed Cycles(Curve F) = 9,328,373.
                           Membrane-to-Bending Ratio = 1.864
                           Bending-to-PL+PB+Q Ratio = 0.349
                           Plot Reference:
                           18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch removed from Junction

      Pl           SPL     Primary Membrane Load Case 2
      32           223     Min Prin. Stress = -30. (94% Neg, 40% NegHi)
```

```
      MPa            MPa      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
          14%

       Qb            SPS      Primary Bending Load Case 2
       11            464      Min Prin. Stress = -30. (94% Neg, 40% NegHi)
      MPa            MPa      Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
           2%

   Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
       40            464      Min Prin. Stress = -30. (94% Neg, 40% NegHi)
      MPa            MPa      Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
           8%

   Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
       32            464      Min Prin. Stress = -30. (94% Neg, 40% NegHi)
      MPa            MPa      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
           6%

  S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
       47            472      Min Prin. Stress = -30. (94% Neg, 40% NegHi)
      MPa            MPa      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
           9%

   Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 3
        8            464      Min Prin. Stress = -6. (66% Neg, 8% NegHi)
      MPa            MPa      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
           1%

   Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 3
        8            464      Min Prin. Stress = -6. (66% Neg, 8% NegHi)
      MPa            MPa      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
           1%

  Membrane          User      Component Evaluation Load Case 3
        7            464      Min Prin. Stress = -6. (66% Neg, 8% NegHi)
      MPa            MPa      Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
           1%

   Bending          User      Component Evaluation Load Case 3
        2            464      Min Prin. Stress = -6. (66% Neg, 8% NegHi)
      MPa            MPa      Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
           0%

   Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
       46            464      Min Prin. Stress = -42. (91% Neg, 58% NegHi)
      MPa            MPa      Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          10%

   Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
       37            464      Min Prin. Stress = -42. (91% Neg, 58% NegHi)
      MPa            MPa      Plot Reference:
                              16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
           8%

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       46      0.000 Life     Stress Concentration Factor = 1.000
      MPa      0.002 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
 Allowable                    "B31" Fatigue Stress Allowable = 589.5
  24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                     WRC 474 Mean Cycles to Failure = 86,172,024.
                              WRC 474 99% Probability Cycles = 20,018,544.
       0%                     WRC 474 95% Probability Cycles = 27,793,228.
                              BS5500 Allowed Cycles(Curve F) = 6,881,620.
                              Membrane-to-Bending Ratio = 3.189
                              Bending-to-PL+PB+Q Ratio = 0.239
                              Plot Reference:
                              17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       37     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.001 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.7048E8
                             WRC 474 99% Probability Cycles = 39,603,136.
       0%                    WRC 474 95% Probability Cycles = 54,983,972.
                             BS5500 Allowed Cycles(Curve F) = 16,564,323.
                             Membrane-to-Bending Ratio = 25.559
                             Bending-to-PL+PB+Q Ratio = 0.038
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Stress Intensification Factors
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Stress Intensification Factors                        $X


Branch/Nozzle Sif Summary

                 Peak      Primary    Secondary      SSI
Axial   :        6.168      4.569       9.137       1.520
Inplane :        2.465      1.826       3.652       1.350
Outplane:        3.291      2.438       4.875       1.315
Torsion :        1.064      1.060       1.576       1.032
Pressure:        1.130      0.920       1.674       1.029

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :       88.900  mm.
Pipe Thk:        6.668  mm.
Z approx:    35411.109  cu.mm.
Z exact :    32970.617  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.835   0.667   0.748   0.939  -0.679

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       16.232
      Header Pressure i-factor =        2.286

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        3.491         Inplane
                        4.337         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        4.337         Inplane
```

	4.337	Outplane
	4.337	Torsional
WRC 330 (Branch)		
Peak Stress Sif	0.000	Axial
	4.553	Inplane
	4.337	Outplane
	4.553	Torsional

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Allowable Loads $X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	87471.	26719.	40079.
Inplane Moment	(mm. N)	4188848.	904774.	1919316.
Outplane Moment	(mm. N)	3138085.	677814.	1437860.
Torsional Moment	(mm. N)	9704841.	2964484.	4446726.
Pressure	(MPa)	6.80	0.68	0.68

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	83965.	25550.	38326.
Inplane Moment	(mm. N)	4020933.	865196.	1835359.
Outplane Moment	(mm. N)	3012291.	648164.	1374963.
Torsional Moment	(mm. N)	6926760.	2107817.	3161726.
Pressure	(MPa)	5.94	0.68	0.68

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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Compressive Stress Summary

Compressive Stress Summary (MPa) $X

Nomenclature:

Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Compression and Bending	Region
1	SUSTAINED	2	-10.	1272	22%	0%	Pad Outer Edge Weld
2	OPERATING	3	-4.	1272	6%	0%	Pad Outer Edge Weld
3	EXPANSION	4	-12.	1272	41%	0%	Pad Outer Edge Weld
4	SUSTAINED	2	-5.	648	25%	0%	Header/Pad removed from Junction
5	OPERATING	3	-2.	648	23%	0%	Header/Pad removed from Junction
6	EXPANSION	4	-2.	648	23%	0%	Header/Pad removed from Junction
7	SUSTAINED	2	-119.	960	82%	40%	Branch at Junction
8	OPERATING	3	-24.	960	63%	11%	Branch at Junction
9	EXPANSION	4	-145.	960	85%	29%	Branch at Junction
10	SUSTAINED	2	-30.	432	94%	40%	Branch removed from Junction
11	OPERATING	3	-6.	432	66%	8%	Branch removed from Junction
12	EXPANSION	4	-42.	432	91%	58%	Branch removed from Junction
13	SUSTAINED	2	-26.	1104	97%	78%	Branch Transition
14	OPERATING	3	-3.	1104	57%	37%	Branch Transition
15	EXPANSION	4	-30.	1104	88%	66%	Branch Transition
16	SUSTAINED	2	-31.	576	67%	0%	Header/Pad at Junction
17	OPERATING	3	-7.	576	29%	0%	Header/Pad at Junction
18	EXPANSION	4	-43.	576	81%	0%	Header/Pad at Junction

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Flexibilities

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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 88.900 mm.
Wall Thickness = 6.668 mm.

Axial Translational Stiffness = 162521. N /mm.
Inplane Rotational Stiffness = 18359652. mm. N /deg
Outplane Rotational Stiffness = 8047242. mm. N /deg
Torsional Rotational Stiffness = 145807360. mm. N /deg

Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (mm.) = 0.538 In-Plane (mm.) = 0.164 Out-Plane (mm.) = 0.280

PRIMARY
Axial (mm.) = 0.517 In-Plane (mm.) = 0.157 Out-Plane (mm.) = 0.269

```
Secondary Conservative Displacement =  0.260 mm.
Secondary Realistic    Displacement =  0.450 mm.

Primary Conservative Displacement =  0.249 mm.
Primary Realistic Displacement    =  0.430 mm.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3   N /mm.
Find bending and torsional stiffnesses: K = EI/(kd)  mm. N per radian.
The EI product is   0.29751E+12    N mm.^2
The value of (d) to use is:  82.232  mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     2.145
Inplane Flexibility Factor   (k) =     3.439
Outplane Flexibility Factor  (k) =     7.847
Torsional Flexibility Factor (k) =     0.433
```

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FEA for Nozzle S1 (4in.)

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Apr 17 11:34:19 2024.

- Model Notes
- Load Case Report
- Solution Data
- ASME Code Stress Output Plots
- Stress Results - Notes
- ASME Overstressed Areas
- Highest Primary Stress Ratios
- Highest Secondary Stress Ratios
- Highest Fatigue Stress Ratios
- Highest Stress Ratios Per Region
- Stress Intensification Factors
- Allowable Loads
- Compressive Stress Summary
- Flexibilities
- Graphical Results

```
 Model Notes
 Model Notes

   Input Echo:

   Model Type                     : Cylindrical Shell

   Parent Geometry
          Parent Outside Diam.    :     712.000 mm.
          Thickness               :       9.000 mm.

   Parent Properties:
          Cold Allowable          :       137.9 MPa
          Hot  Allowable          :       137.9 MPa
          Material DB # 1016422.
          Ultimate Tensile (Amb)  :       482.6 MPa
          Yield Strength (Amb)    :       262.0 MPa
          Yield Strength (Hot)    :       235.8 MPa
          Elastic Modulus (Amb)   :    202720.0 MPa
          Poissons Ratio          :       0.300
          Expansion Coefficient   :   0.1223E-04 mm./mm./deg.
          Weight Density          :   0.0000E+00  N /cu.mm.(NOT USED)

   Nozzle Geometry
          Nozzle Outside Diam.    :     114.300 mm.
          Thickness               :       9.735 mm.
          Length                  :     150.000 mm.
          RePad Width             :      52.850 mm.
```

```
       RePad Thickness        :      12.000 mm.
       Nozzle Tilt Angle      :       0.000 deg.
       Distance from Top      :       0.000 mm.
       Distance from Bottom   :       0.000 mm.

Nozzle Properties
       Cold Allowable         :       117.9 MPa
       Hot  Allowable         :       117.9 MPa
       Material DB # 1010222.
       Ultimate Tensile (Amb) :       413.7 MPa
       Yield Strength (Amb)   :       241.3 MPa
       Yield Strength (Hot)   :       217.2 MPa
       Elastic Modulus (Amb)  :    202720.0 MPa
       Poissons Ratio         :       0.300
       Expansion Coefficient  :  0.1223E-04 mm./mm./deg.
       Weight Density         :  0.0000E+00  N /cu.mm. (NOT USED)

Design Operating Cycles       :          0.
Ambient Temperature (Deg.)    :       21.10
```

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

```
Nozzle Inside  Temperature    :      120.00 deg.
Nozzle Outside Temperature    :      120.00 deg.
Vessel Inside  Temperature    :      120.00 deg.
Vessel Outside Temperature    :      120.00 deg.

Nozzle Pressure               :       2.200 MPa
Vessel Pressure               :       2.200 MPa

Operating Pressure            :         2.2 MPa
```

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 1.000

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the Nozzle/Header Junction
Loads are defined in Global Coordinates

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	-5600.0	5600.0	4200.0	1680.0	1120.0	1460.0

FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	-5600.0	5600.0	4200.0	1050.0	1120.0	620.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

No pad weld dimensions have been given for the pad
connection to the shell. Few correlations have been
performed to investigate the sensitivity of peak stresses
to this value. Reasonable lengths have been assumed.

The cylinder length or nozzle/branch location was adjusted
so that a better mesh could be generated at each end of the
cylinder. The nozzle is now located 400.05 mm.

```
  down the length of the cylinder and the total cylinder length
  is  800.10 mm.

  Vessel Centerline  Vector     :  1.000   0.000   0.000
  Nozzle Orientation Vector     :  0.000   1.000   0.000
```

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```
Load Case Report
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Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   9  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

  4   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1

  5   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   5
        Loads from (Axial)

  6   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   6
        Loads from (Inplane)

  7   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   7
        Loads from (Outplane)
```

```
  8   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   8
        Loads from (Torsion)

  9   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   9
        Pressure Case    1
```

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```
Solution Data
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```

Solution Data

```
Maximum Solution Row Size =     690
Number of Nodes           =    2184
Number of Elements        =     720
Number of Solution Cases  =       8
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	-5600.	5600.	4200.
2	848303.	2246.	4200.
3	853903.	-3354.	0.
4	0.	440969.	0.
5	0.	0.	0.
6	0.	0.	0.
7	0.	0.	0.
8	853903.	-3354.	0.

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```
ASME Code Stress Output Plots
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```

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                $P
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Highest Primary Stress Ratios                        $X


Pad/Header at Junction

       Pl            SPL     Primary Membrane Load Case 2
       86            236     Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            36%


Branch at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      218            458     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            47%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 2
       38            217     Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            17%


Pad Outer Edge Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      230            498     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            46%


Header Outside Pad Area

       Pl            SPL     Primary Membrane Load Case 2
       85            236     Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            36%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                $P
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Highest Secondary Stress Ratios                      $X

In combination case  4 the max range stress divided
by the max component stress is 1.99. The case tensor components
are in some directions additive and so the combination
```

```
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   4         1.990              1.984


Pad/Header at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
      164            498     Min Prin. Stress = -43. (73% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            32%


Branch at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
      249            458     Min Prin. Stress = -170. (82% Neg, 43% NegHi)
      MPa            MPa     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            54%


Branch Transition

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
       46            458     Min Prin. Stress = -39. (84% Neg, 64% NegHi)
      MPa            MPa     Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            10%


Pad Outer Edge Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      230            498     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            46%


Header Outside Pad Area

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
      105            498     Min Prin. Stress = -3. (12% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            21%
```

Table of Contents

```
Highest Fatigue Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             11:34am  APR 17,2024



Highest Fatigue Stress Ratios                         $X


Pad/Header at Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      221     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.009 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 208,642.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 801,548.
                             WRC 474 99% Probability Cycles = 186,207.
```

```
      0%                    WRC 474 95% Probability Cycles = 258,525.
                            BS5500 Allowed Cycles(Curve F) = 156,950.
                            Membrane-to-Bending Ratio = 0.764
                            Bending-to-PL+PB+Q Ratio = 0.567
                            Plot Reference:
                            17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

Branch at Junction

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      336     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.014 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 39,497.
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 417,204.
                             WRC 474 99% Probability Cycles = 96,920.
       1%                    WRC 474 95% Probability Cycles = 134,562.
                             BS5500 Allowed Cycles(Curve F) = 44,759.
                             Membrane-to-Bending Ratio = 0.282
                             Bending-to-PL+PB+Q Ratio = 0.780
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

Branch Transition

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       46     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.002 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 68,015,488.
                             WRC 474 99% Probability Cycles = 15,800,615.
       0%                    WRC 474 95% Probability Cycles = 21,937,166.
                             BS5500 Allowed Cycles(Curve F) = 7,122,108.
                             Membrane-to-Bending Ratio = 7.575
                             Bending-to-PL+PB+Q Ratio = 0.117
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

Pad Outer Edge Weld

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      280     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.011 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 85,213.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 707,346.
                             WRC 474 99% Probability Cycles = 164,323.
       1%                    WRC 474 95% Probability Cycles = 228,142.
                             BS5500 Allowed Cycles(Curve F) = 77,806.
                             Membrane-to-Bending Ratio = 0.579
                             Bending-to-PL+PB+Q Ratio = 0.634
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

Header Outside Pad Area

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      105     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.004 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.3294E10
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 5,447,098.
                             WRC 474 99% Probability Cycles = 1,265,410.
       0%                    WRC 474 95% Probability Cycles = 1,756,863.
                             BS5500 Allowed Cycles(Curve F) = 591,216.
                             Membrane-to-Bending Ratio = 2.602
                             Bending-to-PL+PB+Q Ratio = 0.278
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

```
Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             11:34am  APR 17,2024



Highest Stress Ratios Per Region                       $X


Pad/Header at Junction

       Pl            SPL      Primary Membrane Load Case 2
       86            236      Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            36%

       Qb            SPS      Primary Bending Load Case 2
       89            498      Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
            17%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 2
      159            498      Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            31%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
       79            498      Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            15%

 S1+S2+S3             4S      Part 5 (5.3.2) Load Case 2
      108            552      Min Prin. Stress = -39. (83% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            19%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 3
      127            498      Min Prin. Stress = -19. (63% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            25%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 3
       43            498      Min Prin. Stress = -19. (63% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             8%

 Membrane           User      Component Evaluation Load Case 3
       72            498      Min Prin. Stress = -19. (63% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
            14%

  Bending           User      Component Evaluation Load Case 3
       57            498      Min Prin. Stress = -19. (63% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
            11%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 4
      164            498      Min Prin. Stress = -43. (73% Neg, 0% NegHi)
      MPa            MPa      Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            32%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 4
```

```
       93           498     Min Prin. Stress = -43. (73% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            18%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      221     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.009 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 208,642.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 801,548.
                             WRC 474 99% Probability Cycles = 186,207.
       0%                    WRC 474 95% Probability Cycles = 258,525.
                             BS5500 Allowed Cycles(Curve F) = 156,950.
                             Membrane-to-Bending Ratio = 0.764
                             Bending-to-PL+PB+Q Ratio = 0.567
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      125     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.005 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 3.6436E8
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 5,486,796.
                             WRC 474 99% Probability Cycles = 1,274,632.
       0%                    WRC 474 95% Probability Cycles = 1,769,667.
                             BS5500 Allowed Cycles(Curve F) = 861,803.
                             Membrane-to-Bending Ratio = 0.437
                             Bending-to-PL+PB+Q Ratio = 0.696
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch at Junction

       Pl           SPL     Primary Membrane Load Case 2
       72           217     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa           MPa     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
            33%

       Qb           SPS     Primary Bending Load Case 2
      194           458     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa           MPa     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
            42%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      182           458     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa           MPa     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            39%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      218           458     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa           MPa     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            47%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
      111           472     Min Prin. Stress = -148. (81% Neg, 34% NegHi)
      MPa           MPa     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            23%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
       93           458     Min Prin. Stress = -69. (71% Neg, 33% NegHi)
      MPa           MPa     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            20%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
      112           458     Min Prin. Stress = -69. (71% Neg, 33% NegHi)
      MPa           MPa     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            24%
```

```
 Membrane           User     Component Evaluation Load Case 3
      42             458     Min Prin. Stress = -69. (71% Neg, 33% NegHi)
     MPa             MPa     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 3
             9%

  Bending           User     Component Evaluation Load Case 3
     101             458     Min Prin. Stress = -69. (71% Neg, 33% NegHi)
     MPa             MPa     Plot Reference:
                             9) Bending < User (OPE,Bending) Case 3
            22%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
     209             458     Min Prin. Stress = -170. (82% Neg, 43% NegHi)
     MPa             MPa     Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            45%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
     249             458     Min Prin. Stress = -170. (82% Neg, 43% NegHi)
     MPa             MPa     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            54%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      282     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.011 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 81,702.
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 820,332.
                             WRC 474 99% Probability Cycles = 190,570.
       1%                    WRC 474 95% Probability Cycles = 264,583.
                             BS5500 Allowed Cycles(Curve F) = 75,851.
                             Membrane-to-Bending Ratio = 0.282
                             Bending-to-PL+PB+Q Ratio = 0.780
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      336     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.014 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 39,497.
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 417,204.
                             WRC 474 99% Probability Cycles = 96,920.
       1%                    WRC 474 95% Probability Cycles = 134,562.
                             BS5500 Allowed Cycles(Curve F) = 44,759.
                             Membrane-to-Bending Ratio = 0.282
                             Bending-to-PL+PB+Q Ratio = 0.780
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Branch Transition

       Pl            SPL     Primary Membrane Load Case 2
       38            217     Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            17%

       Qb            SPS     Primary Bending Load Case 2
       15            458     Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             3%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
       39            458     Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             8%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
       39            458     Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa            MPa     Plot Reference:
```

```
                                        4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            8%

 S1+S2+S3            4S         Part 5 (5.3.2) Load Case 2
       51           472         Min Prin. Stress = -35. (87% Neg, 65% NegHi)
      MPa           MPa         Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
           10%

  Pl+Pb+Q           SPS         Primary+Secondary (Inner) Load Case 3
       24           458         Min Prin. Stress = -14. (83% Neg, 60% NegHi)
      MPa           MPa         Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            5%

  Pl+Pb+Q           SPS         Primary+Secondary (Outer) Load Case 3
       23           458         Min Prin. Stress = -14. (83% Neg, 60% NegHi)
      MPa           MPa         Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            5%

 Membrane          User         Component Evaluation Load Case 3
       20           458         Min Prin. Stress = -14. (83% Neg, 60% NegHi)
      MPa           MPa         Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
            4%

  Bending          User         Component Evaluation Load Case 3
       16           458         Min Prin. Stress = -14. (83% Neg, 60% NegHi)
      MPa           MPa         Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
            3%

  Pl+Pb+Q           SPS         Primary+Secondary (Inner) Load Case 4
       46           458         Min Prin. Stress = -39. (84% Neg, 64% NegHi)
      MPa           MPa         Plot Reference:
                                15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
           10%

  Pl+Pb+Q           SPS         Primary+Secondary (Outer) Load Case 4
       40           458         Min Prin. Stress = -39. (84% Neg, 64% NegHi)
      MPa           MPa         Plot Reference:
                                16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            8%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       46     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.002 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 68,015,488.
                             WRC 474 99% Probability Cycles = 15,800,615.
       0%                    WRC 474 95% Probability Cycles = 21,937,166.
                             BS5500 Allowed Cycles(Curve F) = 7,122,108.
                             Membrane-to-Bending Ratio = 7.575
                             Bending-to-PL+PB+Q Ratio = 0.117
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       40     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.002 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 589.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.0071E8
                             WRC 474 99% Probability Cycles = 23,396,360.
       0%                    WRC 474 95% Probability Cycles = 32,482,900.
                             BS5500 Allowed Cycles(Curve F) = 10,840,045.
                             Membrane-to-Bending Ratio = 14.690
                             Bending-to-PL+PB+Q Ratio = 0.064
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Pad Outer Edge Weld

       Pl           SPL      Primary Membrane Load Case 2
```

```
      97           236     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           1) Pl < SPL (SUS,Membrane) Case 2
          41%

      Qb           SPS     Primary Bending Load Case 2
     152           498     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           2) Qb < SPS (SUS,Bending) Case 2
          30%

 Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
     116           498     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
          23%

 Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
     230           498     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
          46%

S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
     154           552     Min Prin. Stress = -2. ( 2% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
          27%

 Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
      95           498     Min Prin. Stress = -1. ( 0% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
          19%

 Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
     139           498     Min Prin. Stress = -1. ( 0% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
          27%

Membrane          User     Component Evaluation Load Case 3
      81           498     Min Prin. Stress = -1. ( 0% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 3
          16%

 Bending          User     Component Evaluation Load Case 3
      73           498     Min Prin. Stress = -1. ( 0% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           9) Bending < User (OPE,Bending) Case 3
          14%

 Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
     126           498     Min Prin. Stress = -3. ( 3% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          25%

 Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
     207           498     Min Prin. Stress = -3. ( 3% Neg, 0% NegHi)
     MPa           MPa     Plot Reference:
                           16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          41%

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
     170     0.000 Life    Stress Concentration Factor = 1.350
     MPa     0.007 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 932,696.
Allowable                  "B31" Fatigue Stress Allowable = 689.5
24,846.2                   Markl Fatigue Stress Allowable = 3378.5
     MPa                   WRC 474 Mean Cycles to Failure = 3,152,230.
                           WRC 474 99% Probability Cycles = 732,292.
      0%                   WRC 474 95% Probability Cycles = 1,016,695.
                           BS5500 Allowed Cycles(Curve F) = 343,030.
                           Membrane-to-Bending Ratio = 1.502
                           Bending-to-PL+PB+Q Ratio = 0.400
                           Plot Reference:
                           17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
```

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      280     0.000 Life     Stress Concentration Factor = 1.350
      MPa     0.011 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 85,213.
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 707,346.
                             WRC 474 99% Probability Cycles = 164,323.
       1%                    WRC 474 95% Probability Cycles = 228,142.
                             BS5500 Allowed Cycles(Curve F) = 77,806.
                             Membrane-to-Bending Ratio = 0.579
                             Bending-to-PL+PB+Q Ratio = 0.634
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Header Outside Pad Area

       Pl           SPL      Primary Membrane Load Case 2
       85           236      Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            36%

       Qb           SPS      Primary Bending Load Case 2
       26           498      Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             5%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
      101           498      Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            20%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
      101           498      Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            20%

 S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
      147           552      Min Prin. Stress = -4. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            26%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 3
       88           498      Min Prin. Stress = -2. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
            17%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 3
       96           498      Min Prin. Stress = -2. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            19%

 Membrane          User      Component Evaluation Load Case 3
       84           498      Min Prin. Stress = -2. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 3
            16%

  Bending          User      Component Evaluation Load Case 3
       21           498      Min Prin. Stress = -2. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             9) Bending < User (OPE,Bending) Case 3
             4%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
      100           498      Min Prin. Stress = -3. (12% Neg, 0% NegHi)
      MPa           MPa      Plot Reference:
                             15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
            20%
```

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
      105           498     Min Prin. Stress = -3. (12% Neg, 0% NegHi)
      MPa           MPa     Plot Reference:
                            16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
           21%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
      100     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.004 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 3.3914E10
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 6,334,007.
                             WRC 474 99% Probability Cycles = 1,471,447.
       0%                    WRC 474 95% Probability Cycles = 2,042,919.
                             BS5500 Allowed Cycles(Curve F) = 685,236.
                             Membrane-to-Bending Ratio = 2.979
                             Bending-to-PL+PB+Q Ratio = 0.251
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      105     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.004 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.3294E10
Allowable                    "B31" Fatigue Stress Allowable = 689.5
 24,846.2                    Markl Fatigue Stress Allowable = 3378.5
      MPa                    WRC 474 Mean Cycles to Failure = 5,447,098.
                             WRC 474 99% Probability Cycles = 1,265,410.
       0%                    WRC 474 95% Probability Cycles = 1,756,863.
                             BS5500 Allowed Cycles(Curve F) = 591,216.
                             Membrane-to-Bending Ratio = 2.602
                             Bending-to-PL+PB+Q Ratio = 0.278
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
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Stress Intensification Factors
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             11:34am  APR 17,2024



Stress Intensification Factors                        $X


Branch/Nozzle Sif Summary

                 Peak      Primary    Secondary      SSI
Axial   :        6.669       4.940       9.881       1.673
Inplane :        2.417       1.790       3.580       1.451
Outplane:        3.383       2.506       5.013       1.432
Torsion :        0.639       0.860       0.947       0.865
Pressure:        1.075       0.962       1.593       1.100

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :      114.300  mm.
Pipe Thk:        9.735  mm.
Z approx:    83595.648  cu.mm.
Z exact :    77138.852  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
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SIF/SSI Exponents: 0.842 0.660 0.754 0.338 -0.536

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 15.841
Header Pressure i-factor = 2.178

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

B31.3 (Branch)		
Peak Stress Sif	0.000	Axial
	3.858	Inplane
	4.783	Outplane
	1.000	Torsional
B31.1 (Branch)		
Peak Stress Sif	0.000	Axial
	4.783	Inplane
	4.783	Outplane
	4.783	Torsional
WRC 330 (Branch)		
Peak Stress Sif	0.000	Axial
	4.422	Inplane
	4.783	Outplane
	4.422	Torsional

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Allowable Loads
FEPipe Version 15.0 Jobname: NOZZLE $P
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Allowable Loads $X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	148391.	37417.	56125.
Inplane Moment (mm. N)	9879366.	1761457.	3736615.
Outplane Moment (mm. N)	7055976.	1258056.	2668741.
Torsional Moment (mm. N)	37356572.	9419439.	14129159.
Pressure (MPa)	7.90	2.20	2.20

PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	140592.	34817.	52225.
Inplane Moment (mm. N)	9360079.	1639060.	3476972.
Outplane Moment (mm. N)	6685095.	1170639.	2483300.
Torsional Moment (mm. N)	19489534.	4828047.	7242070.
Pressure (MPa)	6.20	2.20	2.20

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the

maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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Compressive Stress Summary (MPa) $X

Nomenclature:

Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Compression and Bending	Region
1	SUSTAINED	2	-39.	1344	83%	0%	Pad/Header at Junction
2	OPERATING	3	-19.	1344	63%	0%	Pad/Header at Junction
3	EXPANSION	4	-43.	1344	73%	0%	Pad/Header at Junction
4	SUSTAINED	2	-2.	456	2%	0%	Pad Outer Edge Weld
5	OPERATING	3	-1.	456	0%	0%	Pad Outer Edge Weld
6	EXPANSION	4	-3.	456	3%	0%	Pad Outer Edge Weld
7	SUSTAINED	2	-4.	312	12%	0%	Header Outside Pad Area
8	OPERATING	3	-2.	312	12%	0%	Header Outside Pad Area
9	EXPANSION	4	-3.	312	12%	0%	Header Outside Pad Area
10	SUSTAINED	2	-148.	1080	81%	34%	Branch at Junction
11	OPERATING	3	-69.	1080	71%	33%	Branch at Junction
12	EXPANSION	4	-170.	1080	82%	43%	Branch at Junction
13	SUSTAINED	2	-35.	648	87%	65%	Branch Transition
14	OPERATING	3	-14.	648	83%	60%	Branch Transition
15	EXPANSION	4	-39.	648	84%	64%	Branch Transition

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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff-nesses should be inserted at the surface of the

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branch/header or nozzle/vessel junction.  The general
characteristics used for the branch pipe should be:

Outside Diameter =  114.300  mm.
Wall Thickness   =    9.735  mm.

Axial Translational Stiffness   =        190063.   N /mm.
Inplane Rotational Stiffness    =      35510780.  mm. N /deg
Outplane Rotational Stiffness   =      15159243.  mm. N /deg
Torsional Rotational Stiffness  =     663682560.  mm. N /deg


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (mm.) =  0.781  In-Plane (mm.) =  0.254  Out-Plane (mm.) =  0.425

PRIMARY
Axial (mm.) =  0.740  In-Plane (mm.) =  0.241  Out-Plane (mm.) =  0.402

Secondary Conservative Displacement =  0.318 mm.
Secondary Realistic    Displacement =  0.552 mm.

Primary Conservative Displacement =  0.296 mm.
Primary Realistic Displacement    =  0.514 mm.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3   N /mm.
Find bending and torsional stiffnesses: K = EI/(kd)  mm. N per radian.
The EI product is   0.89492E+12    N mm.^2
The value of (d) to use is: 104.565  mm..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     2.312
Inplane Flexibility Factor   (k) =     4.206
Outplane Flexibility Factor  (k) =     9.854
Torsional Flexibility Factor (k) =     0.225
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