طرح نگهداشت و افزایش تولید 27 مخزن

THERMAL/MECHANICAL CALCULATION BOOK FOR LEAN GLYCOL GAS H.E. (E-300)

نگهداشت و افزایش تولید میدان نفتی بینک

V00	DEC. 2024	IFI	MFS	M.Fakharian	S.Faramarzpour	
Rev.	**Date**	**Purpose of Issue/Status**	**Prepared by:**	**Checked by:**	**Approved by:**	**CLIENT Approval**

Status:

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

REVISION RECORD SHEET

PAGE	V00	V01	V02	V03	V04
1	X				
2	X				
3	X				
4	X				
5	X				
6	X				
7	X				
8	X				
9	X				
10	X				
11	X				
12	X				
13	X				
14	X				
15	X				
16	X				
17	X				
18	X				
19	X				
20	X				
21	X				
22	X				
23	X				
24	X				
25	X				
26	X				
27	X				
28	X				
29	X				
30	X				
31	X				
32	X				
33	X				
34	X				
35	X				
36	X				
37	X				
38	X				
39	X				
40	X				
41	X				
42	X				
43	X				
44	X				
45	X				
46	X				
47	X				
48	X				
49	X				
50	X				
51	X				
52	X				
53	X				
54	X				
55	X				
56	X				
57	X				
58	X				
59	X				
60	X				
61	X				
62	X				
63	X				
64	X				
65	X				

PAGE	V00	V01	V02	V03	V04
66	X				
67	X				
68	X				
69	X				
70	X				
71	X				
72	X				
73	X				
74	X				
75	X				
76	X				
77	X				
78	X				
79	X				
80	X				
81	X				
82	X				
83	X				
84	X				
85	X				
86	X				
87	X				
88	X				
89	X				
90	X				
91	X				
92	X				
93	X				
94	X				
95	X				
96	X				
97	X				
98	X				
99	X				
100	X				
101	X				
102	X				
103	X				
104	X				
105	X				
106	X				
107	X				
108	X				
109	X				
110	X				
111	X				
112	X				
113	X				
114	X				
115	X				
116	X				
117	X				
118	X				
119	X				
120	X				
121	X				
122	X				
123	X				
124	X				
125	X				
126	X				
127	X				
128	X				
129	X				
130	X				

PAGE	V00	V01	V02	V03	V04
131	X				
132	X				
133	X				
134	X				
135	X				
136	X				
137	X				
138	X				
139	X				
140	X				
141	X				
142	X				
143	X				
144	X				
145	X				
146	X				
147	X				
148	X				
149	X				
150	X				
151	X				
152	X				
153	X				
154	X				
155	X				
156	X				
157	X				
158	X				
159	X				
160	X				
161	X				
162	X				
163	X				
164	X				
165	X				
166	X				
167	X				
168	X				
169	X				
170	X				
171	X				
172	X				
173	X				
174	X				
175	X				
176	X				
177	X				
178	X				
179	X				
180	X				
181	X				
182	X				
183	X				
184	X				
185	X				
186	X				
187	X				
188	X				
189	X				
190	X				
191	X				
192	X				
193	X				
194	X				
195	X				

PAGE	V00	V01	V02	V03	V04
196	X				
197	X				
198	X				
199	X				
200	X				
201	X				
202	X				
203	X				
204	X				
205	X				
206	X				
207	X				
208	X				
209	X				
210	X				
211	X				
212	X				
213	X				
214	X				
215	X				
216	X				
217	X				
218	X				
219					
220					
221					
222					
223					
224					
225					
226					
227					
228					
229					
230					
231					
232					
233					
234					
235					
236					
237					
238					
239					
240					
241					
242					
243					
244					
245					
246					
247					
248					
249					
250					
251					
252					
253					
254					
255					
256					
257					
258					
259					
260					

Table of Contents

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version      : 2019

Analysis Performed by :

Job File               : C:\USERS\TECHNICAL2\DESKTOP\BINAK\DESIGN\E-300\E

Date of Analysis       : Dec 29,2024   10:42am

PV Elite 2020, January 2020
```

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 322.262 mm. ID		
Vessel Design Length, Tangent to Tangent	5681.08	mm.
Specified Datum Line Distance	0.00	mm.
Shell Side Design Temperature	145	°C
Channel Side Design Temperature	95	°C
Shell Side Design Pressure	62.000	bars
Channel Side Design Pressure	59.000	bars
Shell Side Hydrostatic Test Pressure	80.600	bars
Channel Side Hydrostatic Test Pressure	76.700	bars
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-106 B	...	...	K03006	No	No
Head	SA-234 WPB	...	...	K03006	No	No
Flange	SA-105	...	...	K03504	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-105	...	...	K03504	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Tubes	SA-179	...	...	K01200	No	No
Tubesheet	SA-266 2	...	...	K03506	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

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

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Channel Cover	59.000	1.03	108.000	3.0000	Yes	No
Channel Barrel	59.000	1.03	93.500	3.0000	N/A	No
Channel FLG.	59.000	1.03	93.900	3.0000	N/A	No
Shell FLG.	62.032	1.03	90.500	3.0000	N/A	No
Shell Barrel	62.032	1.03	93.500	3.0000	N/A	No
Shell Cover	62.032	1.03	109.000	3.0000	Yes	No

Liquid Level: 322.26 mm. Dens.: 999.542 kg/m³ Sp. Gr.: 1.000

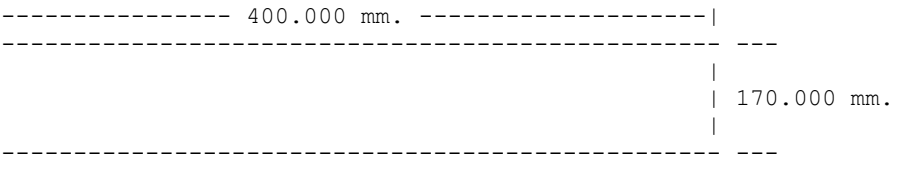
Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	50.0	50.0	19.0	19.0	11.1	4.5	1.00	1.00
Cylinder	400.0	350.0	19.0	16.7	11.5	4.4	1.00	1.00
Body Flg	565.1	165.1	...	69.8	...	...	1.00	1.00
Body Flg	831.1	165.1	...	69.8	...	...	1.00	1.00
Cylinder	5631.1	4800.0	19.0	16.7	11.9	6.1	1.00	1.00
Ellipse	5681.1	50.0	19.0	19.0	11.5	4.5	1.00	1.00

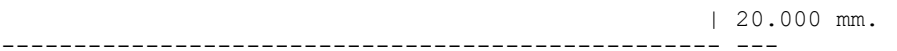
Saddle Parameters:

Saddle Width	150.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	800.000	mm.
Wear Pad Width	200.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	500.000	mm.
Baseplate Length	400.000	mm.
Baseplate Thickness	20.000	mm.
Baseplate Width	170.000	mm.
Number of Ribs (including outside ribs)	3	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	639.000	mm.
Number of Bolts in Baseplate	2	

Baseplate Sketch



Baseplate Plan View



Baseplate Side View

Maximum Tensile Bolt Load	4.	kN

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	41.89	kN
Maximum Transverse Saddle Shear Load	3.33	kN

Maximum Longitudinal Saddle Shear Load 6.66 kN

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

Maximum Vertical Saddle Load 52.42 kN
Maximum Transverse Saddle Shear Load 24.58 kN
Maximum Longitudinal Saddle Shear Load 9.52 kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load 20.39 kN
Maximum Transverse Saddle Shear Load 0.14 kN
Maximum Longitudinal Saddle Shear Load 0.03 kN

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
T1 (6in)	WRC-107/537	0.627	n/a	Passed
T2 (6in)	WRC-107/537	0.627	n/a	Passed
S2 (2in)	WRC-107/537	0.659	n/a	Passed
S1 (2in)	WRC-107/537	0.659	n/a	Passed

Weights:

Fabricated - Bare W/O Removable Internals	2352.2	kg.
Shop Test - Fabricated + Water (Full)	2761.5	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	2429.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	2429.5	kg.
Empty - Fab. + Intls. + Details + Wghts.	2429.5	kg.
Operating - Empty + Operating Liquid (No CA)	2691.0	kg.
Field Test - Empty Weight + Water (Full)	2702.7	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1 (6in)	76	OK	...	OK	9.22	OK	Passed
T2 (6in)	76	OK	...	OK	9.22	OK	Passed
S2 (2in)	78.6	OK	...	OK	7.80	OK	Passed
S1 (2in)	78.6	OK	...	OK	7.80	OK	Passed

Nozzle MAWP Summary:

Minimum MAWP Nozzles : 78.6 Nozzle : S2 (2in) [Shellside]
Minimum MAWP Nozzles : 76 Nozzle : T1 (6in) [Tubeside]

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 (6in)	225.000	90.000	310.145
20	T2 (6in)	225.000	270.000	310.145
50	S2 (2in)	1031.075	270.000	113.600
50	S1 (2in)	5431.075	90.000	113.600

The nozzle spacing is computed by the following:

$= \mathrm{Sqrt}(ll^2 + lc^2)$ 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 !

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	ELLIPTICAL HEAD: 2.0 X 1, 19.0mm. THK X 325.6mm. ID X 50.0mm.	SA-234 WPB
1	CYLINDER: 19.0mm. THK X 322.3mm. ID X 350.0mm.	SA-106 B
2	BODY FLANGE: 69.8mm. THK X 322.3mm. OD	SA-105
1	CYLINDER: 19.0mm. THK X 322.3mm. ID X 4800.0mm.	SA-106 B
1	ELLIPTICAL HEAD: 2.0 X 1, 19.0mm. THK X 322.3mm. ID X 50.0mm.	SA-234 WPB
1	INSULATION: 131mm X 40mm THK	
1	INSULATION: 350mm X 40mm THK	
1	INSULATION: 165mm X 40mm THK	
1	TUBESHEET: 603mm X 85mm THK	SA-266 2
110	TUBES: 4877mm X 19mm DIA X 2mm THK	SA-179
1	INSULATION: 165mm X 80mm THK	
2	SADDLE: 150mm X 120 DEG	SA-106 B
1	INSULATION: 4800mm X 80mm THK	
1	INSULATION: 130mm X 80mm THK	
1	GASKET: 406mm. OD X 361mm. ID	...
20	BODY FLANGE BOLTS: 34mm. DIA	SA-193 B7
40	NUTS FOR BODY FLANGE BOLTS: 34mm. DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm	Reinforcing Pad Diameter	Reinforcing Pad Thk mm	Cut Length in	Flg Class
S2 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	172.2	600
S1 (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	172.2	600
T1 (6in)	6.000 in	80	WN	6.625	10.973	270.00	10.00	190.3	600
T2 (6in)	6.000 in	80	WN	6.625	10.973	270.00	10.00	190.3	600

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
S2 (2in)	SA-105	16.669	10.000	...	...	...
S1 (2in)	SA-105	16.669	10.000	...	...	...
T1 (6in)	SA-106 B	16.669	10.000	10.000	10.000	...
T2 (6in)	SA-106 B	16.669	10.000	10.000	10.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
S2 (2in)	1031.075	270.0	150.00	0.00	Shell Barrel
S1 (2in)	5431.075	90.0	150.00	0.00	Shell Barrel
T1 (6in)	225.000	90.0	150.00	0.00	Channel Barrel
T2 (6in)	225.000	270.0	150.00	0.00	Channel Barrel

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
Nozzle Flg	[5]	A	-29	-48					
Shell Barrel	[8]	B	-13	-22	-29	0.834	16.669	1.00	Yes
Shell Cover	[10]	B	-9	-27	-29	0.670	19.050	1.00	Yes
Shell Cover	[7]	B	-9	-25	-29	0.710	19.050	1.00	Yes
S2 (2in)	[1]	A	7	-104		0.097	16.600	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
S1 (2in)	[1]	A	7	-104		0.096	16.600	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
Tubesheet: SS	[13]	B	-22	-38	-29	0.715	21.250	1.00	Yes
Warmest MDMT:			7	-22					
Nozzle Flg	[5]	A	-29	-48					
Channel Cover	[10]	B	-9	-28	-29	0.654	19.050	1.00	Yes
Channel Cover	[7]	B	-9	-26	-29	0.692	19.050	1.00	Yes
Channel Barrel	[8]	B	-13	-48	-29	0.382	16.669	1.00	Yes
T1 (6in)	[1]	B	-29	-48		0.606	9.601	1.00	Yes
Nozzle Flg	[5]	B	-18	-42					
T2 (6in)	[1]	B	-29	-48		0.606	9.601	1.00	Yes
Nozzle Flg	[5]	B	-18	-42					
Tubesheet: CS	[14]	B	-22	-38	-29	0.715	21.250	1.00	Yes
Bolting	[21]		-48						
Warmest MDMT:			-9	-26					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-29.0	5.0	Pass
Channel/Tube	-29.0	5.0	Pass

Notes:

[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material

[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

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

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

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

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

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

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

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	62	bars
Channel Side Design Pressure	59	bars
Shell Side Design Temperature	145.0	°C
Channel Side Design Temperature	95.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Lethal	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	5.0	°C
MDMT (CET), Tube Side	5.0	°C
User defined MAWP, Shell Side	78.598	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

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

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

Load Case 18		FS+BS+IP+OW	
Load Case 19		FS+BS+EP+OW	
Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	120	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		100	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	
Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.250	
Table Value Fa		1.111	
Table Value Fv		1.575	
Short Period Acceleration value Ss		1.377	
Long Period Acceleration Value Sl		0.367	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		C	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		No	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		1.020	
User Value of Sd1 (used if > 0)		0.385	
Design Pressure + Static Head		Y	
Consider MAP New and Cold in Noz. Design		N	
Consider External Loads for Nozzle Des.		Y	
Use ASME VIII-1 Appendix 1-9		N	
Material Database Year	Current w/Addenda or Code Year		

Configuration Directives:

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

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

Complete Listing of Vessel Elements and Details:

```
Element From Node                                    10
Element To Node                                      20
Element Type                                  Elliptical
Description                                Channel Cover
Distance "FROM" to "TO"                           50  mm.
Inside Diameter                                325.6  mm.
Element Thickness                              19.05  mm.
Internal Corrosion Allowance                       3  mm.
Nominal Thickness                              19.05  mm.
External Corrosion Allowance                       0  mm.
Design Internal Pressure                          59  bars
Design Temperature Internal Pressure              95  °C
Design External Pressure                       1.034  bars
Design Temperature External Pressure             100  °C
Effective Diameter Multiplier                    1.2
Material Name                              SA-234 WPB
    Allowable Stress, Ambient                  117.9  N./mm²
    Allowable Stress, Operating                117.9  N./mm²
    Allowable Stress, Hydrotest                217.2  N./mm²
    Material Density                          7750.4  kg/m³
    P Number Thickness                        30.988  mm.
    Yield Stress, Operating                    221.1  N./mm²
    UCS-66 Chart Curve Designation                 B
    External Pressure Chart Name                CS-2
    UNS Number                                K03006
    Product Form                 Smls. & wld. fittings
Efficiency, Longitudinal Seam                    1.0
Efficiency, Circumferential Seam                 1.0
Elliptical Head Factor                           2.0
Weld is pre-Heated                                No

    Element From Node                            10
    Detail Type                           Insulation
    Detail ID                                Ins: 10
    Dist. from "FROM" Node / Offset dist        -81.4  mm.
    Height/Length of Insulation                131.4  mm.
    Thickness of Insulation                       40  mm.
    Density                                      125  kg/m³

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

Element From Node                                    20
Element To Node                                      30
Element Type                                  Cylinder
Description                                Channel Barrel
Distance "FROM" to "TO"                          350  mm.
Inside Diameter                                322.26  mm.
```

Element Thickness	16.669	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	19.05	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	59	bars
Design Temperature Internal Pressure	95	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.19	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	221.08	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	350	mm.
Thickness of Insulation	40	mm.
Density	125	kg/m³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1 (6in)	
Dist. from "FROM" Node / Offset dist	175	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	600	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.4449	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T2 (6in)	
Dist. from "FROM" Node / Offset dist	175	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	600	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.4449	kN

Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	20	
Detail Type	Weight	
Detail ID	DIVIDER	
Dist. from "FROM" Node / Offset dist	175	mm.
Miscellaneous Weight	0.1961	kN
Offset from Element Centerline	0	mm.

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Channel FLG.	
Distance "FROM" to "TO"	165.1	mm.
Flange Inside Diameter	322.26	mm.
Element Thickness	69.85	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	59	bars
Design Temperature Internal Pressure	95	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-105	
Allowable Stress, Ambient	137.9	N./mm²
Allowable Stress, Operating	137.9	N./mm²
Allowable Stress, Hydrotest	223.4	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	227.29	N./mm²
UCS-66 Chart Curve Designation	A	
External Pressure Chart Name	CS-2	
UNS Number	K03504	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	165.1	mm.
Thickness of Insulation	40	mm.
Density	125	kg/m³

Element From Node	40	

Element To Node	50	
Element Type	Flange	
Description	Shell FLG.	
Distance "FROM" to "TO"	165.1	mm.
Flange Inside Diameter	322.26	mm.
Element Thickness	69.85	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars
Design Temperature Internal Pressure	145	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-105	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of Standard Flange	0	kN
Class of Standard Flange		
Grade of Standard Flange		
Weld is pre-Heated	No	
Element From Node	40	
Detail Type	Liquid	
Detail ID	Liquid: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	322.26	mm.
Liquid Density	999.54	kg/m³
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	165.1	mm.
Thickness of Insulation	80	mm.
Density	125	kg/m³

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description	Shell Barrel	
Distance "FROM" to "TO"	4800	mm.
Inside Diameter	322.26	mm.
Element Thickness	16.669	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	19.05	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars
Design Temperature Internal Pressure	145	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm²

Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.2	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	214.2	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	500	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	800	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.30000001	
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	50	
Detail Type	Saddle	
Detail ID	Sdl 2 Fr50	
Dist. from "FROM" Node / Offset dist	4200	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	800	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	
Friction coefficient	0.0	
Moment Factor	3.0	
Dimension E at base (optional)	0	mm.
Circumferential Eff. over Saddle	1.0	
Circumferential Eff. at Midspan	1.0	
Tangent to Tangent dist. (optional)	0	mm.

Element From Node	50	
Detail Type	Liquid	
Detail ID	Liquid: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	322.26	mm.
Liquid Density	999.54	kg/m³

Element From Node	50	
Detail Type	Insulation	
Detail ID	Ins: 50	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	4800	mm.
Thickness of Insulation	80	mm.
Density	125	kg/m³
Element From Node	50	
Detail Type	Nozzle	
Detail ID	S2 (2in)	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	600	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08914	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	50	
Detail Type	Nozzle	
Detail ID	S1 (2in)	
Dist. from "FROM" Node / Offset dist	4600	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	600	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08914	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	50	
Detail Type	Weight	
Detail ID	BAFFLE	
Dist. from "FROM" Node / Offset dist	2400	mm.
Miscellaneous Weight	0.9806	kN
Offset from Element Centerline	0	mm.

Element From Node	60	
Element To Node	70	
Element Type	Elliptical	
Description	Shell Cover	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	322.26	mm.
Element Thickness	19.05	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	19.05	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	62	bars

Design Temperature Internal Pressure	145	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-234 WPB	
Allowable Stress, Ambient	117.9	N./mm²
Allowable Stress, Operating	117.9	N./mm²
Allowable Stress, Hydrotest	217.19	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	30.988	mm.
Yield Stress, Operating	214.23	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. & wld. fittings	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	60	
Detail Type	Liquid	
Detail ID	Liquid: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	322.26	mm.
Liquid Density	999.54	kg/m³
Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	130.57	mm.
Thickness of Insulation	80	mm.
Density	125	kg/m³

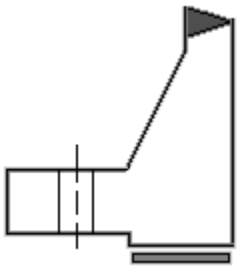
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
Channel Cover		50	...	50	...
Channel Barrel		400	...	350	...
Channel FLG.		565.1	...	165.1	...
Shell FLG.		831.075	...	165.1	...
Shell Barrel		5631.08	...	4800	...
Shell Cover		5681.08	...	50	...

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

Channel FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	59.00	bars
Design Temperature		95	°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	322.262	mm.
Flange Outside Diameter	A	603.250	mm.
Flange Thickness	t	69.8500	mm.
Thickness of Hub at Small End	go	16.6687	mm.
Thickness of Hub at Large End	g1	54.7687	mm.
Length of Hub	h	95.2500	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
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	527.050	mm.
Nominal Bolt Diameter	a	34.9250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	412.750	mm.
Flange Face Inside Diameter	Fid	322.262	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	406.400	mm.
Gasket Inside Diameter	Gi	361.950	mm.
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Flange Class		600	
Flange Grade		GR 1.1	
Flange Series	Series	A	



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)
= (59*(322/2+3))/(138*1-0.6*59)+Ca
= 10.2077 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138 * 1 * 13.7)/(164 + 0.6 * 13.7)
= 109.370 bars

Corroded Flange Thickness,	tc = T-ci	66.850	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	328.262	mm.
Corroded Large Hub,	g1Cor = g1-ci	51.769	mm.
Corroded Small Hub,	g0Cor = go-ci	13.669	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	47.625	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	22.225	mm.
Basic Gasket Width,	bo = N / 2	11.112	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	8.400	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.79 * 406² * 59
= 765.310 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 8.4 * 3.14 * 406 * 0 * 59
= 0.000 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.14 * 328² *59/4
= 499.311 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 765 - 499
= 265.999 kN
Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 765 + 0 + 0, 0 )
  = 765.310 kN
  = 804.634 kN, Mating Flange Load Governs
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 0*8.4*3.141*406+0*0*0
  = 0.000 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 805/172, 0/172
  = 46.683 cm²
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 46.7 + 149 )/2
  = 1686.68 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 805 - 765
  = 39.32 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 527 - 406 )/2
  = 60.3250 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 47.6 + 51.8 + 60.3 )/2
  = 79.8595 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 47.6 + ( 51.8/2.0 )
  = 73.5097 mm.
```

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

```
Loading                 Force  |   Distance |  Bolt Corr |         Moment  |
-------------------------------------------------------------------------------
End Pressure,   Md        499. |    73.5097 |     1.0000 |          36719. |
Face Pressure,  Mt        266. |    79.8595 |     1.0000 |          21251. |
Gasket Load,    Mg         39. |    60.3250 |     1.0000 |           2373. |
Gasket Seating, Matm     1687. |    60.3250 |     1.0000 |         101790. |

Total Moment for Operation,      Mop                              60343. N-m
Total Moment for Gasket seating, Matm                            101790. N-m
```

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

```
Estimated Finished Weight of Flange at given Thk.      140.2 kg.
Estimated Unfinished Weight of Forging at given Thk    261.4 kg.
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)        -48 °C
```

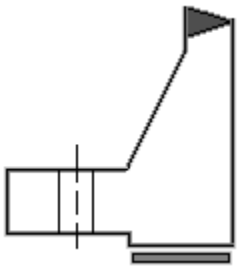
Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 59.00/102.10 = 0.578
```

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

Shell FLG.

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	62.03	bars
Design Temperature		145	°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	322.262	mm.
Flange Outside Diameter	A	603.250	mm.
Flange Thickness	t	69.8500	mm.
Thickness of Hub at Small End	go	16.6687	mm.
Thickness of Hub at Large End	g1	54.7687	mm.
Length of Hub	h	95.2500	mm.
Flange Material		SA-105	
Flange Material UNS number		K03504	
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	527.050	mm.
Nominal Bolt Diameter	a	34.9250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		20	
Flange Face Outside Diameter	Fod	412.750	mm.
Flange Face Inside Diameter	Fid	322.262	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	406.400	mm.
Gasket Inside Diameter	Gi	361.950	mm.
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	N./mm²
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm.
Flange Class		600	
Flange Grade		GR 1.1	
Flange Series	Series	A	



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)
= (62*(322/2+3))/(138*1-0.6*62)+Ca
= 10.5884 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (138 * 1 * 13.7)/(164 + 0.6 * 13.7)
= 109.370 bars

Corroded Flange Thickness,	tc = T-ci	66.850	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	328.262	mm.
Corroded Large Hub,	g1Cor = g1-ci	51.769	mm.
Corroded Small Hub,	g0Cor = go-ci	13.669	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	47.625	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	22.225	mm.
Basic Gasket Width,	bo = N / 2	11.112	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	8.400	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.79 * 406² * 62
= 804.634 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 8.4 * 3.14 * 406 * 0 * 62
= 0.000 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.14 * 328² *62/4
= 524.967 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 805 - 525
= 279.667 kN
Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 805 + 0 + 0, 0 )
  = 804.634 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 0*8.4*3.141*406+0*0*0
  = 0.000 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 805/172, 0/172
  = 46.683 cm²
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172 * ( 46.7 + 149 )/2
  = 1686.68 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 805 - 805
  = 0.00 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 527 - 406 )/2
  = 60.3250 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 47.6 + 51.8 + 60.3 )/2
  = 79.8595 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 47.6 + ( 51.8/2.0 )
  = 73.5097 mm.
```

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

```
Loading                  Force  |   Distance |  Bolt Corr |         Moment  |
-------------------------------------------------------------------------------
End Pressure,    Md        525. |    73.5097 |     1.0000 |          38606. |
Face Pressure,   Mt        280. |    79.8595 |     1.0000 |          22343. |
Gasket Load,     Mg          0. |    60.3250 |     1.0000 |              0. |
Gasket Seating, Matm      1687. |    60.3250 |     1.0000 |         101790. |

Total Moment for Operation,      Mop                              60949. N-m
Total Moment for Gasket seating, Matm                            101790. N-m
```

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

```
Estimated Finished Weight of Flange at given Thk.      140.2 kg.
Estimated Unfinished Weight of Forging at given Thk    261.4 kg.
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)        -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.03/102.10 = 0.608
```

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
Channel Cover		59	19.05	3	325.6	117.9
Channel Barrel		59	19.05	3	322.26	117.9
Channel FLG.		59	...	3	322.26	137.9
Shell FLG.		62.032	...	3	322.26	137.9
Shell Barrel		62.032	19.05	3	322.26	117.9
Shell Cover		62.032	19.05	3	322.26	117.9

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.
Channel Cover		59	108	136	19.05	11.1434
Channel Barrel		59	93.5	115	16.6687	11.4679
Channel FLG.		59	93.9	102	69.85	No Calc
Shell FLG.		62	90.5	102	69.85	No Calc
Shell Barrel		62	93.5	115	16.6687	11.9176
Shell Cover		62	109	138	19.05	11.4755

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      =            78.6 bars
Shell Side MAPnc     =             102 bars
Channel Side  MAWP   =              76 bars
Channel Side  MAPnc  =            82.5 bars
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2019

Elliptical Head From 10 To 20 SA-234 WPB , UCS-66 Crv. B at 95 °C

Channel Cover
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (59*332*0.98)/(2*118*1-0.2*59)
= 8.1434 + 3.0000 = 11.1434 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*16)/(0.98*332+0.2*16)
= 116 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*19)/(1*326+0.2*19)
= 136 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (59*(0.98*332+0.2*16))/(2*1*16)
= 60.110 N./mm²

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (59*166)/(118*1-0.6*59)+3
= 11.554 mm.

Straight Flange Maximum Allowable Working Pressure:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118 * 1 * 16)/(166 + 0.6 * 16)
= 108 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (332/(2 * 84.4))²)/6
= 0.976514

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 19, tr = 10.5, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.65, Temp. Reduction = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-9 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-28 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 19, tr = 11.1, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.69, Temp. Reduction = 17 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-9 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-26 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 20 To 30 SA-106 B , UCS-66 Crv. B at 95 °C

Channel Barrel
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (59*164)/(118*1-0.6*59)
= 8.4679 + 3.0000 = 11.4679 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*13.7)/(164+0.6*13.7)
= 93.5 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*16.7)/(161+0.6*16.7)
= 115 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (59*(164+0.6*13.7))/(1*13.7)
= 74.390 N./mm²

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 16.7, tr = 5.22, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.38, Temp. Reduction = 56 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-13 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Cylindrical Shell From 50 To 60 SA-106 B , UCS-66 Crv. B at 145 °C

Shell Barrel
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (62*164)/(118*1-0.6*62)
= 8.9176 + 3.0000 = 11.9176 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)
= (118*1*13.7)/(164+0.6*13.7)
= 93.5 - 0.032 = 93.5  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118*1*16.7)/(161+0.6*16.7)
= 115 bars
```

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

```
= (P*(R+0.6*t))/(E*t)
= (62*(164+0.6*13.7))/(1*13.7)
= 78.213 N./mm²
```

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 16.7, tr = 11.4, 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 B          -13 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -22 °C
Min Metal Temp. w/o impact per UG-20(f)                 -29 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

Elliptical Head From 60 To 70 SA-234 WPB , UCS-66 Crv. B at 145 °C

Shell Cover
Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (62*328*0.98)/(2*118*1-0.2*62)
= 8.4755 + 3.0000 = 11.4755 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.032 bars

```
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*16)/(0.98*328+0.2*16)
= 117 - 0.032 = 117  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*118*1*19)/(1*322+0.2*19)
= 138 bars
```

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

```
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (62*(0.98*328+0.2*16))/(2*1*16)
= 62.555 N./mm²
```

Straight Flange Required Thickness:

```
= (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
= (62*164)/(118*1-0.6*62)+3
= 11.917 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.032 bars

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (118 * 1 * 16 )/(164 + 0.6 * 16 )
= 109 - 0.032 = 109  bars
```

Factor K, corroded condition [Kcor]:

```
= ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))^2)/6
= ( 2 + ( 328/( 2 * 83.6 ))^2)/6
= 0.976281
```

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 19, tr = 10.8, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.67, Temp. Reduction = 18 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -9 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -27 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 19, tr = 11.4, 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 B          -9 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -25 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C
```

Note:
Post Weld Heat Treatment is required for this Element/Joint and it was specified as being heat treated.

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        102.180  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       80.600  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     132.730  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S         86.460  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    88.660  bars
Pressure per App 27-4  = M.A.W.P.                       78.600  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S         98.742  bars
```

```
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S      76.700  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     107.179  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S         83.551  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    84.370  bars
Pressure per App 27-4  = M.A.W.P.                       75.955  bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 62 * 1
  = 80.600 bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 59 * 1
  = 76.700 bars
```

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

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

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

From To	Stress	Allowable	Ratio	Pressure
Channel Cover	78.2	217.2	0.360	76.73
Channel Barrel	96.7	217.2	0.445	76.73
Shell Barrel	101.7	217.2	0.468	80.63
Shell Cover	81.3	217.2	0.374	80.63

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1 (6in)	Nozzle	117.90	117.90	1.000
T1 (6in)	Pad	137.90	137.90	1.000
T2 (6in)	Nozzle	117.90	117.90	1.000
T2 (6in)	Pad	137.90	137.90	1.000
S2 (2in)	Nozzle	137.90	137.90	1.000
S1 (2in)	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
Channel Cover	117.90	117.90	1.000
Channel Barrel	117.90	117.90	1.000
Channel FLG.	137.90	137.90	1.000
Shell FLG.	137.90	137.90	1.000
Shell Barrel	117.90	117.90	1.000
Shell Cover	117.90	117.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	92.39	92.39	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 (6in)	94.74	217.19	0.436
T2 (6in)	94.74	217.19	0.436
S2 (2in)	21.68	223.40	0.097
S1 (2in)	21.68	223.40	0.097

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	363.7	16.05	0.0061291	121.512
20	30	592.233	355.6	13.6687	0.0059089	121.167
30	40	No Calc	...	66.85	No Calc	No Calc
40	50	No Calc	...	66.85	No Calc	No Calc
50	60	5041.96	355.6	13.6687	0.0016632	99.4028
60	70	No Calc	360.362	16.05	0.0061859	121.596

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	19.05	4.5	1.034	59.6
20	30	16.6687	4.41252	1.034	62.1
30	40	69.85	No Calc	1.034	No Calc
40	50	69.85	No Calc	1.034	No Calc
50	60	16.6687	6.10175	1.034	50.9
60	70	19.05	4.5	1.034	60.2
Minimum					50.9

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	592.233	32221.8	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	5041.96	247921	No Calc	No Calc
60	70	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2019

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 100 °C

Channel Cover

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

Results for Maximum Allowable Ext. Pressure				MAEP
Tca	Outer Dia	Do/t	Factor A	Factor B
16.050	363.70	22.66	0.0061291	121.51

MAEP = B/(K0*Do/t) = 122/(0.9 *22.7) = 59.6 bars

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
0.942	363.70	386.26	0.0003596	35.95

MAEP = B/(K0*Do/t) = 35.9/(0.9 *386) = 1.03 bars

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

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.73*332*0.98)/(2*118*1-0.2*1.73)
= 0.2372 + 3.0000 = 3.2372 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*118*1*16)/(0.98*332+0.2*16))/1.67
= 69.3 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(59.6, 69.3)
= 59.578 bars

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

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 100 °C

Channel Barrel

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
13.669	355.60	592.23	26.02	1.6654	0.0059089	121.17

```
MAEP = (4*B)/(3*(Do/t)) = (4*121 )/(3*26 ) = 62.1 bars

                                                |                                  |
Results for Required Thickness                  |                              Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  1.413 |     355.60 |      592.23 |    251.75 |    1.6654 |  0.0001953 |    19.53 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*19.5 )/(3*252 ) = 1.03 bars

                                                |                                  |
Results for Maximum Stiffened Length            |                             Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
 13.669 |     355.60 |    32221.82 |     26.02 |   50.0000 |  0.0016375 |    99.02 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*99 )/(3*26 ) = 50.7 bars

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

Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 100 °C

Shell Barrel

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                |                                  |
Results for Maximum Allowable Ext. Pressure     |                             MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
 13.669 |     355.60 |     5041.96 |     26.02 |   14.1787 |  0.0016632 |    99.40 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*99.4 )/(3*26 ) = 50.9 bars

                                                |                                  |
Results for Required Thickness                  |                              Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  3.102 |     355.60 |     5041.96 |    114.64 |   14.1787 |  0.0000889 |     8.89 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*8.89 )/(3*115 ) = 1.03 bars

                                                |                                  |
Results for Maximum Stiffened Length            |                             Slen |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
 13.669 |     355.60 |   247921.09 |     26.02 |   50.0000 |  0.0016375 |    99.02 |
-------------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*99 )/(3*26 ) = 50.7 bars

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

Elliptical Head From 60 to 70 Ext. Chart: CS-2 at 100 °C

Shell Cover

Elastic Modulus from Chart: CS-2 at 100 °C: 199943392.000 KPa.

```
                                                |                                |
Results for Maximum Allowable Ext. Pressure     |                           MAEP |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                         Factor B |
 16.050 |     360.36 |       22.45 | 0.0061859 |                           121.60 |
-------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 122/(0.9 *22.5 ) = 60.2 bars

                                                |                                |
Results for Required Thickness                  |                            Tca |
-------------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                         Factor B |
  0.933 |     360.36 |      386.26 | 0.0003596 |                            35.95 |
-------------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 35.9/(0.9 *386 ) = 1.03 bars
```

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

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.73*328*0.98)/(2*118*1-0.2*1.73)
  = 0.2347 + 3.0000 = 3.2347 mm.
```

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*118*1*16)/(0.98*328+0.2*16))/1.67
  = 70 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 60.2, 70 )
  = 60.171 bars
```

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

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	28.9837	8683.24	24.4193	9092.59	2.89837
20	30	55.4109	28553.2	47.0951	29626.4	5.54109
30	40	140.23	13683.1	136.307	13975.1	14.023
40	50	140.23	13683.1	136.307	13975.1	14.023
50	60	759.921	239512	645.876	254230	75.9921
60	70	28.5017	8460.73	24.0132	8863.36	2.85017
Total		1153	312575.88	1014	329762.28	115

For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Insl	1.14972	-15.7	...	Ins: 10
20	Insl	2.17498	175	...	Ins: 20
20	Nozl	49.9022	175	235.668	T1 (6in)
20	Nozl	49.9022	175	235.668	T2 (6in)
20	Wght	20	175	...	DIVIDER
30	Insl	1.82381	82.55	...	Ins: 30
40	Liqd	13.6747	82.55	...	Liquid: 40
40	Insl	3.93829	82.55	...	Ins: 40
50	Sadl	62.5756	500	467.231	Lft Sdl
50	Sadl	62.5756	4200	467.231	Sdl 2 Fr50
50	Liqd	239.366	2400	...	Liquid: 50
50	Insl	65.6887	2400	...	Ins: 50
50	Nozl	9.99917	200	186.531	S2 (2in)
50	Nozl	9.99917	4600	186.531	S1 (2in)
50	Wght	100	2400	...	BAFFLE
60	Liqd	8.45557	76.8552	0.18167E-04	Liquid: 60
60	Insl	2.49067	65.2828	...	Ins: 60
30	FTsh	184.402	213.95	...	TS
30	Tube	534.264	2609.95	...	Tubes

Total Weight of Each Detail Type:

Saddles	125.2
Liquid	261.5
Insulation	77.3
Nozzles	119.8
Weights	120.0
Exchanger Components	718.7

```
-----------------------------------------
Sum of the Detail Weights        1422.4 kg.
```

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	1268.6	1268.6	1268.6	1268.6	1268.6	1268.6
Saddles	125.2	125.2	125.2	125.2	125.2	125.2
Nozzles	119.8	119.8	119.8	119.8	119.8	119.8
Wld Weights	120.0	120.0	120.0	120.0	120.0	120.0
Exchanger	718.7	718.7	718.7	718.7	718.7	718.7
Insulation	...	...	77.3	77.3	77.3	77.3
Ope. Liquid	...	...	...	...	...	261.5
Test Liquid	...	312.4	...	...	...	...
Tube Tst Lqd	...	96.9	...	...	...	...
Totals	2352.2	2761.5	2429.5	2429.5	2429.5	2691.0

Field Installation Options:

Miscellaneous Weight Percent: 10.0 %

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

Weight Summary:

```
Fabricated Wt.   - Bare Weight without Removable Internals          2352.2 kg.
Shop Test Wt.    - Fabricated Weight + Water ( Full )              2761.5 kg.
Shipping Wt.     - Fab. Weight + removable Intls.+ Shipping App.   2429.5 kg.
Erected  Wt.     - Fab. Wt + or - loose items (trays,platforms etc.) 2429.5 kg.
Ope. Wt. no Liq  - Fab. Weight + Internals. + Details + Weights    2429.5 kg.
Operating Wt.    - Empty Weight + Operating Liq. Uncorroded        2691.0 kg.
Oper. Wt. + CA   - Corr Wt. + Operating Liquid                     2537.8 kg.
Field Test Wt.   - Empty Weight + Water (Full)                     2702.7 kg.
```

Exchanger Tube Data

```
Volume of Exchanger tubes  :          96914.3 Cm.
Weight of Ope Liq in tubes :              0.0 kg.
Weight of Water in tubes   :             96.9 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 cm²
10	20	2005.17
20	30	3962.39
30	40	4658.36
40	50	4658.36
50	60	54341.4
60	70	1973.73
Total		71599.414 cm²

Nozzle Flange MAWP Results: (bars & °C)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
T1 (6in)	93.90	102.10	95	600	GR 1.1	33.873	93.900	60.027	93.90
T2 (6in)	93.90	102.10	95	600	GR 1.1	33.873	93.900	60.027	93.90
S2 (2in)	90.50	102.10	145	600	GR 1.1	56.972	78.778	90.500	78.78
S1 (2in)	90.50	102.10	145	600	GR 1.1	56.972	78.778	90.500	78.78

Shellside Flange Rating

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 78.778 bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 102.100 bars

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]: 93.900 bars
Lowest Flange Pressure Rating was (Amb)[TubeSide]: 102.100 bars

Selected Method for Derating ANSI B16.5 Flange MAWP: ASME UG-44(b)

The UG-44(b) Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the UG-44(b) method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used.

The axial force FE must put the nozzle in tension (-P for 107/297; +Fr for PD 5500 AnnexG) to be considered.

Nozzle Description	Gasket Dimension G mm.	Fm Value	Resolved Moment ME N-m	Axial Force FE kN	Design Pressure PD bars	Maximum Pressure Pmax bars	Pass Fail
T1 (6in)	192.151	0.50	4720	0	59.000	93.900	Pass
T2 (6in)	192.151	0.50	4720	0	59.000	93.900	Pass
S2 (2in)	77.851	0.50	528	0	62.000	78.778	Pass
S1 (2in)	77.851	0.50	528	0	62.000	78.778	Pass

Evaluating Flange on Nozzle [T1 (6in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(4720)+4*abs(0)192.151 < pi*192.151^3[(93.9-59.0)+.500*93.900]
= 75526.0 < 182499.2  Check Passes
```

Maximum Pressure for Flange on Nozzle T1 (6in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 93.900, 0.500 * 93.900 + 93.900 - 75526.0/(pi * 192.151^3)
= min( 93.900, 106.977 )
= 93.900 bars
```

Evaluating Flange on Nozzle [T2 (6in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(4720)+4*abs(0)192.151 < pi*192.151^3[(93.9-59.0)+.500*93.900]
= 75526.0 < 182499.2  Check Passes
```

Maximum Pressure for Flange on Nozzle T2 (6in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 93.900, 0.500 * 93.900 + 93.900 - 75526.0/(pi * 192.151^3)
= min( 93.900, 106.977 )
= 93.900 bars
```

Evaluating Flange on Nozzle [S2 (2in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(528)+4*abs(0)77.851 < pi*77.851^3[(90.5-62.0)+.500*90.500]
= 8448.2 < 10936.3  Check Passes
```

Maximum Pressure for Flange on Nozzle S2 (2in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 90.500, 0.500 * 90.500 + 90.500 - 8448.2/(pi * 77.851^3)
= min( 90.500, 78.778 )
= 78.778 bars
```

Evaluating Flange on Nozzle [S1 (2in)]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(528)+4*abs(0)77.851 < pi*77.851^3[(90.5-62.0)+.500*90.500]
= 8448.2 < 10936.3  Check Passes
```

Maximum Pressure for Flange on Nozzle S1 (2in) [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 90.500, 0.500 * 90.500 + 90.500 - 8448.2/(pi * 77.851^3)
= min( 90.500, 78.778 )
= 78.778 bars
```

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

Input Values:

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	120	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		100	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Wind Analysis Results

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

= min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q)/(1 + 1.7 * gV * Izbar)))
= min(0.85,0.925((1+1.7*3.4*0.23*0.99)/(1+1.7*3.4*0.23)))
= min(0.85, 0.92)
= 0.850

Natural Frequency of Vessel (Operating)		33.000 Hz
Natural Frequency of Vessel (Empty)		33.000 Hz
Natural Frequency of Vessel (Test)		33.000 Hz
Force Coefficient	[Cf]	0.627
Structure Height to Diameter ratio		11.865

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

Sample Calculation for the First Element

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

Value of [Alpha] and [Zg]:

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

Effective Height [z]:

= Centroid Height + Vessel Base Elevation
= 800 + 100 = 900 mm.
= 2.95 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z (2.95 ft.) < 15 ft.
$= 2.01 * (15 / Zg)^{2 / Alpha}$

$= 2.01 * (15/900)^{2/9.5}$
$= 0.85$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:
$= 0.95$, per Table 26.6-1

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

Topographical Factor [Kzt]:
$= (1 + K1 * K2 * K3)^2$
$= (1 + 0 * 0 * 0)^2$
$= 1$

Velocity Pressure evaluated at height z, Imperial Units [qz]:
$= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= max(16, 0.00256 * 0.85 * 1 * 0.95 * 74.6^2)$
$= 16$ psf [78.1] Kgs/m²

Force on the first element [F]:
$= qz * G * Cf * WindArea$
$= 16 * 0.85 * 0.63 * 0.81$
$= 6.94$ lbs. [0.031] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Channel Cover	900.0	0.000	0.000	0.000	0.849	1.000	78.120
Channel Barrel	900.0	0.000	0.000	0.000	0.849	1.000	78.120
Channel FLG.	900.0	0.000	0.000	0.000	0.849	1.000	78.120
Shell FLG.	900.0	0.000	0.000	0.000	0.849	1.000	78.120
Shell Barrel	900.0	0.000	0.000	0.000	0.849	1.000	78.120
Shell Cover	900.0	0.000	0.000	0.000	0.849	1.000	78.120

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm²	Elevation mm.	Pressure Kgs/m²	Force kN
DIVIDER	0.00	900.00	78.12	0.00
BAFFLE	0.00	900.00	78.12	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm²	Wind Pressure Kgs/m²	Element Wind Load kN
10	20	900	532.44	755.662	78.12	0.018511
20	30	900	522.72	1829.52	78.12	0.044817
30	40	900	482.714	796.962	78.12	0.019523
40	50	900	578.714	955.458	78.12	0.023406
50	60	900	618.72	29698.6	78.12	0.72752
60	70	900	624.434	1046.29	78.12	0.025631

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

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

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.111
Table Value Fv		1.575
Short Period Acceleration value Ss		1.377
Long Period Acceleration Value Sl		0.367
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		1.020
User Value of Sd1 (used if > 0)		0.385

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.11 * 1.38 = 1.53
Sm1 = Fv * S1 = 1.58 * 0.37 = 0.58
Sds = 2/3 * Sms = 2/3 * 1.53 = 1.02

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.82, 1.02 )
    = 1.020

Sd1 = 2/3 * Sm1 = 2/3 * 0.58 = 0.39

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.31, 0.38 )
    = 0.385
```

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

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

$= 0.020 * (3.16^{0.75})$

$= 0.047$ seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= (1/Natural Frequency) = (1/33)

= 0.030

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

= Minimum Value of (1.4 * 0.047, 0.03) per 12.8.2

= 0.030

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

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

```
  = 0.3 * Sds * W * I
  = 0.3 * 1.02 * 24.9 * 1.25
  = 9.519 kN

 Final Base Shear,       V = 6.66 kN
```

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	162.8	3.11071	0.84043
20	30	161.131	3.11071	0.83182
30	40	161.131	3.11071	0.83181
40	50	161.131	3.11071	0.83181
50	Sadl	161.131	3.11071	0.83182
Sadl	60	161.131	3.11071	0.83182
50	60	161.131	3.11071	0.83182
60	70	161.131	3.11071	0.83182

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 Shop.

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

Center of Gravity of the Saddles	3181.075 mm.
Center of Gravity of the Liquid	3181.342 mm.
Center of Gravity of the Insulation	2986.199 mm.
Center of Gravity of the Nozzles	726.796 mm.
Center of Gravity of the Added Weights (Operating)	2730.063 mm.
Center of Gravity of the Added Weights (Empty)	2730.063 mm.
Center of Gravity of the Tubesheet(s)	613.950 mm.
Center of Gravity of the Tubes	3009.950 mm.
Center of Gravity of Bare Shell New and Cold	2428.679 mm.
Center of Gravity of Bare Shell Corroded	2367.295 mm.
Vessel CG in the Operating Condition	2457.752 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	2406.218 mm.
Vessel CG in the Test Condition	2459.439 mm.

ASME Horizontal Vessel Analysis: Bundle pullout, Left Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

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

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 150 + 1.56*sqrt( 169 * 16.7 ), 2 * 600 )
= 232.9119 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	169.47	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	600.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	80.57	mm.
Shell Allowable Stress used in Calculation		117.90	N./mm²
Head Allowable Stress used in Calculation		117.90	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	800.00	mm.
Coefficient of Friction	mu	0.00	
Tube Bundle Pull out Force		7.00	kN
Tube Bundle Pull out Force Impact Factor		2.000	
Apply Bundle Pull out Force to Fixed Saddle only		Yes	
Saddle Force Q, + Bundle Pull, Force		6.43	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	-2.69	-192.78
Long. Stress at Top of Midspan	2.69	117.90
Long. Stress at Bottom of Midspan	2.69	117.90
Long. Stress at Top of Saddles	3.24	117.90
Long. Stress at Bottom of Saddles	-1.79	-192.78
Long. Stress at Bottom of Saddles	1.79	117.90
Tangential Shear in Shell	1.99	94.32

```
Circ. Stress at Horn of Saddle              2.25 |       176.85 |
Circ. Compressive Stress in Shell           0.13 |       117.90 |
-------------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:

```
= Bundle Pull Out Force * Impact Factor * B / Ls
= 7  * 2 * 800/3700
= 3.0 kN
```

Load Combination Results for Tube Bundle Pull Out [Q]:

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 3.41 + max( 3.03, 1.05, 0, 0 )
= 6.4 kN
```

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)                 7.05   kN
Transverse Shear Load Saddle           Ft               0.00   kN
Longitudinal Shear Load Saddle                         14.00   kN
```

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( 322/2 + 16.7 + 10 )sin( 60/2 ), 2*169 )
= 325.279 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
```

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)]
= -6.43*600[1-(1-600/5015+(169²-80.6²)/
  (2*600*5015))/(1+(4*80.6)/(3*5015))]
= -519.3 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 6.43*5015/4(1+2(169²-80.6²)/(5015²))/(1+(4*80.6)/
  (3*5015))-4*600/5015
= 4052.2 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 0 * 169/(2*16.7 ) - 4052/(pi*169²*16.7 )
= -2.69 N./mm²
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 0 * 169/(2 * 16.7 ) + 4052/(pi * 169² * 16.7 )
= 2.69 N./mm²
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 0*169/(2*16.7)--519/(0.11*pi*169²*16.7)
= 3.24 N./mm²
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 0*169/(2*16.7)+-519/(0.19*pi*169²*16.7)
= -1.79 N./mm²
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 6.43 ( 5015 - 2 * 600 )/(5015 + ( 4 * 80.6/3))
= 4.8 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.17 * 4.79/( 169 * 16.7 )
= 1.99 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 169 * 16.7 )
= 41.456 mm.
```

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

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.76 * 6.43 * 0.1/( 16.7 * ( 150 + 41.5 + 41.5 ) )
= -0.13 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -6.43/(4*16.7 *(150 +41.5 +41.5 )) -
   3*0.053 *6.43/(2*16.7²)
= -2.25 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 150 + 1.56 * sqrt( 169 * 16.7 ), 2 * 600 )
= 232.91 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.

Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	mm.
Friction Coefficient	mu	0.000	

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	280.8	16.7	8.3	46.8	39016.3	0.292E+05
Wearplate	200.0	10.0	21.7	20.0	43337.5	0.112E+05
Web	10.0	592.2	322.8	59.2	1911436.2	0.198E+05
BasePlate	170.0	20.0	628.9	34.0	2138153.5	0.467E+05
Totals	...	...	...	160.0	4131943.8	0.107E+06

Distance to Centroid [C1]:
= AY / A
= 1627/160
= 258.192 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 * 6.43
= 1.3093 kN

Tension Stress, St = (Fh/As)	=	0.1156	N./mm²
Allowed Stress, Sa = 0.6 * Yield Str	=	143.9676	N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 161 * sin(120/2)/1.05
= 666.746 mm.

Bending Moment, M = Fh * d	=	873.2956	N-m
Bending Stress, Sb = (M * C1 / I)	=	0.2108	N./mm²
Allowed Stress, Sa = 2/3 * Yield Str	=	159.9640	N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(6.43 + 0.61)170/(2 * 400 * 160))½
= 5.300 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 )( 161 + 16.7 + 10 )
= 325.279 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 325/( 3 - 1 )
= 162.640 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 163 * 170/2
= 138.244 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 6.43/( 400 * 170 )
= 0.009 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 138 * 0.0095
= 1.308 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 1.31/22.1
= 0.591 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
```

```
  = 116066/22.1
  = 52.443 mm.
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 52.4, 150 - 52.4 )
  = 97.557 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 519/22.1 )
  = 48.411 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 800 - cos( 120/2 )( 161 + 16.7 + 10 ) - 20
  = 686.100 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/240 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 686/48.4
  = 14.172
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 14/( 2 * 400 ) * 163 * 686/2
  = 976.782 N-m
```

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 14.2 )²/(2 * 128² ))240/
    ( 5/3+3*(14.2 )/(8* 128 )-( 14.2³)/(8*128³)
  = 139.6 N./mm²
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 0.59/140 + ( 977 * 97.6/5186964 )/160
  = 0.119
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 120132/30.3
  = 39.695 mm.
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 39.7, abs( 150 - 39.7 ) )
  = 110.305 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 800 - cos( 188/2 )( 20 + 0 + 0 ) - 0
  = 592.200 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 653/30.3 )
  = 46.459 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 592/46.5
  = 12.747
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 14/( 2 * 400 )
  = 0.018 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.018 * 163 * 592
  = 1686.198 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 1686/59220
  = 28.464 N./mm²
```

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.7 )²/(2 * 128² ))240/
    ( 5/3+3*(12.7 )/(8* 128 )-( 12.7³)/(8*128³)
  = 140.1 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 0.88/140 + ( 1686 * 110/653 )/160
  = 0.184
```

ASME Horizontal Vessel Analysis: Bundle pullout, Left Saddle

This saddle was not processed as the coefficient of friction was specified and the directive was set to only analyze the fixed saddle for this case.

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

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 150 + 1.56*sqrt( 171 * 13.7 ), 2 * 600 )
= 225.4125 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	170.97	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	600.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	83.57	mm.
Shell Allowable Stress used in Calculation		117.90	N./mm²
Head Allowable Stress used in Calculation		117.90	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	800.00	mm.
Coefficient of Friction	mu	0.00	
Tube Bundle Pull out Force		7.00	kN
Tube Bundle Pull out Force Impact Factor		2.000	
Apply Bundle Pull out Force to Fixed Saddle only		Yes	
Saddle Force Q, + Bundle Pull, Force		5.68	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	-2.85	-192.78
Long. Stress at Top of Midspan	2.85	117.90
Long. Stress at Bottom of Midspan	2.85	117.90
Long. Stress at Top of Saddles	3.44	117.90
Long. Stress at Bottom of Saddles	-1.91	-192.78
Long. Stress at Bottom of Saddles	1.91	117.90
Tangential Shear in Shell	2.12	94.32

```
Circ. Stress at Horn of Saddle              2.87 |       176.85 |
Circ. Compressive Stress in Shell           0.14 |       117.90 |
-------------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:

```
= Bundle Pull Out Force * Impact Factor * B / Ls
= 7  * 2 * 800/3700
= 3.0 kN
```

Load Combination Results for Tube Bundle Pull Out [Q]:

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 2.65 + max( 3.03, 1.05, 0, 0 )
= 5.7 kN
```

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)                 6.30   kN
Transverse Shear Load Saddle           Ft               0.00   kN
Longitudinal Shear Load Saddle                         14.00   kN
```

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( 322/2 + 16.7 + 10 )sin( 60/2 ), 2*171 )
= 325.279 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
```

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)]
= -5.68*600[1-(1-600/5015+(171²-83.6²)/
  (2*600*5015))/(1+(4*83.6)/(3*5015))]
= -461.0 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 5.68*5015/4(1+2(171²-83.6²)/(5015²))/(1+(4*83.6)/
  (3*5015))-4*600/5015
= 3573.7 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 0 * 171/(2*13.7 ) - 3574/(pi*171²*13.7 )
= -2.85 N./mm²
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 0 * 171/(2 * 13.7 ) + 3574/(pi * 171² * 13.7 )
= 2.85 N./mm²
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 0*171/(2*13.7)--461/(0.11*pi*171²*13.7)
= 3.44 N./mm²
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 0*171/(2*13.7)+-461/(0.19*pi*171²*13.7)
= -1.91 N./mm²
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 5.68 ( 5015 - 2 * 600 )/(5015 + ( 4 * 83.6/3))
= 4.2 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.17 * 4.23/( 171 * 13.7 )
= 2.12 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 171 * 13.7 )
= 37.706 mm.
```

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

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.76 * 5.68 * 0.1/( 13.7 * ( 150 + 37.7 + 37.7 ) )
= -0.14 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -5.68/(4*13.7 *(150 +37.7 +37.7 )) -
   3*0.053 *5.68/(2*13.7²)
= -2.87 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 150 + 1.56 * sqrt( 171 * 13.7 ), 2 * 600 )
= 225.41 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.

Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	mm.
Friction Coefficient	mu	0.000	

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	273.9	13.7	6.8	37.4	25586.1	0.262E+05
Wearplate	200.0	10.0	18.7	20.0	37337.5	0.127E+05
Web	10.0	592.2	319.8	59.2	1893670.6	0.187E+05
BasePlate	170.0	20.0	625.9	34.0	2127953.8	0.428E+05
Totals	...	...	...	150.7	4084547.8	0.100E+06

Distance to Centroid [C1]:
= AY / A
= 1608/151
= 271.115 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 * 5.68
= 1.1564 kN

Tension Stress, St = (Fh/As)	=	0.1021 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str	=	143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 164 * sin(120/2)/1.05
= 664.265 mm.

Bending Moment, M = Fh * d	=	768.4665 N-m
Bending Stress, Sb = (M * C1 / I)	=	0.2074 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str	=	159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(5.68 + 0.61)170/(2 * 400 * 160))½
= 5.009 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 )( 161 + 16.7 + 10 )
= 325.279 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 325/( 3 - 1 )
= 162.640 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 163 * 170/2
= 138.244 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 5.68/( 400 * 170 )
= 0.008 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 138 * 0.0084
= 1.155 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 1.16/22.1
= 0.522 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
```

```
  = 116066/22.1
  = 52.443 mm.
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 52.4, 150 - 52.4 )
  = 97.557 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 519/22.1 )
  = 48.411 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 800 - cos( 120/2 )( 161 + 16.7 + 10 ) - 20
  = 686.100 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/240 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 686/48.4
  = 14.172
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 14/( 2 * 400 ) * 163 * 686/2
  = 976.782 N-m
```

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 14.2 )²/(2 * 128² ))240/
    ( 5/3+3*(14.2 )/(8* 128 )-( 14.2³)/(8*128³)
  = 139.6 N./mm²
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 0.52/140 + ( 977 * 97.6/5186964 )/160
  = 0.119
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 120132/30.3
  = 39.695 mm.
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 39.7, abs( 150 - 39.7 ) )
  = 110.305 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 800 - cos( 188/2 )( 20 + 0 + 0 ) - 0
  = 592.200 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 653/30.3 )
  = 46.459 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 592/46.5
  = 12.747
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 14/( 2 * 400 )
  = 0.018 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.018 * 163 * 592
  = 1686.198 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 1686/59220
  = 28.464 N./mm²
```

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.7 )²/(2 * 128² ))240/
    ( 5/3+3*(12.7 )/(8* 128 )-( 12.7³)/(8*128³)
  = 140.1 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 0.78/140 + ( 1686 * 110/653 )/160
  = 0.183
```

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

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 150 + 1.56*sqrt( 171 * 13.7 ), 2 * 500 )
= 225.4125 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	170.97	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	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	800.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Operating Case		41.28	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	13.90	117.90
Long. Stress at Bottom of Midspan	63.67	117.90
Long. Stress at Top of Saddles	53.26	117.90
Long. Stress at Bottom of Saddles	30.76	117.90
Tangential Shear in Shell	16.56	94.32
Circ. Stress at Horn of Saddle	20.86	147.38
Circ. Compressive Stress in Shell	1.02	117.90

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 ( 0.86/2 + 0 ) * 800/325
= 3.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.082, 5.19, 0 ) * 800/3700
= 1.1 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 6.66, 5.19, 0 ) * 800/3700
= 1.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3 ( 6.66/2 + 0 ) * 800/325
= 24.6 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 16.7 + max( 1.12, 3.17, 1.44, 24.6 )
= 41.3 kN
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766 ( 0 + ( 0.15 * 1.2 ))
= 82.201 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		41.89	kN
Transverse Shear Load Saddle	Ft	3.33	kN
Longitudinal Shear Load Saddle		6.66	kN

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( 322/2 + 16.7 + 10 )sin( 60/2 ), 2*171 )
= 325.279 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	

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)]
= -41.3*500[1-(1-500/5015+(171²-0²)/
  (2*500*5015))/(1+(4*0)/(3*5015))]
= -1938.1 N-m
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
```

```
  = 41.3*5015/4(1+2(171²-0²)/(5015²))/(1+(4*0)/
    (3*5015))-4*500/5015
  = 31245.3 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 62 * 171/(2*13.7 ) - 31245/(pi*171²*13.7 )
  = 13.90 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 62 * 171/(2 * 13.7 ) + 31245/(pi * 171² * 13.7 )
  = 63.67 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 62*171/(2*13.7)--1938/(0.11*pi*171²*13.7)
  = 53.26 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 62*171/(2*13.7)+-1938/(0.19*pi*171²*13.7)
  = 30.76 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 41.3 ( 5015 - 2 * 500 )/(5015 + ( 4 * 0/3))
  = 33.0 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.17 * 33/( 171 * 13.7 )
  = 16.56 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 171 * 13.7 )
  = 37.706 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = -0.76 * 41.3 * 0.1/( 13.7 * ( 150 + 37.7 + 37.7 ) )
  = -1.02 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -41.3/(4*13.7 *(150 +37.7 +37.7 )) -
     3*0.053 *41.3/(2*13.7²)
  = -20.86 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150 + 1.56 * sqrt( 171 * 13.7 ), 2 * 500 )
  = 225.41 mm.
```

Distance between Saddle Supports [Ls]:
= 3700.0 mm.

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls(Design Temperature - Ambient Temperature)
= 0.12394E-04 * 3700 (145 - 21.1)
= 5.681 mm.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	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	273.9	13.7	6.8	37.4	25586.1	0.262E+05
Wearplate	200.0	10.0	18.7	20.0	37337.5	0.127E+05
Web	10.0	592.2	319.8	59.2	1893670.6	0.187E+05
BasePlate	170.0	20.0	625.9	34.0	2127953.8	0.428E+05
Totals	...	...	...	150.7	4084547.8	0.100E+06

Distance to Centroid [C1]:
= AY / A
= 1608/151
= 271.115 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 * 41.3
= 8.4004 kN

Tension Stress, St = (Fh/As) = 0.7420 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 164 * sin(120/2)/1.05
= 664.265 mm.

Bending Moment, M = Fh * d = 5582.3823 N-m

Bending Stress, Sb = (M * C1 / I) = 1.5068 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(41.3 + 0.61)170/(2 * 400 * 160))½
= 12.921 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)(161 + 16.7 + 10)
= 325.279 mm.

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 325/(3 - 1)
= 162.640 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 163 * 170/2
= 138.244 cm²

Bearing Pressure [Bp]:
= Q / (BasePlateLength * BasePlateWidth)
= 41.3/(400 * 170)
= 0.061 kN/cm²

Axial Load [P]:
= Ap * Bp
= 138 * 0.061
= 8.391 kN

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²

Compressive Stress [Sc]:
= P/Ar
= 8.39/22.1
= 3.792 N./mm²

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 116066/22.1
= 52.443 mm.

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(52.4, 150 - 52.4)
= 97.557 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(519/22.1)
= 48.411 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 800 - cos(120/2)(161 + 16.7 + 10) - 20
= 686.100 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 199943008/240)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 686/48.4
= 14.172

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 6.66/(2 * 400) * 163 * 686/2
= 464.888 N-m

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(14.2)²/(2 * 128²))240/
(5/3+3*(14.2)/(8* 128)-(14.2³)/(8*128³)

= 139.6 N./mm²

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

= Sc/Sca + (Rm * C1 / I)/Sba
= 3.79/140 + (465 * 97.6/5186964)/160
= 0.082

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:

= AY / A
= 120132/30.3
= 39.695 mm.

Distance to Centroid [C1]:

= max(ytot, abs(Saddle Width - ytot))
= max(39.7, abs(150 - 39.7))
= 110.305 mm.

Length of Inner Rib [L]:

= Saddle Height - Outside Radius - Bpthk
= 800 - cos(188/2)(20 + 0 + 0) - 0
= 592.200 mm.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(653/30.3)
= 46.459 mm.

Slenderness ratio [KL/r]:

= KL/r
= 1 * 592/46.5
= 12.747

Unit Force [Force,u]:

= Fl / (2 * Baseplate Length)
= 6.66/(2 * 400)
= 0.008 kN/mm.

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

= Unit Force * e * L
= 0.0083 * 163 * 592
= 802.527 N-m

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

= Bending Moment / Section Modulus
= 803/59220

= 13.547 N./mm²

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(12.7)²/(2 * 128²))240/
(5/3+3*(12.7)/(8* 128)-(12.7³)/(8*128³)
= 140.1 N./mm²

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 5.65/140 + (803 * 110/653)/160
= 0.125

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	35.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	17.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.4	kN
Maximum Transverse Force	Ft	3.3	kN
Maximum Longitudinal Force	Fl	6.7	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
= Fl / (Bolt Area * Number of Bolts)
= 6.66/(2.17 * 2)
= 15.4 N./mm². Must be less than 180.0 N./mm².

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 3.33/(2.17 * 2)
= 7.7 N./mm². Must be less than 180.0 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)
= 6.66/(180 * 2)
= 0.1851 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 800 * 3.33 + 0
  = 2666.34 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 2666/17.3
  = 153.99 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 400/2 - 35
   = 165.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (154 - 0.5*400 )
    = -138.03 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1 * 2.17/170 * (165 + 154 )
    = 2443.67 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -2444 * (0.5 * 400 + 165 )
    = -891941.25 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -138 * Y² + 2444 * Y + -891941 = 0
 Y  = 158.21 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (400/2 - 158/3 - 154 )
     = -6.73

 Denom = (Bplen / 2 - Y / 3 + f)
       = (400/2 - 158/3 + 165 )
       = 312.26
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 17.3 * -6.73/312
  = 0.37 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 0.37/( 300 * 1 )
  = 0.0124 cm²
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.19, 0.012 ]
  = 0.1851 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2(QO + Tforce) / (Y * Bpwid)
= 2(17.3 + 0.37)/(158 * 170)
= 13.15 bars

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (400 - 349)/2
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * Adist
= 0.37 * 25.4
= 9.48 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 13.1 * (158 - 25.4)/158
= 11.04 bars

Overturning Moment due to Bearing Pressure [Mc]:
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 170/6) * (11 + 2 * 13.1)
= 68.27 N-m

Baseplate Required Thickness [Treq]:
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(9.48,68.3/(170 * 143))½
= 4.1081 mm.

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

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
= min(b + 1.56*sqrt(Rm * t), 2a)
= min(150 + 1.56*sqrt(171 * 13.7), 2 * 600)
= 225.4125 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	170.97	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	600.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees

```
Inside Depth of Head                              h2        83.57  mm.

Shell Allowable Stress used in Calculation                 117.90  N./mm²
Head Allowable Stress used in Calculation                  117.90  N./mm²
Circumferential Efficiency in Plane of Saddle                1.00
Circumferential Efficiency at Mid-Span                       1.00

Distance from Saddle Base to Centerline            B       800.00  mm.
Coefficient of Friction                           mu         0.00

Saddle Force Q, Operating Case                               31.55  kN

Horizontal Vessel Analysis Results:          Actual |    Allowable |
                                             N./mm² |       N./mm² |
-------------------------------------------------------------------
Long. Stress at Top    of Midspan             22.98 |       117.90 |
Long. Stress at Bottom of Midspan             54.59 |       117.90 |
Long. Stress at Top    of Saddles             57.91 |       117.90 |
Long. Stress at Bottom of Saddles             28.19 |       117.90 |
-------------------------------------------------------------------
Tangential Shear in Shell                     11.76 |        94.32 |
Circ. Stress at Horn of Saddle                15.95 |       147.38 |
Circ. Compressive Stress in Shell              0.78 |       117.90 |
-------------------------------------------------------------------
```

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 ( 0.86/2 + 0 ) * 800/325
= 3.2 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.082, 0, 0 ) * 800/3700
= 0.0 kN
```

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

```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 6.66, 0, 0 ) * 800/3700
= 1.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3 ( 6.66/2 + 0 ) * 800/325
= 24.6 kN
```

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

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 6.96 + max( 0.018, 3.17, 1.44, 24.6 )
= 31.5 kN
```

Longitudinal Wind Force [Fl]:

```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766 ( 0 + ( 0.15 * 1.2 ))
```

= 82.201 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		32.16	kN
Transverse Shear Load Saddle	Ft	3.33	kN
Longitudinal Shear Load Saddle		6.66	kN

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(322/2 + 16.7 + 10)sin(60/2), 2*171)
= 325.279 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		

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)]
= -31.5*600[1-(1-600/5015+(171²-83.6²)/
(2*600*5015))/(1+(4*83.6)/(3*5015))]
= -2559.2 N-m

Moment per Equation 4.15.4 [M2]:

= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 31.5*5015/4(1+2(171²-83.6²)/(5015²))/(1+(4*83.6)/
(3*5015))-4*600/5015
= 19840.5 N-m

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

= P * Rm/(2t) - M2/(pi*Rm²t)
= 62 * 171/(2*13.7) - 19841/(pi*171²*13.7)
= 22.98 N./mm²

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

= P * Rm/(2t) + M2/(pi * Rm² * t)
= 62 * 171/(2 * 13.7) + 19841/(pi * 171² * 13.7)
= 54.59 N./mm²

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

= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 62*171/(2*13.7)--2559/(0.11*pi*171²*13.7)
= 57.91 N./mm²

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

= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 62*171/(2*13.7)+-2559/(0.19*pi*171²*13.7)
= 28.19 N./mm²

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

```
= Q(L-2a)/(L+(4*h2/3))
= 31.5 ( 5015 - 2 * 600 )/(5015 + ( 4 * 83.6/3))
= 23.5 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.17 * 23.5/( 171 * 13.7 )
= 11.76 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 171 * 13.7 )
= 37.706 mm.
```

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

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.76 * 31.5 * 0.1/( 13.7 * ( 150 + 37.7 + 37.7 ) )
= -0.78 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -31.5/(4*13.7 *(150 +37.7 +37.7 )) -
   3*0.053 *31.5/(2*13.7²)
= -15.95 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 150 + 1.56 * sqrt( 171 * 13.7 ), 2 * 600 )
= 225.41 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	mm.
Friction Coefficient	mu	0.000	

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	273.9	13.7	6.8	37.4	25586.1	0.262E+05
Wearplate	200.0	10.0	18.7	20.0	37337.5	0.127E+05
Web	10.0	592.2	319.8	59.2	1893670.6	0.187E+05

BasePlate	170.0	20.0	625.9	34.0	2127953.8	0.428E+05
Totals	...	...	...	150.7	4084547.8	0.100E+06

Distance to Centroid [C1]:
= AY / A
= 1608/151
= 271.115 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 * 31.5
= 6.4202 kN

Tension Stress, St = (Fh/As) = 0.5671 N./mm²
Allowed Stress, Sa = 0.6 * Yield Str = 143.9676 N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 164 * sin(120/2)/1.05
= 664.265 mm.

Bending Moment, M = Fh * d = 4266.4365 N-m

Bending Stress, Sb = (M * C1 / I) = 1.1516 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str = 159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(31.5 + 0.61)170/(2 * 400 * 160))½
= 11.321 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)(161 + 16.7 + 10)
= 325.279 mm.

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 325/(3 - 1)
= 162.640 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2

```
= 163 * 170/2
= 138.244 cm²
```

Bearing Pressure [Bp]:

```
= Q / ( BasePlateLength * BasePlateWidth )
= 31.5/( 400 * 170 )
= 0.046 kN/cm²
```

Axial Load [P]:

```
= Ap * Bp
= 138 * 0.046
= 6.413 kN
```

Area of the Rib and Web [Ar]:

```
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²
```

Compressive Stress [Sc]:

```
= P/Ar
= 6.41/22.1
= 2.898 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:

```
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.
```

Distance to Centroid from Datum [ytot]:

```
= AY / A
= 116066/22.1
= 52.443 mm.
```

Distance to Centroid [C1]:

```
= max( ytot, Saddle Width - ytot )
= max( 52.4, 150 - 52.4 )
= 97.557 mm.
```

Radius of Gyration [r]:

```
= sqrt( Total Inertia / Total Area )
= sqrt( 519/22.1 )
= 48.411 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 800 - cos( 120/2 )( 161 + 16.7 + 10 ) - 20
  = 686.100 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/240 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 686/48.4
  = 14.172
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 6.66/( 2 * 400 ) * 163 * 686/2
  = 464.888 N-m
```

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 14.2 )²/(2 * 128² ))240/
    ( 5/3+3*(14.2 )/(8* 128 )-( 14.2³)/(8*128³)
  = 139.6 N./mm²
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.9/140 + ( 465 * 97.6/5186964 )/160
  = 0.075
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 120132/30.3
  = 39.695 mm.
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 39.7, abs( 150 - 39.7 ) )
  = 110.305 mm.
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 800 - cos( 188/2 )( 20 + 0 + 0 ) - 0
  = 592.200 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 653/30.3 )
= 46.459 mm.
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 592/46.5
= 12.747
```

Unit Force [Force,u]:
```
= Fl / ( 2 * Baseplate Length )
= 6.66/( 2 * 400 )
= 0.008 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
= Unit Force * e * L
= 0.0083 * 163 * 592
= 802.527 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
= Bending Moment / Section Modulus
= 803/59220
= 13.547 N./mm²
```

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 12.7 )²/(2 * 128² ))240/
  ( 5/3+3*(12.7 )/(8* 128 )-( 12.7³)/(8*128³)
= 140.1 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 4.32/140 + ( 803 * 110/653 )/160
= 0.115
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	35.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	7.6	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.4	kN
Maximum Transverse Force	Ft	3.3	kN
Maximum Longitudinal Force	Fl	6.7	kN
Saddle Bolted to Steel Foundation		Yes	

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

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 3.33/( 2.17 * 2 )
  = 7.7 N./mm².  Must be less than 180.0 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 )
  = 6.66/(180 * 2 )
  = 0.1851 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 800 * 3.33 + 0
  = 2666.34 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 2666/7.58
  = 351.72 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 400/2 - 35
   = 165.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (352 - 0.5*400 )
    = 455.15 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1 * 2.17/170 * (165 + 352 )
    = 3958.37 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -3958 * (0.5 * 400 + 165 )
    = -1444803.75 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 455 * Y² + 3958 * Y + -1444803 = 0
 Y  = 49.72 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (400/2 - 49.7/3 - 352 )
     = -168.29

 Denom = (Bplen / 2 - Y / 3 + f)
       = (400/2 - 49.7/3 + 165 )
       = 348.43
```

Total Bolt Tension Force [Tforce]:
```
= - QO * Num / Denom
= - 7.58 * -168/348
= 3.66 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
= Tforce / (Stba * Nbt)
= 3.66/( 300 * 1 )
= 0.1220 cm²
```

Required Area of a Single Bolt [Bltarear]:
```
= max[Bltarearl, Bltarears, Bltareart]
= max[0, 0.19, 0.12 ]
= 0.1851 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(7.58 + 3.66 )/(49.7 * 170 )
= 26.59 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
= (Bplen - Weblngth) / 2
= (400 - 349 )/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
= Tforce * Adist
= 3.66 * 25.4
= 93.00 N-m
```

Equivalent Bearing Pressure (f1):
```
= fc * (Y - Adist) / Y
= 26.6 * (49.7 - 25.4 )/49.7
= 13.01 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 170/6) * (13 + 2 * 26.6 )
= 121.04 N-m
```

Baseplate Required Thickness [Treq]:
```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(93,121/(170 * 143 ))½
= 5.4701 mm.
```

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

Horizontal Vessel Stress Calculations : Test Case

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 150 + 1.56*sqrt( 171 * 13.7 ), 2 * 500 )
= 225.4125 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	170.97	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		192.78	N./mm²
Head Allowable Stress used in Calculation		192.78	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	800.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Test Case, no Ext. Forces		19.78	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	38.49	192.78
Long. Stress at Bottom of Midspan	62.35	192.78
Long. Stress at Top of Saddles	57.36	192.78
Long. Stress at Bottom of Saddles	46.57	192.78
Tangential Shear in Shell	7.93	128.63
Circ. Stress at Horn of Saddle	10.00	289.17
Circ. Compressive Stress in Shell	0.49	192.78

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

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3 ( 0.28/2 + 0 ) * 800/325
= 1.0 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.027, 0, 0 ) * 800/3700
= 0.0 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 18.7 + max( 0.0059, 1.05, 0, 0 )
= 19.8 kN
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766 ( 0 + ( 0.15 * 1.2 ))
= 82.201 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		20.39	kN
Transverse Shear Load Saddle	Ft	0.14	kN
Longitudinal Shear Load Saddle		0.03	kN

Hydrostatic Test Pressure at center of Vessel 80.617 bars

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( 322/2 + 16.7 + 10 )sin( 60/2 ), 2*171 )
= 325.279 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	

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)]
= -19.8*500[1-(1-500/5015+(171²-0²)/
  (2*500*5015))/(1+(4*0)/(3*5015))]
= -928.8 N-m
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 19.8*5015/4(1+2(171²-0²)/(5015²))/(1+(4*0)/
  (3*5015))-4*500/5015
= 14973.4 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 80.6 * 171/(2*13.7 ) - 14973/(pi*171²*13.7 )
= 38.49 N./mm²
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 80.6 * 171/(2 * 13.7 ) + 14973/(pi * 171² * 13.7 )
= 62.35 N./mm²
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 80.6*171/(2*13.7)--929/(0.11*pi*171²*13.7)
= 57.36 N./mm²
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 80.6*171/(2*13.7)+-929/(0.19*pi*171²*13.7)
= 46.57 N./mm²
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 19.8 ( 5015 - 2 * 500 )/(5015 + ( 4 * 0/3))
= 15.8 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.17 * 15.8/( 171 * 13.7 )
= 7.93 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 171 * 13.7 )
= 37.706 mm.
```

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

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.76 * 19.8 * 0.1/( 13.7 * ( 150 + 37.7 + 37.7 ) )
= -0.49 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -19.8/(4*13.7 *(150 +37.7 +37.7 )) -
   3*0.053 *19.8/(2*13.7²)
= -10.00 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 150 + 1.56 * sqrt( 171 * 13.7 ), 2 * 500 )
= 225.41 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	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	273.9	13.7	6.8	37.4	25586.1	0.262E+05
Wearplate	200.0	10.0	18.7	20.0	37337.5	0.127E+05
Web	10.0	592.2	319.8	59.2	1893670.6	0.187E+05
BasePlate	170.0	20.0	625.9	34.0	2127953.8	0.428E+05
Totals	...	...	...	150.7	4084547.8	0.100E+06

Distance to Centroid [C1]:
= AY / A
= 1608/151
= 271.115 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 * 19.8
= 4.0257 kN

Tension Stress, St = (Fh/As)	=	0.3556	N./mm²
Allowed Stress, Sa = 0.6 * Yield Str	=	143.9676	N./mm²

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 164 * sin(120/2)/1.05
= 664.265 mm.

Bending Moment, M = Fh * d	=	2675.1990	N-m
Bending Stress, Sb = (M * C1 / I)	=	0.7221	N./mm²
Allowed Stress, Sa = 2/3 * Yield Str	=	159.9640	N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(19.8 + 0.61)170/(2 * 400 * 160))½
= 9.016 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 )( 161 + 16.7 + 10 )
= 325.279 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 325/( 3 - 1 )
= 162.640 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 163 * 170/2
= 138.244 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 19.8/( 400 * 170 )
= 0.029 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 138 * 0.029
= 4.021 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 4.02/22.1
= 1.817 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
```

```
  = 116066/22.1
  = 52.443 mm.
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 52.4, 150 - 52.4 )
  = 97.557 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 519/22.1 )
  = 48.411 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 800 - cos( 120/2 )( 161 + 16.7 + 10 ) - 20
  = 686.100 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 199943008/240 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 686/48.4
  = 14.172
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.027/( 2 * 400 ) * 163 * 686/2
  = 1.893 N-m
```

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 14.2 )²/(2 * 128² ))240/
    ( 5/3+3*(14.2 )/(8* 128 )-( 14.2³)/(8*128³)
  = 139.6 N./mm²
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1.82/140 + ( 1.89 * 97.6/5186964 )/160
  = 0.013
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 120132/30.3
= 39.695 mm.
```

Distance to Centroid [C1]:
```
= max( ytot, abs( Saddle Width - ytot ) )
= max( 39.7, abs( 150 - 39.7 ) )
= 110.305 mm.
```

Length of Inner Rib [L]:
```
= Saddle Height - Outside Radius - Bpthk
= 800 - cos( 188/2 )( 20 + 0 + 0 ) - 0
= 592.200 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 653/30.3 )
= 46.459 mm.
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 592/46.5
= 12.747
```

Unit Force [Force,u]:
```
= Fl / ( 2 * Baseplate Length )
= 0.027/( 2 * 400 )
= 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
= Unit Force * e * L
= 0.33906E-04 * 163 * 592
= 3.267 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
= Bending Moment / Section Modulus
= 3.27/59220
= 0.055 N./mm²
```

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 12.7 )²/(2 * 128² ))240/
  ( 5/3+3*(12.7 )/(8* 128 )-( 12.7³)/(8*128³)
= 140.1 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 2.71/140 + ( 3.27 * 110/653 )/160
= 0.020
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	35.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	19.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.1	kN
Maximum Longitudinal Force	Fl	0.0	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
= Fl / (Bolt Area * Number of Bolts)
= 0.027/(2.17 * 2)
= 0.1 N./mm². Must be less than 180.0 N./mm².

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 0.14/(2.17 * 2)
= 0.3 N./mm². Must be less than 180.0 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)
= 0.027/(180 * 2)
= 0.0008 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 800 * 0.14 + 0
= 113.49 N-m

Eccentricity (e):
= Rmom / QO
= 113/19.3
= 5.86 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, 0.00075, 0 ]
= 0.0008 cm²
```

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

Note:
Wear Pad Width (200.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 150 + 1.56*sqrt( 171 * 13.7 ), 2 * 600 )
= 225.4125 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	170.97	mm.
Stiffened Vessel Length per 4.15.6	L	5015.10	mm.
Distance from Saddle to Vessel tangent	a	600.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	83.57	mm.
Shell Allowable Stress used in Calculation		192.78	N./mm²
Head Allowable Stress used in Calculation		192.78	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	800.00	mm.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Test Case, no Ext. Forces		8.92	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	45.95	192.78
Long. Stress at Bottom of Midspan	54.89	192.78
Long. Stress at Top of Saddles	55.83	192.78
Long. Stress at Bottom of Saddles	47.42	192.78
Tangential Shear in Shell	3.33	128.63
Circ. Stress at Horn of Saddle	4.51	289.17
Circ. Compressive Stress in Shell	0.22	192.78

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

Saddle Reaction Force due to Wind Ft [Fwt]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3 ( 0.28/2 + 0 ) * 800/325
= 1.0 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.027, 0, 0 ) * 800/3700
= 0.0 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 7.88 + max( 0.0059, 1.05, 0, 0 )
= 8.9 kN
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766 ( 0 + ( 0.15 * 1.2 ))
= 82.201 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		9.54	kN
Transverse Shear Load Saddle	Ft	0.14	kN
Longitudinal Shear Load Saddle		0.03	kN

Hydrostatic Test Pressure at center of Vessel 80.617 bars

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( 322/2 + 16.7 + 10 )sin( 60/2 ), 2*171 )
= 325.279 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	

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)]
= -8.92*600[1-(1-600/5015+(171²-83.6²)/
  (2*600*5015))/(1+(4*83.6)/(3*5015))]
= -723.8 N-m
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 8.92*5015/4(1+2(171²-83.6²)/(5015²))/(1+(4*83.6)/
```

```
   (3*5015))-4*600/5015
  = 5611.4 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 80.6 * 171/(2*13.7 ) - 5611/(pi*171²*13.7 )
  = 45.95 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 80.6 * 171/(2 * 13.7 ) + 5611/(pi * 171² * 13.7 )
  = 54.89 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 80.6*171/(2*13.7)--724/(0.11*pi*171²*13.7)
  = 55.83 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 80.6*171/(2*13.7)+-724/(0.19*pi*171²*13.7)
  = 47.42 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 8.92 ( 5015 - 2 * 600 )/(5015 + ( 4 * 83.6/3))
  = 6.6 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.17 * 6.64/( 171 * 13.7 )
  = 3.33 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 171 * 13.7 )
  = 37.706 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = -0.76 * 8.92 * 0.1/( 13.7 * ( 150 + 37.7 + 37.7 ) )
  = -0.22 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:

```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -8.92/(4*13.7 *(150 +37.7 +37.7 )) -
     3*0.053 *8.92/(2*13.7²)
  = -4.51 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150 + 1.56 * sqrt( 171 * 13.7 ), 2 * 600 )
  = 225.41 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	400.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	639.0	mm.
Friction Coefficient	mu	0.000	

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	273.9	13.7	6.8	37.4	25586.1	0.262E+05
Wearplate	200.0	10.0	18.7	20.0	37337.5	0.127E+05
Web	10.0	592.2	319.8	59.2	1893670.6	0.187E+05
BasePlate	170.0	20.0	625.9	34.0	2127953.8	0.428E+05
Totals	...	...	...	150.7	4084547.8	0.100E+06

Distance to Centroid [C1]:

```
= AY / A
= 1608/151
= 271.115 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 * 8.92
= 1.8158 kN
```

```
Tension Stress, St = ( Fh/As )       =          0.1604  N./mm²
Allowed Stress, Sa = 0.6 * Yield Str =        143.9676  N./mm²
```

Saddle Splitting Dimension [d]:

```
= B - R * sin(theta/2)/(theta/2 in radians)
= 800 - 164 * sin(120/2)/1.05
= 664.265 mm.
```

```
Bending Moment, M  = Fh * d          =       1206.6442  N-m
```

```
Bending Stress, Sb = ( M * C1 / I  ) =          0.3257  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
= ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
= ( 3(8.92 + 0.61 )170/( 2 * 400 * 160 ))½
= 6.165 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 )( 161 + 16.7 + 10 )
= 325.279 mm.
```

Distance between Ribs [e]:

```
= Web Length / ( Nribs - 1 )
= 325/( 3 - 1 )
= 162.640 mm.
```

Baseplate Pressure Area [Ap]:

```
= e * Bpwid / 2
= 163 * 170/2
= 138.244 cm²
```

Bearing Pressure [Bp]:

```
= Q / ( BasePlateLength * BasePlateWidth )
= 8.92/( 400 * 170 )
= 0.013 kN/cm²
```

Axial Load [P]:

```
= Ap * Bp
= 138 * 0.013
= 1.814 kN
```

Area of the Rib and Web [Ar]:

```
= Rib Area + Web Area
= 14 + 8.13
= 22.132 cm²
```

Compressive Stress [Sc]:

```
= P/Ar
= 1.81/22.1
= 0.820 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	335.
Web	81.3	10.0	5.0	8.1	4066.0	184.
Totals	...	...	...	22.1	116066.0	519.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150 - 10
= 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 116066/22.1
= 52.443 mm.
```

Distance to Centroid [C1]:
```
= max( ytot, Saddle Width - ytot )
= max( 52.4, 150 - 52.4 )
= 97.557 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 519/22.1 )
= 48.411 mm.
```

Length of Outer Rib [L]:
```
= Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
= 800 - cos( 120/2 )( 161 + 16.7 + 10 ) - 20
= 686.100 mm.
```

Intermediate Term [Cc]:
```
= sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
= sqrt( 2 * pi² * 199943008/240 )
= 128.255
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 686/48.4
= 14.172
```

Bending Moment [Rm]:
```
= Fl /( 2 * Bplen ) * e * L / 2
= 0.027/( 2 * 400 ) * 163 * 686/2
= 1.893 N-m
```

Compressive Allowable, KL/r < Cc (14.2 < 128) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 14.2 )²/(2 * 128² ))240/
  ( 5/3+3*(14.2 )/(8* 128 )-( 14.2³)/(8*128³)
```

= 139.6 N./mm²

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

= Sc/Sca + (Rm * C1 / I)/Sba
= 0.82/140 + (1.89 * 97.6/5186964)/160
= 0.006

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	80.0	14.0	112000.0	456.
Web	162.6	10.0	5.0	16.3	8132.0	197.
Totals	...	...	...	30.3	120132.0	653.

Distance to Centroid from Datum [ytot]:

= AY / A
= 120132/30.3
= 39.695 mm.

Distance to Centroid [C1]:

= max(ytot, abs(Saddle Width - ytot))
= max(39.7, abs(150 - 39.7))
= 110.305 mm.

Length of Inner Rib [L]:

= Saddle Height - Outside Radius - Bpthk
= 800 - cos(188/2)(20 + 0 + 0) - 0
= 592.200 mm.

Radius of Gyration [r]:

= sqrt(Total Inertia / Total Area)
= sqrt(653/30.3)
= 46.459 mm.

Slenderness ratio [KL/r]:

= KL/r
= 1 * 592/46.5
= 12.747

Unit Force [Force,u]:

= Fl / (2 * Baseplate Length)
= 0.027/(2 * 400)
= 0.000 kN/mm.

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

= Unit Force * e * L
= 0.33906E-04 * 163 * 592
= 3.267 N-m

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

= Bending Moment / Section Modulus
= 3.27/59220

= 0.055 N./mm²

Compressive Allowable, KL/r < Cc (12.7 < 128) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(12.7)²/(2 * 128²))240/
(5/3+3*(12.7)/(8* 128)-(12.7³)/(8*128³)
= 140.1 N./mm²

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 1.22/140 + (3.27 * 110/653)/160
= 0.009

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	300.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	35.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	95.15	N./mm²
Area Available in a Single Bolt	BltArea	2.1705	cm²
Saddle Load QO (Weight)	QO	8.5	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.1	kN
Maximum Longitudinal Force	Fl	0.0	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 0.14/(2.17 * 2)
= 0.3 N./mm². Must be less than 180.0 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)
= 0.027/(180 * 2)
= 0.0008 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 800 * 0.14 + 0
= 113.49 N-m

Eccentricity (e):

```
= Rmom / QO
= 113/8.49
= 13.36 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, 0.00075, 0 ]
= 0.0008 cm²
```

Input, Nozzle Desc: T1 (6in) **From: 20**

Pressure for Reinforcement Calculations	P	59.000	bars
Temperature for Internal Pressure	Temp	95	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	322.26	mm.
Design Length of Section	L	592.2333	mm.
Shell Finished (Minimum) Thickness	t	16.6687	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		225.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

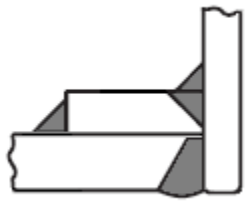
Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	16.6687	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	270.0000	mm.
Thickness of Pad	te	10.0000	mm.

```
Weld leg size between Pad and Shell              Wp      10.0000  mm.
Groove weld depth between Pad and Nozzle         Wgpn    10.0000  mm.
Reinforcing Pad Width                                    50.8625  mm.

Flange Class                                             600
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: T1 (6in)

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

```
Actual Inside Diameter Used in Calculation              5.869  in.
Actual Thickness Used in Calculation                    0.378  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (59*164)/(118*1-0.6*59)
  = 8.4679 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)
  = (59*77.5)/(118*1-0.6*59)
  = 4.0003 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5131 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   26.5030  mm.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 118/118)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 118/118)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 138/118)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	13.131	1.095	NA
Area in Shell	A1	8.065	19.006	NA
Area in Nozzle Wall	A2	1.379	3.227	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.000	2.000	NA
Area in Element	A5	10.172	10.172	NA
TOTAL AREA AVAILABLE	Atot	21.616	34.406	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:	185.1531	10.0000	mm.
Based on given Pad Diameter:	270.0000	1.6592	mm.
Based on Shell or Nozzle Thickness:	185.8541	9.6012	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (155*8.47*1+2*6.6*8.47*1*(1-1))
= 13.131 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 * 13.7 - 1 * 8.47 ) - 2 * 6.6
  ( 1 * 13.7 - 1 * 8.47 ) * ( 1 - 1 )
= 8.065 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 26.5 ) * ( 6.6 - 4 ) * 1
= 1.379 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 1 + (0 )² * 1 + 10² * 1
= 2.000 cm²
```

Area Available in Element [A5]:

```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 270 - 168 ) * 10 * 1
= 10.172 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 7.0003 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 11.4679 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 11.4679 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( 11.5, 4.5 ) ]
= 9.2200 mm.
```

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

```
= max( ta, tb )
= max( 7, 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   :     72.3,  Allowable :    117.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    222.5 N./mm²  Passed
Occasional  :     33.2,  Allowable :    156.8 N./mm²  Passed
Shear       :      7.5,  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, Curve: B

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 10, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.62, Temp. Reduction = 21 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

Gov. MDMT of the Nozzle                             :     -48 °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:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -42 °C
```

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

```
Design Pressure/Ambient Rating = 59.00/102.10 = 0.578
```

Weld Size Calculations, Description: T1 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad    10.0000  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           5.0000 = 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, (13.1 - 8.07 + 2 * 6.6 * 1 *
    (1 * 13.7 - 8.47 ) )118 )
  = 67.83 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.38 + 10.2 + 2 - 0 * 1 ) * 118
  = 159.76 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.38 + 0 + 1 + ( 1.8 ) ) * 118
  = 49.32 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.38 + 0 + 2 + 10.2 + ( 1.8 ) ) * 118
  = 181.04 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 168 * 10 * 0.49 * 118
  = 153. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.14/2.0 ) * 270 * 10 * 0.49 * 118
  = 245. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 80.8 ) * ( 9.6 - 3 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.14/2 ) * 168 * 10 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 168 * ( 16.7 - 3 ) * 0.74 * 118
  = 315. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 245 + 138 ) = 383 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 153 + 270 + 315 + 0 ) = 738 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 245 + 315 + 0 ) = 560 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 383 kN , must exceed W = 67 kN  or W1 = 159 kN
 Path 2-2 = 737 kN , must exceed W = 67 kN  or W2 = 49 kN
 Path 3-3 = 560 kN , must exceed W = 67 kN  or W3 = 181 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    76  bars

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

The Drop for this Nozzle is : 23.7116 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 190.3803 mm.

Input Echo, WRC107/537 Item 1, Description: T1 (6in) :

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
 Internal Corrosion Allowance                  Cas      3.0000  mm.
 Vessel Diameter                               Dv     322.262  mm.
 Vessel Thickness                              Tv      16.669  mm.

 Design Temperature                            T1        95.0  °C
 Vessel Material                                      SA-106 B
 Vessel UNS Number                                    K03006
 Vessel Cold S.I. Allowable                    Smc      117.90  N./mm²
 Vessel Hot  S.I. Allowable                    Smh      117.90  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-106 B

```
 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                   Nbasis      ID
 Corrosion Allowance for Nozzle                 Can      3.0000  mm.
```

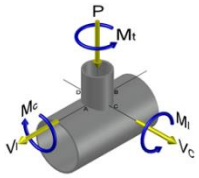
Nozzle Diameter	Dn	149.073	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	270.000	mm.
Design Internal Pressure	Dp	59.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	9.6	kN
Longitudinal Shear	(SUS)	Vl	9.6	kN
Circumferential Shear	(SUS)	Vc	-7.2	kN
Circumferential Moment	(SUS)	Mc	-2880.0	N-m
Longitudinal Moment	(SUS)	Ml	-3740.0	N-m
Torsional Moment	(SUS)	Mt	-4320.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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



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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 168.275 + 2 * 1.65 * sqrt( 170.966 ( 16.669 - 3.0 ) )
= 327.801 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	9.6	kN
Circumferential Shear	VC	-7.2	kN
Longitudinal Shear	VL	9.6	kN
Circumferential Moment	MC	-2880.0	N-m
Longitudinal Moment	ML	-3740.0	N-m
Torsional Moment	MT	-4320.0	N-m

Dimensionless Parameters used : Gamma = 7.43

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.418	4C	1.089	(A,B)
N(PHI) / (P/Rm)	0.418	3C	0.789	(C,D)
M(PHI) / (P)	0.418	2C1	0.040	(A,B)
M(PHI) / (P)	0.418	1C	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.418	3A	0.315	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.418	1A	0.086	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.418	3B	0.882	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.418	1B	0.028	(A,B,C,D)
N(x) / (P/Rm)	0.418	3C	0.789	(A,B)
N(x) / (P/Rm)	0.418	4C	1.089	(C,D)
M(x) / (P)	0.418	1C1	0.063	(A,B)
M(x) / (P)	0.418	2C	0.040	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.418	4A	0.672	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.418	2A	0.045	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.418	4B	0.313	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.418	2B	0.048	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.5	-2.5	-2.5	-2.5	-1.8	-1.8	-1.8	-1.8
Circ. Bend. P	-4.1	4.1	-4.1	4.1	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	3.0	3.0	-3.0	-3.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	35.8	-35.8	-35.8	35.8
Circ. Memb. ML	10.8	10.8	-10.8	-10.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	15.1	-15.1	-15.1	15.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	19.2	-2.7	-32.4	5.9	30.5	-28.2	-47.1	37.5
Long. Memb. P	-1.8	-1.8	-1.8	-1.8	-2.5	-2.5	-2.5	-2.5
Long. Bend. P	-6.5	6.5	-6.5	6.5	-4.1	4.1	-4.1	4.1
Long. Memb. MC	0.0	0.0	0.0	0.0	6.3	6.3	-6.3	-6.3
Long. Bend. MC	0.0	0.0	0.0	0.0	19.0	-19.0	-19.0	19.0
Long. Memb. ML	3.8	3.8	-3.8	-3.8	0.0	0.0	0.0	0.0
Long. Bend. ML	26.0	-26.0	-26.0	26.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	21.5	-17.6	-38.2	26.9	18.7	-11.1	-31.9	14.3
Shear VC	-1.2	-1.2	1.2	1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5

Shear MT	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Tot. Shear	-5.3	-5.3	-3.0	-3.0	-5.6	-5.6	-2.6	-2.6
Str. Int.	25.7	19.2	39.4	27.3	32.8	29.9	47.5	37.8

WARNING: Ratio of Pad Radius/Rm (.790) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 12.51

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.691	4C	!	1.428	(A,B)
N(PHI) / (P/Rm)	0.691	3C	!	0.818	(C,D)
M(PHI) / (P)	0.691	2C1	!	0.018	(A,B)
M(PHI) / (P)	0.691	1C	!	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.691	3A	!	0.507	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.691	1A	!	0.071	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.691	3B	!	1.041	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.691	1B	!	0.014	(A,B,C,D)
N(x) / (P/Rm)	0.691	3C	!	0.818	(A,B)
N(x) / (P/Rm)	0.691	4C	!	1.428	(C,D)
M(x) / (P)	0.691	1C1	!	0.034	(A,B)
M(x) / (P)	0.691	2C	!	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.691	4A	!	1.331	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.691	2A	!	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.691	4B	!	0.518	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.691	2B	!	0.027	(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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-5.9	-5.9	-5.9	-5.9	-3.4	-3.4	-3.4	-3.4
Circ. Bend.	P	-5.5	5.5	-5.5	5.5	-17.0	17.0	-17.0	17.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	5.3	5.3	-5.3	-5.3
Circ. Memb.	MC	0.0	0.0	0.0	0.0	55.5	-55.5	-55.5	55.5
Circ. Memb.	ML	14.1	14.1	-14.1	-14.1	0.0	0.0	0.0	0.0
Circ. Bend.	ML	14.0	-14.0	-14.0	14.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		16.8	-0.3	-39.5	-0.5	40.4	-36.6	-81.1	63.8
Long. Memb.	P	-3.4	-3.4	-3.4	-3.4	-5.9	-5.9	-5.9	-5.9
Long. Bend.	P	-10.6	10.6	-10.6	10.6	-9.9	9.9	-9.9	9.9

Long. Memb. MC	0.0	0.0	0.0	0.0	13.9	13.9	-13.9	-13.9
Long. Bend. MC	0.0	0.0	0.0	0.0	26.7	-26.7	-26.7	26.7
Long. Memb. ML	7.0	7.0	-7.0	-7.0	0.0	0.0	0.0	0.0
Long. Bend. ML	27.4	-27.4	-27.4	27.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	20.5	-13.2	-48.4	27.6	24.8	-8.7	-56.3	16.8
Shear VC	-1.2	-1.2	1.2	1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.7	-1.7	1.7	1.7
Shear MT	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Tot. Shear	-4.0	-4.0	-1.5	-1.5	-4.4	-4.4	-1.1	-1.1
Str. Int.	23.0	15.2	48.7	28.3	41.6	37.2	81.1	63.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	38.2	44.1	38.2	44.1	38.2	44.1	38.2	44.1
Circ. Pl (SUS)	8.2	8.2	-13.3	-13.3	1.1	1.1	-4.8	-4.8
Circ. Q (SUS)	10.9	-10.9	-19.2	19.2	29.4	-29.4	-42.3	42.3
Long. Pm (SUS)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Long. Pl (SUS)	2.0	2.0	-5.6	-5.6	3.8	3.8	-8.8	-8.8
Long. Q (SUS)	19.5	-19.5	-32.5	32.5	14.9	-14.9	-23.1	23.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.2	-1.2	1.2	1.2	-1.5	-1.5	1.5	1.5
Shear Q (SUS)	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Pm (SUS)	38.2	44.1	38.2	44.1	38.2	44.1	38.2	44.1
Pm+Pl (SUS)	46.5	52.4	25.0	30.9	39.4	45.3	33.5	39.4
Pm+Pl+Q (Total)	58.9	42.1	25.5	51.5	69.7	18.8	14.1	81.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.06	117.90	Passed
Pm+Pl (SUS)	52.35	176.86	Passed
Pm+Pl+Q (TOTAL)	81.72	353.71	Passed

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	68.0	73.9	68.0	73.9	68.0	73.9	68.0	73.9
Circ. Pl (SUS)	8.2	8.2	-20.0	-20.0	1.9	1.9	-8.6	-8.6
Circ. Q (SUS)	8.5	-8.5	-19.5	19.5	38.5	-38.5	-72.4	72.4
Long. Pm (SUS)	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Long. Pl (SUS)	3.7	3.7	-10.4	-10.4	8.0	8.0	-19.7	-19.7
Long. Q (SUS)	16.8	-16.8	-38.0	38.0	16.7	-16.7	-36.6	36.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.2	-1.2	1.2	1.2	-1.7	-1.7	1.7	1.7
Shear Q (SUS)	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Pm (SUS)	68.0	73.9	68.0	73.9	68.0	73.9	68.0	73.9
Pm+Pl (SUS)	76.3	82.2	48.1	54.0	70.0	75.9	59.4	65.3
Pm+Pl+Q (Total)	85.3	73.9	43.0	73.6	108.8	38.8	22.4	137.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	73.92	117.90	Passed
Pm+Pl (SUS)	82.19	176.86	Passed
Pm+Pl+Q (TOTAL)	137.72	353.71	Passed

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

Input, Nozzle Desc: T2 (6in) **From: 20**

Pressure for Reinforcement Calculations	P	59.000	bars
Temperature for Internal Pressure	Temp	95	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	322.26	mm.
Design Length of Section	L	592.2333	mm.
Shell Finished (Minimum) Thickness	t	16.6687	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		225.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

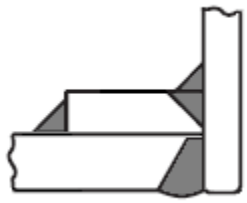
Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm²
Allowable Stress At Ambient	Sna	117.90	N./mm²
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	16.6687	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm²
Pad Allowable Stress At Ambient	Spa	137.90	N./mm²
Diameter of Pad along vessel surface	Dp	270.0000	mm.
Thickness of Pad	te	10.0000	mm.

```
Weld leg size between Pad and Shell              Wp      10.0000  mm.
Groove weld depth between Pad and Nozzle         Wgpn    10.0000  mm.
Reinforcing Pad Width                                    50.8625  mm.

Flange Class                                             600
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: T2 (6in)

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

```
Actual Inside Diameter Used in Calculation              5.869  in.
Actual Thickness Used in Calculation                    0.378  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
= (59*164)/(118*1-0.6*59)
= 8.4679 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)
= (59*77.5)/(118*1-0.6*59)
= 4.0003 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5131 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   26.5030  mm.
```

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 118/118)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 118/118)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 138/118)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	13.131	1.095	NA
Area in Shell	A1	8.065	19.006	NA
Area in Nozzle Wall	A2	1.379	3.227	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.000	2.000	NA
Area in Element	A5	10.172	10.172	NA
TOTAL AREA AVAILABLE	Atot	21.616	34.406	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:	185.1531	10.0000	mm.
Based on given Pad Diameter:	270.0000	1.6592	mm.
Based on Shell or Nozzle Thickness:	185.8541	9.6012	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (155*8.47*1+2*6.6*8.47*1*(1-1))
= 13.131 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 * 13.7 - 1 * 8.47 ) - 2 * 6.6
  ( 1 * 13.7 - 1 * 8.47 ) * ( 1 - 1 )
= 8.065 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 26.5 ) * ( 6.6 - 4 ) * 1
= 1.379 cm²
```

Area Available in Welds [A41 + A42 + A43]:

```
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 1 + (0 )² * 1 + 10² * 1
= 2.000 cm²
```

Area Available in Element [A5]:

```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 270 - 168 ) * 10 * 1
= 10.172 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 7.0003 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 11.4679 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 11.4679 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( 11.5, 4.5 ) ]
= 9.2200 mm.
```

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

```
= max( ta, tb )
= max( 7, 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  :     72.3,  Allowable :    117.9 N./mm²  Passed
Expansion  :      0.0,  Allowable :    222.5 N./mm²  Passed
Occasional :     33.2,  Allowable :    156.8 N./mm²  Passed
Shear      :      7.5,  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, Curve: B

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

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

Govrn. thk, tg = 10, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.62, Temp. Reduction = 21 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.6, tr = 4, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.61, Temp. Reduction = 22 °C

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

Gov. MDMT of the Nozzle                             :     -48 °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:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -18 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -42 °C
```

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

```
Design Pressure/Ambient Rating = 59.00/102.10 = 0.578
```

Weld Size Calculations, Description: T2 (6in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad    10.0000  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           5.0000 = 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, (13.1 - 8.07 + 2 * 6.6 * 1 *
    (1 * 13.7 - 8.47 ) )118 )
  = 67.83 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.38 + 10.2 + 2 - 0 * 1 ) * 118
  = 159.76 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.38 + 0 + 1 + ( 1.8 ) ) * 118
  = 49.32 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.38 + 0 + 2 + 10.2 + ( 1.8 ) ) * 118
  = 181.04 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.14/2.0 ) * 168 * 10 * 0.49 * 118
  = 153. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.14/2.0 ) * 270 * 10 * 0.49 * 118
  = 245. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.14 * 80.8 ) * ( 9.6 - 3 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.14/2 ) * 168 * 10 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.14/2.0 ) * 168 * ( 16.7 - 3 ) * 0.74 * 118
  = 315. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 245 + 138 ) = 383 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 153 + 270 + 315 + 0 ) = 738 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 245 + 315 + 0 ) = 560 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 383 kN , must exceed W = 67 kN  or W1 = 159 kN
 Path 2-2 = 737 kN , must exceed W = 67 kN  or W2 = 49 kN
 Path 3-3 = 560 kN , must exceed W = 67 kN  or W3 = 181 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case    76  bars

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

The Drop for this Nozzle is : 23.7116 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 190.3803 mm.

Input Echo, WRC107/537 Item 1, Description: T2 (6in) :

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
 Internal Corrosion Allowance                  Cas      3.0000  mm.
 Vessel Diameter                               Dv     322.262  mm.
 Vessel Thickness                              Tv      16.669  mm.

 Design Temperature                            T1        95.0  °C
 Vessel Material                                      SA-106 B
 Vessel UNS Number                                    K03006
 Vessel Cold S.I. Allowable                    Smc      117.90  N./mm²
 Vessel Hot  S.I. Allowable                    Smh      117.90  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-106 B

```
 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                   Nbasis      ID
 Corrosion Allowance for Nozzle                 Can      3.0000  mm.
```

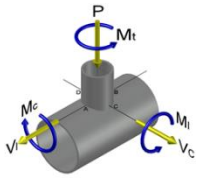
Nozzle Diameter	Dn	149.073	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-106 B	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm²
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	270.000	mm.
Design Internal Pressure	Dp	59.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	9.6	kN
Longitudinal Shear	(SUS)	Vl	9.6	kN
Circumferential Shear	(SUS)	Vc	-7.2	kN
Circumferential Moment	(SUS)	Mc	-2880.0	N-m
Longitudinal Moment	(SUS)	Ml	-3740.0	N-m
Torsional Moment	(SUS)	Mt	-4320.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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



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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 168.275 + 2 * 1.65 * sqrt( 170.966 ( 16.669 - 3.0 ) )
= 327.801 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	9.6	kN
Circumferential Shear	VC	-7.2	kN
Longitudinal Shear	VL	9.6	kN
Circumferential Moment	MC	-2880.0	N-m
Longitudinal Moment	ML	-3740.0	N-m
Torsional Moment	MT	-4320.0	N-m

Dimensionless Parameters used : Gamma = 7.43

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.418	4C	1.089	(A,B)
N(PHI) / (P/Rm)	0.418	3C	0.789	(C,D)
M(PHI) / (P)	0.418	2C1	0.040	(A,B)
M(PHI) / (P)	0.418	1C	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.418	3A	0.315	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.418	1A	0.086	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.418	3B	0.882	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.418	1B	0.028	(A,B,C,D)
N(x) / (P/Rm)	0.418	3C	0.789	(A,B)
N(x) / (P/Rm)	0.418	4C	1.089	(C,D)
M(x) / (P)	0.418	1C1	0.063	(A,B)
M(x) / (P)	0.418	2C	0.040	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.418	4A	0.672	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.418	2A	0.045	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.418	4B	0.313	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.418	2B	0.048	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.5	-2.5	-2.5	-2.5	-1.8	-1.8	-1.8	-1.8
Circ. Bend. P	-4.1	4.1	-4.1	4.1	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	3.0	3.0	-3.0	-3.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	35.8	-35.8	-35.8	35.8
Circ. Memb. ML	10.8	10.8	-10.8	-10.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	15.1	-15.1	-15.1	15.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	19.2	-2.7	-32.4	5.9	30.5	-28.2	-47.1	37.5
Long. Memb. P	-1.8	-1.8	-1.8	-1.8	-2.5	-2.5	-2.5	-2.5
Long. Bend. P	-6.5	6.5	-6.5	6.5	-4.1	4.1	-4.1	4.1
Long. Memb. MC	0.0	0.0	0.0	0.0	6.3	6.3	-6.3	-6.3
Long. Bend. MC	0.0	0.0	0.0	0.0	19.0	-19.0	-19.0	19.0
Long. Memb. ML	3.8	3.8	-3.8	-3.8	0.0	0.0	0.0	0.0
Long. Bend. ML	26.0	-26.0	-26.0	26.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	21.5	-17.6	-38.2	26.9	18.7	-11.1	-31.9	14.3
Shear VC	-1.2	-1.2	1.2	1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5

Shear MT	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Tot. Shear	-5.3	-5.3	-3.0	-3.0	-5.6	-5.6	-2.6	-2.6
Str. Int.	25.7	19.2	39.4	27.3	32.8	29.9	47.5	37.8

WARNING: Ratio of Pad Radius/Rm (.790) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 12.51

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.691	4C	!	1.428	(A,B)
N(PHI) / (P/Rm)	0.691	3C	!	0.818	(C,D)
M(PHI) / (P)	0.691	2C1	!	0.018	(A,B)
M(PHI) / (P)	0.691	1C	!	0.055	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.691	3A	!	0.507	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.691	1A	!	0.071	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.691	3B	!	1.041	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.691	1B	!	0.014	(A,B,C,D)
N(x) / (P/Rm)	0.691	3C	!	0.818	(A,B)
N(x) / (P/Rm)	0.691	4C	!	1.428	(C,D)
M(x) / (P)	0.691	1C1	!	0.034	(A,B)
M(x) / (P)	0.691	2C	!	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.691	4A	!	1.331	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.691	2A	!	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.691	4B	!	0.518	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.691	2B	!	0.027	(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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-5.9	-5.9	-5.9	-5.9	-3.4	-3.4	-3.4	-3.4
Circ. Bend. P	-5.5	5.5	-5.5	5.5	-17.0	17.0	-17.0	17.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	5.3	5.3	-5.3	-5.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	55.5	-55.5	-55.5	55.5
Circ. Memb. ML	14.1	14.1	-14.1	-14.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	14.0	-14.0	-14.0	14.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	16.8	-0.3	-39.5	-0.5	40.4	-36.6	-81.1	63.8
Long. Memb. P	-3.4	-3.4	-3.4	-3.4	-5.9	-5.9	-5.9	-5.9
Long. Bend. P	-10.6	10.6	-10.6	10.6	-9.9	9.9	-9.9	9.9

Long. Memb. MC	0.0	0.0	0.0	0.0	13.9	13.9	-13.9	-13.9
Long. Bend. MC	0.0	0.0	0.0	0.0	26.7	-26.7	-26.7	26.7
Long. Memb. ML	7.0	7.0	-7.0	-7.0	0.0	0.0	0.0	0.0
Long. Bend. ML	27.4	-27.4	-27.4	27.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	20.5	-13.2	-48.4	27.6	24.8	-8.7	-56.3	16.8
Shear VC	-1.2	-1.2	1.2	1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.7	-1.7	1.7	1.7
Shear MT	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Tot. Shear	-4.0	-4.0	-1.5	-1.5	-4.4	-4.4	-1.1	-1.1
Str. Int.	23.0	15.2	48.7	28.3	41.6	37.2	81.1	63.8

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	38.2	44.1	38.2	44.1	38.2	44.1	38.2	44.1
Circ. Pl (SUS)	8.2	8.2	-13.3	-13.3	1.1	1.1	-4.8	-4.8
Circ. Q (SUS)	10.9	-10.9	-19.2	19.2	29.4	-29.4	-42.3	42.3
Long. Pm (SUS)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Long. Pl (SUS)	2.0	2.0	-5.6	-5.6	3.8	3.8	-8.8	-8.8
Long. Q (SUS)	19.5	-19.5	-32.5	32.5	14.9	-14.9	-23.1	23.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.2	-1.2	1.2	1.2	-1.5	-1.5	1.5	1.5
Shear Q (SUS)	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
Pm (SUS)	38.2	44.1	38.2	44.1	38.2	44.1	38.2	44.1
Pm+Pl (SUS)	46.5	52.4	25.0	30.9	39.4	45.3	33.5	39.4
Pm+Pl+Q (Total)	58.9	42.1	25.5	51.5	69.7	18.8	14.1	81.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.06	117.90	Passed
Pm+Pl (SUS)	52.35	176.86	Passed
Pm+Pl+Q (TOTAL)	81.72	353.71	Passed

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm²)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	68.0	73.9	68.0	73.9	68.0	73.9	68.0	73.9
Circ. Pl (SUS)	8.2	8.2	-20.0	-20.0	1.9	1.9	-8.6	-8.6
Circ. Q (SUS)	8.5	-8.5	-19.5	19.5	38.5	-38.5	-72.4	72.4
Long. Pm (SUS)	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Long. Pl (SUS)	3.7	3.7	-10.4	-10.4	8.0	8.0	-19.7	-19.7
Long. Q (SUS)	16.8	-16.8	-38.0	38.0	16.7	-16.7	-36.6	36.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.2	-1.2	1.2	1.2	-1.7	-1.7	1.7	1.7
Shear Q (SUS)	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Pm (SUS)	68.0	73.9	68.0	73.9	68.0	73.9	68.0	73.9
Pm+Pl (SUS)	76.3	82.2	48.1	54.0	70.0	75.9	59.4	65.3
Pm+Pl+Q (Total)	85.3	73.9	43.0	73.6	108.8	38.8	22.4	137.7

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	73.92	117.90	Passed
Pm+Pl (SUS)	82.19	176.86	Passed
Pm+Pl+Q (TOTAL)	137.72	353.71	Passed

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

Input, Nozzle Desc: S2 (2in) **From: 50**

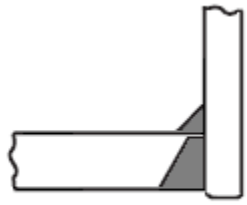
Pressure for Reinforcement Calculations	P	62.032	bars
Temperature for Internal Pressure	Temp	145	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	322.26	mm.
Design Length of Section	L	5041.9556	mm.
Shell Finished (Minimum) Thickness	t	16.6687	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1031.08	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
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)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	16.6687	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: S2 (2in)

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

```
Actual Inside Diameter Used in Calculation          2.000  in.
Actual Thickness Used in Calculation                0.654  in.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
= (62*164)/(118*1-0.6*62)
= 8.9176 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)
= (62*28.4)/(138*1-0.6*62)
= 1.3130 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 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   34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 138/118 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.065	0.881	NA
Area in Shell	A1	2.699	6.002	NA
Area in Nozzle Wall	A2	8.355	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.054	16.017	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*8.92*1+2*13.6*8.92*1*(1-1))
= 5.065 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)
= 56.8 (1 * 13.7 - 1 * 8.92) - 2 * 13.6
(1 * 13.7 - 1 * 8.92) * (1 - 1)
= 2.699 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 1.31)1
= 8.355 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm²

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

Wall Thickness for Internal/External pressures ta = 4.3130 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 11.9176 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 11.9176 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( 11.9, 4.5 ) ]
  = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 4.31, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     17.8,  Allowable :    137.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    327.0 N./mm²  Passed
Occasional  :      5.2,  Allowable :    183.4 N./mm²  Passed
Shear       :      3.3,  Allowable :     96.5 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-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:A, Curve:B)

Govrn. thk, tg = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.097, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          7 °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:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.03/102.10 = 0.608
```

Weld Size Calculations, Description: S2 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (5.07 - 2.7 + 2 * 13.6 * 1 *
  (1 * 13.7 - 8.92 ) )118 )
= 43.13 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 8.36 + 0 + 1 - 0 * 1 ) * 118
= 110.29 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 8.36 + 0 + 1 + ( 3.72 ) ) * 118
= 154.12 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 8.36 + 0 + 1 + 0 + ( 3.72 ) ) * 118
= 154.12 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.14/2.0 ) * 84 * 10 * 0.49 * 118
= 76. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
= 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.14/2.0 ) * 84 * ( 16.7 - 3 ) * 0.74 * 138
= 184. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 76.2 + 145 ) = 221 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 76.2 + 0 + 184 + 0 ) = 260 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 76.2 + 184 + 0 ) = 260 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 221 kN , must exceed W = 43 kN  or W1 = 110 kN
Path 2-2 = 260 kN , must exceed W = 43 kN  or W2 = 154 kN
Path 3-3 = 260 kN , must exceed W = 43 kN  or W3 = 154 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 78.6 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 : 5.5701 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.2388 mm.

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

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	322.262	mm.
Vessel Thickness	Tv	16.669	mm.
Design Temperature	T1	145.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	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-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	62.032	bars
Include Pressure Thrust		No	

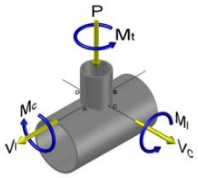
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	-2.4	kN
Circumferential Moment	(SUS)	Mc	-320.0	N-m
Longitudinal Moment	(SUS)	Ml	-420.0	N-m
Torsional Moment	(SUS)	Mt	-480.0	N-m

Use Interactive Control No

```
WRC107 Version                          Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 170.966 ( 16.669 - 3.0 ) )
  = 243.526 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                P          3.2   kN
Circumferential Shear                      VC        -2.4   kN
Longitudinal Shear                         VL         3.2   kN
Circumferential Moment                     MC      -320.0   N-m
Longitudinal Moment                        ML      -420.0   N-m
Torsional Moment                           MT      -480.0   N-m

Dimensionless Parameters used :   Gamma =   12.51
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.215	4C	2.086	(A,B)
N(PHI) / (P/Rm)	0.215	3C	1.723	(C,D)
M(PHI) / (P)	0.215	2C1	0.068	(A,B)
M(PHI) / (P)	0.215	1C	0.097	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.215	3A	0.439	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.215	1A	0.092	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.215	3B	1.413	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.215	1B	0.042	(A,B,C,D)
N(x) / (P/Rm)	0.215	3C	1.723	(A,B)
N(x) / (P/Rm)	0.215	4C	2.086	(C,D)
M(x) / (P)	0.215	1C1	0.100	(A,B)
M(x) / (P)	0.215	2C	0.068	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.215	4A	0.713	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.215	2A	0.052	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.215	4B	0.434	(A,B,C,D)

M(x) / (ML/(Rm * Beta)) 0.215 2B 0.066 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.9	-2.9	-2.9	-2.9	-2.4	-2.4	-2.4	-2.4
Circ. Bend. P	-7.0	7.0	-7.0	7.0	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	1.6	1.6	-1.6	-1.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	25.8	-25.8	-25.8	25.8
Circ. Memb. ML	6.9	6.9	-6.9	-6.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	15.2	-15.2	-15.2	15.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	12.2	-4.1	-32.0	12.5	15.2	-16.6	-39.8	31.8
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-2.9	-2.9	-2.9	-2.9
Long. Bend. P	-10.2	10.2	-10.2	10.2	-7.0	7.0	-7.0	7.0
Long. Memb. MC	0.0	0.0	0.0	0.0	2.7	2.7	-2.7	-2.7
Long. Bend. MC	0.0	0.0	0.0	0.0	14.4	-14.4	-14.4	14.4
Long. Memb. ML	2.1	2.1	-2.1	-2.1	0.0	0.0	0.0	0.0
Long. Bend. ML	24.1	-24.1	-24.1	24.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	13.7	-14.2	-38.9	29.9	7.3	-7.7	-26.9	15.9
Shear VC	-1.3	-1.3	1.3	1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Shear MT	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2
Tot. Shear	-4.5	-4.5	-1.8	-1.8	-4.9	-4.9	-1.4	-1.4
Str. Int.	17.5	15.9	39.3	30.1	17.5	18.8	39.9	31.9

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)	71.5	77.7	71.5	77.7	71.5	77.7	71.5	77.7
Circ. Pl (SUS)	4.0	4.0	-9.8	-9.8	-0.7	-0.7	-4.0	-4.0
Circ. Q (SUS)	8.2	-8.2	-22.3	22.3	15.9	-15.9	-35.8	35.8
Long. Pm (SUS)	35.8	35.8	35.8	35.8	35.8	35.8	35.8	35.8
Long. Pl (SUS)	-0.2	-0.2	-4.5	-4.5	-0.2	-0.2	-5.5	-5.5
Long. Q (SUS)	13.9	-13.9	-34.4	34.4	7.5	-7.5	-21.4	21.4

Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	-1.3	-1.3	1.3	1.3	-1.8	-1.8	1.8	1.8
Shear Q (SUS)	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2
Pm (SUS)	71.5	77.7	71.5	77.7	71.5	77.7	71.5	77.7
Pm+Pl (SUS)	75.6	81.8	61.8	68.0	70.9	77.1	67.6	73.8
Pm+Pl+Q (Total)	84.3	74.0	42.8	90.3	87.2	61.8	31.8	109.6

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	77.72	117.90	Passed
Pm+Pl (SUS)	81.80	176.85	Passed
Pm+Pl+Q (TOTAL)	109.55	353.70	Passed

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

Input, Nozzle Desc: S1 (2in) **From: 50**

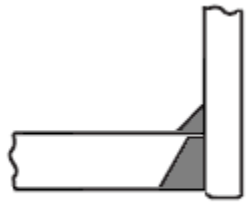
Pressure for Reinforcement Calculations	P	62.000	bars
Temperature for Internal Pressure	Temp	145	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm²
Shell Allowable Stress At Ambient	Sva	117.90	N./mm²
Inside Diameter of Cylindrical Shell	D	322.26	mm.
Design Length of Section	L	5041.9556	mm.
Shell Finished (Minimum) Thickness	t	16.6687	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5431.08	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
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)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material		SA-105	
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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	16.6687	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		600	
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: S1 (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.
```

Note:
Post Weld Heat Treatment is required for this nozzle and it was specified as being heat treated.

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)
  = (62*164)/(118*1-0.6*62)
  = 8.9129 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)
  = (62*28.4)/(138*1-0.6*62)
  = 1.3123 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3430 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   34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/118 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 138/118 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.063	0.881	NA
Area in Shell	A1	2.701	6.002	NA
Area in Nozzle Wall	A2	8.356	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.057	16.017	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*8.91*1+2*13.6*8.91*1*(1-1))
= 5.063 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)
= 56.8 (1 * 13.7 - 1 * 8.91) - 2 * 13.6
(1 * 13.7 - 1 * 8.91) * (1 - 1)
= 2.701 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 1.31)1
= 8.356 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm²

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

Wall Thickness for Internal/External pressures ta = 4.3123 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 11.9129 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 11.9129 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( 11.9, 4.5 ) ]
  = 7.8000 mm.
```

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

```
  = max( ta, tb )
  = max( 4.31, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained   :     17.8,  Allowable :    137.9 N./mm²  Passed
Expansion   :      0.0,  Allowable :    327.0 N./mm²  Passed
Occasional  :      5.2,  Allowable :    183.4 N./mm²  Passed
Shear       :     10.3,  Allowable :     96.5 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-Shell/Head Weld (UCS-66(a)1(b)), min(Curve:A, Curve:B)

Govrn. thk, tg = 16.6, tr = 1.31, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.096, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          7 °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:

```
Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)    -29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -48 °C
```

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

```
Design Pressure/Ambient Rating = 62.00/102.10 = 0.607
```

Weld Size Calculations, Description: S1 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (5.06 - 2.7 + 2 * 13.6 * 1 *
  (1 * 13.7 - 8.91 ) )118 )
= 43.09 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 8.36 + 0 + 1 - 0 * 1 ) * 118
= 110.29 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 8.36 + 0 + 1 + ( 3.72 ) ) * 118
= 154.12 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 8.36 + 0 + 1 + 0 + ( 3.72 ) ) * 118
= 154.12 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.14/2.0 ) * 84 * 10 * 0.49 * 118
= 76. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.14 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 138
= 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.14/2.0 ) * 84 * ( 16.7 - 3 ) * 0.74 * 138
= 184. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 76.2 + 145 ) = 221 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 76.2 + 0 + 184 + 0 ) = 260 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 76.2 + 184 + 0 ) = 260 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 221 kN , must exceed W = 43 kN  or W1 = 110 kN
Path 2-2 = 260 kN , must exceed W = 43 kN  or W2 = 154 kN
Path 3-3 = 260 kN , must exceed W = 43 kN  or W3 = 154 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 78.6 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 : 5.5701 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.2388 mm.

Input Echo, WRC107/537 Item 1, Description: S1 (2in) :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	322.262	mm.
Vessel Thickness	Tv	16.669	mm.
Design Temperature	T1	145.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm²
Vessel Hot S.I. Allowable	Smh	117.90	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-106 B

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-105	
Nozzle UNS Number		K03504	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm²
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm²
Design Internal Pressure	Dp	62.000	bars
Include Pressure Thrust		No	

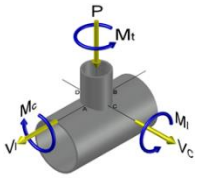
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	2.4	kN
Circumferential Moment	(SUS)	Mc	320.0	N-m
Longitudinal Moment	(SUS)	Ml	420.0	N-m
Torsional Moment	(SUS)	Mt	480.0	N-m

Use Interactive Control No

```
WRC107 Version                              Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 170.966 ( 16.669 - 3.0 ) )
  = 243.526 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
Radial Load                                  P          3.2   kN
Circumferential Shear                       VC          2.4   kN
Longitudinal Shear                          VL          3.2   kN
Circumferential Moment                      MC        320.0   N-m
Longitudinal Moment                         ML        420.0   N-m
Torsional Moment                            MT        480.0   N-m

Dimensionless Parameters used :   Gamma =   12.51
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.215	4C	2.086	(A,B)
N(PHI) / (P/Rm)	0.215	3C	1.723	(C,D)
M(PHI) / (P)	0.215	2C1	0.068	(A,B)
M(PHI) / (P)	0.215	1C	0.097	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.215	3A	0.439	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.215	1A	0.092	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.215	3B	1.413	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.215	1B	0.042	(A,B,C,D)
N(x) / (P/Rm)	0.215	3C	1.723	(A,B)
N(x) / (P/Rm)	0.215	4C	2.086	(C,D)
M(x) / (P)	0.215	1C1	0.100	(A,B)
M(x) / (P)	0.215	2C	0.068	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.215	4A	0.713	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.215	2A	0.052	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.215	4B	0.434	(A,B,C,D)

M(x) / (ML/(Rm * Beta)) 0.215 2B 0.066 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.9	-2.9	-2.9	-2.9	-2.4	-2.4	-2.4	-2.4
Circ. Bend. P	-7.0	7.0	-7.0	7.0	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.6	-1.6	1.6	1.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-25.8	25.8	25.8	-25.8
Circ. Memb. ML	-6.9	-6.9	6.9	6.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	-15.2	15.2	15.2	-15.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-32.0	12.5	12.2	-4.1	-39.8	31.8	15.2	-16.6
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-2.9	-2.9	-2.9	-2.9
Long. Bend. P	-10.2	10.2	-10.2	10.2	-7.0	7.0	-7.0	7.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-14.4	14.4	14.4	-14.4
Long. Memb. ML	-2.1	-2.1	2.1	2.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-24.1	24.1	24.1	-24.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-38.9	29.9	13.7	-14.2	-26.9	15.9	7.3	-7.7
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Shear MT	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Tot. Shear	4.5	4.5	1.8	1.8	1.4	1.4	4.9	4.9
Str. Int.	41.1	31.0	14.9	14.5	39.9	31.9	17.5	18.8

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)	71.5	77.7	71.5	77.7	71.5	77.7	71.5	77.7
Circ. Pl (SUS)	-9.8	-9.8	4.0	4.0	-4.0	-4.0	-0.7	-0.7
Circ. Q (SUS)	-22.3	22.3	8.2	-8.2	-35.8	35.8	15.9	-15.9
Long. Pm (SUS)	35.7	35.7	35.7	35.7	35.7	35.7	35.7	35.7
Long. Pl (SUS)	-4.5	-4.5	-0.2	-0.2	-5.5	-5.5	-0.2	-0.2
Long. Q (SUS)	-34.4	34.4	13.9	-13.9	-21.4	21.4	7.5	-7.5

Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.8	-1.8	1.8	1.8
Shear Q (SUS)	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Pm (SUS)	71.5	77.7	71.5	77.7	71.5	77.7	71.5	77.7
Pm+Pl (SUS)	61.8	68.0	75.6	81.8	67.6	73.8	70.8	77.0
Pm+Pl+Q (Total)	43.5	91.0	83.8	73.6	31.8	109.5	87.2	61.8

Vessel Stress Summation Comparison (N./mm²):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	77.68	117.90	Passed
Pm+Pl (SUS)	81.76	176.85	Passed
Pm+Pl+Q (TOTAL)	109.51	353.70	Passed

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

Input Echo, Tubesheet Number 1, Description: TS

Shell Data:

Main Shell Description: Shell Barrel

Shell Maximum Design Pressure	Psd,max	62.00	bars
Shell Maximum Operating Pressure	Psox,max	62.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	19.0500	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	322.262	mm.
Shell Temperature for Internal Pressure	Ts	145.00	°C
Shell Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Ss	117.90	N./mm²
Shell Allowable Stress at Ambient		117.90	N./mm²

Channel Description: Channel Barrel

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	59.00	bars
Channel Maximum Operating Pressure	Ptox,max	59.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	19.0500	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	322.262	mm.
Channel Design Temperature	TEMPC	145.00	°C
Channel Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Sc	117.90	N./mm²
Channel Allowable Stress at Ambient		117.90	N./mm²

Tube Data:

Number of Tube Holes	Nt	110	
Tube Wall Thickness	et	2.1100	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	4877.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	4792.00	mm.
Design Temperature of the Tubes		145.00	°C
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is this a Welded Tube		No	

Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		92.39	N./mm²
Tube Allowable Stress At Ambient		92.39	N./mm²
Tube Yield Stress At design Temperature	Syt	158.97	N./mm²
Tube Pitch (Center to Center Spacing)	P	23.8130	mm.
Tube Layout Pattern		Triangular	
Fillet Weld Leg	af	2.0000	mm.
Groove Weld Leg	ag	2.0000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Radius to Outermost Tube Hole Center	ro	141.779	mm.
Largest Center-to-Center Tube Distance	Ul	0.0000	mm.
Length of Expanded Portion of Tube	ltx	70.0000	mm.
Distance from Channel Side where Exp. Starts		12.0000	mm.
Min. Distance from Shell Side where Exp. Stops		3.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.
Area of Tube Layout	Ap	539.9	cm²
Perimeter of Tube Layout	Cp	853.5	mm.

Tubesheet Data:

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

Tubesheet Design Metal Temperature	T	145.00	°C
Tubesheet Material		SA-266 2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-266 2

Tubesheet Material UNS Number		K03506	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm²
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm²
Thickness of Tubesheet	h	85.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	603.250	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	409.60	mm.
Step 1 Depth on the Tubeside	ht1	7.00	mm.
Step 2 Diameter on the Tubeside	dt2	314.30	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	409.60	mm.
Step 1 Depth on the Shellside	hs1	7.00	mm.
Step 2 Diameter on the Shellside	ds2	314.30	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		409.60	mm.

Note: Tubesheet diameter is now: 409.600 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	406.400	mm.
Area of the Untubed Lanes	AL	0.0	cm²
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0340	bars
Channel Side Min. Design Pressure	Ptd,min	1.0340	bars

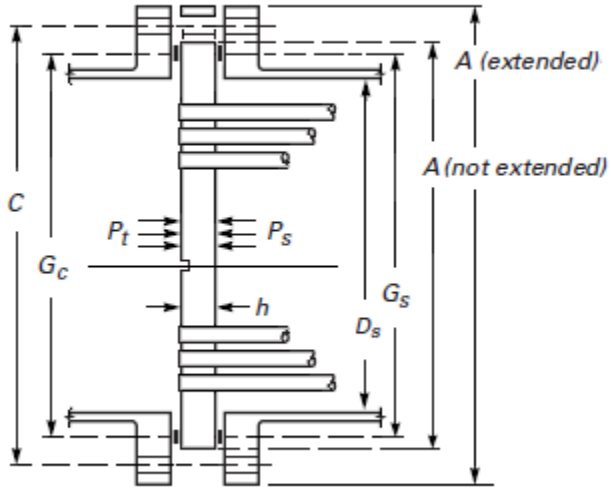
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	603.250	mm.
Flange Inside Diameter	B	322.262	mm.
Flange Face Outside Diameter	Fod	412.750	mm.
Flange Face Inside Diameter	Fid	322.262	mm.
Gasket Outside Diameter	Go	406.400	mm.
Gasket Inside Diameter	Gi	361.950	mm.
Small end Hub thk.	g0	16.6687	mm.
Large end Hub thk.	g1	54.7687	mm.
Gasket Factor,	m	0.00	
Gasket Design Seating Stress	y	0.00	N./mm²
Flange Facing Sketch		Code Sketch 1a	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	3.1750	mm.
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	527.050	mm.
Nominal Bolt Diameter	dB	34.9250	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		804.63	kN
Alternate Flange Design Bolt Load, W		1686.68	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	61.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2019

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

Elastic Mod. at Design Temperature	145.0 °C	0.19536E+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	145.0 °C	0.19536E+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.	145.0 °C	0.19536E+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	145.0 °C	0.19536E+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)
  = (60*(19/2-0)/(92.4*1+0.4*60)
  = 0.6033 + 0.0000 = 0.6033 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-1              at       145.00  °C
Elastic Modulus for Material                     199943392.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   2.1100      19.05    4933.78       9.03    50.0000  0.0134948         95.84
EMAWP = (2.167/(D/T)-0.0833)*B = 150 bars
```

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

```
     TCA         ODCA      SLEN        D/T        L/D    Factor A         B
   0.9812      19.05    4933.78      19.41    50.0000  0.0029183         91.80
EMAWP = (4*B)/(3*(D/T)) = ( 4 *91.8 )/( 3 *19.4 ) = 63 bars
```

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.          0.9812  mm.
Allowable Internal Pressure at Corroded thickness         224.56  bars
Required Internal Design Pressure                          60.03  bars
Allowable External Pressure at Corroded thickness         150.19  bars
Required External Design Pressure                          63.03  bars
Required Thickness due to Shell Side pressure              0.9812  mm.
```

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

```
Gasket Contact Width,       N = (Goc-Gic) / 2            22.225  mm.
Basic Gasket Width,        b0 = N / 2.0                  11.112  mm.
Effective Gasket Width,     b = SQRT(b0) * 2.5            8.397  mm.
Gasket Reaction Diameter,   G = Go (Self-Energizing)    406.400  mm.


Flange Design Bolt Load, Seating Condition    W  :     1686.68  kN
Flange Design Bolt Load, Operating Condition  Wm1:      765.31  kN
```

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

```
  = sqrt( 1.9 * WM1 * hg / ( S * G ) )
  = sqrt( 1.9 * 765 * 60.3/( 138 * 406 ) )
  = 39.564 mm.
```

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:

```
  = sqrt( 1.9 * W * hg / ( Sa * G ) )
  = sqrt( 1.9 * 1687 * 60.3/( 138 * 406 ) )
  = 58.736 mm.
```

```
Gasket Reaction Diameter (Gc or Gs as applicable):     406.400  mm.
```

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

Minimum Required Thickness for Shear [HreqS]:
```
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2 ) * (303/(0.8 * 138 )) * [-1.03 - 59 ] + 0
= 20.5836 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 406/303 = 1.34
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 303²/16 * [ (1.34 - 1) * (1.34² + 1) * -1.03 -
  (1.34 - 1) * (1.34² + 1) * 59 ]
= -330401.3125 bars*mm.²
```

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

Compute the Ratio [rho]:
```
= ltx/h = 70/85 = 0.82 ( 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*2.11 *(195359296/195359296 )*
     ( 92.4/138 )*(0.82 ), 19 -2*2.11 )
= 16.7216 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( 0 *100, 4*303 *23.8 )
  (3.141* 303²) )
= 23.8130 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
= (p* - d*)/p* = (23.8 - 16.7 )/23.8 = 0.3
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
   h/p =    3.569479 ;  mu* =    0.297797
  E*/E =    0.278266 ;  nu* =    0.355352 ;  E* = 54361840. KPa.
```

Note: As h/p (3.569) 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 = 410/303 = 1.35
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.36 )/54361840 * ( 195359296 * ln(1.35 ) )
  = 0.7014
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = -330401 + 765 * (406 - 406 )/(2 * pi * 303 )
  = -330401.3125 bars*mm.²
```

UHX-12.5.7 Step 7:

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

```
  = ((M*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
  = ((-330401 ) - 303²/32 * 0.7 * (-1.03 - 59 ) )/(1 + 0.7 )
  = -123380.0938 bars*mm.²
```

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

```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = -123380 + 303²/64 * (3 + 0.36 )(-1.03 - 59 )
  = -411594.8438 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(-123380 ), abs(-411595 ) )
  = 411594.8438 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

```
  = 6 * M / ( (mu*) * ( h - hg')² )
  = 6 * 411595/( (0.3 ) * ( 85 - 5 )² )
  = 129.5823 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 * 419380/((0.32) * (58.5 - 5)²
= 275.5691 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 58.5 + 0 + 0 = 58.5 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(58.5, 20.6) = 58.5 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 59) = 60 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 85/303 = 248 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(303/85)*[-1.03-59]N./mm²
= 26.72 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19 - 2.11) * 92.4 = 10.4 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 6.5097 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 10.0605 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10.3740 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg afr 1.2810 mm.
Minimum Required Groove Weld Leg agr 1.2810 mm.

Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
Note: This tube-tubesheet joint is a Full Strength joint

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	129.6	<=	275.8 N./mm²	Ok
Tubesheet shear stress	26.7	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	58.524	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	22.225	mm.
Basic Gasket Width,	b0 = N / 2.0	11.112	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.397	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Flange Design Bolt Load, Seating Condition W : 1686.68 kN
Flange Design Bolt Load, Operating Condition Wm1: 804.22 kN

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

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2) * (303/(0.8 * 138)) * [62 - -1.03] + 0
= 21.6122 mm.

UHX-12.5.1 Step 1:

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

```
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 406/303 = 1.34
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 303²/16 * [ (1.34 - 1) * (1.34² + 1) * 62 -
  (1.34 - 1) * (1.34² + 1) * -1.03 ]
= 346912.0312 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 70/85 = 0.82 ( 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*2.11 *(195359296/195359296 )*
     ( 92.4/138 )*(0.82 ), 19 -2*2.11 )
= 16.7216 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( 0 *100, 4*303 *23.8 )
  (3.141* 303²) )
= 23.8130 mm.
```

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

```
= (p* - d*)/p* = (23.8 - 16.7 )/23.8 = 0.3
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
 h/p =   3.569479 ;  mu* =   0.297797
E*/E =   0.278266 ;  nu* =   0.355352 ;  E* = 54361840. KPa.
```

Note: As h/p (3.569) 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 = 410/303 = 1.35

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.36)/54361840 * (195359296 * ln(1.35))
= 0.7014

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 346912 + 804 * (406 - 406)/(2 * pi * 303)
= 346912.0312 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((346912) - 303²/32 * 0.7 * (62 - -1.03))/(1 + 0.7)
= 129545.6094 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 129546 + 303²/64 * (3 + 0.36)(62 - -1.03)
= 432162.9375 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(129546), abs(432163))
= 432162.9375 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 432163/((0.3) * (85 - 5)²)
= 136.0577 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 * 440338/((0.32) * (59.8 - 5)²
= 275.6885 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 59.8 + 0 + 0 = 59.8 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(59.8, 21.6) = 59.8 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62 - -1.03) = 63 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 85/303 = 248 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(303/85)*[62--1.03]N./mm²
= 28.05 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19 - 2.11) * 92.4 = 10.4 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 6.5097 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 10.0605 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10.3740 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg	afr	1.2810	mm.
Minimum Required Groove Weld Leg	agr	1.2810	mm.

Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
Note: This tube-tubesheet joint is a Full Strength joint

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	136.1	<=	275.8 N./mm²	Ok
Tubesheet shear stress	28.1	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	59.834	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	22.225	mm.
Basic Gasket Width,	b0 = N / 2.0	11.112	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.397	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Flange Design Bolt Load, Seating Condition	W :	1686.68	kN
Flange Design Bolt Load, Operating Condition	Wm1:	804.22	kN

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

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2) * (303/(0.8 * 138)) * [62 - 59] + 0
= 1.0286 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34
```

Compute the Ratio [Rhoc]:

```
= Gc / Do (Configurations d)
= 406/303 = 1.34
```

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 303²/16 * [ (1.34 - 1) * (1.34² + 1) * 62 -
  (1.34 - 1) * (1.34² + 1) * 59 ]
= 16510.6934 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 70/85 = 0.82 ( 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*2.11 *(195359296/195359296 )*
      ( 92.4/138 )*(0.82 ), 19 -2*2.11 )
= 16.7216 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( 0 *100, 4*303 *23.8 )
  (3.141* 303²) )
= 23.8130 mm.
```

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

```
= (p* - d*)/p* = (23.8 - 16.7 )/23.8 = 0.3
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
 h/p =   3.569479 ;  mu* =   0.297797
E*/E =   0.278266 ;  nu* =   0.355352 ;  E* = 54361840. KPa.
```

Note: As h/p (3.569) 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 = 410/303 = 1.35
```

Determine Coefficient [F]:

```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.36 )/54361840 * ( 195359296 * ln(1.35 ) )
```

= 0.7014

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 16511 + 805 * (406 - 406)/(2 * pi * 303)
= 16510.6934 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)
= ((16511) - 303²/32 * 0.7 * (62 - 59))/(1 + 0.7)
= 6165.5054 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 6166 + 303²/64 * (3 + 0.36)(62 - 59)
= 20568.0645 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(6166), abs(20568))
= 20568.0645 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 20568/((0.3) * (85 - 5)²)
= 6.4754 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 * 20953/((0.32) * (17 - 5)²
= 275.3917 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 17 + 0 + 0 = 17 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(17, 1.03) = 17 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62 - 59) = 3 bars

Shear Stress check [Tau_limit]:

```
  = 3.2 * S * mu * h/Do
  = 3.2 * 138 * 0.2 * 85/303 = 248 bars
```

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

```
  = 1/(4* Mu) * (Do/h) * [Ps - Pt]
  = 1/(4*0.2)*(303/85)*[62-59]N./mm²
  = 1.33 N./mm²
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:

```
  = pi( do - t )t
  = pi( 19 - 2.11 )2.11
  = 1.123 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.11 * ( 19 - 2.11 ) * 92.4 = 10.4 kN
```

Fillet Weld Strength [Ff]:

```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 2 * (19 + 0.67*2 ) * 92.4
  = 6.5097  kN
```

Groove Weld Strength [Fg]:

```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2 * (19 + 0.67*2 ) * 92.4
  = 10.0605  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 10.3740 kN
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

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

Min Weld Length [ar]:

```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5620  mm.

 Minimum Required Fillet Weld Leg             afr      1.2810  mm.
 Minimum Required Groove Weld Leg             agr      1.2810  mm.

 Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
```

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

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	6.5	<=	275.8 N./mm²	Ok
Tubesheet shear stress	1.3	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	16.968	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	22.225	mm.
Basic Gasket Width,	b0 = N / 2.0	11.112	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.397	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Flange Design Bolt Load, Seating Condition	W :	1686.68	kN
Flange Design Bolt Load, Operating Condition	Wm1:	765.31	kN

Required Tubesheet Flanged Extension thk. per UHX-9 (operating) [hr_opr]:
= sqrt(1.9 * WM1 * hg / (S * G))
= sqrt(1.9 * 765 * 60.3/(138 * 406))
= 39.564 mm.

Required Tubesheet Flanged Extension thk. per UHX-9 (seating) [hr_seat]:
= sqrt(1.9 * W * hg / (Sa * G))
= sqrt(1.9 * 1687 * 60.3/(138 * 406))
= 58.736 mm.

Gasket Reaction Diameter (Gc or Gs as applicable): 406.400 mm.

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

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2) * (303/(0.8 * 138)) * [-1.03 - 59] + 6
= 26.5836 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34
```

Compute the Ratio [Rhoc]:
```
= Gc / Do (Configurations d)
= 406/303 = 1.34
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 303²/16 * [ (1.34 - 1) * (1.34² + 1) * -1.03 -
  (1.34 - 1) * (1.34² + 1) * 59 ]
= -330401.3125 bars*mm.²
```

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

Compute the Ratio [rho]:
```
= ltx/h = 70/79 = 0.89 ( 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*2.11 *(195359296/195359296 )*
     ( 92.4/138 )*(0.89 ), 19 -2*2.11 )
= 16.5447 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( 0 *100, 4*303 *23.8 )
  (3.141* 303²) )
= 23.8130 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
= (p* - d*)/p* = (23.8 - 16.5 )/23.8 = 0.31
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
 h/p =   3.317516 ;  mu* =   0.305224
E*/E =   0.288006 ;  nu* =   0.350325 ;  E* = 56264700. KPa.
```

Note: As h/p (3.318) 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 = 410/303 = 1.35

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.35)/56264700 * (195359296 * ln(1.35))
= 0.6829

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= -330401 + 765 * (406 - 406)/(2 * pi * 303)
= -330401.3125 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((-330401) - 303²/32 * 0.68 * (-1.03 - 59))/(1 + 0.68)
= -126613.6094 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= -126614 + 303²/64 * (3 + 0.35)(-1.03 - 59)
= -414396.5938 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(-126614), abs(-414397))
= 414396.5938 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 414397/((0.31) * (79 - 2)²)
= 137.4020 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 * 419380/((0.32) * (55.5 - 2)²
= 275.7964 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 55.5 + 3 + 3 = 61.5 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(61.5, 26.6) = 61.5 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(-1.03 - 59) = 60 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 79/303 = 230 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(303/79)*[-1.03-59]N./mm²
= 28.74 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19 - 2.11) * 92.4 = 10.4 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 6.5097 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 10.0605 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10.3740 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg	afr	1.2810	mm.
Minimum Required Groove Weld Leg	agr	1.2810	mm.

Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
Note: This tube-tubesheet joint is a Full Strength joint

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	137.4	<=	275.8 N./mm²	Ok
Tubesheet shear stress	28.7	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	61.502	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	22.225	mm.
Basic Gasket Width,	b0 = N / 2.0	11.112	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.397	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Flange Design Bolt Load, Seating Condition	W :	1686.68	kN
Flange Design Bolt Load, Operating Condition	Wm1:	804.22	kN

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

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2) * (303/(0.8 * 138)) * [62 - -1.03] + 6
= 27.6122 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)
= 406/303 = 1.34

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
= $Do^2/16$ * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt]
= $303^2/16$ * [(1.34 - 1) * (1.34^2 + 1) * 62 -
(1.34 - 1) * (1.34^2 + 1) * -1.03]
= 346912.0312 bars*$mm.^2$

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

Compute the Ratio [rho]:
= ltx/h = 70/79 = 0.89 (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*2.11 *(195359296/195359296)*
(92.4/138)*(0.89), 19 -2*2.11)
= 16.5447 mm.

Compute the Effective Tube Pitch [p*]:
= p / sqrt(1 - 4 * min(AL * CNV_factor, 4*Do*p)/(Pi * Do^2))
= 23.8/sqrt(1 - 4 * min(0 *100, 4*303 *23.8)
(3.141* 303^2))
= 23.8130 mm.

Compute the Effective Ligament Efficiency for Bending [mu*]:
= (p* - d*)/p* = (23.8 - 16.5)/23.8 = 0.31

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
h/p = 3.317516 ; mu* = 0.305224
E*/E = 0.288006 ; nu* = 0.350325 ; E* = 56264700. KPa.

Note: As h/p (3.318) 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 = 410/303 = 1.35

Determine Coefficient [F]:
= (1 - nu*)/E* * (E * ln(K))
= (1 - 0.35)/56264700 * (195359296 * ln(1.35))

= 0.6829

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 346912 + 804 * (406 - 406)/(2 * pi * 303)
= 346912.0312 bars*mm.²

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:
= ((M*) - Do²/32 * F * (Ps - Pt)) / (1 + F)
= ((346912) - 303²/32 * 0.68 * (62 - -1.03))/(1 + 0.68)
= 132940.7188 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 132941 + 303²/64 * (3 + 0.35)(62 - -1.03)
= 435104.6875 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(132941), abs(435105))
= 435104.6875 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 435105/((0.31) * (79 - 2)²)
= 144.2682 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 * 440338/((0.32) * (56.8 - 2)²
= 275.7959 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 56.8 + 3 + 3 = 62.8 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(62.8, 27.6) = 62.8 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62 - -1.03) = 63 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 79/303 = 230 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(303/79)*[62--1.03]N./mm²
= 30.18 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:
= pi(do - t)t
= pi(19 - 2.11)2.11
= 1.123 cm²

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.11 * (19 - 2.11) * 92.4 = 10.4 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 6.5097 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2 * (19 + 0.67*2) * 92.4
= 10.0605 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10.3740 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5620 mm.

Minimum Required Fillet Weld Leg afr 1.2810 mm.
Minimum Required Groove Weld Leg agr 1.2810 mm.

Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
Note: This tube-tubesheet joint is a Full Strength joint

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	144.3	<=	275.8 N./mm²	Ok
Tubesheet shear stress	30.2	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	62.823	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

Detailed Results for load Case D3 corr. (Psd,max + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2019

Gasket Contact Width,	N = (Goc-Gic) / 2	22.225	mm.
Basic Gasket Width,	b0 = N / 2.0	11.112	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	8.397	mm.
Gasket Reaction Diameter,	G = Go (Self-Energizing)	406.400	mm.

Flange Design Bolt Load, Seating Condition	W :	1686.68	kN
Flange Design Bolt Load, Operating Condition	Wm1:	804.22	kN

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

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
= 1/(4 * 0.2) * (303/(0.8 * 138)) * [62 - 59] + 6
= 7.0286 mm.

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 142 + 19 = 303 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)
= 406/303 = 1.34

Compute the Ratio [Rhoc]:
= Gc / Do (Configurations d)
= 406/303 = 1.34

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

```
= Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
= 303²/16 * [ (1.34 - 1) * (1.34² + 1) * 62 -
  (1.34 - 1) * (1.34² + 1) * 59 ]
= 16510.6934 bars*mm.²
```

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

Compute the Ratio [rho]:

```
= ltx/h = 70/79 = 0.89 ( 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*2.11 *(195359296/195359296 )*
     ( 92.4/138 )*(0.89 ), 19 -2*2.11 )
= 16.5447 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( 0 *100, 4*303 *23.8 )
  (3.141* 303²) )
= 23.8130 mm.
```

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

```
= (p* - d*)/p* = (23.8 - 16.5 )/23.8 = 0.31
```

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.

```
 h/p =   3.317516 ;  mu* =   0.305224
E*/E =   0.288006 ;  nu* =   0.350325 ;  E* = 56264700. KPa.
```

Note: As h/p (3.318) 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 = 410/303 = 1.35
```

Determine Coefficient [F]:

```
= (1 - nu*)/E* * ( E * ln(K) )
= (1 - 0.35 )/56264700 * ( 195359296 * ln(1.35 ) )
= 0.6829
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
= Mts + W* * (Gc - Gs)/(2 * pi * Do)
= 16511 + 805 * (406 - 406 )/(2 * pi * 303 )
= 16510.6934 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)
= ((16511) - 303²/32 * 0.68 * (62 - 59))/(1 + 0.68)
= 6327.0894 bars*mm.²

Maximum Bending Moment acting on Center of Tubesheet [Mo]:
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 6327 + 303²/64 * (3 + 0.35)(62 - 59)
= 20708.0723 bars*mm.²

Maximum Bending Moment acting on Tubesheet [M]:
= Max(abs(Mp), abs(Mo))
= Max(abs(6327), abs(20708))
= 20708.0723 bars*mm.²

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:
= 6 * M / ((mu*) * (h - hg')²)
= 6 * 20708/((0.31) * (79 - 2)²)
= 6.8662 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 * 20842/((0.32) * (13.9 - 2)²
= 275.5159 N./mm²

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= H + CATS + CATC = 13.9 + 3 + 3 = 19.9 mm.

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= Max(HreqB, HreqS) = Max(19.9, 7.03) = 19.9 mm.

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(62 - 59) = 3 bars

Shear Stress check [Tau_limit]:
= 3.2 * S * mu * h/Do
= 3.2 * 138 * 0.2 * 79/303 = 230 bars

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
= 1/(4* Mu) * (Do/h) * [Ps - Pt]
= 1/(4*0.2)*(303/79)*[62-59]N./mm²
= 1.44 N./mm²

Note: Analysis Completed for Tubesheet Configuration d.

Tube Metal Area [At]:

```
  = pi( do - t )t
  = pi( 19 - 2.11 )2.11
  = 1.123 cm²
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.11 * ( 19 - 2.11 ) * 92.4 = 10.4 kN
```

Fillet Weld Strength [Ff]:
```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 2 * (19 + 0.67*2 ) * 92.4
  = 6.5097  kN
```

Groove Weld Strength [Fg]:
```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2 * (19 + 0.67*2 ) * 92.4
  = 10.0605  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 10.3740 kN
```

Design Strength Ratio [fd]:
```
  = 1.0000
```

Weld Strength Factor [fw]:
```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:
```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5620  mm.

 Minimum Required Fillet Weld Leg             afr      1.2810  mm.
 Minimum Required Groove Weld Leg             agr      1.2810  mm.

 Tube-Tubesheet Jt allowable, 10.4 is >= tube strength 10.4 kN
```
Note: This tube-tubesheet joint is a Full Strength joint

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

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	6.9	<=	275.8 N./mm²	Ok
Tubesheet shear stress	1.4	<=	110.3 N./mm²	Ok

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

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	19.933	85.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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	58.524	58.736	130	276	27	110	Ps+Pt D1	Ok
D2uc	59.834	...	136	276	28	110	Ps+Pt D2	Ok
D3uc	16.968	...	6	276	1	110	Ps+Pt D3	Ok
D1c	61.502	58.736	137	276	29	110	Ps+Pt-c D1	Ok
D2c	62.823	...	144	276	30	110	Ps+Pt-c D2	Ok
D3c	19.933	...	7	276	1	110	Ps+Pt-c D3	Ok
Max:	62.8229	58.736	mm.	0.523		0.274	(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 :	62.823	85.000	Ok
Tubesheet Thickness Flanged Extension :	58.736	61.000	Ok
Tube Thickness :	0.981	2.110	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	2.000	Ok

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

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	120.502	1.000	120.502	1.000
Tubesheet Shear Stress	247.909	1.000	275.456	1.000
Tube Pressure Stress	224.556	1.000	150.191	1.000
Tubesheet Extension Stress	82.470	...	No Calc	No Calc
Minimum MAWP	82.470		120.502	

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	127.774	1.000	127.774	1.000
Tubesheet Shear Stress	247.909	1.000	296.429	1.000
Tube Pressure Stress	224.556	1.000	150.191	1.000
Tubesheet Extension Stress	82.470	...	No Calc	No Calc
Minimum MAPnc	82.470		127.774	

(*) Only the design 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
= 85/4
= 21.250 mm.
```

Thickness Ratio = 0.72, Temperature Reduction per Fig. UCS 66.1 = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -6 °C
Min Metal Temp per UCS-66 and UCS-68(c),PWHT credit        -22 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -38 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

```
= max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
= max( 59/82.5, 62/128 )
= 0.715
```

FEA Nozzle T1,T2 6INCH

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: Sun Dec 29 10:40:37 2024.

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Cylindrical Shell

  Parent Geometry
        Parent Outside Diam.    :     355.600 mm.
        Thickness               :      13.600 mm.

  Parent 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)    :       221.3 MPa
        Elastic Modulus (Amb)   :    202720.0 MPa
        Poissons Ratio          :       0.300
        Expansion Coefficient   :  0.1207E-04 mm./mm./deg.
        Weight Density          :  0.0000E+00  N /cu.mm.(NOT USED)

  Nozzle Geometry
        Nozzle Outside Diam.    :     168.300 mm.
        Thickness               :       6.600 mm.
```

```
       Length                 :     200.000 mm.
       RePad Width            :      50.800 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)   :       221.3 MPa
       Elastic Modulus (Amb)  :    202720.0 MPa
       Poissons Ratio         :       0.300
       Expansion Coefficient  :  0.1207E-04 mm./mm./deg.
       Weight Density         :  0.0000E+00  N /cu.mm. (NOT USED)

Design Operating Cycles       :       7000.
Ambient Temperature (Deg.)    :       21.10

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature    :       95.00 deg.
Nozzle Outside Temperature    :       95.00 deg.
Vessel Inside  Temperature    :       95.00 deg.
Vessel Outside Temperature    :       95.00 deg.

Nozzle Pressure               :       5.900 MPa
Vessel Pressure               :       5.900 MPa

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(  N )  Moments (N-m)

Load Case        FX         FY         FZ         MX         MY         MZ
-------------------------------------------------------------------------
 WEIGHT:     9600.0    -9600.0    -7200.0        0.0        0.0        0.0


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:     9600.0    -9600.0    -7200.0        0.0        0.0        0.0

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 589.05 mm.
down the length of the cylinder and the total cylinder length
is 1178.10 mm.

Vessel Centerline Vector : 1.000 0.000 0.000
Nozzle Orientation Vector : 0.000 1.000 0.000

Table of Contents

Load Case Report
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

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
```

Table of Contents

```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            10:40am  DEC 29,2024



Solution Data


Maximum Solution Row Size =     756
Number of Nodes           =    2112
Number of Elements        =     696
Number of Solution Cases  =       8

Summation of Loads per Case

Case #               FX                  FY                  FZ

   1              9600.               -9600.              -7200.
   2            551623.              -19288.              -7200.
   3            542023.               -9688.                  0.
   4                 0.              462333.                  0.
   5                 3.                   0.                  0.
   6                 0.                   0.                  3.
```

7	0.	0.	0.
8	542023.	-9688.	0.

Table of Contents

ASME Code Stress Output Plots
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

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

Table of Contents

Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

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.

Table of Contents

ASME Overstressed Areas
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

Table of Contents

Highest Primary Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

Highest Primary Stress Ratios $X

Pad/Header at Junction

```
       Pl            SPL     Primary Membrane Load Case 2
      141            221     Min Prin. Stress = -16. (50% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            63%
```

Branch at Junction

```
       Pl            SPL     Primary Membrane Load Case 2
      127            221     Min Prin. Stress = -92. (57% Neg, 5% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            57%
```

Branch Transition

```
       Pl            SPL     Primary Membrane Load Case 2
       82            221     Min Prin. Stress = -31. (61% Neg, 42% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            37%
```

Pad Outer Edge Weld

```
       Pl            SPL     Primary Membrane Load Case 2
       82            221     Min Prin. Stress = -5. (37% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            37%
```

Header Outside Pad Area

```
       Pl            SPL     Primary Membrane Load Case 2
       74            221     Min Prin. Stress = -13. (65% Neg, 0% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            33%
```

Branch removed from Junction

```
       Pl            SPL     Primary Membrane Load Case 2
       86            221     Min Prin. Stress = -25. (72% Neg, 23% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            39%
```

Table of Contents

```
Highest Secondary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            10:40am  DEC 29,2024
```

```
Highest Secondary Stress Ratios                        $X
```

In combination case 4 the max range stress divided
by the max component stress is 1.78. 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	1.782	1.763

Pad/Header at Junction

Pl+Pb+Q	SPS	
200 MPa	463 MPa	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -18. (55% Neg, 0% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
43%		

Branch at Junction

Pl+Pb+Q	SPS	
165 MPa	463 MPa	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -62. (56% Neg, 0% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
35%		

Branch Transition

Pl+Pb+Q	SPS	
129 MPa	463 MPa	Primary+Secondary (Inner) Load Case 4 Min Prin. Stress = -28. (57% Neg, 39% NegHi) Plot Reference: 15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
27%		

Pad Outer Edge Weld

Pl+Pb+Q	SPS	
166 MPa	463 MPa	Primary+Secondary (Outer) Load Case 4 Min Prin. Stress = -6. (48% Neg, 0% NegHi) Plot Reference: 16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
35%		

Header Outside Pad Area

Pl+Pb+Q	SPS	
98 MPa	463 MPa	Primary+Secondary (Inner) Load Case 2 Min Prin. Stress = -13. (65% Neg, 0% NegHi) Plot Reference: 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
21%		

Branch removed from Junction

Pl+Pb+Q	SPS	
94 MPa	463 MPa	Primary+Secondary (Outer) Load Case 2 Min Prin. Stress = -25. (72% Neg, 23% NegHi) Plot Reference: 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
20%		

Table of Contents

Highest Fatigue Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

Highest Fatigue Stress Ratios $X

Pad/Header at Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
270	0.070 Life	Stress Concentration Factor = 1.350
MPa	0.466 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 100,516.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 377,541.
		WRC 474 99% Probability Cycles = 87,706.
46%		WRC 474 95% Probability Cycles = 121,769.
		BS5500 Allowed Cycles(Curve F) = 81,667.
		Membrane-to-Bending Ratio = 1.915
		Bending-to-PL+PB+Q Ratio = 0.343
		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
223	0.035 Life	Stress Concentration Factor = 1.350
MPa	0.385 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 201,013.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 1,695,415.
		WRC 474 99% Probability Cycles = 393,860.
38%		WRC 474 95% Probability Cycles = 546,825.
		BS5500 Allowed Cycles(Curve F) = 153,155.
		Membrane-to-Bending Ratio = 1.795
		Bending-to-PL+PB+Q Ratio = 0.358
		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
129	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.222 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 2.1288E8
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 3,860,478.
		WRC 474 99% Probability Cycles = 896,824.
22%		WRC 474 95% Probability Cycles = 1,245,128.
		BS5500 Allowed Cycles(Curve F) = 322,545.
		Membrane-to-Bending Ratio = 0.577
		Bending-to-PL+PB+Q Ratio = 0.634

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
224	0.035 Life	Stress Concentration Factor = 1.350
MPa	0.386 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 198,671.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 1,051,042.
		WRC 474 99% Probability Cycles = 244,167.
38%		WRC 474 95% Probability Cycles = 338,995.
		BS5500 Allowed Cycles(Curve F) = 151,802.
		Membrane-to-Bending Ratio = 0.696
		Bending-to-PL+PB+Q Ratio = 0.590
		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 (Inner) Load Case 4
96	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.165 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 8.2969E10
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 5,625,707.
		WRC 474 99% Probability Cycles = 1,306,903.
16%		WRC 474 95% Probability Cycles = 1,814,470.
		BS5500 Allowed Cycles(Curve F) = 788,985.
		Membrane-to-Bending Ratio = 1.739
		Bending-to-PL+PB+Q Ratio = 0.365
		Plot Reference:
		17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Branch removed from Junction

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
93	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.160 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 9,871,953.
		WRC 474 99% Probability Cycles = 2,293,344.
16%		WRC 474 95% Probability Cycles = 3,184,020.
		BS5500 Allowed Cycles(Curve F) = 861,507.
		Membrane-to-Bending Ratio = 7.084
		Bending-to-PL+PB+Q Ratio = 0.124
		Plot Reference:
		17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Table of Contents

Highest Stress Ratios Per Region
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

Highest Stress Ratios Per Region $X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 2
141	221	Min Prin. Stress = -16. (50% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
63%		
Qb	SPS	Primary Bending Load Case 2
75	463	Min Prin. Stress = -16. (50% 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
200	463	Min Prin. Stress = -16. (50% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
43%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
106	463	Min Prin. Stress = -16. (50% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
22%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
171	472	Min Prin. Stress = -16. (50% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
36%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
188	463	Min Prin. Stress = -15. (49% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
40%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
94	463	Min Prin. Stress = -15. (49% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
20%		
Membrane	User	Component Evaluation Load Case 3
139	463	Min Prin. Stress = -15. (49% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
29%		
Bending	User	Component Evaluation Load Case 3
55	463	Min Prin. Stress = -15. (49% 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
200	463	Min Prin. Stress = -18. (55% Neg, 0% NegHi)
MPa	MPa	Plot Reference:

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
43%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
116	463	Min Prin. Stress = -18. (55% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

25%

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
270	0.070 Life	Stress Concentration Factor = 1.350
MPa	0.466 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 100,516.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 377,541.
		WRC 474 99% Probability Cycles = 87,706.
46%		WRC 474 95% Probability Cycles = 121,769.
		BS5500 Allowed Cycles(Curve F) = 81,667.
		Membrane-to-Bending Ratio = 1.915
		Bending-to-PL+PB+Q Ratio = 0.343
		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
156	0.002 Life	Stress Concentration Factor = 1.350
MPa	0.270 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 4,616,474.
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 2,081,890.
		WRC 474 99% Probability Cycles = 483,642.
26%		WRC 474 95% Probability Cycles = 671,476.
		BS5500 Allowed Cycles(Curve F) = 422,094.
		Membrane-to-Bending Ratio = 3.950
		Bending-to-PL+PB+Q Ratio = 0.202
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch at Junction

Pl	SPL	Primary Membrane Load Case 2
127	221	Min Prin. Stress = -92. (57% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

57%

Qb	SPS	Primary Bending Load Case 2
119	463	Min Prin. Stress = -92. (57% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2

25%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
128	463	Min Prin. Stress = -92. (57% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

27%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
150	463	Min Prin. Stress = -92. (57% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

32%

S1+S2+S3	4S		Part 5 (5.3.2) Load Case 2
230	472		Min Prin. Stress = -92. (57% Neg, 5% NegHi)
MPa	MPa		Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
		48%	
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 3
122	463		Min Prin. Stress = -19. (58% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
		26%	
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 3
111	463		Min Prin. Stress = -19. (58% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
		23%	
Membrane	User		Component Evaluation Load Case 3
114	463		Min Prin. Stress = -19. (58% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
		24%	
Bending	User		Component Evaluation Load Case 3
40	463		Min Prin. Stress = -19. (58% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
		8%	
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 4
142	463		Min Prin. Stress = -62. (56% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
		30%	
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 4
165	463		Min Prin. Stress = -62. (56% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
		35%	
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
191	0.017 Life		Stress Concentration Factor = 1.350
MPa	0.329 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 407,824.
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 2,793,732.
			WRC 474 99% Probability Cycles = 649,009.
32%			WRC 474 95% Probability Cycles = 901,068.
			BS5500 Allowed Cycles(Curve F) = 243,779.
			Membrane-to-Bending Ratio = 1.795
			Bending-to-PL+PB+Q Ratio = 0.358
			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
223	0.035 Life		Stress Concentration Factor = 1.350
MPa	0.385 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 201,013.
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 1,695,415.
			WRC 474 99% Probability Cycles = 393,860.
38%			WRC 474 95% Probability Cycles = 546,825.

BS5500 Allowed Cycles(Curve F) = 153,155.
Membrane-to-Bending Ratio = 1.795
Bending-to-PL+PB+Q Ratio = 0.358
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch Transition

Pl	SPL	Primary Membrane Load Case 2
82	221	Min Prin. Stress = -31. (61% Neg, 42% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
37%		

Qb	SPS	Primary Bending Load Case 2
88	463	Min Prin. Stress = -31. (61% Neg, 42% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
19%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
127	463	Min Prin. Stress = -31. (61% Neg, 42% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
27%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
88	463	Min Prin. Stress = -31. (61% Neg, 42% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
18%		

S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
146	472	Min Prin. Stress = -31. (61% Neg, 42% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
30%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
123	463	Min Prin. Stress = -24. (60% Neg, 40% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
26%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
80	463	Min Prin. Stress = -24. (60% Neg, 40% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
17%		

Membrane	User	Component Evaluation Load Case 3
74	463	Min Prin. Stress = -24. (60% Neg, 40% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
16%		

Bending	User	Component Evaluation Load Case 3
83	463	Min Prin. Stress = -24. (60% Neg, 40% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
17%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
129	463	Min Prin. Stress = -28. (57% Neg, 39% NegHi)
MPa	MPa	Plot Reference:

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

27%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 4
84	463	Min Prin. Stress = -28. (57% Neg, 39% 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
129	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.222 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 2.1288E8
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 3,860,478.
		WRC 474 99% Probability Cycles = 896,824.
22%		WRC 474 95% Probability Cycles = 1,245,128.
		BS5500 Allowed Cycles(Curve F) = 322,545.
		Membrane-to-Bending Ratio = 0.577
		Bending-to-PL+PB+Q Ratio = 0.634
		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
84	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.145 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 13,481,437.
		WRC 474 99% Probability Cycles = 3,131,857.
14%		WRC 474 95% Probability Cycles = 4,348,190.
		BS5500 Allowed Cycles(Curve F) = 1,164,146.
		Membrane-to-Bending Ratio = 10.579
		Bending-to-PL+PB+Q Ratio = 0.086
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Pad Outer Edge Weld

Pl	SPL	Primary Membrane Load Case 2
82	221	Min Prin. Stress = -5. (37% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

37%

Qb	SPS	Primary Bending Load Case 2
101	463	Min Prin. Stress = -5. (37% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2

21%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
110	463	Min Prin. Stress = -5. (37% 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
164	463	Min Prin. Stress = -5. (37% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

35%

S1+S2+S3	4S		Part 5 (5.3.2) Load Case 2
135	472		Min Prin. Stress = -5. (37% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
		28%	
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 3
98	463		Min Prin. Stress = -5. (40% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
		21%	
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 3
157	463		Min Prin. Stress = -5. (40% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
		33%	
Membrane	User		Component Evaluation Load Case 3
78	463		Min Prin. Stress = -5. (40% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
		16%	
Bending	User		Component Evaluation Load Case 3
96	463		Min Prin. Stress = -5. (40% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
		20%	
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 4
105	463		Min Prin. Stress = -6. (48% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
		22%	
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 4
166	463		Min Prin. Stress = -6. (48% Neg, 0% NegHi)
MPa	MPa		Plot Reference:
			16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
		35%	
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
142	0.000 Life		Stress Concentration Factor = 1.350
MPa	0.244 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 30,110,850.
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 4,167,606.
			WRC 474 99% Probability Cycles = 968,173.
24%			WRC 474 95% Probability Cycles = 1,344,186.
			BS5500 Allowed Cycles(Curve F) = 596,804.
			Membrane-to-Bending Ratio = 1.966
			Bending-to-PL+PB+Q Ratio = 0.337
			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
224	0.035 Life		Stress Concentration Factor = 1.350
MPa	0.386 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 198,671.
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 1,051,042.
			WRC 474 99% Probability Cycles = 244,167.
38%			WRC 474 95% Probability Cycles = 338,995.

BS5500 Allowed Cycles(Curve F) = 151,802.
Membrane-to-Bending Ratio = 0.696
Bending-to-PL+PB+Q Ratio = 0.590
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl	SPL	Primary Membrane Load Case 2
74	221	Min Prin. Stress = -13. (65% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
33%		
Qb	SPS	Primary Bending Load Case 2
44	463	Min Prin. Stress = -13. (65% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
9%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
98	463	Min Prin. Stress = -13. (65% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
21%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
88	463	Min Prin. Stress = -13. (65% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
19%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
132	472	Min Prin. Stress = -13. (65% 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
97	463	Min Prin. Stress = -13. (67% Neg, 0% 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
81	463	Min Prin. Stress = -13. (67% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
17%		
Membrane	User	Component Evaluation Load Case 3
73	463	Min Prin. Stress = -13. (67% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
15%		
Bending	User	Component Evaluation Load Case 3
42	463	Min Prin. Stress = -13. (67% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
9%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
96	463	Min Prin. Stress = -13. (68% 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
81	463	Min Prin. Stress = -13. (68% Neg, 0% NegHi)
MPa	MPa	Plot Reference:
		16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17%

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
96	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.165 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 8.2969E10
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 5,625,707.
		WRC 474 99% Probability Cycles = 1,306,903.
16%		WRC 474 95% Probability Cycles = 1,814,470.
		BS5500 Allowed Cycles(Curve F) = 788,985.
		Membrane-to-Bending Ratio = 1.739
		Bending-to-PL+PB+Q Ratio = 0.365
		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
81	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.139 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 589.5
579.9		Markl Fatigue Stress Allowable = 575.0
MPa		WRC 474 Mean Cycles to Failure = 9,323,647.
		WRC 474 99% Probability Cycles = 2,165,968.
13%		WRC 474 95% Probability Cycles = 3,007,174.
		BS5500 Allowed Cycles(Curve F) = 1,308,106.
		Membrane-to-Bending Ratio = 3.105
		Bending-to-PL+PB+Q Ratio = 0.244
		Plot Reference:
		18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Branch removed from Junction

Pl	SPL	Primary Membrane Load Case 2
86	221	Min Prin. Stress = -25. (72% Neg, 23% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

39%

Qb	SPS	Primary Bending Load Case 2
17	463	Min Prin. Stress = -25. (72% Neg, 23% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2

3%

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
88	463	Min Prin. Stress = -25. (72% Neg, 23% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

18%

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
94	463	Min Prin. Stress = -25. (72% Neg, 23% 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
154	472		Min Prin. Stress = -25. (72% Neg, 23% NegHi)
MPa	MPa		Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
32%			
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 3
81	463		Min Prin. Stress = -12. (75% Neg, 18% 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
89	463		Min Prin. Stress = -12. (75% Neg, 18% NegHi)
MPa	MPa		Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
19%			
Membrane	User		Component Evaluation Load Case 3
77	463		Min Prin. Stress = -12. (75% Neg, 18% NegHi)
MPa	MPa		Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
16%			
Bending	User		Component Evaluation Load Case 3
14	463		Min Prin. Stress = -12. (75% Neg, 18% NegHi)
MPa	MPa		Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
3%			
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 4
93	463		Min Prin. Stress = -18. (69% Neg, 19% 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
91	463		Min Prin. Stress = -18. (69% Neg, 19% NegHi)
MPa	MPa		Plot Reference:
			16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
19%			
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
93	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.160 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 9,871,953.
			WRC 474 99% Probability Cycles = 2,293,344.
16%			WRC 474 95% Probability Cycles = 3,184,020.
			BS5500 Allowed Cycles(Curve F) = 861,507.
			Membrane-to-Bending Ratio = 7.084
			Bending-to-PL+PB+Q Ratio = 0.124
			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
91	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.157 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 589.5
579.9			Markl Fatigue Stress Allowable = 575.0
MPa			WRC 474 Mean Cycles to Failure = 10,422,850.
			WRC 474 99% Probability Cycles = 2,421,320.
15%			WRC 474 95% Probability Cycles = 3,361,698.

```
BS5500 Allowed Cycles(Curve F) = 908,065.
Membrane-to-Bending Ratio = 7.737
Bending-to-PL+PB+Q Ratio = 0.114
Plot Reference:
18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

Table of Contents

```
Stress Intensification Factors
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            10:40am  DEC 29,2024



Stress Intensification Factors                          $X


Branch/Nozzle Sif Summary

                  Peak      Primary    Secondary      SSI
Axial    :       5.554       4.114        8.228      1.483
Inplane :        2.140       1.585        3.171      1.288
Outplane:        4.110       3.044        6.089      1.384
Torsion :        0.739       1.024        1.095      0.860
Pressure:        1.644       1.798        2.435      1.121

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :      168.300  mm.
Pipe Thk:        6.600  mm.
Z approx:   135535.625  cu.mm.
Z exact :   130437.461  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.825   0.606   0.788  -0.079   1.181

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =        3.508
      Header Pressure i-factor =        3.418

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
                        1.172         Inplane
                        1.402         Outplane
```

```
                          1.000         Torsional
B31.1   (Branch)
Peak Stress Sif ....      0.000         Axial
                          1.402         Inplane
                          1.402         Outplane
                          1.402         Torsional
WRC 330   (Branch)
Peak Stress Sif ....      0.000         Axial
                          2.888         Inplane
                          1.402         Outplane
                          2.888         Torsional
```

Table of Contents

```
Allowable Loads
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             10:40am  DEC 29,2024
```

Allowable Loads $X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	175054.	43335.	65003.
Inplane Moment	(mm. N)	17671650.	3093384.	6562058.
Outplane Moment	(mm. N)	9203446.	1611043.	3417539.
Torsional Moment	(mm. N)	51159024.	12664672.	18997008.
Pressure	(MPa)	13.50	5.90	5.90

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	180352.	29019.	43529.
Inplane Moment	(mm. N)	18206500.	2071467.	4394245.
Outplane Moment	(mm. N)	9481997.	1078826.	2288535.
Torsional Moment	(mm. N)	28181518.	4534516.	6801774.
Pressure	(MPa)	9.41	5.90	5.90

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.

Table of Contents

Compressive Stress Summary
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 10:40am DEC 29,2024

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	-16.	1344	50%	0%	Pad/Header at Junction
2	OPERATING	3	-15.	1344	49%	0%	Pad/Header at Junction
3	EXPANSION	4	-18.	1344	55%	0%	Pad/Header at Junction
4	SUSTAINED	2	-5.	456	37%	0%	Pad Outer Edge Weld
5	OPERATING	3	-5.	456	40%	0%	Pad Outer Edge Weld
6	EXPANSION	4	-6.	456	48%	0%	Pad Outer Edge Weld
7	SUSTAINED	2	-13.	312	65%	0%	Header Outside Pad Area
8	OPERATING	3	-13.	312	67%	0%	Header Outside Pad Area
9	EXPANSION	4	-13.	312	68%	0%	Header Outside Pad Area
10	SUSTAINED	2	-92.	768	57%	5%	Branch at Junction
11	OPERATING	3	-19.	768	58%	0%	Branch at Junction
12	EXPANSION	4	-62.	768	56%	0%	Branch at Junction
13	SUSTAINED	2	-25.	288	72%	23%	Branch removed from Junction
14	OPERATING	3	-12.	288	75%	18%	Branch removed from Junction
15	EXPANSION	4	-18.	288	69%	19%	Branch removed from Junction
16	SUSTAINED	2	-31.	1056	61%	42%	Branch Transition
17	OPERATING	3	-24.	1056	60%	40%	Branch Transition
18	EXPANSION	4	-28.	1056	57%	39%	Branch Transition

Table of Contents

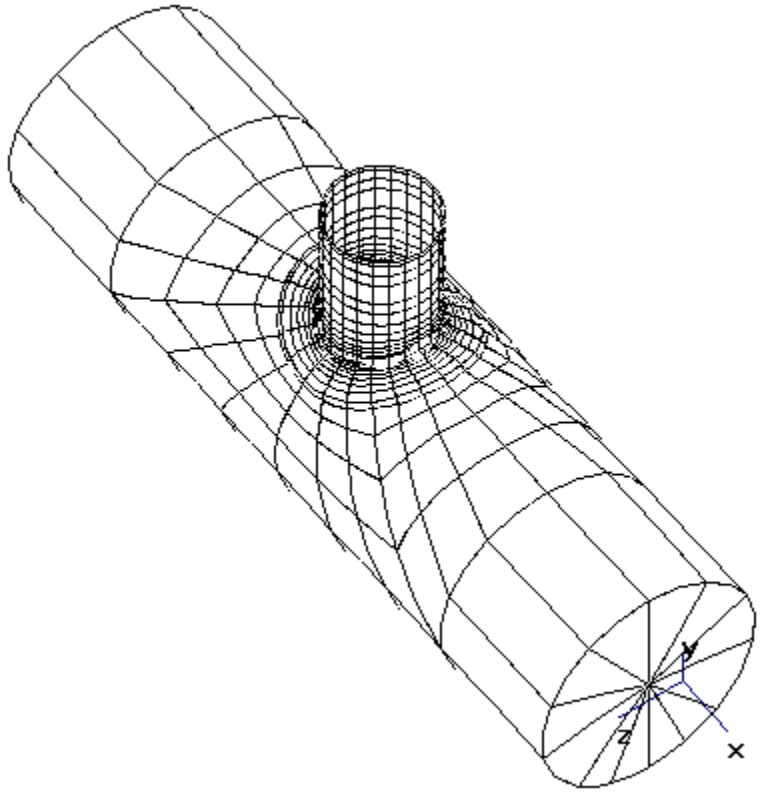
Flexibilities

```
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            10:40am  DEC 29,2024


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
  branch/header or nozzle/vessel junction.  The general
  characteristics used for the branch pipe should be:

  Outside Diameter =  168.300  mm.
  Wall Thickness   =    6.600  mm.

  Axial Translational Stiffness   =        566654.   N /mm.
  Inplane Rotational Stiffness    =     142233904.  mm. N /deg
  Outplane Rotational Stiffness   =      54113692.  mm. N /deg
  Torsional Rotational Stiffness  =     614149824.  mm. N /deg


  Estimated Radial Shell Displacement due to Allowable Loads
  SECONDARY:
  Axial (mm.) =  0.309  In-Plane (mm.) =  0.175  Out-Plane (mm.) =  0.240

  PRIMARY
  Axial (mm.) =  0.318  In-Plane (mm.) =  0.181  Out-Plane (mm.) =  0.247

  Secondary Conservative Displacement =  0.149 mm.
  Secondary Realistic    Displacement =  0.269 mm.

  Primary Conservative Displacement =  0.100 mm.
  Primary Realistic Displacement    =  0.180 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   0.22282E+13    N mm.^2
  The value of (d) to use is: 161.700  mm..
  The resulting bending stiffness is in units of force x length per radian.

  Axial Flexibility Factor     (k) =     1.408
  Inplane Flexibility Factor   (k) =     1.691
  Outplane Flexibility Factor  (k) =     4.444
  Torsional Flexibility Factor (k) =     0.392
```

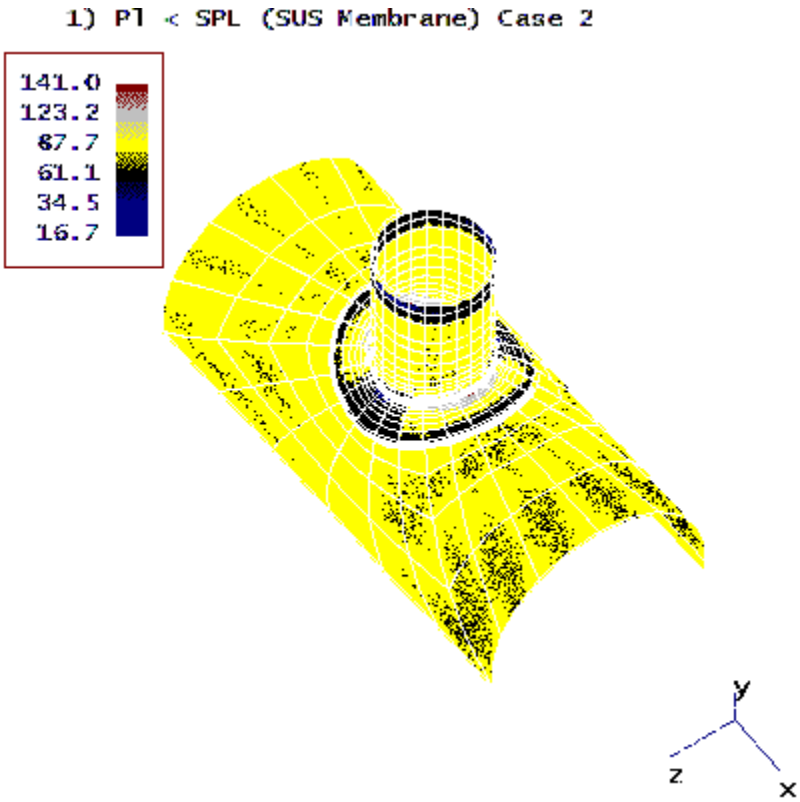
Table of Contents

Finite Element Model

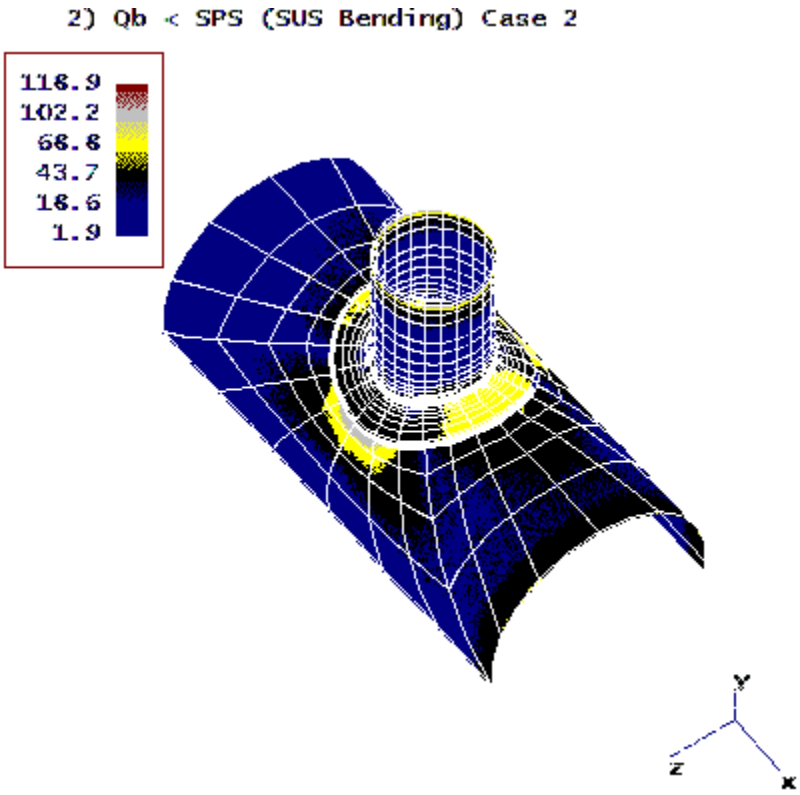
Finite Element Model



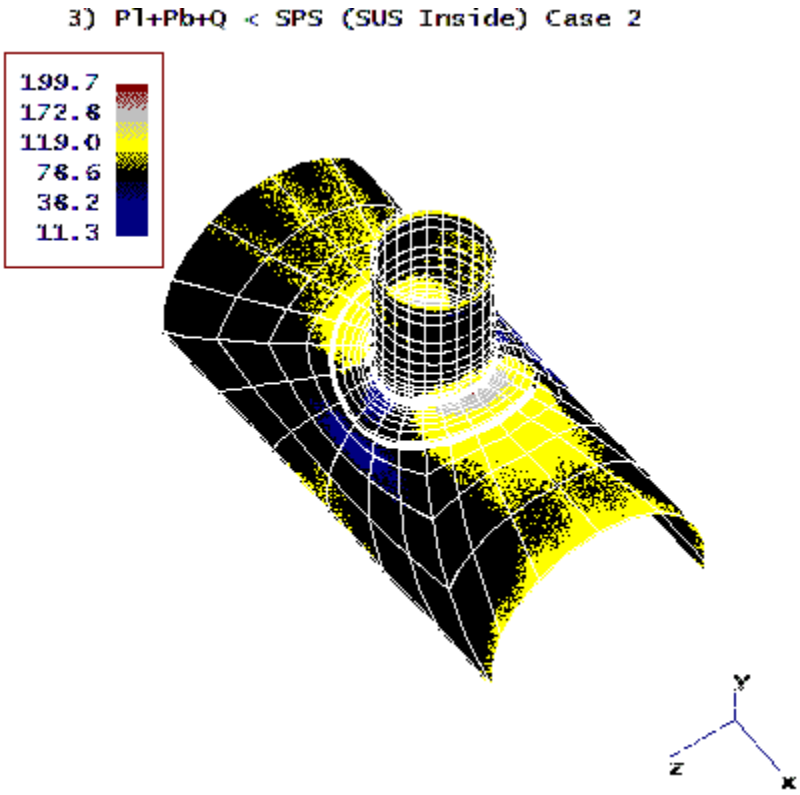
3d


1) Pl < SPL (SUS Membrane) Case 2
141.0
123.2
87.7
61.1
34.5
16.7
y
z
x
3d
3d(Deformed)

-
-

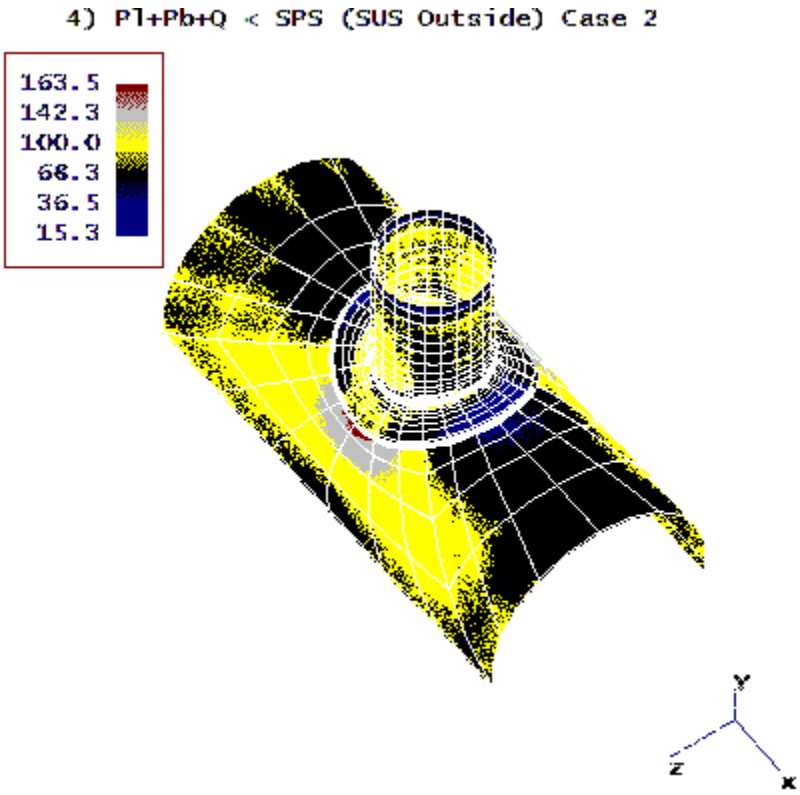

2) Qb < SPS (SUS Bending) Case 2
118.9
102.2
68.8
43.7
18.6
1.9
Y
Z
X
3d
3d(Deformed)

-
-



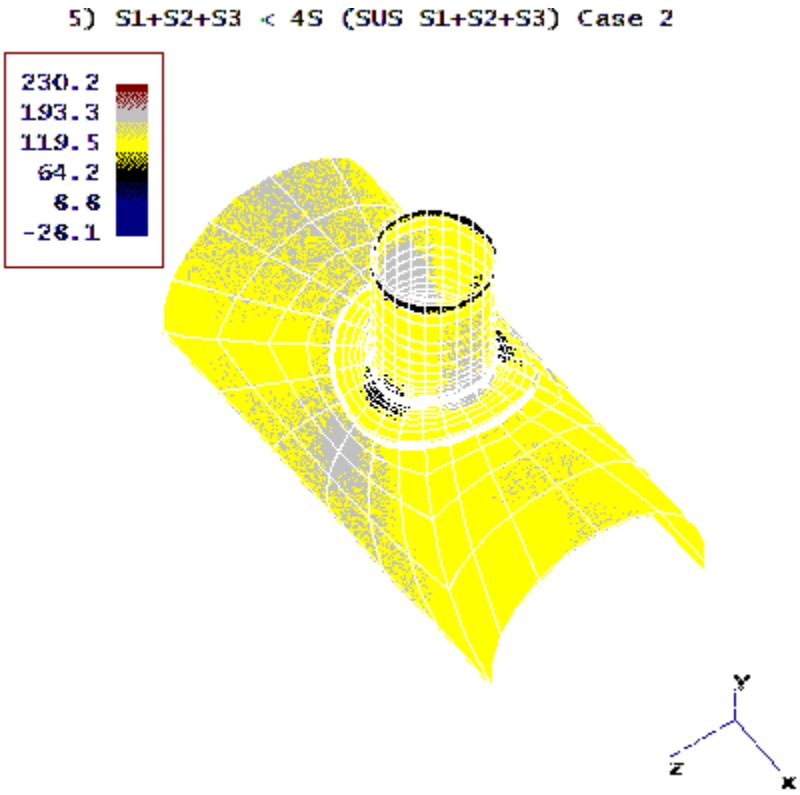
3d | 3d(Deformed)

-
-



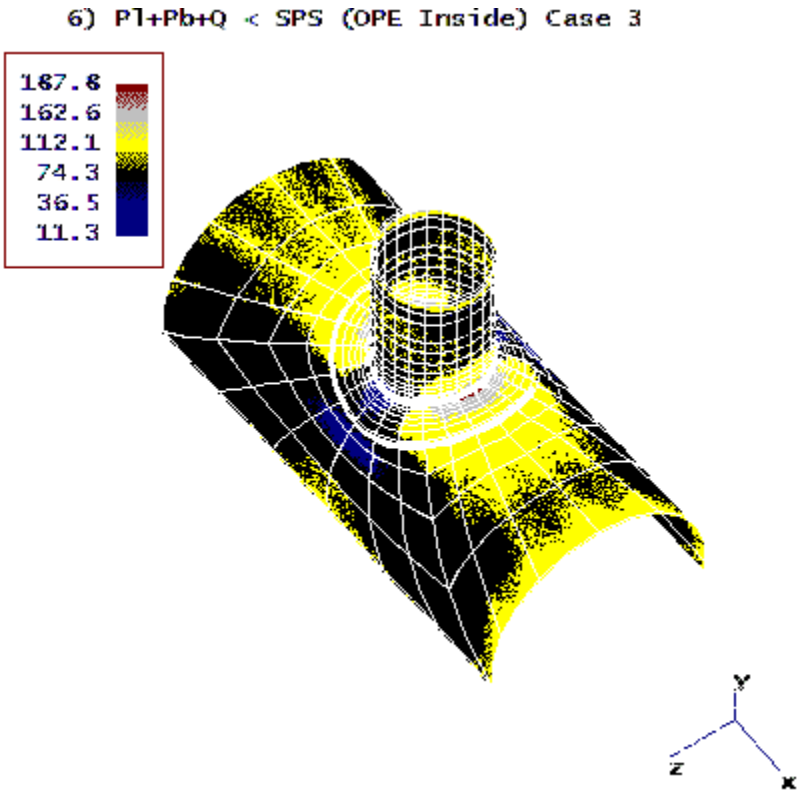
3d | 3d(Deformed)

-
-

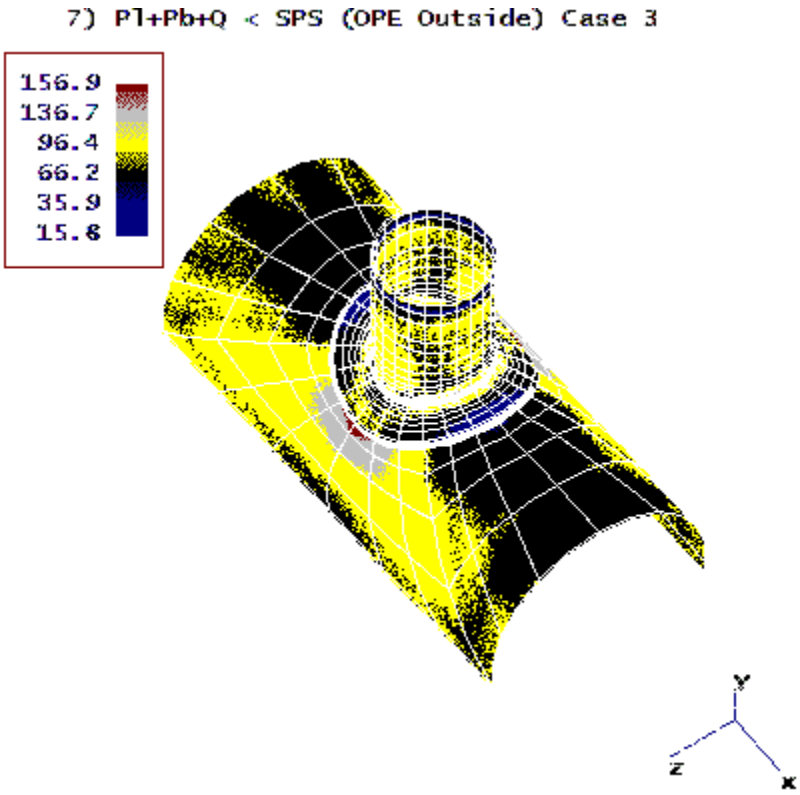


3d | 3d(Deformed)

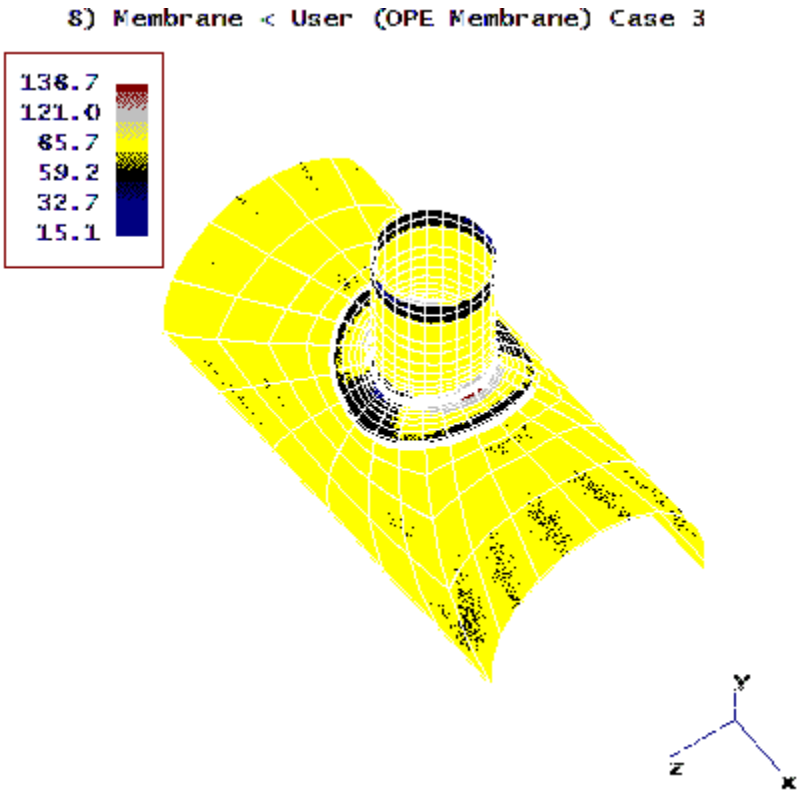
-
-


6) Pl+Pb+Q < SPS (OPE Inside) Case 3
187.8
162.6
112.1
74.3
36.5
11.3
Y
Z
X
3d
3d(Deformed)

-
-

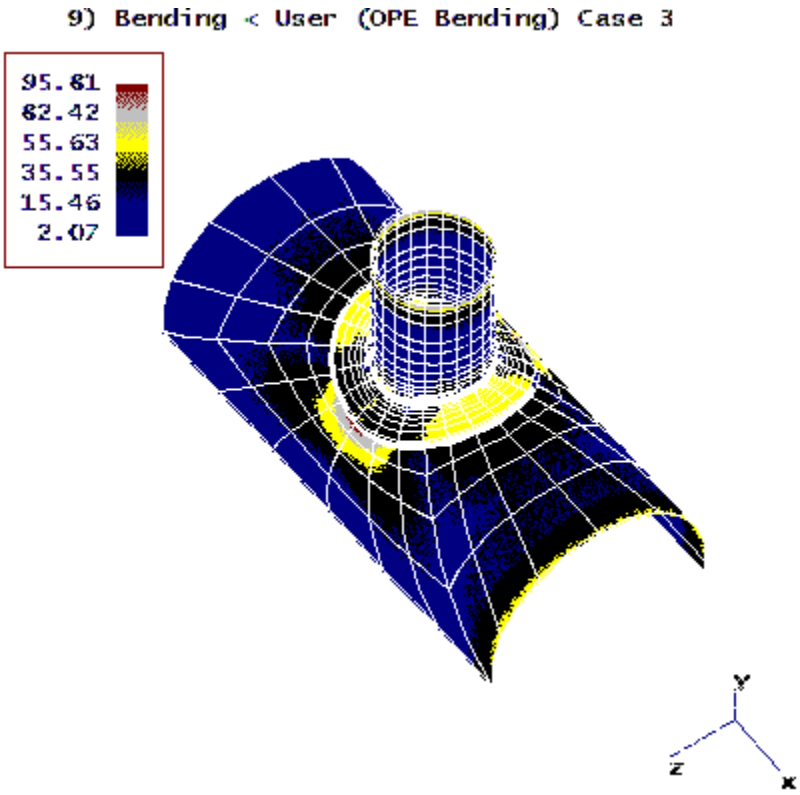

7) Pl+Pb+Q < SPS (OPE Outside) Case 3
156.9
136.7
96.4
66.2
35.9
15.8
Y
Z
X
3d
3d(Deformed)

-
-

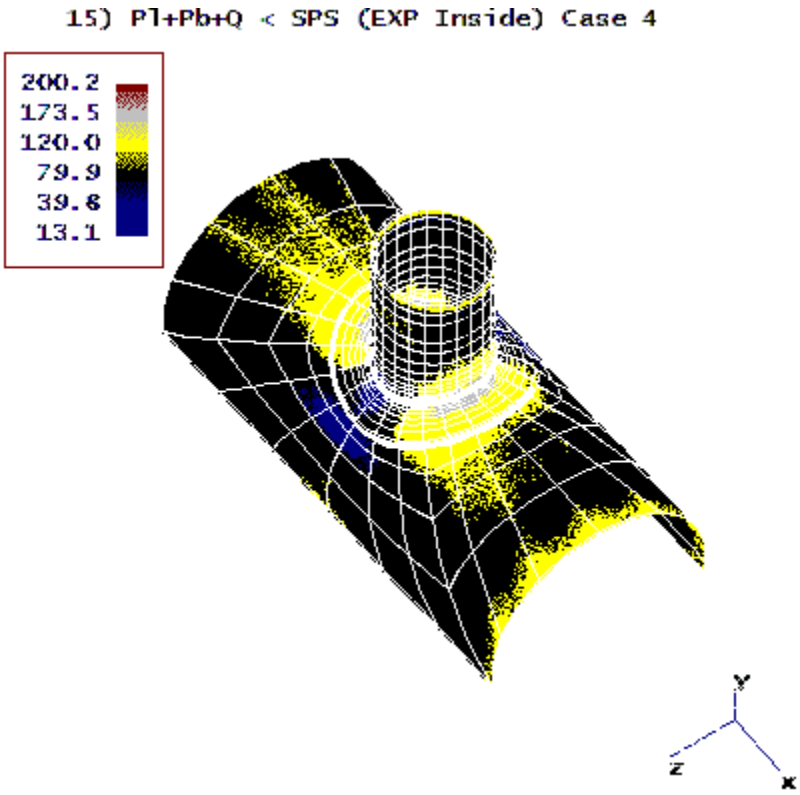


3d | 3d(Deformed)

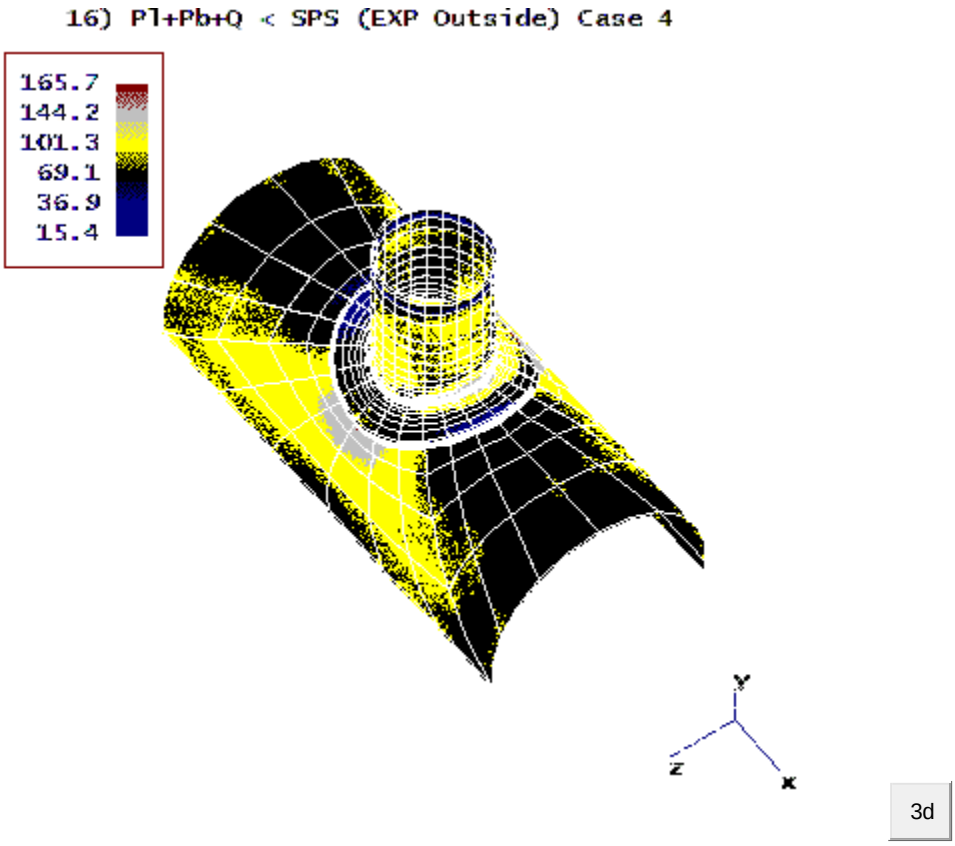
-
-


9) Bending < User (OPE Bending) Case 3
95.61
82.42
55.63
35.55
15.46
2.07
Y
Z
X
3d
3d(Deformed)

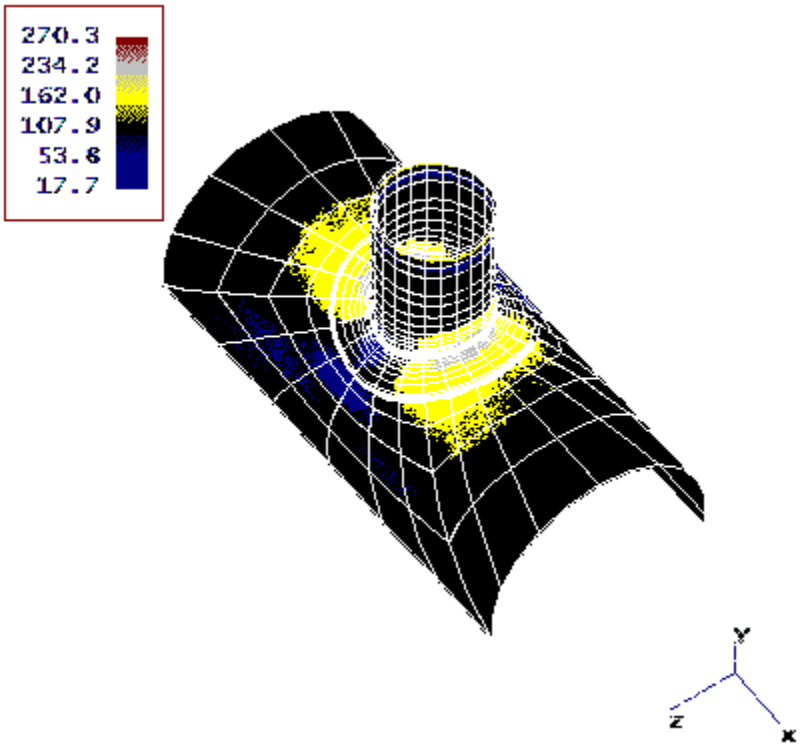
-
-



3d

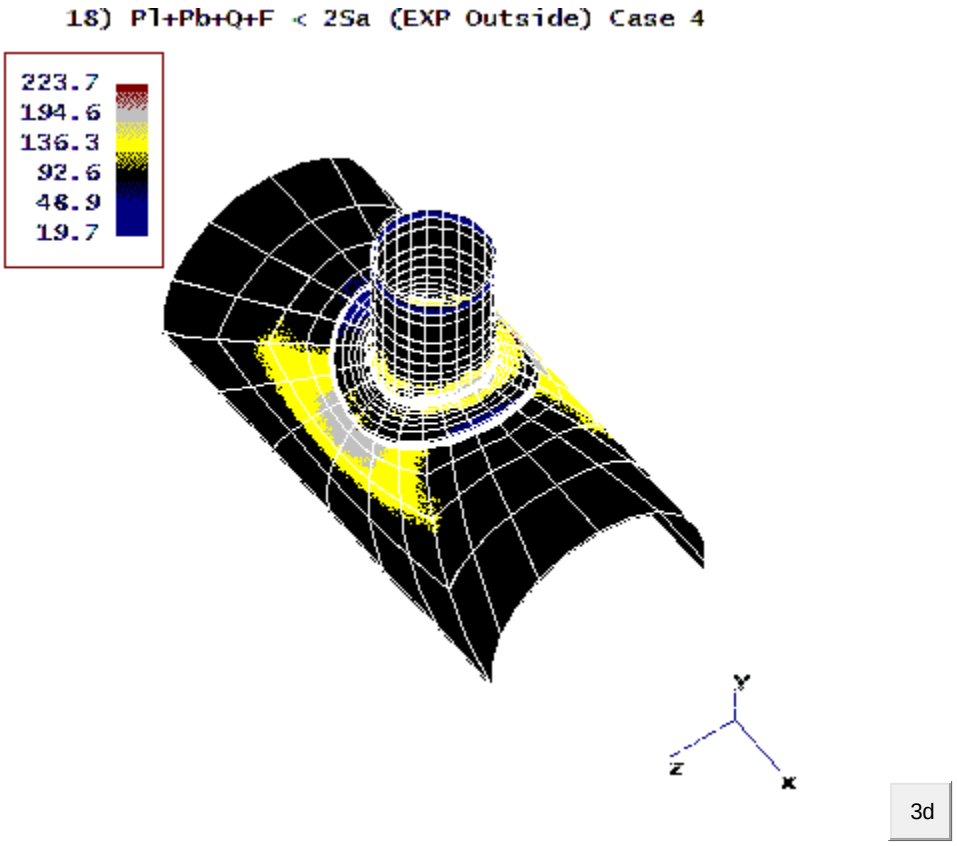

16) Pl+Pb+Q < SPS (EXP Outside) Case 4
165.7
144.2
101.3
69.1
36.9
15.4
Y
Z
X
3d

17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4



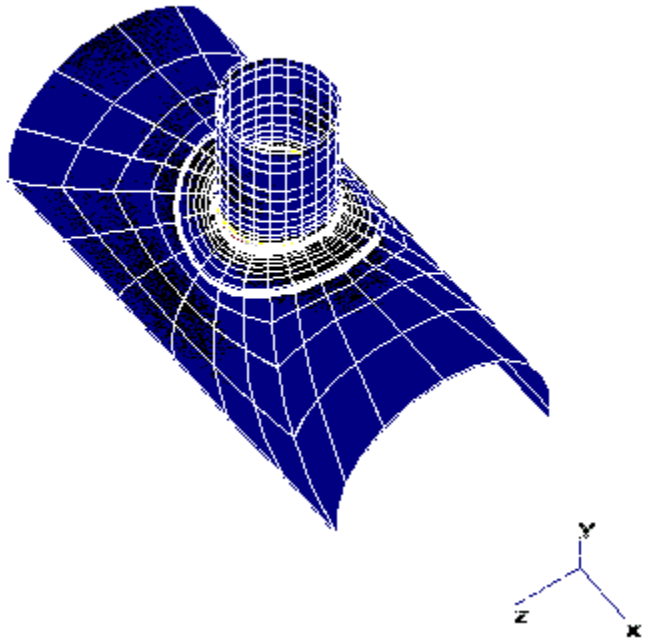
3d

-
-


18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4
223.7
194.6
136.3
92.6
46.9
19.7
Y
Z
X
3d

-
-

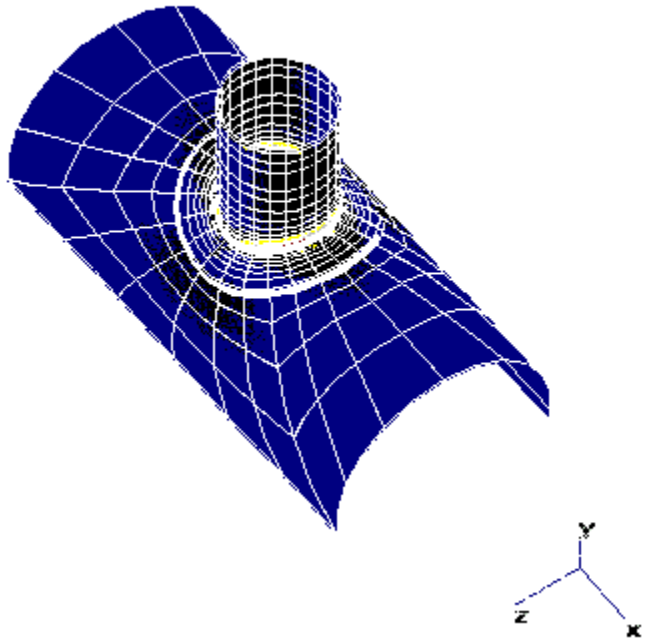
10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5



3d | 3d(Deformed)

-
-

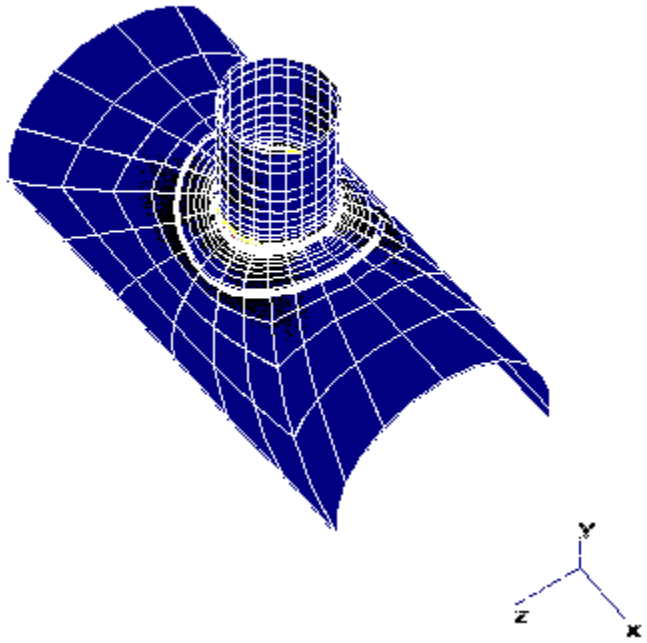
11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6



3d | 3d(Deformed)

-
-

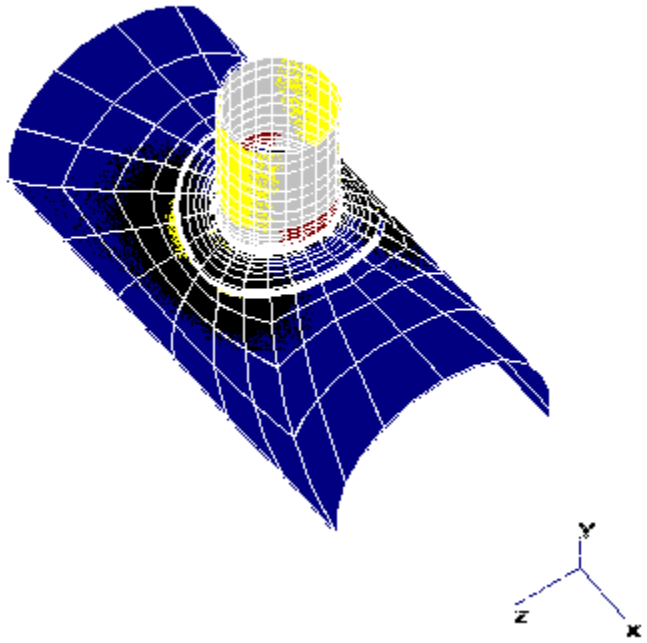
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7



3d | 3d(Deformed)

-
-

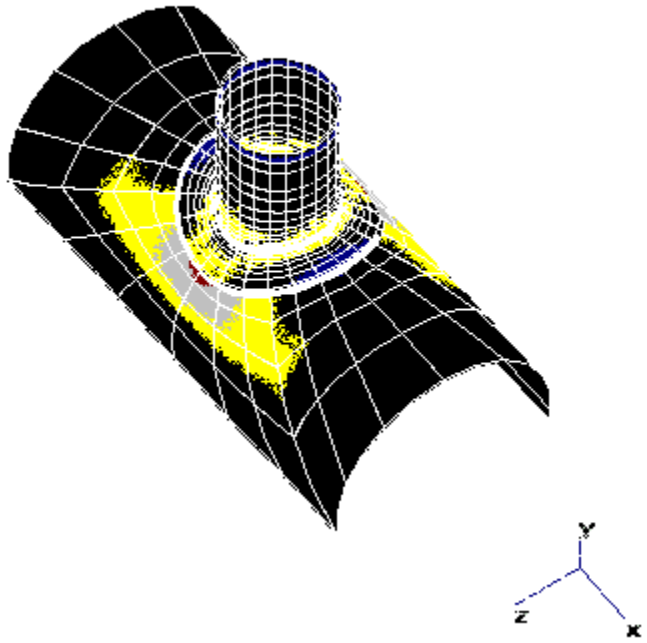
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8



3d | 3d(Deformed)

-
-

14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9



3d | 3d(Deformed)